VOLUME I

COMMUNITY BASED RISK ASSESSMENT - PORT COLBORNE, ONTARIO

ECOLOGICAL RISK ASSESSMENT - NATURAL ENVIRONMENT

Jacques Whitford

INCO

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PORT COLBORNE, ONTARIO

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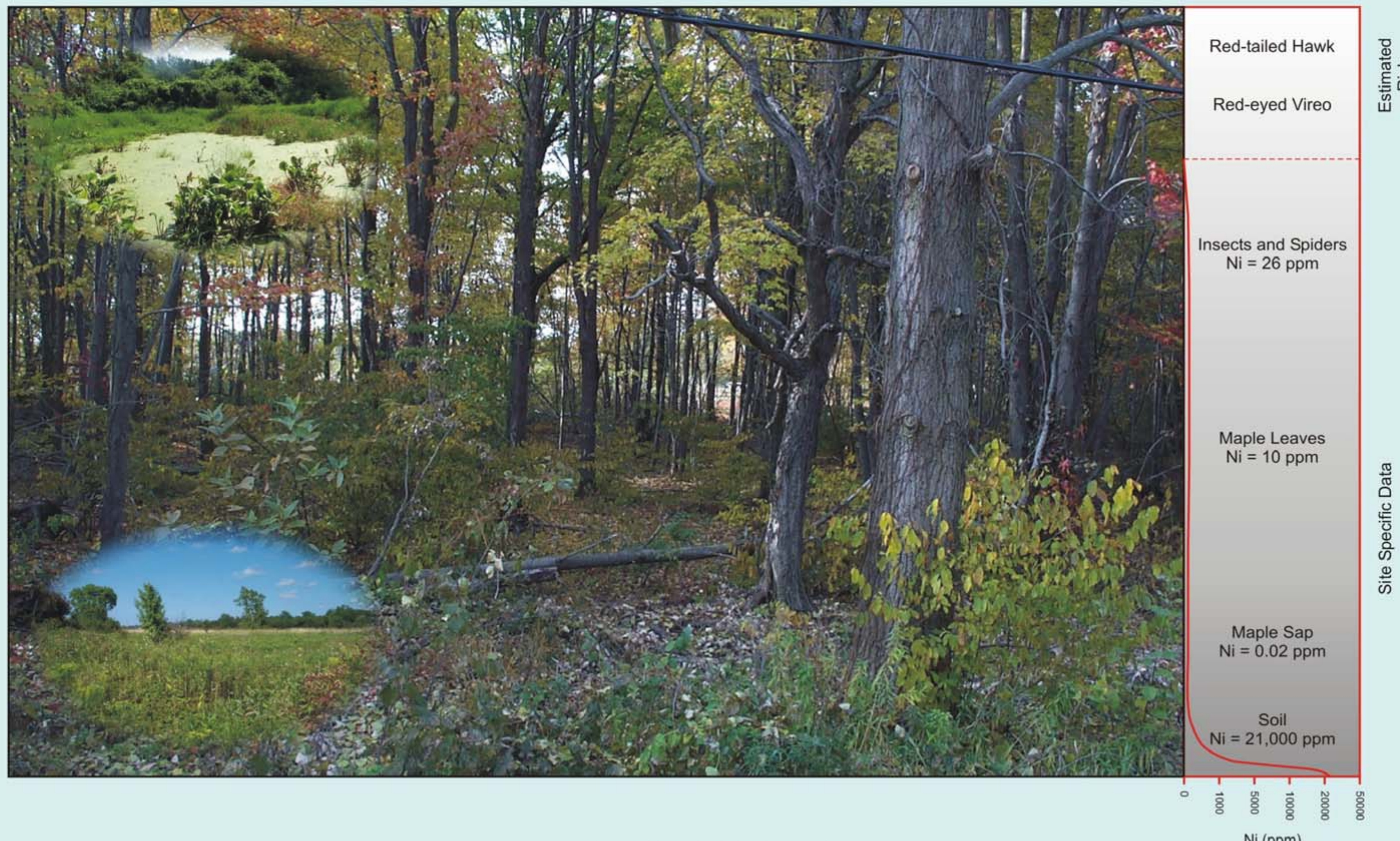

VOLUME I

September 2004

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INCO

PORT COLBORNE CBRA – ECOLOGICAL RISK ASSESSMENT

NATURAL ENVIRONMENT

Volume I – Main Report

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

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FOREWORD

This report presents the Ecological Risk Assessment for the Natural Environment prepared by Jacques Whitford Limited for the Community Based Risk Assessment (CBRA), Port Colborne, Ontario. Following two years of field investigations (2001-2002) a draft of the report was completed in July 2003 and provided to the CBRA's Public Liaison Committee (PLC) for public review and comment. In addition, the draft report received independent third party review. The report presented under this cover has taken into account the comments provided by this review process and, where required, comments have been addressed within the body of this report.

This report has been prepared for submission to the PLC and Ontario Ministry of the Environment as one component of the CBRA that is being conducted in the City of Port Colborne. Should public or government agency review and comment of this report require Jacques Whitford to address specific aspects of this report, addenda to the report will be prepared and submitted to the PLC and MOE.

ES0 EXECUTIVE SUMMARY

ES1 Introduction

This report presents details on the Ecological Risk Assessment (ERA) conducted for Inco Limited (Inco) by Jacques Whitford Limited (Jacques Whitford) as part of the Port Colborne Community Based Risk Assessment (CBRA).

The City of Port Colborne (the City) is located along the north shore of Lake Erie in the Regional Municipality of Niagara, in southern Ontario. The Welland Canal divides the City into east and west, and runs north-south across the Niagara Peninsula from the City northward to Lake Ontario and the City of St. Catharines. The City of Port Colborne has a population of 18,450. Over 80% of the City's developed areas (commercial/residential) lie on the west side of the Canal.

Inco has operated a nickel refinery in the City of Port Colborne since 1918. Peak commercial production for nickel occurred during the 1940s and operations for the production of electrolytic nickel ended in 1984. Particulate emissions resulting from refinery operations between 1918 and 1960 principally contributed to the accumulation of particulate matter and increased levels of metals in local soils, particularly downwind of the Refinery.

Inco has acknowledged responsibility for airborne dust emissions resulting from their operations and is the proponent of the CBRA process. The purpose of the CBRA process is to assess the potential environmental and human health risks of these residual depositions in soils.

ES1.1 CBRA

Inco has committed itself to the community of Port Colborne (represented by the Public Liaison Committee, or PLC), the City and the Ontario Ministry of the Environment (MOE) to conduct a CBRA. The CBRA was conducted for the chemicals of concern (CoCs) in the Port Colborne area that have elevated concentrations in soil as a result of historical emissions from the Inco Refinery. Presented under a separate cover, the CoCs were determined to be:

- Nickel,
- Copper,
- Cobalt, and
- Arsenic.

The ERA is one component of the overall CBRA process. The components of the CBRA process include:

- An evaluation to confirm that all relevant CoCs have been considered;
- A quantitative ecological risk assessment (ERA) for the natural environment (**the focus of this report**);
- Quantitative crop studies (phytotoxicity testing);
- A quantitative Human Health Risk Assessment; and
- An evaluation of all applicable remediation options.

The ERA was conducted under two component studies, the ERA-Natural Environment, and ERA-Crop Studies. For the assessment of potential risk of CoCs in soils to vascular plants, the ERA-Natural Environment investigated the potential risk to woody vascular plants (trees and shrubs). The results of the ERA-Crop Studies, which conducted dose-response experiments under controlled greenhouse trials and test field plots, will be used to assess the potential risk to naturally occurring populations of non-woody vascular plants.

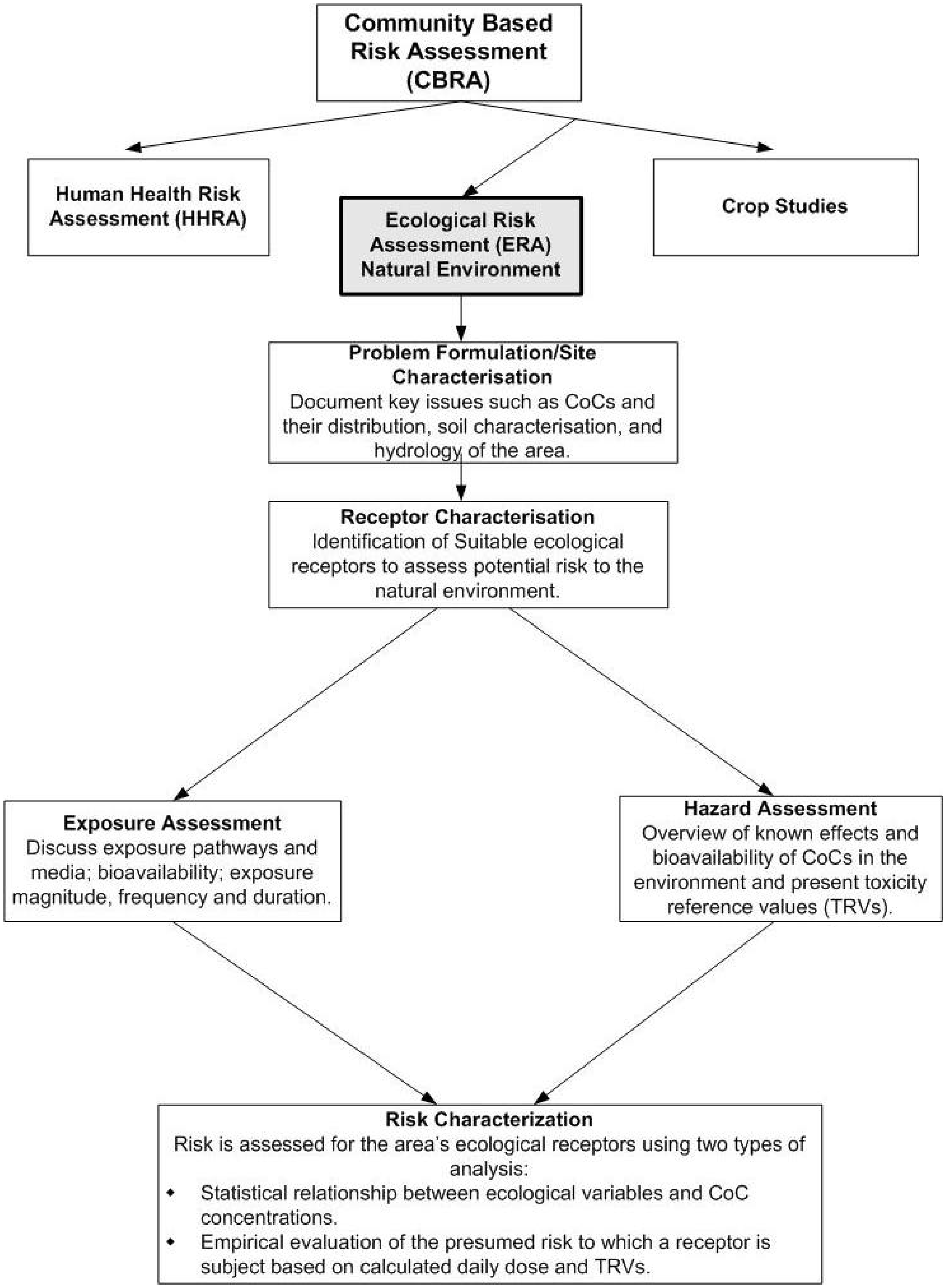
ES1.2 ERA Process

The ERA for the natural environment was conducted according to accepted Canadian and Ontario guidelines, including, *A Framework for Ecological Risk Assessment, General Guidance-National Contaminated Sites Remediation Programme (*CCME 1996*); A Framework for Ecological Risk Assessment-Technical Appendices (*CCME 1997a*) and Guidance on Site Specific Risk Assessment Use at Contaminated Sites in Ontario* (MOE 1997b). Following these guidelines, the ERA conducted assessment and analysis that included:

- Site Characterization;
- Problem Formulation and Identification of CoCs;
- Hazard Assessment;
- Receptor Characterization
- Exposure Assessment; and
- Risk Characterization.

A deterministic approach was used for this ERA, following a detailed quantitative assessment methodology based on a combination of site-specific data collected and existing information found in the literature. The steps involved in a site-specific risk assessment approach are illustrated in Figure ES-1.

Figure ES-1: Design Approach to Site-Specific Risk Assessment



ES.1.2.1 ERA Objectives

The primary objective of the ERA-Natural Environment was to determine if CoCs in soils, as a result of Refinery emissions, present a potentially unacceptable risk to the natural environment found in the Port Colborne area. For the ERA, an unacceptable risk is defined as an estimated risk linked to the occurrence of soil concentrations of CoCs that prevents sustainable populations(s) of flora and fauna, or prevents a sustainable level of ecological functioning, within the defined Study Area. If an unacceptable risk was estimated, the ERA had the follow-up objective of estimating the levels to which CoCs must be lowered or controlled in order to produce safe or acceptable levels at which adverse effects on populations or ecological processes are not expected.

ES1.3 Scope of Work

Since the present ERA focuses on the natural environment, human-influenced environments such as parks, playgrounds, gardens, residential yards and rock quarries were not considered natural environments for the ERA. Livestock and pets, which are not naturally occurring fauna, were not considered as receptors for the ERA. For the determination of potential risk to the natural environment, assessment of risk was undertaken for naturally occurring receptors found in the terrestrial environments including woodlot and field habitats and the shoreline of Lake Erie. However, the aquatic environment of Lake Erie was not examined within the scope of the ERA, as water and sediment in Lake Erie are potentially influenced by factors other than those associated with the chemical and physical behaviour of soils. Inland aquatic environments, including ponds, ditches and municipal drains were considered to have a direct linkage to the occurrence of CoCs in soils, and as a result of public concern for potential exposure of amphibians to CoCs, these inland aquatic environments were included within the scope of the ERA.

Generally, Inco lands directly associated with the Refinery site and identified within the Refinery site's Closure Plan were excluded from the ERA's scope of work. The environmental management of these lands is pursuant to the requirements of the *Mining Act* of Ontario and is outside the CBRA process. However, a limited set of field data were collected from the eastern portion of the lands covered by the Closure Plan, where significant natural areas were identified and where soil CoC concentrations were known to be high. Although these natural areas occurred on lands identified within the Closure Plan, it was apparent that the simple presence of a road and fence would not provide a barrier to the movement of bird and mammal receptors.

ES1.4 Study Design and Approach

For conducting the ERA, the lands east of the Refinery site where soil nickel concentrations exceeded the MOE generic guideline of 200 mg/kg were identified as the Study Area for investigation. Based on soil data collected by the Ministry of the Environment in 1998 and 1999, a Study Area of approximately 22 km^2 of natural environment was identified. Within this Study Area, a Primary Study Area was identified where soil nickel concentration were greater than 500 mg/kg, according to 1998 and 1999 MOE data. A Secondary Study Area was identified where soil nickel values ranged from 200 to 500 mg/kg, according to the aforementioned MOE data. These two nested study areas were identified to direct data collection efforts in areas where soil CoCs are high to moderate.

The characterization of potential risk to a receptor, or valued ecological component (VEC), was based on potential exposure to a VEC's population. For the purpose of this ERA, a VEC's population was defined as all individuals of a species (plant or animal) that inhabit or occur within the entire Study Area (both Primary and Secondary Study Areas combined). To determine various exposures of biota in the Study Area to CoCs, two natural habitat types – fields and woodlots – were identified, and two soil types – clay soils and organic soils – were identified. Data were collected, where possible, based on the following matrix:

Habitat Type	Primary Study Area (>500 mg/kg Ni)		Secondary Study Area (<500 to 200 mg/kg Ni)	
	Clay Soil	Organic Soil	Clay Soil	Organic Soil
Fallow/Old Fields	X	X	X	X
Woodlots	X	X	X	X

The ERA was conducted using site-specific data of sufficient scope to represent all natural lands and biota in the CoC impacted areas. The data were collected following data collection protocols that were specifically developed for the CBRA. Site-specific parameters were used to the maximum extent practical to calculate a receptor's exposure to the CoCs. Site-specific field data collected for the CBRA and used in the ERA include:

- Soil types (clay, organic);
- Ecological Land Classification (ecosite);
- Significant Natural Areas;
- Species inventory (trees, shrubs, birds, mammals, reptiles, amphibians, earthworms and insects);

- Soil CoC concentrations;
- Groundwater CoC concentrations (drilled wells);
- Surface water CoC concentrations (ponds, ditches, municipal drains);
- Sediment CoC concentrations (ponds, ditches, municipal drains);
- Ambient air/dust CoC concentrations;
- biotic tissue CoC concentrations (plant, animal, maple sap, invertebrate);
- Maple leaf health;
- Woodlot health; and
- Leaf litter decomposition

In addition to the data collected from the field, the following specific studies were undertaken using site-specific clay and organic soils:

- Relative oral bioavailability of nickel from soils to mammals;
- Bioaccessibility of copper and cobalt;
- Maple seed germination-sapling growth dose response greenhouse trials; and,
- Earthworm toxicity tests.

Data were collected over a two year period, during which detailed species inventories were conducted and over 700 site-specific samples were collected for analysis. Combined, the qualitative and quantitative data collected for the study represents the largest site specific data set ever collected for conducting an ERA in Canada.

ES2 Problem Formulation

For the ERA it is necessary to describe the nature and scope of the CoCs released to the environment from the Refinery in order to identify the key issues and concerns to help focus the efforts of the studies. Based on an assessment of historic emissions from the Inco Refinery, peak particulate air emissions occurred during the operation period from 1918-1930, during which nickel emissions approached 700 tonnes annually.

The local natural environment predominantly downwind (northeast) of the Refinery was exposed to the greatest atmospheric deposition of particulates for a period of approximately forty years (1918-1960). It is during this period that the particulate matter principally accumulated in the local soils. From the 1980s, and particularly through the 1990s to the present, potential harmful environmental effects on local biota due to direct atmospheric depositions are considered to have been greatly reduced compared to past-elevated levels. The levels of historic accumulated particulate matter in the local surface soils have remained unchanged from the late 1970s through to the present.

Analyses of soils for the CBRA have found that soil CoC concentrations decrease with distance from the source in a north-easterly direction, since prevailing winds from the southwest distribute the majority of particulate emissions in a northeast direction across the Study Area. Based on the results of soil sampling in the Study Area, surface (0-20 cm depth) soil CoC concentrations are similar for both the organic and clay soils that are located at similar distance northeast from the Refinery, even though the organic soils are more permeable than the clays. To determine the vertical distribution of CoCs in soil, a test-pitting program was conducted to a depth of 1.0 m in Study Area soils. Generally, it was determined that CoCs are restricted to upper regions of the soil profile from 0 to 20 cm, for both clay and organic soils. For this study, the 0-5 cm horizon is considered to represent the area of primary interaction of soil CoCs with most biological receptors. In addition, for both clay and organic soils, the 0-5 cm soil depth interval represents a zone where CoC values can be considered to be representative of higher concentrations. The 0-5 cm soil depth interval therefore is the depth at which most soil samples were obtained and chemically analyzed throughout the Study Area.

Tables ES-1 and ES-2 present a summary of the concentrations of the CoCs in the 0-5 cm soil layer in the fields and woodlots of the Study Area and reference area.

Table ES-1 Soil CoCs in Fields

Calculation	Primary Study Area (mg/kg)				Secondary Study Area (mg/kg)				Reference (mg/kg)			
	Nickel (Ni)	Copper (Cu)	Cobalt (Co)	Arsenic (As)	Ni	Cu	Co	As	Ni	Cu	Co	As
Minimum (Min)	103	30	8	2.9	16	1	4	0.5	13	9	3	1.3
Maximum (Max)	10525	1400	153	48.1	1280	139	24	19.9	1100	140	27	10.0
Mean	1354	177	30	10.4	293	49	11	5.0	81	27	9	3.9
Standard Deviation (SD)	1391	173	20	7.4	225	27	4	3.6	111	15	4	1.5
Sample Size (N)	127	127	127	114	36	36	36	36	112	112	112	104

Derived from Jacques Whitford, MOE, AMEC data. For a listing of data please refer to Volume III

Table ES-2 Soil CoCs in Woodlots

Calculation	Primary Study Area (mg/kg)				Secondary Study Area (mg/kg)				Reference Area (mg/kg)			
	Ni	Cu	Co	As	Ni	Cu	Co	As	Ni	Cu	Co	As
Min	303	52	9	4.0	126	31	7	2.8	16	8	1	0.9
Max	33000	3930	427	137.0	2110	275	57	15.4	185	55	12	11.0
Mean	7158	921	110	43.1	777	115	22	7.5	96	28	7	5.6
SD	8196	1083	112	40.6	540	62	13	3.2	51	15	3	2.6
N	38				17				23			

Derived from Jacques Whitford and MOE data. For a listing of data refer to Volume III

Further analysis of the distribution of the CoCs in the local soils determined that woodlots nearest the Refinery had the highest concentrations, when compared to fields, and that the highest levels in woodlots were found on the western, windward edge of the woodlots closest to the Refinery (Table ES-3).

Table ES-3 A Comparison of Soil Nickel Concentrations in Woodlots and Adjacent Fields at Various Distances from the Inco Refinery

Approximate Linear Distance of Woodlot from Refinery (km)	Woodlot Soil Ni Concentration (mg/kg)	Approximate Linear Distance of Woodlot from Adjacent Field (km)	Adjacent Field Ni Concentration (mg/kg)
1.0	33 000 (A3-0-5)	0.35	1860 (I-H-3)
4.2	709 (LL6)	0.7	145 (I-M-2)
4.8	550 (LL10)	0.4	156 (I-M-4)

*Code in brackets represents field sample/laboratory code.

Sampling of sediments in ponds and ditches found that CoC concentrations in sediment generally follow a pattern similar to soil CoCs, with the CoC concentrations increasing in sediment as one moves closer to the source of the emissions. Sampling of surface water found trends related to distance from the source and habitat type. On average, higher nickel concentrations in surface water occur in areas closer to the Refinery. Also, nickel concentrations in surface water were found to be greater in woodlots compared to fields (Table ES-4).

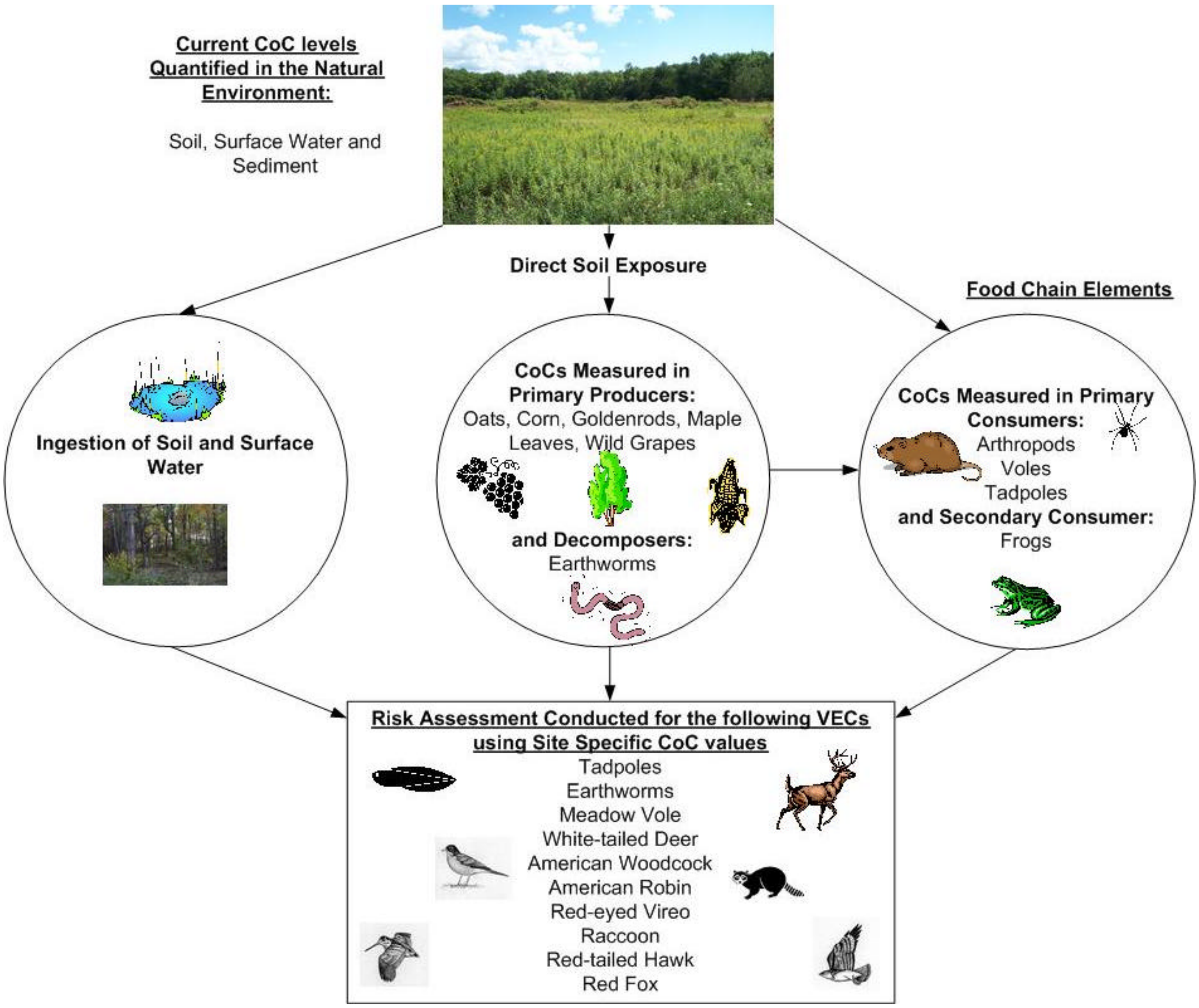
Table ES-4 Mean Surface Water CoC Values

Calculation	Primary Study Area (mg/kg)				Secondary Study Area (mg/kg)				Reference Area (mg/kg)			
	Ni	Cu	Co	As	Ni	Cu	Co	As	Ni	Cu	Co	As
Min	0.004	0.0015	0.0001	0.001	0.003	0.0014	0.0002	0.001	0.001	0.0005	0.0001	0.001
Max	0.884	0.0820	0.0377	0.038	0.092	0.0124	0.0042	0.001	0.013	0.0137	0.0041	0.001
Mean	0.159	0.0179	0.0064	0.004	0.040	0.0063	0.0018	0.001	0.005	0.0045	0.0011	0.001
SD	0.302	0.0295	0.0119	0.011	0.028	0.0035	0.0013	0.001	0.005	0.0045	0.0014	0.001
N	11				13				8			
Mean pH	7.2				7.1				7.3			
Site Codes	(S1-S4,S8,S19-S20,S22,S28,S31-S32)				(S5-S6,S9,S11,S13-S18,S21,S29,S33)				(S23-S26,S34-S37)			

Ambient air quality was monitored between 11 August and 10 September 2001 at various locations in and near Port Colborne. The results of this analysis found CoC ambient air concentrations are elevated in the Study Area when compared to the reference area, however, all measured CoCs in ambient air during this sampling program within the Study Area were within MOE guidelines.

Information gathered for the ERA indicates that historical atmospheric particulate emissions from the Refinery have resulted in deposition of CoCs in soil of the Study Area at concentrations greater than MOE generic soil quality guidelines. The CoCs have been identified to be present in four environmental media: soil, sediment, surface water (in ditches and ponds) and ambient air. Since CoC concentrations in soil exceed MOE Guidelines, a potential risk exists for plants (primary producers) and soil fauna (decomposers) from direct soil exposure, and to fauna through exposure to soil, water and diet. A potential risk to the natural environment is a product of a hazard (CoCs), a receptor (or VEC), and a route of exposure. Thus, a risk to a VEC from a CoC can only occur if there is an operational route of exposure. Based on the assessment of the occurrence of CoCs in the environment, Figure ES-2 presents the conceptual model for the ERA.

Figure ES-2: Schematic Illustration of the Conceptual Model for Natural Environment Receptors



ES3 Ecological Site Characterization

Field investigations and review of existing reports identified that the Port Colborne area is representative of much of the Niagara Region's natural landscape, where only small pockets of historically cut and logged woodlots remain. In this respect, the lands east of the Refinery are typical for the region, with only a highly altered and significantly fragmented natural landscape remaining. Much of the Study Area is agricultural land consisting of cash crops (mostly feed corn), hay/pasture lands and fallow lands. Forested areas, represented by small woodlots, represent only 15% of the Study Area. Due primarily to the rarity of forest habitat in the Niagara Region, two woodlots within the Study Area in close proximity to the Refinery have been identified by the Regional Municipality of Niagara as Environmentally Sensitive Areas. Table ES-5 presents the Significant Natural Areas identified for the ERA.

Table ES-5 Known Significant Natural Areas

Natural Feature		Area (ha)	Designation*
Primary Study Area			
1	Nickel Beach Wetland	58	PSW
2	Nickel Beach Woodlot	47	ESA
Secondary Study Area			
3	Weaver Road Woodlot	82	ESA
4	Humberstone Swamp/Forest	380	PSW, ESA, ANSI

* PSW – Provincially Significant Wetland, as evaluated by the Ontario Wetland Evaluation System, MNR
ESA – Environmentally Sensitive Area, Regional Municipality of Niagara Environmentally Sensitive Area
ANSI – Area of Natural and Scientific Interest, MNR

Within the Study Area, the sand dunes along the lakeshore are, for the most part, disturbed by historical human activity associated with Nickel Beach. Nevertheless, select pockets of the dunes are representative of active dune communities, a community type that is under threat in southern Ontario. In addition the provincially rare Hop-Tree (*Ptelea trifoliata*) is present in this community.

Field investigations found that plant and animal species common to Niagara Region were also found to be widespread and common in the Study Area. No significant obvious gaps in species occurrence or representation were noted during the assessment. Thirty-eight tree species and forty six shrub species were recorded for the Study Area. Although the total area of woodlands in the Study Area is relatively small (<50 ha), the number of woody plant species recorded is considered to represent high species richness for woodlots in southern Ontario. Based on the known distribution of tree and shrub species in the Niagara Region and their habitat requirements, over 90% of the tree species and 80% of the shrub species that should occur were recorded in the Primary Study Area. In addition to the observed species richness, four tree species found to occur in the Primary Study Area are considered rare in the province: Pignut Hickory (*Carya glabra*), Pin Oak (*Quercus palustris*), Swamp White Oak (*Q. bicolor*), and Hop-Tree.

During this study, a total of 78 species of birds were considered to be breeding in the Study Area, the majority of which (80%) were associated with the woodlot habitats. Evidence of breeding was observed for three provincially significant species and for an additional three species considered regionally significant. A total of 20 mammal species were recorded in the Study Area, representing approximately 50% of the Region's mammal species. Mammal species not recorded may well occur in the Study Area, as the vast majority of those species not recorded are small mammals (e.g., bats, shrews, voles and moles) that are difficult to detect and/or identify. Nine species of amphibian and five species of reptile were documented during field surveys. Of particular interest was the identification of a breeding site for the provincially and nationally threatened Fowler's Toad (*Bufo fowleri*), a species which is limited to shoreline dune habitats along the north shore of Lake Erie.

ES4 Receptor Characterization

A critical element of the ERA was the selection of receptors or VECs on which a risk assessment was undertaken. The selection of VECs for the study was based on specific criteria developed for the ERA, on information gathered during site characterisation, and on input from the PLC and MOE. Criteria for determining suitable VECs for this ERA included the following:

- The potential VEC represents organisms in a major trophic level;
- The potential VEC is prevalent in, and typical of, the Study Area;
- The potential VEC represents a major vegetation component in the Study Area;
- The potential VEC is an important ecosystem process; and/or,
- For animals in higher trophic levels, life history and metabolic data necessary for quantitative risk assessment are either readily available or could be estimated using recognized (standard) equations.

Based on these factors, Table ES-6 presents the 14 VECs that were identified for the risk assessment.

Table ES-6 VECs Selected for the ERA

Decomposers	**Plants**	**Birds**
Earthworms	Maple (leaves/seeds)	Red-tailed Hawk
Woodlot litter	Woodlots (tree species)	American Woodcock
(decomposition by invertebrates/		American Robin
bacteria/fungi)		Red-eyed Vireo
Amphibians	**Mammals**	
Frogs, general (adults/tadpoles)	Meadow Voles	
Fowler's Toad	Raccoon	
	Red Fox	
	White-tailed Deer	

ES5 Toxicity and Hazard Assessment

The toxicity assessment attempts to identify how chemicals can enter and move through the environment and their potential effects on biota (e.g., mortality of an individual, reduction in growth, reduced reproduction, etc.). A detailed review of the toxicological properties for each CoC was conducted and evaluated based upon literature pertaining to routes of exposure and site specific properties of the chemical.

Literature reviews for each of the four CoCs were conducted to establish Toxicity Reference Values (TRVs) that are protective of the ecological receptors identified for the ERA. The selection of appropriate endpoints (e.g., mortality or reduced weight) was guided by the protection goals for the ERA. In the current assessment, a sustainable level of a population or ecological functioning was selected as the most appropriate level of protection and thus the assessment goal.

Up to a 20% effect level of a non-severe nature (i.e., Effect Concentration - EC_{20}) was selected in this study as an adequate measure of protection for survival of the species. The 20% effect level has been applied in numerous assessments and criteria for quickly reproducing species such as plants, microbes, earthworms and fish. The 20% effect level or less has been referenced as a No Observable Effect Concentration (NOEC) in plants, soil and litter invertebrates and heterotrophic processes. For slower reproducing species with less dense populations, such as larger mammals, a 20% decrease in population may not be acceptable. For these types of populations, an effect level at or near the Lowest Observable Adverse Effect Level (LOAEL) was considered a more appropriate endpoint, provided the effect is not severe (e.g., reduced weight gain). Where LOAEL for non-severe effects were not available, No Observed Adverse Effect Levels (NOAELs) were considered more appropriate endpoints.

ES6 Exposure Assessment

Exposure to a chemical describes any contact a plant or animal may have to that chemical or media carrying that chemical. The potential exposures of VECs to CoCs were assessed using reasonable exposure pathways and site specific data for various environmental media. Bringing together selected receptor characteristics with routes of exposure and medium-specific CoC concentrations, the exposure assessment established the frequency, duration, and magnitude of potential exposures.

ES6.1 Routes of Exposure

For mammal and bird VECs, potential exposure though ingestion, including water, soil and dietary items, was identified as the primary exposure route. Potential exposure through air inhalation and dermal exposure was not considered in the exposure assessment due to a lack of a developed methodology for evaluation of these exposure routes. For frogs and toads, exposure of tadpoles to CoCs in surface water was identified for evaluation in the exposure assessment. Tadpole ingestion of sediment and diet was identified as a potential CoC exposure route, but no literature based effects to tadpoles due to this exposure route for the CoCs were found. For trees, shrubs and earthworms, exposure to CoCs found in the surface soils was identified as the primary exposure route.

ES6.2 CoC Concentrations in the Environment

Statistical analyses of data found that accumulation of CoCs did vary based on soil types (clay and organic), but that habitat type (fields or woodlot) was generally a poor predictor of accumulation of CoCs. Examination of the data demonstrated that the relationship between the plants and animals to CoCs in soils, sediment and water, and the bioavailability of CoCs through a food chain varies significantly between the four CoCs. However, it is clear that a receptor's tissue concentration of nickel is positively related to nickel concentrations in soil and sediment. This relationship was also found to be similar for cobalt, though not as strongly as for nickel. Increasing concentrations of arsenic in soil, sediment or water were not found to be a reliable predictor of increased concentrations in biological receptors. For copper, only increasing concentrations in aquatic media (water, sediment) were found to be able to predict increased concentrations in aquatic receptors. Increasing concentrations of copper in terrestrial soils did not result in significantly higher concentrations in tissues of terrestrial plants and animals (except for earthworms, where copper in gut soil is related to copper levels in the soil).

ES6.3 Availability of CoCs

A VEC's exposure to CoCs in the environment is dependent on CoC concentrations in soils, water and dietary items. Analyses of animal and plant tissues collected from the Study Area identified that CoC concentrations in biotic receptors are significantly lower than those found in soils, and only very small amounts of CoCs transfer from soils to higher trophic levels. Analyses of soils and vegetation tissue identified that the movement of CoCs through the food chain is significantly reduced due to a soil-plant barrier. These findings indicate that the primary source of exposure to CoCs for primary and secondary consumers in the food chain is through the ingestion of soil.

ES6.4 Bioavailability of CoCs Soil Concentrations

The bioavailability of a CoC describes its ability to be absorbed into the body and reach the blood stream or ability to be taken up by a plant. Many of the selected TRVs used in the ERA are based upon studies that examined specific forms of chemicals that are typically highly bioavailable. However, these forms of chemicals are not necessarily the same as those found in the Port Colborne soils.

For the determination of exposure to CoCs through a VEC's diet, concentrations found in plant and animal tissues were considered to be 100% bioavailable. For nickel in soils, bioavailability experiments using rats and Port Colborne clay and organic soils found that, the percentage relative bioavailability for mammals was 3.2% for organic soils and 3.9% for clay soils, compared to the bioavailability of nickel in the TRV study.

For copper, cobalt and arsenic, the bioaccessibility of these CoCs in Port Colborne clay and organic soils was assessed using a two-stage laboratory extraction method to mimic the stomach digestion and intestinal digestion in humans. The results of these tests of the bioaccessibility of cobalt, copper and arsenic in Port Colborne clay and organic soils are presented in Table ES-7.

Table ES-7 Mean Percent Bioaccessibility of Copper, Cobalt and Arsenic in Port Colborne Organic and Clay Soils using Mammalian Intestinal Phase Extraction.

Soil Type	Stage 2 Mean Percent Bioaccessible (n=2)		
	Cu	Co	As
Organic	5.3	4.2	37.0
Welland Clay	2.9	2.2	13.5

The ERA used the percentage relative bioaccessibility as presented in Table ES-7 to estimate how much copper, cobalt and arsenic is bioavailable to mammals in the Port Colborne area. For nickel, the percentage bioavailability for mammals was used. It is likely that the relative bioavailability of the CoCs for mammals and birds are alike, but given some differences in digestion physiology between birds and mammals, the ERA used double the mammal bioavailability and bioaccessibility values for birds (i.e. an uncertainty factor of 2 was applied).

For tadpoles, CoC concentrations found in surface water were considered to be 100% bioavailable via direct absorption through the skin. For earthworms, the primary exposure route is via concentrations of CoCs in the soil porewater. Concentrations of CoCs in porewater were not directly measured from field collected soils. Rather, results from aqueous extraction and acid ammonium oxalate extraction of clay and organic Port Colborne soils were used.

ES6.5 Medium-Specific CoC Concentrations

Site-specific CoC concentrations were used to estimate the exposure a VEC receives from food items and surrounding media (soil, surface water) when occupying the affected area. Exposure was assessed for different scenarios to help determine risks associated with different soil types or habitats. The exposure scenarios used in the ERA are as follows: overall Study Area (pooling all data from woodlots and fields, organic and clay), fields on clay soils, fields on organic soils, woodlots on clay soils, and woodlots on organic soils. Where possible, the average daily dose (ADD) was derived for each of the scenarios using scenario-specific data sets; these scenario-specific data sets were possible for soils, arthropods and earthworms. Other data sets (e.g., maple leaf tissue concentrations, frog tissue concentrations) could not be separated according to these scenarios; only an overall number was derived for these other data.

To determine what CoC concentrations should be employed to calculate a VEC's ADD, two approaches were followed, where appropriate. Where data were numerous, an Upper Confidence Limit of the Mean (UCLM) was calculated. This is an upper estimate of the mean concentration with 95%. For each set of data, the UCLM was calculated using raw data collected from the Study Area, without transformation, since this gave a more conservative (higher) value than UCLMs calculated on log-transformed data. For several data sets, observations were too few (i.e., less than 10 samples) to derive UCLMs. Instead, actual values from the data were chosen to represent a conservative (over-) estimate of the CoC concentrations available to the VECs from that source. Overall concentrations of CoCs in relevant media are presented in Table ES-8. Scenario-specific values for soils, arthropods and earthworms are presented in ES-9. These values were used to calculate the ADD of the receptors.

Table ES-8 CoC Concentrations in Exposure Media within the Study Area and Local Environs used to Calculate CoC Doses.

	Nickel[7]	Copper[7]	Cobalt[7]	Arsenic[7]
Soil (mg/kg)[1]	2650	350	47	18
Surface Water (mg/l)[6]	0.178	0.018	0.006	0.005
Maple Tissue – leaves (mg/kg)	12.3	10.5	0.4	0.4
Goldenrod Tissue (mg/kg)[3]	29.6	12.4	1.4	0.3
Corn Tissue – seeds (mg/kg) [2,3]	2.7	3.2	0.3	0.2
Oat Tissue – seeds (mg/kg) [2,3]	62.3	6.8	0.2	0.1
Oat Tissue – leaves (mg/kg) [2,3]	23.6	9.9	0.4	1.9
Wild Grape Tissue (mg/kg)	1.6	12.0	0.03	0.1
Frog Tissue (mg/kg)[4]	3.9	36.0	0.4	0.5
Meadow Vole Tissue (mg/kg)[5]	18.6	11.0	1.3	0.6

Notes

1 Based on all data (clay and organic, field and woodlot combined) sampled by MOE and Jacques Whitford in the Study Area and within 2km of the eastern boundary. Only data from the 0-5cm depth were used.
2 Calculated from analytical results of crops growing on unamended clay soils and, for corn, supplementary 2002 sampling.
3 Data on which these calculations are based are available in Jacques Whitford (2003a).
4 Based on total frog (weighted average of tissue concentrations, using mass)
5 Based on total vole (weighted average of tissue concentrations, using mass)
6 Total CoC concentration.
7 Identification of values as either UCLMs or maximums is presented in Table 6-16.

Table ES-9 CoC Concentrations in Soils, Arthropods and Earthworms within the Study Area used to Calculate CoC Doses for the Four Habitat/Soil Type Scenarios.

		Clay		Organic	
		Woodlot	Field	Woodlot	Field
Soil	**Ni**	1630	1090	15,200	2020
	Cu	180	140	2020	308
	Co	33	27	219	37
	As	12	8	83	20
Worms[1]	**Ni**[2]	180	180	180	180
	Cu[2]	52	52	52	52
	Co	10.1	13.7	21.9	10.6
	As	4.2	9.6	8.9	8.2
Arthropods	**Ni**[2]	12.5	12.5	12.5	12.5
	Cu	29.6	57.0	72.6	44.6
	Co[2]	0.46	0.46	0.46	0.46
	As	0.3	0.3	0.8	0.5

Notes

1 Corrected using ratios in Table 6-10.

2 UCLM of all scenarios combined.

ES7 Risk Characterization

The ERA approach for assessing risk to the ERA's VECs involved two series of analyses. The first analysis was a statistical examination of the relationship between ecological variables, such as biomass, and concentrations of CoCs in the local environment. The second analysis was an empirical evaluation of the presumed risk to which a VEC is subject. This was based on the Quotient Method using toxicity reference values (TRVs) taken from published studies and an average daily dose (calculated using site-specific data and parameter estimates based on other published studies) or an estimated exposure concentration. A quotient is derived by dividing the TRV into the average daily dose or exposure concentration. Following the Quotient Method, a calculated ratio of greater than one was considered to represent a potential risk that should be more closely examined. A quotient value of less than one was considered to indicate that no adverse effects are expected.

Taken as a whole, the risk to receptors was assessed using a line of evidence approach, with the characterization of risk integrating results of the conservative risk calculations following the Quotient Method, qualitative field observations and experimental results for specific VECs. Following the examination of these lines of evidence, characterization of risk was based on informed professional judgement to reach conclusions of whether VECs are potentially at risk.

Generally, the study found that the populations of primary producers (plants), secondary consumers (birds, mammals, frogs/toads) and top predators (birds and mammals) are not at risk in the Study Area. However, the study identified that very high levels of CoCs in the woodlots nearest the Refinery, on organic soils, are likely having an adverse effect on the decomposer community. This potential adverse effect was indicated by lower numbers of earthworms and increased amounts of forest litter found in these woodlots. However, the level of the effect on the decomposer community, and therefore the nutrient cycle, in these woodlots, is not at a level that is impacting long-term health or productivity of these woodlots.

A summary of the overall evaluation of the results is presented below.

ES7.1 Decomposers

For an assessment of risk to the soil decomposer fauna, earthworms were studied in the field and in controlled toxicity tests. Potential risk was also calculated following the Quotient Method based on a review of published TRVs and soil CoC concentrations. Results of these lines of evidence were found not be supportive of one another with respect to what concentrations of soil CoCs produce a potential adverse effect. Ultimately, the results of field observations and studies, which sampled the earthworm community to document species richness, overall abundance and overall biomass, were considered the most reasonable line of evidence to assess risk to earthworms. The results showed that no negative response to increases in soil CoC concentrations was evident. Only for soils with very high concentrations of nickel (20,000 mg/kg) and copper (3600 mg/kg) were significant reductions in species richness and abundances of earthworms found. However, even in these soils, reproduction was found to occur. The results of the study found that the earthworm species populations across the Study Area are not at significant risk due to exposure to CoCs in soil.

In addition to the assessment of earthworms, potential impacts to decomposition of forest litter and the nutrient cycle was assessed by measuring standing litter (dry weight) in woodlots in the Study Area and control reference sites. Investigations into litter found that increasing soil CoCs were likely resulting in slower rates of decomposition, particularly for woodlots on organic soils nearest to the Refinery. However, although the rate of decomposition may be slowed, current rates of decomposition are sufficient to maintain equilibrium between fresh litter input and amount of litter decomposing each year. This assessment indicates that no significant impairment in the woodlots' nutrient cycles is occurring. This result is supported by the general assessment of individual woodlots, which found that there was no significant difference in woodlot productivity in the Study Area when compared to woodlots in reference sites. This was true even for woodlots located nearest to the Refinery where the highest soil CoC concentrations were recorded for the study (i.e., 33,000 mg/kg Ni). Based on the assessment of a number of different but linked factors, the ERA concludes that existing soil CoC levels found in the woodlots of the Study Area do not pose a significant adverse effect on the nutrient cycle or a risk to woodlot health, either for the short term or long term.

ES7.2 Woody Vascular Plants

For this component of the ERA, assessment of risk to woody vascular plants was undertaken through the field inventory of tree and shrub species, and a detailed assessment of potential risk to maple trees. Assessment of risk to non-woody vascular plants is addressed based on the results of the ERA-Crops Studies. Soft maple (including Red Maple, *Acer rubrum*, and Freeman's Maple, *A. X freemani*) was identified as representative of woody vascular plants. These trees are the predominant trees species of the Study Area's woodlots, and soft maple is reported in the literature to be sensitive to soil metals, including nickel.

Assessment of risk of soil CoCs to maple trees was undertaken following three lines of evidence: 1) maple seed germination and sapling growth in a controlled greenhouse setting; 2) leaf health assessment of naturally occurring maples trees east of the Refinery; and, 3) a general woodlot health assessment.

Greenhouse experiments that assessed maple seed germination success, sapling growth and leaf health found that no significant negative effect was found for clay or organic soils for varying soil nickel concentrations up to 3000 mg/kg of nickel. Assessment of leaf health for leaves collected from trees in the Study Area found that existing levels of CoCs in the soils did not have a significant influence on the frequency or incidence of unhealthy leaves. A review of the concentrations of CoCs in leaf tissue for trees in the area with highest soil nickel concentrations (over 20,000 mg/kg for nickel) found that tissue levels are below the MOE current upper limit of normal concentrations for metals in tree foliage. In addition, an assessment of woodlot health for 18 woodlots in the Study Area, many of which had maples as a predominant component, found no significant difference in stand structure or productivity when compared to areas with different soil CoC concentrations within the Study Area or control reference woodlots located east and west of the Study Area.

It is concluded that existing soil CoC levels as found in the Study Area do not pose an unacceptable risk to maple tree populations, measured as either long term health of trees or decrease in populations. In addition, as soft maple had been identified as a sensitive species to soil metals, the low potential risk identified for this species indicates that populations of other woody vascular plant species in the Study Area are also not at risk. This conclusion is also supported by field inventory results, which documented a high species diversity of trees and shrubs in the Study Area.

ES7.3 Amphibians

Frogs and toads were examined to determine if existing soil CoC levels, as reflected in surface water concentrations, are having significant adverse effects on their populations. Two lines of evidence were used in the assessment: 1) potential risk to tadpoles using the Quotient Method; and, 2) the collection of field data to record the incidence and relative abundance of local frogs in the Study Area. Based on the assumption of 100% exposure to concentrations of CoCs in breeding ponds sampled, tadpoles are not at risk due to exposure to arsenic and cobalt concentrations. However, the analysis identified that nickel and copper concentrations in pond water pose a potential risk to tadpoles, with the calculated quotient values of 18 and 2 respectively. For the rare Fowler's Toad, the nickel TRV specific to this species and low levels of the CoCs in its specific breeding environment (the lakeshore) give a calculated quotient of 0.05 for nickel and <0.01 for copper. Therefore, the potential that this species is at risk is very low. For other frog and toad species, it was determined that approximately 80% of the ponds sampled throughout the Study Area have nickel concentrations that would put tadpoles potentially at risk, based on sensitive TRVs derived from the literature.

Structured spring field surveys conducted throughout the Study Area found that frog and toad species richness, incidence and relative abundance (based on calling codes) were not influenced by soil nickel concentrations. Based on this line of evidence, the calculated potential risk for nickel and copper was not found to be supported by general field observations or an analysis of field data as it relates to soil nickel in the Study Area. However, based on field surveys of calling male frogs, it was noted that the expected very high densities at quality breeding sites for some species (Spring Peeper, Chorus Frog) were not encountered. These observations indicate, at least qualitatively, that there may be some suppression in population numbers, but not at levels that affect the long term persistence of the frog and toad populations in the Study Area. Based on all available information, it is concluded that the potential risk of soil CoCs adversely affecting the maintenance of frog and toad populations in the Study Area is low.

ES7.4 Birds and Mammals

To assess the risk to terrestrial vertebrates, four species of bird and four species of mammal were identified as VECs for which risk calculations would be undertaken. Collectively, these species were selected because they represent species that occur in the Study Area and have life histories that are representative of the mammal and bird species known to occur in the Study Area. In addition, the species represent primary and secondary consumers in the ecosystem with specific and generalist dietary requirements. Taken as a whole, assessment of potential risk to these eight species is considered to represent an assessment of potential risk to all mammal and bird species that have been documented to occur in the Study Area.

Only the Quotient Method was used to determine the potential risk posed by soil CoC concentrations to these species. For the exposure assessment, the expected average daily dose (ADD) was calculated from biological tissue, water, and soil collected from the Study Area. The use of an extensive set of data collected from the Study Area for the determination of the ADD for each receptor significantly increases the relevance of the calculated risk quotients.

A summary of the findings of risk characterization for the eight receptors is provided in Table ES-10 below. For a measure of the uncertainty of the Quotient Method, values which are <0.1 are considered to represent a high certainty of no risk. For values greater than one, a possible risk cannot be ruled out based on the analysis performed.

Table ES-10 Summary of Calculated Quotient for Birds and Mammals

Receptor	Calculated Quotient for CoCs (Highest value of all soil types and habitat types)			
	Ni	Cu	Co	As
Red-tailed Hawk	0.01	0.01	0.01	0.01
American Woodcock	0.24	0.12	0.50	0.21
American Robin	0.12	0.18	0.11	0.11
Red-eyed Vireo	0.07	0.27	0.05	0.07
Meadow Vole	0.18	0.01	<0.01	0.03
White-tailed Deer	0.03	0.03	<0.01	0.01
Racoon	0.13	0.28	0.01	0.07
Red Fox	0.05	0.09	0.01	0.07

The results of the assessment show that the potential risk of soil CoCs to bird and mammal populations of the Study Area is very low. The assessment found that no receptor was considered to be at risk on clay soils or organic soils associated with field or woodlot habitats. The calculated quotients for birds and mammals are low, even where high levels of soil CoCs occur, due to the fact that the occurrence of the four CoCs in the environment is significantly reduced at the soil-plant interface, thereby restricting the transfer of CoCs through subsequent trophic levels. For the bird and mammal species assessed, the American Woodcock can be considered to be the most sensitive to CoCs in the environment, as this species' diet consists of earthworms that contain soils in their gut and are captured by the bird by probing soils. However, even for this species, using exposure data for organic soil woodlots with 15,200 mg/kg soil nickel, the calculated average daily dose for nickel was 14.29 (mg/kg d) resulting in a quotient of only 0.24, a ratio that is well below our potential risk threshold of 1.

Based on this study's findings, it is concluded that existing soil CoC concentrations in the Study Area do not present an unacceptable risk to the populations of mammals and birds found in the Study Area. This conclusion is supported by field observations, which noted a high number of bird and mammal species occurring at expected abundance levels.

ES8 Uncertainty Analysis

In an attempt to limit the uncertainty in the ERA, while still ensuring its desired conservative nature, the ERA has:

- Collected a considerable amount of site specific biogeochemical data on CoC concentrations in the Port Colborne area;
- Conducted numerous laboratory studies using Port Colborne soils; and,
- Conducted a rigorous review of literature values selected for use in all aspects of the ERA.

The overall confidence in the risk characterization is considered high and the potential risks to VECs in the Port Colborne area are not underestimated. The use of Port Colborne specific data, scientifically defensible and regulatory accepted data from the literature, coupled with scientifically credible sampling and analysis protocols, has produced an ecological risk assessment with a high degree of confidence in its conclusions.

ES9 Conclusions

For the ERA, detailed assessment of potential risk was undertaken for 14 ecological components (VECs), including mammal and bird species, amphibians (frogs and toads), earthworms, maple trees, leaf litter and woodlots. Combined, the VECs selected were considered representative of the species and ecological processes in the local area's natural environment. An assessment of potential risk to these VECs was used to determine if existing CoC soil concentrations represent a risk to the local natural environment, both now and into the future.

The objective of the CBRA was to assess the risk of adverse effects, at the scale of the community, caused by soil concentrations of CoCs. For this ERA, risk was considered unacceptable if soil concentrations of CoCs are at a level that prevents sustainability of ***population(s)*** of flora and fauna or to prevent the sustainability of ecological functioning within the defined Study Area. Based on both qualitative and quantitative assessments, the evaluation of potential risk to the Study Area's flora, fauna, and natural processes found no unacceptable risk. This description of risk to the natural environment is based on analysis of an extensive series of data specific to the soils of the Port Colborne area. In addition, the study's sampling design allowed for the collection of data in natural areas with the highest soil concentrations of the four CoCs.

Following a number of lines of evidence to assess potential risk caused by soil CoCs, no unacceptable risk to elements of the natural environment in the Study Area as a whole was identified. As a result of these findings, no *immediate* need to mitigate or manage risk to the natural environment has been identified.

ES10 Recommendations

The results of this assessment indicate that current concentrations of nickel, copper, cobalt and arsenic in the Port Colborne environment do not pose an unacceptable risk to the local populations of flora (trees, shrubs) and fauna. However the study did identify that very high soil concentrations of CoCs (>20,000 mg Ni/kg) in woodlots located directly adjacent to the Refinery site is potentially causing a local effect on earthworm abundance. Additionally, these high soil CoC concentrations may be affecting other soil decomposers, as indicated by an assessment of leaf litter decomposition. Even though these localized potential effects are not found elsewhere in the Study Area and CoCs do not pose a risk to the earthworm community or the productivity of woodlots in the Study Area on the whole, it is recommended that management of potential risk to the natural elements of these woodlots should be considered.

Based on the assessment of risk for the various VECs considered in this ERA, it is proposed that potential risk to earthworms be considered to determine "safe" soil CoC values for the purpose of assessing future management options. This recommendation is based on the following considerations:

- Earthworms, as soil-dwelling animals, have the greatest exposure to soil CoCs;
- Due to their low mobility in the environment, local earthworm communities are at a higher potential risk in woodlots and fields with high CoC concentrations;
- Earthworms are a key component for decomposition and the nutrient cycle, a process that has been identified as potentially impaired in woodlots with high soil CoCs based on an assessment of leaf litter; and,
- A "safe" soil CoC concentration for earthworms would be protective for other flora and fauna that inhabit these areas of high soil CoCs.

Based on a review of the three lines of evidence, Table ES-11 presents the recommended "safe" soil CoC concentrations based on potential adverse effects to earthworms as identified by the ERA. "Safe" soil concentrations of nickel and copper are derived from the results of soil sampling, balanced with consideration for literature-derived TRVs. "Safe" cobalt concentrations for earthworms are derived from the TRV. "Safe" arsenic concentrations in clay soils are derived from MOE's generic table guidelines, while the results of field surveys are the basis for "safe" arsenic concentrations in organic soils.

Table ES-11 Recommended "Safe" Soil CoC Concentrations for Earthworms

Soil Type	Safe Soil CoC Concentration (mg/kg) for Earthworms			
	Ni	**Cu**	**Co**	**As**
Organic	3500	550	3000	40
Clay	3000	350	3000	25

It is not known which of the CoCs, or a combination of CoCs, is responsible for an observed effect in the field surveys or toxicity tests. However, for the woodlots on organic soil with very high nickel concentrations, it is assumed that nickel is the major cause of the observed effect. As a result, it is recommended that management options for these woodlots should target the reduction of soil nickel concentrations.

LIST OF REPORTS FOR THE

PORT COLBORNE COMMUNITY BASED RISK ASSESSMENT

Technical Scope of Work – Community Based Risk Assessment Plan for Port Colborne, Ontario. JW Project No. 33826. November 2000.

Summary Report on Chemicals of Concern Evaluation. Port Colborne Community Based Risk Assessment, Port Colborne, Ontario, JW Project No. 34645. November 2001.

Potential CoC Identification using Soil Chemical Concentration Data in Exceedance of MOE Generic Guidelines. Port Colborne Community Based Risk Assessment, Port Colborne, Ontario, JW Project No. 34645. November 2001.

Potential CoC Identification Using Emission Inventories and Dispersion Modelling of Inco and Algoma Operations. JW Project No. 34648. November 2001.

Potential CoC Identification using Statistical Analyses . Port Colborne Community Based Risk Assessment, Port Colborne, Ontario, JW Project No. 34647. November 2001.

Re-evaluation of Lead as a Potential Chemical of Concern (CoC). . Port Colborne Community Based Risk Assessment, Port Colborne, Ontario, Volume 1-Main Report, JW Project No. 35313. June 2004.

Bioaccessibility of Copper, Nickel, Cobalt and Arsenic in Soils Northeast of Inco Refinery, Port Colborne. Environmental Sciences Group, Royal Military College, Kingston, Ontario, Queen's University Analytical Services Unit, Kingston, Ontario. November 2002.

Port Colborne CBRA - Human Health Risk Assessment, Volume I - Main Report. Jacques Whitford Limited. December 2004.

Port Colborne CBRA - Human Health Risk Assessment, Volume II through V – Supporting Documentation. Jacques Whitford Limited. December 2004.

Port Colborne CBRA – Ecological Risk Assessment-Natural Environment, Volume I – Main Report. Jacques Whitford. September 2004.

Port Colborne CBRA – Ecological Risk Assessment-Natural Environment, Volume I through V – Supporting Documentation. Jacques Whitford. September 2004.

Port Colborne CBRA – Crop Studies, Volume I – Main Report. Jacques Whitford Limited. In Press.

Port Colborne CBRA – Crop Studies, Volume II through IV – Supporting Documentation. Jacques Whitford Limited. In Press.

GLOSSARY OF ABBREVIATIONS AND ACRONYMS

Acceptable risk	-	A level of risk to flora and fauna due exposure to CoCs in Port Colborne soils that is acceptable to the Ontario Ministry of the Environment.
ADD	-	Average Daily Dose
Analyte	-	The substance one analyses in an experiment.
ANSI	-	Area of Natural and Scientific Interest as identified by the Ontario Ministry of Natural Resources.
Aqueous	-	A water based solution.
Arthropod	-	Phylum (including major classes Insecta, Crustacea, Myriapoda, Arachnida), characterised by a rigid external skeleton, paired and jointed legs and a haemocoel (cavity where organs are).
As	-	Symbol for the metalloid arsenic.
BAF	-	Bioaccumulation Factors.
Basal Area	-	The total area of a forest plot covered by the area a tree trunks.
Beak	-	Beak International Inc., the PLC's consultant for the CBRA. Now known as Stantec Limited.
Bioaccumulate	-	To accumulate into a biological system.
Bioavailability	-	The fraction of a total chemical that can interact with a biological target (e.g., a plant or animal).
Bioconcentration	-	The increase in concentration of a chemical in an organism resulting from tissue absorption levels exceeding the rate of metabolism and excretion.
Biomagnify	-	Increase in concentration of a chemical from one link in a food chain to another.
Biomass	-	Total mass of living matter within a given unit of environmental area.
Biota	-	All living organisms in an environment.
Biotic Receptor	-	An organism or group of organisms in an environment that in a risk assessment is/are identified as being potentially exposed to chemicals of concern.
BW	-	Body Weight.
CBRA	-	Community Based Risk Assessment.
CCME	-	Canadian Council of Ministers of the Environment.
CEC	-	Cation Exchange Capacity.
City	-	The City of Port Colborne.

GLOSSARY OF ABBREVIATIONS AND ACRONYMS
(Continued)

Clay Soils	-	Mineral soils where soil particles of <0.002 mm diameter represent 30% of the soil.
Closure Plan	-	A plan developed by Inco to be submitted to the Ontario Ministry of the Environment detailing the requirements for the closure of the Port Colborne Inco Refinery Site.
Co	-	Symbol for the metal element cobalt.
CO_2	-	Carbon dioxide.
CoCs	-	Chemicals of concern, identified for the CBRA. The CoCs are as follows, nickel, copper, cobalt, and arsenic.
Community	-	All potential receptors (human and ecological) within an area of Port Colborne defined by previous MOE studies as having concentrations of CoCs in soil from Inco's historical operations above the MOE generic Table A guideline.
Confidence Limits	-	An interval estimate for the mean, generating an upper and lower limit for the mean. These limits give an indication of how much uncertainty there is in the estimate of the true mean.
COSEWIC	-	Committee of the Status of Endangered Wildlife in Canada. A committee that ranks species rarity in Canada based on a number of criteria
Cu	-	Symbol for the metal element copper.
Detritus	-	Dead and decaying plant organic matter.
Dose-Response Experiments	-	Experiments designed to identify the concentration or amount of a substance that result in a measured effect on a test receptor.
Downwind	-	In the direction towards which the wind blows – prevailing winds from the southwest distribute the majority of particulate emissions in a northeast direction across the Study area
DTPA	-	Diethylenetriamine pentaacetic acid
DW	-	Dry Weight. The mass of dried tissue (dry matter) remaining from plant parts after drying in an oven at 65 ° C for a time period allowing the plant matter to reach a stable dried weight (48 to 72 hours).
EC_{20}	-	Effects Concentration where 20% of the population shows an effect.
EC_{50}	-	Effects Concentration where 50% of the population shows an effect.

GLOSSARY OF ABBREVIATIONS AND ACRONYMS
(Continued)

Edaphic Factors	-	Factors pertaining to soil.
ELC	-	Ecological Land Classification. A standard method for defining amd mapping vegetation communities.
Emissions	-	That which is sent out, or put in circulation.
EQL	-	Estimated Quantitation Limit the lowest level of a parameter that can be identified with confidence by an analytical laboratory.
ERA	-	Ecological Risk Assessment, as defined in the TSOW.
ERA Study Area	-	Area of land located east of the Welland Canal where risk of soil CoCs to flora and fauna is assessed. Specifically, natural or agricultural lands where soils contain nickel concentrations of 200 mg/kg or greater occur, based on data collected in 1998 and 1999 by the Ontario Ministry of the Environment, excluding residential areas, the Inco Refinery site proper and large quarry located northeast of the refinery.
ESA	-	Environmental Sensitive Area, as identified by the Niagara Region.
Exposure Pathway	-	Routes for transfer of CoCs to biotic receptors.
Fallow	-	Agricultural lands not in active crop production.
Fauna	-	Animal life.
Fields	-	Lands were cover by woody species (trees and shrubs) is 25% or less, including agricultural lands that are either actively cultivated or fallow.
Flora	-	Plant life.
glm	-	Generalized linear models. A statistical analysis method.
GPS	-	Global Positioning System. Refers to a method for accurately determining locations on the surface of the earth using electronic triangulation using satellites.
HCl	-	Hydrochloric acid.
Heterogeneous	-	Made up of parts that are not alike, or varied.
HGAA	-	Hydride Generation Atomic Absorption.
HHRA	-	Human Health Risk Assessment, as defined in the TSOW.
HI-	-	Hazard Index.
Hybrid	-	The offspring of two animals or plants of different species or varieties.

GLOSSARY OF ABBREVIATIONS AND ACRONYMS
(Continued)

IBA	-	Important Bird Area.
ICPMS	-	Inductively Coupled Plasma Mass Spectrometry. An analytical technique used for the detection of trace elements in environmental samples.
ILCR -	-	Incremental Lifetime Cancer Risk.
In vivo	-	In the living body of an animal.
In vitro	-	Outside the living body and in an artificial environment.
Inco	-	Inco Limited.
Ingestion	-	To take into body by mouth for digestion or absorption.
Invertebrates	-	mites, collembola, nematodes, earthworms, insects, millipedes, molluscs.
Isolines / Isopleths	-	Lines used to represent points of equal value.
Jacques Whitford	-	Jacques Whitford Limited.
LC_{50}	-	Lethal Concentration, where 50% of the population dies.
LCL	-	Lower Confidence Limit.
LD_{50}	-	Lethal dose where 50% of a test population dies.
Line of evidence approach	-	Information derived from different sources or by different techniques that can be used to describe and interpret risk estimates. Unlike the term "weight of evidence", it does not necessarily imply assignment of quantitative weightings to information.
LOAEL	-	Lowest Observed Adverse Effects Level. A level at which an adverse effect is first measurable for a receptor. Typically used as an assessment endpoint in conducting risk analysis.
LOEC	-	Lowest Observed Effect Concentration. A concentration of a chemical at which an effect is first measurable for a receptor. Typically used as an endpoint in conducting risk analysis.
Microbes	-	Bacteria, fungi & protozoa.
Mg/kg-day	-	Milligrams of chemical exposure or dose per kilogram body weight per day.
MNR	-	Ontario Ministry of Natural Resources.
MOE	-	Ontario Ministry of the Environment.
NAWQC	-	National Ambient Water Quality Criteria.
NC	-	not calculated (due to small sample size).

GLOSSARY OF ABBREVIATIONS AND ACRONYMS
(Continued)

ND	-	Non-detect, or non-detectable.
NHIC	-	Natural Heritage Information Centre, A data base compiled and administered by the Ontario Ministry of Natural Resources.
Ni	-	Symbol for the metal element nickel.
NOAEL	-	No Observed Adverse Effects Level. A level at which no adverse effect is measurable for a receptor. Typically used as an assessment endpoint in conducting risk analysis.
NOEC	-	No Observed Effects Concentration. A concentration of a chemical at which no effect is measurable for a receptor. Typically used as an endpoint in conducting risk analysis.
Non-linear regression models	-	Regression models in which the terms do not enter in a purely additive fashion.
OMAFRA	-	Ontario Ministry of Agriculture Food & Rural Affairs
Order of Magnitude	-	An exponential change of plus or minus 1 in the value of a quantity or unit. Generally used in conjunction with power of 10 scientific notation.
Organic Soils	-	Soil of 40 cm or depth with 30% or more organic matter, or 17% or more organic carbon.
PCBs	-	Polychlorinated Biphenyls.
Phytotoxicity	-	Being toxic to plants.
PLC	-	The Public Liaison Committee of the City of Port Colborne CBRA.
Port Colborne area	-	The City of Port Colborne and the rural regions around it potentially impacted by historical emissions of CoCs from the Inco Refinery.
ppm	-	Parts per million – equivalent to milligrams of analyte per kilogram of medium (mg/kg) or milligrams per litre (mg/l).
Primary Consumers	-	Soil and terrestrial invertebrates & and planting vertebrates.
Primary Producers	-	(soil microfauna & plants).
Primary Study Area	-	Lands with the Study Area where soil nickel concentration are greater or equal to 500 mg/kg.
Proponent	-	A supporter of something.
Protocol	-	Sets of procedures used to define how the Phytotoxicity Testing was to be carried out. These were presented to and reviewed by Beak, the TSC and the PLC.

GLOSSARY OF ABBREVIATIONS AND ACRONYMS
(Continued)

PSC	-	PSC Analytical Services.
PSW	-	Provincially Significant Wetland.
Purged (worms)	-	Worms that have no food or soils in their gut.
Quadrants	-	A standard square measure with a defined area used to standardised the collection of field data.
Qualitative	-	Of, relating to, or expressed as a quality, not a measured amount.
Quantitative	-	Of, relating to, or expressed as a quantity, measure or amount.
Quotient Method	-	A standardised risk assessment method using estimated dose exposure of a CoC to a receptor against a literature based toxicity dose value for the CoC and receptor or surrogate.
Receptor	-	Ecosystem component, biotic or abiotic, that is exposed to Chemicals of Concern.
Reference Area	-	For the purpose of this ERA, a reference area is defined as any area where the soil value of nickel is below 200 mg/kg.
Refinery	-	The Inco facility at Port Colborne, Ontario.
RfD	-	Reference Dose.
SD	-	Standard deviation.
Secondary Consumers	-	(birds, mammals, amphibians).
Secondary Study Area	-	Lands within the Study Area where soil nickel concentration are between 200 and 500 mg/kg.
Sediment	-	Mineral and organic matter that has settled to the bottom of a lake, pond or stream.
SRM	-	Standard Reference Materials.
SSRA	-	Site Specific Risk Assessment.
Stantec	-	The PLC's consultant.
Top predators	-	A bird or mammal that is located at the top of a food chain.
Toxicological	-	Pertaining to toxicology, the study of toxins and their effect.
Transect	-	A straight line through a woodlot or field along which field data is collected.
Trophic Level	-	A level within the food chain.
TRV -	-	Toxicity Reference Value.
TSC -	-	Technical Sub-Committee to the PLC.
TSOW	-	Technical Scope of Work.
TSP -	-	Total Suspended Particulate Matter in air.

GLOSSARY OF ABBREVIATIONS AND ACRONYMS
(Continued)

UCL	-	Upper Confidence Limit.
UCLM -	-	Upper Confidence Limit for the Mean.
USEPA -	-	United States Environmental Protection Agency.
Unacceptable Risk	-	For the characterisation of risk for this ERA, an unacceptable risk to a VEC's population is defined as an estimated risk linked to the occurrence of soil concentrations of CoCs that prevents sustainable population(s) of flora and fauna or sustainable level of ecological functioning within the defined study area.
VEC	-	Valued Ecological Component, a species, population or process identified for conducting Risk Assessment.
VEC's Population	-	For the purpose of this ERA, a VEC's population is defined as all individuals of species (plant or animal) that inhabit or occur within the entire Study Area as defined by this ERA.
Woodlots	-	Natural forested habitats where trees (woody vegetation greater than 6 m in height) cover 60% or more of an area.

LIST OF ECOLOGICAL RISK ASSESSMENT VOLUMES

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CHAPTER 10

CHAPTER 11

1.0 INTRODUCTION

This report presents details on the Ecological Risk Assessment – Natural Environment (ERA), conducted for Inco Limited (Inco) by Jacques Whitford Limited (Jacques Whitford) as part of the Port Colborne Community Based Risk Assessment (CBRA). The following sections provide information on the purpose of the study, its objectives and general approach, background to the CBRA process and the ERA in particular, and information on how this five-volume report is structured.

1.1 The Port Colborne CBRA

The City of Port Colborne is located along the north shore of Lake Erie in the Regional Municipality of Niagara, in southern Ontario (Figure 1-1). The Welland Canal divides the City into east and west, and runs north-south across the Niagara Peninsula from the City of Port Colborne northward to Lake Ontario at the City of St. Catharines. The City of Port Colborne has a population of 18,450. Over 80% of the City's developed areas (commercial/residential) lie on the west side of the Canal.

The Inco Refinery is located on the east side of the City, adjacent to Nickel Beach on the north shore of Lake Erie and approximately half a kilometre east of the Welland Canal (Figure 1-1). Small residential communities lie directly adjacent to the refinery lands to the west and north. Rural agricultural lands lie to the east and northeast of the refinery site.

Inco has operated a nickel refinery in the City of Port Colborne since 1918. Peak commercial production for nickel occurred during the 1940s and operations for the production of electrolytic nickel ended in 1984. Refinery operations during the period 1920-1960 accounted for the majority of particulate emissions to the local environment that have resulted in increased levels of metals in soil, particularly downwind from the refinery site.

The Ontario Ministry of the Environment (MOE) has conducted sampling over the past three decades to determine the levels of metals in soil and has reported their results and findings (e.g., two reports presented in 2000 summarized phytotoxicity soil investigations done during 1998 and 1999). Inco has acknowledged responsibility for airborne dust emissions resulting from their operations and is the proponent of the CBRA process, to assess the potential environmental and human health risks from these residual depositions in soils.

Ecological Risk Assessment - Natural Environment - Community Based Risk Assessment - Port Colborne, ON

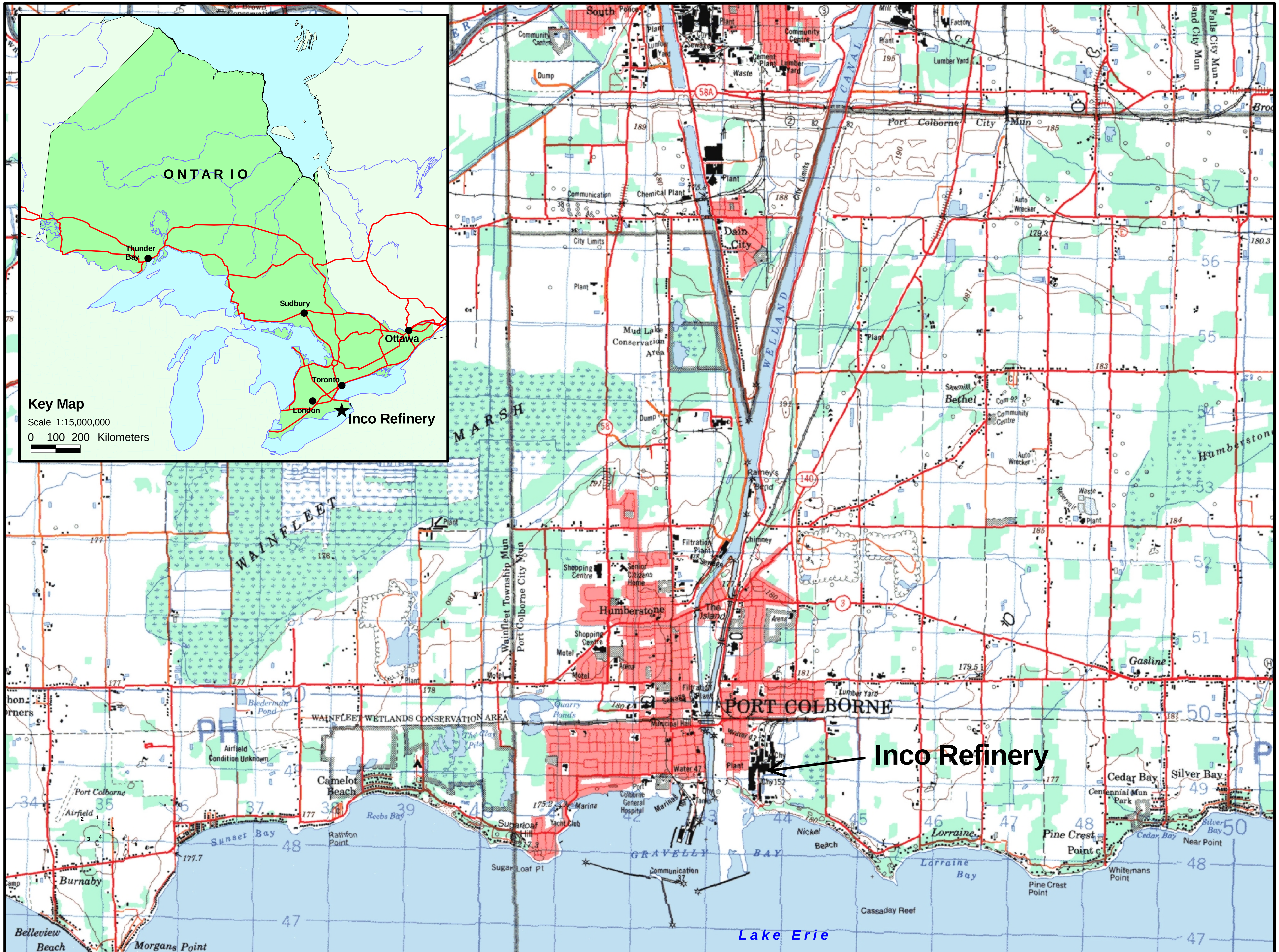


Figure 1-1

Geographic Location of Port Colborne

0 1 2 3

Kilometres

N

Legend

- Roads
- Drainage
- Waterbody

Job Number: ONT34644
Date: October 2003
Dwn by: C. Amirault
Approved by: Oliver Curran

Map Parameters
Projection: UTM
Datum: NAD 83

Regional NIAGARA

Jacques Whitford

Consulting Engineers
Environmental Scientists
Risk Consultants

.../AV_Projects/ERA_Figures.APR

1.2 Purpose of the CBRA

Inco has committed itself to the community of Port Colborne (represented by the Public Liaison Committee, or PLC), the City of Port Colborne (the City) and the MOE, to conduct a CBRA. The CBRA was conducted for chemicals of concern (CoCs – Nickel, Copper, Cobalt and Arsenic) in the Port Colborne area that have elevated concentrations in soil as a result of historical emissions from Inco's refinery. The ERA is one component of the overall CBRA process. The components of the CBRA process include:

- An evaluation to confirm that all relevant CoCs have been considered;
- A quantitative ERA (***the focus of this report)***;
- Quantitative crop studies (phytotoxicity testing);
- A quantitative human health risk assessment (HHRA); and,
- An evaluation of all applicable remediation options.

Components of the CBRA, other than the ERA, are reported under separate cover. Details regarding the CBRA process are presented in Section 1.3.

1.3 CBRA Process

Inco is committed to resolving potential health issues that could result as a consequence of Inco's historical operations through the development of effective and practical risk management solutions that protect human health and the environment. Within the MOE's 1997 *Guideline for Use at Contaminated Sites in Ontario*, there are several approaches that can be used by a proponent to achieve site risk management. One of these, the Site-Specific Risk Assessment (SSRA) approach, has been adopted by Inco for the CBRA. The SSRA is a scientific technique that estimates risks to humans and the natural environment from exposure to chemicals of concern at the site. Because of specific site characteristics, differences may exist between safe concentrations of chemicals in the site's soil and the safe levels reported by MOE for generic sites. The SSRA approach is used to determine the safe concentrations of chemicals at a specific site. Site-specific concentrations of chemicals as determined through the CBRA process will achieve the same level of human health and environmental protection as intended by the MOE guidelines for generic sites.

In the Port Colborne area, soil studies show that certain chemicals from refinery operations have been spread over a large area, not confined to a single site or property. While it might be possible to conduct individual SSRAs on the hundreds of properties within the affected area, the lack of uniformity of methods and high cost make this option impractical. Furthermore, time to accomplish all the assessments, including individual approvals by the MOE, would likely be ten years or more. Due to these factors, Inco initiated discussions with the MOE as to whether a CBRA, where the concepts and approach used in SSRAs could be applied over a large area, would be more efficient. The MOE agreed that the concept of a CBRA approach could be an extension of various SSRAs.

The CBRA process involves two stages. Stage 1 involves the application of technical and scientific information, both from the general scientific literature and specific studies for Port Colborne, to derive a model to determine potential risks from possible exposures to the chemicals of concern. Following the identification of the chemicals of concern, Human Health Risk Assessments (Hares) and Ecological Risk Assessments (ERAs) were conducted for each CoC. The ERA component of Stage 1 is a process that quantifies risks from a particular CoC to the non-human, biotic receptors (e.g., flora and fauna) in the environment. The assessment involves an analysis of exposure pathways for CoCs to biotic receptors in the local environment. The HHRA component of Stage 1 evaluates the probability of adverse health consequences, and the accompanying uncertainties, to humans caused by exposure to a CoC. The evaluation takes into consideration the possibility that contaminants may occur simultaneously in several media such as food, air, water, soil or dust and that they may reach humans through multiple pathways.

The results of the Stage 1 HHRA and ERA are integrated into the community-specific risk model. The model is used to identify community wide risk-based soil clean-up guidelines using the specific characteristics of Port Colborne's environmental media. The development of the CBRA project has proceeded with the scrutiny and benefit of review by peers, the PLC and the MOE to ensure, to the extent possible, that the predictions by the model regarding safe levels of CoCs in the environment and associated risks are acceptable.

Stage 2 involves application of the model developed in Stage 1 to individual properties. This stage will only be carried out if the property owner gives consent. For sites having a concentration of a chemical of concern at or above the Port Colborne community specific risk-based safe guideline for that chemical, soil characteristics from that site will be fed into the community specific risk-based model. The model will determine whether remediation is necessary and what remedial options are possible for the site.

The CBRA process has the objective of finding out what risks exist, if any, and determining how to minimize such risks in a scientifically sound and practical manner. Each property owner will determine whether they want to participate in having the CBRA process applied to his or her property.

An outline of the CBRA process is shown in Figure 1-2.

1.3.1 CBRA Participants

Inco is the proponent of the CBRA process and receives input from the Community, the City and the appropriate government agencies for conducting the CBRA.

The MOE is the environmental government agency responsible for ensuring that Inco and their consultant, Jacques Whitford, conduct the CBRA according to the principles of the SSRA process, as outlined in the MOE (1997) *Guideline for Use at Contaminated Sites in Ontario.* The Director of the West Central Region of the MOE will make decisions pursuant to the provisions of the *Environmental Protection Act*.

The Regional Niagara Public Health Department is the government agency ensuring that human health issues are suitably addressed by the CBRA.

The property owners of Port Colborne can use the findings of the CBRA to their benefit as outlined in Section 1.3.

The City of Port Colborne is a participant in the CBRA process.

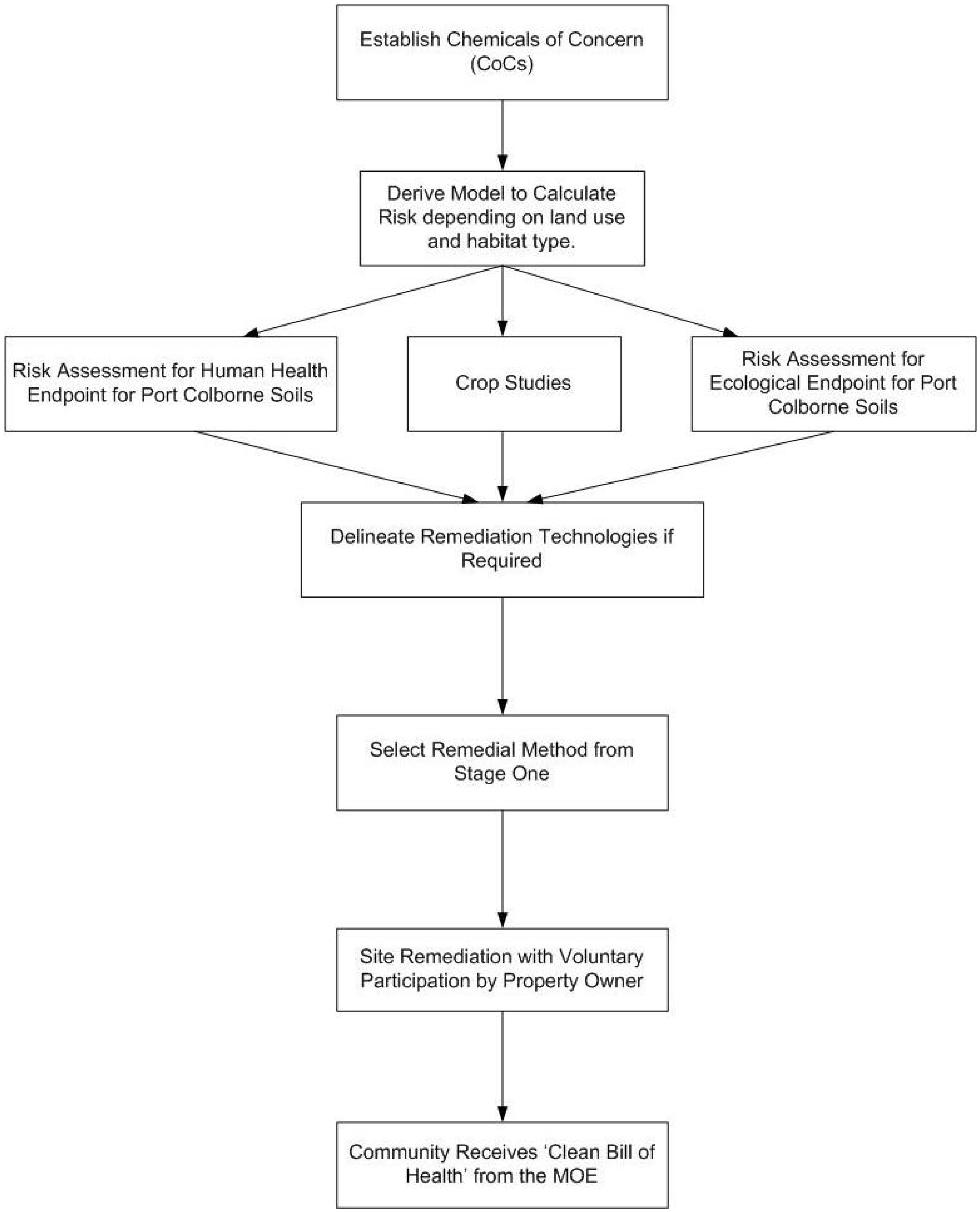
A Public Liaison Committee (PLC) was established by the City Council to perform and provide a number of functions including: 1)solicit public input 2)inform the public and 3)provide input to Inco and to the Director of the MOE with respect to the scope of work for conducting the CBRA.

Stantec Consulting Limited (Stantec - formerly known as Beak International Incorporated), is the PLC's independent consultant to provide technical support and advice respecting the CBRA.

Jacques Whitford was retained by Inco to prepare and implement a Technical Scope of Work (STOW) for Stage 1 of the CBRA process for Port Colborne.

A Technical Sub-Committee (TSC) of the PLC was formed with members from the PLC, Beak, the MOE, Jacques Whitford, the Public Health Department and Inco. This committee reports its findings to the PLC. The purpose of the TSC is to resolve technical issues throughout the CBRA process. The public is invited to attend and observe TSC meetings.

Figure 1-2 Outline of the CBRA Process.



1.4 General Study Design and Approach

A summary of past studies conducted by the MOE in the Port Colborne area and a discussion of the process, objectives, scope, approach and general methods for this ERA are presented here. Subsequent chapters present aspects of the ERA in greater detail, supported by the other volumes of this CBRA.

1.4.1 MOE Studies in the Port Colborne Area

The MOE conducted studies of the Port Colborne area in 1998, particularly around the Refinery (MOE 2000a). Soil samples were analyzed for 20 parameters: aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, phosphorous, selenium, silver, titanium, vanadium and zinc. The MOE concluded from their sampling that soil concentrations of nickel, copper and cobalt were elevated above MOE effects-based generic soil clean up guidelines (MOE 1997) and should be considered to be CoCs.

The levels of nickel in soils, collected by the MOE in 1998 and reported in 2000, were measured at concentrations of up to about 5000 mg/kg, generally with the highest concentrations closest to the refinery and decreasing with distance downwind from the source (MOE 2000a). Soil concentrations of copper and cobalt were measured at up to 350 mg/kg and 150 mg/kg, respectively. As with nickel, the concentrations of copper and cobalt were found to be highest near where the old Refinery stack was located, and decreased with distance from it. The concentration of nickel, copper and cobalt that exceeded the MOE Table A Generic guidelines, generally occurred in the eastern portions of the City and agricultural and forested areas to the north and east of the Refinery.

A more detailed phytotoxicology soils investigation of the Port Colborne area by the MOE in 1999 added more soil chemical data, including arsenic analyses, to the existing data set (MOE 2000b). The area of surface soil (0-5cm) containing nickel concentrations estimated to exceed the Table A soil criterion was approximately 29 km^2, based on a statistical approximation from 1998 and 1999 data (MOE 2000b, Map 7).

Following further review of the soil investigation undertaken in 1998 and 1999, the MOE noted that soil nickel concentrations in woodlots were higher than in adjacent fields. In the fall of 2000, the MOE conducted soil sampling in five woodlots and adjacent fields to assess the spatial distribution of soil metals. The study concluded that downwind woodlots located near the Refinery have soil metal concentrations that are highest at the field/woodlot interface, consistently higher in woodlots than in adjacent fields and lowest in the field immediately downwind of the woodlot (MOE 2000c). For woodlots located further from the Refinery, the only pattern that was found was that soil metal levels in the centre of woodlots are higher than at the edges of the woodlot and in adjacent fields.

Prior to the CBRA, no ERA had been conducted for Port Colborne area lands where soil metal concentrations had been identified as elevated by the MOE. However, starting in 1969, and then almost annually through the 1970s and 1980s, the MOE conducted assessments of Silver Maple (*Acer saccharinum*) leaves for trees located in the Port Colborne area. Smith (1975) reviewed five years of data and found nickel concentrations in maple leaves (washed prior to tissue analysis) that showed injury symptoms were highest near the Refinery (200-670 mg/kg) and declined with distance (30 mg/kg at 3.2 km). In an expanded study, Temple (1976) reviewed nickel, cobalt, and copper concentrations in maple leaf samples collected from 21 stations located at various distances from the Refinery. The analysis found that leaf tissue concentrations of nickel, copper and cobalt were correlated with the prevailing wind direction. Average concentrations for nickel were reported as 200 mg/kg, while copper concentrations were 30 mg/kg . Values for cobalt were found to range from 9 to 19 mg/kg. The report concluded that atmospheric deposition of particulates, rather than soil concentrations of metals, was the primary determinant for concentrations of CoCs in maple leaves.

In 1978 the Refinery was shut down for a six-week period. Based on maple leaf sampling data and moss bag data during 1978, Rinne (1981) determined that for nickel levels in maple leaves, 70% of the nickel could be attributed to direct emissions, and 10% to re-entrainment of contaminated soil (re-suspension of contaminated soil particles into the air). The remaining 20% could be attributed to plant uptake from contaminated soil. Rinne (1989) reviewed maple leaf concentration data collected from 1977 to 1986. During this period, the Refinery was shut for periods in 1982 and 1983, and production of electrolytic nickel ceased in 1984. The data show that the 1986 nickel concentrations in maple leaves were the lowest recorded since studies had started, with most values for 24 stations having less than 30 mg/kg. Results were similar for cobalt (1-7 mg/kg) and copper (7-24 mg/kg). These results indicated that atmospheric deposition was the primary factor that had contributed to past-elevated levels of metals in the area's maple leaves. In 1991, an MOE study concluded that soil metal concentrations had not changed between the 1970s and early 1990s (McLaughlin and Bisessar 1994). In addition, the study showed that maple leaves still contained elevated nickel (12-29 mg/kg), but not cobalt (4-13 mg/kg) or copper (0.1-1.1 mg/kg). Injuries characteristic of nickel toxicity were observed on maple leaves during visual surveys from 1991 through to 1993. It was concluded that the vegetation injury was related to uptake of nickel from contaminated soil rather than ambient (fugitive) emissions from the refinery (McLaughlin and Bisessar 1994).

1.4.2 ERA Process

The ERA was conducted according to accepted Canadian guidelines, including: *A Framework for Ecological Risk Assessment: General Guidance – The National Contaminated Sites Remediation Program* (CCME 1996); *A Framework for Ecological Risk Assessment: Technical Appendices* (CCME 1997), and *Guidance on Site Specific Risk Assessment for Use at Contaminated Sites in Ontario* (MOE 1996).

ERA methods follow a set process, which includes:

- Problem Formulation and Identification of CoCs;
- Site Characterization;
- Receptor Characterization;
- Exposure Assessment;
- Hazard Assessment; and
- Risk Characterization.

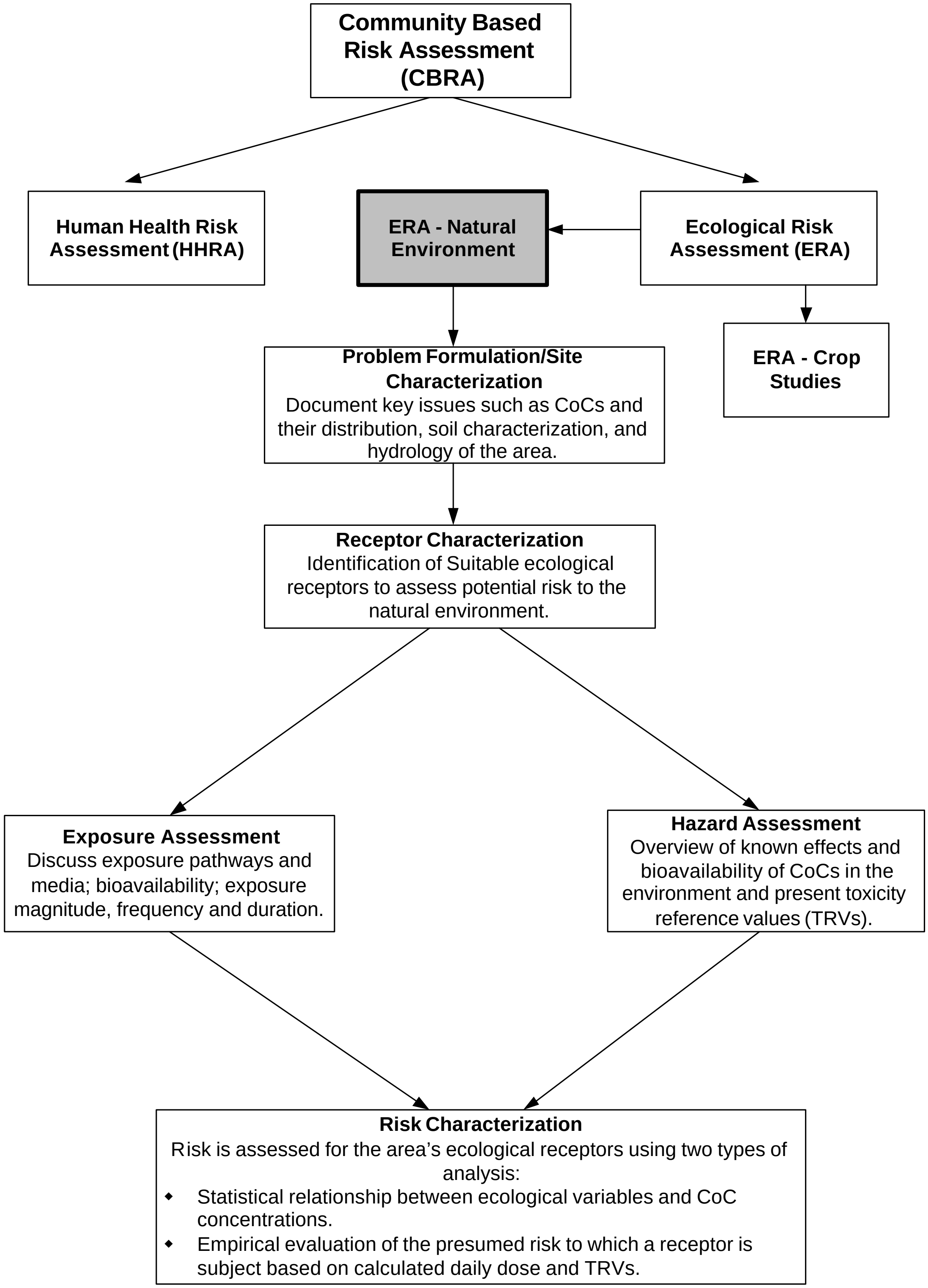
The deterministic approach was used for this ERA. Deterministic ERAs use quantitative methods which are based on a combination of site-specific, field-collected data and existing information found in the literature. Two general methods can be undertaken using this approach: Preliminary Quantitative ERA and Detailed Quantitative ERA. For the CBRA, the ERA has followed a detailed quantitative assessment approach based on an extensive set of site-specific data. Uncertainties, limitations and data gaps are discussed in each of the interpretive and analytical sections of the report.

1.4.3 Components of this ERA

The ERA consists of two related component studies, the ERA – Natural Environment and ERA – Crop Studies (Jacques Whitford 2004a). These two components of the ERA will be summarized and integrated with the HHRA (Jacques Whitford 2004b) in an Integration Report to be prepared for the CBRA. For the ERA, the results of the Crop Studies will be used to assess the potential risk of elevated levels of soil CoCs on non-woody vascular plants that occur in the natural environment. This assessment will be undertaken during the integration phase of the CBRA, and will be detailed in the Integration Report.

Figure 1-3 presents the structure of the ERA - Natural Environment within the context of the CBRA.

Figure 1-3 Overview of the ERA Process within the CBRA Framework



1.4.3.1 ERA-Crop Studies

For the ERA, the risk (phytotoxicity) to non-woody vascular plants due to elevated levels of CoCs in soils was assessed through conducting detailed field trials and greenhouse experiments using Port Colborne soils with specific crop plants (oat, soybean, radish and corn). In addition to the assessment of risk to crop plant species, a field program was conducted for goldenrod (*Solidago spp.*) to assess potential phytotoxicity of soil CoC concentrations to naturally growing native plants. Findings of the Crop Studies conducted for the Port Colborne CBRA are presented in four volumes (Jacques Whitford 2004a) as follows:

- Volume 1 details the findings and results of phytotoxicity testing on crops with Port Colborne soils in both greenhouse and field trials, and represents the primary documentation for this component of the CBRA.
- Volume 2 presents the protocols that were developed for field data collection and conducting field trials and greenhouse experiments. Volume 3 presents the raw laboratory data that were used in the analysis as well as Quality Assurance and Quality Control reports.
- Volume 4 presents the Soil Characterization Report that details the soil types found in the Port Colborne area, their chemical properties and how CoC concentrations are distributed vertically through the various soil types.

1.4.4 Outline of the ERA – Natural Environment Report

The ERA conducted for the Port Colborne CBRA is presented in five volumes. Volume I, presented under this cover, details the findings and results of the ERA for the natural environment and represents the primary documentation for this component of the CBRA. The other four volumes of the ERA – Natural Environment report are technical appendices that present all supporting documentation for conducting the study, including technical appendices for exposure assessment and risk characterization, additional support studies, data collection protocols and raw data for field and laboratory sample analyses. The supporting Volumes II-V are provided in digital format enclosed at Tab 17. The content of each of the supporting Volumes is as follows:

Volume II — Presents the protocols developed for data collection and analyses used in conducting the ERA.

Volume III — Provides supporting documentation with respect to analysis, calculations, data sets, parameters and values used for exposure assessment and risk characterization as part of the ERA – Natural Environment. In addition, this volume presents documentation of the CBRA public participation process for the ERA.

Volume IV Provides copies of reports presenting the findings of supporting studies conducted for the ERA – Natural Environment.

Volume V Provides data quality assurance and quality control (QA/QC) and data sets from the laboratory analyses of all media sampled and analyzed for CoCs for this study, including, soils, sediment, water and vegetation/animal tissues.

For a comprehensive technical review of the ERA – Natural Environment, the reader should consult all five volumes of this report. In addition, in conjunction with the five volumes of this report, two other reports are identified as required for a detailed technical review, these include "Potential CoC identification Using Soil Chemical Concentration Data in Exceedance of MOE Generic Guidelines" (JW 2001a) and "Soil Characterization. Port Colborne Community Based Risk Assessment" (JW 2002c).

Under this cover, Volume I of this report is presented in twelve (12) sections, as follows:

Section 1 - Introduction provides the background to the CBRA process, the ERA process and the study's objectives and scope of work.

Section 2 - Problem Formulation provides a historical overview of the operation of the Inco Port Colborne Refinery and the identification of the CoCs, including their concentrations and distribution in environmental media (soil/sediment, water and air) in the Port Colborne environment. This information is then summarised to develop a Conceptual Site Model for the ERA.

Section 3 - Site Characterization provides an overview of the natural environment within the Study Area (as described in Section 1.4.8). The overview is based on field surveys and a review of available published and unpublished information. It includes descriptions of vegetation communities, flora and fauna, including significant natural features and significant species noted for the area. The results of the site characterization are used in identifying meaningful receptors [Valued Ecological Components (VECs)] for the risk characterization, as well as a qualitative assessment of the environmental risk to flora and fauna from exposure to CoCs.

Section 4 - Receptor Characterization identifies the receptors (VECs) on which the ERA was undertaken. The criteria for the selection of VECs are presented and a discussion of each VEC's characteristics, relevant to the ERA, is provided.

Section 5 - Data Collection Methods provides a summary of the study's data collection methods, the types of data collected, locations from where samples were collected as part of the ERA, and laboratory procedures for chemical analysis of samples. This section is intended to provide a brief overview for the reader. Volumes II and V provide the detailed protocols for the data collection and the results of the sample data analysis for the ERA, respectively.

Section 6 - **Exposure Assessment** describes the exposure of the identified VECs to the CoCs in detail, including such aspects as pathways, magnitude, duration and frequency of exposure. An assessment of CoC accumulation in site-specific animals and plants exposed to CoCs in soils, sediments and water is provided.

Section 7 - Hazard Assessment describes the methods (assessment endpoints), and Toxicity Reference Values (TRV) against which the risk to VECs were evaluated. A general overview of the literature regarding potential adverse effects of CoCs in the natural environment is also presented.

Section 8 - Risk Characterization describes the risk to identified VECs in the natural environment in the Port Colborne area. Potential risk is calculated following the Quotient Method and discussed for VECs, and where potential risk is identified, soil CoC concentrations at which VECs are not at risk are identified.

Section 9 – Study Integration integrates three lines of investigation: 1) qualitative assessment, 2) quantitative analysis of site-specific data and 3) quantitative risk characterization. This synthesis is used to draw conclusions about environmental CoC concentrations in Port Colborne soils at which there is an acceptable level of risk. A line-of-evidence approach is used to synthesize risks associated with various CoC concentration scenarios (e.g., field vs. forest, organic vs. clay soil) for each VEC and assessment endpoint. The analysis presents "safe" (acceptable) CoC soil concentration values for the overall natural environment.

Section 10 – Uncertainties and Limitations presents an analysis of potential study limitations and uncertainties that could result in an over or under estimate of the potential risk of soil CoCs to the natural environment.

Section 11 – Study Summary and Conclusions provides a brief summary of the studies key findings and provides recommendations for consideration in the CBRA Intergration Report that will provided the guidance for Stage II of the CBRA.

Section 12 – References provides all references cited in this report

In addition to the above 12 sections, there are 4 Appendices.

Appendix A presents independent third party review comments by CH2MHill on the draft report and Jacques Whitford's response to these comments. This appendix has been included in keeping with the CBRA's commitment to an open public process.

Appendix B presents written public review comments on the draft report and Jacques Whitford's response to these comments. This appendix has been included in keeping with the CBRA's commitment to an open public process.

Appendix C presents the PLC consultant's review comments on the initial draft of the report and Jacques Whitford's response to these comments. This appendix has been included in keeping with the CBRA's commitment to an open public process.

Appendix D presents Maps 1 through 3 that detail the study areas and locations of samples and data collected for the study.

Volumes II through V in digital format are found at the end of the document**.**

1.4.5 ERA Process within the Context of the CBRA

For the CBRA, the ERA was undertaken following a process developed and agreed to by the CBRA participants. The key steps for the ERA included:

- CBRA process initiated in January 2000;
- Development of the Technical Scope of Work (TSOW) for the CBRA – 2nd and 3rd Quarter 2000;
- Initial site characterization – 2nd and 3rd Quarter 2000;
- ERA Report, existing conditions, receptor identification – 2nd Quarter 2001;
    - PLC/TSC review of draft report – 2nd Quarter 2001;
- Development of Field Data Collection Protocols – 2nd and 3rd Quarter 2001;
    - PLC/TSC review of Protocols – 2nd and 3rd Quarter 2002;
- Collection of site-specific field data – 2nd and 3rd Quarter 2001;
- Development of Data Interpretation Protocols – 2nd and 3rd Quarter 2002;
    - PLC/TSC review of Protocols – 4th Quarter 2002;

- Qualitative and quantitative analysis of data – 3rd and 4th Quarter 2002;
- Initial Draft ERA Report – 1st Quarter 2003;
  - PLC consultant review of initial Draft Report– 1st Quarter 2003;
- Draft Report preparation and public release -3rd and 4th Quarter2003;
- Public review and external peer review of Draft Report– 3rd Quarter 2003 to 2nd Quarter 2004
- Completion of Final Draft Report– 2ndst Quarter 2004;
  - PLC/TSC review of finial Draft Report– 3rd Quarter 2004;
- Final ERA Report submission for MOE Approval – 4th Quarter 2004.

1.4.6 Objectives of this ERA

The primary objective of the ERA is to determine if historical emissions of CoCs from the refinery and deposited in soil present an unacceptable risk to the natural environment of the Port Colborne area. Ultimately, the Regulatory Authority, the Ontario Ministry of the Environment, will determine what constitutes safe or acceptable levels following review of the CBRA reports. However, **for this ERA, an unacceptable risk is defined as an estimated risk linked to the occurrence of soil concentrations of CoCs that prevents sustainable *population(s)* of flora and fauna or a sustainable level of ecological functioning within the defined Study Area.** Where an unacceptable risk is estimated, the ERA has the follow-up objective of estimating the levels to which CoCs must be lowered or controlled in order to produce "safe" (acceptable) levels of risk for the natural environment.

Specific objectives of the study are to:

- Identify receptors (species or species groups, communities, habitats) that allow for an assessment as to whether soil CoCs represent a risk to the natural environment within the defined Study Area;
- Undertake an assessment of risk that is based on the integration of three lines of investigation: 1) qualitative assessment of the natural environment, 2) quantitative statistical analysis of study area data and 3) quantitative exposure and risk assessment;
- Determine ecological risk at a population level for ecological receptors found within the Study Area;
- Determine if any potential risks associated with CoCs are different for the major soil types (clay and organic) and habitat types (woodlots and fields) found in the Study Area; and,
- Determine "safe" (acceptable) soil CoC concentrations for the soil types (clay and organic) and habitat types (field and woodlot) if an unacceptable risk is found to occur.

1.4.7 Scope of Work

Since the present ERA focuses on the ***natural environment***, human-influenced environments such as parks, playgrounds, gardens and residential yards were not considered receptors for the ERA. In addition, for assessment of risk to the natural environment livestock or pets were also not considered as receptors for the ERA. However, a number of mammals species that were identified as receptors for the assessment of risk can be considered to represent surrogates for pets such as dogs and cats. Initially, only the terrestrial environment had been included for the screening of ecological conditions and potential effects of CoCs. However, as the study progressed, inland water bodies (ponds) and watercourses (municipal drains) were included in the scope of work in direct response to the PLC's concern for aquatic receptors such as amphibians. Although the shoreline of Lake Erie lies within the Study Area, the nearshore aquatic environment does not fall within the scope of work for the ERA (see Sections 2.1.6 and 2.1.7).

Generally, lands associated with the Inco Port Colborne Refinery that are identified within the site's Closure Plan (Inco 1998), approximately 120 ha, are excluded from this ERA's Scope of Work. The environmental management of these lands is pursuant to the requirements of the *Mining Act of Ontario* and is outside of the CBRA process. However, a limited number of samples were collected from the eastern portion of the lands covered under the Closure Plan, where soil CoC concentrations were known to be high and where it is apparent that the simple presence of a road and a fence would not provide a barrier to the movement of bird and mammal receptors.

1.4.8 General Study Design and Approach

This section has been provided so that the reader may gain a general understanding of the study design and approach for data collection and assessment of risk. Where required, methodological details are provided in later sections of the report. For a complete detailed discussion of the study's approach to data analysis and interpretation, the reader is directed to Volume II (Tab 18).

At the initiation of the project, a Study Area was defined for the purpose of site characterization and data collection of the ERA. The Study Area (Map 1, located at Tab 16) is located east of the Welland Canal and is defined as natural or agricultural lands where soils contain nickel concentrations of 200 mg/kg or greater, based on data collected in 1998 and 1999 by the MOE (2000a,b). Based on these data, it was shown that soil nickel concentrations generally reflected the concentrations of the other CoCs. Thus, soil nickel concentration could be used in defining the Study Area for conducting the ERA.

Residential areas, the Inco Refinery site property, and a large quarry located northeast of the refinery were excluded for the ERA (Map 1). This resulted in a Study Area of approximately 22 km^2 . It is important to note that the Study Area as defined here was identified for the purpose of data collection used to assess risk to the local natural environment. The Study Area does not represent all the lands in Port Colborne where soil nickel concentrations are found to exceed the 200 mg/kg MOE generic guideline.

At the initiation of the study it was recognized that additional soil sampling and analysis undertaken for the CBRA would expand upon the data collected by the MOE and that these new data could change the area where soil values for the CoCs exceed current generic guidelines (based on the complete soil data set the total area where soil nickel >200 mg/kg is 26.4 km^2, see Figure 2-2). For the ERA study to be completed on the CBRA schedule, collection of biological data had to begin before all soil data collected for the CBRA could be analyzed.

The Study Area defined for conducting the ERA is considered to be representative of all natural areas for lands where soil nickel values exceed 200 mg/kg. The Study Area was partitioned according to soil nickel concentrations reported by MOE (2000a,b) to structure sampling efforts within areas of high levels of soil nickel and moderate levels of soil nickel. The Primary Study Area includes land within the ERA's Study Area where soil nickel concentrations exceed 500 mg/kg, according to MOE (2000a,b). The Secondary Study Area includes land within the ERA's Study Area where soil nickel concentrations lie between 200 mg/kg and 500 mg/kg. Additionally, sampling was conducted in areas west and east of the Study Area (Map 2. Tab 16) where soil nickel concentrations were below 200 mg/kg, based on data presented in MOE (2000a,b). These samples were representative of background levels of CoC concentrations, and hereafter denoted as occurring in the Reference Area.

Although Primary and Secondary Study Areas were identified to ensure that field data collection was structured and data were representative of the areas where soil CoC concentrations were high to moderate, characterization of risk to VECs was based on potential exposures to a VEC's population. ***For the purpose of this ERA, a VEC's population is defined as all individuals of a species (plant or animal) that inhabit or occur within the entire Study Area (i.e., both Primary and Secondary Study Areas).*** For the characterization of risk for the ERA, ***an unacceptable risk to a VEC's population is defined as an estimated risk linked to the occurrence of soil concentrations of CoCs that prevents sustainable population(s) of flora and fauna or a sustainable level of ecological functioning within the defined Study Area.*** Separate risk characterization was not undertaken for sub-populations represented by the Primary and Secondary Study Areas, or other specific areas within the Study Area.

Site-specific ERAs in Ontario are typically undertaken for a limited area (lots, individual properties, streets, etc.) with risk characterization undertaken for one or two receptors (VECs). In most cases, hazard assessment and risk characterization are based on accepted and approved models, equations and reference values based on other empirical studies, with no field data collection for the chosen receptors. For this ERA, the scope of the study was expanded and considerable effort has been made to collect field data for a number of receptors in order that real site-specific values for exposure and risk assessments could be used. In addition, a number of controlled experiments, greenhouse studies and earthworm dose-response tests were conducted using soils collected from the Study Area to further detail and assess effects of CoCs on the local environment.

Soil samples and other environmental media that may be involved in food pathways for VECs were collected throughout the Study Area to determine the concentrations of CoCs. These site-specific CoC values were used in the exposure characterization for any particular VEC based on the environmental media characterizing five "scenarios" comprising the Study Area. These scenarios included:

- Woodlots on organic soils;
- Woodlots on clay soils;
- Fields on organic soils;
- Fields on clay soils; and,
- The Study Area in general.

Figure 1-4 shows woodlots and fields on clay and organic soils within the Study Area on which the above scenarios apply.

For the purpose of this study, woodlots and field are defined following the Ecological Land Classification for Southern Ontario (Lee *et al*. 1998) as follows:

- Woodlots are natural forested habitats where trees (woody species greater than 6m in height) cover 60% or more of an area.
- Fields are lands where cover by woody species (trees and shrubs) is 25% or less, including agricultural lands that are either actively cultivated or fallow.

For the purpose of this study, organic and clay soils will be defined following the Field Manual for Describing Soils in Ontario (Denholm and Schut 2003) as follows:

- Clay soils are mineral soils where soil particles of <0.002 mm diameter represent 30% of the soil. This would include soils identified as Heavy Clay and Shallow Clay.

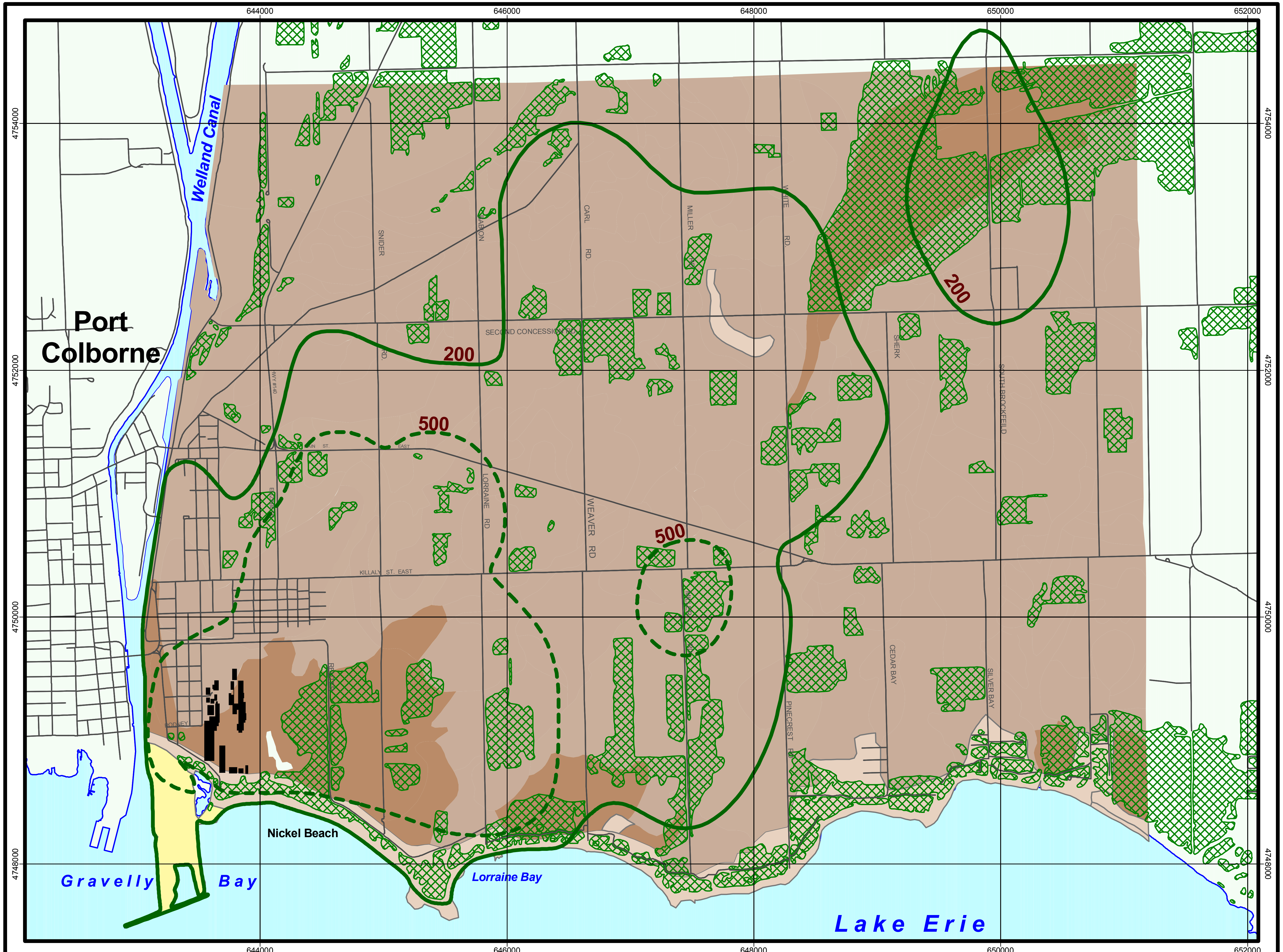


Figure 1-4

Woodlot and Field Habitat on Clay and Organic Soils

0 500 1000 1500
Metres

N

Legend

MOE Nickel Contours
- Secondary Study Area (200-500 mg/kg)
- Primary Study Area (>500 mg/kg)

Soil Groupings
- Clay
- Organic
- Sand
- Built Land

Map Features
- Woodlot
- Inco Refinery
- Roads

Job Number: ONT34561
Date: July 03, 2002
Dwn by: C. Amirault
Approved by: Oliver Curran

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

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- Clay Loam soils are mineral soils where soil particles of <0.002 diameter represent between 20 to 40% of the soil.
- Organic soils are soils of 40 cm or more depth with 30% or more organic matter, or 17% or more organic carbon.

Many data sets were large enough to determine mean CoC concentrations and the Upper Confidence Limits for the Means (UCLMs). As a conservative approach, UCLMs were derived from raw data instead of log-transformed data, since these values are higher than those derived from log-transformed data sets. Additionally, many data sets were not normally or log-normally distributed, which made appropriate the calculation of UCLMs on raw data. In many cases, the UCLM approached the maximum for a particular data set and scenario, and represented a reasonable maximum for the Study Area. Where sample sizes were too small (N<10) to calculate a UCLM, maximum values were used to calculate a VEC's exposure instead.

The risk characterization for each of the VECs in each of the scenarios was then based on population responses to estimated levels of CoCs. The population responses by any particular VEC may include changes in the size of a population through any combination of productivity (e.g., birth rate and mortality rate), emigration and immigration. Responses by individual organisms may also change the overall population's characteristics. CCME and US EPA recommend the selection of ecological endpoints for VECs that are based on the level of environmental protection sought. For this ERA, a sustainable level of ecological functioning was selected as the most appropriate level of environmental protection desired.

For some VECs, it was considered appropriate that in order to sustain ecological functioning, an adverse effect on up to 20% of the population was acceptable. Thus, for several VECs, the risk characterization of a level represented by an EC_{20} (Effects Concentration at the 20% level, where undesirable effects observed) was appropriate.

However, for some VECs that are either more widely distributed in the Study Area or are slower in reproducing (i.e., birds and mammals), an EC_{20} for the population was not considered acceptable. For these VECs, the lowest level of exposure to CoCs that produced an observable adverse effect was used as the ecological endpoint for the risk characterization. In some instances where the lowest observable adverse effects level (LOAEL) for a CoC could not be determined for such VECs, the level of CoCs that resulted in no observable adverse effects (NOAEL) to the VEC were conservatively used as the ecological endpoint for the risk characterization in this ERA.

1.4.9 ERA and Public Participation

The CBRA process was initiated in January 2000. A key component of the CBRA process was extensive public consultation and participation in the undertaking of all aspects of risk assessment and studies. To this end the Port Colborne City Council established a Public Liaison Committee (PLC), comprised of both council members and members of the public. The primary purpose of the PLC was to solicit public input and inform the public with respect to ongoing studies and their findings. Starting in January 2000, and throughout the duration of the CBRA, PLC meetings were held regularly (often once a month during the initial stages of the CBRA) to which the public was invited to attend and participate. In addition to the PLC, a Technical Sub-committee (TSC) was established and comprised of members of the PLC, government agency representatives, Inco representatives and consultants. As with the PLC, the TSC held meetings on a regular basis to resolve technical issues. These TSC meetings were also open to the public. Throughout the CBRA, notices were placed in local newspapers informing the general public of the time and place of all PLC and TSC meetings. Representative examples of newspaper notices for PLC and TSC meeting are provided in Volume III.

In order to ensure public consultation and input, specific PLC and TSC meetings were held where JW presented summaries of reports and specific data collection protocols prepared for the ERA-Natural Environment. In addition to presentations at PLC and TSC meetings, a number of open house meetings were held by JW and the PLC's consultant (Stantec) to both inform the public and solicit public input. Following completion of the first draft report, PLC presentations and open houses were held in order to detail the studies' findings. During these presentations, the public was encouraged to provide written comments to the PLC or City. In addition, a copy of the first draft report was placed in the public library for public review. Finally a notice was placed in local newspapers indicating the closure date for public written comment on the first draft report. Following the review period, a final draft report was prepared with presentations to both the TSC and PLC. Following public review period a final report was prepared.

The following provides a summary of the key public meetings and open houses that were held during the ERA-Natural Environment study. Copies of newspaper notices for these meetings (as well as others) are provided in Volume III.

Year 2000

- PLC/TSC - Presentations of Scope of Work for CBRA (Sept 7; Oct 19, Nov 9,23,30)
- Open House (October 26)

Year 2001

- PLC/TSC – Presentation of ERA Existing Conditions Report and Identification of VECs (April 12)
- PLC/TSC – Presentation of Data Collection Protocols (April 12, June 28)
- PLC Open House (May 3)
- PLC/TSC – Update of data collection programs (Oct 25)
- Open House – Year 2001 data collection (Nov 21)

Year 2002

- PLC – ERA Updates (Jan 17, Feb 21)
- TSC/PLC – Data Interpretation Protocol (April 4, July 11, 8, Oct 24, Nov 26, Dec 5)
- Open House – Data Interpretation Protocol (April 7)

Year 2003

- PLC – Notice of completion of Draft ERA-Natural Environment Report (July 2)
- Open House – JW presentation on Draft ERA-Natural Environment Report (July 31)
- Open House – PLC presentation on Draft ERA-Natural Environment Report (Oct 23)

Year 2004

- Notice for end of Comments – Notice indicating end of public review and public written comments on Draft ERA-Natural Environment Report (June 16)
- TSC/ PLC– JW presentation of final Draft Report (September)
- Notice for end of Comments – Notice indicating end of public review and public written comments on Final Draft ERA-Natural Environment Report (to be determined)
- Notice of submission of Final Report to the Ministry of the Environment (to be determined)

2.0 PROBLEM FORMULATION

Problem formulation is a critical step in any ERA. It is necessary to describe the nature and scope of the environmental contaminants released to the environment from the Refinery and identifies key issues and concerns to help focus the ERA. This section provides a history of the Refinery's emissions, as well as the identification of the CoCs, and their spatial distribution in the Port Colborne environment, using existing documentation and studies undertaken during the CBRA. This information was used to determine the potential exposure of receptors to CoCs, and to define the Study Area prior to onsite data collection, as discussed in Section 1.4.

2.1 Site Characteristics of Study Area

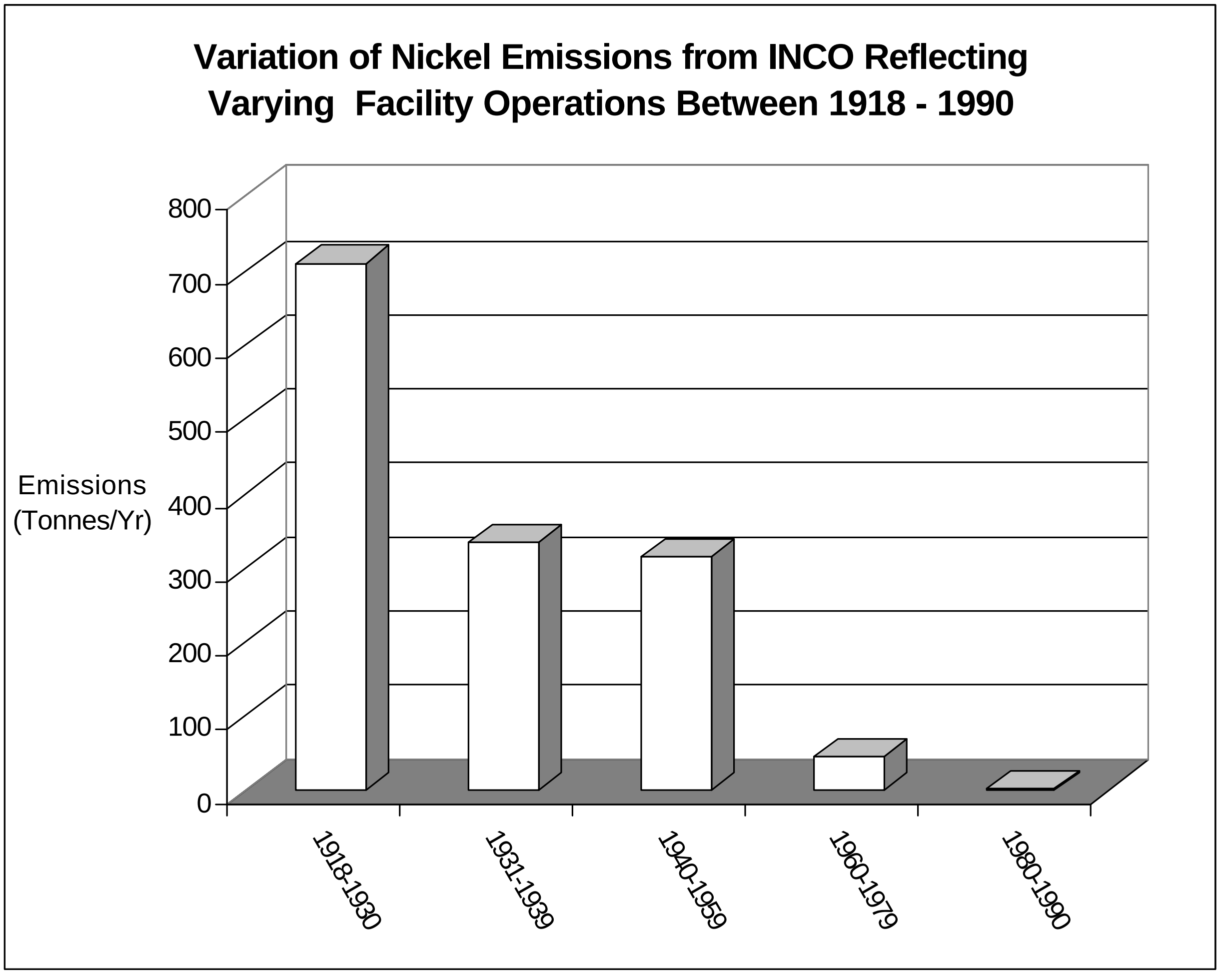
2.1.1 Historical Overview of Contamination

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

Based on an assessment of historic emissions from the Inco Refinery, peak particulate air emissions occurred during the operation period from 1918-1930, during which nickel emissions were less than 700 tonnes annually as shown in Figure 2-1. Through the 1960s and 1970s particulate emissions were significantly reduced (< 60 tonnes annually). Further reductions in particulate air emissions continued since the 1970s.

The local natural environment predominantly downwind (northeast) of the Refinery was exposed to the greatest atmospheric deposition of particulates for a period of approximately forty years (1918-1960). It is during this period that the particulate matter principally accumulated in the local soils. From the 1980s, and particularly through the 1990s to the present, potential harmful environmental effects on local biota due to direct atmospheric depositions are considered to have been greatly reduced compared to past-elevated levels. However, the levels of historic accumulated particulate matter in the local surface soils have remained unchanged from the late 1970s through to the present (McLaughlin and Bisessar 1994).

Figure 2-1 Historical Nickel Emissions of the Inco Refinery, Port Colborne.



Source: Jacques Whitford 2003

2.1.2 CBRA Chemicals of Concern

For the CBRA, Jacques Whitford has undertaken various studies and soil investigations to evaluate all potential relevant chemicals of concern that originated from the Inco Refinery. In addition, other historical industrial sources within the affected area, such as the former Canada Furnace (later Algoma Steel) steel plant, have also been assessed to determine if their emissions may have contributed significantly to potential CoCs. The studies included the sampling and chemical analyses of other environmental media for CoCs to assess the possible migration of CoCs from soil through various exposure pathways to a receptor.

For the CBRA, the definition of a CoC is a chemical found in Port Colborne soils originating from the Inco Refinery where all of the following conditions are met:

Condition 1 Chemicals that were historically used or generated by the Inco Refinery or its processes, and

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

Condition 3 Chemicals whose presence in soil show a scientific linkage to the historical operations of the Inco Refinery.

NOTE: MOE generic effects-based guidelines as defined in Condition 2 refer to the MOE Table 'A' Generic Guidelines (MOE 1997).

Documentation on the studies and investigations undertaken independently by Jacques Whitford in evaluating each of the three Conditions are as follows:

- For Condition 1, refer to the report entitled *Potential CoC Identification using an Emissions Inventory and Dispersion Modelling*, dated March 2003 (Jacques Whitford 2003);
- For Condition 2, refer to the reports entitled *Potential CoC Identification using Soil Chemical Concentration Data in Exceedance of MOE Generic Guidelines*, dated November 23, 2001 (Jacques Whitford 2001a), and *CoC Identification using an Emissions Inventory and Dispersion Modelling*, dated March 2003 (Jacques Whitford 2003); and,
- For Condition 3, refer to the report entitled *Potential CoC Identification using Statistical Analyses*, dated November 16, 2001 (Jacques Whitford 2001b).

Jacques Whitford's evaluation concluded that **Nickel, Copper, Cobalt** and **Arsenic** are the CoCs for the Port Colborne CBRA based on the above criteria.

2.1.3 Drainage Characteristics and General Soil Type

The City of Port Colborne falls within the Limestone Plain region of the Niagara area, which extends eastward to Fort Erie. The Limestone Plain is characterized by shallow bedrock, which is commonly exposed or covered with a thin veneer of clayey silt to stoney silt till and glaciolacustrine sediments. Soils of the Port Colborne area have developed on soil parent materials ranging in texture from heavy clays to coarse sand. The outstanding characteristics of the soils of Port Colborne are heavy textured soils and poor drainage dotted with wet depressions of irregular size and shape (Chapman and Putnam 1984).

Existing Ontario Ministry of Agriculture, Food and Rural Affairs soil maps of the Regional Municipality of Niagara (OMAFRA 1998) were reviewed to evaluate various soil types that fall within the CoC plume identified by Jacques Whitford (2003c, 2001a and 2001b). Detailed soil studies undertaken for the Port Colborne area have identified and mapped five primary soil groups (clay loam, heavy clay, shallow clay, organic, and sand) and they are discussed in Jacques Whitford (2003a), and summarized in Section 3.4. For simplicity, field data collection efforts for the ERA were focused on three general soil types (clay, organic and sand).

2.1.3.1 Distribution of CoCs in Soils

The following provides a summary of the distribution of CoCs in soils in the local Port Colborne area. For a detailed assessment, the following reports should be consulted, "Potential CoC identification Using Soil Chemical Concentration Data in Exceedance of MOE Generic Guidelines" (Jacques Whitford 2001a) and "Soil Characterization. Port Colborne Community Based Risk Assessment" (Jacques Whitford 2002c).

Analysis of soils for the CBRA has found that soil CoC concentrations decrease with distance from the source in a north-easterly direction, since prevailing winds from the southwest distribute the majority of particulate emissions in a northeast direction across the Study Area. Based on the results of soils sampled in the Study Area, surface (0-20 cm depth) soil CoC concentrations are similar for both the organic and clay soils that are located at similar distance from the Refinery, even though the organic soils are more permeable than the clays (Jacques Whitford 2001a).

Table 2-1 summarizes the recommended MOE soil concentration guidelines, based on the generic effects to plants, livestock and humans for the four identified CoCs. (MOE 1997).

Table 2-1 MOE Guidelines for CoC Concentrations for Fine to Medium Textured Soils

Chemical of Concern (CoC)	Agricultural and Residential/Parkland (mg/kg)	Industrial/Commercial (mg/kg)
Arsenic	<25	<50
Cobalt	<50	<100
Copper	<200	<300
Nickel	<200	<200

Figures 2-2, 2-3, 2-4 and 2-5 illustrate the distributions of each of these four CoCs with respect to soil concentrations. Data for the production of these maps was obtained from 0-5 cm surface soil data analyses (excluding samples from woodlots) from MOE (2000a,b), from AMEC (2001a,b) and from the soil sampling and analysis program conducted in 2000-2001 for the completion of the CBRA (Jacques Whitford 2001a). Tab 9 in Volume III describes how the isolines are generated using computer software and lists the soil data used to generate the isolines presented in Figure 2-2 through Figure 2-5.

To determine the vertical distribution of CoCs in soil, a test-pitting program was conducted to a depth of 1.0 m in Study Area soils. Table 2-2 presents the results of the test-pitting program. Details regarding the data presented in Table 2-2 are found in the Soils Characterization report in Volume IV of the ERA-Crop Studies Report (Jacques Whitford 2004a). Generally, it was determined that CoCs are restricted to upper regions of the soil profile from 0 to 20 cm, for both clay and organic soils. For organic soils, soil concentrations for each of the four CoCs remain evenly distributed throughout the first 0-15 cm. CoC concentrations from 15-20 cm were found to drop off sharply to below guideline levels. For clay soils, for all CoCs, the concentrations in the soil profile are lower at the 10-15 cm depth when compared to either the 0-5 cm or 5-10 cm depth. Concentration of soil CoCs at 0-5 cm and 5-10 cm are very similar, particularly given the range of the concentrations of each CoC at these two intervals. As with organic soils, in clay soils from 15-20 cm, CoC concentrations drop below guideline levels. Therefore, for both clay and organic soils, the zone of potential adverse effects of soil CoCs on the area's biota and ecological processes is from the soil surface to a lower depth of approximately 20 cm. For this study the 0-5 cm horizon is considered to represent the area of primary interaction of soil CoCs with most biological receptors. In addition, for both clay and organic soils, the 0-5 cm soil depth interval represents a zone where CoC values can be considered to be representative of higher concentrations. The 0-5 cm soil depth interval therefore is the depth at which most soil samples were obtained and chemically analyzed throughout the study area.

The area of lands where soil CoC concentrations exceed MOE generic guidelines are provided in Table 2-3. These estimates are derived from land area within the isolines shown in Figures 2-2 through 2-5 for each of the CoCs on clay, organic, and sandy soils.

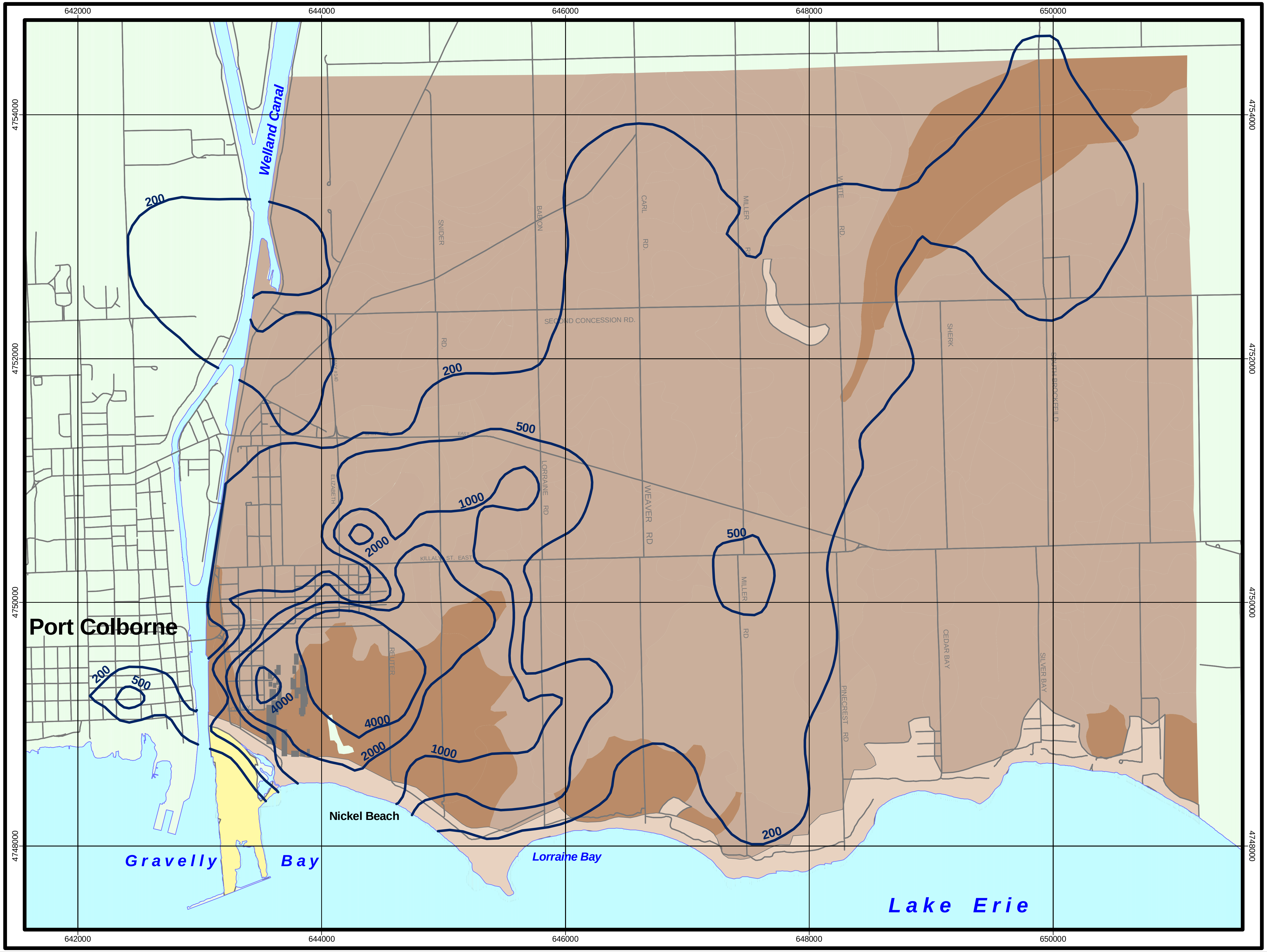


Figure 2-2

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

0 500 1000 1500
Metres

N

Legend

Nickel Contours
200, 500, 1000, 2000 and 4000 mg/kg

Soil Groupings
- Clay
- Organic
- Sand
- Built Land

Topographic Features
- Inco Refinery
- Roads

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

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

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

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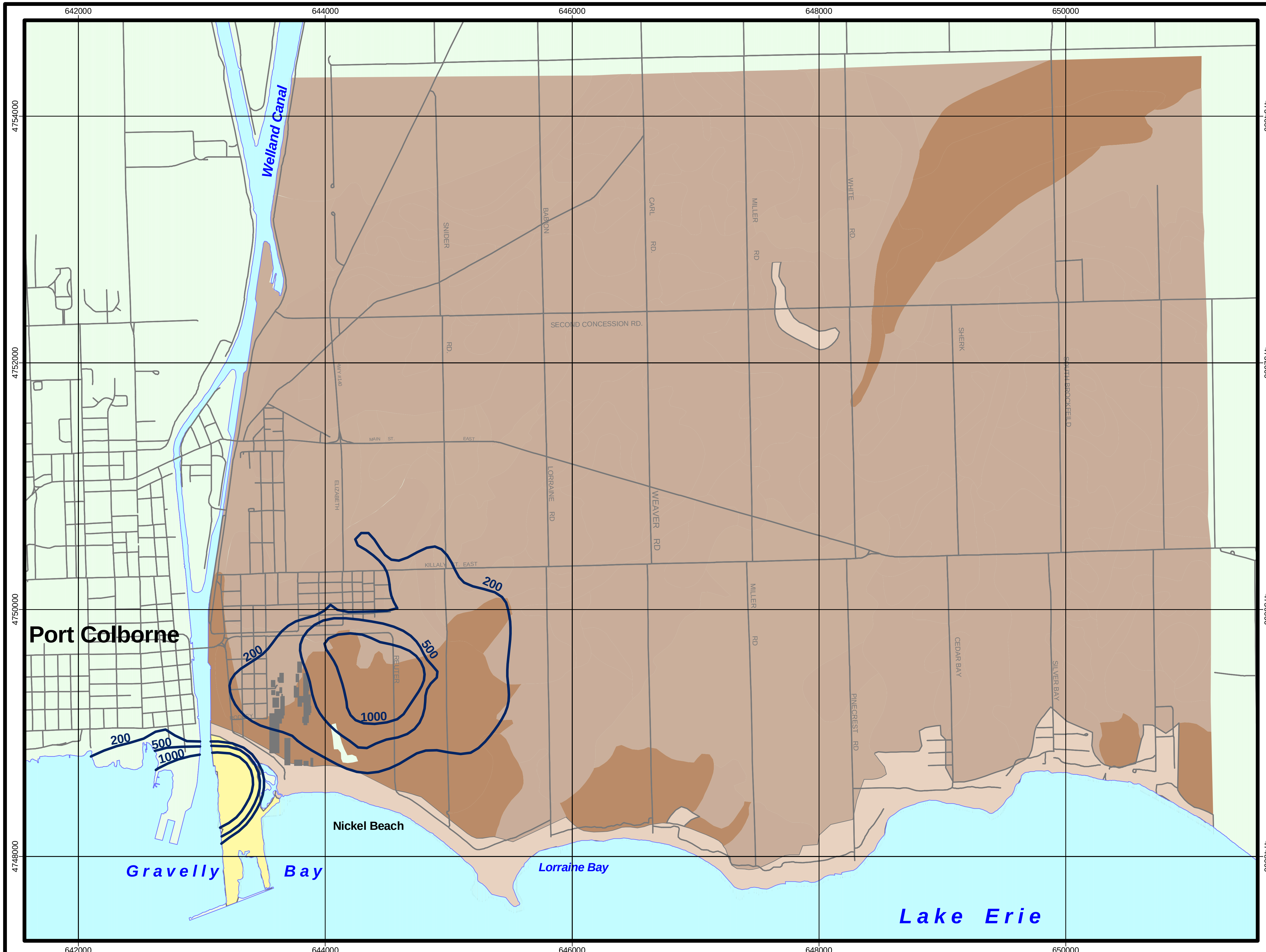

Figure 2-3

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

0 500 1000 1500
Metres

N

Legend

Copper Contours
200, 500 and 1000 mg/kg

Soil Groupings
- Clay
- Organic
- Sand
- Built Land

Topographic Features
- Inco Refinery
- Roads

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

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

Map Parameters
Projection: UTM
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Ecological Risk Assessment-Community Based Risk Assessment-Port Colborne, Ontatio

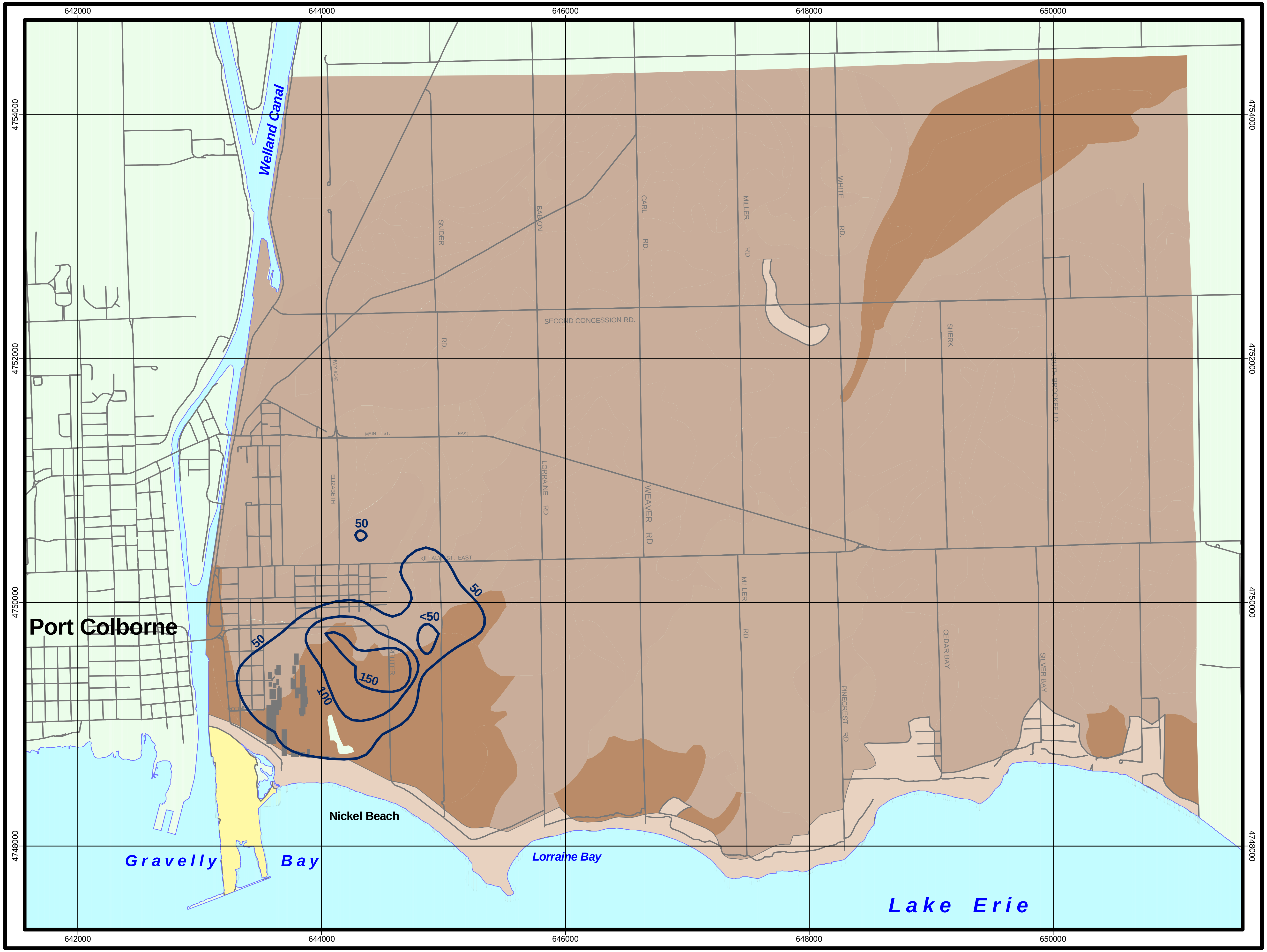

Figure 2-4

Cobalt in Soil (0-5 cm deep) Port Colborne CBRA

0 500 1000 1500

Metres

N

Legend

Cobalt Contours

50, 100 and 150 mg/kg

Soil Groupings

- Clay
- Organic
- Sand
- Built Land

Topographic Features

- Inco Refinery
- Roads

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

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

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

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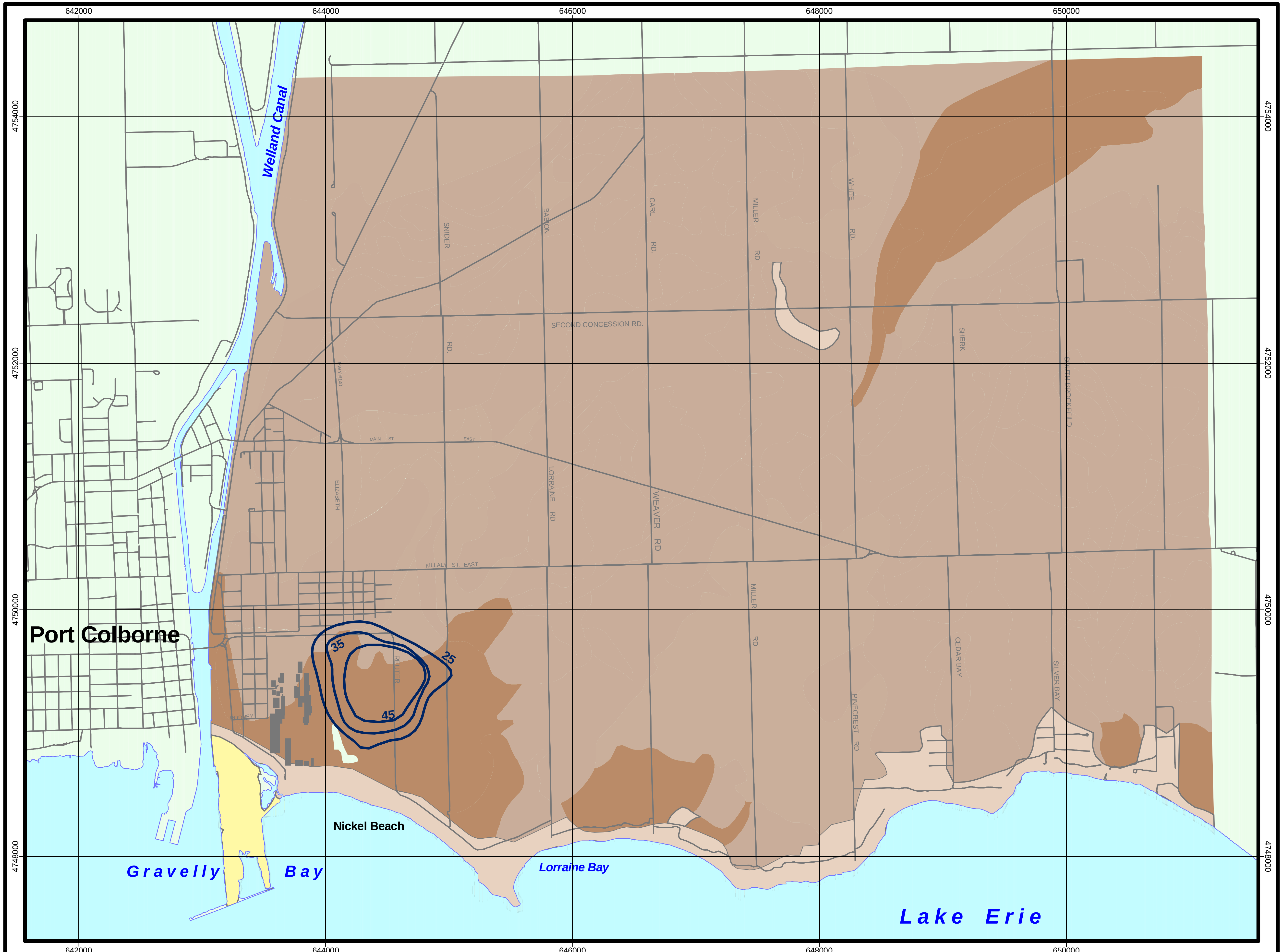
Figure 2-5

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



0 500 1000 1500

Metres

N

Legend

Arsenic Contours

25, 35 and 45 mg/kg

Soil Groupings

- Clay
- Organic
- Sand
- Built Land

Topographic Features

- Inco Refinery
- Roads

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

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

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

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Although a gradient occurs in relation to distance from the source, woodlots have generally elevated levels of CoCs in comparison to surrounding fields and agricultural lands (MOE 2000c). These elevated levels are a result of trees and their leaves acting as traps for the atmospheric particulate matter, that, once trapped, is transferred to the forest floor by rain and leaf fall. This phenomenon gives rise to a 'patchy' distribution of CoCs in soil across the landscape, with any one woodlot representing a 'hot spot' in a local area. Table 2-4 shows soil nickel concentrations in woodlots and adjacent fields at different distances from the Refinery.

Table 2-2 COC Concentrations by Soil Depth

CoC	Soil Type	Range of CoC Concentrations (mg/kg) By Soil Depth From Surface		
		0-5 cm	5-10 cm	10-15 cm
Nickel	Heavy Clay	7660-2550	11950-2220	4720-1510
	Shallow Clay	1350-344	1510-380	1140-259
	Clay Loam	787-405	672-417	524-175
	Organic	2000-1600	2190-1610	2200-1510
	Sand	1280-176	266-148	234-62
Copper	Heavy Clay	833-328	1310-278	722-208
	Shallow Clay	215-81	239-66	228-66
	Clay Loam	98-55	89-52	121-28
	Organic	379-220	409-222	394-206
	Sand	139-19	43-16	31-8
Cobalt	Heavy Clay	116-58	158-33	71-29
	Shallow Clay	35-16	34-9	23-9
	Clay Loam	19-15	18-15	17-14
	Organic	33-27	43-27	34-25
	Sand	21-4	8-3	5-4
Arsenic	Heavy Clay	24-20.4	64.5-17.6	37.4-9.2
	Shallow Clay	10.5-4.9	7.8-5.5	17-5.5
	Clay Loam	6.3-5.1	7.9-6.7	7.8-6.3
	Organic	23.9-16.9	28-19.4	26.5-18.4
	Sand	9.6-2.1	7.1-2.5	4.9-2.7

Table 2-3 Areas of CoC Soil Concentration Exceedances within the Study Area.

Respective Areas	CoC			
	Arsenic	Cobalt	Copper	Nickel
MOE Guideline (mg/kg)	25	50	200	200
Organic Area (ha)	62.18	104.03	157.81	429.07
Clay Area (ha)	15.86	77.31	106.35	1967.91
Sand (ha)	0.0	0.29	0.81	57.53
Residential Land West of Welland Canal (ha)	0	0	27.58	175.66
Total Area (ha)	78.04	181.63	292.55	2630.17

Table 2-4 A Comparison of Soil Nickel Concentrations in Woodlots and Adjacent Fields at Various Distances from the Inco Refinery.

Approximate Linear Distance of woodlot from Refinery (km)	Woodlot Soil Ni Concentration (mg/kg)	Approximate Linear Distance of Woodlot from Adjacent Field (km)	Adjacent Field Ni Concentration (mg/kg)
1.0	33 000 (A3-0-5)	0.35	1860 (I-H-3)
4.2	709 (LL6)	0.7	145 (I-M-2)
4.8	550 (LL10)	0.4	156 (I-M-4)

*Code in brackets represents field sample/laboratory code

Figure 2-6 shows CoC concentrations in woodlot soils (0-5 cm deep), since these data were not used to generate the isolines for open spaces shown in Figure 2-2 through Figure 2-5. Woodlot data used to produce Figure 2-6 is provided in Volume III, tab 9.

Though woodlot soil CoC levels are elevated when compared with adjacent fields in any one area, woodlots and fields both follow the same gradient in relation to distance from the Refinery, with woodlots and fields closer to the Refinery having higher CoC soil levels than those further away from the Refinery. Tables 2-5 and 2-6 provide a summary of CoC distributions in fields and woodlots for the Primary and Secondary Study Area, and the Reference Area. All CoC values represent the soil horizon from 0-5 cm depth.

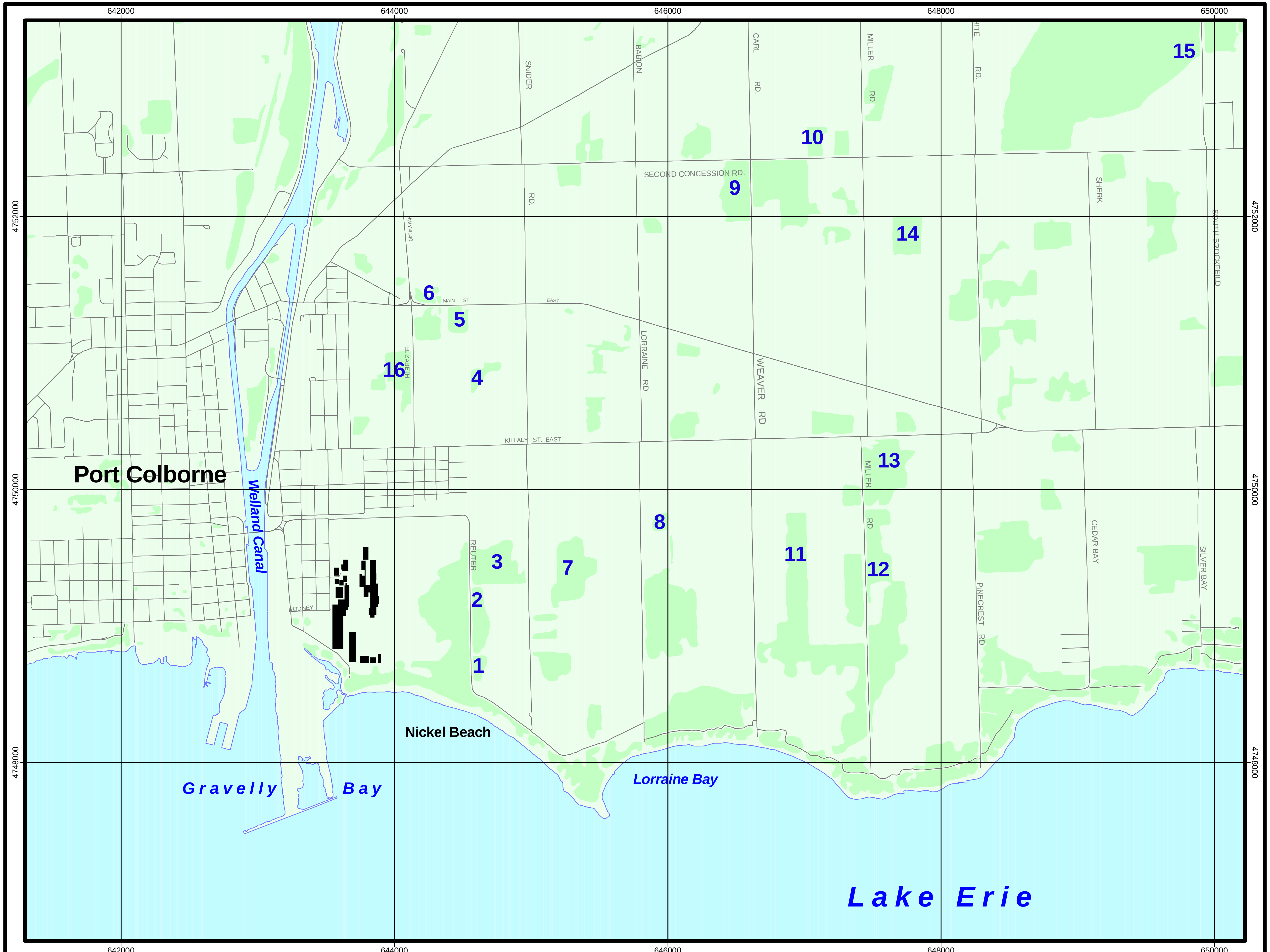


Figure 2-6

CoC Concentrations in Woodlot Soils (0-5 cm Deep) Port Colborne, ON

0 0.5 1 1.5
Kilometres

N

Woodlot Number	Calculation	Soil CoC (mg/kg) from 0-5 cm deep			
		Ni	Cu	Co	As
1	*	12,900	1,453	211	92.5
2	*	22,700	2,755	311	127.5
3	Maximum	33,000	3,930	427	137
	Mean	15,257	2,094	218	82.2
	SD	9,290	1,160	125	38.5
	n	11			
4	Maximum	4,650	320	56	16
	Mean	2,530	227	39	13.1
	SD	1,274	63	12	2.5
	n	5			
5	Maximum	3,100	270	65	16
	Mean	2,166	200	43	13.4
	SD	830	59	16	2.1
	n	5			
6	*	780	106	17	8.2
7	Maximum	4,745	680	79	45
	Mean	2,498	343	47	23.5
	SD	1,249	173	20	9.5
	n	9			
8	*	2,025	252	40	14.0
9	*	1,505	176	23	7.4
10	*	550	73	16	7.7
11	Maximum	1,070	125	28	15
	Mean	642	94	19	7.7
	SD	325	30	6	5.2
	n	4			
12	*	288	125	12	8.2
13	*	709	95	18	6.9
14	Maximum	2,110	275	57	12
	Mean	1,161	162	33	9.0
	SD	716	89	19	3.0
	n	5			
15	*	431	80	17	5.4
16	*	4,130	436	70	29.9

* indciates a value based on the results of one soil sample that was collected and chemcially analysed.

CoC Values in selected woodlots are based on MOE woodlot data (2000), and data collected by Jacques Whitford for the CBRA.

Inco Refinery
Woodlot
Road

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

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 27,500

Regional NIAGARA

Jacques Whitford
Consulting Engineers
Environmental Scientists
Risk Consultants

Finally, in addition to woodlots having higher CoCs levels, sampling of woodlots has identified that surface (0-5 cm) soil CoC concentrations in woodlots also have a patchy distribution. Generally, for woodlots near the Refinery, CoCs levels are highest along the windward leading, western edge of the woodlot. These levels then decline through the woodlot to the downwind, eastern edge. However, even within this general distribution pattern, soil CoCs are still locally patchy due to the past/present occurrence of tall, large-crowned trees, which acted/act as highly efficient local filters. Table 2-7 shows the surface soil values for nickel for a 250 m x 350 m woodlot located approximately 500 m east of the Refinery along Reuter Road. The locations of these sample points are shown on Map 1 and are numbered 1 through 5, under the heading "Maple Sap".

Table 2-5 Soil CoCs in Fields

Calculation	Primary Study Area (mg/kg)				Secondary Study Area (mg/kg)				Reference Area (mg/kg)			
	Ni	Cu	Co	As	Ni	Cu	Co	As	Ni	Cu	Co	As
Min	103	30	8	2.9	16	1	4	0.5	13	9	3	1.3
Max	10525	1400	153	48.1	1280	139	24	19.9	1100	140	27	10.0
Mean	1354	177	30	10.4	293	49	11	5.0	81	27	9	3.9
SD	1391	173	20	7.4	225	27	4	3.6	111	15	4	1.5
n	127	127	127	114	36	36	36	36	112	112	112	104

Derived from JW, MOE, AMEC data. For a listing of data please refer to Volume III, tab 9.

Table 2-6 Soil CoCs in Woodlots

Calculation	Primary Study Area (mg/kg)				Secondary Study Area (mg/kg)				Reference Area (mg/kg)			
	Ni	Cu	Co	As	Ni	Cu	Co	As	Ni	Cu	Co	As
Min	303	52	9	4.0	126	31	7	2.8	16	8	1	0.9
Max	33000	3930	427	137.0	2110	275	57	15.4	185	55	12	11.0
Mean	7158	921	110	43.1	777	115	22	7.5	96	28	7	5.6
SD	8196	1083	112	40.6	540	62	13	3.2	51	15	3	2.6
n	38				17				23			

Derived from JW and MOE data. For a listing of data refer to Volume III, tab 9.

Table 2-7 Soil Nickel Concentrations for a Woodlot near the Inco Refinery

Location in Woodlot	Sample ID	Nickel Concentration (mg/kg)	Relative Position
SW Quadrant	A1-0-5	5,400	South leading edge
West Side	A2-0-5	24,500	Centre leading edge
NW Quadrant	A3-0-5	33,000	North leading edge
Centre	A4-0-5	14,200	Centre of Woodlot
East Side	A5-0-5	18,900	Centre downwind edge
Mean		19,200	
Standard Deviation		10,400	

2.1.3.2 Leaching Characteristics of Soil

Due to the type of chemical compounds present and the complexity of chemical interactions among the different components of any given soil, not all chemicals in a soil matrix are accessible to living organisms and thereby beneficial or harmful to biota. Thus, only a limited portion of a soil contaminant may be available to an organism in contact with that soil.

Four extraction methods (aqueous, DTPA, strontium nitrate and acid ammonium oxalate) were used in the phytotoxicity trials (Jacques Whitford 2004a) as a means of appropriately assessing plant-available CoC levels in Port Colborne soils. For this study, these values are important as an estimate of the leaching capacity of clay and organic soils of the study area as well as predicting the proportion of CoCs that are phytoavailable to plants in the Port Colborne area.

Aqueous (water) extraction is presumed to represent the most immediately available metals from the soil solution as near-neutral conditions only extract those metals from the soil that are readily water soluble. The method used for the aqueous extraction for this study in 2000 and 2001 followed that of Haq *et al*. (1980). The DTPA (diethylenetriamine pentaacetic acid) extraction has been correlated to soil micronutrient and metal availability, and can be a highly successful predictive technique. Strontium nitrate ($SrNO_3$) extractions have been correlated with plant shoot nickel concentrations when the plants are grown on several different soils adjusted to different pH levels (Ernst 1996). The $SrNO_3$ method can measure the effect of changing soil pH on plant uptake of nickel from low to phytotoxic concentrations. Finally, acid ammonium oxalate extraction is used to extract metals such as aluminum, manganese and iron from their associated oxides, and is a particularly aggressive extraction method. Metals extracted using this method include those that are either strongly adsorbed to surfaces (inner-sphere complexes) or incorporated into the structures of iron and manganese oxyhydroxides.

Tables 2-8 and 2-9 summarize the percentage of nickel, copper and cobalt that were extracted, in a laboratory setting, from clay and organic soils of various nickel concentrations in the Study Area using the four different methods mentioned above. Data for arsenic were not obtained due to the limitations of these extraction methods with arsenic.

Table 2-8 Percentage of CoCs Leached from Clay Soils

CoC Extracted	Calculation	Percentage of CoC Extracted from Clay Soil			
		Aqueous Extraction	DTPA Extraction	Oxalate Extraction	Strontium Nitrate Extraction
Nickel	Mean	0.37	18.36	30.80	0.14
	SD	0.14	1.09	1.58	0.14
Copper	Mean	0.68	64.40	94.06	0.14
	SD	0.45	6.08	8.12	0.13
Cobalt	Mean	0.46	7.64	14.19	0.23
	SD	0.31	0.75	2.43	0.15

Table 2-9 Percentage of CoCs Leached from Organic Soils

CoC Extracted	Calculation	Percentage of CoC Extracted from Organic Soil			
		Aqueous Extraction	DTPA Extraction	Oxalate Extraction	Strontium Nitrate Extraction
Nickel	Mean	0.30	30.54	34.40	0.08
	SD	0.04	6.87	5.44	0.05
Copper	Mean	0.23	47.42	71.09	0.05
	SD	0.07	8.99	8.61	0.03
Cobalt	Mean	0.88	29.69	51.42	0.44
	SD	0.51	3.68	6.05	0.25

From Tables 2-8 and 2-9 it is evident that the percentage of CoCs leached from clay and organic soils is dependent on the extraction method used. Overall, DTPA and acid ammonium oxalate extracted proportionally more copper than nickel or cobalt, and extracted proportions were higher from clay soils than from organic soil. However, extractable nickel and cobalt are higher in the organic soils tested compared to the clay soils. When considering conditions in the Study Area, the aqueous extraction is the closest representation of potential conditions where heavy rains or snowmelt would leach CoCs from the soil, thereby mobilizing CoCs.

Under the DTPA and oxalate extraction methods, a greater proportion of CoCs, particularly copper, is removed from the soil due to the acidity of the solutions used. When soil is exposed to an aqueous extraction however, less than 1% of soil CoCs are removed, indicating that soils in the Study Area have a low leaching capacity under neutral water conditions. Nickel, copper and cobalt appear to be tightly bound to the soil matrix, as is the case with most historically contaminated areas, lowering the leaching capacity of these soils under ambient environmental conditions (Anderson *et al*. 1997). In reality, one would expect higher leaching capacity of soils compared with the aqueous extraction due to lower pH in rainwater. However, surface water data shown in Table 2-11, with neutral pH (mean 7.1-7.3) and low CoC concentrations relative to surrounding soils, indicate that the leaching capacities of organic and clay soils in the Study Area are low.

2.1.4 Sediment in Aquatic Systems

For the study, sediment samples were only collected from ponds and ditches from which frogs and tadpoles were collected. Sediment in ponds, ditches and watercourses were sampled for depth, composition and CoC parameters. In general, sediments consisted of a thin (2 – 15 cm) horizon of organic material over clay. In some locations, where ditches or ponds had recently been dredged, sediments consisted mainly of fine silt (1.5 – 20 cm) over clay. Table 2-10 summarizes CoC parameters present in sediments sampled in the Study Area.

Table 2-10 Pond Sediment CoC Concentrations

Calculation	Primary Study Area (mg/kg)				Secondary Study Area (mg/kg)				Reference Study Area (mg/kg)			
	Ni	Cu	Co	As	Ni	Cu	Co	As	Ni	Cu	Co	As
Min	193	56.25	11	3.6	25	25	5.5	2.3	21	24	5	2.4
Max	429	85	16	4.7	195	66	11	4.7	44	50	10	7.3
Mean	279	65	14	4.2	77	38	9	3.6	30	34	8	4.6
SD	103	14	2	0.5	61	15	2	0.8	10	10	2	2.2
n	4				6				6			
Site Codes	(F-H-1, F-H-2, F-H-4, F-H-5)				F-M-1 through F-M-6)				(F-C-1 through F-C-6)			

As can be seen from the above table, the CoC concentrations in sediment generally follow a pattern similar to soil CoCs, with the CoC concentrations increasing in sediment as one moves closer to the source of the emissions. The exception however is arsenic, where concentrations in sediment in the reference area are higher than those found in the Primary Study Area.

2.1.5 Hydrogeology and Groundwater Flow Direction

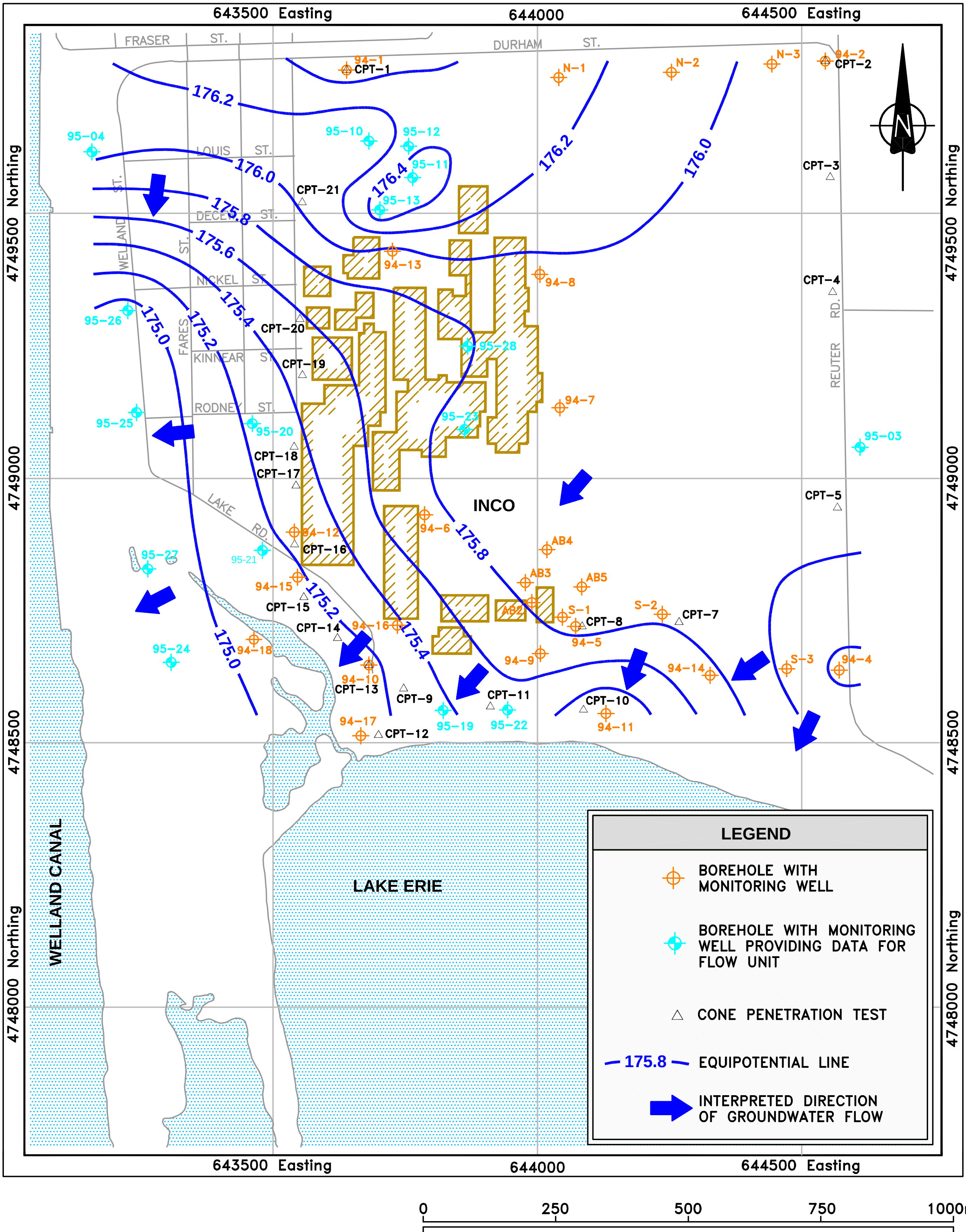
The Study Area lies within the Haldimand Clay Plain physiographic region, which covers the entire Niagara Region (Chapman and Putnam 1984). This physiographic region can best be summarized as a limestone plain overlain with clay and till.

There are three subsurface hydrogeologic units on the east side of Port Colborne (Klohn-Crippen 1996). These are:

- A surficial overburden aquifer consisting of discrete areas of peat, sand, gravel and shallow groundwater;
- An underlying overburden aquitard (non-producing strata) consisting of glaciolacustrine varved clay and glacial till deposits; and,
- A fractured bedrock aquifer consisting of potable groundwater in several moderate to highly transmissive fractures with intervening layers of low-permeability rock.

The main aquifer used for drinking water wells in the Port Colborne area is the latter of these three units, the upper fractured bedrock units of the Bois Blanc and Onandaga limestone formations. The glaciolacustrine silty clay found in the second unit between the overlying surficial fill/peat and underlying bedrock acts locally as an aquitard, or a less permeable unit, which protects the lower fractured limestone aquifer from the surficial aquifer.

Measurements of flow through the local overburden aquifers estimated groundwater velocities of 3 m/year for peat, 54 m/year for gravel and sands and 4 cm/year for clay-silt till soils (Klohn-Crippen, 1996). Klohn-Crippen (1996) indicate that the groundwater flow in the overburden deposits is generally southwest toward Lake Erie and the Welland Canal. The groundwater flow direction in the shallow bedrock in the vicinity of the Refinery is in the west-southwest direction towards the Welland Canal (Figure 2-7). It is expected that the regional bedrock groundwater flow direction east of Reuter Road is likely more southward to discharge at Lake Erie.



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

SHALLOW BEDROCK GROUNDWATER FLOW
AFTER KLOHN-CRIPPEN MAY 1, 1995 MAP
EAST SIDE OF PORT COLBORNE, ONTARIO

Job No.:	Dwg. No.:	
ONT34651	3	
Date:	Dwn. by:	Appd.:
02/06/12	LMV LMV	MA

Jacques Whitford

A hydrogeological study on the former Canada Furnace and Seaway properties indicated that the groundwater flow within the overburden is from west to east towards the Rodney Street area (AMEC 2001a) (Figure 2-8). The perched shallow groundwater flow within the fill reflects the low topographic gradient from west to east towards Rodney Street. The study also showed that at the former Canada Furnace property, south of the CNR yard and Rodney Street area, the shallow groundwater flow is radial and flows toward the north and south (AMEC 2001b) (Figure 2-9).

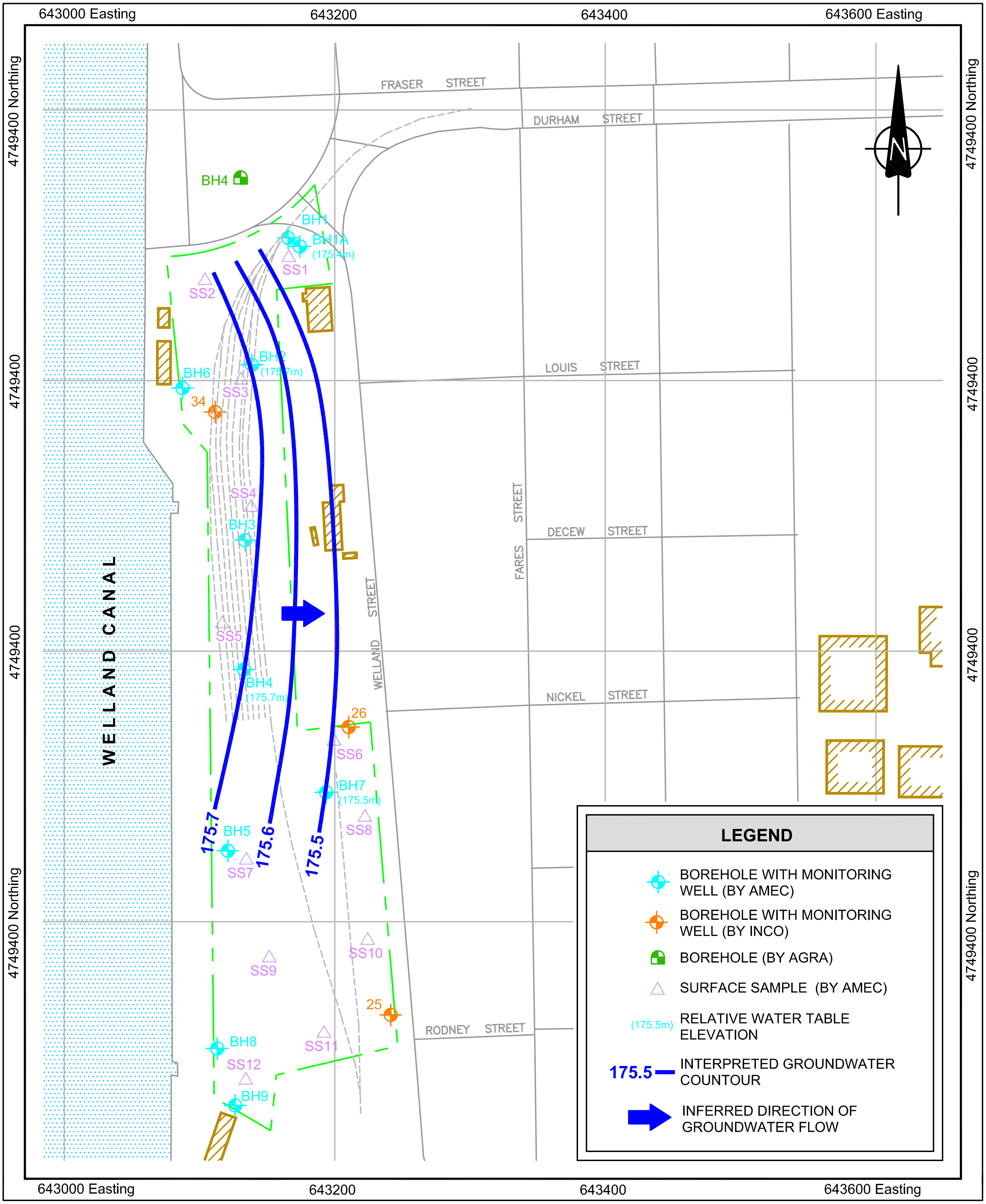
It is apparent from these reviews that the dominant shallow bedrock groundwater flow around the Inco Refinery is south toward Lake Erie and west to the Welland Canal. The overburden groundwater regime is perched and the flow pattern is dependent on site-specific conditions such as the type of overburden deposits, thickness and amount of fill material present at the site.

The chemical quality of the overburden and shallow bedrock groundwater at the Inco Refinery site (north, east and southeastern sections of the property) was fresh and uncontaminated (Klohn-Crippen 1996). The study showed that elevated levels of metals, such as nickel, copper and cobalt, occurred in groundwater for both the shallow bedrock and overburden in the south and southwestern portions of the Refinery site. Klohn-Crippen (1996) concluded that the primary source of the groundwater contamination by metals was not due to local air deposition of CoCs on soils, but primarily from an abandoned electrolytic nickel-refining building and residual contamination from the site of the decommissioned No. 1 building on the Refinery site. The study showed that the contamination of local groundwater was restricted to the Refinery site, with movement of the contaminant plume directly west-southwest to the Welland Canal and south to Lake Erie.

A groundwater sampling program of residents' wells was conducted during the summers of 2000 and 2001 as part of the CBRA's HHRA to assess the levels of CoCs present in groundwater in the region of Port Colborne. Testing results of 172 well samples found that CoCs were present in well water, but at levels that were below all applicable MOE guidelines (Jacques Whitford 2001b).

Based on the existing hydrogeological conditions found in the Port Colborne area, and the results of private water well testing in the Study Area, regional contamination[E14] of groundwater by CoCs is not present and is not expected to occur. As a result, potential adverse effects of CoCs in groundwater discharged to the natural environment are not considered as a pathway for ecological exposures in the natural environment, and groundwater as a pathway is not assessed further in the ERA.

34651-13



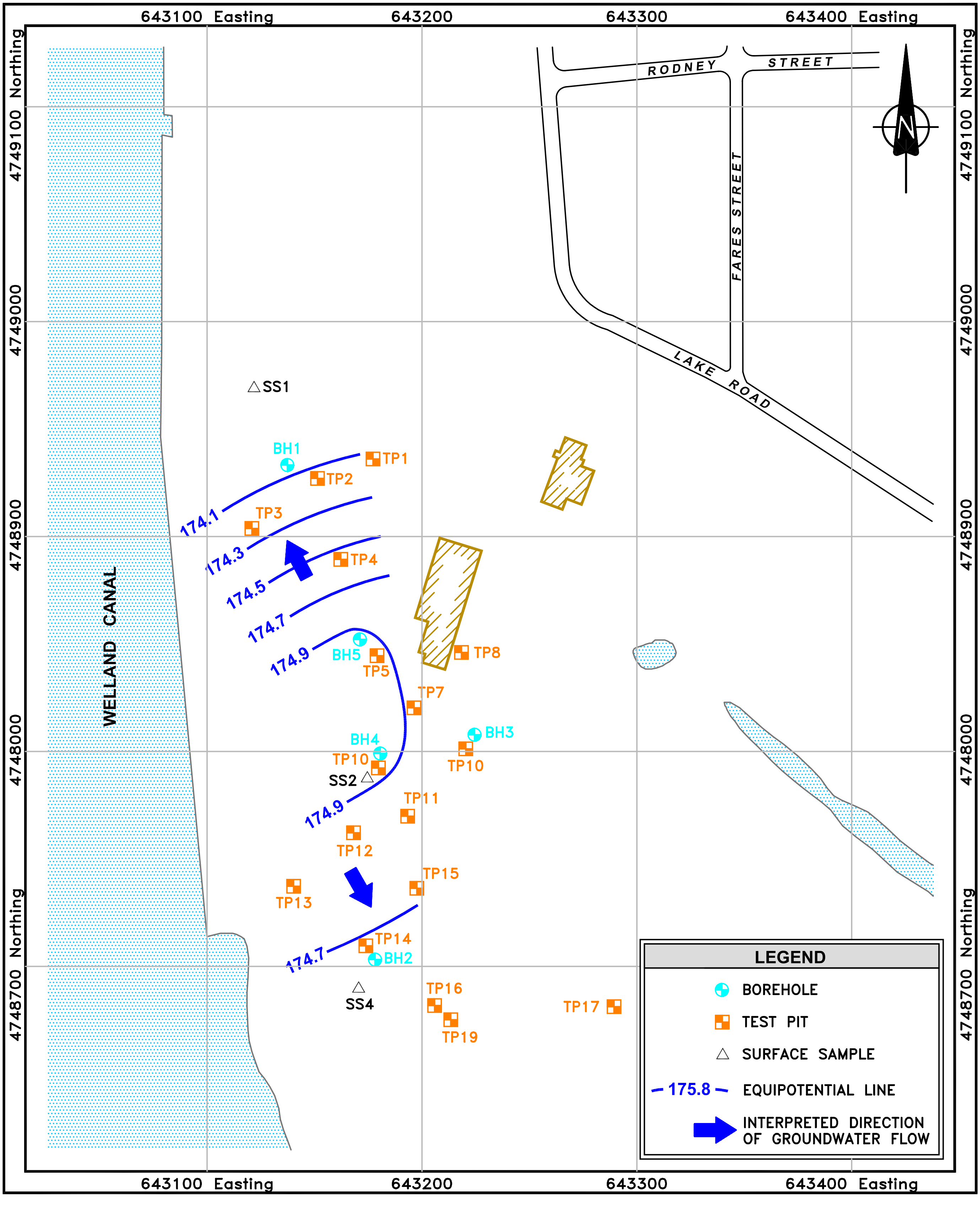
NOTE: LOCATIONS OF SITE FEATURES ARE APPROXIMATE AND MAY VARY FROM THAT SHOWN.

GROUNDWATER FLOW WITHIN OVERBURDEN
AMEC, JULY 2001
EAST SIDE OF PORT COLBORNE, ONTARIO

Job No.:	Dwg. No.:	
ONT34651	2.8	
Date: 02/11/21	Dwn. by: LMV LMV	Appd.: MA

Jacques Whitford

34651\2002\34651-3



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

GROUNDWATER FLOW WITHIN OVERBURDEN
FORMER ALGOMA STEEL SITE, AFTER AMEC, JULY 2001
EAST SIDE PORT COLBORNE, ONTARIO

Job No.:	Dwg. No.:	
ONT34651	2.9	

Date:	Dwn. by:	Appd.:
02/06/16	LMV LMV	MA

Jacques Whitford

2.1.6 Hydrological Parameters

The landscape of the Study Area and surrounding areas consists mainly of agricultural lands that are hydrologically managed through agricultural drainage tiles, ditching, and municipal drains. No naturally occurring (unaltered) streams or creeks occur in the Study Area. The main surface water drainage features are the Wignell Drain and Beaverdam Drain, which drain from north to south. The Wignell drain, which runs parallel to Snider Road, 400 m east of the Refinery property boundary, has a watershed of approximately 1200 ha and is connected to the majority of the Study Area's agricultural ditches and smaller drains between Reuter Road and Weaver Road. The Beaverdam Drain has a watershed of approximately 1400 ha and collects surface water from lands around Miller Road to the eastern limits of the Study Area. Both drains empty into Lake Erie with flood gate and pump controls at the mouth of the drains at the Lake Erie shore.

Municipal drains have been used for draining the lands in the Port Colborne area for one hundred years (AMEC 2001c). As a result of these management practices, the landscape is efficiently drained leaving only a small percentage of ditches and watercourses with flowing or standing surface water during the drier summer months of the year. Similarly, due to the clay-based soils, shallow standing water in woodland swamps is present in early spring but these areas typically become dry by early June due to ditching. A review of the drainage systems in the Study Area by Fisheries and Oceans Canada (DFO) identified that all branches to the Wignell and Beaverdam drains are intermittent in nature and do not support fish populations (City of Port Colborne 2000). Based on the fisheries assessment conducted by DFO, and supported by field investigations conducted for this study, potential impacts of CoCs on inland fisheries is not a concern. However, CoCs may be ingested by certain terrestrial receptors through the capture and predation of aquatic invertebrates not sampled as part of this CBRA. Surface water that persists year-round is present only in farm ponds dug deep into the clay soil, and at the very lower sections and mouth of the larger municipal drainage ditches that feed directly into Lake Erie.

Surface water was sampled by Jacques Whitford in 2001 from 32 locations across the Study Area and Reference Area, in woodlots, fields and municipal ditches; Maps 1 and 2 present the locations of sample sites. Concentrations of CoCs found in surface water during this study are summarized in Table 2-11.

Table 2-11 Mean Surface Water CoC Values

Calculation	Primary Study Area (mg/kg)				Secondary Study Area (mg/kg)				Reference Area (mg/kg)			
	Ni	Cu	Co	As	Ni	Cu	Co	As	Ni	Cu	Co	As
Min	0.004	0.0015	0.0001	0.001	0.003	0.0014	0.0002	0.001	0.001	0.0005	0.0001	0.001
Max	0.884	0.0820	0.0377	0.038	0.092	0.0124	0.0042	0.001	0.013	0.0137	0.0041	0.001
Mean	0.159	0.0179	0.0064	0.004	0.040	0.0063	0.0018	0.001	0.005	0.0045	0.0011	0.001
SD	0.302	0.0295	0.0119	0.011	0.028	0.0035	0.0013	0.001	0.005	0.0045	0.0014	0.001
n	11				13				8			
Mean pH	7.2				7.1				7.3			
Site Codes	(S1-S4,S8,S19-S20,S22,S28,S31-S32)				(S5-S6,S9,S11,S13-S18,S21,S29,S33)				(S23-S26,S34-S37)			

There exist several trends in surface water CoC concentrations, related to distance from the presumed source and habitat. On average, higher nickel concentrations in surface water occur in areas closer to the Refinery. Also, nickel concentrations in surface water are greater in woodlots compared to fields. Figure 2-10 illustrates these trends, based on surface water samples collected from adjacent fields and woodlots at various distances from the Refinery, in a northeast direction. Samples S20 and S3 are closest to the Refinery, while S13 and S10 are the furthest away. Map 1 shows the location where the surface water samples in Figure 2-10 were collected.

An attempt was also made to determine whether CoCs in surface water are being concentrated in drainage ditches and the main trunks of the municipal drains as water flows south towards Lake Erie. Surface water CoC concentrations in the Wignell Drain and Beaverdam Drain were reviewed from the headwaters to near the discharge point at Lake Erie. Surface water in the Wignell drain indicates elevated CoC levels directly east of the Refinery; however, this is more a function of proximity to the Refinery and not downstream accumulation. For the Beaverdam Drain, which originates at the northern limits of the Study Area, CoC concentrations in surface water decrease towards Lake Erie indicating that no accumulation of CoCs is occurring downstream (Figure 2-11). Cumulative distances from S13 to S14, S13 to S15, and S13 to S16 are 1.5 km, 2.5 km, and 4.6 km respectively (see Map 1 for sample locations). Overall, CoCs in surface water can be approximated by soil CoCs, with higher values of CoCs in surface water present in areas where soil CoCs are elevated.

Figure 2-10 Surface Water Nickel Concentrations in Fields and Woodlots with Increasing Distance from the Refinery (NE Direction). Sample Codes are Included on the X-axis.

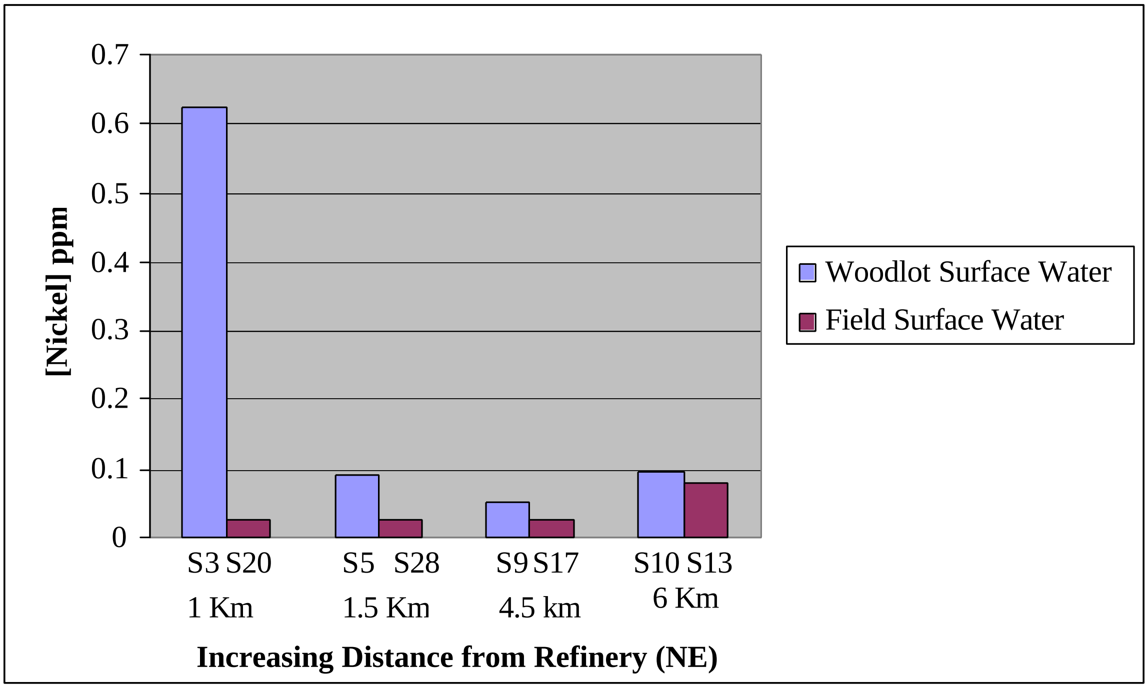
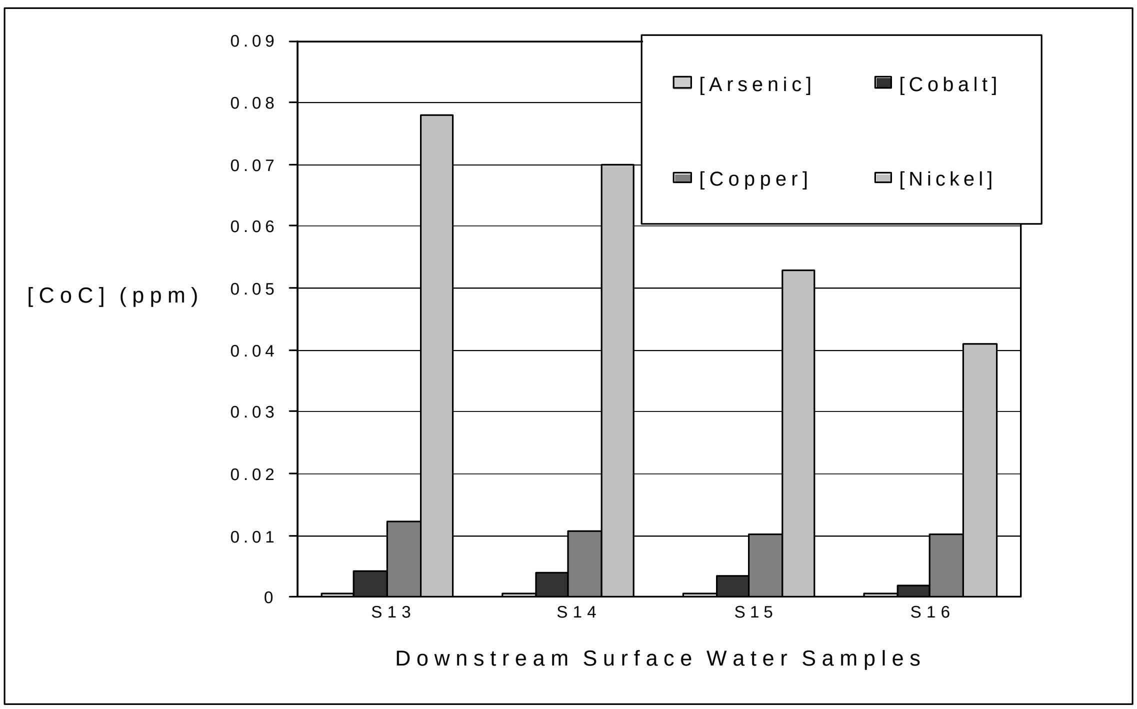


Figure 2-11 CoC Concentrations in Surface Water of the Beaverdam Drain



2.1.7 Lake Erie Nearshore

The risk assessments being conducted under the CBRA aim to answer the question of what risks, if any, exist for receptors having contact with soil that has been impacted by historical dust deposition originating at the Inco facility. Media other than soil, namely, air and ground water, may be considered potential pathways of exposure because of the direct linkage they have to soil (i.e., leaching contaminants into ground water and/or re-suspension of soil dust into air by means of wind erosion).

Water and sediment in Lake Erie are not being examined within the scope of the CBRA. The reason for this is that water and sediment in Lake Erie are potentially influenced by factors other than those associated with the chemical and physical behaviour of soils. However, the occurrence of CoCs along the shoreline of Lake Erie and in inland aquatic environments, such as ponds and municipal drains, can be considered to have direct linkage to the occurrence of CoCs in soils. As a result of concern for potential exposure of amphibian to CoCs in inland aquatic environments, and occurrence of a rare toad species along the shore of Lake Erie, the CBRA Environmental Risk Assessment was altered, at the request of the public, to include consideration of these types of aquatic valued ecosystem components. However, assessment of risk to the aquatic environment of Lake Erie is outside the CBRA.

2.1.8 Ambient Air Monitoring

Ambient air quality was monitored between 11 August and 10 September 2001 at various locations in and near Port Colborne. Refer to Jacques Whitford (2002b) for sampling information and locations. For the ERA, data from two locations (J5 and J7) in the Primary Study Area using a TSP (Total Suspended Particulate) air monitoring station were used to characterize CoCs in ambient air. Table 2-12 summarizes results collected from J5 and J7 in the Primary Study Area. Mean values for the reference area are presented in Table 2-12 for comparative information.

Table 2-12 Total Suspended Particulate (TSP) Matter Ambient Air Results

Calculation	Primary Study Area (μg/m³)				Reference Study Area (μg/m³)			
	Nickel	Copper	Cobalt	Arsenic	Nickel	Copper	Cobalt	Arsenic
Min	0.0025	0.0165	0.0002	0.0015	0.0019	0.0048	0.0001	0.0005
Max	0.2875	0.4508	0.0197	0.0086	0.0150	0.1626	0.0005	0.0032
Mean	0.0667	0.0995	0.0031	0.0030	0.0054	0.0692	0.0003	0.0016
SD	0.0881	0.1172	0.0044	0.0018	0.0037	0.0616	0.0001	0.0008
n	21				11			

Note: "n" is the total number of TSP samples that were analyzed in each Study Area between 11 August and 10 September 2001.

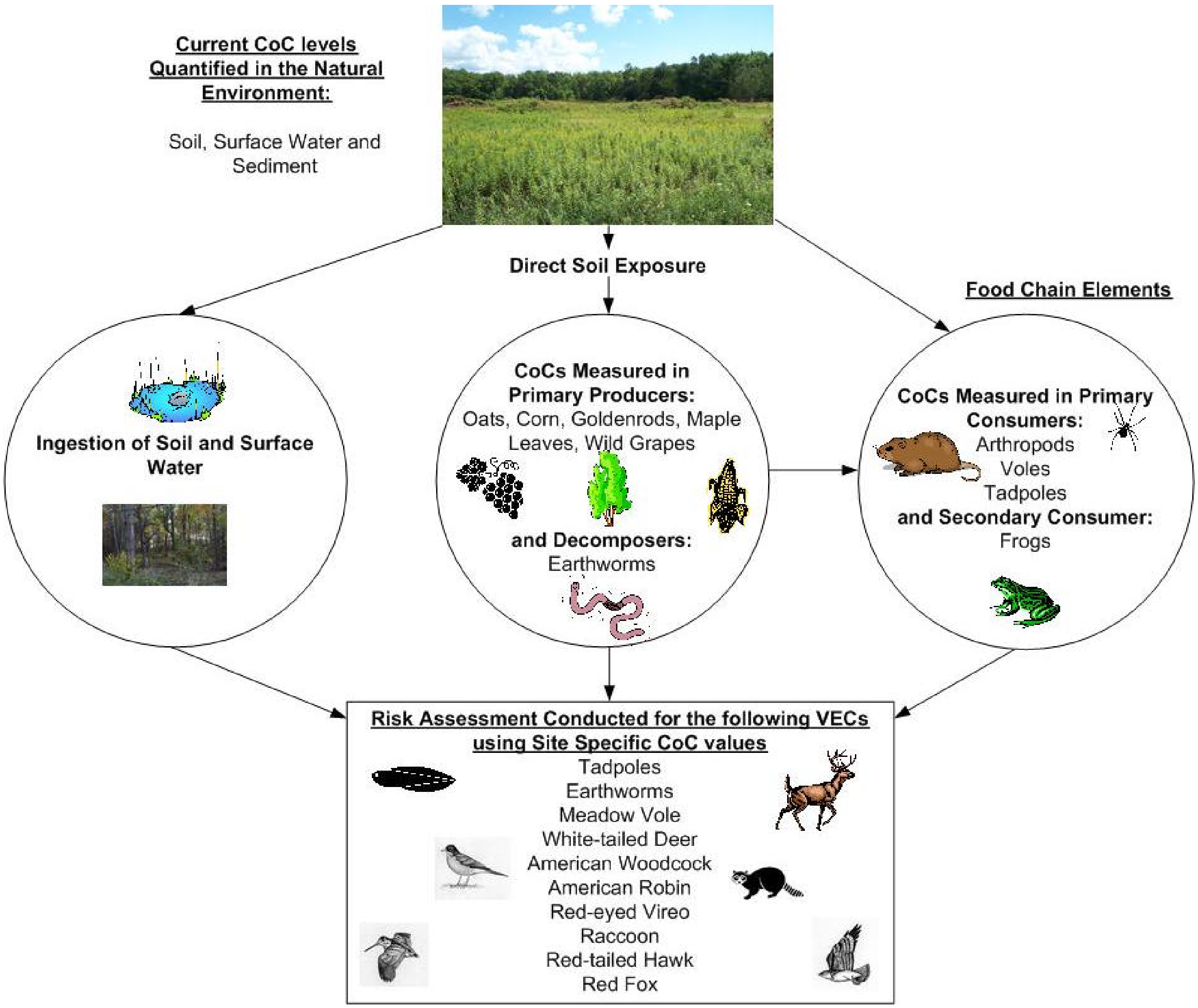
CoC ambient air concentrations are elevated in the Study Area when compared to the reference area. However, it is important to note that all measured CoCs in ambient air monitored during this sampling program were within MOE guidelines.

2.1.9 Site Conceptual Model

Information gathered for the CBRA indicates that historical atmospheric particulate emissions from the Refinery have resulted in deposition of CoCs in soil of the Study Area at concentrations greater than MOE generic soil quality guidelines. The four CoCs are nickel, copper, cobalt and arsenic. The CoCs have been identified to be present in four environmental media: soil, sediment, surface water (in ditches and ponds) and ambient air. Since CoC concentrations in soil exceed MOE Guidelines, a potential risk exists for plants (primary producers) and soil fauna (decomposers) from direct soil exposure. These risks include reduced growth or productivity and mortality. In addition to direct soil exposure, the presence of CoCs in other environmental media represents a potential for food chain bioaccumulation or cumulative dose exposure for both primary and secondary consumers.

The ERA examines the diversity of flora and fauna in the Study Area, and identifies receptors considered representative of important populations and trophic levels. These receptors (referred to as Valued Ecological Components, VECs) and their habitats are examined in detail in the remainder of this report, to determine if the CoCs are causing or are likely to cause a potential risk of adverse affects to these VECs and the natural environment of Port Colborne. Figure 2-12 provides an illustration of the conceptual model that summarizes our general approach and methodology for undertaking this ERA.

Figure 2-12 Schematic Illustration of the Conceptual Model for Natural Environment Receptors



3.0 ECOLOGICAL SITE CHARACTERIZATION

This section provides an overview of the natural environment within the Study Area. The primary purpose of site characterization is to generate the background data on species and habitats that could potentially be at risk from CoCs in specific environmental media. An initial site characterization was undertaken for the study in the summer of 2000 (Jacques Whitford 2001d). The results of the initial study were used for the development of the ERA work program and risk assessment approach undertaken in 2001. In addition, the site characterization for the natural environment was undertaken at a level of detail so as to be able to provide a meaningful qualitative assessment of the risk of CoCs to the environment in and around the Port Colborne area.

3.1 Identification of the Study Area

The Study Area for the ERA was identified as those lands in and around the Inco Refinery where soil concentrations of nickel were reported by the MOE to be greater than 200 mg/kg (MOE 2000a,b), east of the Welland Canal, excluding industrial and residential areas (Map 1). For the purpose of data collection for the ERA, the Study Area was divided into two general areas for field investigations, the Primary Study Area and Secondary Study Area (Section 1.4.8, Map 1). This area was identified for the sole purpose of data collection and assessing risk to the natural environment, and does not necessarily exclude or include areas subject to possible future remediation.

The Primary Study Area, where soil nickel concentrations were reported by the MOE to be above 500 mg/kg (MOE 2000a,b), is assumed to represent an area where ecological receptors would have a higher potential risk. The Secondary Study Area, where soil nickel concentrations were reported by the MOE to be between 200 mg/kg and 500 mg/kg (MOE 2000a,b), represents lands where ecological receptors could still be exposed to moderate soil concentrations of CoCs.

3.2 Assessment Methods for Site Characterization

Information for the ecological site characterization was obtained by field investigations undertaken by Jacques Whitford field biologists and through a review of existing literature and databases for the Port Colborne area. In addition, personal communications with staff at the Ontario Ministry of Natural Resources (OMNR) and local residents also provided valuable information on the area's flora and fauna.

With respect to the natural environment, the primary objectives of the site characterization were to:

- Characterize the primary soil types in the Study Area;
- Characterize the flora and fauna communities;
- Conduct ecological land classification (ELC) for the Study Area;
- Identify important ecological/wildlife functions and attributes; and,
- Identify any rare or significant species.

Initial fieldwork undertaken in July 2000 focused on documenting the flora, fauna and habitats for land directly adjacent to the Inco Refinery (Jacques Whitford 2001d). Fieldwork continued from April 2001 through to February 2002. For the field study, much of the detailed field investigation focused on those lands with natural habitats located in the Primary Study Area. These areas received a greater level of investigation as they represented areas that have been identified as significant natural areas in the Regional Municipality of Niagara (see Section 3.4) and were areas that, due to the recorded high soil CoC concentrations, could show the effect of CoCs on biota.

Documentation of the Study Area's fauna (mammals, birds, amphibians and reptiles) occurred while conducting various field surveys throughout the study period. Structured surveys were conducted to document bird species (transect surveys) and amphibians (breeding call road surveys for frogs and toads). The methods used for these structured surveys are detailed in field data collection protocols presented in Volume II. Reptiles and mammals were identified and noted when encountered while conducting other surveys and fieldwork. Live-traps were set in fields and woodlots to provide an indication of the small mammal species that are present. Night surveys conducted for amphibians provided opportunities for detecting larger mammals. Also, during the winter (December 2001-February 2002), surveys were conducted following snowfalls to document mammal tracks in areas within the Primary Study Area.

Collection of invertebrates (earthworms and arthropods) was conducted as part of the ERA's field program to acquire representative biomass samples from woodlots and fields for chemical analysis. The methods used for the collection of earthworms and arthropods are presented in Volume II. For earthworms, additional information such as species and age were documented. Arthropod biomass data were collected for the various orders represented in each sample. These data are summarized in Volume III.

The inventory of vascular plants focused on native woody species (trees and shrubs), based on the rationale that these species have persisted over long periods (five to greater than 100 years) of exposure to climate changes and to both airborne CoCs and soil CoCs. The field inventory for shrubs and trees focused on those areas that were identified as having high soil CoC concentrations.

For the Study Area, it was determined that qualitative investigations into the species richness of non-woody vascular plants in the Study Area would not be helpful in assessing potential adverse effects of elevated levels of CoCs in the soil on plants due to four factors. First and foremost, investigations of the fields and woodlots found that significant disturbance to their natural state had occurred due to historic agricultural use of the lands for growing crops and pasturing of cattle in both fields and woodlots. Combined tilling of the land and pasturing of cattle can significantly reduce the occurrence of native flora that could be expected to occur in a local area. Second, clay soils are the dominant soil type for the Study Area. Due to the nature of clay soils, years with lower than average rainfall quickly dry the soil to almost drought conditions and years with greater than average rainfall result in prolonged standing water. Under these conditions, the occurrence of many non-wood plant species, or their local abundance, can fluctuate greatly from year to year or from decade to decade. Third, due to the poor drainage of clay soil (and organic soils associated with swamps in the area), significant effort has been undertaken in the past to drain the lands for agriculture use by the construction of an extensive municipal drain and ditch system throughout the Study Area. This historic draining activity has significantly altered the floristic composition of the Study Areas forested swamps, which now have many more upland plant species than true wetland species.

As a final consideration, generally in any one local area where natural habitats cover a landscape, the number of vascular plant species that occur is highly dependent on local micro-habitat conditions (soil type, soil moisture, terrain, groundwater influence, past land use, etc.) and therefore comparisons of species richness between one local area to another are very difficult. Due to the inherent variability of plant species richness between sites, comparisons between sites cannot provide the resolution required for separating naturally occurring effects and adverse effects directly due to elevated levels of the CoCs in the soils of the Study Area. Such a comparison method could only identify catastrophic effects of soil CoCs on vascular plants.

Natural habitats in the Study Area were evaluated and mapped following the Ecological Land Classification (ELC) system developed for southern Ontario (Lee et al. 1998). The ELC is a well-established and accepted methodology for ecosystem description and interpretation. The ELC is a six-level hierarchical system, of which the finer elements, ecosite and vegetation type, were used for the purpose of this study.

Additional information was researched from appropriate atlases for each wildlife group (Weller and Oldham 1986, Cadman et al. 1987, Dobbyn 1995) and from the OMNR Natural Heritage Information Centre (NHIC) databases. For the Port Colborne area, many of the NHIC records refer to rare plant and animal species recorded at the Wainfleet Bog Wetlands, Mud Lake and The Clay Pits. These areas are outside of the Study Area. Nevertheless, the potential for rare species of flora and fauna to occur in the Study Area that had not been documented in existing data bases was recognized and therefore extensive field investigations were undertaken over a two year period. These field investigations identified the occurrence of provincially rare bird, amphibian and tree species within the study area.

3.3 General Ecological Setting

The Port Colborne area is located in the Mixed Wood Plains Ecozone (Wiken 1986). Within this ecozone, the Study Area lies within the Carolinian or Deciduous Forest Region (Hosie 1979, Lamb and Rhynard 1994), an area hosting an assemblage of animals and plants whose distribution is roughly centred on the Carolinas in the United States. The Niagara Peninsula is close to the northern limit of the Carolinian Zone, located south of a line generally extending from Toronto on Lake Ontario to Goderich on Lake Huron (Lamb and Rhynard 1994). Due to the limited physical area of the Carolinian Zone in Canada and extensive clearing of the land for agriculture, many Carolinian species are recognized as vulnerable, threatened or endangered both within Ontario (OMNR) and across Canada (Committee on the Status of Endangered Wildlife in Canada (COSEWIC). For example, of the 550 plant species listed as rare in Canada, 40% are Carolinian species with Canadian distributions restricted to southern Ontario.

In addition to the influence of the Carolinian Zone on species diversity, the Regional Municipality of Niagara also represents the southern limit of many species associated with the Great Lakes-St. Lawrence Forest Region. For example, many species of trees that are common in much of central and eastern Ontario, such as White Birch (*Betula papyrifera*), Eastern White Pine (*Pinus strobus*) and Balsam Fir (*Abies balsamea*), are rare or uncommon in the region, and are sparsely distributed. In the transition between these two major forest regions, many species of birds, plants and mammals that are common elsewhere in Ontario or the eastern United States are considered rare or uncommon in the region. As a result of these factors, the Regional Municipality of Niagara represents an area that has a more diverse flora and fauna than most other areas in Canada.

However, the Regional Municipality of Niagara also represents a part of Canada that was settled by European settlers early in the country's history. As a result of settlement over the past two centuries, most of Niagara's natural forests have been cleared and drained for agriculture. Undisturbed natural areas remain in very few, small patches within the region. The Port Colborne area is representative of much of the region's natural landscape, where much of the area has been cleared and developed and only small areas of secondary growth woodlots remain. In this respect, from an ecological perspective, the Port Colborne area is dominated by a highly altered and significantly fragmented natural landscape.

3.4 Soil Types

The existing Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) soil maps of the Regional Municipality of Niagara (OMAFRA 1998) were reviewed to evaluate various soil types that occur within the Study Area. The review of the soil maps indicated that approximately 25% of the Study Area is "not mapped". To fill in data gaps a soil mapping, sampling and chemical analysis program was conducted in the Study Area (Jacques Whitford 2002c). Soils in the Study Area comprise five primary soil groups that are shown in Figure 3-1. These are:

- Heavy Clay soils,
- Shallow Clay soils,
- Clay Loam soils,
- Organic soils, and,
- Sand soils.

The following section describes the general characteristics of each soil type identified in the Study Area. However, for the purpose of conducting the ERA, soil types were grouped into two categories: clay and organic, with clay representing Heavy Clay, Shallow Clay and Clay Loam soils. Sand soils are limited to small areas along the north shore of Lake Erie and generally were not included in the ERA, with the exception of one specific VEC (Fowler's Toad) that breeds on the beach in the Study Area.

3.4.1 Heavy Clay Soils Group

The majority of the area north and northwest of the Inco Refinery and west of the Welland canal comprises poorly drained, heavy, intractable clay identified as Heavy Clay and comprises three soil series. These are: Welland, Niagara and Haldimand. Surface runoff in Heavy Clay soil is slow to moderate and they are poorly drained. They have slow permeability and groundwater levels remain close to the surface most of the year, except during the summer. Heavy Clay soils have relatively high water holding capacity. The surface horizons of Heavy Clay soils usually range between 15 and 20 cm thick. An average organic matter content is between 3.8 to 6%. The pH value of the surface horizons can range from 5.5 to 6.5 and the average clay content is usually more then 40%.

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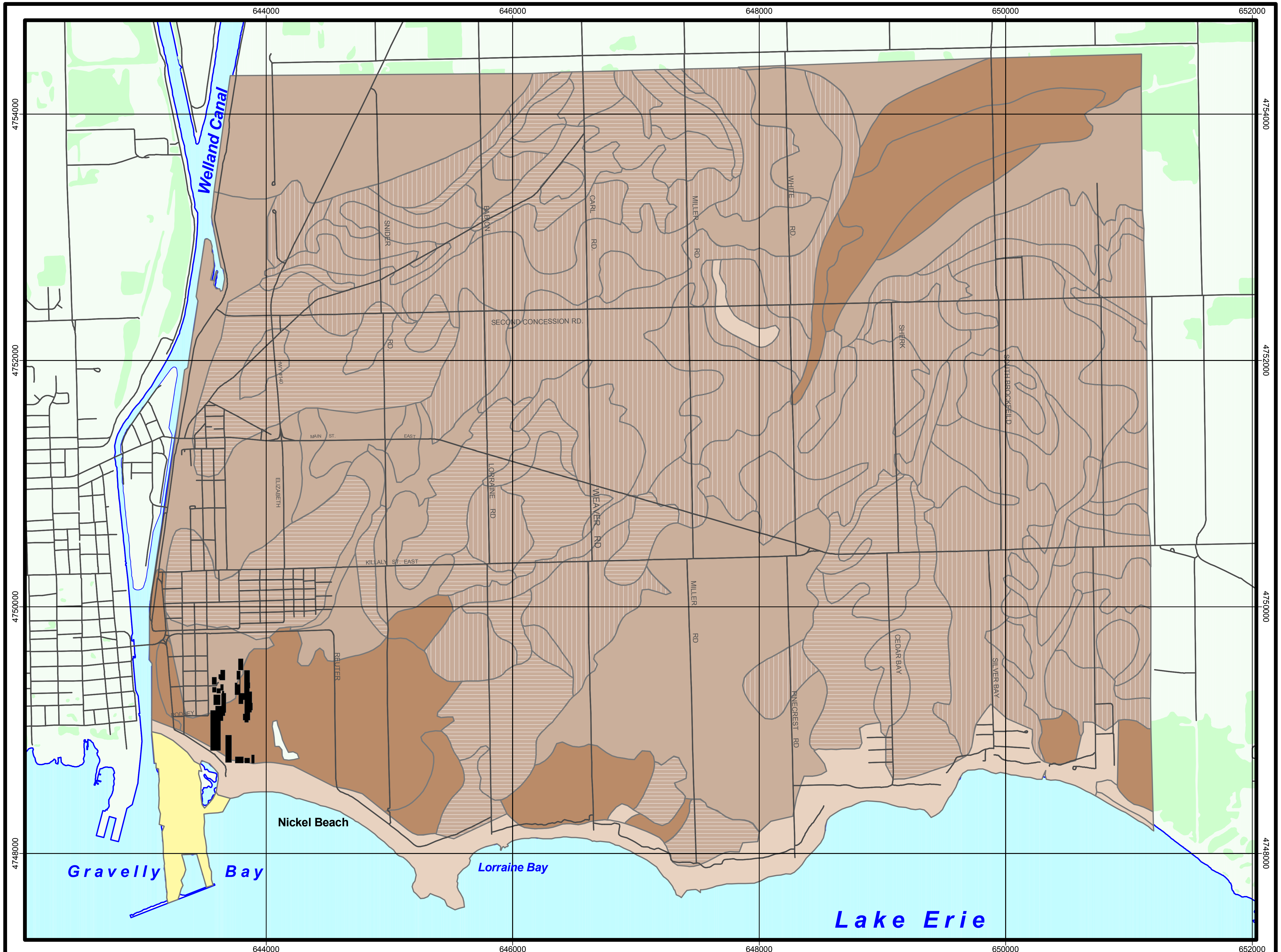

Figure 3-1

Soil Groupings east of the Welland Canal Port Colborne CBRA

0 500 1000 1500
Metres

N

Legend

Soil Groupings

- Heavy Clay
- Shallow
- Clay Loam
- Organic
- Sand
- Built Land

Topographic Features

- Inco Facility
- Roads

Job Number: ONT34561
Date: July 03, 2002
Dwn by: C. Amirault
Approved by: Oliver Curran

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

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Consulting Engineers
Environmental Scientists
Risk Consultants

3.4.2 Shallow Clay Soils Group

In and around the Port Colborne area, the Shallow Clay soil group comprises four soil series these are: Farmington, Alluvial, Franktown and Brooke series of soils. The surface horizons of Shallow Clay soil range in thickness from 10 to 20 cm, with fairly high (3 to 6%) organic matter content and pH ranges from 6.0 to 6.9. The soil textures are usually loam or clay loam with a variable amount of clay content, commonly less then 30%. Soils are poorly drained and permeability, water holding capacity and surface runoff vary from moderate to high depending on soil textures, slopes and horizon thickness. In general, the thickness of Shallow Clay soils ranges from 50 to 100 cm overlying limestone and dolostone bedrock.

3.4.3 Clay Loam Soils Group

The Clay Loam soil group comprises four soil series, these are: Jeddo, Chinguacousy, Peel and Malton series of soils. The Clay Loam soils are poorly drained and have moderate to slow permeability. They are saturated by groundwater most of the year. In Clay Loam soils temporary perching of water in soil B horizons is a common phenomenon. Surface runoff is moderate to rapid, depending on slope. Clay Loam soils in general have a mean surface horizon thickness of about 15 to 20 cm with an average 20 to 40% clay content, with fairly high (2 to 5%) organic matter content and pH value ranging from 6.2 to 7.2. Soil textures vary, but are usually silty clay loam, occasionally clay loam or silty clay.

3.4.4 Organic Soils Group

The Organic soil group comprises two soil series: Quarry and Lorraine. Generally, the Organic soils extend to depths of 40 to 160 cm over clayey mineral soil material. The average organic matter content of these soils ranges from 69% to 80% and pH ranges from 4.8 to 5.6. The organic soils are very poorly drained. They are highly permeable, have high water holding capacities and very little surface runoff. The nature of the organic materials ranges from woody fen peat to sedge fen peat, and the texture of the underlying mineral soil usually varies from silty clay loam to silty clay and clay.

3.4.5 Sand Soils Group

The Sand soil comprises two soil series: Fonthill and Walshingham (undifferentiated) series of soils. The area along the shore of Lake Erie south and east of the Inco Refinery comprises well drained sandy soils. These soils are of moderate to high permeability and have moderately low water holding capacities. Surface runoff is slow to moderate, increasing with slope. Texture of sandy soils is distinctive, ranging from sandy loam to gravelly loam. The surface horizons of the Sand soils group usually average between 20 and 25 cm in thickness and have a low organic matter content of 1.6% to 2.1%. The pH of the surface horizons ranges from 6.0 to 7.3. Limestone bedrock shelves are exposed locally at the south edge of the Sand Group along the shore of Lake Erie.

3.5 Known Significant Natural Features

Table 3-1 lists the known significant natural features in the vicinity of Port Colborne (RMON 1980, NHIC 2002). The natural features are identified numerically on Figure 3-2.

Table 3-1 Known Significant Natural Features

Natural Feature		Area (ha)	Designation*
Primary Study Area			
1	Nickel Beach Wetland	58	PSW
2	Nickel Beach Woodlot	47	ESA
Secondary Study Area			
3	Weaver Road Woodlot	82	ESA
4	Humberstone Swamp/Forest	380	PSW, ESA, ANSI
Reference Area			
5	Upper's Woodlot	81	ESA
6	Babion Road Woodlot	134	ESA
7	Mud Lake Conservation Area	46	PSW, ESA
8	Wainfleet Bog Wetland	250	PSW, ESA, ANSI
9	Cement Plant Road Quarry Wetland	10	PSW
10	Wainfleet Wetlands Conservation Area	180	PSW, ESA
11	Empire Beach Backshore Forest/Wetland	61	PSW
12	Shisler Point Woods	77	ESA

* PSW – Provincially Significant Wetland, as evaluated by the Provincial Wetland Evaluation System, MNR
ESA – Environmentally Sensitive Area, Regional Municipality of Niagara Environmentally Sensitive Area
ANSI – Area of Natural and Scientific Interest, MNR

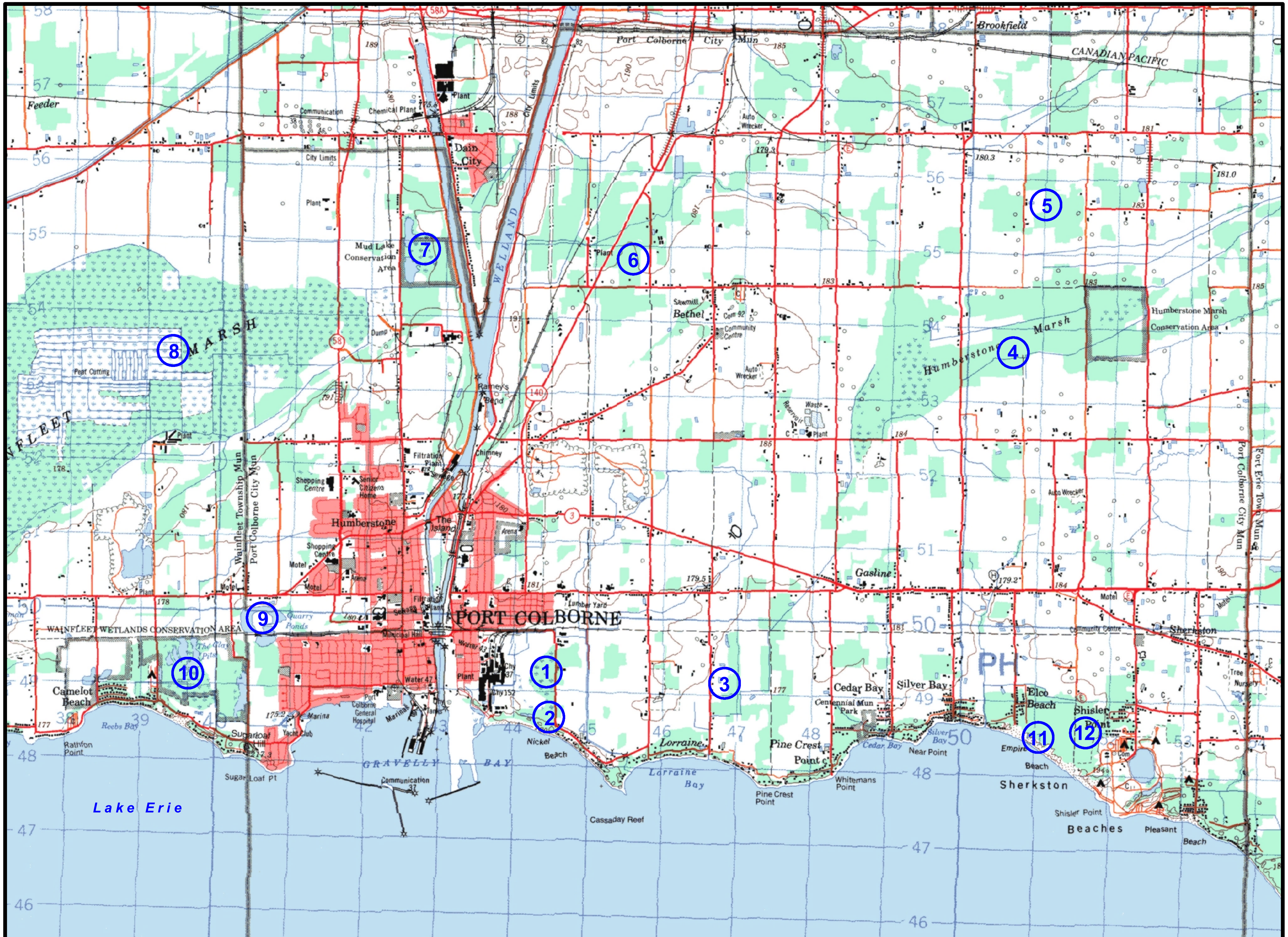

Figure 3-2

Locations of Significant Natural Features Map Port Colborne, ON

0 1 2
Kilometres

N

Legend

1. Nickel Beach Wetland
2. Nickel Beach Woodlot
3. Weaver Road Woodlot
4. Humberstone Swamp/Forest
5. Upper's Woods
6. Babion Road Woodlot
7. Mud Lake Conservation Area
8. Wainfleet Bog Wetland
9. Cement Plant Road Quarry wetland
10. Wainfleet Wetlands Conservation Area
11. Empire Beach Backshore Forest/Wetland
12. Shisler Point Woods

Job Number: ONT34651
Date: July 03, 2003
Dwn by: C. Amirault
Approved by: Oliver Curran

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 50,000

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Environmental Scientists
Risk Consultants

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The designation of significance for the woodlots identified in Table 3-1 is primarily due to these areas representing rare examples of old dune ridge forests and/or remaining larger fragments of deciduous forests which contain elements of Carolinian species that are provincially or regionally rare. The wetland areas have been identified as provincially significant due to the presence of rare flora and fauna, and due to the rarity and importance of Great Lakes coastal wetlands.

The Wainfleet Bog, which lies a few kilometres to the northwest of the Study Area, represents one of few remaining large peatlands in southern Ontario and is a highly significant natural area in the Regional Municipality of Niagara. Based on a review of existing reports, Varga and Allen (1990) identified three sites listed in Table 3-1 as belonging to 24 of the most significant botanical sites in the Niagara Regional Municipality: Wainfleet Bog, Empire Beach Backshore Forest/Wetland and Humberstone Swamp/Forest. None of these three sites are located in the Primary Study Area, and only the southernmost portion of the Humberstone Swamp is located in the Secondary Study Area.

The Point Abino Peninsula Forest, which lies along the shores of Lake Erie a few kilometres outside the eastern boundary of the Study Area, has been identified as one of 38 priority Carolinian Sites in Canada (Allen *et al*. 1990). No areas within the Study Area have been designated as a priority Carolinian Site.

3.6 Ecological Land Classification

Natural areas within the Study Area were classified to the Ecosite level following the Ecological Land Classification system for Southern Ontario (Lee *et al*. 1998). Table 3-2 summarizes ecosites identified by the ELC, and Map 3 presents the distribution of ecosites in the Study Area. A large proportion of the Study Area is agricultural land, consisting of cash crops (mostly feed corn), hay/pasture lands and fallow fields. For the agricultural lands, fallow fields that have not been actively cultivated for a number of years have reverted to various stages of old field regeneration. These fields were identified as Cultural Meadows (CUM1) following the ELC, and are considered to represent “natural” environments for the purpose of this study.

Table 3-2 Ecological Land Classification and Soil Types

ELC Ecosite Code	Description	Soil Type
Upland Forest Woodlots		
FOD2	Dry -Fresh Oak-Maple-Hickory Deciduous Forest	Clay
		Organic
		Sand
FOD3	Dry -Fresh Poplar-White Birch Deciduous Forest	Clay
FOD7	Fresh-Moist Lowland Deciduous Forest	Clay
		Organic
		Sand
FOD8	Fresh-Moist Poplar-Sassafras Deciduous Forest	Organic
FOD9	Fresh-Moist Oak-Maple-Hickory Deciduous Forest	Clay
Tree and Thicket Swamp		
SWD4	Organic over Mineral Deciduous Swamp	Organic
SWD3	Maple Mineral Deciduous Swamp	Clay
SWD6	Red Maple-Silver Maple Organic Deciduous Swamp	Organic
Beach/Bar		
BBO1	Mineral Open Beach	Sand/Limestone Shelf
Sand Dune		
SDT1	Treed Sand Dune	Sand
Cultural Plantation		
CUP1	Deciduous Plantation	Clay
CUP3	Coniferous Plantation	Clay
Cultural Woodland		
CUW1	Mineral Cultural Woodland	Clay
MAS2	Mineral Shallow Marsh	Clay
Marsh		
MAS3	Organic Shallow Marsh	Organic
Human Land Use		
AGRA	Agriculture – crops-pasture, hay, fallow fields	Clay
		Organic

Natural forested areas make up approximately 15% of the Study Area (a total of 283 ha) and are represented by small (10-20 ha), generally rectangular-shaped woodlots that are scattered throughout the Study Area. During the last 200 years, these woodlots have been logged and drained. In this respect, most of the woodlots have had a significant level of human influence so that many could be considered Cultural Woodland ecosites, rather than natural systems. Similarly, many of the area's meadow fields and shrub thickets represent old agricultural fields that are in various stages of natural regeneration and are representative of cultural thickets, rather than natural systems.

The majority of woodlots in the Study Area occur on organic soils dominated by Red Maple (*Acer rubrum*) and the hybrid Freeman's Maple (*A. x freemanii)*, a hybrid between Red Maple and Silver Maple (*A. saccharinum*)). All other forested areas occur on clay soils, the exception being forested sand dunes along the Lake Erie shoreline. Upland forests are a mixture of tree species, including Red Oak (*Quercus rubra*), White Ash (*Fraxinus americana*) and maples.

3.7 Significant Vegetation Communities

For the lands in the immediate vicinity of the Inco Refinery, the dune upland forest and sand dune communities are considered to represent significant natural areas (see Nickel Beach Woodlot in Section 3.5). The sand dune forest is well developed and undisturbed and is a good representation of the Lake Erie shoreline dune complex, a natural feature that has been identified as significant along the lake's shoreline (RMON 1980). This community is also representative of the Carolinian forests of southern Ontario and supports a number of rare Carolinian tree species. It is for these reasons that this forest community has been identified as an environmentally sensitive area in the Regional Municipality of Niagara.

The sand dunes along the lakeshore are, for the most part, disturbed by historic human activity associated with Nickel Beach. Nevertheless, select pockets of the dunes are representative of active dune communities, a community type that is under threat in southern Ontario. The small section of the dune where Hop-Tree (*Ptelea trifoliata*) is present, though small in size, may be considered representative of a Hop-Tree dune community. This community type has been identified as extremely rare in Ontario (Bakowsky 1999).

In addition to the dune communities, the mature Red Maple swamp on the Inco site that is part of the provincially significant wetlands may be considered a significant feature, as mature swamp forest is rare in the region (see Nickel Beach Wetland in Section 3.5).

3.8 Flora and Fauna

3.8.1 Flora

Tables 3-3 and 3-4 list the woody plant species identified in the Primary Study Area during field investigations. Thirty-eight tree species and 46 shrub species were recorded for this area. Although the total area of woodlands in the Study Area is relatively small (<50 ha), the number of woody plant species recorded is considered to represent high species richness for woodlots in southern Ontario (Bricker and Reader 1990). Based on the known distribution of tree species in the Niagara Region (Hosie 1979), a total of 57 tree species could potentially occur when suitable habitat is present. Therefore, for the Primary Study Area, 67% of the Niagara Region's tree species are represented. When habitat requirements and rarity of occurrence in the Region are taken into account, over 90% of the tree species that should occur were recorded for the Primary Study Area.

For shrubs, based on known distributions in the Niagara Region (Soper and Heimburger 1994), 106 species could potentially occur when suitable habitat is present. The shrubs documented for the Primary Study Area represent 43% of the Niagara Region's shrub species. However, almost a third of the 106 species of shrubs reported for the Region have specialized habitat requirements and occur in the region due to either the presence of the large peatlands of Wainfleet Bog or the limestone talus slopes and cliffs of the Niagara Escarpment. These habitats are not found in the Study Area. When habitat requirements and rarity of occurrence in the Region are taken into account, over 80% of the shrub species that should occur in the area were recorded for the Primary Study Area.

The vast majority of the tree and shrub species were found to be growing on lands directly adjacent to the Inco Refinery site in areas where existing soil concentrations of CoCs are the highest (concentrations as high as 24,000 to 33,000 mg/kg Ni were recorded for woodlots along Reuter Road). Most of the species occur in general abundance where suitable habitat is present. The observed species richness of woody vegetation in the Primary Study Area can be attributed to a number of biophysical factors. These factors include diversity of habitat types, presence of three soil types (clay, organic and sand), presence of mature forests, presence of successional forest and high occurrence of forest edge due to forest fragmentation.

Table 3-3 Tree Species Identified in Primary Study Area.

Tree Species	Latin Name
American Beech	*Fagus grandifolia* Ehrh.
Balsam Fir	*Abies balsamea* (L.) Mill.
Balsam Poplar	*Populus balsamifera* L.
Basswood	*Tilia americana* L.
Bitternut Hickory	*Carya cordiformis* (Wang.) Koch
Black Cherry	*Prunus serotina* Ehrh.
Black Maple	*Acer nigrum* Michx. F.
Black Walnut	*Juglans nigra* L.
Black Willow	*Salix nigra* Marsh.
Blue-Beech	*Carpinus caroliniana* Walt.
Bur Oak	*Quercus macrocarpa* Michx.
Butternut	*Juglans cinerea* L.
Eastern Cottonwood	*Populus deltoides* Bartr.
Eastern Hemlock	*Tsuga canadensis* (L.) Carr.
Eastern Red Cedar	*Juniperus virginiana* L.
Eastern White Cedar	*Thuja occidentals* L.
Eastern White Pine	*Pinus strobes* L.
Freeman's Maple	*Acer x freemanii* E. Murr.
Hawthorns	*Crataegus* spp.
Hop-Hornbeam	*Ostrya virginiana* (Mill.) Koch
Hop-Tree	*Ptelea trifoliate* L.
Largetooth Aspen	*Populus grandidentata* Michx.
Manitoba Maple	*Acer megundo* L.
Mountain Ash	*Sorbus americana* Marsh.
Pignut Hickory	*Carya glabra* (Mill.) Sweet
Pin Oak	*Quercus palustris* Muenchh.
Red Ash	*Fraxinus pennsylvanica* Marsh.
Red Maple	*Acer rubrum* L.
Red Oak	*Quercus rubra* L.
Shagbark Hickory	*Carya ovata* (Mill.) Koch
Silver Maple	*Acer saccharium* L.
Sugar Maple	*Acer saccharum* Marsh.
Swamp White Oak	*Quercus bicolor* Willd.
Trembling Aspen	*Populus tremuloides* Michx.
White Ash	*Fraxinus americana* L.
White Elm	*Ulmus Americana* L.
White Oak	*Quercus alba* L.
Yellow Birch	*Betula alleghaniensis* Britton

Table 3-4 Shrub Species Identified in Primary Study Area.

Shrub Species	Latin Name
Allegheny Serviceberry	*Amelanchier laevis* Wiegand
Alternate-leaved Dogwood	*Cornus alternifolia* L. fil.
American Yew	*Taxus canadensis* Marsh.
Bebb's Willow	*Salix bebbiana* Sarg.
Beaked Hazel	*Corylus cornuta* Marsh.
Bittersweet	*Celastrus scandens* L.
Bladdernut	*Staphylea trifolia* L.
Bush Honeysuckle	*Diervilla lonicera* Mill.
Choke Cherry	*Prunus virginiana* L. fil.
Common Blackberry	*Rubus allegheniensis* Porter
Common Juniper	*Juniperus communis* L.
Diamond Willow	*Salix eriocephala* Michx.
Downy Serviceberry	*Amelanchier arborea* (Michx. f.) Fern.
Dryland Blueberry	*Vaccinium pallidum* Ait.
Grey Dogwood	*Cornus racemosa* Lam.
Moonseed Vine	*Menispermum canadense* L.
Nannyberry	*Viburnum lentago* L.
Bittersweet Nightshade	*Solanum dulcamara* L.
Ninebark	*Physocarpus opulifolius* (L.) Maxim.
Peach-leaved Willow	*Salix amygdaloides* Anderss
Pin Cherry	*Prunus pensylvanica* L. fil.
Poison Ivy	*Rhus rydbergii* Small ex Rydb.
Prickly Ash	*Zanthoxylum americanum* Mill.
Prickly Gooseberry	*Ribes cynosbati* L.
Prickly Greenbrier	*Smilax tamnoides* L.var. *hispida*
Purple-flowering Raspberry	*Rubus odoratus* L.
Pussy Willow	*Salix discolor* Muhl.
Red Elderberry	*Sambucus pubens* Michx.
Red-osier Dogwood	*Cornus stolonifera* Michx.
Red Raspberry	*Rubus idaeus* L. var. *strigosus*
Riverbank Grape	*Vitis riparia* Michx.
Round-leaved Dogwood	*Cornus rugosa* Lam.
Running Strawberry	*Euonymus obovatus* Nutt.
Sandbar Willow	*Salix exigua* Nutt.
Slender Willow	*Salix petiolaris* J.E.Sm.
Smooth Wild Rose	*Rosa blanda* Ait.
Southern Arrow-wood	*Viburnum recognitum* Fern.
Speckled Alder	*Anus rugosa (*DuRio) Spreng.
Spicebush	*Lindera benzoin* (L.) Blume
Spirea	*Spirea alba* Du Roi
Staghorn Sumac	*Rhus typhina* L.
Virginia Creeper	*Parthenocissus inserta* (Kern.) Fritsch
Virgin's Bower	*Clematis virginiana* L.
Wild Black Currant	*Ribes americanum* Mill.
Wild Red Currant	*Ribes triste* Pall.
Wild Red Raspberry	*Ribes idaeus* L. var. *strigosus* (Michx.) Maxim

In addition to the observed species richness, four tree species identified in the Primary Study Area are considered rare in the province (Oldham 1999). These include:

- Pignut Hickory (*Carya glabra*),
- Pin Oak (*Quercus palustris*),
- Swamp White Oak (*Q. bicolor*), and
- Hop-Tree.

These four tree species are part of the Carolinian Zone flora of southern Ontario and are at the northern limit of their range in North America. Each of these four species is provincially designated as an S3 species, indicating that the species is rare in the province with between 21 to 100 element occurrences (separate populations) in the province (NHIC 2002). Pin Oak and Swamp White Oak are scattered but are fairly common in the wet forested areas in and around the Inco Refinery site. Pignut Hickory is limited to the sand dune forest located just inland from Nickel Beach and occurs in low numbers throughout the forested dunes. Five individual Hop-Tree specimens were located at the southeastern corner of the Inco Refinery site at the sand dune-forest interface. Due to their restricted range in Ontario and Canada, these species are important attributes of the area.

3.8.2 Birds

Information on breeding birds was collected for the Study Area over two breeding seasons (2000-2001). For the study, a total of 78 species of birds were considered to be breeding in the Study Area. Birds were considered to be breeding if some evidence of breeding was noted (e.g., song on territory, pairs, nest or young observed). Using the survey techniques (see protocols in Volume II) and by visiting most areas of the Study Area over a two-year period, it is believed that more than 90% of the bird species that breed annually in the Study Area were recorded. The results of the breeding bird survey are presented in Table 3-5.

Table 3-5 Breeding Birds Recorded in the Study Area

Common Name	Scientific Name	Diet	Foraging Level	Habitat	Estimated Breeding Pairs
Green Heron	*Butorides virescens*	Fish, frogs, invertebrates	Ground (water)	Marsh/Swamp	1-5
Wood Duck	*Aix sponsa*	Vegetation, invertebrates	Ground (water)	Marsh/Swamp	1-5
Mallard	*Anas platyrhynchos*	Vegetation, invertebrates	Ground (incl. water)	Marsh/Swamp	5-10
Red-tailed Hawk	*Buteo jamaicensis*	Mammals, birds	Ground	Forest/Field	1-5
American Kestrel	*Falco sparverius*	Birds, mammals, invertebrates	Ground/Air	Field	1-5
Ruffed Grouse	*Bonasa umbellus*	Vegetation, invertebrates	Ground	Forest/ Successional	5-10
Sora	*Poranza carolina*	Invertebrates	Ground (incl. water)	Marsh	1-5
Killdeer	*Charadrius vociferus*	Invertebrates	Ground (incl. water)	Field/ Generalist	5-10
Spotted Sandpiper	*Actitis macularia*	Invertebrates	Ground (incl. water)	Field	1-5
Wilson's Snipe	*Gallinago delicata*	Invertebrates	Ground (incl. water)	Field/ Marsh	1-5
American Woodcock	*Scolopax minor*	Invertebrates	Ground	Forest/ Successional	10-50
Rock Dove	*Columba livis*	Vegetation	Ground	Field/ Generalist	10-50
Mourning Dove	*Zenaida macroura*	Vegetation	Ground	Successional/ Forest	10-50
Black-billed Cuckoo	*Coccyzus erythropthalmus*	Invertebrates	Ground/ Shrubs/Trees	Successional/ Forest	1-5
Great Horned Owl	*Bubo virginianus*	Mammals, birds	Ground/ Trees	Forest	1-5
Common Nighthawk	*Chordeiles minor*	Invertebrates	Air	Generalist	1-5
Chimney Swift	*Chaetura vociferus*	Invertebrates	Air	Generalist	5-10

Notes:
- Species identification based on direct observation or bird song or both.
- Underlined species are those that usually require large areas of habitat for successful breeding.
- Bold face indicates a provincially rare species (as determined by MNR S-ranks 1, 2 or 3).
- Foraging height layer refers to the vegetation strata where most feeding takes place.
- Pair estimates were placed into one of 4 standard categories, 1-5, 5-10, 10-50, and 50-100. The estimates are based on a combination of the availability of habitat, breeding territorial requirements of each species and species occurrence in the study area as noted during surveys conducted for the study over two breeding seasons.

Table 3-5 Breeding Birds Recorded in the Study Area (cont'd)

Common Name	Scientific Name	Diet	Foraging Level	Habitat	Estimated Breeding Pairs
Ruby-throated Hummingbird	*Archilochus colubris*	Vegetation (nectar), invertebrates	Shrub	Field/ Successional	1-5
Belted Kingfisher	*Ceryle alcyon*	Fish	Ground (water)	Marsh/ Swamp	1-5
Red-bellied Woodpecker	*Melanerpes carolinus*	Invertebrates	Trees/Shrubs	Forest	1-5
Downy Woodpecker	*Picoides pubescens*	Invertebrates	Trees/Shrubs	Successional/ Forest	10-50
<u>Hairy Woodpecker</u>	*Picoides villosus*	Invertebrates	Trees/Shrubs	Forest	5-10
Northern Flicker	*Colaptes auratus*	Invertebrates	Ground/ Trees/Shrubs	Successional/ Forest	1-5
Eastern Wood-Pewee	*Contopus virens*	Invertebrates	Air/Trees/ Shrubs	Forest	10-50
Willow Flycatcher	*Empidonax traillii*	Invertebrates	Air/Trees/ Shrubs	Field/ Successional	5-10
Least Flycatcher	*Empidonax minimus*	Invertebrates	Air/Trees/ Shrubs	Forest	1-5
Great Crested Flycatcher	*Myiarchus crinitus*	Invertebrates	Air/Trees/ Shrubs	Forest	10-50
Eastern Kingbird	*Tyrannus tyrannus*	Invertebrates	Air/Trees/ Shrubs	Successional/ Field	10-50
Warbling Vireo	*Vireo gilvus*	Invertebrates	Trees/Shrubs	Successional	10-50
Red-eyed Vireo	*Vireo olivaceus*	Invertebrates	Trees/Shrubs	Forest/ Successional	10-50
Blue Jay	*Cyanocitta cristata*	Omnivore	All levels	Generalist	10-50
American Crow	*Corvus brachyrhynchos*	Omnivore	All levels	Generalist	5-10
Horned Lark	*Eremophila alpestris*	Invertebrates	Ground	Field	5-10
Purple Martin	*Progne subis*	Invertebrates	Air	Field	5-10

Notes:
- Species identification based on direct observation or bird song or both.
- Underlined species are those that usually require large areas of habitat for successful breeding.
- Bold face indicates a provincially rare species (as determined by MNR S-ranks 1, 2 or 3).
- Foraging height layer refers to the vegetation strata where most feeding takes place.
- Pair estimates were placed into one of 4 standard categories, 1-5, 5-10, 10-50, and 50-100. The estimates are based on a combination of the availability of habitat, breeding territorial requirements of each species and species occurrence in the study area as noted during surveys conducted for the study over two breeding seasons.

Table 3-5 Breeding Birds Recorded in the Study Area (cont'd)

Common Name	Scientific Name	Diet	Foraging Level	Habitat	Estimated Breeding Pairs
Tree Swallow	*Tachycineta bicolor*	Invertebrates	Air	Forest/ Successional	10-50
Northern Rough-wing Swallow	*Stelgidopteryx serripennis*	Invertebrates	Air	Field	5-10
Barn Swallow	*Hirundo rustica*	Invertebrates	Air	Generalist	10-50
Black-capped Chickadee	*Peocile atricapillus*	Invertebrates	Trees/Shrubs	Forest/ Successional	50-100
Tufted Titmouse	*Baeolophus bicolor*	Invertebrates	Trees/Shrubs	Forest	1-5
Red-breasted Nuthatch	*Sitta canadensis*	Invertebrates	Trees/Shrubs	Forest/ Successional	1-5
<u>White-breasted Nuthatch</u>	*Sitta carolinensis*	Invertebrates	Trees/Shrubs	Forest	1-5
Brown Creeper	*Certhia americana*	Invertebrates	Trees/Shrubs	Forest	1-5
Carolina Wren	*Thryothorus ludovicianus*	Invertebrates	Ground/ Shrubs	Forest/ Successional	1-5
House Wren	*Troglodytes aedon*	Invertebrates	Ground/ Shrubs	Generalist	50-100
Sedge Wren	*Cistothorus platensis*	Invertebrates	Ground/ Shrubs	Marsh/ Field	1-5
Marsh Wren	*Cistothorus palustris*	Invertebrates	Ground/ Shrubs	Marsh	1-5
Blue-gray Gnatcatcher	*Polioptila caerulea*	Invertebrates	Trees/Shrubs	Forest/ Successional	1-5
Eastern Bluebird	*Sialia sialis*	Invertebrates	Ground/ Shrubs/Air	Field	5-10
Wood Thrush	*Hylocichla mustelina*	Invertebrates	Ground/ Shrubs	Forest	1-5
American Robin	*Turdus migratorius*	Invertebrates, vegetation	Ground/ Shrubs	Generalist	50-100
Gray Catbird	*Dumetella carolinensis*	Invertebrates, vegetation	Ground/ Shrubs	Forest/ Successional	10-50
Brown Thrasher	*Toxostoma rufum*	Invertebrates, vegetation	Ground/ Shrubs	Successional/ Field	1-5
European Starling	*Sturnus vulgaris*	Invertebrates, vegetation	Ground/ Shrubs	Generalist	50-100

Notes:

- Species identification based on direct observation or bird song or both.
- Underlined species are those that usually require large areas of habitat for successful breeding.
- Bold face indicates a provincially rare species (as determined by MNR S-ranks 1, 2 or 3).
- Foraging height layer refers to the vegetation strata where most feeding takes place.
- Pair estimates were placed into one of 4 standard categories, 1-5, 5-10, 10-50, and 50-100. The estimates are based on a combination of the availability of habitat, breeding territorial requirements of each species and species occurrence in the study area as noted during surveys conducted for the study over two breeding seasons.

Table 3-5 Breeding Birds Recorded in the Study Area (cont'd)

Common Name	Scientific Name	Diet	Foraging Level	Habitat	Estimated Breeding Pairs
Cedar Waxwing	*Bombycilla cedrorum*	Invertebrates, vegetation	Trees/ Shrubs/Air	Forest/ Successional	1-5
Yellow Warbler	*Dendroica petechia*	Invertebrates	Trees/Shrubs	Successional/ Field	10-50
Chestnut-sided Warbler	*Dendroica pensylvanica*	Invertebrates	Trees/Shrubs	Successional	1-5
American Redstart	*Setophaga ruticlla*	Invertebrates	Trees/Shrubs	Forest/ Successional	1-5
Common Yellowthroat	*Geothylpis trichas*	Invertebrates	Ground/ Shrubs	Successional	10-50
Yellow-breasted Chat	*Icteria virens*	Invertebrates	Ground/ Shrubs	Successional/ Field	1-5
Eastern Towhee	*Pipilo erythropthalmus*	Invertebrates, vegetation	Ground/ Shrubs	Successional/ Field	1-5
Chipping Sparrow	*Spizella passerina*	Invertebrates, vegetation	Ground/ Shrubs	Generalist	10-50
Field Sparrow	*Spizella pusilla*	Invertebrates, vegetation	Ground/ Shrubs	Field	5-10
Vesper Sparrow	*Pooecetes gramineus*	Invertebrates, vegetation	Ground/ Shrubs	Field	1-5
Savannah Sparrow	*Passerculus sandwichensis*	Invertebrates, vegetation	Ground	Field	50-100
Song Sparrow	*Melospiza melodia*	Invertebrates, vegetation	Ground/ Shrubs	Successional	50-100
Swamp Sparrow	*Melospiza georgiana*	Invertebrates, vegetation	Ground/ Shrubs	Marsh	5-10
Northern Cardinal	*Cardinalis cardinalis*	Invertebrates, vegetation	Ground/ Trees/Shrubs	Forest/ Successional	10-50
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	Invertebrates, vegetation	Trees/Shrubs	Forest/ Successional	10-50
Indigo Bunting	*Passerina cyanea*	Invertebrates, vegetation	Trees/Shrubs	Successional	10-50
Bobolink	*Dolicohnyx oryzivorus*	Invertebrates, vegetation	Ground	Field	10-50
Red-winged Blackbird	*Agelaius phoeniceus*	Invertebrates, vegetation	Ground/ Shrubs	Marsh/ Successional	50-100
Eastern Meadowlark	*Sturnella magna*	Invertebrates, vegetation	Ground	Fields	10-50

Notes:

- Species identification based on direct observation or bird song or both.
- Underlined species are those that usually require large areas of habitat for successful breeding.
- Bold face indicates a provincially rare species (as determined by MNR S-ranks 1, 2 or 3).
- Foraging height layer refers to the vegetation strata where most feeding takes place.
- Pair estimates were placed into one of 4 standard categories, 1-5, 5-10, 10-50, and 50-100. The estimates are based on a combination of the availability of habitat, breeding territorial requirements of each species and species occurrence in the study area as noted during surveys conducted for the study over two breeding seasons.

Table 3-5 Breeding Birds Recorded in the Study Area (cont'd)

Common Name	Scientific Name	Diet	Foraging Level	Habitat	Estimated Breeding Pairs
Common Grackle	*Quiscalus quiscula*	Invertebrates, vegetation	Ground/ Trees/Shrubs	Successional	50-100
Brown-headed Cowbird	*Molothrus ater*	Invertebrates, vegetation	Ground/ Shrubs	Field/ Successional	10-50
Baltimore Oriole	*Icterus galbula*	Invertebrates, vegetation	Trees	Forest/ Successional	10-50
House Finch	*Carpodacus mexicanus*	Vegetation	Shrubs/ Ground	Generalist	5-10
American Goldfinch	*Carduelis tristis*	Invertebrates, vegetation	Ground/ Shrubs	Field/ Successional	50-100
House Sparrow	*Passer domesticus*	Invertebrates, vegetation	Ground/ Shrubs	Generalist	50-100

Notes:
- Species identification based on direct observation or bird song or both.
- Underlined species are those that usually require large areas of habitat for successful breeding.
- Bold face indicates a provincially rare species (as determined by MNR S-ranks 1, 2 or 3).
- Foraging height layer refers to the vegetation strata where most feeding takes place.
- Pair estimates were placed into one of 4 standard categories, 1-5, 5-10, 10-50, and 50-100. The estimates are based on a combination of the availability of habitat, breeding territorial requirements of each species and species occurrence in the study area as noted during surveys conducted for the study over two breeding seasons.

The breeding bird data indicated the presence of five breeding bird communities, namely:

- Forest-associated habitat species;
- Mid-successional forest habitat species;
- Field (fallow/old field) habitat species;
- Marsh habitat species; and,
- Habitat generalist species.

For the Study Area, over 80% of the breeding bird species are associated with forests and mid-successional forest habitat (forest edge and regeneration of old fields). The relatively small areas of fragmented forest of the Study Area precluded the presence of species that are usually observed in larger tracts of forested habitat in southern Ontario. Only three area-sensitive species, Hairy Woodpecker, White-breasted Nuthatch and Wood Thrush (only one pair of each species), were noted for the Study Area. Marsh habitat in the Study Area is poorly represented and limited to the wetland areas located on the Inco Refinery site. However, a number of marsh habitat species, including Marsh Wren and Sora were documented as breeding in these small marsh areas. Bird species typical of mid-successional field habitat were well represented, including Eastern

Meadowlark, Bobolink, Vesper Sparrow and Savannah Sparrow, although this habitat type is limited and small in size where it occurs.

Overall, the breeding bird community of the Study Area is represented by species with quite varied diets, including both animal and plant matter. Species that consume fruits as part of their regular diet include American Robin, Gray Catbird, Brown Thrasher, Cedar Waxwing and European Starling, and many species eat other plant matter, especially seeds. However, the diets of the Study Area's breeding birds are dominated by different types of animals. Over 80% of the bird species have invertebrates as a part of their diet, with approximately half of the breeding bird species feeding almost entirely on insects and spiders. Frogs are preyed upon by Green Heron and Great Blue Heron, although this latter species is known only as a non-breeding but regular visitor to the Study Area. These two herons, and Belted Kingfisher, also feed on small fish that occur in the Study Area's ponds and drains. Only three breeding bird species noted during surveys regularly hunt birds and small mammals, these being Red-tailed Hawk, Great Horned Owl and American Kestrel.

The avifauna of the Regional Municipality of Niagara is well represented in the Study Area. Out of 103 species known to regularly breed in the Niagara Region (excluding colonial waterbirds; Cadman *et al*. 1987), 78 were recorded during the study surveys. Evidence of breeding was observed for three provincially significant birds (NHIC 2002; Table 3-6) and for an additional three species considered regionally significant (Ontario Breeding Bird Atlas 2002; Table 3-6). Two further species regarded as rare breeders in Ontario, Hooded Warbler (*Wilsonia citrina*) and Prairie Warbler (*Dendroica discolor*), were observed in the Study Area during the early or late breeding season, but no clear evidence of breeding was obtained.

Table 3-6 Rare Breeding Bird Species Recorded in the Study Area

Common Name	**S-rank[1]**
Tufted Titmouse[3]	S2S3
Red-breasted Nuthatch[2]	S5B
Carolina Wren[3]	S3S4
Sedge Wren[2]	S4B
Chestnut-sided Warbler[2]	S5B
Yellow-breasted Chat[3]	S2S3B

Notes:
1 S-rank follows designation and protocol of Natural Heritage Information Centre
2 Regionally Significant
3 Rare in Ontario

Compared to other parts of the Regional Municipality of Niagara, the Study Area has good representation of the local avifauna based on available bird breeding data collected from 1981-1985 (Cadman *et al*. 1987). Results from five squares (17PH27, 17PH35, 17PH45, 17PH65 and 17NH95), that received 82-127 hours of survey effort and were from similar landscapes in the region were directly compared with each other and with this study's survey results. When certain species were excluded because they were colonial waterbirds or otherwise very unlikely to be observed during our survey efforts, tallies were comparable (Table 3-7).

Table 3-7 Species Counts and Effort Contributed to Five Mapsquares as Part of the Ontario Breeding Bird Atlas (Cadman *et al.* 1987).

Area/Mapsquare[1]	Number of Species[2]	Hours of Effort
17PH27	76	122
17PH35	89	83
17PH45	91	127
17PH65	70	99
17NH95	92	90
Study Area (2000-2001)	78	64

Notes

1 Mapsquare corresponds to 10 km x 10 km squares marked in National Topographic System

2 Number of species observed in area exhibiting breeding behaviour, excluding the following species: Pied-billed Grebe, American Bittern, Least Bittern, Great Blue Heron, Virginia Rail, Sora, Common Moorhen, American Coot, Eastern Screech-Owl, Great Horned Owl, Short-eared Owl, Common Nighthawk, Whip-poor-will

Despite the diversity of breeding birds within the Study Area, some apparent absences were noted. Species that were expected to occur in the Study Area (based on current breeding range and occurrence in the Regional Municipality of Niagara) but were not seen include: Virginia Rail (*Rallus limicola*), Upland Sandpiper (*Bartramia longicauda*), Yellow-billed Cuckoo (*Coccyzus americanus*), Red-headed Woodpecker (*Melanerpes erythrocephalus*), Yellow-throated Vireo (*Vireo flavescens*), Veery (*Catharus fuscescens*), Scarlet Tanager (*Piranga olivacea*) and Grasshopper Sparrow (*Ammodramus savannarum*). None of these species are common or are expected to be abundant in the Region due to their habitat requirements. The apparent absence of these species in the Study Area is likely due to a combination of habitat paucity and general limitations of bird surveys.

In conclusion, the diversity of breeding birds in the Study Area is considered to be typical and representative of the Region. In addition, the presence of several provincially and regionally significant breeding bird species indicates that the Study Area's bird community is of high quality.

3.8.3 Mammals

Due to the extent and duration of field surveys and the employment of small mammal live-traps, the Study Area's mammals were well documented. A total of 20 mammal species were recorded in the Study Area (Table 3-8). Gibson (1991) reported 41 species of mammals in the Regional Municipality of Niagara. Therefore, approximately 50% of the Region's mammal species were documented to occur in the Study Area. Species not recorded may well occur in the Study Area, as the vast majority of those species not recorded are small mammals (e.g., bats, shrews, voles and moles), that are difficult to detect and/or identify.

Table 3-8 Mammals Recorded in the Study Area

Common Name	Scientific Name	Status Notes
Virginia Opossum	*Didelphis virginiana*	Common, road-kill only
Common Shrew	*Sorex cinereus*	Common, observations, live trapped
Little Brown Bat	*Myotis lucifugus*	Uncommon, observation
European Hare*	*Lepus europaeus*	Common, winter tracks
Eastern Cottontail	*Sylvilagus floridanus*	Locally very common, observations, winter tracks
Woodchuck	*Marmota monax*	Common, present at Inco plant site
Gray Squirrel	*Sciurus carolinensis*	Common, observations, winter tracks
Deer Mouse	*Peromyscus maniculatus*	Abundant in local woodlots, live trapped, winter tracks
White-footed Mouse	*Peromyscus leucopus*	Abundant in local woodlots, live trapped, winter tracks
Meadow Vole	*Microtus pennsylvanicus*	Common, observations, live trapped
Meadow Jumping Mouse	*Zapus hudsonius*	Common, observations
Muskrat	*Ondatra zibethicus*	Uncommon, one observation
Coyote	*Canis latrans*	Locally very common, observations, summer and winter tracks
Red Fox	*Vulpes vulpes*	Locally very common, observations, summer and winter tracks
Raccoon	*Procyon lotor*	Common, observations, live trapped, summer & winter tracks
Short-tailed Weasel/Ermine	*Mustela erminea*	Locally very common, live trapped, winter tracks
Long-tailed Weasel	*Mustela frenata*	Uncommon, one observed nearby off-site
Mink	*Mustela vison*	Uncommon, one winter track
Striped Skunk	*Mephitis mephitis*	Common, observations, summer & winter tracks
White-tailed Deer	*Odocoileus virginianus*	Locally very common, observations, summer and winter tracks
* The European Hare is not native to Canada and was introduced into Ontario from Europe in the early 1900s		

The mammals occurring in southern Ontario are mostly species that have benefited from agricultural expansion and other human activities. Since many of the sensitive species have been extirpated (e.g., wolf, river otter, black bear, elk), the species that remain are generally widespread and common (Gibson 1991). This is true for the Study Area, where common and expected mammals were documented to occur and were generally found to be abundant locally.

Live trapping for small mammals within Study Area showed *Peromyscus* mice to be very abundant, in the woodlots and field edges, for lands directly adjacent to the Inco Refinery. In 2000, trapping in fields and woodlots found Meadow Vole and *Peromyscus* mice populations in good numbers, based on trapping success rates. The results of two trap nights in 2001 are presented in Table 3-9, which demonstrate that the small mammal community is typical of the habitat and that trapping rates are within or greater than anticipated values (usually 10-15%). (Ingstrom pers. comm.). Compared to 2000, 2001 trapping results indicated that much of the area's vole population had declined. These population fluctuations are typical for the species, which undergoes population cycles over a number of years.

Table 3-9 Results of the Live Trapping Study for Small Mammals

Habitat	Traps Set (two nights)	Trap Nights[1]	Trapping Results	Trap Rate[2]	Released Animals
Wooded swamp	88	71	18 *Peromyscus* mice	25%	All 18 released
Field	88	86	8 Meadow Voles 1 Meadow Jumping Mouse	10%	All 9 released

Notes
1 Disturbed traps sprung with no capture count as 0.5 trap nights
2 Likely includes some re-traps over the two nights

Based on surveys of winter tracks, Eastern Cottontail, Raccoon, Gray Squirrel and Coyote are very common in the area's woodlots and field edges. Woodlots on and directly adjacent to the Inco Refinery site showed a particularly high density for Eastern Cottontail and Gray squirrel. In addition, winter track surveys and observations of White-tailed Deer provided evidence that deer over-winter in high densities in the woodlots on and adjacent to the Inco Refinery site. Based on these observations, the deer population within the Study Area was conservatively estimated to be approximately 20 animals, or a density of 1 individual per km^2.

Though not observed during field investigations, as the species is nocturnal, there remains the possibility that the Southern Flying Squirrel (*Glaucomys volans*) exists in the Study Area. This species is restricted to the Carolinian Zone and is considered rare in Ontario. Habitat requirements are met for the species, including a good density of nut mast trees such as beech and oak, in the woodlots in the local area. However, the woodlots in the Study Area are likely too fragmented and lack sufficient interior habitat, providing habitat only marginally suitable to support the species. The possibility that this species occurs in the Study Area is low.

3.8.4 Reptiles and Amphibians

For the Study Area, nine (9) species of amphibian and five (5) species of reptile were recorded (Table 3-10). Four species of snake and one turtle species, the Common Snapping Turtle (*Chelydra serpentina*), were found. The species of snakes recorded are the most common in the Niagara Region (Weller and Oldham 1986), including the Eastern Milk Snake (*Lampropeltis triangulum*), a species designated as of Special Concern by COSEWIC and considered provincially rare by the OMNR (NHIC 2002). Other species of snake that occur in the Regional Municipality of Niagara are either rare, limited in distribution, or have been recorded only historically (Weller and Oldham 1986).

One species of salamander, the Eastern Redback Salamander (*Plethodon cinereus*), was found in the Study Area, in leaf litter and under logs in woodlots located near the Inco Refinery. Two other woodland salamander species that could potentially occur, the Blue-spotted Salamander (*Ambystoma laterale*) and Yellow-spotted Salamander (*Ambystoma maculatum*), were not found while conducting the study. Adults of *Ambystoma* species spend most of their time underground (they are often referred to as "mole" salamanders) and are rarely seen outside the early spring breeding season. These species might occur in the Study Area.

Frogs were systematically surveyed as part of the ERA, following a protocol presented in Volume II. The results of "road survey nights" to document the breeding calls of frogs and toads are presented in Volume III-Tab 1. All frog species reported to occur in the Region (Weller and Oldham 1986) were found to occur in the Study Area, including Fowler's Toad (see Section 3.8.4.1), but with one exception: the Gray Tree Frog (*Hyla versicolor*). Discussions with the OMNR indicated that their frog surveys have found the distribution of the Gray Tree Frog to be very sporadic, principally occurring near relatively large tracts of forest (A. Yagi OMNR, pers. comm.).

Based on the survey data, the Spring Peeper and the Chorus Frog are the most commonly distributed and most abundant frogs in the Study Area. However, while the road survey documented a number of "Code 3" calling sites (indicating calls were too numerous to count individuals) for the Spring Peeper and Chorus Frog, it was noted that the density of calling adults was nevertheless lower than would be expected compared to other areas in southern Ontario.

The American Toad is also well distributed, but occurs in lower numbers in any one location. The Wood Frog was only recorded at four stations, and its distribution appears to be limited to the occurrence of deep-water swamps, which is the species' preferred breeding habitat. In addition, the Wood Frog's breeding calls are not easily detected by roadside survey methods, so the occurrence (numbers and locations) of the species in the Study Area is likely under-recorded.

Table 3-10 Amphibians and Reptiles Recorded in the Study Area

Common Name	Scientific Name	Status Notes
Amphibians		
Eastern Redback Salamander	*Plethodon cinereus*	Uncommon, Woodlots
American Toad	*Bufo americanus*	Common, habitat generalist
Fowler's Toad	*Bufo woodhousei fowleri*	Uncommon, along shore of Lake Erie
Spring Peeper	*Hyla crucifer*	Common, woodlots
Chorus Frog	*Pseudacris triseriata triseriata*	Common, fields, woodlots
Wood Frog	*Rana sylvatica*	Uncommon, woodlots
Northern Leopard Frog	*Rana pipiens*	Common, old field, ponds
Green Frog	*Rana clamitans*	Common, ponds, creek
Bullfrog	*Rana catesbeiana*	Uncommon, ponds
Reptiles		
Common Snapping Turtle	*Chelydra serpentina*	Uncommon, ponds and ditches
Eastern Garter Snake	*Thamnophis sirtalis sirtalis*	Common, old field
Northern Redbelly Snake	*Storeria occipitomaculata*	Uncommon, old field, woodlot edge
Brown Snake	*Storeria dekayi*	Common, old field, woodlot edge
Eastern Milk Snake	*Lampropeltis triangulum*	Uncommon, old field

The roadside survey appeared to underestimate the distribution and abundance of the commonly recognized *Rana* species, Bullfrog, Northern Leopard Frog and Green Frog. The roadside survey found the Bullfrog to be uncommon in the Study Area, being recorded in low numbers at only two stations with large, well established dugout ponds. The Green Frog was recorded at three stations and the Northern Leopard Frog was found to be sporadically distributed, recorded at ten stations. However, surveys of ditches and ponds (old and new farm ponds dug into the clay soil) in the summer of 2001 found that all ponds and deep water ditches held large numbers of both adult and tadpole Green Frogs and Northern Leopard Frogs, and both species were common and well distributed throughout the Study Area. The underestimation of the abundance of these two frog species by the roadside call survey was probably due to the soft nature of the calls these species produce, which are not easily detected by roadside survey methods. In a review of monitoring data for frog calls using roadside surveys over a two year period in Ontario, Bishop et al (1997) found that although observers recorded all the species expected to commonly occur, the results of the analysis indicate that species with calls that are much lower in volume such as Green Frogs and Leopard Frogs are under reported and that this can account for apparent low numbers in local landscape.

Based on the spring and summer survey results, the key principal breeding areas for amphibians in the Study Area are:

- The swamp and marsh areas associated with the wetlands on the Inco Refinery site;
- A large swamp area located along both sides of Miller Road south of the CN railbed;
- A large swamp area located west of Weaver Road south of the CN railbed;
- A large cattail marsh in open field west of Elizabeth Road, north of Killaly Street; and
- Numerous small farm ponds in clay fields throughout the Study Area.

As discussed later, tadpoles and frogs were collected for tissue analysis. Specimens were examined to record the presence of structural deformities or other abnormalities. For both tadpoles and adults, no abnormalities were observed. In addition, tadpoles were observed to be abundant in dugout ponds, with population numbers in July typically in the hundreds, indicating good survivorship of tadpoles from egg to pre-emergent adults.

3.8.4.1 Fowler's Toad

During the study, the determination of the occurrence and breeding status of the Fowler's Toad in the Study Area was identified as important due to the rarity of the species in Ontario and Canada, and the historical records of its rare occurrence in the Port Colborne area. The Fowler's Toad, a Carolinian species, is only found to occur in Canada in a few widely separated areas along the shore of Lake Erie, from the Niagara River to Point Pelee, and is designated as Threatened both provincially and nationally. The species has been given a rarity rank of S2 by the OMNR (an S2 rank indicates that only 5 to 20 occurrences have been documented for the species in Ontario). The species' primary habitat in Ontario is limited to sandy beaches and near shore areas along Lake Erie.

Spring surveys conducted along the lakeshore, within the Study Area, identified the call of the Fowler's Toad at one station. Further, specific lakeshore surveys identified a number of calling sites and one primary breeding pond (estimated to have 50 males) for the species, located along the lakeshore, east of Lorraine Road. Discussions with the OMNR, who had also conducted an independent study in the spring and summer of 2001, found calling males along the shore of Gravelly Bay, located 2 km west of the Study Area.

The survival of the eggs and tadpoles at breeding ponds were monitored from May to July 2001. Following the peak egg-laying period in the third week of May, eggs had hatched by the last week of May. Tadpoles (approximately 2,000-3,000; based on counting the number of tadpoles in a 30 x 30 cm area and extrapolating for the entire pond area) grew through the month of June, with the appearance of hind legs by the first week of July. Full metamorphosis to young adult, with complete emigration from the pond was completed by July 17.

3.8.5 Invertebrates

Earthworms and arthropods (insects and spiders) were collected for the ERA to investigate the presence of CoCs. Earthworms were identified to species and to age class, providing information on diversity and age structure for the Study Area's earthworm community. Additionally, earthworms were analyzed for CoC concentrations, to provide data for input into receptor exposure calculations. Arthropods were collected from both woodlot and field habitats in order to determine CoC concentrations in the potential prey items of birds and small mammals. Information on tissue CoC concentrations for both earthworms and arthropods are presented in Section 6.

The earthworms found in the Study Area are typical of southern Ontario, and include the commonest species of the province. Five species were found in the Study Area: *Allolobophora chlorotica*, *Aporrectodea tuberculata*, *Dendrodrilus rubidus*, *Lumbricus rubellus* and *L. terrestris*. One individual of a sixth species, *Eisenia foetida*, was found at one site in the Reference Area. A brief description of the habitat and known distribution, as reported by Reynolds (1977), are presented in Table 3-11.

Table 3-11 Earthworm Species of Study Area and Reference Area[1].

Scientific Name	Habitat	Ontario Distribution
Allolobophora chlorotica	Many habitats, including gardens, fields and forests on both clay and organic soils	In southern Ontario restricted to areas near Lake Ontario, Lake Erie, Lake Huron and the St. Lawrence River
Aporrectodea tuberculata	Fields, under logs and rocks	Widespread across southern Ontario, north to Sudbury
Dendrodrilus rubidus	Most commonly under logs, but occurs in many habitats including gardens, fields, peat and compost	Widespread through parts of southern Ontario, north to Nipigon and Cochrane
Eisenia foetida[2]	Compost and manure with high moisture, and under logs near human habitation	Scattered and local in southern Ontario, not widespread
Lumbricus rubellus	Wide range of habitats, including fields and woodlots	Widespread through much of southern Ontario, west to Lambton County, north to Sudbury
Lumbricus terrestris	Wide range of habitats, including fields and woodlots, primarily under logs	Widespread across southern Ontario, north to Sudbury

Notes	
1	Based on results of field surveys. Habitat and distributional information taken from Reynolds (1977).
2	Found in Reference Area only.

Earthworms, especially *L. terrestris* are important animals in the litter decomposition process (Reynolds 1977). As such, data on the age class and relative abundance of this group of decomposers were noted at sample locations in the Primary Study Area, the Secondary Study Area and the Reference Area. Juveniles were found at each sample location in 2000 with one exception. Earthworms were not found at one site along Reuter Road in 2001, although a repeat survey at this site in 2002 was successful in finding earthworms. More information on earthworm data collection is found in Volume II. Results of the chemical analysis are found in Section 6 and more specific details on the incidence and relative abundance of earthworm species in the Study Area are found in Section 8.

Arthropods include insects and arachnids (spiders) found within fields and forests of the Port Colborne area. Collected taxa include 12 insect orders (Table 3-12) and two arachnid orders: Opiliones (harvestmen or daddy longlegs) and Araneae (spiders). All spiders are carnivorous in the Port Colborne area, feeding exclusively on insect and spider prey, while harvestmen are scavengers and predators of small insects. Certain beetles (e.g., Coccinellidae), bugs (e.g., Phymatidae, Reduviidae), scorpionflies, wasps, lacewings, damselflies and flies (e.g., Empididae) are also predaceous, preying upon other arthropods. Other insects collected were herbivorous, including grasshoppers and crickets, beetles (e.g., Chrysomelidae), hoppers, earwigs, flies (e.g., Syrphidae), walkingsticks, butterflies and moths, bugs (e.g. Miridae) and bees.

Table 3-12 Insect Orders Found in the Study Area and Reference Area.

Scientific Name	**English Name**
Odonata	Dragonflies and damselflies
Orthoptera	Grasshoppers, crickets, mantids, cockroaches and walkingsticks
Dermaptera	Earwigs
Psocoptera	Booklice and Barklice
Hemiptera	True bugs
Homoptera	Hoppers, aphids and cicadas
Neuroptera	Lacewings and allies
Coleoptera	Beetles
Mecoptera	Scorpionflies and allies
Lepidoptera	Butterflies and moths
Diptera	Flies
Hymenoptera	Wasps, bees and ants

Certain insects have disjunct life phases, separating the immature and adult phases. These insects include beetles, butterflies and moths, wasps and bees, flies and damselflies. The diet of an insect belonging to these groups may be considerably different between the life stages. For example, the diet of a hoverfly (Diptera: Syrphidae) changes from being predatory during the immature stage to herbivorous when an adult (Vockeroth 1992). The spatial difference in diet can also be varied, such as that seen in the damselfly, where the larva is aquatic, feeding on aquatic invertebrates underwater, and the adult is aerial, feeding on terrestrial and aerial prey (Corbet 1998). Further information on the ecology and ethology of insects and arachnids may be found in Schowalter (2000) and Wise (1993).

Although certain groups of insects exhibit migratory behaviour, or at least movements at large spatial scales (Corbet 1998), it can be expected that most insects and arachnids have restricted home ranges and are exposed to only local environmental conditions. Herbivorous arthropods are exposed to elevated CoC levels through their direct contact with deposited CoCs in the soil and their ingestion of CoCs contained within plant tissue. Predatory arthropods are exposed to CoCs through direct contact with soil and ingestion of arthropod prey. The precise pathway of CoC exposure is dependent upon the spatial and behavioral arrangement of the organism, which, as outlined above, may change considerably during its lifetime.

Arthropods are considered a food item for exposure assessment for this ERA, and no attempt was made to evaluate diversity or abundance of insects or spiders in the Study Area. Results of the chemical analyses of arthropod tissue from woodlots and fields sampled in the Study Area are presented in Section 6.

3.9 Significant Wildlife Habitat

Significant wildlife habitat typically represents areas that support larger than normal concentrations of animals (e.g., nesting colonies, deer yards, migration stopover areas), critical and/or limited feeding habitat for local populations, or habitats for rare or endangered species.

A large gull and tern colony is found on break-walls at Gravelly Bay and due to the high numbers of breeding birds, the colony has been identified as an Important Bird Area (IBA) by Bird Studies Canada. However, the colony lies outside the Study Area. In addition, the Common Terns that breed on the colony do not forage inland, but remain along the waterfront. During the study, gulls were found to feed in low number on inland fields near the Refinery, however, these fields are not critical for supporting the breeding colony.

Based on the above criteria, no significant wildlife habitat was identified for the woodlots or fields in the Study Area. However, given the rarity of woodlots in the landscape, all woodlots in the Study Area should be considered important wildlife habitat for maintaining local populations of flora and fauna.

Where Fowler's Toads were documented breeding, the Lake Erie shoreline is identified as significant wildlife habitat. The sand dune-flat limestone habitat, where the species breeds and lives a significant portion of its life, is very limited in the landscape. Where this habitat occurs, it is critical to maintain local population numbers of a species that is rare in Ontario and Canada. In addition, the shallow waters and shoreline of Lake Erie from Port Colborne east to the Niagara River are identified as important migratory stopover areas for shorebirds and waterfowl (Lewis and Winger 1991).

3.10 Summary

Field investigations of the Study Area's flora and fauna identified that the woodlots and fields (fallow/old fields) support a species diversity that is typical for the Regional Municipality of Niagara. Species that are common to the Region were also found to be widespread and common in the Study Area. No significant or obvious gaps in species occurrence or representation were noted during the assessment. The Study Area was also found to support a number of flora and fauna species that are rare in the Niagara Region and Ontario. In addition, a number of important woodlots and habitats are present in the Study Area.

Based on the results of the field assessment of the Study Area's natural environment, there are no observable dramatic negative effects of high soil CoC concentrations on flora and fauna. Even in woodlots and fields located near the Refinery, where recorded levels of soil nickel are orders of magnitude above the current MOE generic soil nickel guideline of 200 mg/kg, the community structure and diversity of flora and fauna appear to be typical of the local Port Colborne area and Niagara Region.

The information regarding the ecological diversity of the site has identified fauna and flora (receptors) and natural habitats. The next task in the ERA is to select those receptors considered most representative or valued in the environment to assess exposure to CoCs. Selection criteria and characterization of Valued Ecological Components are described in Section 4.

4.0 RECEPTOR CHARACTERIZATION

For an ERA, specific ecological receptors must be identified to address concerns for the potential risk of CoCs to the natural environment. Here, we refer to these receptors as Valued Ecological Components (VECs). Additionally, one must identify potential adverse effects against which one wishes to protect the VECs (the assessment endpoints) and the characteristics of the VECs that may influence their exposure to the CoCs. This process of VEC selection is referred to as receptor characterization and answers the following four questions (following MOE 1996):

- What species or habitats (receptors) should the ERA protect?
- Against what effects should the ERA protect these receptors (i.e., what are the assessment endpoints)?
- What measurements can be used to assess the effect? (hereafter, “measurement endpoints”)
- What characteristics of the receptors influence their exposure to the potential CoC?

In the following sections, we address these four questions, identifying the VECs used for this ERA, the features that influence their exposure, the VEC-specific assessment endpoints and the VEC-specific measurement endpoints. Statements are based on initial fieldwork examining the biological and physical environment of the Study Area (Section 3).

4.1 Criteria for VEC Selection

All flora and fauna in the study area with elevated CoC concentrations are potential receptors. However, for most ecological risk assessments, one or several species of plants or animals are identified as VECs for which detailed information is collected to assess potential exposure and risk. The local ecosystem as outlined in Section 3 is the focus of this ERA, and chosen receptors must be appropriate components of this system. Although rare and significant species have been identified in the Study Area (see Section 3), detailed data collection for them was not considered appropriate because of their low population density (see Section 1). Criteria for determining suitable VECs for this ERA include the following:

- The potential VEC represents organisms in a major trophic level;
- The potential VEC is prevalent in, and typical of, the Study Area;
- The potential VEC represents a major vegetation component in the Study Area; and/or,
- For animals in higher trophic levels, life history and metabolic data necessary for quantitative risk assessment are either readily available or could be estimated using recognized (standard) equations.

Additionally, an ERA should consider receptors with the following list of characteristics (MOE 1996, CCME 1997):

- Terrestrial plants;
- Terrestrial animals;
- Soil-dwelling organisms;
- Aquatic species that could be affected through surface water or groundwater discharging to surface water;
- Migratory species;
- Avian species; and,
- Ecosystem processes.

4.2 Selected Receptors

Based on the criteria listed in Section 4.1, and following a review of existing documents, field investigations and consultation with the Port Colborne community through meetings with the TSC and PLC, Jacques Whitford (2001d) identified four receptors as VECs for which detailed field data would be collected from the Study Area through the spring, summer and fall of 2001. These included:

- Meadow Vole,
- Frogs/tadpoles,
- Earthworms, and
- Maple Trees.

Voles and earthworms were selected as they represented both important prey items and taxa for which typical approaches for an assessment of potential risk could be undertaken. Frogs were selected as they represented the most typical amphibian receptor in the local environment. Maples ("soft maple", including *Acer rubrum*, *A. saccharinum* and *A. x freemanii*) were selected as important plant species in the area, since soft maples dominate the majority of the Study Area's woodlots. Field collection of frogs and tadpoles, earthworms, voles and maple leaves was undertaken for the analysis of tissue CoCs. In addition, laboratory toxicity tests on earthworms and maples were conducted using Port Colborne soils.

Following this initial selection of VECs, subsequent PLC and TSC meetings identified the need to assess potential impacts on soil nutrient cycles as well as long term ecological health of woodlots in the local environment. In response, a leaf litter study in woodlots was undertaken to address soil nutrient cycles and a woodlot health assessment was developed and conducted by a professional forester.

Eight additional receptors were selected as VECs for this ERA. Seven were chosen to represent primary and secondary consumers typical of, and prevalent in, the Study Area. Mammals selected to represent a large herbivore, a carnivore and a generalist omnivore were White-tailed Deer, Red Fox and Raccoon, respectively. Including Meadow Vole, there were four mammals chosen to be VECs for this ERA. For birds, the predatory Red-tailed Hawk, the worm-eating American Woodcock, the insect-eating Red-eyed Vireo and the generalist American Robin were also selected as VECs. Additionally, the rare Fowler's Toad was selected as a VEC due to its significance as a provincially and nationally 'Threatened' amphibian, and its presence in the Study Area. Table 4-1 lists the 14 VECs for which risk of exposure to CoCs was assessed.

Table 4-1 List of VECs for this ERA.

Decomposers	**Plants**	**Birds**
Earthworms[a,b,c]	Maple (leaves[a,b]/seeds[b])	Red-tailed Hawk[c]
Leaf litter[a]	Woodlots[a]	American Woodcock[c]
		American Robin[c]
Amphibians	**Mammals**	Red-eyed Vireo[c]
Frogs, general (adults[a]/tadpoles[c])	Meadow Vole[c]	
Fowler's Toad[c]	Raccoon[c]	
	Red Fox[c]	
	White-tailed Deer[c]	

Notes
- a risk characterization performed using quantitative analysis of ecological field data
- b risk characterization performed using toxicity testing
- c risk characterization performed using Quotient Method (see Section 8)

The selected receptors are prevalent in the Study Area and represent the basic trophic levels found in terrestrial and aquatic environments (Table 4-2). Examination of primary producers include studies on maple trees (tissue CoC concentrations, germination success, leaf health, seedling growth) and a woodlot health study. Wild grapes (*Vitis riparia*) and goldenrods (*Solidago* spp.) were also collected from the Port Colborne area to determine site-specific tissue CoC concentrations for use in exposure calculations. Earthworms, Meadow Voles and White-tailed Deer represent primary consumers that have the potential to facilitate movement of CoCs through the food chain. Site-specific tissue CoC concentrations were determined from collected samples of earthworms, frogs, tadpoles, Meadow Voles and arthropods (from both field and woodlot habitat) for use in exposure calculations and to directly assess what CoCs are being taken up by some of this study's receptors. American Robin, American Woodcock and Red-eyed Vireo were chosen to represent secondary consumers, and Red-tailed Hawk, Red Fox and Raccoon were chosen to represent general omnivors. For the aquatic environment, adult frogs (Northern Leopard and Green) and their tadpoles were selected as VECs.

It is not known if the VECs selected for study are "the most sensitive". They can, however, be considered representative of the species and ecological processes in the vicinity of Port Colborne, and were agreed to be the VECs for this ERA by the PLC and the TSC. Many of the VECs selected here are "classic" species typically used in ERA and thus provide a level of standardization to the study. In addition, various field studies have been conducted to produce quantitative data that provide an added level of rigour to the overall assessment.

Soil CoC concentrations in the Port Colborne area are potentially harmful to vegetation found growing there (McIlveen and Negusanti 1994), and to processes that support vegetative growth, such as leaf litter decomposition (e.g., Babich *et al.* 1983). Field examination of leaf litter decomposition is useful in assessing impact on the decomposer community (micro-organisms, and soil invertebrates). Earthworms may comprise up to 90% of the biomass of soil invertebrates and are very important in the total ecosystem (ASTM 1998). Considering this, earthworms are also useful indicators of the health of the decomposer community. These assessments of field data, together with toxicity testing, combine to provide a clearer picture of how CoCs are impacting nutrient recycling.

Table 4-2 List of VECs, Assessment and Measurement Endpoints, and Exposure Pathways

VEC	Trophic Level	Assessment Endpoint	Measurement Endpoint	Exposure Assumed to Occur Via
Aquatic				
Fowler's Toad	1°Consumer	Tadpole Survival	20% effects level based on technical literature	Surface water
Frogs/American Toad	1°Consumer	Tadpole Survival	20% effects level based on technical literature	Surface water
	2°Consumer	Adult Survival, Abundance	20% effects level based on statistical analyses of field data	Water, food, sediment
Terrestrial				
Red Fox	Top Predator	Survival, reproduction, growth	LOAEL or NOAEL based on technical literature	Food, air, water, soil
Racoon	2°Consumer	Survival, reproduction, growth	LOAEL or NOAEL based on technical literature	Food, air, water, soil
White-tailed Deer	1°Consumer	Survival, reproduction, growth	LOAEL or NOAEL based on technical literature	Food, air, water, soil
Red-tailed Hawk	Top Predator	Survival, reproduction, growth	LOAEL or NOAEL based on technical literature	Food, air, water, soil
American Robin	2°Consumer	Survival, reproduction, growth	LOAEL or NOAEL based on technical literature	Food, air, water, soil
American Woodcock	2°Consumer	Survival, reproduction, growth	LOAEL or NOAEL based on technical literature	Food, air, soil
Red-eyed Vireo	2°Consumer	Survival, reproduction, growth	LOAEL or NOAEL based on technical literature	Food, air, soil
Earthworms	1°Consumer	Reproduction, survival, biomass	20% effects level based on technical literature and statistical analyses of dose-response experiment and field data	Soil

1° Producer- Primary Producer
1° Consumer- Primary Consumer
2° Consumer- Secondary Consumer

LOAEL – Lowest observable adverse effect level
NOAEL – No observable adverse effect level

Table 4-2 List of VECs, Assessment and Measurement Endpoints, and Exposure Pathways (Cont'd)

VEC	Trophic Level	Assessment Endpoint	Measurement Endpoint	Exposure Assumed to Occur Via
Forest-specific				
Maple Tree	1°Producer	Maple Leaf damage	20% effects level based on statistical analyses of dose-response experiment and field data	Soil
	1°Producer	Maple Key Germination, growth	20% effects level based on statistical analyses of dose-response experiment	Soil
Decomposers (Soil microbes and invertebrates)	1°Producer	Leaf litter Biomass	20% effects level based on statistical analyses of field data	Soil
Woodlots	1°Producer Community	Forest health (survival, diversity, biomass, growth)	20% effects level based on statistical analyses of field data	Soil
Field-specific				
Meadow Vole	1°Consumer	Survival, reproduction, growth	LOAEL or NOAEL based on technical literature	Food, air, water, soil

1° Producer- Primary Producer
1° Consumer- Primary Consumer
2° Consumer- Secondary Consumer

LOAEL – Lowest observable adverse effect level
NOAEL – No observable adverse effect level

Amphibians are important components of both the terrestrial and aquatic ecosystems. Since they have a life cycle comprised of two phases (one aquatic, the other primarily terrestrial), a permeable skin and behaviour that constrains them to direct exposure with potentially contaminated media, they can serve as good bio-indicators of potential risk in ecosystems. Direct examination of the frog community through field surveys is valuable to the integrated assessment process.

Assessment endpoints may be based on individual or population responses. Individual responses may include survival, growth, reproduction, behaviour or histopathology (e.g., lesions, tumours, etc.). Population responses may include changes in size of a population through a combination of birth, death, emigration and immigration. Individual responses may also change the overall population characteristics. Some research has found that measures of individual responses are not as sensitive as measures of population responses (CCME 1997).

CCME and US EPA recommend the selection of ecological endpoints based on the goals and the sought level of protection of the environment. In the current assessment, the objective is to determine ecological risk at a population level. A sustainable level of ecological functioning was selected as the most appropriate level of protection in determining a population level risk. Based on this, survival, reproduction and growth were selected (see Chapter 1) as the assessment endpoints for individual species of mammals and birds, where a literature-based hazard assessment was conducted. The US EPA (1997) reported that at a 40% mortality effects level as an example, a population is likely to be unable to sustain itself. Up to a 20% effects level of a less severe nature (i.e., EC_{20}) was determined to be an adequate level of protection for survival of the species.

The 20% effects level or less has been referenced as a No Observable Effects Concentration (NOEC) in plants, soil and litter invertebrates and heterotrophic processes (Efroymson, *et al.*, 1997a,b) because of difficulties identifying effects below this level. For slower reproducing species with less dense populations, such as larger mammals, a 20% decrease in population may not be acceptable. For these types of populations, an effect level at or near the No Observable Effects Level (NOAEL) is considered a more appropriate endpoint.

The measurement endpoints shown in Table 4-2 were selected to achieve the study objective of determining ecological risk at a population level. For frogs, survival of tadpoles described with a 20% effects level was selected as appropriate since the tadpole is a particular sensitive life stage. Adult survival and abundance at a 20% effects level was selected as the lowest directly measurable population response for both adult frogs and earthworms. For forest-specific effects, the 20% effects level was again selected as the lowest directly measurable risk at a population level. For mammals and birds, a NOAEL (or the LOAEL if judged to be at or near the NOAEL or threshold response level) was selected as a measure of the study objective since this no or lowest observable effect level is considered indicative of not having populations effects.

4.3 VEC Characteristics

Apart from environmental concentrations, basic biology and life histories influence VEC exposure to CoCs. In the following sections, elements of receptor biology and life history are discussed as they pertain to influencing CoC exposure and environmental risk.

4.3.1 Maple Trees

Maple is defined as “soft maple”, either Silver Maple (*Acer saccharinum*), Red Maple (*A. rubrum*) or their hybrids (*A. x freemanii*). The extensive mixing of genotypes, due to ready cross-pollination of the two species, allowed consideration of them as one entity for this assessment. Field surveys have shown that many maples in the Port Colborne area are of hybrid origin.

Although Red Maple is tolerant of many growing conditions and can be found commonly in both dry and moist sites, Silver Maple grows best in moist conditions with good drainage. Both species flower from February or March to May and begin to produce seeds within 24 hours of pollination (by wind), ripening in several weeks. Red Maples can produce seeds at four years of age, while Silver Maples produce seeds no earlier than 11 years of age. Seeds are capable of germinating immediately upon maturation. Young seedlings are most successful in moist mineral soil and do not grow well in soils saturated with water or that are poor in potassium (Perala and Sucoff 1965, Weitzman and Hutnik 1965). However, growth is faster in moist organic soil as compared to dry organic soils or mineral soil (Hutnick and Yawney 1961). Mortality is high in the first year due to competition with taller vegetation.

Soft maples are exposed to CoCs through absorption of material and water through their root system in the soil. Being stationary, their exposure depends on the location at which a seed germinates, closely linked to the spatial pattern of CoC concentrations. Their height and spatial clustering trap airborne CoCs, creating islands of elevated soil CoC concentrations within the woodlots. Therefore, their influence on CoC deposition heightens their exposure to CoCs.

4.3.2 Decomposers

One of the general processes in an ecosystem is that of the cycling of nutrients. The general concept of element cycling in the natural environment is well established and is outlined in numerous texts (Dickinson 1974, Bormann and Likens 1979, Begon *et al*. 1986). Although there are some differences between CoCs, the general pattern remains the same for all. Mineral elements are accumulated from soil, water or air, and are then transferred upward through the food chain. At any level in the food chain, they may be returned to the soil or water via the process generally referred to as decomposition. The decomposition process is a critical one. Without it, large amounts of organic matter would accumulate on the surface of the soil, nutrients would be locked up and not available for sustaining plants, and other components of the ecosystem relying on those plants would be unable to acquire their needed sustenance.

Due to the critical nature of the decomposition process, it becomes a key consideration in any evaluations needed to complete an ecological risk assessment. It has been suggested that the levels of CoCs derived from aerial fallout may have reached levels that are harmful to the vegetation growing in those woodlots and that leaf litter decomposition may have been negatively impacted. Therefore, it was deemed necessary to conduct a field assessment of any possible impacts of the elevated CoC concentrations on the leaf litter decomposition process to complete the required ecological risk assessment.

Soils in woodlands include a complex network of organisms, each with its own role in the progressive breakdown of organic materials (Heath *et al.* 1964, Reichle 1977, Sylvia *et al.* 1998, Griffiths and Bardgett 1999). These organisms include bacteria, viruses, fungi, protozoa, mites, springtails, nematodes, earthworms, enchytraeid worms, molluscs, millipedes, insects and vertebrates (Sylvia *et al.* 1998). Evidence is available in the literature to support different views about the relative roles of soil fauna in the decomposition process. The general view is that the presence of soil fauna increases the rate of breakdown. Behan *et al.* (1978) noted that their presence increased the rate of breakdown by six times that of conditions where they were not present. Crossley and Witkamp (1960) also found that soil arthropods increased the rate of breakdown. By contrast, Malone and Reichle (1973) found that their presence decreased the decomposition rate presumably because they fed upon some of the other organisms that were responsible for the decomposition.

Earthworms are one of the most important and largest soil invertebrates in the breakdown of litter in soils (Lofty 1974). These organisms, and other important agents of litter decomposition, including millipedes, isopods and certain insects, may be exposed to elevated CoC concentrations through two ways: through direct contact and ingestion of CoCs in the soil; and through ingestion of litter with elevated tissue CoC concentrations. There is some evidence to suggest that certain elements, including nickel and other metals, bioaccumulate (Gish and Christensen 1973, Morgan and Morgan 1990). If toxic effects are found to occur in the decomposer community, there can be significant implications on the transfer of CoCs through the food chain and on nutrient cycling. Impacts on predators, due to consumption of earthworms with elevated concentrations of CoCs, have been reported (Cooke *et al.* 1992, Spurgeon and Hopkin 1996). Edaphic factors, such as soil pH and cation exchange capacity, can influence the degree to which earthworms accumulate metals in their tissues (Ma 1982, Corp and Morgan 1991).

4.3.3 Amphibians

The amphibians of the Study Area include six frog species, two toad species and one salamander (see Section 3.8.4). Due to their prevalence, the relative ease with which they can be surveyed, and the existence of benchmark data existing in the literature, frogs and toads (both adults and tadpoles) were chosen as representatives of the amphibian community in the Study Area. As discussed earlier, frogs and toads are important components of the Port Colborne ecosystem. Generally, adults occur at water bodies during the spring, where the males vocally advertize their presence to females. Eggs are laid in the water by the females and externally fertilized by the males during copulation. The egg stage lasts two to three weeks, depending on conditions and species. After hatching, the aquatic larval (tadpole) stage lasts two to three months in Northern Leopard, Green and most other frogs, but longer (13-14 months) in Bullfrogs (Vogt 1981). Tadpole respiration is achieved through gills, which absorb oxygen directly from the water. Diet during the larval stage is restricted to algae and aquatic plants, but the diet begins to include invertebrates during metamorphosis from tadpole to adult. Adult frogs and toads prey upon insects and other invertebrates, and larger individuals may opportunistically prey upon small vertebrates, including other frogs, small snakes, fish and small mammals (Cook 1984).

Amphibians are considered to be declining globally, as has been reported by numerous researchers and confirmed by Houlahan *et al.* (2000). This decline has been attributed to many stressors, including UV-B radiation and a variety of contaminants, such as pesticides and polychlorinated biphenyls (PCBs). Furthermore, UV-B radiation, contaminants and parasite infection have been associated with body deformities, which include missing, malformed or extra limbs and malformation of the central nervous system (Ouellet et al. 1997, Ankley et al. 1998, Johnson et al. 1999). Exposure to contaminants appears to have the greatest impact to the survivorship and health of a frog or toad when it is developing during the egg and larval stages.

Frogs and toads may be exposed to CoCs through their diet (algae in tadpoles, mostly invertebrates in adults), through direct contact and ingestion of the surrounding water and sediment, and through respiration (water in tadpoles, predominantly air in adults). For our purposes, potential risk was assessed for tadpoles only, based on total exposure to surface water. This is due to a lack of published information on the effects due to CoC exposure through other exposure pathways (skin exposure to CoCs in soil or sediment for example), and a similar lack of information on CoC effects on the adult life stage. For adult frogs and toads, potential effects of CoCs in soil, sediment, water and food was assessed indirectly by analysis of field data (calling surveys of males) that was used to document species occurrence, general abundance and distribution in the study area.

4.3.4 Mammals

Mammal VECs for this study are Meadow Vole, White-tailed Deer, Red Fox and Raccoon. General biology of mammals can be found in Banfield (1977). Each species has a different life history, and is discussed separately.

4.3.4.1 Meadow Voles

Meadow Voles are terrestrial mammals, occupying grassland habitats across Canada, from large salt marshes and wet meadows, to vacant lots and forest openings (Banfield 1977). Reproduction principally occurs between April and October, with females producing an average of three to four litters, each of approximately six young, during the year (Banfield 1977). Females mature quickly and mate at the age of approximately 25 days, but males require 45 days to mature (Banfield 1977). They do not hibernate but instead remain active during the winter, using tunnels to move between short burrows, communal toilet areas and nests made of woven grass. The home range varies between habitat and seasons, ranging from approximately 300 to 900 m^2 at its maximum during the summer months (Banfield 1977).

The diet of Meadow Voles is primarily composed of grasses and sedges (monocots), and herbs (dicots) to a lesser degree. Different plant parts (e.g., seeds, stems, fruits, leaves, roots) are harvested in various proportions, differing seasonally. Insects and other invertebrates are eaten in small amounts to supplement their vegetable diet (Banfield 1977). CoC concentrations found within these tissues would be accessible to the vole through ingestion. Voles spend considerable time grooming their fur, which increases their exposure to CoCs through soil ingested during the grooming process.

4.3.4.2 White-tailed Deer

White-tailed Deer are found across much of southern Canada, occupying habitats ranging from swamps to second-growth forest, forest edge and glades (Banfield 1977). Reproduction begins with a rut, which is performed from October to December, during which time males (bucks) will joust, resulting in the privilege to court females (does) in oestrus (usually in November). Young (fawns) are born 6-7 months later, usually in June (Banfield 1977). Individuals become sexually mature from six months to 18 months of age, but males are normally prevented from mating until they are much older.

The movement patterns of White-tailed Deer vary with the location, influenced by local population density and the abundance and spatial distribution of food, water and cover. Summer home range is typically different from the winter home range, depending on snow conditions. During the winter, deer may "yard" in certain areas where snow depths are shallower, and will occupy a home range extending 1-3 km^2. During the summer, deer inhabit larger ranges, males with ranges of approximately 8 km^2 and females with smaller ranges of approximately 4 km^2 (A. Yagi, OMNR, pers.comm.). Movement between winter and summer ranges may be as much as 97 km (Broadfoot and Voigt 1996) or may not occur at all. Movement is expected to be in the range of 5-15 km in the Port Colborne area, and is frequent throughout the year, especially in years with mild winters (A.Yagi, OMNR pers.comm.). However, as a conservative approach, we will consider deer to be present within the Study Area for the entire year.

White-tailed Deer are herbivorous, feeding on a wide variety of plants. The types of plants eaten depend on the abundance of food available at a particular location and time. During the spring and summer, many forbs and grass shoots are eaten, while many fruit are eaten during the autumn. Woody vegetation comprise much of a White-tailed Deer's diet, particularly in the winter, and although they will generally eat whatever is available, deer prefer certain woody species, such as eastern white cedar, maple and dogwood over other species (Bartlett 1958, Banfield 1977). It is difficult to quantify the diet composition of White-tailed Deer in the Port Colborne area, since populations can exhibit a great amount of variation, depending on local conditions, and little is known regarding the diet of this population. However, the agricultural development present in the area makes it likely that a large proportion of the deer's diet is composed of crops, such as corn and soy and other grain crops, as has been found in agricultural areas in north-central USA. For example, in an agricultural area of Nebraska, 51% of a deer's diet (in this case, a Mule Deer *Odocoileus hemionus*) is composed of crops, with corn, alfalfa and wheat being among the preferred foods (Bouc 1997). Where no crops are present, however, 77% of a deer's diet is woody vegetation (Bouc 1997). We have assumed a Port Colborne deer's diet is composed of both local crops and wild vegetation (see Section 6.3).

4.3.4.3 Raccoon

Raccoons occur across much of North America, with the highest population densities east of the Great Plains (Sanderson 1987). They occupy a wide range of habitats but are usually more abundant in woodland near swamps, marshes and streams. Raccoons mate from late winter through the spring and litters of usually three to four young are born approximately two months later (Banfield 1977). Females are sexually mature during their first spring.

The home range of a Raccoon varies with many factors, such as sex, age, season and food, and a multitude of home range estimates have been reported. Kaufmann (1982) summarized data on Raccoon home range size, and stated most maximum home ranges were between 1 km^2 and 6 km^2, but values ranged widely, with some calculated home ranges as small as 0.05 km^2 (Fritzell 1978). Sanderson (1987) reports that most home ranges fall within 0.4 km^2 to 1 km^2, but Banfield (1977) considered movement at the range of 1-2 km^2 to be the norm. Environment Canada (1989b) states that home ranges of 1 to 4 km^2 are common in rural agricultural areas in eastern North America, and we use these values in assessing potential risk.

A Raccoon's exposure to CoCs is affected by the composition of its diet. Their diet is omnivorous diet and consists of many varieties of plant and animal matter. Diets are dependent upon the available food at a location seasonally. In agricultural areas, corn and other crops comprise much of the diet during the fall, but insects and other arthropods are a major food source during the summer (Sanderson 1987 and references cited therein). We adapt the full year data from Llewellyn and Uhler (1952) for our analyses, making relevant replacements to suit our data (e.g., considering grapes as representing all fruits). For our purposes, a typical Raccoon diet for the year consists of frogs, arthropods, earthworms, Meadow Voles, corn, oats and grapes (see Section 6.3).

4.3.4.4 Red Fox

Red Foxes are widely distributed worldwide and inhabit most of mainland Canada and some Arctic islands, including Baffin and Ellesmere islands (Banfield 1977). They prefer semi-open habitat and, in developed regions, are associated with agricultural areas interspersed with woodlots (Voigt 1987). Breeding in southern Ontario occurs from late January to early February (Voigt 1987), and a litter of four to eight pups is born seven to eight weeks later (Asdell 1946). Sexual maturity is attained at ten months of age (Banfield 1977).

Their movement habits and their diet influence the exposure of Red Foxes to CoCs. Home ranges in Ontario range from 5-20 km^2 in farmland, with 9 km^2 as the average (Voigt and Tine 1980). Primarily, their diet is composed of mammals, with Meadow Voles alone sometimes making up 50% of their diet (Voigt 1987). However, foxes are opportunistic and will eat carrion, frogs, birds, insects and plant matter (Voigt 1987). For our purposes, a typical Red Fox diet for the year consists of Meadow Voles, birds (American Woodcock, American Robin and Red-eyed Vireo), arthropods and grapes, based on published literature (Knable 1974), and includes a small percentage of frogs, based on professional judgement.

4.3.5 Birds

Bird VECs for this study are American Robin to represent omnivorous birds, American Woodcock to represent primarily worm-eating birds, Red-eyed Vireo to represent insect-eating birds (including the Study Area's rare birds identified in Section 3), and Red-tailed Hawk to represent predatory birds. The robin, woodcock and vireo represent migratory birds that do not occupy the Study Area throughout the year. Our estimates of risk to these birds should be considered conservative estimates for overall risk to other migratory birds found in the area, either as breeding birds, wintering birds or as migrants.

The four bird VECs selected for this study all have different life histories and biology. They are discussed separately below.

4.3.5.1 American Robin

American Robins are migratory, with a summer breeding range that stretches across mainland Canada (Godfrey 1986). Although very small numbers overwinter in southern Ontario, most return from southern wintering areas in March and depart from southern Ontario from September to November (Sallabanks and James 1999). Robins occupy small breeding territories, ranging in size from 1,100 to 2,100 m^2 (Howell 1942), but they may move up to 300 m from the nest to forage (Knupp *et al.* 1977). Territories are most often found in open habitat, interspersed with trees and shrubs in which to nest and forage (Sallabanks and James 1999). Nests are built in tall shrubs or trees and the first clutch of 3-4 eggs is laid in late April or early May (Peck and James 1987). Eggs are incubated for approximately 12 days, and the hatched young are fed invertebrates until they fledge 13-16 days later (Sallabanks and James 1999). Fledglings may linger in their parents' territory for three weeks, fed by the adult male, before they disperse (Sallabanks and James 1999). Depending on the conditions, two or three clutches of eggs are laid during the breeding season (Sallabanks and James 1999).

The primary exposure pathway of American Robins to CoCs is through ingestion of food. It has been estimated that approximately 93% of their time is spent foraging for invertebrates, on the ground or on vegetation (Sallabanks and James 1999). However, averaged over the spring, summer and fall, 56% of their diet consists of fruits, while the remainder is composed of invertebrates, including arthropods and worms (Wheelwright 1986). Their absence from the Port Colborne area from November to March limits their exposure to these contaminated tissues and any other contaminated media found in the local area. Exposure to CoCs is assumed to occur through soil ingestion, breathing and drinking surface water.

4.3.5.2 American Woodcock

American Woodcocks are migratory, with a summer breeding range that covers much of Ontario north to Lake of the Woods (Cadman *et al*. 1987). They inhabit open forest and woodland in southern Ontario from their arrival in March and April until their departure for southern wintering areas in October and November (Cadman *et al*. 1987, Keppie and Whiting 1994). Woodcocks prefer moist areas with sandy or loam soils for foraging, usually in areas with forest regeneration, although open areas provided by fields or forest openings are required for courtship purposes (Keppie and Whiting 1994). American Woodcocks nest on the ground and a clutch of four eggs is usually laid in May, which is incubated by the female for approximately three weeks (Peck and James 1983). Young woodcocks begin foraging at only a few days of age, and the family disperses after 6 8 weeks. Home ranges differ between the sexes, with males occupying larger areas than females (0.7 km^2 vs. 0.4 km^2, respectively; Sepik and Derleth 1993).

A woodcock's exposure to CoCs is strongly influenced by its foraging habits. The principal component of its diet is earthworms, harvested by probing the earth with its long bill. Soil is readily ingested during this foraging activity. Other invertebrates are also taken, as is a small volume of seeds (Keppie and Whiting 1994). Keppie and Whiting state that food provides adequate moisture and woodcocks are not known to drink water. Thus, exposure to CoC concentrations is restricted to the soil and food ingested and particles inhaled during the seven months of the year woodcocks inhabit the Port Colborne area.

4.3.5.3 Red-eyed Vireo

Red-eyed Vireos are migratory songbirds that breed throughout Ontario, found in the province from May to September (Cadman *et al*. 1987, Cimprich *et al*. 2000). Territory size has been calculated to be roughly 6,900 m^2, based on studies in aspen forest habitat in Michigan (Southern 1958). Nests are on outer limbs of trees from the midstorey down to shrub level, and are often well hidden by deciduous foliage (Cimprich *et al*. 2000). Young leave the nest after 10-12 days, and despite their poor flying ability within the first ten days of fledging, apparently disappear from the nest site three days later (Lawrence 1953, Southern 1958). One clutch of eggs during a breeding season is the norm (Cimprich *et al*. 2000).

A Red-eyed Vireo's exposure to CoCs is influenced most strongly by its diet, which is composed of mostly arthropods with a small percentage of fruit (Cimprich *et al*. 2000); and by its migratory habits, which restricts its exposure to CoCs in the Port Colborne area to four months of the year. Water is imbibed from either wet leaves (Southern 1958), or is acquired from their prey items, as is typical with other insect-eating songbirds; water is not considered an exposure pathway. Ingested soil is minimal, but is considered an exposure pathway.

4.3.5.4 Red-tailed Hawk

Red-tailed Hawk is a top predator, common across much of North America (Godfrey 1986). Although the species does migrate from northern areas in the fall, individuals in southern Ontario are resident throughout the year, and we are making the assumption that Red-tailed Hawks that breed near Port Colborne remain in the area during the winter. They prefer open habitat with elevated perches, such as trees and human-made structures, and nest in hardwood trees or white pines in woodlots; three such nests were found in the Study Area. One clutch of 1-3 eggs is laid, which is incubated for approximately a month, and the chicks fledge at six to seven weeks (Preston and Beane 1993). Their home range varies with such factors as habitat structure, food availability and human disturbance, but ranges from 0.31-3.90 km^2 over the year, with an average of 1.65 km^2 (Petersen 1979).

Red-tailed Hawks are opportunistic predators that primarily prey upon small mammals, but birds comprise a significant portion of their diet (Luttich *et al.* 1970). Exposure to CoCs will be primarily due to ingestion of prey tissues, although exposure to CoCs found in water, soil and air are also considered for this ERA.

4.4 Summary

Based on existing conditions of the Study Area as detailed in Section 3 and criteria for VEC selection for conducting the ERA, a total of 14 VEC were identified for which risk of exposure to CoCs will be assessed. The selected VECs are prevalent and representative of the flora and fauna of the local area and were selected to represent all trophic levels of the food chain. In addition VECs selected for the ERA were chosen based on consultation with the TSC and PLC, Identification of VECs for the ERA required the collection of field samples to determine VEC exposure to COCs. Section 5 outlines the methodology used to obtain representative samples of receptors and their habitats.

5.0 DATA COLLECTION METHODS

The following section provides information on the methods used to collect data, including the collection of field data and chemical analysis. These methods follow detailed protocols presented in Volume II, to which the reader is referred for specific details on the data collection employed for the ERA. For the locations where various samples and data were collected for the study, the reader is referred to Maps 1, 2, and 3 at Tab 16.

5.1 General Study Design for Site-Specific Data Collection

To reduce uncertainty with respect to receptor exposure to CoCs and to better reflect the real situation for the risk characterization of receptors, extensive site-specific data were collected for the study. To evaluate the potential risk of CoCs in the natural environment, certain biological receptors were sampled from inland ponds, fields (fallow or old fields) and woodlots from the Study Area (see Tab 16 – Map 1). As noted in Section 1, the Study Area was separated into two sections, based on soil CoC concentrations, as follows:

- Primary Study Area: >500 mg/kg nickel
- Secondary Study Area: 200-500 mg/kg nickel

Additionally, samples were taken from sites to the west and east of Port Colborne where soil nickel concentrations were below 200 mg/kg; these samples were considered to be taken from the Reference Area (see Tab 16 – Map 2). Within each of these areas, soil type (clay/organic) and habitat type (field/woodlot) were also taken into consideration for the collection of data.

5.1.1 Data Collection Protocols

As part of the ERA process under the CBRA, detailed field data collection protocols were developed, which were reviewed for comment by the TSC and PLC prior to the collection of field data. These protocols document the rationale or need for the collection of the data, the field methodology, treatment of field samples, laboratory analyses of the samples and quality assurance/quality control [QA/QC] requirements. All protocols developed for the ERA are contained in Volume II of the present report. As the protocols are an important component of the ERA, the reader is encouraged to review these protocols to gain a clear understanding of the approaches and methods undertaken for conducting the ERA. The following sections present a general summary of the site-specific data collected and the types of chemical analyses employed.

5.1.2 Data Overlap from HHRA and Crop Studies

A portion of the data collected for the HHRA and ERA-Crop Studies was used by the ERA-Natural Environment to broaden existing databases. Data were collected on maple sap for the HHRA, including actual sap samples and corresponding soil data. These data were used in the ERA to calculate bioaccumulation factors between soil, sap and maple leaves (Section 6). From the Crop Studies, CoC concentrations of crop tissues and goldenrod tissues were used to calculate the potential exposure of certain ERA receptors (*i.e.*, White-tailed Deer, Meadow Vole and Raccoon).

A portion of the soil CoC values (0-5 cm depth) obtained during the HHRA field program contributed to the database used to generate the isopleths shown in Figures 2-2 through 2-5. These data are listed in Volume III, tab 9.

5.2 Biological Field Data

Table 5-1 is a summary of the number of sites sampled or surveyed for each receptor in the Study Area and at reference sites. Included is the time of year sampling was undertaken and the number of replications or specimens collected at each sample station.

For the selection of specific sampling sites in the Study Area or reference sites, no rigorous selection criteria process was established. Within the Study Area generally the selection of sampling sites was based on satisfying a number of basic general parameters including:

- Where possible selection of sample sites should result in an equal and similar distribution of sample sites between the Primary Study Area and Secondary Study Area based on soil nickel concentrations as identified by MOE mapping (MOE 2000a,b);
- Woodlots with similar tree species composition, on clay and organic soils;
- Fields of the same general size that were either fallow or dominated by field weeds species on clay and organic soils; and
- Where possible, the collection of different biologic data sets should be collected from the same general location within the same woodlot or field.

Reference sites were selected from areas located west and east of the Study Area. Generally, land use history for lands in the vicinity of Port Colborne are similar, with a predominance of cleared and drained lands for agriculture, through which are scattered small remnant woodlots. In addition, in the local area clay and organic soils are similar in type. For the selection of reference sample sites the following basic general parameters had to be met:

- Site located as near the Study Area as possible (i.e. within 10-20 km);
- Soil nickel less than 200 mg/kg;
- Site located within a few kilometres of the Lake Erie shoreline;
- Site located in a local agricultural setting;
- Soils that were either organic or clay and similar to those of the Study Area;
- Woodlots of the same general size with similar tree species composition to woodlots sampled in the Study Area; and
- Fields of the same general size that were either fallow or dominated by field weeds species similar to those of the Study Area.

Table 5-1 ERA Field Sampling Structure

Receptor	Sample Period 2001	Reference		Primary Area		Secondary Area	
		# Stations	# Replicates/ Station	# Stations	# Replicates/ Station	# Stations	# Replicates/ Station
Frogs							
Call Survey	May-June	8	4[1]	9	4[1]	12	4[1]
Adult Frogs	June-August	5	5[2]	5	5[2]	5	5[2]
Tadpoles	June	2	1[3]	3	1[3]	3	1[3]
Earthworms	September	5	3[3]	5	3[3]	5	3[3]
Arthropods	July-August	10	1[3]	10	1[3]	10	1[3]
Tent Caterpillars	August	1	1[3]	1	5[3]	0	0
Soft Maple							
Leaves	August	5	3[3]	5	3[3]	5	3[3]
Sap	March	1	1[2]	3	1[2]	3	1[2]
Leaf Litter	July-October	9	15[3]	7	15[3]	5	15[3]
Wild Grapes	September	3	1[3]	3	1[3]	4	1[3]
Meadow Vole	September	3	4[2]	2	5[2]	1	1[2]
Bird Survey	May-July	0	-	7[4]	-	6[4]	-

Notes General – Please refer to the data collection protocols in Vol. II for a description of how samples were collected, handled, and chemically analyzed.

1 each station was visited four times during the sample period
2 indicates the number of specimens retained from each station
3 each replicate/station is composed of a composite sample
4 these represent individual transects walked for the bird survey

5.2.1 Quality Assurance and Quality Control for Collection of Field Data

A representative of Stantec (the PLC's consultant) accompanied field study teams during the collection of all biological datasets. This procedure served two purposes. First, to observe that collection methods were in accordance with protocols, and secondly, to collect additional biological specimens for external QA/QC. For the bird and frog surveys, a representative of Stantec served as an observer for the qualitative data collection.

During the collection of biological receptors, Stantec collected an additional sample (20%) from each treatment area. In a few instances, fewer specimens than anticipated were collected in the field, eliminating the possibility for Stantec to collect an additional 20%. In this situation, Stantec received 100% of the field data for QA/QC once analyzed by PSC Analytical Services (PSC). Table 5-2 summarizes the QA/QC process for each receptor with respect to sizes and role of Stantec.

Table 5-2 Field QA/QC for Biological Specimens

Additional sample sizes of 20% collected by Stantec[1]	Adult frogs Tadpoles Maple leaves Maple sap	Earthworms Arthropods Wild grapes
Full data set provided to Stantec[2]	Meadow Voles	
Observational Role Played by Stantec[3]	Frog call survey	Bird survey

Notes
1 Stantec present during animal dissections
2 Stantec present during earthworm identification and age classification
3 Stantec present during qualitative data collection

All biological samples were shipped to PSC for elemental analysis including the four CoCs. All additional biological specimens collected were prepared and shipped to PSC by Stantec. Data collected by both parties were compared by Stantec as part of the QA/QC process.

5.3 CoCs in Environmental Media

5.3.1 CoCs in Soils and Sediments

A comparison of CoCs in biological tissues, to that of concentrations in soils, is an integral part of the ERA study design. To facilitate this, soil samples were obtained from the general location of biological specimen collection. For frog and tadpole sampling, sediment samples were obtained from the general area of capture.

All soil samples were collected using a stainless steel Oakfield soil corer in accordance with soil sampling protocols (Volume II, Tab 4). A minimum of eight soil or sediment cores were taken to constitute one composite soil sample that was sent to PSC for elemental analysis. Sampling of soil in the field required both Jacques Whitford and Stantec to collect an additional 10% (duplicate samples) for QA/QC purposes.

Table 5-3 summarizes the ERA sampling programs for which soil and sediment were collected. Soils collected as part of one component study (*e.g.*, leaf litter study) were also used for other component studies done at the same sites (*e.g.*, woodlot arthropod collection). The table identifies where this sharing of data occurs.

5.3.2 CoCs in Surface Water

Surface water samples were collected from 37 locations in the Primary Study Area (12 stations), Secondary Study Area (17 stations) and Reference Area (8 stations). Table 5-4 summarizes the sampling scheme for the surface water collected as part of the ERA.

Table 5-3 ERA Sampling Programs for Which Soil and Sediment Were Collected

Sampling Program	Stations Sampled	Depth (cm)	Studies for Which Soils Used	Collection Methods for Each Sample
Leaf Litter Study	21	0-5	➢ Leaf litter ➢ Woodlot arthropods ➢ Woodlot earthworms ➢ Maple leaves ➢ Tent caterpillars ➢ Wild grapes	➢ 30 soil cores from each station
Maple Sap Study	17	0-5 and 5-15 at each station	➢ Maple sap ➢ Maple leaves ➢ Woodlot arthropods	➢ 8-10 soil cores from around each tree
Field Arthropod Sampling	15	0-5	➢ Field arthropods ➢ Meadow Voles ➢ Field earthworms	➢ 8-10 soil cores from each transect
Frog Collection (sediment)	15	0-5	➢ Frogs ➢ Tadpoles	➢ 8-10 sediment cores from each pond
Maple Keys	2	0-5	➢ Maple keys	➢ 8-10 soil cores from around each tree
Maple Leaf Sampling	1	0-5	➢ Maple leaves ➢ Woodlot arthropods ➢ Woodlot earthworms	➢ 8-10 soil cores from around each tree
Field Corn Sampling	12	0-5	➢ Field Corn	➢ 8-10 soil cores from the base of each plant
Meadow Vole Sampling	2	0-5	➢ Meadow Voles	➢ 8-10 soil cores from each transect
2002 Earthworm Sampling	38	0-5	➢ 2002 Earthworms	➢ 8-10 soil cores from perimeter of each quadrat
Goldenrod Sampling	31	0-15	➢ Biomonitoring Study	➢ 10-15 cores from each site

Table 5-4 Summary of Surface Water Sampling Scheme for the ERA

# Stations Sampled	Sampling Period	Collection Methods	Travel Blanks	QA/QC
37	May – September	Surface water was sampled from a central portion in the water column with effort made not to disturb sediment. The pH and temperature were measured in the field with a Fisher Scientific portable Accumet pH meter (model AP61).	Exposed to ambient air during sampling	20% additional samples taken by Stantec

5.3.3 CoCs in Air

Air monitoring was conducted to determine the level of particulate matter and metals in the ambient air in the Port Colborne community (Jacques Whitford 2002b). Data collected in the Study Area as part of this separate study were used for the ERA (see Table 5-5). Laboratory analysis of the collected particulate matter involved a full metal scan for 28 different elements, including the four identified CoCs.

Table 5-5 Sampling Scheme for Air Quality Data Collection

Study Type	Date Sampled	Sampling in Study Area	Travel Blanks	QA/QC
Ambient Air Sampling	August-September	2 PM 10 5 PM 2.5 2 TSP	Glass and quartz filters (blanks) were exposed to ambient air during field collection of used filters.	A Stantec consultant was present to monitor collection methods.

Notes
PM_{10} Suspended Particulate Matter <10 microns
$PM_{2.5}$ Suspended Particulate Matter<2.5 microns
TSP Total Suspended Particulate Matter

5.3.4 Database for ERA

Extensive collections of biophysical and biological data were undertaken during various field programs of the ERA, with the objective of obtaining site-specific values for CoCs in the various media. Table 5-6 summarizes the number of samples collected in the field for each of the sample types. Duplicate samples collected by Stantec or Jacques Whitford are not included in Table 5-6.

Table 5-6 Total Number of Samples Collected and Chemically Analyzed for the ERA

Medium Analyzed	Number of Composite Samples
2002 Earthworm Soils	38
Field Arthropod Soils	17
Frog Pond Sediment	16
Leaf Litter Soils	21
Maple Key Soils	2
Maple Leaf Soils	1
Maple Sap Soils (0-5 cm)	21
Maple Sap Soils (5-15 cm)	21
Surface Water	37
Vole Soils	2
Corn Soils	12
Goldenrod Soils	31
Total Biophysical Samples	**219**
Arthropod Tissue	30[1]
Tent Caterpillars	6[1]
Corn Kernels	12[1]
Earthworm Tissue (2001)	13[1]
Earthworm Tissue (2002)	35[1]
Frog Carcass	74[2]
Frog Liver	74[2]
Frog GI Tract	74[2]
Maple Keys	6[1]
Maple Leaves	48[1]
Maple Sap Analysis	23[2]
Tadpole Body	8[1]
Tadpole GI Tract	8[1]
Vole Carcass	23[2]
Vole Liver	23[2]
Wild Grapes	10[1]
Goldenrods	124[2], 31[1]
Total Biological Samples	**622**
Total Number of Samples for Natural Environment	**841**

Notes

1 Indicates the number of composite samples collected and chemically analyzed.

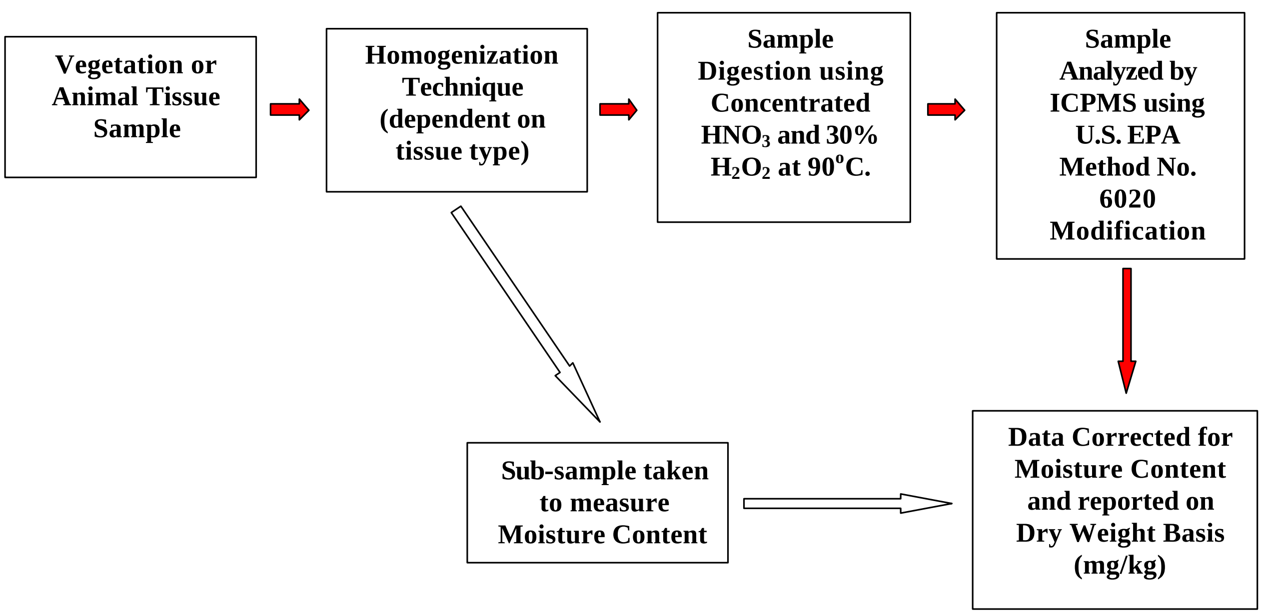
2 Indicates the number of individual samples obtained and chemically analyzed.

5.4 CoCs Laboratory Analysis

5.4.1 Vegetation and Animal Tissues

All tissues were submitted to PSC in labelled plastic vials or zip-lock plastic bags. Sample preparation and digestion procedures that were followed by PSC for tissue analyses were in accordance with Section 5.1 of the MOE (1996) guidance document (Figure 5-1). For detailed methodology on instrumentation used for chemical analysis, we refer the reader to the Laboratory Protocols (Tabs 1 and 2) in Volume II. Results of all chemical analysis on biological tissue were reported by PSC on a dry weight basis in mg/kg. All CoC concentrations presented in this report use these units, in dry weight.

Figure 5-1 Analytical Procedures for Determination of CoCs in Vegetation and Animal Tissues



HNO_3 = Nitric Acid
H_2O_2 = Hydrogen Peroxide
ICPMS = Inductively Coupled Plasma Mass Spectrometry

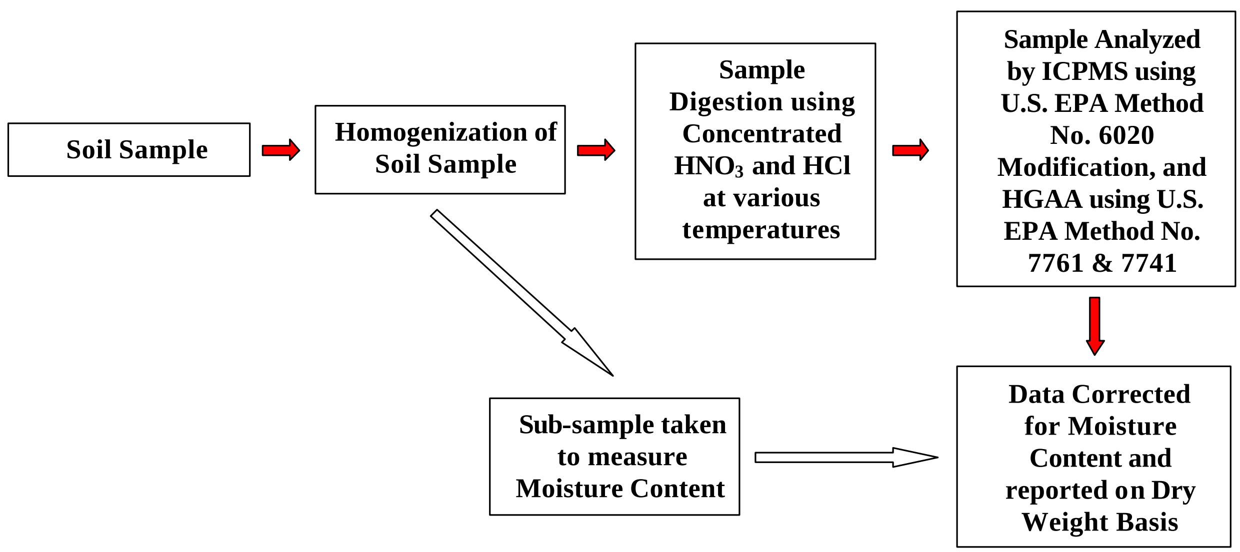
5.4.2 Laboratory QA/QC for Vegetation and Animal Tissues

Samples were processed in batches not exceeding a total of 15 samples. With each batch of samples, Standard Reference Materials (SRM), spikes and replicate analysis were processed at PSC as part of QA/QC. SRMs included spinach leaves (QA/QC for vegetation) and Bovine Liver and Oyster Tissue (QA/QC for animal tissue).

5.4.3 Lab Analysis of Soils

All soil samples were submitted to PSC in labelled glass jars. Sample preparation and digestion procedures that were followed by PSC for inorganic analyses were in accordance with Section 5.1 of the MOE (1996) guidance document (Figure 5-2). For detailed methodology on instrumentation used for chemical analysis, please refer to the Soil/Sediment Sampling and Analysis Protocol (Volume II, Tab 4). Results of all chemical analyses on soils were reported by PSC on a dry weight basis in mg/kg. All CoC concentrations presented in this report use these units, in dry weight.

Figure 5-2 Analytical Procedures for Soils



HNO_3 = Nitric Acid
HCl = Hydrochloric Acid
ICPMS = Inductively Coupled Plasma Spectrometry
HGAA = Hydride Generation Atomic Absorption

5.4.4 Laboratory QA/QC for Soil Analysis

Samples were processed in batches not exceeding a total of 15 samples. With each batch of samples, Standard Reference Materials (SRM), spikes and replicate analysis were processed at PSC as part of QA/QC. The SRM used was San Joaquin Soil (SRM 2709). For a detailed explanation of QA/QC laboratory processes, please refer to Volume II.

5.4.5 Surface Water

All surface water samples were submitted to PSC in labelled plastic sample bottles. No digestion was required for surface water samples prior to analysis. For chemical analysis of 27 elements in water, a portion of each surface water sample was analyzed using ICPMS instrumentation (see Volume II, Tab 5). For accurate detection of antimony, arsenic and selenium, a portion of each water sample was analyzed using Hydride Generation Atomic Absorption.

5.4.6 Laboratory QA/QC for Surface Water

Samples were processed in batches not exceeding a total of 15 samples. With each batch of samples, spikes and replicate analysis were processed at PSC as part of QA/QC.

5.4.7 Jacques Whitford QA/QC for Laboratory Data

As a means of determining the reproducibility or variability related to analytical procedures and sample homogeneity, Jacques Whitford calculated the percentage differences between the analyzed values for the original and duplicate (obtained in the field) or replicate (analysis performed in the laboratory) samples. In situations where more than one duplicate was collected, the duplicates with the largest variance were used to calculate percentage difference.

For sample reproducibility calculations, percentage differences were calculated for those chemical parameters with analytical values greater than 3 times EQL (EQL is the estimated quantitation limit, i.e., the lowest level of a parameter that can be identified with confidence by an analytical laboratory). For the purposes of reporting, results of Test 1 of a sample are considered “Original” and results of Test 2 are considered “Duplicate” or “Replicate” results.

Percentage differences were determined using the following formula:

$$Percentage\ difference\ of\ \ Analyte\ A = \frac{(Analyte\ A\ in\ test\ 1 - Analyte\ A\ in\ test\ 2)\ x\ 100}{(Analyte\ A\ in\ test\ 1 + Analyte\ A\ in\ test\ 2)\ /\ 2}$$

This formula was also applied to QA/QC for SRMs where percent differences were calculated between known expected values for a specific SRM (Test 1) and those actually obtained from PSC during the analysis of the various media (Test 2).

For reporting of percent differences, the use of "NC" indicates that a percent difference was not calculated due to a value that is less than three times the EQL or that a value was not quantified by PSC (i.e., "nd", or non-detect).

6.0 EXPOSURE ASSESSMENT

This section provides detail on the potential exposure of the selected receptors to CoCs. Below, landscape elements that are evaluated as part of the ERA are identified (Section 6.2), the pathways through which receptors may be exposed to CoCs are discussed (Section 6.3), and the potential bioavailability of the CoCs in the natural environment is assessed (Section 6.4). This chapter is concluded with a discussion of the magnitude, frequency and duration of CoC exposure for eleven animal VECs identified in Section 4 (Section 6.5).

6.1 Approach

The objective of the exposure assessment is to identify and evaluate exposures to CoCs through potential exposure pathways relevant to each VEC. By determining concentrations of CoCs within various media existing in the Port Colborne area, how selected receptors may be exposed to CoCs was examined and the magnitude, duration and frequency of their exposure was assessed. Availability of CoCs will differ between areas and media, and subsequent sections address this variability. Pathways were identified, and empirical data were used to estimate each receptor's exposure to each CoC, either as an exposure concentration (for earthworms, tadpoles and Fowler's Toad) or as an average daily dose (for birds and mammals).

6.2 Landscape Elements Evaluated

For assessing exposure of VECs to CoCs, two landscape elements were considered: woodlots and fields (as defined in Section 1.4.8). Due to differences in CoC availability in clay versus organic soils (e.g., Kukier and Chaney 1999), the effect of soil type was also included in assessments of exposure. Other possible elements, such as wetland habitat, were not present in the Study Area to any appreciable degree.

As discussed in Section 2.1.4, woodlots may have elevated CoC levels due to their physical structure, and they may exhibit a different dynamic of nutrient flow and trophic structure. Additionally, different animal and plant species may be characteristic of woodlots versus open field habitat. A VEC's exposure may be strongly dependent on the CoC concentrations found in each habitat type, and the affinity of either the VEC or its prey to different habitat types. Where appropriate, we assessed the exposure of a VEC for each separate habitat type and soil type. Further discussion is provided in Sections 6.4 and 6.5.

6.3 Exposure Pathways and Media

The following sections present significant pathways of exposure to CoCs for biological receptors representing different trophic levels in the ecosystem (see Figures 6-1 to 6-5). CoC concentrations in soil, sediment, surface water and plant/animal tissue were quantified for the Study Area and are presumed to contribute to the risk of the VECs in Figures 6-1 through 6-5, where appropriate. Tissues of some animals and plants (e.g., arthropods, goldenrods) were chemically analyzed to obtain CoC concentrations for use in calculating VEC exposure to CoCs. Figures 6-1 to 6-5 are generally simplified and do not show the contributions of environmental media (e.g., soil) to a VEC's exposure to a CoC, either through direct routes of exposure (e.g., ingestion of soil) or indirectly (movement of CoCs from soil to a diet item, such as a foodplant). However, these pathways are acknowledged to exist and are incorporated in the calculations of exposure where relevant. In Figures 6-1 to 6-5, hatched boxes indicate the VEC's.

Figure 6-1 Biological Pathways of Exposure Considered for Tadpoles.

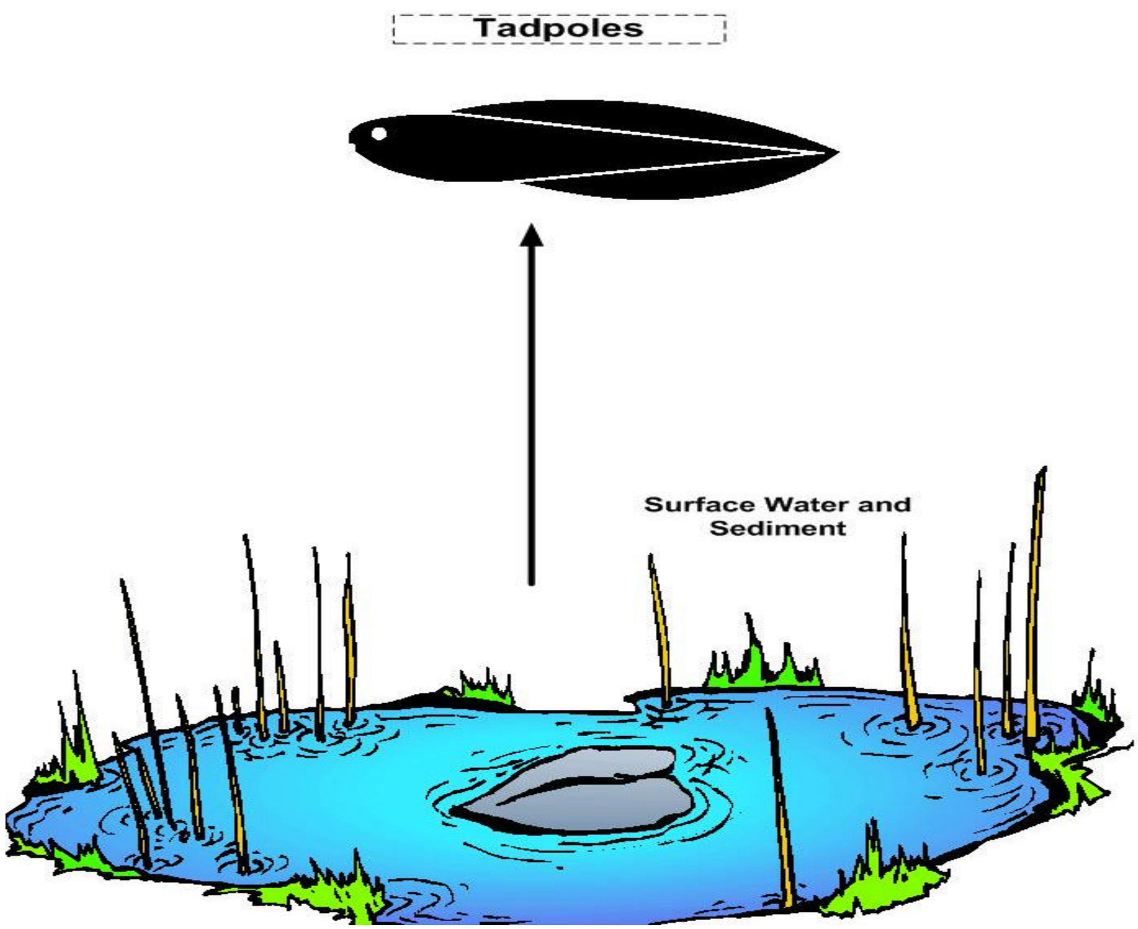


Figure 6-2 Biological Pathways of Exposure Considered for Red-tailed Hawk, American Robin, American Woodcock and Red-eyed Vireo.

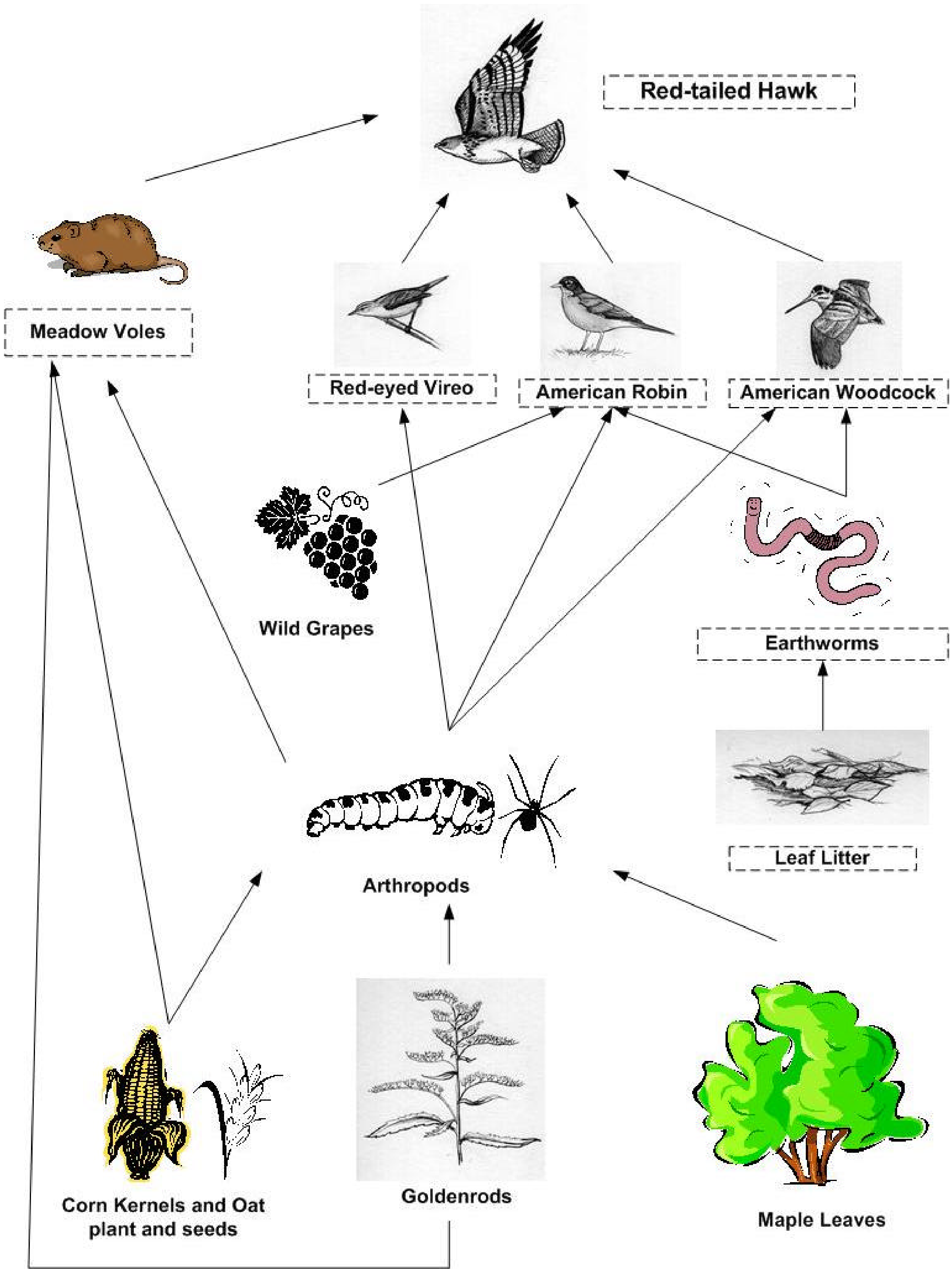


Figure 6-3 Biological Pathways of Exposure Considered for White-tailed Deer.

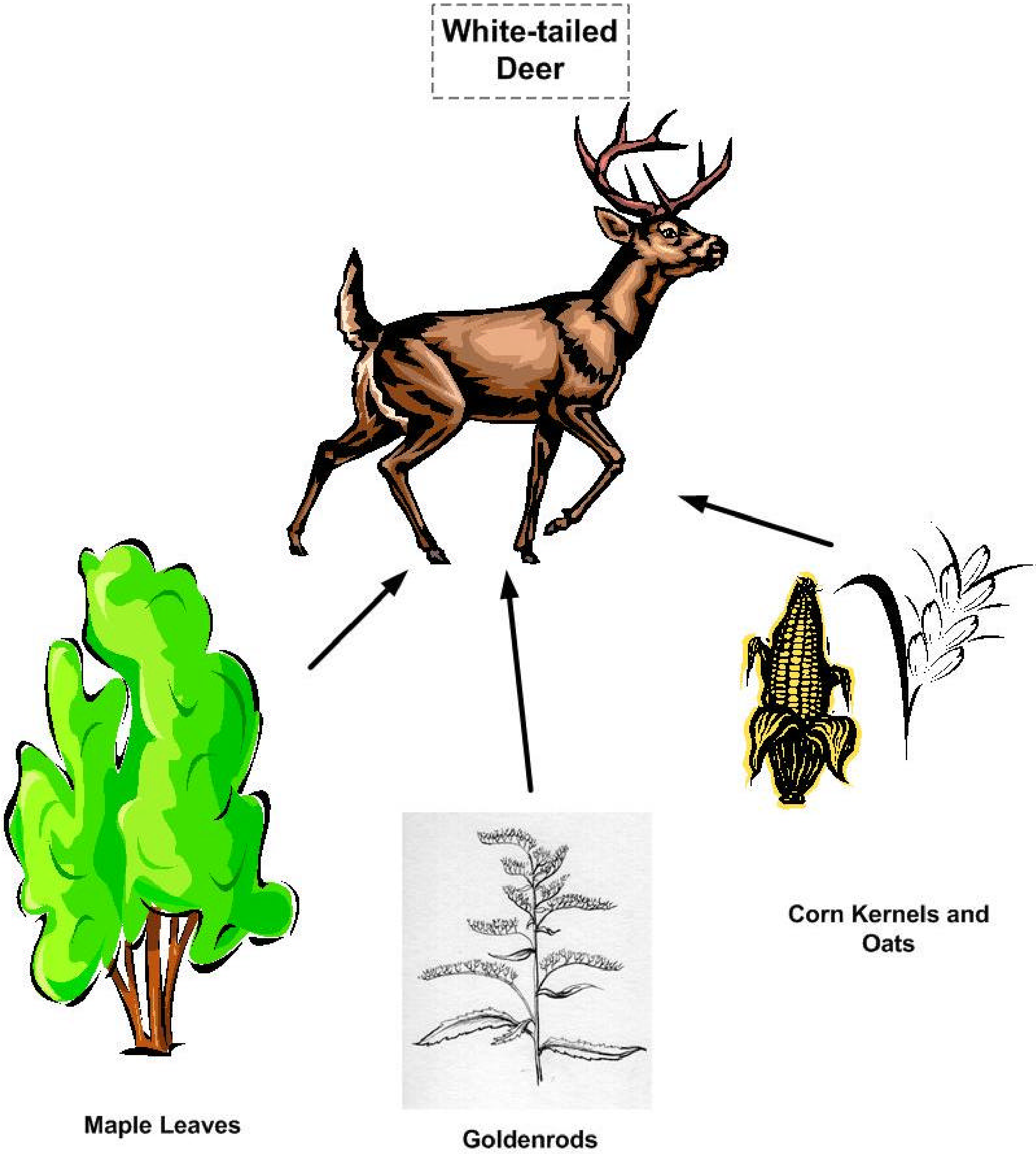


Figure 6-4 Biological Pathways of Exposure Considered for a Raccoon.

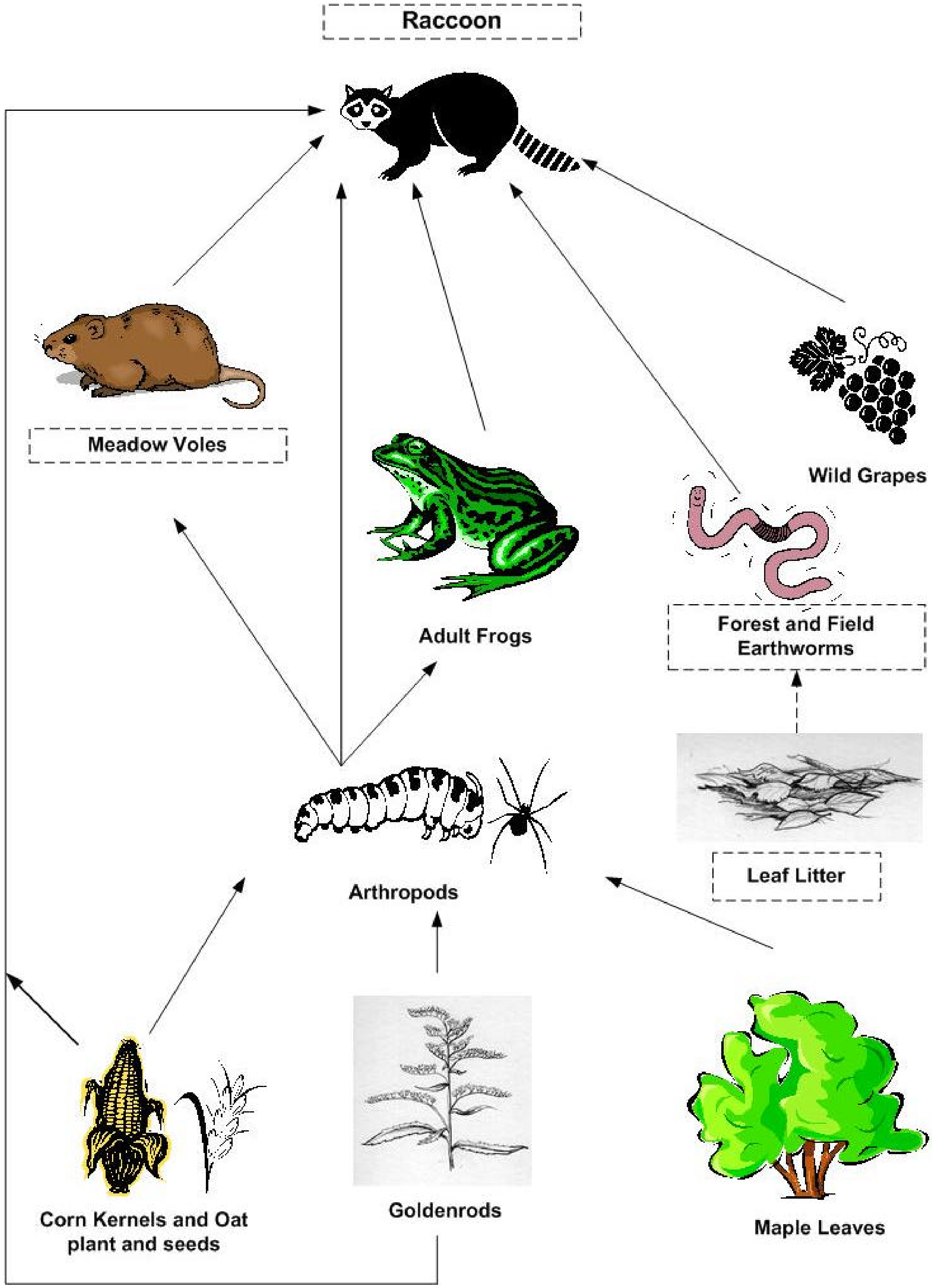
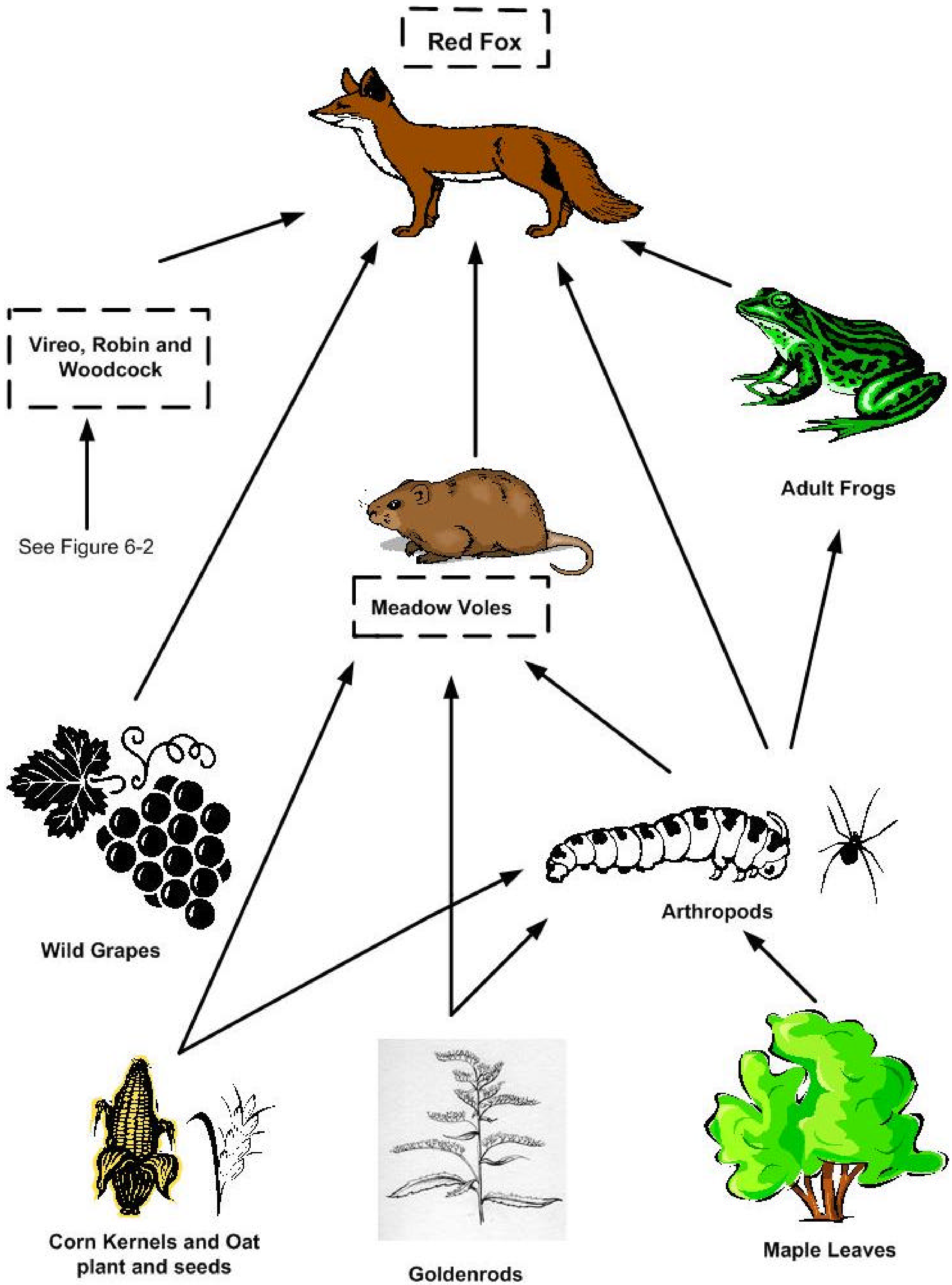


Figure 6-5 Biological Pathways of Exposure Considered for Red Fox and Meadow Vole.



6.3.1 Source of Exposure

Potential sources of contaminants in the Port Colborne area are listed in Jacques Whitford (2002b). This earlier report focuses on sources from the Inco Refinery in southeastern Port Colborne, which processed electrolytic nickel from 1918 to 1984. Additionally, a summary of past and present sources of CoCs in the local environment is presented in Section 2, and a detailed discussion of past and present sources of CoCs is presented in Jacques Whitford (2001a).

6.3.2 Receiving Media

CoCs from Refinery emissions generally occur in the Port Colborne area in the following environmental media: surface soils, from past and present source emissions; air, from present source emissions and disturbance of surface soils (Jacques Whitford 2002e); surface water, from aerial deposition and erosion of surface soils; sediment, from aerial deposition and erosion of surface soils, and subsequent settlement from the water column; and accumulation of CoCs in organic tissue, as discussed in Section 6.4. Further discussions of how receptors are exposed to CoCs through these media are presented in the following sections.

6.3.3 Exposure Points

An important component of an ERA is the determination of where receptors can be exposed to CoCs. For this specific case, receptors may be exposed through any of the environmental media in the area of Port Colborne, particularly east and northeast of the city, as described in Section 2.1. In addition to the environmental media through which receptors may be exposed to CoCs, additional exposure to CoCs occurs through the ingestion of plant and/or animal tissue by some receptors. Exposure of VECs to CoCs assumed exposure to a population through the entire Study Area.

6.3.4 Exposure Routes

For receptors that are in direct contact with soil, such as plants and earthworms, exposure to CoCs occurs through contact with soils and soil porewater concentrations of CoCs. Additional exposure of earthworms to CoCs is also assumed to occur through ingestion of surface soils and CoCs in food (i.e. leaf tissue or insect tissue). Earthworms are included in Figures 6-2 and 6-4, and are assumed to receive all of their exposure by ingestion of, and dermal contact with, soil.

However, there is no existing literature that allows for a calculated assessment of potential risk to earthworms as a direct result of exposure through the ingestion of the CoCs in food or soil.

For birds and mammals exposure to CoCs is assumed to occur via inhalation of air, ingestion of soil and water and diet consumption. Figures 6-1 to 6-5 present the routes of exposure through diet, assuming that ingestion of soil and water are additional exposure routes for bird and mammal receptors (with the exception of American Woodcock and Red-eyed Vireo, which do not drink surface water; see Section 4). Though the inhalation of air is identified as a exposure route, for the exposure assessment for birds and mammals, the contribution of CoCs in air was not included with respect to determining an average daily dose (see Section 6.5). In addition, there is no existing literature that allows for a separate calculated assessment of potential risk due to exposure through the inhalation of CoCs in air for the selected bird and mammal VECs. Therefore, only risk resulting from exposure through diet can be evaluated.

Exposure to CoCs for adult frogs and tadpoles is through water and sediment of the ponds they inhabit, and through the ingestion of food (plants, algae, insects and sediment). However, there is no existing literature that allows for a calculated assessment of potential risk to adult frogs and tadpoles as a result of exposure through the ingestion of the CoCs in food or sediment. Therefore, only risk resulting from exposure through water can be evaluated.

The potential exposure pathway for a Red-tailed Hawk is presented in Figure 6-2 and is based on a diet of Meadow Voles and birds, represented by Red-eyed Vireo, American Robin and American Woodcock. CoC concentrations in Meadow Vole tissue were measured directly from specimens collected in the Study Area and used to calculate exposure of Red-tailed Hawk. However, bird tissue CoC concentrations were not measured but were derived using bioaccumulation factors and calculated dose (as described in Section 6.5). Exposure to CoCs through diet for each species are assumed to be through consumption of food items depicted in Figure 6-2. Red-eyed Vireos are assumed to eat only arthropods (insects and spiders), American Robins are assumed to eat wild grapes, arthropods and earthworms, and American Woodcocks are assumed to eat arthropods and earthworms. For each of these bird receptors, exposure is assessed for four different scenarios (woodlots and fields on clay and organic soils), as discussed in Section 6.5.

The potential exposure pathways for White-tailed Deer in the Study Area include consumption of a diet that includes vegetation from natural fields (goldenrods), agricultural fields (oats and corn) and woodlots (maple leaves) (Figure 6-3). Due to the range of movement of deer in the Study Area and their habit of exploiting both field and forest habitat for foraging, exposure was assessed for the general Study Area scenario only. Figure 6-3 also illustrates the exposure pathway for maple, which shows the presumed movement of CoCs from soil to sap to leaves.

Figure 6-4 shows a Raccoon's potential exposure through consumption of diet in the Study Area, which assumes a diet consisting of wild grapes, earthworms, arthropods, frogs, Meadow Voles and vegetation. Four exposure scenarios were examined, based on soil type and habitat type (woodlots and fields on clay and organic soils).

For the purposes of this study, Red Fox has a diet consisting of Meadow Voles, frogs, arthropods, wild grapes and birds (Figure 6-5). Of these five food items, tissue CoC concentrations were directly measured from collected samples of Meadow Voles, frogs, arthropods and wild grapes from the Study Area. Tissue CoC concentrations of birds were derived using bioaccumulation factors and calculated daily doses for each species (see Section 6.5). Four scenarios were evaluated, based on habitat and soil type (woodlots and fields on clay and organic soils). The Meadow Vole is also shown in Figure 6-5 and is assumed to have a diet consisting of field arthropods, crop plants and goldenrods. Meadow Voles are restricted to field habitat in the Study Area, and exposure was calculated for two scenarios: field habitat on clay soils and field habitat on organic soils.

Further information on exposure calculations and exposure scenarios is presented in Section 6.5. Values used to calculate an average daily dose of each CoC, including CoC concentrations in soil, water, and diet, are given in Section 6.5.3 and Volume III (Tab 5).

6.3.5 Limitations of Predicted Exposure Routes

Along with soil, water and air, many tissues were collected in the Study Area, which allow the input of actual CoC concentrations into exposure calculations for each receptor. The pathways represented in Figures 6-1 to 6-5 include those prey items for which we have actual CoC calculations, but exclude other items for which we do not have data (e.g., snakes, which may be eaten by Red-tailed Hawk). Also, some of the food items shown in the diagrams are surrogates for actual diet items. For example, Red-tailed Hawks are shown to eat Meadow Voles (representative of small mammals) and three birds (American Woodcock, American Robin and Red-eyed Vireo), which are representative of birds in general. Despite a few absences and the use of surrogate food items, we believe that the diets presented in Figures 6-1 to 6-5 are representative of actual diets of VECs in the Study Area.

The biological pathways presented in Figure 6-2 and 6-5 include the movement of CoCs from American Woodcock, American Robin and Red-eyed Vireo to predators. Tissue CoC concentrations for these birds were not measured, but were instead predicted using their calculated exposure and the most appropriate bioaccumulation factors found in the literature. Without measured values of tissue CoC concentrations, we cannot evaluate the accuracy of these predictions. However, we expect that actual CoC concentrations in these birds would be lower than predicted (based on our approach to calculating exposure for every receptor that would overestimate the tissue CoC concentrations of the woodcock, robin and vireo).

6.4 Assessment of Bioavailability

Here we present a discussion of potential CoC availability through plant and animal tissues sampled from the Primary and Secondary Study Areas and the Reference Area. Relationships between CoC concentrations in tissue and those of the surrounding soil, sediment or water are presented below. An overview of the distribution and abundance of the CoCs in the environment is found in Section 7.1.

6.4.1 Bioaccumulation Factors

Bioaccumulation factors (BAFs) were derived from CoC concentrations of various environmental media collected during this study as well as for other receptor media (plant and animal tissues). This section provides an overall account of CoCs that are present in environmental media and at different trophic levels as measured or estimated in plant and animal tissues. Illustrations presenting BAFs between different receptors for every location or study area are not provided. Rather, representative examples, indicating mean BAFs for site-specific data are illustrated below in order to summarise the overall reduction of CoCs in biotic receptors, compared with CoCs present in soils, sediment and water. These are examples only, since CoC concentrations in diet items likely contribute to the overall exposure (and tissue CoC concentration) of receptors. Further examination of the relationships between CoC concentrations in plant and animal tissues and environmental media is reported in Section 6.4.2.

Figure 6-6 presents mean CoC concentrations for sediment (S-H1, S-H2, SF-H-4, SF-H-5), surface water (S4, S28, S31, S32) and frogs (F-H-1, F-H-2, F-H-4, F-H-5) collected from four ponds in the Primary Study Area. Figure 6-7 presents mean CoC concentrations obtained from sediment (S-M1, S-M2, S-M3), surface water (S11, S30, S10) and composite tadpole samples (T-M-1, T-M-2, T-M-3) collected in three ponds. The BAFs between environmental media and receptors are indicated in bold beside the respective arrows, which are means of BAFs calculated for each specimen. CoC concentrations in tadpole and frog tissue represent weighted averages calculated from component tissues that were analyzed (Volume III, Tab 3).

Figure 6-6 Mean Bioaccumulation Factors (BAFs) for Four Ponds in the Primary Study Area, Including Respective Mean CoC Concentrations (mg/kg) for Sediment, Surface Water and F Tissue.

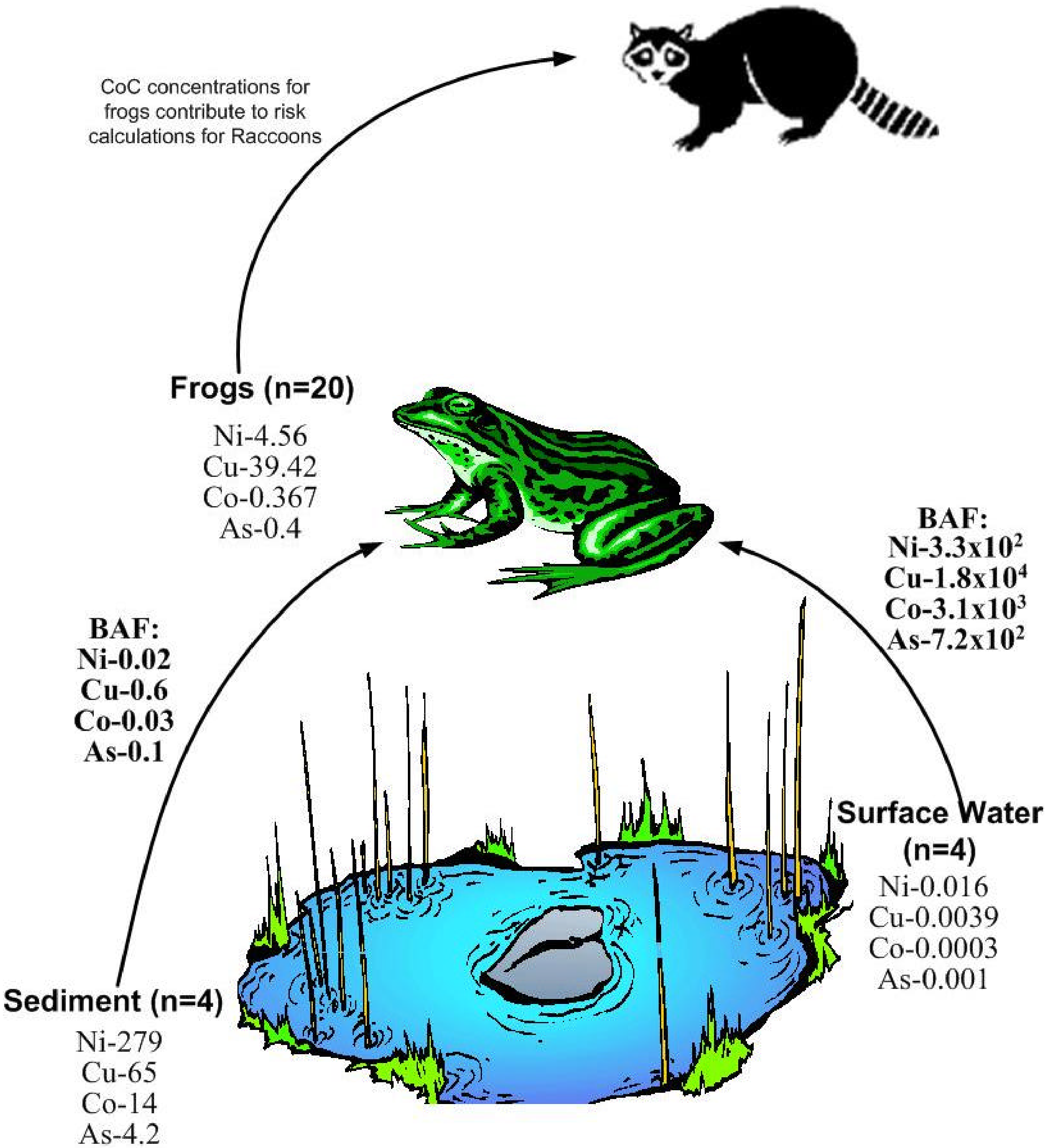
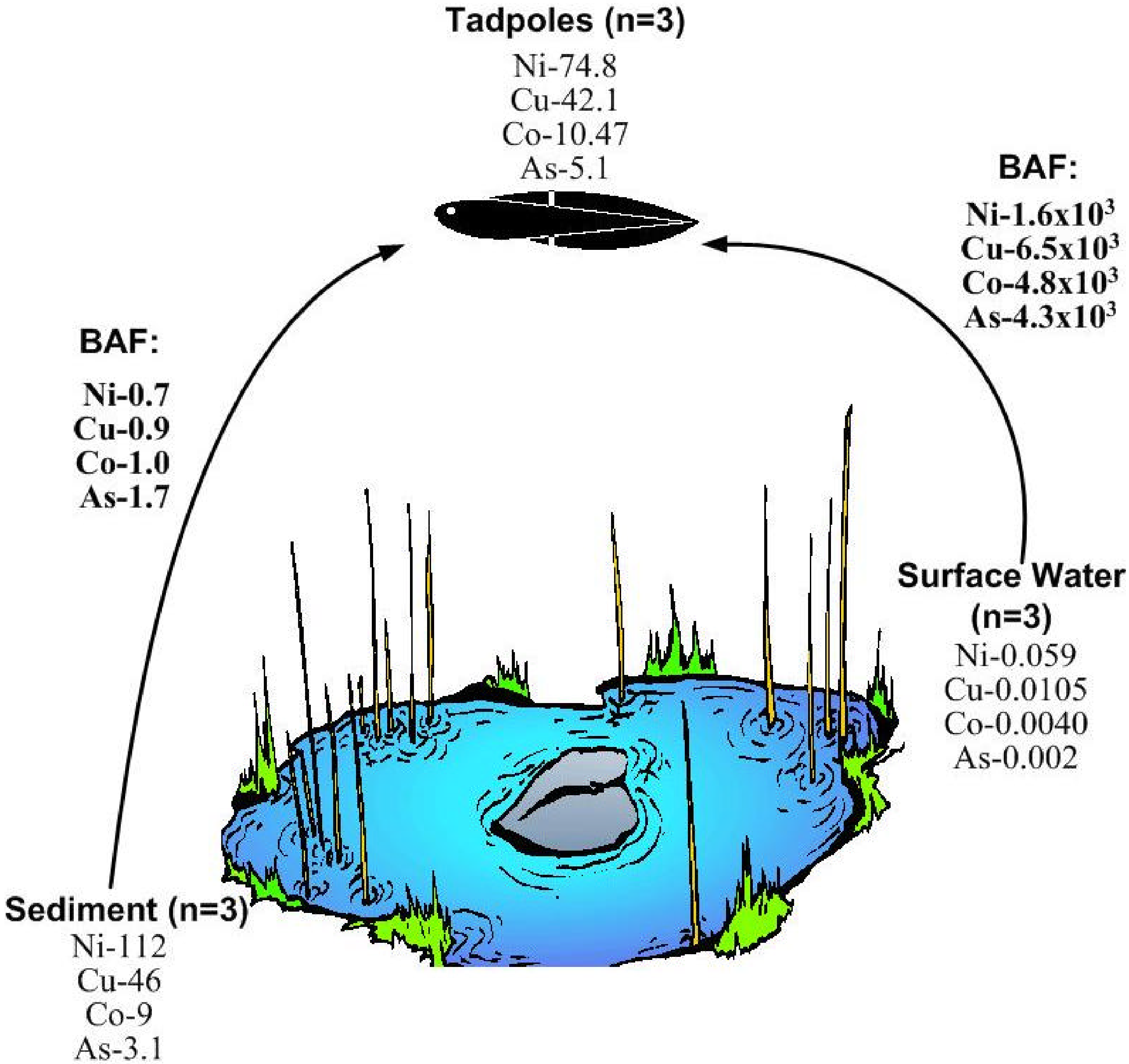


Figure 6-7 Mean Bioaccumulation Factors (BAFs) for Three Ponds, Including Respective Mean CoC Concentrations (mg/kg) for Sediment, Surface Water and Composite Tadpole Samples.



For frogs and tadpoles there are a number of noteworthy results. Apparently large BAFs from water to organism are primarily due to trace quantities of CoCs in water (e.g., 0.0038 mg/kg copper in frog ponds), which are very small compared to total organism concentrations (e.g., 35.45 mg/kg copper in frogs). Further accentuating the difference between the water and total organism concentrations was the presence of sediment and food items in the GI tracts of these animals, particularly tadpoles. The CoC concentrations of these gut contents would not necessarily reflect what CoC concentrations are taken up by the organism, but instead are overestimating the amount of CoCs actually absorbed. Despite this likely exaggeration of uptake, at least with tadpoles, concentrations of CoCs in tadpoles and frogs are reduced compared to those concentrations found in sediment. One exception to this are copper values in frog livers that are higher than sediment and surface water copper values indicating that bioconcentration is occurring in frog livers.

One of the key pathways for metal exposure to animals is the metal uptake by plants from soil in which terrestrial plants grow. Fortunately, metal retention in soils combined with reduced metal uptake and translocation in plants usually creates a "soil-plant barrier" that greatly reduces metals from entering the food chain (Chaney 1980). Figures 6-8 and 6-9 below use site-specific data to illustrate estimated BAFs in a woodlot (Figure 6-8) and a field (Figure 6-9) in the Primary Study Area.

Figure 6-8 shows that CoC concentrations in biotic receptors are much reduced compared with those found in soils, indicating that small amounts of CoCs transfer from soils to higher trophic levels (e.g., arthropods). However, it is important to note that although a significant uptake barrier exists at the soil-plant interface, CoC concentrations in arthropods are generally greater than those found in plants suggesting that accumulation of CoCs is occurring at the plant-arthropod trophic level. Both spiders and insects comprise the arthropod samples that were analyzed to yield the numbers shown in Figure 6-8. Although this sample represents both herbivorous and carnivorous arthropods, it accurately reflects the diet of birds in the woodlot. On average, spiders and insects accounted for approximately equal proportions of biomass of woodlot arthropod samples (Section 6.4.3.5).

Figure 6-9 illustrates mean BAFs between environmental media and receptors within a specific field environment of the Primary Study Area (sample site V-H-5 – Map 1). Site-specific data for soils, goldenrods and voles of this field were used to calculate the BAFs. CoC concentrations in biotic receptors are much reduced when compared with soils, suggesting that small amounts of CoCs are transferred from soils to higher trophic levels, especially at the soil-plant transition. For example, goldenrods growing in field V-H-5 have an estimated 0.3%, or three thousandths, of the nickel found in the field's soil (Figure 6-9). However, if one examines the pathway from goldenrods to voles, it is apparent that CoCs are greater in a voles tissue compared with that of goldenrods suggesting that some accumulation is occurring at this interface, even though an overall significant reduction is occurring at the soil interface.

Figure 6-8 Mean Bioaccumulation Factors (BAFs) in a Woodlot (Maple Sap A) in the Primary Study Area, Including Mean CoC Concentrations (mg/kg) for Soil, Maple Sap, Maple Leaves and a Composite Arthropod Sample (insects and spiders).

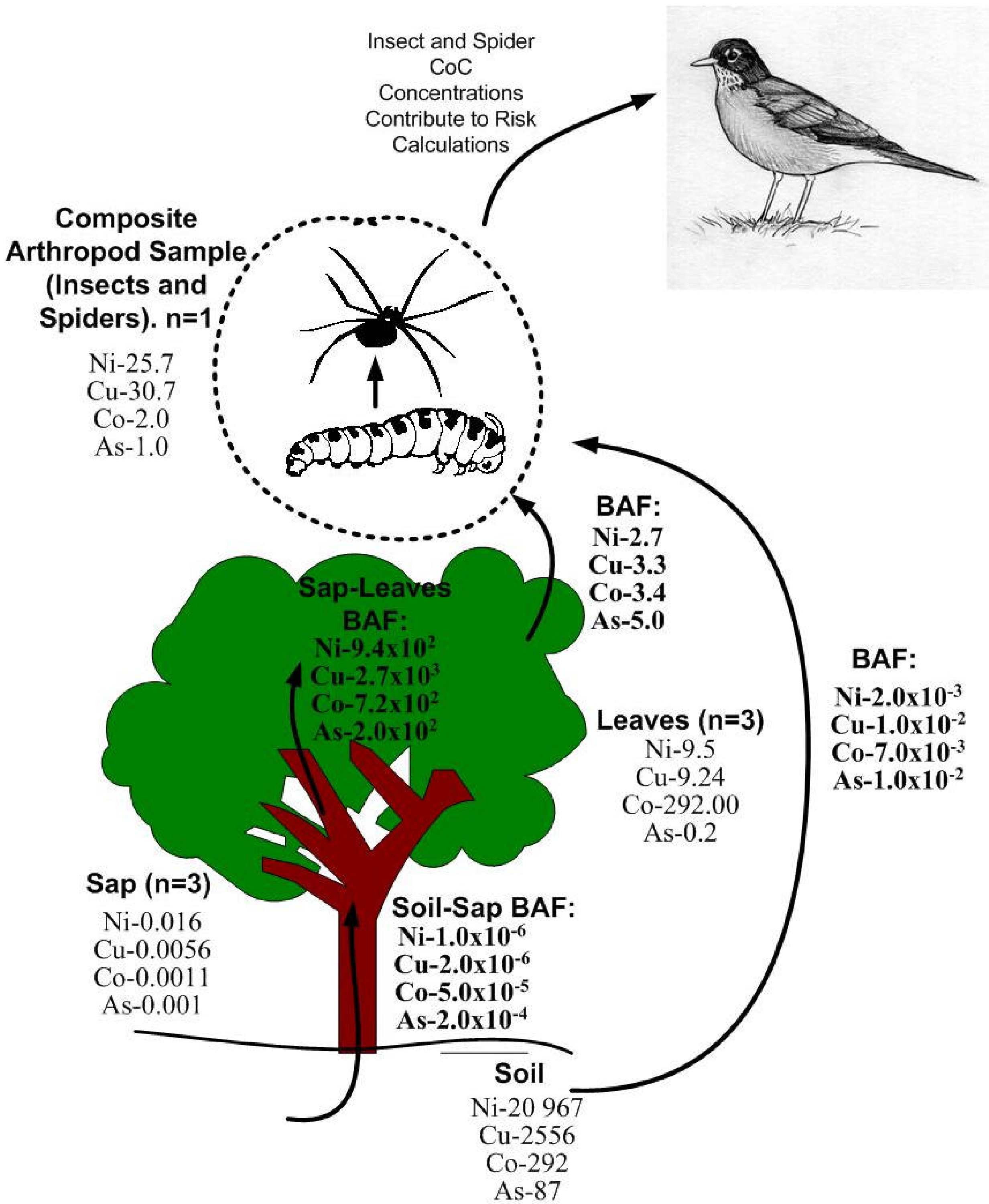


Figure 6-9 Mean Bioaccumulation Factors for a Fallow Field (V-H-5) in the Primary Study Area, Including Mean CoC Concentrations (mg/kg) for Soil, Goldenrods, and Meadow Voles.

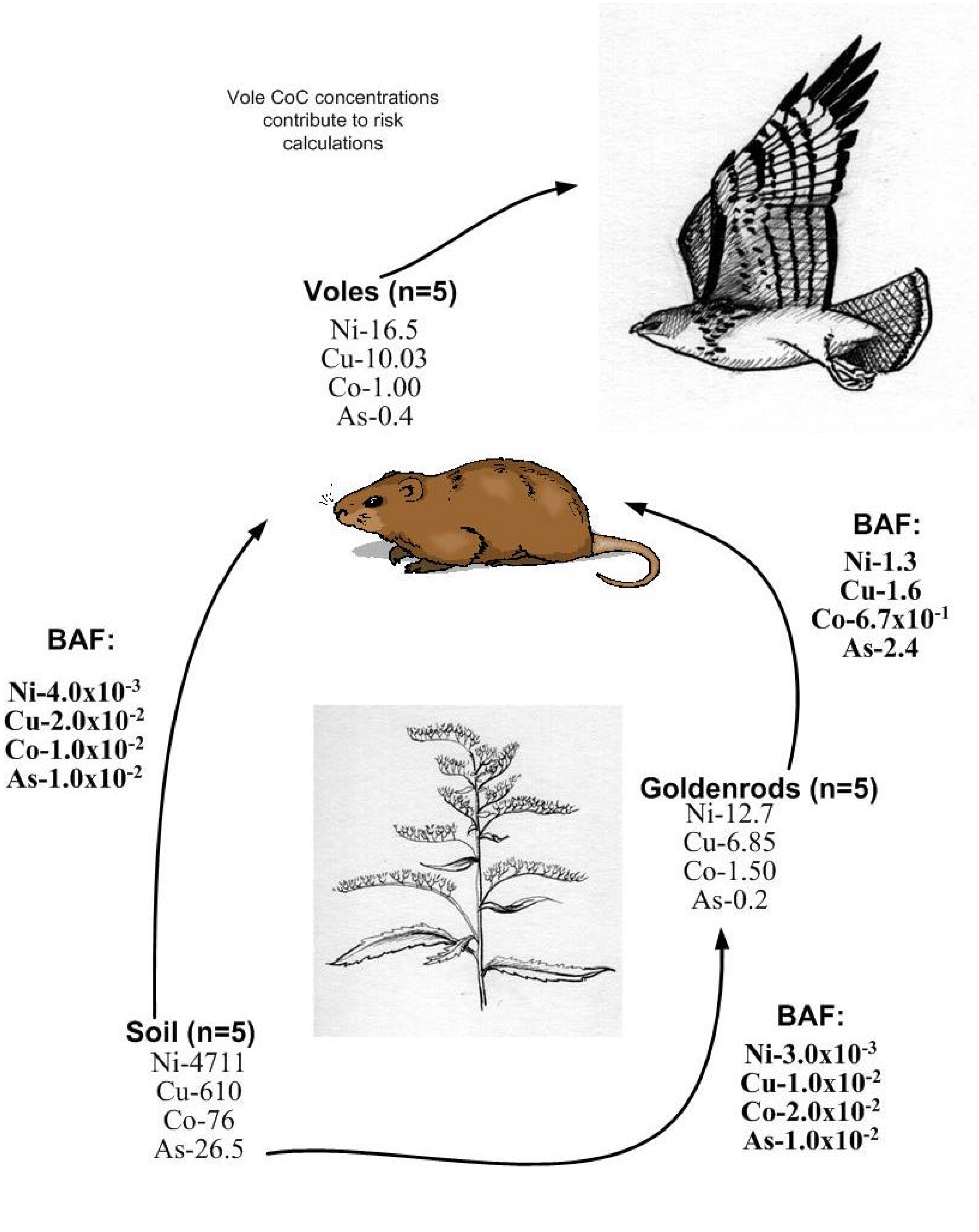


Table 6-1 presents BAFs based on soil and composite earthworm samples (with gut contents purged) collected from four clay fields within the Study Area (PCW-H-4 PCW-H-7, PCW-H-8, PCW-H-10), showing the concentrations of CoCs in the soil and those found in worm tissue. These BAFs indicate that worm tissue concentrations are much lower than the soils in which they live, with ratios ranging from 0.11 for nickel to 0.53 for arsenic and cobalt; no BAF was greater than 1.

Table 6-1 Mean Bioaccumulation Factors (BAFs) for Composite Earthworm Samples from Four Clay Fields of the Study Area.

	Ni	Cu	Co	As
Soil (mg/kg)	859	135	18	4.7
Purged Earthworms (mg/kg)	66.7	28.0	8.3	2.5
BAF	0.11	0.29	0.53	0.53
Notes n=4				

Overall, these comparisons suggest that CoCs are not accumulating to any appreciable degree in plant and animal tissue, with low BAFs between soil and biotic tissue. Additionally, regardless of the BAF, animal and plant tissue concentrations remain relatively low. However, relationships do exist between CoC concentrations found in environmental media (e.g., soil) and those found in animal and plant tissue, as discussed below.

6.4.2 Predictors for Tissue CoCs

The data collected and analyzed to support the ERA was also used to investigate the possibility that the levels of CoCs in soils or other environmental media (e.g., surface water or sediments), soil type (e.g., clay or organic) and/or habitat type (e.g., woodlot or field) could be used as reliable predictors of CoC concentrations in biological tissues of receptors. The analysis focused on the relationship between these predictors and biotic receptors such as amphibians, maple trees, earthworms, arthropods and meadow voles. Exploring the nature of the positive relationships between CoC concentrations in environmental media and those levels of CoCs occurring in biological tissue is a useful exercise. The presence of strong positive predictors can be used confidently in making assumptions regarding the expected level of CoCs in such receptors over a broader area and provide an adequate basis for decision making.

Generalized linear models (*glm*s) are statistical "tools" that are successful at analyzing data such as those supporting this ERA and seek to assess the strength of any relationship between a predictor and the levels of various CoCs in biological tissue. Generalized linear models include aspects of classical linear regression analysis of variables and the analysis of variance around a sample mean. While a significant result from a *glm* analysis does not necessarily indicate that variables are directly or closely related, a significant result does suggest which is the best of all the predictors that accounts for significant influence on the receptor. For example, high nickel concentrations in a receptor's tissue may occur in an area of high nickel concentrations in soil, but if the *glm* result is not statistically significant then there are other factors influencing the nickel concentration in tissue. In such cases, nickel concentrations in soil would not be a reliable or good predictor of nickel concentrations in the tissue of the receptor. The remainder of this section simply summarises the key aspects and results of the *glm* analysis of the data used to support this ERA. More detail on the *glm* analysis and technical detail on the *glm* outputs are provided in Volume III. McCullagh and Neldar (1989) provide a comprehensive treatment of *glm*s, including their development and application.

In the Exposure Assessment, the occurrence of CoCs in biological receptors was measured and BAFs were determined for the transfer of CoCs from environmental media to receptors and between receptors as appropriate. The *glm* analysis explored the relationships between CoCs in predictors and receptors to:

- show the positive relationships between predictors and key biological receptors; and
- identify whether good predictors exist that account for much of the influence on receptors from CoCs.

For example, earthworm tissue copper concentrations were fit against habitat type, soil type and soil copper concentrations. First-order interactions between variables were included in the *glm* analysis and tested for significance to determine if, for example, the relationship shown between copper concentrations in tissue and copper levels in soil was influenced by soil type or habitat type.

Generalized linear models estimate the coefficients for the predictor effects and predictor interactions on the response variable. For each *glm*, the likelihood that each coefficient could be obtained in the absence of a true predictor effect is also provided in the model's output and used to evaluate whether it is likely the predictor effect actually exists, where the estimated $p<0.05$. These values are provided for each *glm*, as are Analysis of Deviance tables showing the contribution of each predictor to the model. Relevant output is provided in Volume III.

Key summary data presented here are meant to clarify for the reader how the environment (predictors) are influencing the concentration of CoCs in the tissues of the receptors.

6.4.2.1 Summary of Predictor Analysis

As described above, analysis was undertaken that examined the relationship of CoC concentrations in soils, water and sediment with measured concentrations of CoCs in various biological tissues from plants and animals sampled from the Study Area. These analyses were used to assess whether concentrations of CoCs in each specific tissue were significantly influenced by soil type and habitat type. Table 6-2 provides a summary of the findings of these analyses, which are discussed in more detail in Volume III.

Table 6-2 Summary of Results from *glm* Analysis of Tissue and Environmental Media CoC Concentrations.

<table>
<tr><th colspan="2" rowspan="2">Biological Tissue</th><th colspan="4">Concentrations of CoCs in Tissue Linked to Soil/Sediment/Water CoC Concentrations</th><th rowspan="2">Soil Type (Clay/Organic) a Predictor</th><th rowspan="2">Habitat Type (Field/woodlot) a Predictor</th></tr>
<tr><th>Ni</th><th>Cu</th><th>Co</th><th>As</th></tr>
<tr><td rowspan="2">Tadpole</td><td>GI Tract</td><td>+ (sediment)</td><td>None</td><td>None</td><td>None</td><td>No</td><td>N/A</td></tr>
<tr><td>Carcass</td><td>None</td><td>+ (sediment)</td><td>None</td><td>None</td><td>No</td><td>N/A</td></tr>
<tr><td rowspan="3">Frog</td><td>GI tract</td><td>+ (water) + (sediment)</td><td>None</td><td>+ (water)</td><td>+ (sediment)</td><td>Yes for Ni</td><td>N/A</td></tr>
<tr><td>Liver</td><td>+ (sediment)</td><td>None</td><td>None</td><td>None</td><td>Yes for Ni</td><td>N/A</td></tr>
<tr><td>Carcass</td><td>+ (sediment)</td><td>+ (water) + (sediment)</td><td>+ (water) + (sediment)</td><td>None</td><td>Yes for Ni, Co, As</td><td>N/A</td></tr>
<tr><td colspan="2">Maple Leaves</td><td>+ (soil)</td><td>None</td><td>+ (soil)</td><td>+ (soil)</td><td>Yes for Ni and Co</td><td>N/A</td></tr>
<tr><td colspan="2">Earthworms (whole)</td><td>+ (soil)</td><td>+ (soil)</td><td>+ (soil)</td><td>+ (soil)</td><td>Yes for Cu and Co</td><td>Potential for As</td></tr>
<tr><td colspan="2">Arthropods</td><td>+ (soil)</td><td>None</td><td>+ (soil)</td><td>None</td><td>Yes for Cu and As</td><td>Yes for Cu and As</td></tr>
<tr><td rowspan="2">Meadow Vole</td><td>Liver</td><td>+ (soil)</td><td>None</td><td>+ (soil)</td><td>None</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Carcass</td><td>+ (soil)</td><td>None</td><td>+ (soil)</td><td>None</td><td>N/A</td><td>N/A</td></tr>
<tr><td colspan="8">+ Concentrations of CoCs in biological tissues show an increase as CoCs concentrations increase in soil, sediment and water.</td></tr>
</table>

This analysis demonstrates that the relationship between the exposure of plants and animals to CoCs in soils, sediment and water, and bioavailability through the food chain shown by tissue CoC concentrations, varies between the four CoCs. Clearly a receptor's exposure to nickel increases as nickel concentrations increase in soil and sediment. This relationship appears to be similar for cobalt, though not as strongly as for nickel. Increasing concentrations of arsenic in soil, sediment and water do not appear to be reliable predictors of increased exposures to biological receptors, with a few exceptions. For copper, increasing concentration in aquatic media (water and sediment) is a good predictor for increased exposure to amphibians. Increasing concentrations of copper in terrestrial soils are not expressed as significantly high concentrations in terrestrial plants and animals, except for earthworms, where copper in gut soil is related to copper levels in the soil.

This analysis also shows that soil type and habitat type are generally poor predictors for determining the relationship between CoC concentrations in soils and a biological receptor's exposure to CoCs. The interrelationships between soil type (clay vs. organic), habitat type (field vs. woodlot) and bioavailability of CoCs through a food chain may be very complex, but a more detailed analysis and interpretation of this complexity is well beyond the scope of this study.

6.4.3 Key Receptor Data Used in the *glm*s

The following sections describe the results of chemical analyses conducted on plant and animal tissues sampled from the Study Area and the Reference Area. The CoC concentrations of certain tissues were subject to statistical analyses, which were performed to assess if relationships exist between these CoC concentrations in tissue and those found in environmental media at each sample site. These analyses also evaluated if soil type and habitat have apparent influences on tissue CoC concentrations. Section 6.4.2 presents a summary of the statistical methods used in the subsequent sections.

6.4.3.1 Amphibian Tissues

Amphibian tissue sampled for this ERA consisted of tadpoles (with separate chemical analyses performed on gastrointestinal tracts and carcass remainder) and adult frogs (with separate chemical analyses performed on livers, gastrointestinal tracts and carcass remainder). Tables 6-3 and 6-4 summarize CoC concentrations in these tissues sampled from the Study Area and Reference Area. Generally, CoC concentrations are higher in tissues of tadpoles and frogs sampled from the Study Area, although mean concentrations of arsenic are roughly equivalent between the Study Area and Reference Area and were not found to be significantly different in frog tissue using a single-factor Analysis of Variance (ANOVA); see Table 6-4. Differences between tissue samples were also noted, with the highest concentrations of nickel, cobalt and arsenic occurring in the GI tracts of both tadpole and adult frogs. This indicates that tadpoles and frogs are ingesting food and other indigestible material (e.g., sediment) but absorbing only a small fraction of these CoCs (<30% based on a comparison of GI tract CoC concentrations to those of the remaining carcass). However, copper was much higher in frog livers than in any other tissue sample, for both the Study Area and Reference Area, which indicates an accumulation of copper in the body. The amount of variability, as judged by the standard deviation (SD), is high within the Study Area and the Reference Area, reflecting the variability in the environment (hence, the utility of analyzing for predictors; Section 6.4.2 and Volume III). Without considering the influence of site-specific CoC concentrations of environmental media and the potential influence of underlying soil type, care must be taken when attempting to draw conclusions from the summary data presented in Tables 6-3 and 6-4.

6.4.3.2 Maple Tissues

Tissue taken from maple trees and analyzed as part of the CBRA included sap, seeds (keys) and leaves. Table 6-5 presents summaries of CoC concentrations found in each of these tissues sampled from the Study Area and Reference Area. Nickel and copper concentrations were generally higher in maple leaves taken from trees in the Study Area compared to those sampled in the Reference Area. However, this did not hold true for cobalt or arsenic, which were actually higher in leaves sampled from the Reference Area. Maple sap had much lower CoC concentrations than those of maple leaves. Variability was relatively high as judged by the standard deviation, and conclusions based on these summary data should be used with caution without acknowledging the influence of environmental factors, such as site-specific soil CoC concentrations (Section 6.4.2, Volume III). Additionally, maple seeds were taken from only three individual trees (three samples from one tree in the Reference Area, three samples from two trees in the Primary Study Area). The limitations of these seed data prevent generalisations from being made, but the data may give a general indication of CoC uptake in maple seeds.

Table 6-3 CoC Concentrations (mg/kg) of Tadpole GI Tracts, Remaining Carcass and Total Body.

Calculation		Primary and Secondary Area				Reference Area			
		Ni	Cu	Co	As	Ni	Cu	Co	As
GI Tracts[1] (mg/kg)	Min	43.7	32.3	6.78	6.6	16.7	22.2	6.18	6.8
	Max	335.0	128.0	36.30	15.1	79.5	102.0	19.70	20.4
	Mean	192.5	84.6	18.09	10.6	48.1	62.1	12.94	13.6
	SD	98.5	33.8	10.78	3.5	44.4	56.4	9.56	9.6
	UCLM	271.3	111.7	26.71	13.4	109.6	140.3	26.19	26.9
	N	6				2			
Remaining Carcass[1] (mg/kg)	Min	2.1	4.1	0.63	1.3	2.6	7.9	1.16	1.4
	Max	104.0	52.8	8.28	6.9	4.4	11.4	1.40	1.9
	Mean	29.6	22.5	3.04	2.5	3.5	9.6	1.28	1.7
	SD	38.3	16.9	2.97	2.2	1.3	2.5	0.17	0.4
	UCLM	60.3	36.0	5.42	4.2	5.3	13.1	1.52	2.1
	N	6				2			
Total Body[2] (mg/kg)	Min	15.6	13.2	2.19	2.2	7.5	12.9	2.91	3.3
	Max	143.5	75.2	18.82	10.3	30.0	42.3	7.64	8.2
	Mean	85.1	44.3	8.56	5.4	18.8	27.6	5.28	5.7
	SD	52.8	23.4	6.32	3.1	15.9	20.8	3.34	3.5
	UCLM	127.3	63.1	13.61	7.9	40.8	56.4	9.91	10.6
	N	6				2			

Calculation		Study Area Ni	Reference Area Ni
Pond Sediment[3] (mg/kg)	Min	60	41
	Max	252	44
	Mean	188	42
Pond Water[4] (mg/L)	Min	0.004	0.001
	Max	0.053	0.004
	Mean	0.027	0.002

1 GI tract and remaining carcass raw data located in Vol. V, tab 45.

2 Derived from tissue CoC concentrations and tissue mass for each composite tadpole sample, then summarised. See Volume III, Tab 8.

3 Pond sediment raw data located in Vol. V, tab 27.

4 Pond Water raw data located in Vol. V, tab 32.

Table 6-4 CoC Concentrations (mg/kg) Found in Frog Tissues.

Calculation		Study Area				Reference Area			
		Ni	Cu	Co	As	Ni	Cu	Co	As
GI Tracts[1] (mg/kg)	Min	0.6	8.5	0.12	0.3	0.3	6.2	0.08	0.2
	Max	108.0	236.0	8.63	4.6	47.8	119.0	17.50	3.8
	Mean	21.0	42.1	1.73	1.0	5.6	30.2	2.30	1.1
	SD	26.7	42.5	2.15	1.2	9.4	24.6	3.55	1.2
	UCLM	28.5	54.0	2.33	1.4	9.3	39.8	3.69	1.6
	n	49				25			
	ANOVA[3]	<0.01	0.37	0.56	0.75	-	-	-	-
Livers[1] (mg/kg)	Min	0.1	0.3	0.05	0.2	0.1	8.7	0.21	0.3
	Max	2.2	734.0	1.79	3.7	1.3	250.0	2.43	2.3
	Mean	0.5	193.4	0.67	0.8	0.3	120.5	0.54	0.7
	SD	0.4	151.8	0.39	0.6	0.3	71.2	0.43	0.5
	UCLM	0.6	235.9	0.77	0.9	0.4	148.4	0.71	0.8
	n	49				25			
	ANOVA[3]	0.07	<0.01	0.39	0.45	-	-	-	-
Remaining Carcass[1] (mg/kg)	Min	0.1	2.8	0.02	0.2	0.1	4.4	0.02	0.3
	Max	6.2	225.0	0.42	1.0	0.6	34.6	0.38	0.4
	Mean	0.8	17.5	0.14	0.3	0.2	10.2	0.07	0.3
	SD	1.0	33.0	0.08	0.1	0.1	6.9	0.07	0.0
	UCLM	1.1	26.8	0.16	0.3	0.3	12.9	0.09	0.3
	n	49				25			
	ANOVA[3]	<0.01	0.01	<0.01	0.57	-	-	-	-
Total Body[2] (mg/kg)	Min	0.13	3.9	0.03	0.2	0.13	6.6	0.03	0.3
	Max	17	220	1.10	1.4	4.4	33.6	1.68	0.8
	Mean	3.0	24.6	0.33	0.4	0.82	16.2	0.34	0.4
	SD	3.6	31.5	0.29	0.2	0.88	6.5	0.36	0.1
	UCLM	4.0	33.4	0.41	0.5	1.2	18.7	0.48	0.5
	n	49				25			
Calculation		**Study Area Ni**				**Reference Area Ni**			
Pond Sediment[4] (mg/kg)	Min	25				21			
	Max	429				44			
	Mean	158				30			
Pond Water[5] (mg/L)	Min	0.003				0.001			
	Max	0.070				0.053			
	Mean	0.025				0.013			

1 GI tract, liver and remaining carcass raw data located in Vol. V, tab 38.

2 Derived from tissue CoC concentrations and tissue mass for each individual frog, then summarised. See Volume III, Tab 8.

3 P-values of a single factor ANOVA comparing the Reference Area with the Study Area

4 Pond sediment raw data located in Vol. V, tab 27.

5 Pond water raw data located in Vol. V, tab 32.

Table 6-5 CoC Concentrations (mg/kg) Found in Maple Tissues (soil nickel values are shown in parenthesis for comparison).

Calculation		Study Area				Reference Area			
		Tissue/Sap Ni (Soil Ni)	**Cu**	**Co**	**As**	**Tissue/Sap Ni (Soil Ni)**	**Cu**	**Co**	**As**
Maple Leaves[1] (mg/kg)	Min	1.0 **(288)** [5]	4.5	0.06	0.2	0.1 **(18)** [5]	3.92	<0.1	0.2
	Max	31.5 **(22 700)** [5]	22.7	1.22	1.1	2.9 **(167)** [5]	15.80	0.2	0.2
	Mean	10.0 **(5 932)**[5]	8.9	0.29	0.3	1.1 **(72)**[5]	8.84	0.1	0.2
	SD	6.8	4.6	0.25	0.2	0.7	3.53	0.1	0.0
	UCLM	12.3	10.5	0.38	0.4	1.5	10.63	0.1	0.2
	n	33				15			
Maple Sap [2] (mg/kg)	Min	0.004 **(126)** [6]	0.0017	0.0004	0.001	0.001 **(39)** [6]	0.0064	0.0003	0.001
	Max	0.335 **(24 500)**[6]	0.0139	0.0053	0.001	0.121 **(171)** [6]	0.0311	0.0036	0.001
	Mean	0.048 **(2 973)**[6]	0.0072	0.0017	0.001	0.051 **(79)**[6]	0.0203	0.0014	0.001
	SD	0.083	0.0043	0.0015	0.000	0.044	0.0092	0.0014	0.000
	UCLM	0.091	0.0094	0.0024	0.001	0.089	0.0283	0.0026	0.001
	n	15				5			
Maple Cotyledons[3, 4] (mg/kg)	Min	9.8 **(1290)** [7]	7.1	0.22	0.1	1.1 **(25)** [7]	10.3	0.07	0.1
	Max	10.5 **(1320)** [7]	7.2	0.23	0.1	1.2 **(25)** [7]	10.6	0.08	0.1
	Mean	10.1 **(1 305)**[7]	7.2	0.23	0.1	1.2 **(25)**[7]	10.4	0.07	0.1
	SD	0.4	0.1	0.01	0.0	0.1	0.2	0.01	0.0
	UCLM	nc	nc	nc	nc	nc	nc	nc	nc
	n	3				3			

[1] Maple leaf raw data located in Vol. V, tab 41.
[2] Maple sap raw data located in Vol. V, tab 42.
[3] Maple cotyledon raw data located in Vol. V. tab 40.
[4] Seeds were sampled from the Primary Study Area and the Reference Area only.
[5] Soil nickel data pertaining to maple leaves located in Vol. V. tab 30.
[6] Soil nickel data pertaining to maple sap located in Vol. V. tab 31.
[7] Soil nickel data pertaining to maple cotyledons located in Vol. V. tab 29.

6.4.3.3 Wild Grape Tissue

Table 6-6 presents mean CoC concentrations present in wild grapes sampled from the edge of woodlots in the Reference and Study Areas. Sampling grapes was not a main objective of the sampling program of this ERA due to their limited distribution. However, grapes were collected when encountered to assess what CoCs were present in grape tissue, for use in assessing the exposure of grape-eating receptors (e.g., American Robin, Raccoon; Section 6.5.4).

Table 6-6 CoC Concentrations (mg/kg) Found in Wild Grape Tissues (soil nickel values are presented in parenthesis for comparison).

Calculation		Study Area				Reference Area			
		Grape Ni (Soil Ni)	Cu	Co	As	Grape Ni (Soil Ni)	Cu	Co	As
Wild Grapes[1] (mg/kg)	Min	0.3 (**288**)[2]	5.15	0.01	0.1	0.1 (**16**)[2]	5.61	0.01	0.1
	Max	1.6 (**22 700**)[2]	12.00	0.03	0.1	0.9 (**431**)[2]	14.20	0.01	0.2
	Mean	0.9 (**7111**)[2]	8.54	0.02	0.1	0.4 (**155**)[2]	9.51	0.01	0.1
	SD	0.4	2.25	0.01	0.0	0.5	4.35	0.00	0.1
	UCLM	1.2	10.21	0.02	0.1	0.9	14.43	0.01	0.2
	n	7				3			

[1] Wild grape raw data located in Vol. V, tab 47.

[2] Soil nickel data pertaining to wild grapes located in Vol. V, tab 28 (grape soil data obtained from leaf litter study).

6.4.3.4 Earthworm Tissue

Tables 6-7 and 6-8 present mean CoC concentrations in whole non-purged worms (soil in gut) sampled in 2001 and 2002, characterized by soil type (clay and organic) and habitat type (woodlot and field). Table 6-9 presents data summaries for the Reference and Study Areas and Table 6-10 displays mean concentrations from the Study Area on clay and organic soils and in woodlot and field habitats.

The data in Table 6-7 indicate that earthworm CoC concentrations are highest in the Study Area. Table 6-8 shows that CoC concentrations are generally higher in earthworms sampled from organic soils, and differences exist between habitats within soil types when one compares mean values. Despite these differences, habitat does not appear to be a significant predictor on tissue CoC concentrations and soil type appears to influence only copper uptake (Section 6.4.2, Volume III). The influence of soil type on tissue CoC concentrations in whole earthworms is difficult to explain, and further investigation with an increase in sample size was deemed appropriate. Earthworms were sampled at 30 additional sites in field habitats across the Primary Study Area, Secondary Study Area and Reference Area during June 2002 (Volume II, Tab 10). On average, 21 earthworms were sampled from each site and submitted to PSC for chemical analyses, accompanied by separate soil samples collected at each sample site. Table 6-9 presents a summary of the earthworm data collected from fields on organic and clay soils.

Table 6-7 CoC Concentrations (mg/kg) Found in Whole (non-purged) Earthworms of the Study Area and the Reference Area Sampled in 2001 and 2002.

Calculation		**Study Area**				**Reference Area**			
		Ni	**Cu**	**Co**	**As**	**Ni**	**Cu**	**Co**	**As**
Whole Earthworms[1] (mg/kg)	Min	39.8	15.0	4.39	1.2	6.6	8.1	1.44	1.1
	Max	1250.0	195.0	38.50	37.8	70.2	22.5	10.30	28.1
	Mean	304.9	60.0	13.37	6.1	16.2	14.0	3.89	4.2
	SD	262.8	43.7	8.95	6.4	15.6	3.5	2.17	6.7
	UCLM	394.5	74.9	16.42	8.3	24.1	15.8	4.99	7.6
	n	33				15			

Calculation		**Study Area Ni**	**Reference Area Ni**
Earthworm Soils[2] (mg/kg)	Min	125	13
	Max	21 100	167
	Mean	2 128	41

1 Whole worm raw data located in Vol. V, tab 37.

2 Soil nickel data pertaining to worm collection located in Vol. V, tab 25, 26, 28.

Table 6-8 CoC Concentrations (mg/kg) Found in Whole (non-purged) Earthworms of the Study Area (2001 and 2002 data).

Calculation		CoCs in Whole non-purged Worms in Clay Soil							
		Woodlot				Fallow Field			
		Ni	Cu	Co	As	Ni	Cu	Co	As
Whole Earthworms[1] (mg/kg)	Min	52.7	27.1	11.80	2.9	39.8	15.0	4.39	1.2
	Max	251.0	47.7	13.50	4.9	782.0	195.0	32.60	37.8
	Mean	151.6	40.5	12.90	3.6	215.1	51.4	12.53	5.6
	SD	99	11.6	0.95	1.2	248.0	56.9	10.20	10.2
	UCLM	nc	nc	nc	nc	355	83.6	18.30	11
	n	3				12			
Earthworm Soils[2] (mg/kg)		Ni				Ni			
	Min	1070				125			
	Max	1505				2460			
	Mean	1288				747			

Calculation		CoCs in Whole non-purged Worms in Organic Soil							
		Woodlot				Fallow Field			
		Ni	Cu	Co	As	Ni	Cu	Co	As
Whole Earthworms[1] (mg/kg)	Min	210.0	43.2	10.60	3.8	67.3	27.7	6.25	3.6
	Max	713.0	105.0	36.30	9.6	1250.0	174.0	38.50	12.1
	Mean	402.7	67.7	16.73	6.3	384.0	69.5	12.65	7.2
	SD	168.2	22.3	9.75	2.5	312.3	42.1	8.8	2.8
	UCLM	NC	NC	NC	NC	560.7	93.3	17.65	8.8
	n	6				12			
Earthworm Soils[2] (mg/kg)		Ni				Ni			
	Min	4745				151			
	Max	18 250				21 100			
	Mean	11 498				3 147			

NC Not calculated, due to small sample size.
1 Whole earthworm raw data located in Vol. V, tab 37.
2 Soil nickel data pertaining to earthworm collection located in Vol. V, tab 25, 26, 28.

Table 6-9 Summary of Earthworm Data Collected in Fields in June 2002[1].

		Study Area		Reference Area	
		Organic	Clay	Organic	Clay
Number of Sample Sites		**9**	**10**	**6**	**5**
Average Number of Worms per Site		26 ± 11	22 ± 13	19 ± 5	15 ± 7
Earthworm CoC	Ni	438 ± 341	193 ± 238	21.3 ± 24.1	11.2 ± 2.0
	Cu	74.3 ± 46.7	46.9 ± 57.8	14.0 ± 2.6	11.8 ± 2.5
	Co	13.0 ± 10.2	11.1 ± 8.7	2.62 ± 1.03	3.43 ± 0.60
	As	7.3 ± 3.2	2.6 ± 1.3	2.5 ± 0.5	2.1 ± 0.7
Soil CoC	Ni	1700 ± 1120	669 ± 837	42 ± 26	19 ± 5
	Cu	291 ± 169	114 ± 130	22 ± 9	13 ± 3
	Co	31 ± 21	16 ± 12	4 ± 1	5 ± 2
	As	20 ± 6	5.3 ± 3.5	3.9 ± 0.8	2.8 ± 0.9

Notes

1 Chemical concentrations are presented in mg/kg and are presented as the mean ± standard deviation.

As seen in the 2001 data for copper, earthworms in clay soils had higher concentrations of copper and cobalt than earthworms sampled from organic soils with the same soil CoC concentrations (Volume III). Although overall higher concentrations of CoCs were found in worms sampled from organic soils, these were collected from sites with markedly higher soil CoC concentrations (Table 6-9).

To assess the bioaccessible fraction of the CoCs to worms, a replicate quadrant was sampled at a subset of sites during the 2002 sampling. These replicate samples were maintained alive until they had evacuated their digestive tracts of contaminated soil, then analyzed for CoC concentrations (see Volume II, Tab 10). Summaries of these paired data (sample non-purged vs. sample purged) are presented in Table 6-10.

As expected, CoC concentrations were generally lower in purged earthworms as opposed to whole earthworms that had not been purged, although this was most notable in the samples collected in the Study Area. Much of the CoCs in the whole earthworms are due to high concentrations in the soil found in the digestive tract of the animal, and are considered to be no more available to earthworm predators than in other ingested soil. Indeed, considering total CoC concentrations of whole earthworms as bioavailable to such animals as American Robins would be over-estimating the concentrations of CoCs actually available to the bird. In response, we extrapolate the ratios presented in Table 6-10 and use these as correction factors to estimate tissue concentrations of earthworms eaten by certain VECs, as explained in Section 6.5.3.

Table 6-10 Summary of purged and non-purged Earthworm Data Collected in June 2002.

		Study Area		Reference Area	
		Organic	Clay	Organic	Clay
Number of Sample Sites		2	4	4	1
Average Number of Worms/sample	Purged	44.0 ± 7.7	23.8 ± 7.3	23.8 ± 7.3	28
	Non-purged	28.5 ± 7.8	18.8 ± 13.4	18.8 ± 7.9	15
Ni	Purged	213 ± 267	66.7 ± 52.3	32.2 ± 34.0	9.07
	Non-purged	303 ± 97	188 ± 173	26.3 ± 29.4	8.73
	Ratio[1]	0.595	0.388	1.48	1.04
Cu	Purged	35.0 ± 24.3	28.0 ± 20.2	14.4 ± 4.1	13.4
	Non-purged	52.0 ± 3.3	43.9 ± 38.2	14.5 ± 3.1	10.8
	Ratio[1]	0.659	0.705	0.995	1.24
Co	Purged	5.37 ± 2.81	8.33 ± 4.29	2.66 ± 1.03	2.68
	Non-purged	8.76 ± 0.91	13.1 ± 10.8	2.68 ± 1.03	2.94
	Ratio[1]	0.599	0.78	1.01	0.912
As	Purged	6.7 ± 4.5	2.5 ± 1.9	2.5 ± 0.6	2.4
	Non-purged	7.1 ± 4.5	2.9 ± 1.5	2.5 ± 0.6	2.5
	Ratio[1]	0.93	0.85	0.99	0.96

Notes

1 Average of ratios (purged: non-purged) calculated for each pair, not mean: mean.

2 Chemical concentrations are presented in mg/kg and are presented as the mean ± standard deviation.

6.4.3.5 Arthropod Tissue

Arthropods (insects and spiders) were sampled from both fields and woodlots in the Primary and Secondary Study Areas and at sites in the Reference Area. Certain groups of arthropods were initially sorted from the samples (spiders from woodlot samples, grasshoppers from field samples) and submitted separately for chemical analyses. The homogenization of grasshopper samples prior to subsampling was problematic. Specifically, the grinding of the grasshopper tissue was incomplete and left parts of the exoskeleton intact or partially intact. Although the digestion process allowed for complete homogenization of each subsample, each subsample was not representative of the whole sample. To address this problem, the entire grasshopper sample for each site was digested and analyzed through multiple subsamples, and the resulting CoC concentrations for each subsample were averaged. Mean biomass for spiders and insects are roughly equal in woodlots of the Study Area and the Reference Area, but insects comprise a much larger proportion of samples from fields (Table 6-11). Summaries of CoC data are presented in Table 6-12.

Table 6-11 Mean Biomass of Spiders and Insects in Composite Arthropod Samples Obtained from Woodlots and Fields of the Study Area and Reference Area.

Arthropod Class		Study Area		
		Primary	Secondary	Reference
Woodlots	Insects (g)	14.73	15.33	10.20
	Spiders (g)	15.36	13.45	14.34
Fields	Insects (g)	9.93	10.07	10.57
	Spiders (g)	0.47	0.27	4.14

Notes Sampling was done in five woodlots and five fields for each study area.
Raw data is located in Volume V.

Nickel and cobalt appeared to be higher in arthropods sampled in the Study Area, but copper was found in higher concentrations in arthropods sampled from the Reference Area (Table 6-12). Arsenic in arthropod tissue showed no real difference between the Study Area and the Reference Area. With respect to differences in concentrations between habitats, field arthropods tended to have slightly higher concentrations of CoCs, particularly copper, but the variability (as judged by standard deviation) was relatively high and no strong conclusions can be made based on these summary data without considering environmental factors (Section 6.4.2, Volume III).

Table 6-12 CoC Concentrations for Composite Field and Woodlot Arthropods (soil nickel values are presented in parenthesis for comparison).

Calculation		Study Area				Reference Area			
		Tissue Ni (Soil Ni)	Cu	Co	As	Tissue Ni (Soil Ni)	Cu	Co	As
Woodlot Arthropods[1] (mg/kg)	Min	4.0 (**126**) [4]	22.0	0.14	0.2	0.6 (**16**) [4]	24.6	0.03	0.2
	Max	20.5 (**24 500**) [4]	72.6	1.03	0.8	2.8 (**171**) [4]	43.6	0.12	0.7
	Mean	8.2 (**4 109**)[4]	35.3	0.30	0.3	1.2 (**75**)[4]	32.5	0.07	0.4
	SD	5.1	16.1	0.27	0.2	0.9	7.6	0.03	0.2
	UCLM	11.3	45.3	0.47	0.5	NC	NC	NC	NC
	n	10				5			
Field Arthropods[2] (mg/kg)	Min	1.0 (**119**) [5]	35.7	0.06	0.1	0.5 (**23**) [5]	47.3	0.05	0.1
	Max	27.1 (**4310**) [5]	57.0	1.21	0.5	2.5 (**34**) [5]	188	0.29	0.9
	Mean	10.5 (**1425**)[5]	44.9	0.35	0.2	0.1 (**28**)[5]	79.7	0.12	0.3
	SD	8.9	6.9	0.37	0.1	0.8	60.7	0.10	0.5
	UCLM	16.0	49.1	0.57	0.3	NC	NC	NC	NC
	n	10				5			
Total[3] (mg/kg)	Min	1.0 (**119**) [6]	22.0	0.06	0.1	0.5 (**16**) [6]	24.6	0.03	0.1
	Max	27.1(**24 500**) [6]	72.6	1.21	0.8	2.8 (**171**) [6]	188	0.29	0.9
	Mean	9.3 (**2 767**) [6]	40.1	0.33	0.3	1.1 (**52**) [6]	56.1	0.09	0.3
	SD	7.2	13.0	0.31	0.2	0.8	47.8	0.07	0.3
	UCLM	12.5	45.8	0.46	0.4	1.6	85.7	0.14	0.5
	n	20				10			

NC Not calculated, due to small sample size
1 Woodlot arthropod raw data located in Vol. V, tab 34.
2 Field Arthropod raw data located in Vol. V, tab 34.
3 Total based on woodlot and field arthropods. Calculations in Vol. III, tab 8.
4 Soil nickel data pertaining to woodlot arthropod collection located in Vol. V, tab 28, 31.
5 Soil nickel data pertaining to field arthropod collection located in Vol. V, tab 26.
6 Soil nickel data is an average of woodlot and field arthropod soils, data located in Vol. V, tab 26, 28, and 31.

6.4.3.6 Meadow Vole Tissue

Meadow Voles were successfully sampled in the Primary Study Area and the Reference Area, and mean CoC concentrations are presented in Table 6-13 for two samples from each vole: liver tissue and the remaining carcass. Although attempts were made to sample voles in the Secondary Study Area, only one vole was captured; CoC concentrations from this vole are incorporated into Table 6-13 for completeness.

Overall, more copper was found in the liver than in the rest of the body combined, although no apparent difference was noted between the Study Area and the Reference Area. Nickel and cobalt were higher in Meadow Voles sampled from the Study Area, and were lower in the liver compared to the rest of the body combined (Table 6-13).

Table 6-13 CoC Concentrations Found in Meadow Vole Tissues.

Calculation		Primary and Secondary Area				Reference Area			
		Ni	Cu	Co	As[3]	Ni	Cu	Co	As[2]
Livers[1] (mg/kg)	Min	0.2	10.6	0.29	0.2	0.1	9.6	0.05	0.1
	Max	1.1	20.9	2.27	0.4	0.6	18.7	0.18	0.4
	Mean	0.4	15.3	1.13	0.2	0.2	14.1	0.11	0.2
	SD	0.3	3.1	0.63	0.1	0.1	2.2	0.03	0.1
	UCLM	0.6	17.1	1.50	0.3	0.3	15.4	0.13	0.2
	N	11				12			
Remaining Carcass[1] (mg/kg)	Min	3.3	8.1	0.22	0.2	0.7	8.0	0.07	0.2
	Max	27.8	13.4	1.90	1.1	2.8	17.9	0.36	0.2
	Mean	14.8	9.9	0.98	0.4	1.5	9.4	0.18	0.2
	SD	7.8	1.6	0.52	0.4	0.6	2.8	0.07	0.0
	UCLM	19.4	10.8	1.28	0.6	1.8	11.0	0.22	0.2
	N	11				12			
Total Body[2] (mg/kg)	Min	3.2	8.4	0.22	0.2	0.7	8.1	0.07	0.1
	Max	26.3	13.3	1.90	1.0	2.6	17.8	0.35	0.2
	Mean	14.2	10.1	0.98	0.4	1.4	9.6	0.18	0.2
	SD	7.4	1.5	0.51	0.4	0.6	2.7	0.07	0.0
	UCLM	18.6	11.0	1.29	0.6	1.7	11.1	0.22	0.2
	N	11				12			
Vole Soils[4] (mg/kg)		Ni				Ni			
	Min	421				17			
	Max	4 310				25			
	Mean	2 840				21			

Notes

1 Raw data located in Vol. V, tab 46.

2 Derived from tissue CoC concentrations and tissue mass for each individual vole, then summarised. Calculations in Vol. III, tab 8.

3 Indicates a mean that has one or more instances where half an EQL value was used in place of a "nd" (see Glossary)

4 Soil nickel data pertaining to vole field habitat located in Vol. V, tab 26 and 33.

6.4.4 Summary

The collection of site-specific data has been invaluable for reducing uncertainty associated with determining exposure of biological receptors to CoCs in the local natural environment. Key findings of the assessment of the bioavailability of the CoCs in the Port Colborne environment include:

- A soil-plant barrier greatly reduces a receptors exposure to CoCs through the food chain;
- Tissue analysis indicates that CoCs in soils and water are not biomagnified by plants, invertebrates or vertebrates that occur in the Study Area;
- Increases in soil and sediment nickel values are reflected in increases in tissue nickel concentrations of receptors;
- For bird and mammal receptors, the primary source exposure to CoCs in the environment is through soil ingestion, and ingestion of prey that have soil/sediment in their gut (i.e. worms/tadpoles/frogs); and,
- Soil type (clay-organic) and habitat type (woodlot-field) do not have a strong predictive relationship with respect to CoC tissue concentrations.

When conducting risk assessment without the use of site-specific data, determining dose exposures to receptors is based on models of contaminant uptake by plant and animals. These models rely heavily on uptake factors obtained through results under laboratory conditions and are often adapted from human exposure models (CCME 1997). Clearly the complexity of CoC exposure pathways through the natural environment in the Port Colborne area as identified by this study would be difficult, if not impossible, to capture through the use of such contaminant uptake models that rely heavily on numerous assumptions. The approach taken for this ERA stands out as being much more comprehensive and informative through the collection of extensive suites of site-specific data. These data include the CoC concentrations of plant and animal tissue from a variety of species, which:

- allow more accurate estimation of BAFs relevant to the Port Colborne area, and
- provide actual CoC concentrations (not assumed or estimated from the literature) of diet items necessary for calculating average daily doses of selected VECs (Section 6.5).

The collection of biotic and abiotic data on CoC concentrations provide valuable insight into the actual distribution of CoCs in the Port Colborne natural environment. As presented above, CoCs are generally higher in the Study Area than at reference sites, both in the physical environment and in the biological environment. Receptors collected as part of this field program show a general elevation of tissue CoC concentrations within the Study Area compared to the Reference Area, although the magnitude of that difference is generally small and varies across tissues and individual CoCs. The use of real data, as opposed to projections or estimates, in the calculation of CoC exposure allows for a more realistic assessment of the risk posed by CoCs on the natural environment.

6.5 Exposure Magnitude, Frequency and Duration

In this section, the direct exposure of VECs to CoCs is quantified. Detailed calculations are presented that quantify the average daily dose received by VECs for each exposure pathway. For determining the magnitude of exposure to CoCs, three primary exposure pathways were assessed, ingestion of food, soil and water to determine an average daily dose. Parameters required for these calculations that modify a VEC's exposure are detailed below, and our computation of CoC values used for these calculations are described. For each VEC, the average daily doses of each CoC are used to estimate the potential risk incurred by the VEC through its exposure, presented in Section 8.

Two potential exposure pathways for CoCs where not included in the exposure assessment; dermal exposure (CoCs on the skin of animals) and exposure through the inhalation of air. For dermal exposure, assessment of dose was not undertaken due to the lack of accepted models available for determining dermal uptake in wildlife. Further, the fur on mammals, or feather on birds, precludes significant direct contact of soil to skin. For soils on fur and feathers, the major exposure pathway is through ingestion of soils during grooming and this potential exposure was taken into account in the determination of the soil ingestion in the daily diet (ADD_{soil} in equation 6-1 below).

For Exposure to CoC through the inhalation air, though a potential exposure pathway for many of the VECs, this exposure pathway was also not assessed. For the calculation of an average daily dose for a VEC, it is not appropriate to sum inhalation exposure with exposure of ingested soil, water and food. Though the units of CoC exposure may be comparable (i.e. mg/kg/day) the mechanisms of gastric absorption differ dramatically from pulmonary absorption. In addition, toxicity values also differ for inhalation and dietary exposure. Therefore, inhalation exposure and risk associated with CoCs in the air can only be evaluated independently. However, conducting separate risk assessments for inhalation of CoCs for the selected VECs is not possible as there is little to no toxicity data, or literature benchmarks, with respect to quantitative assessments for potential risk.

Data collected for ambient air for the HHRA (see Table 2-11), found that though concentrations of the CoCs are elevated in the Study Area, when compared to reference areas, the values in the Study Area are nevertheless very low and below current MOE guidelines. Therefore, for the ERA, the potential risk to VECs as a result of the inhalation of CoCs will be considered to be negligible when compared to the exposure and risk associated with the ingestion of CoCs.

6.5.1 General Calculations

Other than tadpoles and earthworms, exposure to CoCs was calculated following CCME (1997). The potential average daily dose (ADD_{pot}) is generally considered equivalent to the combined doses from consumption of water, soil and through diet, so that:

$$ADD_{pot} = ADD_{water} + ADD_{diet} + ADD_{soil} \qquad [6\text{-}1]$$

The average daily dose from consuming water was calculated using the following:

$$ADD_{water} = (C_w \bullet FR) \bullet NIR_w \qquad [6\text{-}2]$$

where, ADD_{water} = Potential average daily dose from water (mg/kg d);

C_w = CoC concentration in the water source (mg/L);

FR = Fraction of total water ingested from the contaminated water source (unitless); and

NIR_w = Normalised water ingestion rate (fraction of body weight consumed as water per unit time, L/kg/d).

The average daily dose from the diet was calculated using the following:

$$ADD_{diet} = \sum (C_k \bullet FR \bullet DF_k \bullet NIR_f) \qquad [6\text{-}3]$$

where, ADD_{diet} = Potential average daily dose (mg/kg d);

C_k = Average CoC concentration in the k^{th} type of food (mg/kg dw);

FR = Fraction of total diet ingested from the contaminated food source (unitless);

DF_k = Fraction of total diet accounted for by the k^{th} food group (unitless); and

NIR_f = Normalised ingestion rate of food on a weight-to-weight basis (dry weight) (kg/kg d).

The average daily dose from consumption of soil was calculated using the following:

$$ADD_{soil} = (C_s \bullet FS \bullet NIR_s \bullet FR) \bullet BF \qquad [6\text{-}4]$$

where, ADD_{soil} = Potential average daily dose (mg/kg d);

C_s = CoC concentration in soil in the contaminated foraging area (mg/kg dw);

FS = Fraction of soil in diet (kg/kg dw);

NIR_s = Food ingestion rate on a dry weight basis (kg/day);

FR = Fraction of total soil intake from the contaminated foraging area (unitless);

BW = Average body weight (kg) of an adult of the species; and

BF = Bioaccessible fraction (unitless; see Section 6.5.4).

For the most part, there are site-specific field data on concentrations of CoCs in diet items (Section 6.5) of all receptors in the food chain models except the Red-tailed Hawk and Red Fox. As part of their diets, hawks and foxes are expected to consume primarily Meadow Voles, as well as other small mammals and birds. For the exposure assessment, field data for CoCs in voles were used to represent small mammals. No field data were collected for American Robins, American Woodcock and Red-Eyed Vireo. Therefore, it was necessary to estimate tissue concentrations for these three bird species. The concentration of CoCs in birds can be estimated by multiplying the ADDs for water, diet and soil by appropriate uptake factors:

$$C_{bird} = \begin{bmatrix} (ADD_{water} \bullet UF_{water-bird}) + (ADD_{soil} \bullet UF_{soil-bird}) + (ADD_{prey} \bullet UF_{prey-bird}) + \\ (ADD_{veg} \bullet UF_{veg}) \end{bmatrix} \bullet BW_{bird} \qquad [6\text{-}5]$$

where, C_{bird} = CoC concentration in the bird's tissue;

UF = Uptake factor (see below);

BW_{bird} = Body weight of the bird (kg);

ADD_{water} = Average daily dose to the bird accounted for by water consumption;

ADD_{soil} = Average daily dose to the bird accounted for by soil ingestion;

ADD_{prey} = Average daily dose to the bird accounted for by animal prey items;

ADD_{veg} = Average daily dose to the bird accounted for by terrestrial vegetation; and

For fowl in particular, air-to-flesh transfer factors are not readily available for the majority of inorganic chemicals. In the absence of suitable air-to-flesh transfer factors for bird or mammal species, ingestion transfer factors were used as an approximation. This assumes that all of the CoCs in all air inhaled eventually enter the digestive tract and are available for absorption there as part of the whole body dose. The UFs used in these calculations are presented in Table 6-14.

Table 6-14 Uptake Factors (UFs) used to Estimate Body CoC Concentrations in American Woodcock, American Robin and Red-eyed Vireo for the four CoCs.

CoC	UF (d/kg)	Source
Nickel	0.001	For poultry; Napier 1988
Copper	0.5	For poultry; IAEA 1994
Cobalt	2	For poultry; IAEA 1994
Arsenic	0.83	For poultry; Napier 1988

6.5.2 Parameter Estimates

Necessary for the dose equations presented in Section 6.5.1 are specific parameter values, which include such factors as exposure duration and ingestion rate. We present the species specific parameter values in Volume III (Tab 5). Discussion of the parameter estimates used for this study is detailed below.

For most VECs (seven out of ten) for which risk was calculated using the Quotient Method, exposure to the affected area was assumed to be 100%, due to published home range size and residency. The other three species are migratory birds and their exposure to the Study Area was assumed to be less than 100%. Although their breeding territories are much smaller than the size of the affected area, they do not occupy their breeding ranges for a full twelve months of the year, instead spending several months during the winter in areas south of Ontario. Their exposure was adjusted according to the proportion of the year they are assumed to occupy their breeding ranges in southern Ontario.

Home range sizes were taken from US EPA (1993) or other applicable sources for Canadian (particularly southern Ontario) populations (e.g., Environment Canada 1989a,b, Environment Canada 1993) and compared with the size of the affected area. Movement behaviour and residency was based on published accounts relevant to southern Ontario populations (e.g., Banfield 1977, Preston and Beane 1993, Keppie and Whiting 1994, Kroodsma and Verner 1997, Sallabanks and James 1999).

Other parameters include body weight, ingestion rates of air, water and food, and diet composition. Where possible, empirical values were used for the individual species, following US EPA (1993) and studies cited therein. In the absence of empirical values, estimates were calculated using equations presented by US EPA (1993), Sample *et al.* (1996) and Sample *et al.* (1997). To estimate diet composition, relevant available literature was used as guidance. In certain cases where CoC concentrations of food items were unknown and could not be estimated (such as crayfish as part of a Raccoon's diet), then either a suitable food item where the CoC concentration was known was used as a surrogate (e.g., goldenrods for field plants), or the food item was excluded and the percent composition was recalculated. For specific references and explanations of parameter values derivation, see Volume III (Tab 5).

6.5.3 Employed CoC Concentrations

Site-specific CoC concentrations were used to estimate the exposure a VEC receives from food items and surrounding media when occupying the affected area. Exposure was assessed for different scenarios to help determine risks associated with different soil types or habitats. The exposure scenarios are as follows: overall Study Area (pooling all data from woodlots and fields, organic and clay), fields on clay soils, fields on organic soils, woodlots on clay soils, and woodlots on organic soils. Not all scenarios were calculated for each VEC; see Table 6-15 for information on the scenarios calculated for each VEC. Where possible, ADD was derived for each of the scenarios using scenario-specific data sets; these scenario-specific data sets were possible for soils, arthropods and earthworms. For other data sets, only an overall number was derived for each set.

Table 6-15 Exposure Scenarios Calculated for each VEC.

Receptor	Overall Study Area	Field		Woodlot	
		Clay	Organic	Clay	Organic
Tadpoles	X[1]				
Earthworms		X	X	X	X
Meadow Vole		X	X		
White-tailed Deer	X				
American Woodcock		X	X	X	X
American Robin		X	X	X	X
Red-eyed Vireo		X	X	X	X
Raccoon		X	X	X	X
Red-tailed Hawk		X	X	X	X
Red Fox		X	X	X	X

Notes

1 Surface water samples from the Study Area.

To determine what CoC concentrations should be employed, two approaches were followed where appropriate. Where sets of data were numerous, an Upper Confidence Limit for the Mean (UCLM), which is the confidence limit above the mean set with an $\alpha = 0.05$ for this study, was calculated. For each set of data, the UCLM was calculated using raw data, without transformation, since this gave a more conservative value than UCLMs calculated on log-transformed data when the latter was appropriate. Only data from sample sites within the Study Area, and sites within ~2 km to the east of the Study Area, were used to calculate the UCLM for each data set. The rationale for including sample sites just outside of the Study Area was the need to capture areas with elevated soil CoC concentrations noted by Jacques Whitford (*Potential CoC Identification using Soil Chemical Concentration Data in Exceedance of MOE Generic Guidelines*), but not previously captured by MOE (2000a,b).

For several data sets, observations were too few ($n < 10$) to derive UCLMs. Instead, actual values from the data were chosen to represent a conservative (over-) estimate of the CoC concentrations available to the VECs from that source. Tissues for which we chose values other than UCLMs were wild grapes, arthropods and earthworms. For wild grapes, the highest CoC concentrations seen in the data were noted and used for input into the relevant dose equations. For earthworms and arthropods, two methods were followed. Based on the statistical analysis presented in Section 6.4, neither soil type nor habitat significantly influenced the uptake of nickel and copper in earthworms or nickel and cobalt in arthropods. For these values, data were pooled and UCLMs were calculated from the pooled data (Table 6-16). For the other CoCs (cobalt and arsenic in earthworms and copper and arsenic in arthropods), separate values were derived for each of the four scenarios (Table 6-16). Where data were numerous (i.e., field data for earthworms), UCLMs were derived, otherwise maximum values were used to calculate dose due to diet. Table 6-16 presents information on sample size and what summary statistics were used for each tissue and medium for the calculation of VEC ADD.

Table 6-16 Sample Size and Summary Statistics used to Calculate Average Daily Dose of VECs (overall scenario).

	Scenario	N	Nickel	Copper	Cobalt	Arsenic
Soil	Overall	203	UCLM	UCLM	UCLM	UCLM
	Field/organic	21	UCLM	UCLM	UCLM	UCLM
	Field/clay	121	UCLM	UCLM	UCLM	UCLM
	Woodlot/organic	20	UCLM	UCLM	UCLM	UCLM
	Woodlot/clay	41	UCLM	UCLM	UCLM	UCLM
Surface Water	-	24	UCLM	UCLM	UCLM	UCLM
Air	-	21	UCLM	UCLM	UCLM	UCLM
Maple Leaf Tissue	-	33	UCLM	UCLM	UCLM	UCLM
Goldenrod Tissue	-	20	UCLM	UCLM	UCLM	UCLM
Corn Tissue – seeds	-	31	UCLM	UCLM	UCLM	Maximum[1]
Oat Tissue – leaves	-	16	UCLM	UCLM	UCLM	UCLM
Oat Tissue – seeds	-	24	UCLM	UCLM	UCLM	Maximum[1]
Wild Grape Tissue	-	7	Maximum	Maximum	Maximum	Maximum
Arthropod Tissue	Overall	20	UCLM	*	UCLM	*
	Field/organic	4	*	Maximum	*	Maximum
	Field/clay	6	*	Maximum	*	Maximum
	Woodlot/organic	2	*	Maximum	*	Maximum
	Woodlot/clay	8	*	Maximum	*	Maximum
Earthworm Tissue	Overall	33	UCLM	UCLM	*	*
	Field/organic	12	*	*	Maximum	Maximum
	Field/clay	12	*	*	Maximum	Maximum
	Woodlot/organic	7	*	*	Maximum	Maximum
	Woodlot/clay	2	*	*	Maximum	Maximum
Frog Tissue	-	49	UCLM	UCLM	UCLM	UCLM
Meadow Vole Tissue	-	11	UCLM	UCLM	UCLM	UCLM

Notes

* Not calculated

1 Due to non-detectable levels, half the maximum EQL was used

Overall concentrations of CoCs in relevant media are presented in Table 6-17. Scenario-specific values for soils, arthropods and earthworms are presented in Table 6-18. These values were used to calculate the ADD of the receptors, as presented in Section 6.5.4.

For earthworm predators, a correction was made to whole earthworm CoC concentrations, to eliminate those concentrations due to soil associated with each worm (which is accounted for in the ADD_{soil}). Comparing the mean CoC concentrations from the purged earthworms sampled from the Primary Study Area with the mean CoC concentrations from the unpurged earthworms from the same sample stations, a ratio was derived for each CoC (Table 6-10). These ratios were multiplied by the whole earthworm concentrations discussed in the previous paragraph to derive CoC concentrations used in the exposure calculations of ADD_{diet} for earthworm predators (i.e., American Woodcock, American Robin and Raccoon). These corrected values are presented in Table 6-18.

The assumption that 100% of the CoCs found in the air, water, soil and diet items are bioavailable (i.e., can be absorbed into the circulatory system) is very conservative and is almost certainly overestimating what is truly available for uptake (see Section 7). As part of the HHRA, experiments were done assessing the bioavailability of nickel to rats (Midwest Research Institute 2002; Jacques Whitford 2003b). Male rats were fed (dosed) clay and organic soils from the Port Colborne Study Area with known CoC concentrations. Following dose exposure, blood samples were collected four times and analyses were undertaken to determine nickel concentrations in blood, urine and tissue. By comparing soil nickel concentrations of the dose to those of blood following the animal's exposure, the percent of soil nickel that is bioavailable to the rats could be determined. Results from this experiment are applicable to many of the receptors assessed in the ERA – Natural Environment and we present nickel ADD reflecting actual bioavailability in line with these results (Jacques Whitford 2003b). For mammals, we used the percentage bioavailability as follows: 3.2% for organic soils, 3.9% for clay soils.

Table 6-17 CoC Concentrations in Exposure Media within the Primary and Secondary Study Areas and Local Environs used to Calculate CoC Doses.

	Nickel[8]	Copper[8]	Cobalt[8]	Arsenic[8]
Soil (mg/kg)[1]	2650	350	47	18
Surface Water (mg/l)[7]	0.178	0.018	0.006	0.005
Air ($\mu g/m^3$)[2]	0.104	0.150	0.005	0.004
Maple Tissue – leaves (mg/kg)	12.3	10.5	0.4	0.4
Goldenrod Tissue (mg/kg)[4]	29.6	12.4	1.4	0.3
Corn Tissue – seeds (mg/kg) [3,4]	2.7	3.2	0.3	0.2
Oat Tissue – seeds (mg/kg) [3,4]	62.3	6.8	0.2	0.1
Oat Tissue – leaves (mg/kg) [3,4]	23.6	9.9	0.4	1.9
Wild Grape Tissue (mg/kg)	1.6	12.0	0.03	0.1
Frog Tissue (mg/kg)[5]	3.9	36.0	0.4	0.5
Meadow Vole Tissue (mg/kg)[6]	18.6	11.0	1.3	0.6

Notes

1 Based on all data (clay and organic, field and woodlot combined) sampled by MOE and Jacques Whitford in the Study Area and within 2km of the eastern boundary. Only data from the 0-5cm depth were used.
2 Calculated based on sampling of Total Suspended Particulate at sampling sites identified as "Stormwater" and "Soccer Club" by Jacques Whitford (2002b).
3 Calculated from analytical results of crops growing on unamended clay soils and, for corn, supplementary 2002 sampling.
4 Data on which these calculations are based are available in Jacques Whitford (2003a).
5 Based on total frog (weighted average of tissue concentrations, using mass)
6 Based on total vole (weighted average of tissue concentrations, using mass)
7 Total CoC concentration.
8 Identification of values as either UCLMs or maximums is presented in Table 6-16.

Table 6-18 CoC C in Soils, Arthropods and Earthworms within the Study Area used to Calculate CoC Doses for the Four Habitat/Soil Type Scenarios.

		Clay		Organic	
		Woodlot	**Field**	**Woodlot**	**Field**
Soil	**Ni**	1630	1090	15,200	2020
	Cu	180	140	2020	308
	Co	33	27	219	37
	As	12	8	83	20
Worms[1]	**Ni**[2]	180	180	180	180
	Cu[2]	52	52	52	52
	Co	10.1	13.7	21.9	10.6
	As	4.2	9.6	8.9	8.2
Arthropods	**Ni**[2]	12.5	12.5	12.5	12.5
	Cu	29.6	57.0	72.6	44.6
	Co[2]	0.46	0.46	0.46	0.46
	As	0.3	0.3	0.8	0.5

Notes

1 Corrected using ratios in Table 6-10.

2 UCLM of all (scenarios.combined)

For copper, cobalt and arsenic, the bioaccessibility of these CoCs in Port Colborne clay and organic soils was assessed (Environmental Sciences Group 2002). A Two-Stage extraction method was used to mimic the stomach digestion and intestinal digestion conditions in humans. In Stage 1, which mimics gastric conditions, soils were extracted using HCl (pH 1.5) with and without the use of glycine following 1 hour; the liquid phase was then sampled for dissolved CoC. For Stage 2, which mimics intestinal conditions, the solutions were adjusted to pH 7 (NaOH solution), shaken with bile extract and pancreatin for another 4 hours, then analyzed for dissolved CoCs.

The application of a single stage (*i.e.* stomach) extraction using glycine has previously been validated for arsenic, and was considered appropriate for application as both pH and glycine were previously found not to change the bioaccessibility of arsenic from soils (Ruby et al., 1996; Ollson, 2003). However, no such validation has been made for nickel, copper and cobalt, therefore selection of the methodology adopted must be made based upon an understanding of the physiological conditions in mammals. Gastrointestinal absorption is known to occur primarily in the intestinal phase (NRC, 2003) and is absorbed by passive paracellular transport, by passive, transcellular diffusion or by active, transcellular transport fitting into a transport system already present (Danish EPA 2003). This suggests that the application of an intestinal equivalent bioavailability (*i.e.* Stage 2) would best mimic the physiological conditions of metal absorption in mammals. With respect to glycine, results of the *in vitro* study suggest that the addition of glycine significantly increases the bioaccessibility of nickel, copper and cobalt in the stage 2 extraction. The degree of increase ranges from a factor of 2 to 20 depending on the CoC and the soil type. The increase suggests that in the neutralized solution, glycine is bonding with the nickel, copper and cobalt in the soil to increase the bioaccessible fraction. This is consistent with previous literature findings at which a measurable interaction between divalent cations and polysaccharides compounds were observed (Debon and Tester, 2001). A comparison of the *in vitro* and *in vivo* results for nickel indicate that the bioavailability is similar to the Stage 2, without glycine, bioaccessibility. Given copper, and cobalt behaves similar to nickel in the presence of glycine, Stage 2 without glycine bioaccessibility were adopted. The bioaccessibility values adopted are presented in Table 6-19.

Table 6-19 Mean Percent Bioaccessibility of Copper, Cobalt and Arsenic in Organic and Clay Soils using Mammalian Intestinal Phase Extraction.

Soil Type	Stage 2 Mean Percent Bioaccessible (n=2)		
	Cu	Co	As
Organic	5.3	4.2	37.0
Welland Clay	2.9	2.2	13.5

For mammals, we used the percentage bioaccessibility as presented in Table 6-19 to estimate how much copper, cobalt and arsenic is bioavailable to mammals in the Port Colborne area. Although these results are most directly applicable to mammals, we believe they also have applicability to birds. A recent study (Levengood and Skowron 2001) notes that Mallards (*Anas platyrhynchos*) were exposed to only a small percentage of what was thought to be available to them in the environment. Extraction methods, using a simulated gizzard environment, were similar to those used in the study to yield values in Table 6-19. In particular, it was determined that Mallards were exposed to values of copper in the same order of magnitude as values presented in Table 6-19, providing a measure of consistency between both studies. It is likely that the relative bioavailability of the CoCs for mammals and birds are alike, but given some uncertainty in differences in digestion physiology between birds and mammals, we have chosen to use double the percentage of the bioavailability test as a conservative estimate. This was done for all four CoCs, using double the nickel percentage of the *in vivo* bioavailability test and double the percentage *in vitro* bioaccessibility tests for copper, cobalt and arsenic. These corrections were performed for soil only; for the purpose of this study, we assumed doses from water and diet are 100% bioavailable.

6.5.4 Calculated Receptor Exposure

For each receptor, appropriate exposure scenarios are presented, with the calculated ADD (or exposure concentrations for earthworms and tadpoles) presented in associated tables. Parameter values and CoC concentrations in relevant media are presented in Volume III (Tab 5) and Tables 6-17 and 6-18, respectively.

6.5.4.1 Frog and American Toad Tadpoles

For tadpoles of frogs and American Toads, estimated exposure is based entirely on contact with surface water. It is not expected that the exposure of tadpoles to CoCs would be through surface water only, but restrictions are imposed on this assessment due to the paucity of available literature detailing the toxicological effects of CoCs through pathways other than water ingestion and contact. The Toxicity Reference Values selected for tadpoles (Section 7) are based on the results of studies where tadpoles were exposed to contaminated water, and do not consider other pathways, such as ingestion of sediment or food items. To enable a direct comparison, exposure to tadpoles in this assessment was restricted to CoC concentrations in surface water.

The UCLM used to calculate potential exposure for tadpoles was derived from surface water data collected throughout the Study Area. Only one exposure scenario was calculated, using a UCLM based on data from all surface water samples taken within the Study Area, to assess the population throughout the Study Area rather than components of it. The potential exposure of tadpoles in the Port Colborne area is presented in Table 6-20.

Table 6-20 Potential Exposure of Tadpoles to CoCs in the Port Colborne Area.

CoC	Exposure Concentration (mg/kg)
Nickel	0.178
Copper	0.018
Cobalt	0.006
Arsenic	0.005
Note: Exposure calculations presented in Vol. III.	

6.5.4.2 Fowler's Toad

The Fowler's Toad is designated as 'Threatened' by the Committee on the Status of Endangered Wildlife in Canada, and the Committee on the Status of Species at Risk in Ontario. As noted in Section 3, spring breeding frog surveys identified an apparently healthy breeding population of Fowler's Toads along the shore of Lake Erie within the Study Area. Due to the rarity of the species in Canada and Ontario, special field monitoring and data collection was undertaken so that the risk of CoC exposure to this population could be assessed.

Based on surveys conducted in the Port Colborne area by this study and those by the Ministry of Natural Resources during the same time period (A. Yagi, OMNR, pers.comm.), it is clear that the life cycle of the local population (egg-larva-juvenile-adult) occurs entirely along a narrow band (500-700 m) of lakeshore associated with Lake Erie. No inland calling adults were identified during the breeding season, and juveniles and adults have only been reported to occur along the sand dunes and beaches in close proximity to the lakeshore.

Frog surveys conducted during the study identified only one breeding pond to occur in the Study Area for the Fowler's Toad. The pond was represented by a deep depression in limestone bedrock located within the high water wave action zone along the lakeshore. To assess exposure of eggs and larvae (tadpoles) to CoCs, water samples and sediment samples were collected from the breeding pond and analyzed. In addition, sand associated with the back shore sand dunes was sampled as adult toads and recently emerged metamorphosed young spend almost all their adult life feeding and burrowing in these sand dunes. Table 6-21 presents the results of the analysis of pond water, sediment and beach sand.

Table 6-21 Concentrations of CoCs in Water, Sediment and Sand Associated with Fowler's Toad Breeding site in Study Area.

CoCs	Breeding Pond Water[1] (mg/L)	Breeding Pond Sediment[2] (mg/kg)	Sand Dune at Breeding Pond[3] (mg/kg)	Sand Dunes at Nickel Beach[4] (mg/kg)
Nickel	0.019	21	62	187-230
Copper	0.003	3	4	8-9
Cobalt	0.001	nd	5	14-15
Arsenic	0.006	1.1	1.4	4.0-4.6

Notes General: Exposure calculations presented in Vol. III.
1 Surface Water Sample Site S27
2 Sample Site FOW-1
3 Sample Site FOW-2
4 Value for sand at Nickel Beach is a range based on four sample locations

Toxicity reference values have only been reported for eggs and tadpoles exposed to CoCs in a solution of freshwater. As a result, exposure calculations were only undertaken based on exposure to CoCs in the breeding pond water, assuming 100% exposure from this source. Further discussion on CoCs in pond sediment and beach sand is presented in Section 8.3.1.3.

6.5.4.3 Earthworms

Exposure of earthworms to CoCs is assumed to occur through ingestion of surface soils (0-5 cm). However, total CoC concentrations in soil are not wholly bioavailable to earthworms, but rather some soluble components are available for uptake. Soil porewater concentrations of CoCs are more appropriate for assessing exposure to soil invertebrates, including earthworms, as stated by Peijnenburg (1999) and Doyle *et al*. (2003). Soil porewater CoC concentrations were not measured, but chemical extractions were performed on subsets of soils from the Port Colborne area. Results from aqueous extraction and acid ammonium oxalate extraction of blended clay and blended organic soils were taken from Jacques Whitford (2003a). The concentrations of extracted nickel, copper and cobalt were compared to total concentrations of these CoCs in the soil to derive proportions of the elements that may be available for uptake. To be conservative, the maximum proportion from each set of blends and extraction was used to estimate how much of the total soil CoC concentrations in four scenarios (presented as the UCLMs in Table 6-18) may be available, as measured using the two extraction methods.

It is anticipated that the aqueous extraction may be underestimating what CoC concentrations may be available to earthworms, yet the acid ammonium oxalate extraction may overestimate their bioavailability. Without knowing the true bioavailability of CoCs in these soils specific to earthworms, two sets of scenarios are presented below based on CoC concentrations considered to be available based on the aqueous extraction (Table 6-22) and the acid ammonium oxalate extraction (Table 6-23); these are believed to represent two extremes of bioavailability. In both tables, arsenic is assumed to be 100% bioavailable due to the absence of chemical extraction for this CoC.

Table 6-22 Potential Exposure of Earthworms to CoCs in the Port Colborne Area, based on Aqueous Extraction.

CoC	Exposure Concentration (mg/kg)			
	Clay		Organic	
	Woodlot	Field	Woodlot	Field
Nickel	11.4	7.6	45.6	6.1
Copper	2.9	2.2	6.0	0.9
Cobalt	0.3	0.3	3.7	0.6
Arsenic	12	8	83	20
Note: Exposure calculations presented in Vol. III.				

Table 6-23 Potential Exposure of Earthworms to CoCs in the Port Colborne Area, Based on Acid Ammonium Oxalate Extraction.

CoC	Exposure Concentration (mg/kg)			
	Clay		Organic	
	Woodlot	Field	Woodlot	Field
Nickel	539	360	5960	792
Copper	180	140	1621	248
Cobalt	5.4	4.5	134	23
Arsenic	12	8	83	20
Note: Exposure calculations presented in Vol. III.				

6.5.4.4 American Woodcock

Calculations of potential exposure of American Woodcock populations in the Port Colborne area were based on the ingestion of arthropods and earthworms from both fields and woodlots on clay and organic soils, in addition to exposure to soil and air. American Woodcocks retain moisture from their prey items and are not known to drink water, so exposure to surface water was not included in the assessment. Exposure of American Woodcock was calculated for four separate scenarios to reflect foraging activity in woodlots and fields, and on clay and organic soils. The potential ADDs of American Woodcock in the Port Colborne area are provided in Table 6-24.

Table 6-24 Potential Exposure of American Woodcocks to CoCs in the Port Colborne Area.

CoC	Average Daily Dose (mg/kg d)			
	Clay		Organic	
	Woodlot	Field	Woodlot	Field
Nickel	9.1	8.8	14	9.1
Copper	2.9	3.2	4.7	3.2
Cobalt	0.47	0.63	1.1	0.50
Arsenic	0.21	0.45	.079	0.47
Note: Exposure calculations presented in Vol. III.				

6.5.4.5 American Robin

To assess the risk to American Robin populations by CoCs in the Port Colborne area, potential exposure was calculated based on ingestion of earthworms, wild grapes and arthropods, and exposure through soil ingestion, drinking surface water and inhalation of air. Four different scenarios were employed to estimate the potential exposure of robins to CoCs in the natural environment: woodlots on clay, woodlots on organic, fields on clay and fields on organic soils. The potential exposure of American Robins to CoCs, measured as an average daily dose, is presented in Table 6-25.

Table 6-25 Potential Exposure of American Robins to CoCs in the Port Colborne Area.

CoC	Average Daily Dose (mg/kg d)			
	Clay		Organic	
	Woodlot	Field	Woodlot	Field
Nickel	3.6	3.5	6	3.6
Copper	3.0	4.3	5.7	3.8
Cobalt	0.16	0.21	0.38	0.18
Arsenic	0.09	0.16	0.35	0.18
Note: Exposure calculations presented in Vol. III.				

6.5.4.6 Red-eyed Vireo

Potential exposure of Red-eyed Vireos to CoCs in the natural environment of Port Colborne was calculated based on ingestion of wild grapes and arthropods, and exposure through soil ingestion and inhalation of air; Red-eyed Vireos retain necessary moisture from their prey items and through drinking of water off foliage, so drinking of surface water was not considered a pathway for this species. Four different scenarios were employed to estimate the potential exposure of vireos to CoCs in the natural environment: woodlots on clay, woodlots on organic, fields on clay and fields on organic soils. Although the Red-eyed Vireo is a songbird primarily of forested areas, its role as a representative of the insect-eating songbird community persuaded the additional scenarios including field habitat, although the vireo itself rarely uses field habitat. The potential exposure of Red-eyed Vireo populations to CoCs, measured as an average daily dose, is presented in Table 6-26.

Table 6-26 Potential Exposure of Red-eyed Vireos to CoCs in the Port Colborne Area.

CoC	Average Daily Dose (mg/kg d)			
	Clay		Organic	
	Woodlot	Field	Woodlot	Field
Nickel	1.3	1.9	2.7	1.3
Copper	2.5	4.7	6.4	3.8
Cobalt	0.04	0.04	0.07	0.04
Arsenic	0.03	0.02	0.17	0.06
Note: Exposure calculations presented in Vol. III.				

6.5.4.7 Meadow Vole

To assess the risk to Meadow Voles within the Study Area, a diet of seeds from oat and corn, oat leaves and goldenrod plants were used to calculate potential exposure, in addition to soil, water and air. Due to the preference of field habitat for Meadow Voles, two scenarios were explored: exposure in clay fields and exposure in organic fields. The potential exposure calculated for Meadow Voles are presented in Table 6-27.

Table 6-27 Potential Exposure of Meadow Voles to CoCs in the Port Colborne Area.

CoC	Average Daily Dose (mg/kg d)	
	Field	
	Clay	Organic
Nickel	6.1	0.59
Copper	0.13	0.17
Cobalt	0.01	0.02
Arsenic	0.02	0.04
Note: Exposure calculations presented in Vol. III.		

6.5.4.8 Raccoon

The risk to a Raccoon is based on a broad diet of wild grapes, corn, oats, earthworms, arthropods, voles and frogs. Four scenarios were examined: exposure in each of fields and woodlots on clay soils, and exposure in each of fields and woodlots on organic soils. The potential exposure of Raccoon populations to CoCs in the Port Colborne area is presented in Table 6-28.

Table 6-28 Potential Exposure of Raccoons to CoCs in the Port Colborne Area.

CoC	Average Daily Dose (mg/kg d)			
	Clay		Organic	
	Woodlot	Field	Woodlot	Field
Nickel	1.4	1.3	3.3	1.4
Copper	1.1	1.7	2.5	1.5
Cobalt	0.04	0.05	0.11	0.05
Arsenic	0.03	0.05	0.19	0.07
Note: Exposure calculations presented in Vol. III.				

6.5.4.9 Red Fox

To assess the risk to the Red Fox population within the Port Colborne area, a diet of birds (for this ERA, represented by American Robin, American Woodcock and Red-eyed Vireo), wild grapes, Meadow Voles, arthropods and frogs was used. Four different scenarios encompassing this broad diet over a variety of habitat types was used: woodlots and fields on both clay and organic soils. Potential exposures of Red Fox populations to CoCs in the Port Colborne area are presented in Table 6-29.

Table 6-29 Potential Exposure of Red Foxes to CoCs in the Port Colborne Area.

CoC	Average Daily Dose (mg/kg d)			
	Clay		Organic	
	Woodlot	Field	Woodlot	Field
Nickel	0.74	0.71	1.4	0.74
Copper	0.58	0.63	0.81	0.62
Cobalt	0.04	0.04	0.05	0.04
Arsenic	0.02	0.02	0.06	0.03
Note: Exposure calculations presented in Vol. III.				

6.5.4.10 Red-tailed Hawk

The potential exposure of Red-tailed Hawk populations to CoCs in the Port Colborne area was based on a diet consisting of birds (represented by Red-eyed Vireo, American Robin and American Woodcock) and Meadow Voles. UCLMs of Meadow Vole tissue CoC concentrations from clay fields were used for each of four scenarios (clay fields, organic fields, clay woodlots, organic woodlots), and tissue CoC concentrations were estimated for each of the birds for each scenario (e.g., the ADD of a robin in clay field habitat, modified using the BAF, was incorporated into the Red-tailed Hawk scenario for clay field). The potential exposures of Red-tailed Hawk populations calculated for each of the scenarios in the Port Colborne area are presented in Table 6-30.

Table 6-30 Potential Exposure of Red-tailed Hawks to CoCs in the Port Colborne Area.

CoC	Average Daily Dose (mg/kg d)			
	Clay		Organic	
	Woodlot	Field	Woodlot	Field
Nickel	0.5	0.47	1	0.5
Copper	0.26	0.25	0.38	0.27
Cobalt	0.03	0.03	0.04	0.03
Arsenic	0.01	0.01	0.05	0.02
Note: Exposure calculations presented in Vol. III.				

6.5.4.11 White-tailed Deer

To assess the risk of White-tailed Deer in the Study Area, forest, field and agricultural vegetation were incorporated into one scenario that represented daily foraging behaviours of deer in the Port Colborne area. In calculating the potential exposure of White-tailed Deer, a diet of maple leaves, goldenrods, oat seeds and corn seeds was assumed. Due to the wide-ranging movements of White-tailed Deer in the Study Area (Section 3.8.3), only one overall scenario was deemed appropriate, and potential exposure to the four CoCs is presented in Table 6-31.

Table 6-31 Potential Exposure of White-tailed Deer to CoCs in the Port Colborne Area.

CoC	Average Daily Dose (mg/kg d)
Nickel	0.69
Copper	0.21
Cobalt	0.01
Arsenic	0.01
Note: Exposure calculations presented in Vol. III.	

7.0 HAZARD ASSESSMENT

The objective of the hazard assessment is to describe the relationship between the CoCs and the receptor assessment endpoints (CCME 1997). Ultimately the hazard assessment determines "safe" levels of CoCs that have been demonstrated to have no significant biological effects. These "safe" levels are referred to as the Toxicity Reference Values (TRV). Literature reviews, field and laboratory studies and field surveys are integrated to determine the "safe" levels specific to the local environment, receptors under consideration, and assessment endpoints.

In the following sections, an overview of the CoCs with respect to their distribution and abundance in the environment and a summary of present knowledge of the effects of the CoCs on organisms (Section 7.1) are provided. Section 7.2 provides the TRVs for the ERA's receptors, including some rationale for their selection; further rationale is presented in Volume III (Tab 4). This is followed by a discussion of the potential bioavailability of the CoCs in the natural environment (Section 7.3), the potential additive effects of the CoCs (Section 7.4) and limitations and uncertainty related to the Hazard Assessment (Section 7.5).

7.1 Overview of CoCs

The following provides a brief overview of the literature regarding potential adverse effects to various exposure levels of CoCs to plants and animals. This section is not intended to present an exhaustive review and discussion of the literature, but is provided for general background purposes. Detailed discussion on the TRVs used for this study's risk assessment is provided in Section 7.2 and in Volume III (Tab 4).

The primary sources for the information presented here include the following:

- Toxicological Profiles For *Arsenic(2000), Cobalt(2001 draft), Copper(2002 draft)* and *Nickel (2003 draft)*; by the Agency for Toxic Substances and Disease Registry (ATSDR).
- Copper Hazards to Fish, Wildlife, and Invertebrates 1998: A Synoptic Review. Biological Science Report, USGS/BRD/BSR – 1997-0002. U.S. Department of the Interior; U.S. Geological Survey; Patuxent Wildlife Research Centre.
- Nickel Hazards to Fish, Wildlife, and Invertebrates 1998: A Synoptic Review. Biological Science Report, USGS/BRD/BSR – 1997-0002. U.S. Department of the Interior; U.S. Geological Survey; Patuxent Wildlife Research Centre.

- Arsenic and its Compounds, 1993 and Nickel and its Compounds, 1994. Canadian Environmental Protection Act, Priority Substance List Assessment Report. Government of Canada, Health and Welfare Canada, Environment Canada.
- Toxicity Summary for Copper, 1992. Chemical Hazard Evaluation and Communication Group, Biochemical and Environmental Information Analysis Section, Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee. Prepared for Oak Ridge Reservation Environmental Restoration Program.
- Toxicity Summary For Nickel Compounds, 1995. Chemical Hazard Evaluation and Communication Group, Biochemical and Environmental Information Analysis Section, Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee. Prepared for Oak Ridge Reservation Environmental Restoration Program.

7.1.1 Arsenic

Arsenic is a metalloid that is most often found in compounds with sulphur and in combination with metal ores. The principal anthropogenic arsenic sources for soils are from metal refineries, with other sources including pesticides and herbicides used in agriculture and in wood preservation. In Canada, arsenic is present naturally in varying amounts in the aquatic and terrestrial environments, due to weathering and erosion of rock and soils. Arsenic typically occurs at a concentration of less than 2 µg/l for surface water and less than 50 µg/l for groundwater. For uncontaminated soils in Canada, arsenic levels range from 4.8 to 13.6 mg/kg dry weight. In Ontario, levels in farm soils are reported to range from 6 to 20 mg/kg. Arsenic occurs predominately in an inorganic form in soils.

Most forms of dissolved arsenic in soils can be quickly removed from soil pore waters by adsorption onto iron/manganese oxides and clay minerals. This process significantly reduces the amount available for absorption by plant roots. Although known to bioaccumulate in aquatic organisms such as fish, arsenic does not biomagnify through aquatic or terrestrial food chains.

In studies with experimental animals, the main organs affected by ingestion include the liver, kidney and spleen, as well as the organism’s total body weight. The No observed adverse affects level (NOAEL) for chronic ingestion of arsenic appears to be in the region of 0.19 to 2.5 mg As/kg-day. Little information is available for developmental or reproductive toxicity effects levels for arsenic. Based on experiments with mice, the lowest concentration reported to induce reproductive effects (decreased litter size; male/female ratio) was 1.5 mg As/kg-day.

Amphibians appear to be quite sensitive, with concentrations as low as 40 µg/L causing 7-day LC_{50} (concentration lethal to 50% of the test group) in exposed embryo-larvae of toads and concentrations as low as 450 µg/L causing 8-day LC_{50} in exposed embryo-larvae of salamanders. Birds are most sensitive as eggs and chicks. Chicken eggs injected with 0.05 mg As/kg egg yolk showed 50% mortality. Oral LD_{50} (dose lethal to 50% of the test group) values (as mg As/kg-body weight) have been reported for quail (25), Mallard *Anas platyrhynchos* (185) and Ring-necked Pheasant *Phasianus colchicus* (220).

Vascular plants have also been shown to be affected by soil arsenic. Growth of green beans has been reported to be reduced by up to 60% in soil containing 10 mg As/kg and 25 mg As/kg. Sweet corn has demonstrated reduced growth at soil values ranging from 70 to 100 mg As/kg.

Interactions with other chemicals or additive effects appear to be few. No additive effects between arsenic with copper, cobalt and nickel have been identified.

7.1.2 Cobalt

Cobalt is a metal that occurs naturally in many different forms. The principal anthropogenic cobalt sources for soils are from metal refineries and the burning of fossil fuels. Small amounts of cobalt occur in soil, surface water, groundwater, plants and animals. Small amounts of cobalt are added to, or naturally occur in foods; vitamin B_{12} is a cobalt-containing compound that is essential for good health in humans. Soils with cobalt concentrations less than 0.5 mg/kg are considered deficient because plants growing on them have insufficient cobalt. Normal levels in plants typically range from 0.4 to 0.6 mg/kg. Naturally occurring concentrations of cobalt in air is very low, while in drinking water in North America, its values range from 0.002 to 0.05 mg/kg.

The typical background concentration of cobalt in soils is approximately 7 mg/kg. In most soils, cobalt has a greater mobility than other metals such as nickel, zinc and lead. The mobility of cobalt in soil depends on the nature of the soil, including chelating/complexing agents, pH and redox potential. In most soils, the transfer of cobalt to plants is not appreciable. The transfer coefficient [(concentration in plant)/(concentration in soil)] for cobalt has been determined to be 0.01 to 0.3. However, some plants in highly acidic soils show significantly higher cobalt transfer to plants. For example, concentrations of cobalt in Rye (*Secale cereale*) grass in soil with pH less than 5, was 19.7 mg/kg, compared to 1.1 mg/kg for soil with pH greater than 5.

The literature suggests that there is negligible biomagnification of cobalt in animals found at higher trophic levels.

Death has been reported for inhalation exposure at 19 mg/m^3 to rats and mice over a period of 16 days. Systemic effects on the respiratory tract over prolonged inhalation exposures (3-4 months) on rats and rabbits occurred at levels as low as 0.4 mg/m^3. Oral LD_{50} for several cobalt compounds have been determined for rats with values ranging from 91 mg (cobalt fluoride)/kg to 317 mg (cobalt carbonate)/kg. Guinea pigs fed 20 mg Co/kg-day for five weeks suffered 20 to 25% mortality. Oral doses resulting in systemic effects on the heart, liver and kidney vary from 26 to 30.2 mg/kg-day (over 2 to 3 months) for heart to 10 mg/kg-day (over 5 months) for liver, to 10-18 mg/kg-day (over 4 to 5 months) for renal effects. Data for oral dose effects on reproduction is limited, with values ranging from a 5 mg/kg-day NOAEL to a 30 mg/kg-day Lowest Observed Adverse Effects Level (LOAEL).

Interactions with other chemicals or additive effects appear to be few. Research has found that specific chelators can mitigate the toxic effects of cobalt. An interrelationship between cobalt and nickel sensitization has been reported in individuals exposed to the two metals, with the combination of nickel sensitivity and irritant eczema resulting in a high risk for developing an allergy to cobalt. Mixtures of cobalt and nickel in drinking water of rats suggested that they may be additive in mammal toxicity. There is also a high correlation between cobalt and nickel concentrations in plants, however, additive toxicity has not been demonstrated.

7.1.3 Copper

Copper, in trace amounts, is an essential dietary element for the normal growth and metabolism of all living organisms. The principal anthropogenic copper sources for soils are from metal refineries and the application of agricultural fertilizers, pesticides, fungicides and molluscicides. In Canada, copper is present naturally in varying amounts in the aquatic and terrestrial environments due to weathering and erosion of rock and soils. The concentration of copper in ambient air ranges from a few nanograms to 200 ng/m^3. For waters of lakes and rivers in Canada, values range from 1 to 8 µg/L. Naturally occurring, non-mineralized, soil values for copper across the World normally range from 2 to 250 mg/kg.

In terrestrial vegetation, copper is usually less than 35 mg/kg, while aquatic vegetation shows a larger range from 3 to 256 mg/kg. Terrestrial invertebrates from industrialized areas have copper levels that range from 137 to 408 mg/kg. Information on copper concentrations in amphibians is scarce, but whole tadpoles of Northern Cricket Frog (*Acris crepitans*) had values of 9.8 to 15.7 mg/kg, and Green Frog (*Rana clamitans*) values for gut and gut removed were 21.5 and 6.7 mg/kg, respectively. Values for birds differ by tissues (muscle *vs* liver *vs* kidney) but average values (all tissues) range from 7 to 30 mg/kg. As for levels for terrestrial mammals, all tissues range from 3 to 300 mg-Cu/kg body weight.

Most copper, deposited in soil from the atmosphere or agricultural use, is readily absorbed and remains in the upper few centimetres of the soil. Copper movement in soils is determined by a number of factors, but in general copper will adsorb to organic matter, carbonate minerals, clay minerals and manganese oxides. Copper binds to soil, particularly organic soils, more strongly than other metals, and is less affected by pH. Therefore, although known to bioaccumulate in aquatic and terrestrial organisms, copper does not significantly biomagnify through the aquatic or terrestrial food chains.

Copper is not significantly accumulated by most crop plants, suggesting a soil-plant barrier for copper. Copper is toxic to sensitive plants when plant nutrient solutions contain greater than 40 to 200 μg/L, when leaves have greater than 10 to 12 mg-Cu/kg and when extractable copper in soils is greater than 60 mg/kg soil. Plants that have been identified as sensitive to soil copper include Eastern White Pine (*Pinus strobus*) and Red Maple (*Acer rubrum).*

No studies have documented death to animals following inhalation exposure to copper. For mice, acute inhalation exposure NOAEL was 0.0033 $\mu g/m^3$ for 3 hours. Rabbits exposed to 600 $\mu g/m^3$ for 4 to 6 weeks showed no adverse systemic effects. For oral exposure, increased mortality, due to acute exposure, occurred in rats fed a diet containing 4,000 mg/kg of copper (approximately 133 mg/kg-d) for 1 week. A life time exposure of 42.5 mg/kg-d, as copper gluconate in drinking water, resulted in a 12.8% reduction in life span in mice. In mammals, hepatotoxicity of copper is the most prominent systemic effect. For mice and rats LOAEL for systemic concentration effects range from 20 to 100 mg/kg/d.

Earthworms (*Eisenia foetida*) held in soils containing 53 mg Cu/kg dry weight showed a 50% reduction in cocoon production in 56 days, while 32 mg-Cu/kg soil had no effect on cocoon production. The LC_{50} (56 days) for earthworms is 555 mg-Cu/kg dry weight soil, and no death has been reported for soils at 210 mg-Cu/kg soil. However, *Lumbricus* worms have been reported to have almost 100% mortality rate in surface soil concentrations of 260 mg-Cu/kg (copper sulfate).

In general, toxic effects of copper are greater in aquatic systems when compared to terrestrial environments. For amphibians, LC_{50} for Northern Leopard Frog (*Rana pipiens*) and Gray Treefrog (*Hyla versicolor*) embryos have been reported at 40 to 50 µg/l. Values for LC_{50} on adult frogs are significantly higher at over 6000 µg/l for 72 hrs for the Leopard frog.

Sparse data are available on acute toxicity to avian and mammalian wildlife. However, controlled laboratory experiments show that mammals and birds are 100 to 1000 times more resistant to copper than other animals. At 250 to 350 mg-Cu/kg ration and at 500 and 1,000 mg/kg ration, experiments with domestic poultry show a reduction in chick weight gain, decreased growth, decreased feed efficiency and a high frequency of gizzard erosion. Ruminant mammals are significantly more sensitive to copper than non-ruminant mammals. Intoxication has been reported for cattle fed diets containing 20-125 mg/kg ration for an extended period, and a single dose of 200 mg/kg-body weight was lethal. Ewes receiving a daily dietary intake of 10.7 mg/kg-body weight were dead by day 89. However, horses fed a diet containing 800 mg/ration for six months showed no adverse effects.

In mice, a drinking water equivalent of 4.2 mg-Cu/kg-body weight daily for 850 days resulted in decreased growth and survival. Laboratory rats fed a diet of 250 mg-Cu/kg for 3 months had no deaths, however, systemic effects (growth and tissue effects on organs) have been documented for diets ranging from 10 to 150 mg/kg-dry weight. For mink, a dietary equivalent of 13.5 mg-Cu/kg-body weight daily for 50 weeks resulted in some deaths, but there was no effect on the reproduction of survivors. Domestic pigs fed a diet less than 150 mg/kg ration for 9 months showed no adverse effects, however, diets supplemented with 238-250 mg/kg ration fed to 3 week old pigs for 9 months, resulted in high mortality at 14 to 20 weeks of age.

Interactions with other chemicals, or additive effects, occur in water and depend on water pH, temperature and alkalinity. Direct additive effects of other metals with copper in soil are not reported. In animals, dietary interactions with other metals such as zinc, cadmium and molybdenum interfere with intestinal absorption and/or retention of copper, thereby reducing potential dietary toxic effects. No additive or cumulative effects are reported for copper with nickel, cobalt or arsenic.

7.1.4 Nickel

Nickel is an abundant and common element in the earth's crust, with a global average concentration of 75 mg/kg in soils. It is an essential dietary element for the normal growth and metabolism of many species of micro-organisms and plants, as well as several species of vertebrates, including chickens, cows, goats, pigs, rats and sheep. The principal anthropogenic nickel sources for soils are from atmospheric deposition from metal refineries and the burning of fossil fuels. Additional sources include waste incineration, sewage effluent, cement manufacturing and asbestos mining or milling.

In Canada, nickel is present naturally in varying amounts in the aquatic and terrestrial environments from weathering and erosion of rock and soils, as well as atmospheric anthropogenic sources. In air, the average concentration of nickel in larger cities such as Toronto may range from 0.003 $\mu g/m^3$ to a maximum of 0.011 $\mu g/m^3$. For surface waters of lakes and rivers in Canada, values range from 1 to 10 µg/l for relatively "uncontaminated" fresh waters. For cultivated soils in Canada, the average dry weight concentration of nickel ranges between 5 and 50 mg/kg. Nickel (in various forms) is strongly adsorbed by soil, although to a lesser degree than copper. The movement and adsorption of nickel varies significantly with the chemistry and structure of site-specific soils. Generally, nickel is more mobile in soils with lower pH (5.5 or less) and less mobile in soils with higher clay and organic matter content.

In terrestrial and aquatic vegetation, nickel concentrations are usually less than 10 mg/kg. However, in soils with elevated nickel levels, plant tissue concentration of nickel can range from 100 to 1000 mg/kg. Terrestrial invertebrates in Canada have nickel values ranging from 2 to 7 mg/kg dry weight. For amphibians, the concentrations of tissue nickel is typically less than 10 mg/kg dry weight. For most terrestrial birds and mammals, tissue concentrations typically range between 2 and 10 mg/kg. For invertebrates and vertebrate species living near smelters with elevated nickel levels in the environment, tissue nickel concentrations have been demonstrated to be higher when compared to reference sites. However the literature shows that nickel accumulation rates in tissues are highly variable based on species, form of nickel and site soil types.

In Maryland, nickel concentrations in tadpoles of Gray Treefrog and Northern Cricket Frog increased with increasing levels of soil nickel concentrations, with a maximum nickel concentration of 7.1 mg/kg and 10.0 mg/kg, respectively. Studies of Ruffed Grouse (*Bonasa umbellus)* near a smelter in Sudbury, Ontario found that less than 10% of dietary nickel levels were found in bird tissues. For mammals, uptake of nickel varies greatly between species and study locations. Some studies of rabbits and voles in areas with elevated soil nickel did not indicate any accumulation of nickel. Other studies have identified that in nickel elevated soils, the nickel concentrations in internal organs are usually similar, regardless of the degree of soil contamination. Meadow Vole whole body nickel levels in contaminated areas versus reference were only slightly elevated: 2.5 mg/kg versus 1.8 mg/kg. For the same area, similar results were found for the White-footed Mouse (*Peromyscus leucopus*), with mice in the contaminated area showing nickel concentrations only two times higher than controls, 3.1 mg/kg versus 1.5 mg/kg.

For mammals, studies have identified that retention of dietary nickel is low. The half-time residence of soluble forms of nickel is several days after ingestion. Most (greater than 90%) dietary nickel that is ingested in food remains unabsorbed within the gastrointestinal tract and is excreted in the faeces. The majority of absorbed nickel is present primarily in the kidney, liver, heart and lung and is excreted in urine. In general, the lack of significant bioaccumulation of nickel in aquatic and terrestrial organisms indicates that nickel is not biomagnified in the food chain.

No studies have documented death to wild animals related to inhalation exposure to nickel. Under laboratory conditions, rats exposed to 0.7 mg nickel/m^3 showed significant mortality during the last 26 weeks of a 78-week inhalation study. Numerous studies have assessed chronic (greater than 1 year) inhalation systemic effects on mice and rats. These studies have LOAEL values that range from 50 to 10,000 μg nickel/m^3.

The most common pathway for nickel exposure in the natural environment is through root absorption by plants and dietary intake by animals. In general, long-term effects of elevated soil nickel on plants include the reduction of growth at low levels and stunted growth with wilting, chlorosis, necrosis twisted stalks and leaf drop for soils with excessive bioavailable nickel. Accumulations in plant tissue of 50 mg-Ni/kg or higher is considered to be toxic to most plants. Depending on soil conditions and the chemical form of nickel, soil is toxic to most plants when concentrations exceed 500 mg-Ni/kg soil with more than 25 mg-Ni/l extractable in 2.5% acetic acid solution. There are sparse data on soil nickel toxicity to terrestrial invertebrates other than earthworms. An eight week exposure to soil nickel ranging from 1,200 to 12,000 mg/kg found no observed effects for the earthworm *Eisenia foetida*.

Salamander (*Ambystoma* sp.) larvae after four days after hatching at 420μg-Ni/l had an eight day LC_{50}. Fowler's Toad (*Bufo woodhousei fowleri*) larvae after being hatched for four days had a LC_{50} reported for 11.03 mg-Ni/l, while Narrow-mouthed Toad (*Gastrophryne carolinensis*) larvae of similar age had a LC_{50} at 0.05 mg-Ni/l.

Toxic effects of elevated soil nickel on birds have not been reported; however, studies on the effects of dietary nickel on birds have been undertaken under laboratory conditions for ducks, quail and chickens. Adult Mallards with diets containing up to 800 mg-Ni/kg for 90 days, showed no effects on body weight, histological changes in the liver or kidney or blood chemistry. However, newly hatched ducklings fed the same diet for 90 days showed effects at 800 mg/kg dry weight. Chicks fed dietary nickel showed significantly slower growth rates at 300 mg/kg dry weight and higher, with 50% mortality at 900 mg/kg dry weight. Quail (*Coturnix* *risoria*) fed a diet containing 74 mg/kg dry weight for four generations showed no observed adverse effects.

A significant body of work has been undertaken to assess nickel effects on mammals under laboratory conditions; however, few studies of wild animals are reported. A review of laboratory studies indicated that lifetime exposure via dietary intake by resistant mammal species (e.g., cows, dogs) show no lethal effects for foods at levels as high as 2,500 mg-Ni/kg dry weight and drinking water at 10,000 mg-Ni/l. Lethal nickel doses reported in the literature are usually derived from laboratory studies, often using injected nickel, and do not reflect realistic exposure routes for animals in the wild. In addition, significant differences in effects to nickel have been shown between closely related species, as well as adults and young of the same species. Single oral doses of 136 to 410 mg-Ni/kg-body weight have been shown to be lethal to mice. However, for laboratory animals with chronic exposure (greater than 1 year), systemic effects (including reproductive), as a result of oral exposure, typically range from 50 to 100 mg-Ni/kg-day.

A number of interactions between nickel and other metals resulting in additive effects have been reported in the literature. In water, mixtures of metals (arsenic, cadmium, copper, chromium, mercury, lead, zinc) containing nickel salts have been demonstrated to be more toxic to daphnids and fish. For example, chromium-nickel mixtures have been demonstrated to be more than additive in toxicity to guppies in 96-hr tests. Interactions have also been shown to differ between terrestrial and aquatic environments. Copper-nickel mixtures are beneficial to the growth of terrestrial plants but are more than additive in toxic action on aquatic plants. However, nickel is less than additive in toxicity to aquatic algae in combination with zinc. Pre-treatment of animals with cadmium has been shown to enhance the toxicity of nickel to the kidney and liver. Nickel toxicity in soybeans has been shown to be inhibited by calcium.

7.2 Bioavailability of CoCs

Bioavailability is a widely accepted concept based on the implicit knowledge that before an organism may accumulate or show a biological response to a chemical, that element or compound must be systematically available to the organism. The following summaries discuss different chemical forms of each of the CoCs, and how different molecular interactions influence their bioavailabilities.

For reference purposes, a range of site specific soil pH values for the Port Colborne region are summarized below for reference (OMAFRA 1989). Further information on soil characteristics is provided in section 3.4.

- Organic Soils – pH range 4.8 – 5.6
- Sandy Soils – pH range 6.0 – 7.3
- Shallow Clay Soils – pH range 6.0 – 6.9
- Heavy Clay Soils – pH range 5.5 to 6.5

For all soil types, those with high CoC concentrations have exhibited an increased cation exchange capacity (CEC) compared to the soils in the reference area. At higher CECs, soils may have the potential to retain increased concentrations of metal ions, thus reducing the risk of CoC release from the soil (USDA 2001). Table 7-1 provides a summary of CEC values for soils used in the 2001 Greenhouse Studies.

Table 7-1 Cation Exchange Capacity of Year 2001 Soils Following pH Adjustment

Soil Type	CoC Level (mg Ni/kg)	CEC (meq/100 g)
Organic Soils	Reference	52.7 ± 67.9
	Very High	145.5 ± 0.7
Sandy Soils	Reference	5.3 ± 5.8
	Very High	11.8 ± 1.8
Shallow Clay Soils	Reference	11.7 ± 11.6
	Very High	15.0 ± 9.5
Heavy Clay Soils	Reference	14.05 ± 16.41
	Very High	63.00 ± 0.00

7.2.1 Arsenic

In the environment, arsenic will take on many chemical forms (structures) that influence its mobility and potential harmful effects on biota. In soils, arsenic can be categorized as either organic or inorganic. These forms of arsenic are dependent on the type and amounts of sorbing components of the soil, the pH and the redox potential. The biological availability and physiological and toxicological effects of arsenic depend on its chemical form. Typically arsenites (As^{3+}) are more toxic, more soluble and more mobile than arsenates (As^{5+}) (Mandal and Suzuki 2002).

In soils and sediments, arsenic is commonly found in one of three oxidation states: +5 (arsenate, As(V)), +3 (arsenite, As(III)), and as 0 (metalloid, As(0)) (Cullen and Reimer 1989, CCME 2001). Arsenate is the dominant arsenic species, typically greater than 95%, in oxic soil and sediment zones and is present as an anion ($H_xAsO_4^{x-3}$) in pH range of 4 to 8 (Cullen and Reimer 1989, Pongratz 1998, LaForce *et al*. 2000). Arsenate is also the dominant form of arsenic found in oxic surface waters (Cullen and Reimer 1989, Azcue and Nriagu 1994, CCME 2001).

In Port Colborne soils, there are a variety of factors that would contribute to the presence of As^{5+} over As^{3+}. Firstly, under oxidizing conditions, in the presence of air, As^{5+} is the stable species and is strongly sorbed onto clays, iron and manganese oxides/hydroxides and organic matters. Furthermore, in one study it was shown that arsenite can be transformed into arsenate in a process known as biomethylation (Mandal and Suzuki 2002). In this process, the addition of methane (CH_4) from biological activity, namely bacteria and fungus, causes As^{3+} to become oxidised to As^{5+} as CH_4 is reduced to CH_3. The presence of air and methane (CH_4) in clay and organic surface soils in Port Colborne would likely strongly favour these aforementioned processes and thus the presence of As^{5+} over As^{3+} (Mandal and Suzuki 2002).

One of the main pathways for arsenic to be transferred from soil to various stages of the trophic level is through uptake in plants. However, based on the collection of various plants in Port Colborne (i.e., maple leaves, grapes and goldenrods) it would appear that only a small proportion of soil arsenic is being translocated into above-ground biomass.

7.2.2 Cobalt

In the natural environment, cobalt occurs in two oxidation states, Co^{2+} and Co^{3+}, and sometimes in the formation complex anion $[Co(OH)_3]^-$. Due to a high sorption affinity with iron and manganese oxides and with clay minerals, this metal does not migrate in a soluble phase under natural conditions. In certain soils, various bacteria are known to mobilize cobalt already complexed as chelated compounds, thereby enabling Co^{3+} to be transported in solution. In soils, the weathering, transforming and adsorption mechanisms of cobalt compounds and forms are complicated due to variable oxidation stages of cobalt and due to microbial activity. The solubility and availability of cobalt in soil is of great nutritional concern for plants and has therefore received a lot of research. Soil organic matter and clay content have been found to be important factors that govern cobalt distribution and behaviour. The mobility of cobalt is strongly related to the kind of organic matter in soils. Organic chelates of cobalt are known to be easily mobilized and translocated in soils, making them readily bioavailable. Clay soils, on the other hand, have been cited by numerous studies to exhibit a great sorption capacity for cobalt while at the same time are able to release cobalt just as easily. The pH of a soil appears to be a major contributing factor to mobility and bioavailability of cobalt in both organic and clay soils. Liming of agricultural soils has been found in some situations to greatly reduce the availability of cobalt, causing significant deficiencies in herbaceous plants and dangerous cobalt deficiency in livestock (Kabata-Pendias 2001).

7.2.3 Copper

Copper is widely distributed in the environment with a variety of concentrations ranging from levels that may be nutrient deficient to those that are potentially harmful to biota. Animals can be exposed to copper by inhalation, ingestion and dermal contact since copper is present in a variety of environmental media. Copper exists in four oxidation states: Cu^0 (elemental copper), Cu^{+1} (cuprous copper), Cu^{+2} (cupric copper) and Cu^{+3} (trivalent copper). Elemental copper is readily bound to organic and mineral acids in the environment. Cuprous copper exists only in water solution and is unstable at a pH range of 6 to 8, and will undergo auto-oxidation-reduction into Cu^0 and Cu^{+2}. Trivalent copper probably does not occur naturally and only occurs in a few compounds that are not considered environmentally significant. The cupric ion is generally encountered in water and is the most readily bioavailable and toxic inorganic species of copper. In theory, only free copper ions (Cu^{+2}) are bioavailable and are potentially harmful to biota. However, this free ion state is prone to complexation and is less bioavailable to aquatic biota in the presence of natural organic chelators or mineral matter (Hrudey *et al.* 1996, Eisler 1998).

The major chemical species of copper in freshwater are $Cu\ (CO_3)_2^{-2}$ and $CuCO_3$. At a pH between 6.0 to 9.3 (mean pH 7.1 in surface water sampled in Port Colborne), these aforementioned aqueous carbonate copper complexes are the dominant form which are significantly less toxic compared with ionic cupric copper (Cu^{+2}). Generally, the bioavailability of copper is dependant on many substantial interactions which reduce bioavailability with increasing pH, suspended materials, dissolved organics and sedimentation of particulates (Eisler 1998).

If one assumes that the majority of copper in the environment is bioavailable, then the following process can occur in mammals. The distribution of copper takes place in two stages once absorbed. In the first stage, desirable levels of copper are bound to amino acids in the blood. Copper present in these amino acids is then complexed with a variety of proteins that can then act as cofactors of some enzymes. When an abundance of copper is absorbed into an animal's body, copper complexes formed in the blood are transferred to the liver and are then excreted from the animal via the biliary tract. Consequently, copper levels in the liver usually remain relatively constant, making the liver a primary homeostatic (regulatory) organ for copper

(Hrudey *et al.* 1996). In some instances, the uptake of essential elements such as copper results in rapid accumulation within animal tissues (Stone and Johnson 1997, Peijnenburg *et al.* 1999).

7.2.4 Nickel

As with arsenic and copper, the bioavailability of nickel is related to its solubility. Generally it has been found that in surface soil horizons, Ni appears to occur mainly in organically bound forms and clay fractions depending on the soil type (Kabata-Pendias 2001). Given that soils in Port Colborne are generally either organic or clay, the bioavailability of nickel in Port Colborne soils is relatively low. However, the extent to which nickel is bound is dependent on pH, which is the most profound factor in the bioavailability of nickel. More acidic soils reduce the sorption or complexing of Ni and render it more bioavailable. In one study it was shown that by raising the pH from 4.5 to 6.5 the nickel content in oat seeds was reduced by a factor of 8. Regardless of the bioavailability of nickel, biological effects are almost entirely related to nickel speciation. In plants, it has been found that regardless of the chemical form added to the soil, Ni was only found in neutral and negative complexes in the plant biomass. The most typical indication of toxicity in plants is chlorosis, which seems to result from an iron deficiency that is induced by nickel. In situations where bioavailability of nickel is sufficient to cause stress in plants, the absorption of nutrients, root development, and metabolism are strongly retarded (Kabata-Pendias 2001).

As part of this ERA, maple leaves were examined and rated for potential evidence of chlorosis and other CoC related symptoms from the primary, secondary and reference areas. Through statistical analysis using a generalized linear model, it was found that no relationship existed between nickel concentrations in soil and visual leaf health. Thus, maple trees are not being exposed to quantities of nickel sufficient to cause phytotoxicity.

Generally it has been widely accepted and documented that pH of soils and water is a critical variable that influences the bioavailability of arsenic, cobalt, copper and nickel. In soils, cation exchange capacity (CEC) is also very important in estimating bioavailability as this parameter is a measure of the amount of available sorption sites and thus incorporates the clay, metal oxyhydroxides as well as organic matter of a soil (Lock and Janssen 2000).

7.3 Toxicity Reference Values (TRVs)

Literature reviews for each of the four CoCs have been conducted to establish TRVs that are protective of ecological receptors. A detailed discussion on the selection of the toxicity reference values used in the risk assessment is provided in Volume III (Tab 4).

Assessment endpoints may be based on individual or population responses. Individual responses may include survival, growth, reproduction, behaviour or histopathology (e.g., lesions, tumours, etc.). Population responses may include changes in size of a population through a combination of birth, death, emigration and immigration. Individual responses may also change the overall population characteristics. Some research has found that measures of individual responses are not as sensitive as measures of population responses (CCME 1997).

The selection of appropriate endpoints is guided by the protection goals for different land use categories. Agricultural, residential and park land use categories require a sustainable level of ecological functioning in order to sustain activities associated with those land uses. The activities associated with industrial/commercial land uses do not require a sustainable level of ecological functioning (CCME 1998). The Canadian Council of Ministers of the Environment (CCME) recommends protection of wildlife for agricultural, residential and park land uses, protection of livestock and crops for agricultural land uses and protection of plants, invertebrates and nutrient cycling processes for all land uses (CCME 1998).

The CCME and the United States Environmental Protection Agency (US EPA) recommend the selection of ecological endpoints based on the goals and the sought level of protection of the environment. In the current assessment, a sustainable level of ecological functioning was selected as the most appropriate level of protection and thus the assessment goal. Based on this, survival was selected (see Chapter 1) as the assessment endpoint for individual species of mammals and birds as well as for amphibians, where a literature-based hazard assessment was conducted. The US EPA (1997) reported that at a 40% mortality effects level as an example, a population is likely to be unable to sustain itself. Up to a 20% effects level of a less severe nature (i.e., Effect Concentration - EC_{20}) was selected in this study as an adequate level of protection for survival of the species.

The 20% effects level has been applied in numerous assessments and criteria for quickly reproducing species such as plants, microbes, earthworms and fish (e.g., US chronic National Ambient Water Quality Criteria (NAWQC), as cited in Suter and Tsao 1996, Cameco Corp. 1994, SENES, 2001). The 20% effects level or less has been referenced as a No Observed Effects Concentration (NOEC) in plants, soil and litter invertebrates and heterotrophic processes (Efroymson, *et al.*, 1997a; Efroymson, *et al.*, 1997b). For slower reproducing species with less dense populations, such as larger mammals, a 20% decrease in population may not be acceptable. For these types of populations, an effect level at or near the No Observed Effects Level (NOAEL) is considered a more appropriate endpoint

For tadpoles of frogs and toads, an initial review of the literature found effects levels, particularly for nickel and copper, that were below natural background surface water concentrations for southern Ontario (Based on data from Ontario Ministry of the Environment (MOE) water quality sampling stations located throughout southern Ontario). These reported effects levels would suggest that all frogs and toads in southern Ontario could potentially be at risk for these CoCs based on literature reported effects levels. As a result literature based effects levels that were below the upper estimate of typical background surface water quality concentrations for southern Ontario were not selected since these are not considered applicable to Southern Ontario tadpoles of frogs and toads. For the determination of TRVs, consideration was given for a 20% effects level (EC_{20}), or 10% lethal concentration (LC_{10}), for selecting TRV values.

For earthworms, 20% reductions for non-lethal effects (i.e., reduced weight, reduced reproduction) were selected as TRVs. For the evaluation of mammals and birds, LOAELs were selected as the TRVs. The NOAEL was chosen as the TRV in cases where the LOAEL was based on severe effects. The selected LOAEL-based TRVs represent threshold levels of adverse effects based on the methodology of selection outlined by Sample *et al.* (1996). For significant effects, such as mortality of 50% (LC_{50}) of the test population, these were converted to TRVs by approximating the concentration that would affect 10% of the population assuming a linear dose-response relationship. The relationship (see Efroymson *et al*. 1997a; Efroymson *et al*. 1997b) for estimating the TRV from a 50% mortality concentration (i.e., LC_{50}) is as follows:

$$TRV = \frac{LC_{50}}{5} \quad (7\text{-}1)$$

where

LC_{50}	=	Lowest concentration at which 50% mortality has been observed.
TRV	=	Threshold response value or EC_{20} (concentration at which less severe effect to 20% of the population is estimated)

For mammals and birds, the methods of Sample *et al*. (1996) and Sample and Arenal (1999) were used to scale the test species LOAEL to a wildlife receptor LOAEL based on body weight as follows:

$$LOAEL_w = LOAEL_t \left(\frac{BW_t}{BW_w} \right)^{1-f} \quad (7\text{-}2)$$

where,

$LOAEL_w$ = lowest observed adverse effects level for wildlife species

$LOAEL_t$ = lowest observed adverse effects level for test species

BW_w = body weight for wildlife species

BW_t = body weight for test species

f = scaling factor (1.2 for birds; 0.94 for mammals; Sample and Arenal, 1999)

For the ERA, the selected TRVs for VECs are presented and summarised in Table 7-2 located at the end of this section. Detail discussion on the rationale and selection for each endpoint chosen from the literature and estimation of the TRVs is in Volume III (Tab 4).

7.3.1 Additive and Less than Additive Effects

When a receptor is exposed to CoCs in the environment, there is the potential for biophysical and biochemical interactions to result in a hazard where toxicity effects on receptor assessment endpoints are greater than or less than when only one CoC is considered. Additive effects of CoCs typically increase the risk to a receptor by the CoCs targeting the same organs or tissues (histopathology such as lesions, tumours, etc.), increasing bioavailability of another CoC (from environmental media or within biological tissue), or affecting specific biochemical processes in a similar manner and magnitude. Similarly, less than additive effects of multiple CoCs exposure to a receptor typically occur when one CoC interferes with the bio-availability of another CoC from environmental media or reduces its bio-physical or bio-chemical toxic effect on a receptor.

Based on a review of the literature, few investigations have identified any additive, less than additive, or greater than additive effects between the four CoCs. As a result, for hazard assessment and risk characterization, the TRVs for each of the four CoCs were used separately in this assessment. However, combined effects or interactions of the CoCs with respect to toxicity can be addressed for specific field data and toxicity testing. In the field, observations are based on the presence of all CoCs and thus address combined affects. Similarly, the greenhouse testing for maple seed germination and seedling growth, and toxicity testing of earthworms, used actual Port Colborne soils containing all of the CoCs and thus account for potential combined effects.

Since the potential combined effects of the CoCs, if any, that may impact on toxicity are not well understood (i.e., effects of the CoCs on the VECs used in this study), a detailed *numerical analysis* of additive, synergistic or other interactions is not feasible (CCME 1997). Field observations and ecotoxicity testing performed in this study for maple trees, leaf litter (decomposers), earthworms, frogs and toads take into account potential combined effects of the CoCs. For mammals and birds, this is not the case. Dose additivity is typically considered for similar acting compounds that do not interact (US EPA 1986). Recent guidance (US EPA 2000) recommends implementation of several approaches and evaluation of a range of risk estimates.

Arsenic is known to be a systemic poison. The main organs affected by ingestion include the liver, kidney and spleen. The selected TRV for arsenic to birds is based on no observed behavioral effects. In mammals, the LOAEL is based on a decreased litter size and an increased ratio of males to females. Because arsenic is the only CoC that is a systemic poison, its effects are considered unique among the CoCs.

Cobalt inhalation has been seen to cause respiratory tract effects. Lowest effects exposures have been seen to cause effects to the heart, liver and kidney. The TRV selected for birds is based on a decrease in weight gain. For mammals, the TRV is based on histological changes. Histological changes noted for cobalt in mammals are not typically associated with lowest effects levels for the other CoCs.

Copper is an essential nutrient. The copper TRV for birds is based on effects on growth and mortality. For mammals, an increased mortality in mink pups was the basis of the TRV. As an essential nutrient, copper is also unique among the CoCs. Little effects are seen at doses lower than those causing increased mortality. Intestinal interactions with other metals such as zinc, cadmium and molybdenum interfere with intestinal absorption of copper and the presence of other CoCs may therefore reduce the absorption of, and effects associated with, copper.

The TRV for nickel to birds was selected based on a NOAEL for mortality. For mammals, decreased organ and body weights were the basis of the TRV. Nickel exposure can also lead to reproductive effects and at higher doses, gastrointestinal effects.

Table 7-2 TRVs and Test Endpoints

Metal	TRV	Endpoint	Test Species	Test Endpoint	Rationale	Reference
Earthworms						
Ni	3000 mg/kg	$NOEC_{est}$	*Eisenia fetida*	NOEC for reproduction based on NOEC for nickel of 12000 mg/kg nickel for reduction in body weight for earthworms.	The selected TRV is based on exposure to nickel oxide, the predominant form of nickel present in the natural environment of Port Colborne.	Hartenstein, 1981; Malecki *et al*. 1982
Cu	50 mg/kg	$EC20_{est}$	*Eisenia fetida*	Benchmark based on 20% effects level based on soluble forms of copper in the review of 24 measured endpoints (reduction in reproduction based on cocoons)	The benchmark derived by Efroymson *et al*. based on a comprehensive review of available data was considered applicable.	Efroymson *et al*. 1997
Co	3000 mg/kg	NOEC	*Eisenia fetida*	Chronic NOEC of 3000 mg/kg cobalt for weight change for earthworms.	The selected NOEC value is considered conservative and was selected in the absence of a suitable 20% effect level	Hartenstein *et al*. 1981.
As	21 mg/kg	$EC20_{est}$	*Eisenia fetida*	50 mg/kg potassium 20% decrease in worm mass	No other applicable studies were identified.	Fischer and Koszorus, 1992
Frogs (tadpole)						
Ni	0.01 mg/l	$EC20_{est}$	*Gastrophryne carolinensis*	20% effects level derived (see Note 1) based on a 7 day LC50 of 50 µg/l nickel for mortality on embryo/Larval stages of narrow-mouthed toad.	A more recent study developed LC10s for northern leopard frog and eastern narrow-mouthed toad; however, these were below regional background concentrations and were thus not considered relevant to the study area.	Birge, 1978; Birge, *et al*., 1979; Birge and Black, 1980
Cu	0.008 mg/l	$EC20_{est}$	*Rana hexadactyla; Gastrophryne carolinensis*	20% effects level derived (see Note 1) from 27 endpoints based on LC50 of 0.039 mg/l as copper sulphate for 96 h and 0.040 mg/l as copper sulphate for 7 day embryo mortality studies. This benchmark is not considered applicable to Fowlers Toad that is much less sensitive to copper.	A more recent study developed LC10s; however, these were an order of magnitude below regional background concentrations and were thus not considered relevant to the study area.	ECOTOX 2002; Khangarot *et al*. 1985a and b; Birge *et al*. (1979)
Co	0.01 mg/l	$EC20_{est}$	*Gastrophyryne carolinensis*	50 µg/L cobalt LC50 (7 day) for embryo mortality.	The selected TRV is equal to the LC10 from another recent study.	Birge, 1978; Birge et al., 2000
As	0.01 mg/l	LC10	*Gastrophryne carolinensis*	40 µg/L as sodium arsenite LC50 (7 day) for embryo mortality.	The LC10 TRV is similar to the lowest estimated EC20.	Birge et al., 1979; Birge et al., 2000

Table 7-2 TRVs and Test Endpoints (cont'd)

Metal	TRV	Endpoint	Test Species	Test Endpoint	Rationale	Reference
Fowler's Toad (tadpole)						
Ni	0.4 mg/l	LC10	*Bufo woodhousei*	LC10 of 0.41 mg/l for the species of interest.	The selected TRV is conservative compared to an earlier LC50. The selected TRV is specific to Fowler's Toad.	Birge et al., 2000
Cu	6 mg/l 5 mg/l	LC10; $EC20_{est}$	*Bufo woodhousei*	26.96 mg/l as copper sulfate LC50 (7 day) for embryo mortality.	The selected TRV is consistent with both studies. The selected TRV is specific to Fowler's Toad.	Birge et al., 2000; Birge and Black 1979
Co	0.2 mg/l	LC10	*Bufo woodhousei*	0.2 mg/l LC10	The selected TRV is specific to Fowler's Toad.	Birge et al., 2000
As	50 mg/l	LC10	*Bufo woodhousei*	54.9 mg/l LC10	The selected TRV is specific to Fowler's Toad.	Birge et al., 2000
Red-tailed hawk						
Ni	83 mg/kg-day(1)	NOAEL	Mallard	774 mg/kg nickel as nickel sulphate in diet of mallard caused no significant difference in weight gain.	The NOAEL was selected since increased mortality was observed at the LOAEL.	Cain and Pafford (1981)
Cu	48 mg/kg-day(1)	NOAEL	Day-old chicks	NOEC of 570 mg/kg copper in diet for chicks.	The NOAEL was selected since increased mortality was observed at the LOAEL.	Mehring *et al*. (1960)
Co	3.2 mg/kg-day(1)	LOAEL	Day-old chicks	116 mg/kg feed to chicks as cobalt chloride LOEC (LOAEL of 21 mg/kg-day) reduced growth by 20% over 14 days. The LOAEL was based on reduced growth.	No chronic studies were available. This was considered the most robust subchronic study. An uncertainty factor of 10 was applied to convert from subchronic to chronic. Since the LOAEL was not related to a severe affect, this value was selected as appropriate for use in this study.	Diaz *et al*. 1994
As	5.3 mg/kg-day(1)	NOAEL	Mallard	100 mg/kg sodium arsenite (51.35 mg/kg As^{+3}) NOAEL (128 days).	Cowbirds were selected as more representative than mallard ducks as well as being more sensitive to arsenic. The NOAEL was selected since 20% mortality was observed at the LOAEL.	USFWS (1964)

Table 7-2 TRVs and Test Endpoints (cont'd)

Metal	TRV	Endpoint	Test Species	Test Endpoint		Reference
American Woodcock						
Ni	59 mg/kg-day(1)	NOAEL	Mallard	774 mg/kg nickel as nickel sulphate in diet of mallard caused no significant difference in weight gain.	The NOAEL was selected since increased mortality was observed at the LOAEL.	Cain and Pafford (1981)
Cu	34 mg/kg-day(1)	NOAEL	Day-old chicks	NOEC of 570 mg/kg copper in diet for chicks.	The NOAEL was selected since increased mortality was observed at the LOAEL.	Mehring *et al*. (1960)
Co	2.2 mg/kg-day(1)	LOAEL	Day-old chicks	116 mg/kg feed to chicks as cobalt chloride LOEC (LOAEL of 21 mg/kg-day) reduced growth by 20% over 14 days. The LOAEL was based on reduced growth.	No chronic studies were available. This was considered the most robust subchronic study. An uncertainty factor of 10 was applied to convert from subchronic to chronic. Since the LOAEL was not related to a severe affect, this value was selected as appropriate for use in this study.	Diaz *et al*. 1994
As	3.7 mg/kg-day(1)	NOAEL	Mallard	100 mg/kg sodium arsenite (51.35 mg/kg As^{+3}) NOAEL (128 days).	Cowbirds were selected as more representative than mallard ducks as well as being more sensitive to arsenic. The NOAEL was selected since 20% mortality was observed at the LOAEL.	USFWS (1964)

Table 7-2 TRVs and Test Endpoints (cont'd)

Metal	TRV	Endpoint	Test Species	Test Endpoint		Reference
American Robin						
Ni	49 mg/kg-day[(1)]	NOAEL	Mallard	774 mg/kg nickel as nickel sulphate in diet of mallard caused no significant difference in weight gain.	The NOAEL was selected since increased mortality was observed at the LOAEL.	Cain and Pafford (1981)
Cu	29 mg/kg-day[(1)]	NOAEL	Day-old chicks	NOEC of 570 mg/kg copper in diet for chicks.	The NOAEL was selected since increased mortality was observed at the LOAEL.	Mehring *et al*. (1960)
Co	1.9 mg/kg-day[(1)]	LOAEL	Day-old chicks	116 mg/kg feed to chicks as cobalt chloride LOEC (LOAEL of 21 mg/kg-day) reduced growth by 20% over 14 days. The LOAEL was based on reduced growth.	No chronic studies were available. This was considered the most robust subchronic study. An uncertainty factor of 10 was applied to convert from subchronic to chronic. Since the LOAEL was not related to a severe affect, this value was selected as appropriate for use in this study.	Diaz *et al*. 1994
As	3.1 mg/kg-day[(1)]	NOAEL	Mallard	100 mg/kg sodium arsenite (51.35 mg/kg As^{+3}) NOAEL (128 days).	Cowbirds were selected as more representative than mallard ducks as well as being more sensitive to arsenic. The NOAEL was selected since 20% mortality was observed at the LOAEL.	USFWS (1964)

Table 7-2 TRVs and Test Endpoints (cont'd)

Metal	TRV	Endpoint	Test Species	Test Endpoint		Reference
Red-eyed vireo						
Ni	37 mg/kg-day(1)	NOAEL	Mallard	774 mg/kg nickel as nickel sulphate in diet of mallard caused no significant difference in weight gain.	The NOAEL was selected since increased mortality was observed at the LOAEL.	Cain and Pafford (1981)
Cu	22 mg/kg-day(1)	NOAEL	Day-old chicks	NOEC of 570 mg/kg copper in diet for chicks.	The NOAEL was selected since increased mortality was observed at the LOAEL.	Mehring *et al*. (1960)
Co	1.4 mg/kg-day(1)	LOAEL	Day-old chicks	116 mg/kg feed to chicks as cobalt chloride LOEC (LOAEL of 21 mg/kg-day) reduced growth by 20% over 14 days. The LOAEL was based on reduced growth.	No chronic studies were available. This was considered the most robust subchronic study. Since the LOAEL was not related to a severe affect, this value was selected as appropriate for use in this study. An uncertainty factor of 10 was applied to convert from subchronic to chronic.	Diaz *et al*. 1994
As	2.4 mg/kg-day(1)	NOAEL	Mallard	100 mg/kg sodium arsenite (51.35 mg/kg As^{+3}) NOAEL (128 days).	Cowbirds were selected as more representative than mallard ducks as well as being more sensitive to arsenic. The NOAEL was selected since 20% mortality was observed at the LOAEL.	USFWS (1964)

Table 7-2 TRVs and Test Endpoints (cont'd)

Metal	TRV	Endpoint	Test Species	Test Endpoint		Reference
Meadow Vole						
Ni	34 mg/kg-day[(1)]	LOAEL	Rat	In a one generation study, increases in unborn pups were seen at 30, 50 and 75 mg/kg-day. In a two generation study, no affects were seen at the highest dose of 10 mg/kg-day. A two year feeding by Ambrose et al (1976) produced a NOAEL of 5 mg/kg-day and a LOAEL of 50 mg/kg-day. The LOAEL from the Springborn study was selected for reproductive effects as reasonable for use in this study.	The selected TRV is considered a threshold effects level based on the available data.	Springborn (2000a and b)
Cu	12 mg/kg-day[(1)]	NOAEL	Mink	110.5 mg/day dose dietary copper for 1 kg specimens was considered the NOAEL for a 357 day exposure.	The NOAEL for reproductive effects was considered the threshold effect level.	Bleavins and Aulerich (1981)
Co	14 mg/kg-day[(1)]	LOAEL	Rat	13.25 mg/kg-day cobalt in diet caused histological changes over 98 days. Although a somewhat lower NOAEL was estimated for cobalt chloride exposure to rats, the histological change endpoint are considered non severe and the LOAEL based on these was thus considered appropriate for use in this study.	The LOAEL from this study was selected since it was considered the threshold effect level.	Mollenhauer *et al*. 1985
As	1.2 mg/kg-day[(1)]	LOAEL	Mice	1.26 mg As/kg-day as soluble arsenite LOAEL (3 generation). Since the NOAEL developed for dogs (Byron *et al.*, 1967) is almost identical to the LOAEL developed from the 3 generation mice study, the latter was determined to be applicable for all mammals in this study. Sample *et al*. (1996) also report lethal doses in rodents similar to those observed in other mammals and concluded that the LOAEL of 1.26 mg As/kg-day selected in the current study is considered appropriate for assessing all mammals.	The LOAEL for dogs was almost identical to the NOAEL for mice and thus was considered a threshold response level.	Schroeder and Mitchener (1971)

Table 7-2 TRVs and Test Endpoints (cont'd)

Metal	TRV	Endpoint	Test Species	Test Endpoint		Reference
Raccoon						
Ni	26 mg/kg-day(1)	LOAEL	Rat	In a one generation study, increases in unborn pups were seen at 30, 50 and 75 mg/kg-day. In a two generation study, no affects were seen at the highest dose of 10 mg/kg-day. A two year feeding by Ambrose et al (1976) produced a NOAEL of 5 mg/kg-day and a LOAEL of 50 mg/kg-day. The LOAEL from the Springborn study was selected for reproductive effects as reasonable for use in this study.	The selected TRV is considered a threshold effects level based on the available data.	Springborn (2000a and b)
Cu	9.2 mg/kg-day(1)	NOAEL	Mink	110.5 mg/day dose dietary copper for 1 kg specimens was considered the NOAEL for a 357 day exposure.	The NOAEL for reproductive effects was considered the threshold effect level.	Bleavins and Aulerich (1981)
Co	10 mg/kg-day(1)	LOAEL	Rat	13.25 mg/kg-day cobalt in diet caused histological changes over 98 days. Although a somewhat lower NOAEL was estimated for cobalt chloride exposure to rats, the histological change endpoint are considered non severe and the LOAEL based on these was thus considered appropriate for use in this study.	The LOAEL from this study was selected since it was considered the threshold effect level.	Mollenhauer *et al*. 1985
As	0.94 mg/kg-day(1)	LOAEL	Mice	1.26 mg As/kg-day as soluble arsenite LOAEL (3 generation). Since the NOAEL developed for dogs (Byron *et al.*, 1967) is almost identical to the LOAEL developed from the 3 generation mice study, the latter was determined to be applicable for all mammals in this study. Sample *et al*. (1996) also report lethal doses in rodents similar to those observed in other mammals and concluded that the LOAEL of 1.26 mg As/kg-day selected in the current study is considered appropriate for assessing all mammals.	The LOAEL for dogs was almost identical to the NOAEL for mice and thus was considered a threshold response level.	Schroeder and Mitchener (1971)

Table 7-2 TRVs and Test Endpoints (cont'd)

Metal	TRV	Endpoint	Test Species	Test Endpoint		Reference
Shrew						
Ni	39 mg/kg-day(1)	LOAEL	Rat	In a one generation study, increases in unborn pups were seen at 30, 50 and 75 mg/kg-day. In a two generation study, no affects were seen at the highest dose of 10 mg/kg-day. A two year feeding by Ambrose et al (1976) produced a NOAEL of 5 mg/kg-day and a LOAEL of 50 mg/kg-day. The LOAEL from the Springborn study was selected for reproductive effects as reasonable for use in this study.	The selected TRV is considered a threshold effects level based on the available data.	Springborn (2000a and b)
Cu	14 mg/kg-day(1)	NOAEL	Mink	110.5 mg/day dose dietary copper for 1 kg specimens was considered the NOAEL for a 357 day exposure.	The NOAEL for reproductive effects was considered the threshold effect level.	Bleavins and Aulerich (1981)
Co	15 mg/kg-day(1)	LOAEL	Rat	13.25 mg/kg-day cobalt in diet caused histological changes over 98 days. Although a somewhat lower NOAEL was estimated for cobalt chloride exposure to rats, the histological change endpoint are considered non-severe and the LOAEL based on these was thus considered appropriate for use in this study.	The LOAEL from this study was selected since it was considered the threshold effect level.	Mollenhauer *et al*. 1985
As	1.4 mg/kg-day(1)	LOAEL	Mice	1.26 mg As/kg-day as soluble arsenite LOAEL (3 generation). Since the NOAEL developed for dogs (Byron *et al.*, 1967) is almost identical to the LOAEL developed from the 3 generation mice study, the latter was determined to be applicable for all mammals in this study. Sample *et al*. (1996) also report lethal doses in rodents similar to those observed in other mammals and concluded that the LOAEL of 1.26 mg As/kg-day selected in the current study is considered appropriate for assessing all mammals.	The LOAEL for dogs was almost identical to the NOAEL for mice and thus was considered a threshold response level.	Schroeder and Mitchener (1971)

Table 7-2 TRVs and Test Endpoints (cont'd)

Metal	TRV	Endpoint	Test Species	Test Endpoint		Reference
Red Fox						
Ni	26 mg/kg-day(1)	LOAEL	Rat	In a one generation study, increases in unborn pups were seen at 30, 50 and 75 mg/kg-day. In a two generation study, no affects were seen at the highest dose of 10 mg/kg-day. A two year feeding by Ambrose et al (1976) produced a NOAEL of 5 mg/kg-day and a LOAEL of 50 mg/kg-day. The LOAEL from the Springborn study was selected for reproductive effects as reasonable for use in this study.	The selected TRV is considered a threshold effects level based on the available data.	Springborn (2000a and b)
Cu	9.1 mg/kg-day(1)	NOAEL	Mink	110.5 mg/day dose dietary copper for 1 kg specimens was considered the NOAEL for a 357 d exposure.	The NOAEL for reproductive effects was considered the threshold effect level.	Bleavins and Aulerich (1981)
Co	10 mg/kg-day(1)	LOAEL	Rat	13.25 mg/kg-day cobalt in diet caused histological changes over 98 days. Although a somewhat lower NOAEL was estimated for cobalt chloride exposure to rats, the histological change endpoint are considered non severe and the LOAEL based on these was thus considered appropriate for use in this study.	The LOAEL from this study was selected since it was considered the threshold effect level.	Mollenhauer *et al*. 1985
As	0.92 mg/kg-day(1)	LOAEL	Mice	1.26 mg As/kg/d as soluble arsenite LOAEL (3 generations). Since the NOAEL developed for dogs (Byron *et al.*, 1967) is almost identical to the LOAEL developed from the 3 generation mice study, the latter was determined to be applicable for all mammals in this study. Sample *et al*. (1996) also report lethal doses in rodents similar to those observed in other mammals and concluded that the LOAEL of 1.26 mg As/kg/day selected in the current study is considered appropriate for assessing all mammals.	The LOAEL for dogs was almost identical to the NOAEL for mice and thus was considered a threshold response level.	Schroeder and Mitchener (1971)

Table 7-2 TRVs and Test Endpoints (cont'd)

Metal	TRV	Endpoint	Test Species	Test Endpoint		Reference
White tailed deer						
Ni	22 mg/kg-day(1)	LOAEL	Rat	In a one generation study, increases in unborn pups were seen at 30, 50 and 75 mg/kg-day. In a two generation study, no affects were seen at the highest dose of 10 mg/kg-day. A two year feeding by Ambrose et al (1976) produced a NOAEL of 5 mg/kg-day and a LOAEL of 50 mg/kg-day. The LOAEL from the Springborn study was selected for reproductive effects as reasonable for use in this study.	The selected TRV is considered a threshold effects level based on the available data.	Springborn (2000a and b)
Cu	7.9 mg/kg-day(1)	NOAEL	Mink	110.5 mg/day dose dietary copper for 1 kg specimens was considered the NOAEL for a 357 day exposure.	The NOAEL for reproductive effects was considered the threshold effect level.	Bleavins and Aulerich (1981)
Co	8.8 mg/kg-day(1)	LOAEL	Rat	13.25 mg/kg-day cobalt in diet caused histological changes over 98 days. Although a somewhat lower NOAEL was estimated for cobalt chloride exposure to rats, the histological change endpoint are considered non severe and the LOAEL based on these was thus considered appropriate for use in this study.	The LOAEL from this study was selected since it was considered the threshold effect level.	Mollenhauer *et al*. 1985

Table 7-2 TRVs and Test Endpoints (cont'd)

Metal	TRV	Endpoint	Test Species	Test Endpoint		Reference
As	0.8 mg/kg-day(1)	LOAEL	Mice	1.26 mg As/kg/day as soluble arsenite LOAEL (3 generation). Since the NOAEL developed for dogs (Byron *et al.*, 1967) is almost identical to the LOAEL developed from the 3 generation mice study, the latter was determined to be applicable for all mammals in this study. Sample *et al*. (1996) also report lethal doses in rodents similar to those observed in other mammals and concluded that the LOAEL of 1.26 mg As/kg/day selected in the current study is considered appropriate for assessing all mammals.	The LOAEL for dogs was almost identical to the NOAEL for mice and thus was considered a threshold response level.	Schroeder and Mitchener (1971)

Notes:

(1) TRVs scaled using equation 7-2.

Endpoints:

- $EC20_{est}$ Effects concentration estimated at which effects are expected in 20% of the population.
- LC_{10} Concentration lethal to 10% of test organisms
- LC_{50} Concentration lethal to 50% of test organisms
- LOAEL Lowest observed adverse effects level.
- LOEC Lowest observed effects concentration
- NOEC No observed effects concentration
- $NOEC_{est}$ Estimated no observed effects concentration
- NOAEL No observed adverse effects level

In summary, the TRVs for the CoCs are not based on the same effects. Following the methodology set out by the US EPA (2000) for human health risk assessment:

- The data are adequate for a quantitative evaluation of potential risks.
- The CoCs do not constitute a whole mixture comprised of similar components.
- Quantitative information is not available on interactions between the CoCs.

This leaves for consideration combined effects associated with toxicological similarity and toxicological independence of components of the mixture. For copper, the additivity of effects is not considered appropriate since the presence of other CoCs may serve to reduce the effects of copper. For the evaluation of combined effects based on toxicological independence, the addition of potential risk is recommended. The addition of risk quotients, where risk is identified for individual CoCs, is intended to provide information on the potential for combined effects, but is associated with a high degree of uncertainty.

For the evaluation of potential effects based on toxicological similarities, effects on some of the same organs have been observed for arsenic and cobalt, namely the liver and kidney. Although weight change in these organs has been observed for nickel exposure, the effects are not considered toxicologically similar. In the case of arsenic and cobalt, the addition of doses was considered appropriate for comparative purposes in evaluating the range of potential risks that may result from combined toxicologically similar effects.

8.0 RISK CHARACTERIZATION

8.1 Approach

Our integrated approach for assessing risk to the ERA's VECs involved two series of analyses. The first analysis, as described below, is a statistical examination of the relationship between ecological variables, such as biomass, and concentrations of CoCs in the local environment. The second analysis is an empirical evaluation of the presumed risk to which a VEC is subject. This was based on a calculated average daily dose (calculated using site-specific data and parameter estimates based on other published studies) or an estimated exposure concentration (see Section 6), and toxicity reference values (TRVs) taken from published studies (see Section 7). Taken as a whole, the potential risks to receptors were assessed using a line of evidence approach. Such an integrated system takes into consideration results of the conservative risk calculations, qualitative observation and examination of the site and its biota, together with informed professional judgement, to reach conclusions of whether VECs are potentially at risk. The following sections describe the process of quantifying risk of CoC exposure to the selected receptors and present results of these analyses. Overall evaluation of the results is presented in Section 9.

8.2 Mathematical Methods

Mathematical analysis for this ecological risk assessment comprised two parts: statistical analyses of site-specific biophysical data and quantitative estimation of potential risks based on TRVs and estimated exposures. The first analyses were performed to determine whether any observed relationships between ecological measures (e.g., biomass) and soil CoC concentrations were statistically significant (Section 8.2.1). The second set of analyses (Section 8.2.2) was done to determine the relationship between a receptor's estimated average daily dose of CoCs within the local environment and a TRV, as discussed in Section 7. Following the Quotient Method an assessment of potential risk was determined quantitatively by calculating a quotient, the ratio of the estimated VEC-Specific daily dose (Section 6.5) and CoC-specific TRV (Section 7.3).

8.2.1 Influence of CoC Concentrations on Measured Ecosystem Receptors

In this section, the method for statistically determining the effect of CoC concentrations on observed variation in receptor populations is described. The main statistical tool used was the Generalized Linear Model (*glm*), which is explained in Section 6.4.1 and in McCullagh and Neldar (1989). ESG International (now Stantec) using methods described in Section 8.3.2.2 performed statistical analyses of earthworm dose-response experiments. The variables used in the *glm* analysis for each component study are identified in Table 8-1. First-order interactions between the predictors were fitted against each response to determine, for example, if the relationship between earthworm abundance and soil nickel concentrations was influenced by soil type. More details regarding these analyses are provided in Section 8.3. Diagnostic plots and associated tables are provided in Volume III (Tab 3).

Table 8-1 List of VEC Responses, as well as Variables that may be used to Explain Variation in Responses

Response	Modifiers and Predictors
Frog Calls	
Species Richness	distance from lakeshore, habitat quality, soil nickel concentrations
Relative Abundance Western Chorus Frog Spring Peeper American Toad	distance from lakeshore, habitat quality, soil nickel concentrations
Incidence Northern Leopard Frog	distance from lakeshore, habitat quality, soil nickel concentrations
Earthworm Field Data	
Frequency Total *Lumbricus rubellus* *Aporrectodea tuberculata*	habitat, soil type, soil CoC concentrations
Incidence *Lumbricus terrestris*	habitat, soil type, soil CoC concentrations
Biomass Total *Lumbricus rubellus* *Aporrectodea tuberculata*	habitat, soil type, soil CoC concentrations
Species Richness	habitat, soil type, soil CoC concentrations
Maple Dose-Response	
Germination Success	soil type, seed origin, soil nickel concentrations
Seedling Height	soil type, seed origin, soil nickel concentrations
Seedling Leaf Number	soil type, seed origin, soil nickel concentrations
Seedling Leaf Health Class 1 (frequency) Class 2 (frequency) Class 3 (frequency)	soil type, seed origin, soil nickel concentrations
Maple Field Data	
Seedling Leaf Health Class 1 (frequency) Class 2 (frequency) Class 3 (frequency) Galls (frequency)	soil CoC concentrations, sampling design
Leaf Litter	
Leaf litter dry weight	soil type, total tree basal area, soil CoC concentrations
Dropped fruit dry weight	soil type, total tree basal area, soil CoC concentrations
Woody debris dry weight	soil type, total tree basal area, soil CoC concentrations

8.2.2 Quantitative Assessment of Potential Risk

For the VECs denoted in Table 4-1, an assessment of potential risk was quantitatively calculated using the Quotient Method (Equation 8-1; CCME 1997). A similar approach was used to evaluate potential risk to tadpoles and earthworms, using exposure concentrations in place of expected ADD.

$$Quotient = \frac{ADD}{TRV} \qquad \textbf{[8-1]}$$

where: ADD is the expected Average Daily Dose for a CoC; and,
TRV is the toxicity reference value for a CoC (see Section 7).

The Quotient Method is a standardized risk assessment method that is used to determine the ***potential or likelihood*** that ecological effects as a result of a CoC may be occurring or have occurred. For this method, where a calculated quotient has a value that is < 1, the potential for risk is considered to be low, in that there is a low probability that effects exist or will exist according to the specified TRV for the CoC and receptor being assessed. Where a calculated quotient has a value that is ≥ 1, an effect or effects have the potential to occur according to the specified TRV (CCME 1997) and a potential for risk is identified.

In risk assessment, the determination of potential for risk following the Quotient Method is considered a conservative assessment due to the often conservative approaches used in determining the TRV values for the CoCs and average daily dose for a specific VEC. As a result, derived quotient values that are less than 1, are considered to indicate that there is indeed a low potential risk and that further assessment is not required. However, a derived quotient greater than 1, indicates that a risk cannot be ruled out by the assessment performed. This initial assessment is then often further investigated following other lines of evidence, or through a more thorough investigation of the TRV and dose values used, species dynamics, or other methods.

For this ERA, since the way in which combined effects of the CoCs, if any, may impact on toxicity is not well understood (Section 7), a detailed numerical analysis of additive, synergistic or other interactions was not feasible (CCME 1997). Instead, the potential risk as indicated by a calculated quotient of each CoC was generally considered to be non-additive, and considered separately in this assessment. Available literature on such potential interactions are reviewed and discussed as a source of uncertainty in Section 7 and Section 10. An integrated evaluation of the calculated quotient for the identified receptors is presented in Section 9.

8.2.3 Combined Effects of Chemical Mixture

The US EPA (1986; 2000) recommendations and methodology for the quantitative evaluation of combined effects of chemical mixtures were used as the basis for the current evaluation of the CoCs as a chemical mixture. The hazard assessment previously identified evaluation of toxicologically independent effects of the components as appropriate as well as the evaluation of toxicologically similar effects from arsenic and cobalt. The following discussion is an adaptation of the human health methodologies outlined by the US EPA (2000) for evaluating these combinations of effects, adapted as appropriate to the evaluation of mammals and birds.

8.2.3.1 Evaluation of Combined Toxicologically Independent Effects

For the combining of independent effects, the methodology used is the addition of responses. In the ecological assessment the ratio of dose to TRV for mammals and birds is representative of risk or responses, with a ratio greater than 1.0 indicating a potential risk or response and a ratio less than 1.0 indicating no potential risk or response. In the summing of responses based on the independence of effects, ratios for component chemicals of less than one indicate no response. An example adapted from the US EPA (2000) is as follows:

Chemical	Exposure	TRV	Potential Risk
A	13	16	0
B	7	8	0
C	22	24	0
		Mixture Potential Risk = 0	

Zero is used to indicate a risk that is either a true zero (ie. sub-threshold risk) or small enough to be considered safe.

8.2.3.2 Evaluation of Combined Toxicologically Similar Effects

Effects were reviewed in Chapter 7 and similar effects were identified between arsenic and cobalt. For similar effects, the summation of doses is considered appropriate based on US EPA (2000) documentation. For the three chemical examples given above, the mixture risk would be estimated as follows for combined effects:

Chemical	Exposure	TRV	Ratio
A	13	16	0.8
B	7	8	0.9
C	22	24	0.9
		Mixture Potential Risk = 2.6	

In this case, although the risk of the individual components may be below a threshold, toxicologically similar effects may potentially pose a risk.

8.2.4 Safe Levels

Where significant potential ecological risk was identified, it was necessary to determine safe concentrations of CoCs in soils that do not pose an unacceptable risk (as defined for this ERA). Safe concentrations were determined in two ways. First, relationships between measured (in the field and laboratory) ecological responses and soil concentrations were estimated and used to predict safe concentrations through an evaluation of plotted results. Second, quantitative quotient calculations (Section 8.2.2) were modified to determine CoC concentrations at which the quotient for a VEC was < 1. The methods for calculating these safe levels are described below.

For each scenario, specific CoC concentrations were used for diet and soil, and the contribution of soil to an animal's average daily dose differed with the scenario. The proportion of an animal's daily dose due to soil for each CoC was calculated by dividing its soil dose by its total dose (Equation 8-2).

$$a = \frac{\mathrm{ADD}_{\mathrm{soil}}}{\mathrm{ADD}_{\mathrm{tot}}} \qquad \textbf{[8-2]}$$

This proportion, a, is then multiplied by the TRV (Section 7.2) to determine what dose due to soil exposure would allow for a total ADD equal to the TRV (i.e., where potential risk of adverse effects would have a value of 1). This assumes that the proportion holds true as CoC concentrations increase or decrease in soil and diet (see Equation 8-3).

$$b = a \bullet TRV \qquad \textbf{[8-3]}$$

The resulting dose due to soil, *b*, was used in the following formula (Equation 8-4) to solve for the soil CoC concentration, CoC_{safe}:

$$CoC_{safe} = \frac{b \bullet BW}{IR \bullet FR \bullet FS} \qquad \textbf{[8-4]}$$

where, BW = Body weight (kg)
IR = Food ingestion rate on a dry weight basis (kg/day)
FR = Fraction of total soil intake from the contaminated area (unitless)
FS = Fraction of soil in diet (kg/kg dry).

Assessment of the quantitative quotient calculations and other observations were considered together to estimate CoC concentrations that provide a general level of safety to the natural populations or community in the vicinity of Port Colborne (Section 9).

8.3 Risk Characterization for Receptors

Here results of mathematical methods used in assessing potential risk to selected receptors are presented. Each analysis is presented separately, and is followed by a discussion of the results for each receptor. A more complete, holistic discussion of the results is provided in Section 9.

8.3.1 Amphibians

As an indicator of the amphibian community in the area and as a representative of the local ***inland*** aquatic environment, frogs were assessed to estimate if the CoCs produced significant adverse effects. To assess potential risk to frog populations within the Study Area: tissue CoC concentrations were determined through chemical analyses for adult frogs (Section 6.4.2); potential risk to tadpoles was assessed using the Quotient Method (Section 8.2.2) and the incidence; and, relative abundance of local frogs and toad species was ascertained in the field for the Study Area through call surveys. Results of the latter two components are detailed below, as is a discussion regarding the presence and health of the nationally and provincially threatened Fowler's Toad.

8.3.1.1 Calculated Quotient for Tadpole

Based on toxicity data from sources discussed in Section 7, the potential risk of CoC concentrations in surface water (breeding ponds and ditches) to tadpoles was assessed for each CoC. For exposure, considering all surface water chemical data from the Study Area (24 sample sites), an upper confidence limit of the mean (UCLM) was derived for each CoC and used to evaluate risk to tadpoles under the assumption that 100% of their exposure to the CoCs was through absorption of surface water.

Where species-specific data for the Study Area's frog and toad species were unavailable, reported values for the related species were reviewed and the most appropriate conservative TRVs for a frog or toad species were selected. For reported LC_{50} values, EC_{20} values were calculated following Efroymson *et al*. (1997a,b). Section 7 details the TRVs reported in the literature and selected for this ERA. For the assessment two TRVs were used when possible, an estimated 20% effects concentrations (EC_{20}) and a 10% lethal concentration (EC_{10}) (Table 8-2).

Quotient calculations show that the frog population in the Study Area, as measured through tadpole exposure to CoCs, has a low potential risk from cobalt and arsenic, with each having a quotient value considerably less than 1. However, a calculated quotient of 18 for nickel and 2 for copper indicates that surface water concentrations for these CoCs are at levels that place tadpoles at a potential risk. The quotient values suggest that nickel possesses a greater potential risk than does copper. For nickel, with a safe level being 0.01 mg/l and following a simple back calculation of risk based on the TRV, specific nickel concentrations at roughly 80% (19/24) of the ponds and ditches within the Primary and Secondary Study Areas would put tadpoles at potential risk according to this conservative TRV.

Table 8-2 Calculated Quotient for Tadpoles in the Port Colborne Area.

CoC	Toxicity Reference Value (mg/l)		Exposure (Water) Concentration (mg/l)	Calculated Quotient	
	EC20	LC10		EC20	LC10
Nickel	0.01	N/A	0.178	**18**	-
Copper	0.008	N/A	0.018	**2**	-
Cobalt	0.01	0.01	0.006	0.6	0.6
Arsenic	0.008	0.01	0.005	0.6	0.5

Notes Bold type indicates calculated quotient > 1.
N/A – literature value for LC10 is less than background water concentrations in Southern Ontario.

8.3.1.2 Frogs in the Natural Environment

The health of the frog population in the Port Colborne area was assessed by surveying calling adults at 29 sites within and near the Study Area. Overall, frog species richness was typical of the region, as discussed in Section 3.8.4. A *glm* was fit to assess what relationship may occur between species richness at each survey station and soil nickel concentrations. Similarly, *glm*s were fit to evaluate if predictors cause a difference between sites where there was only one or no calling adults and sites where there were multiple adults for three widespread species: American Toad, Western Chorus Frog and Spring Peeper. Due to the larger number of sites where Northern Leopard Frog was not detected, this species' incidence (presence/absence) was fit in a *glm*. Other frog species were too infrequently encountered to assess statistically, although a discussion of Fowler's Toad is presented in Section 8.3.1.3.

Since site-specific CoC concentrations were not available for the frog survey stations (a limitation of this analysis), appraisal of CoC concentrations was done by categorizing areas within zones of contamination based on all available data pertaining to nickel concentrations in the 0-5 cm soil horizon. These zones (0-1000 mg Ni/kg, 1001-2000 mg Ni/kg and 2000+ mg Ni/kg) were fit into the model, as were the UTM Northing (used as a measure of location relative to Lake Erie, to control for modifying effects of habitat associated with climate and topography) and habitat quality score (0-4); based on the presence of non-urban and non-industrial land in the four quadrants surrounding the sampling station).

Results of these generalized linear models are presented in Volume III (Tab 3). No predictor provided a good fit to any of these *glm*s, leading to the conclusion that soil nickel concentration does not influence species richness, incidence or relative abundance of frogs in the area.

8.3.1.3 Fowler's Toad

To assess the risk to the Fowler's Toad population, a specific literature search was undertaken to review toxicity data on the effects of the CoCs on the egg, larval and adult stages for the species. This review identified that there are no reported TRVs based on exposures to CoCs in sediment or soil/sand for toads (egg/tadpole/adults for any species). However, species specific TRVs are found in the literature for all four CoCs with respect to eggs and tadpoles exposed in a solution of freshwater. As a result, quotient calculations could only be undertaken based on exposure of eggs and tadpoles to CoCs in the pond water.

The risk characterization was assessed based on the assumption of 100% exposure of eggs and tadpoles to pond water. As detailed in Table 8-3, the quotient calculation (i.e. <0.1) indicates that the potential risk to the Fowler's Toad population in the Study Area is very low, as estimated for 100% exposure of eggs and tadpoles to CoCs in the breeding pond water.

Table 8-3 Estimated Quotient for Fowler's Toad Eggs and Tadpoles due to CoCs in Breeding Pond Water.

CoCs	TRV (mg/l)		Exposure (Water) Concentration (mg/l)	Estimated Quotient	
	EC20	LC10		EC20	LC10
Nickel	N/A	0.40	0.019	-	0.05
Copper	5.0	6.0	0.003	<0.01	<0.01
Cobalt	N/A	0.2	0.001	-	<0.01
Arsenic	N/A	50.0	0.006	-	<0.01

The very low calculated quotient due to exposure to CoCs in water is considered critical as this exposure pathway represents the greatest risk to eggs and tadpoles (Sparling *et al*. 2000). With respect to exposure of tadpoles to CoCs in sediments in the breeding pond (Section 6.5.4.2), two exposure pathways were identified: direct dermal exposure (tadpole lying on the bottom of the pond) and ingestion of sediment during feeding. However, given the low potential risk associated with CoCs in water, potential additive risk of CoCs in the pond sediment would have to be an order of magnitude higher for all the CoCs before it was potentially significant. This magnitude of additive risk as a result of CoCs in pond sediment is not expected and is not supported by field observations (see Section 3.8.4.1) that documented successful survival of tadpoles and emergence of young adults from the breeding pond.

With respect to the potential risk to young and adult toads that live on and burrow in the sand dunes along the lakeshore, no data are reported in the literature that has investigated the potential risk of the four CoCs in sand or soil for adult toads (of any species). However, results of sampling of the sands along the lakeshore in the Study Area have shown that values for arsenic, copper and cobalt are below current MOE Guidelines for coarse textured soils (MOE 1997). Sand nickel values range from a high of 239 mg/kg (based on 0-15 cm soil cores) at Nickel Beach to 62 mg/kg (based 0-5 cm soil cores) at the breeding pond location. The MOE guideline for nickel in coarse textured soil is 150 mg/kg and 200 mg/kg for fine textured soils. Based on these criteria, it is reasonable to conclude that the low values found in the sand dunes along the shoreline do not pose an unacceptable risk to adult Fowler's Toads. Again, this conclusion is supported by field observations that indicate a viable breeding population has persisted in the local area for an extended period of time, with the last reported record prior to this study being in the 1940s (NHIC 2002).

8.3.1.4 Summary of the Effects of CoCs on Frogs

An assessment of potential risk using the Quotient Method based on effects described in the published literature is conservative and not specific to the Port Colborne area. However, these calculations do indicate that nickel, and to a lesser degree copper, are found in sufficient concentrations in surface water to pose a potential risk to larval frogs (tadpoles). As a measure of the health of the local frog community, breeding call surveys indicate that a typical suite of frog species is present in the Port Colborne area. Also analysis of the data found that the distribution of calling males is not related to soil nickel concentrations. However, CoCs found in water and sediment may have more bearing on the CoC uptake of frogs (Section 6.4.2). Furthermore, data available for this analysis do not allow a finer examination of distribution and CoC concentrations, although no significant difference in frog distribution was apparent between areas with >2000 mg/kg of nickel and <1000 mg/kg of nickel. A full analysis of the potential risk to the local frog and toad populations of the Study is detailed in Section 9.

The provincially and nationally threatened Fowler's Toad was found in the Study Area, along the Lake Erie shoreline. Based on available information in the literature and site-specific CoC concentrations collected for water of the breeding pond, existing concentrations of CoCs in surface water do not pose a risk to tadpoles. Due to the lack of toxicity data for an evaluation of potential adverse effects of CoCs in pond sediments on tadpoles, and sand for adult toads, risk for these pathways could not be assessed. However, observations of Fowler's Toad populations, including observations of successful hatching and metamorphosis of larvae to adults, support the low potential for risk based on the calculated quotients. Overall, our field observations indicate that the frog populations in the Port Colborne area are typical of the region and appear healthy (based on local abundance identified by calling surveys), despite the conservative quotient calculation indicating a potential risk from nickel concentrations present in surface water.

8.3.2 Maples

The risk to soft maples (Silver Maple, Red Maple or hybrids) in the Port Colborne area was assessed in three different ways. Firstly, seeds were taken from wild-growing maples and grown in a controlled experimental setting to examine their response to varying CoC concentrations in Port Colborne soils. Secondly, health of individual trees growing in a natural setting was assessed by evaluating leaf condition in relation to CoC concentrations found in the surrounding soils. Thirdly, the overall health of woodlots found in the area was assessed. The following sections quantify the potential risk of CoC exposure to maples and describe the overall health of the woodlots within the Port Colborne area.

8.3.2.1 Dose-response Experiments with Maple

As outlined in Volume II (Tab 9), soft maples were grown in a controlled environment within a greenhouse to assess their response to soil CoC concentrations in Port Colborne clay and organic soils. Responses examined were germination success, plant height, number of leaves and leaf health (Table 8-4; see also Volume III, Tab 2). Leaf health was assessed using a four-class qualitative system (1 = most healthy, 4= most unhealthy), and the number of leaves dropped by the seedling during the trial was noted (Volume III, Tab 2). Soil CoC concentrations were derived by mixing soils in proportions intended to result in nickel concentrations of background levels, 500 mg/kg, 1500 mg/kg and 3000 mg/kg; these values were used for statistical analyses and fit as a predictor (soil nickel concentration) in the *glm.* This predictor is representative of all CoC levels present in each treatment, and the influence of what we present as soil nickel concentrations may actually be an influence of one or more other CoCs found in the soil.

Table 8-4 Analysis of Deviance Table. The Response Variables are Maple Germination Success, Seedling Height and Numbers of Class 1 and Class 3 Leaves.

		Germination Success		Seedling Height		Number of Class 1 Leaves		Number of Class 3 Leaves	
Term	**df**	**Dev**	***p***	**Dev**	***p***	**Dev**	***p***	**Dev**	***P***
Null	47	58.67		33.18		91.13		92.56	
Soil Nickel Concentration	1	<0.01	0.98	0.61	0.28	0.35	0.55	4.42	**0.04**
Seed Origin	1	8.10	**<0.01**	1.65	0.08	0.64	0.42	1.93	0.17
Soil Type	1	1.53	0.21	7.18	**<0.01**	18.82	**<0.01**	20.71	**<0.01**
Soil Nickel Concentration: Seed Origin (Interaction)	1	5.14	**0.02**	2.70	**0.03**	1.08	0.30	4.00	**0.05**
Soil Nickel Concentration: Soil Type (Interaction)	1	1.53	0.22	<0.01	0.94	1.67	0.20	5.24	**0.02**
Seed Origin: Soil Type (Interaction)	1	0.50	0.48	0.43	0.36	0.09	0.77	1.04	0.31
Residual	41	41.88		20.61		68.49		55.22	

Notes The model of seedling height was fit as Gaussian while the others were fit as binomial models. Bold type indicates a p-value of ≤0.05.

Figure 8-1 and similar graphs plot data and general trend lines, created using locally weighted regressions with spans of 0.9. They are used only for the purpose of illustrating trends or general patterns, and are not intended to be used for quantitative prediction or modelling of response. Further information is provided in Volume III.

Plant germination ranged from 20-100% (1-5 seeds; Figure 8-1). Although there was no significant overall effect of CoC concentration, an interaction between nickel concentration and seed origin was noted (Table 8-4), with germination success of seeds from the Reference Study Area decreasing with an increase in soil nickel concentrations. Seeds from the Primary Study Area were less successful at germinating overall, but showed increased success at higher nickel levels (Figure 8-1). Although this is based on multiple seeds taken from a few trees, there is an indication that local adaptation may have taken place, since local seeds responded better than seeds from outside of the CoC impacted area. The influence of seed origin also contributed to the fit of *glm*s of seedling height and the number of relatively unhealthy, Class 3 leaves (Table 8-4). Although soil nickel concentration was not noted as a significant predictor of seedling height, an interaction between nickel concentrations and seed origin was observed (Table 8-4), with local seedlings growing to taller heights as nickel increases while reference seedlings do not show this effect (Figure 8-2). Overall, seedlings in organic soils grew taller than those grown in clay soils (Figure 8-3). No predictors provided a significant fit to the *glm* for leaf number.

In further relation to plant health, only four leaves dropped from plants. Over 70% of the leaves were considered referable to the healthiest class, and only 12 leaves were considered to belong to the worst health class (11 from organic soils). These Class 4 leaves were too rare to analyze using *glm*, and Class 2 leaves were not linked to any predictor (Volume III, Tab 3). Relatively unhealthy, Class 3 leaves were related to CoC concentration, soil type and seed origin (Table 8-4). A slight difference between the two seed types was noted at the nickel concentration of 1500 mg/kg, although the number of Class 3 leaves was lower at the highest concentration (Figure 8-4). This was true overall, with higher numbers of Class 3, unhealthy leaves at lower nickel concentrations, particularly on plants grown on organic soils (Figure 8-5). A difference between soil types was also noted for Class 1 leaves, with fewer found on seedlings grown on organic soils than on clay soils (Figure 8-6).

Overall, despite differences between soil types and the origin of seeds, the Greenhouse study indicates that increased CoC concentrations up to 3000 mg/kg nickel do not negatively affect maple germination or growth.

Figure 8-1 Germination Success of Maple Seeds Planted in Soils with Different CoC Concentrations (Represented by Nickel Concentrations) in a Controlled Environment. Circles & solid line = seeds from Reference Study Area, triangles & dotted line = seeds from Primary Study Area.

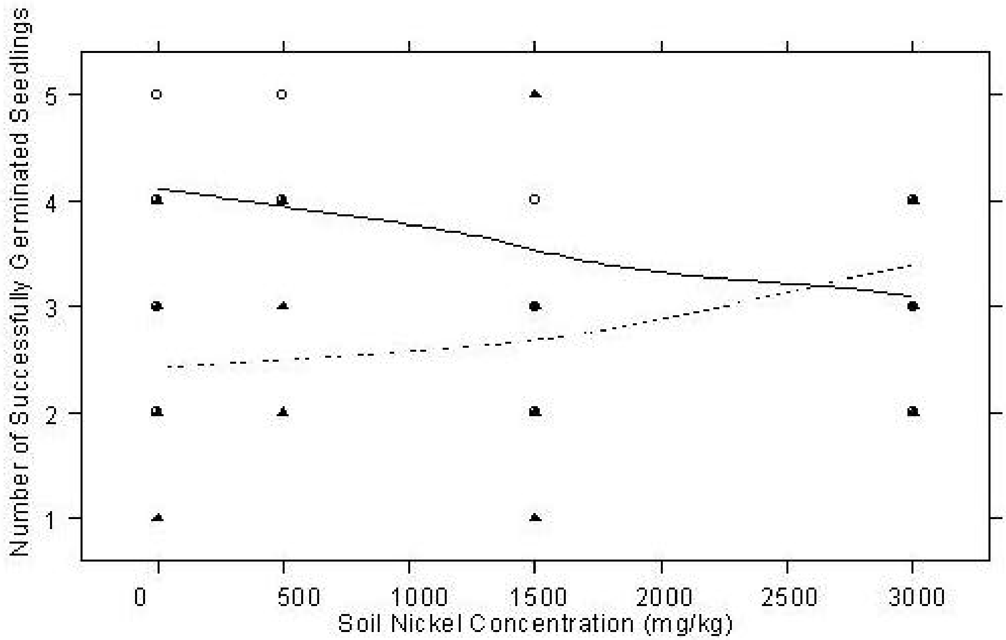


Figure 8-2 Height of Maple Seedlings Planted in Soils with Different CoC Concentrations (Represented by Nickel Concentrations) in a Controlled Environment. Circles & solid line = seeds from Reference Study Area, triangles & dotted line = seeds from Primary Study Area.

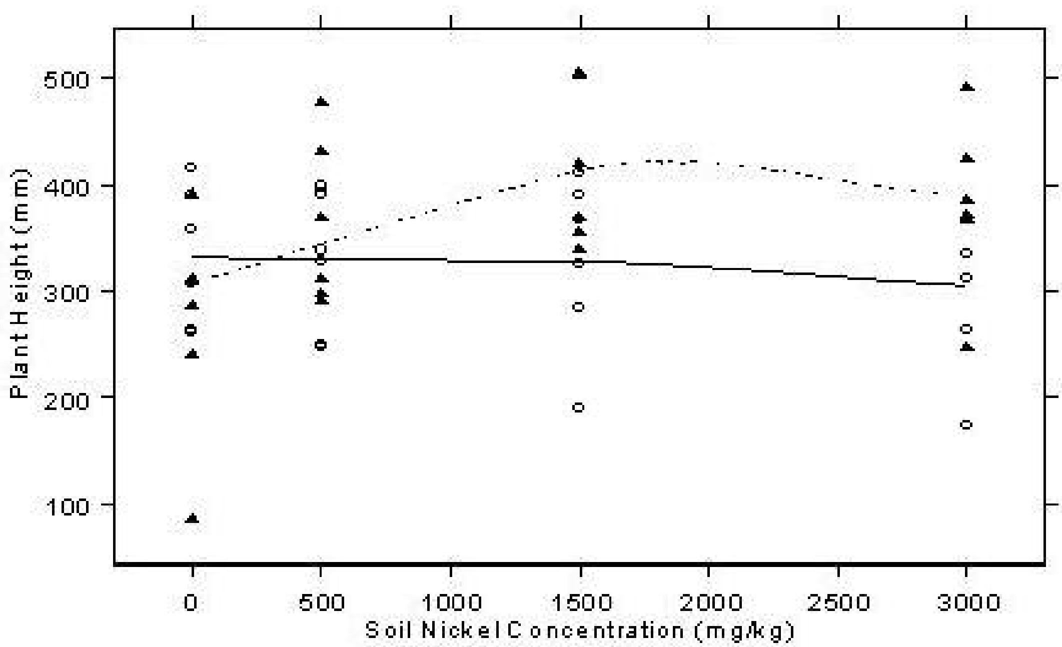


Figure 8-3 Height of Maple Seedlings Planted in Different Soils.

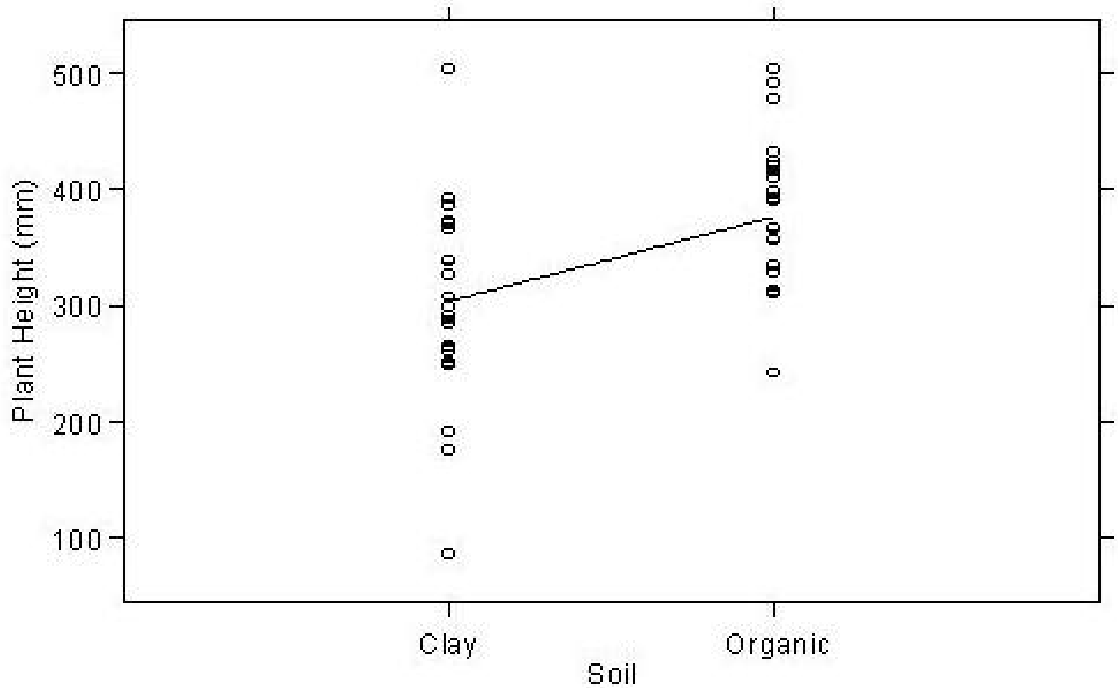


Figure 8-4 Number of Class 3 Leaves on Seedlings Grown in Soils with a Range of CoC Concentrations. Circles & solid line = seeds from Reference Study Area, triangles & dotted line = seeds from Primary Study Area.

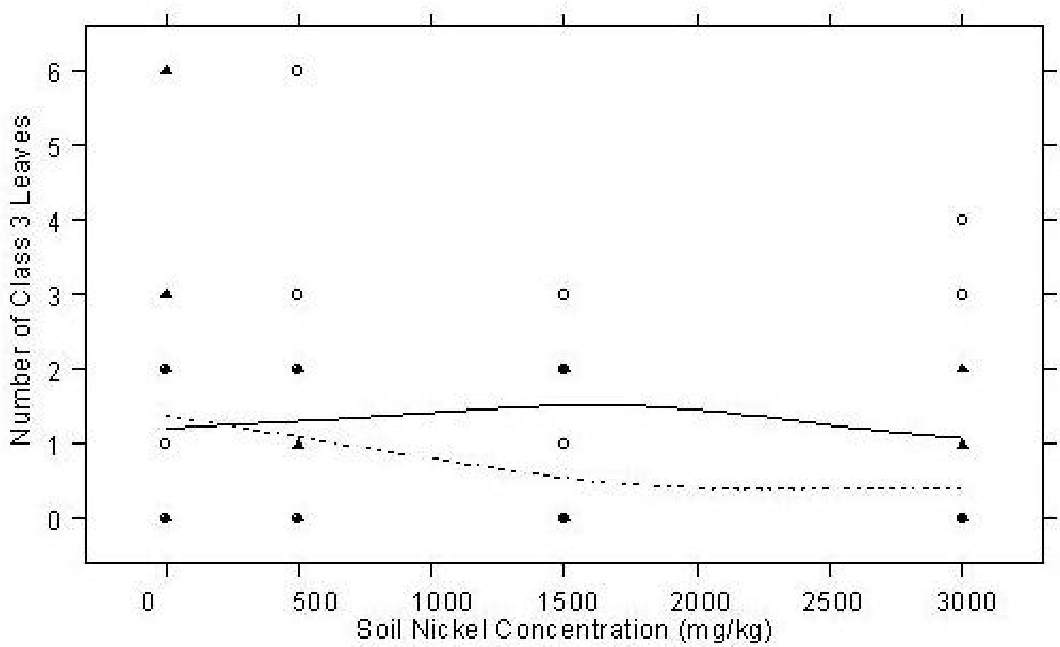


Figure 8-5 **Number of Class 3 Leaves on Seedlings Grown in Soils with a Range of CoC Concentrations. Circles & solid line = clay soils, triangles & dotted line = organic soils.**

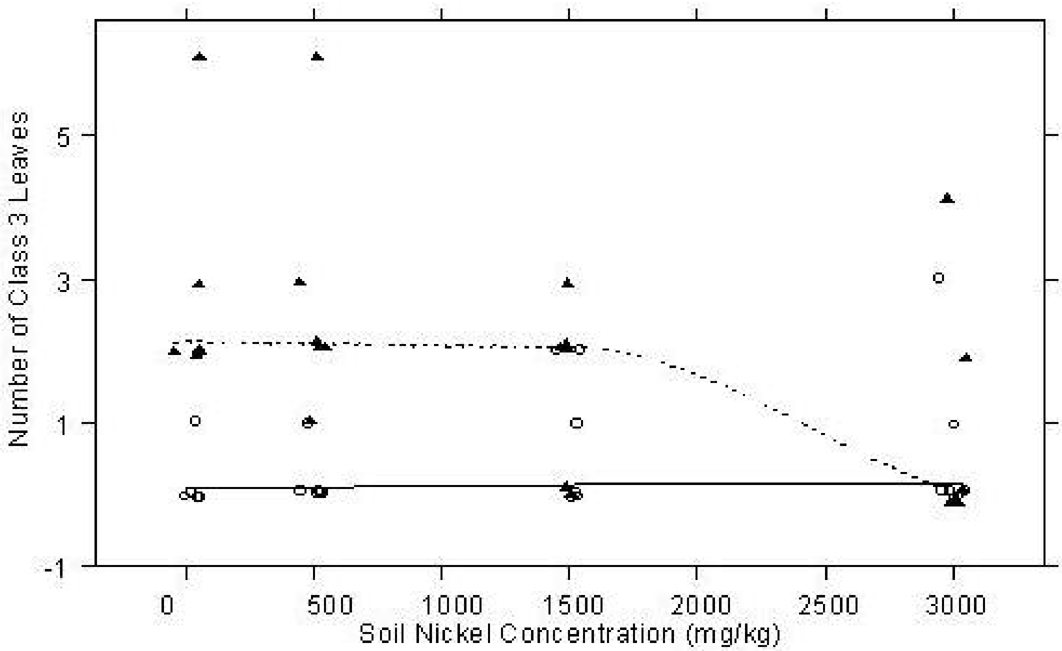
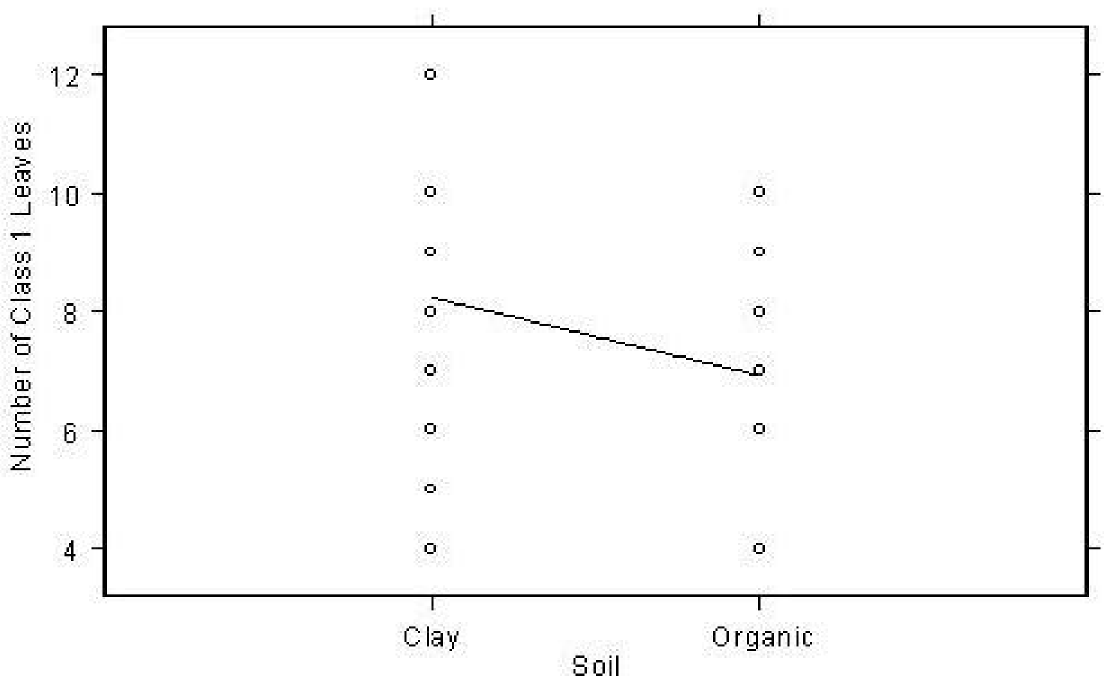


Figure 8-6 **Number of Class 1 Leaves on Seedlings Grown in Soils with a Range of CoC Concentrations.**



8.3.2.2 Maples in the Natural Environment

The health of twelve leaves from each tree sampled in the Study Area was evaluated using a four-level classification (McIlveen and McLaughlin 1993), and recorded in addition to the incidence of galls on each leaf (Volume II, Tab 14). The response of naturally growing maple to CoCs was assessed by examining the relationship between the frequency of each of the four leaf classes and the frequency of leaves exhibiting galls with soil CoC concentrations. Sampling design was incorporated into the models as a modifying variable (a necessary addition to the model, but uninteresting to the analysis).

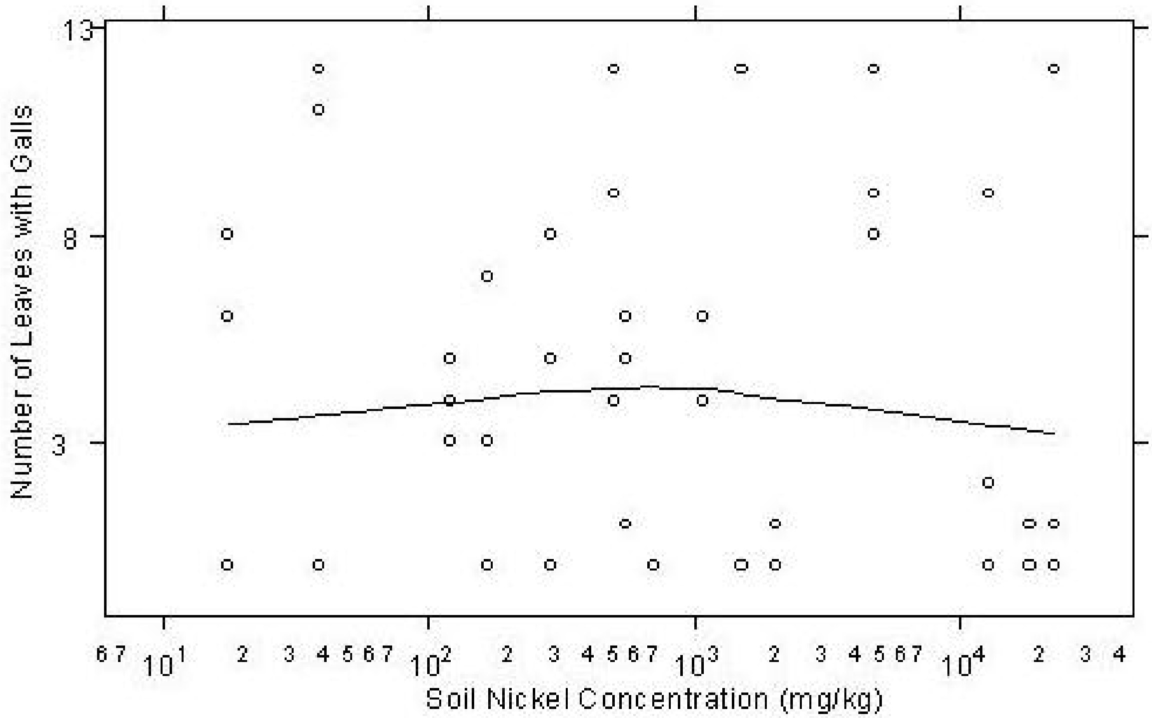
Of the 576 leaves assessed (Volume III, Tab 1), over three-quarters were identified as having a Class 2 health (2-10% injured; McIlveen and McLaughlin 1993) and one-seventh of the leaves were classed as Class 3 (11-35% injured). Only four leaves were found to be so badly injured as to warrant placement in Class 4 (>35% injured) and were not analyzed statistically as a result. Approximately 35% of the leaves exhibited galls, probably created by Maple Bladder Gall Mites (*Vasates* sp.).

Only soil nickel concentration emerged as a significant predictor of leaf galls (Table 8-5). The number of leaves displaying galls decreased once soil levels of nickel exceeded 10,000 mg/kg (Figure 8-7). The frequencies of leaf health classes were not linked to any CoC (Volume III, Tab 3).

Table 8-5 Analysis of Deviance Table. The Response Variable is Frequency of Maple Leaves with Galls, Fit as a Binomial Model. Bold type Indicates a p-value of £0.05.

		Galls	
Term	**df**	**Dev.**	***p***
Null	47	405.94	
Soil Nickel Concentration	1	4.02	**0.05**
Treatment	2	3.08	0.21
Site within Treatment	3	9.09	**0.03**
Residual	41	389.75	

Figure 8-7 Number of Leaves Exhibiting Galls on Trees Sampled Over a Range of Soil Nickel Concentrations in the Port Colborne Area.



8.3.2.3 Woodlot Health Assessment

For the ERA, the need for the assessment of the overall health and long-term viability of woodlots in the Study Area was identified for two reasons. First, as detailed in Section 3.2.1, a number of woodlots within the Study Area have been identified as Environmentally Significant Areas (ESAs) within the Niagara Region. The ESA designation of these woodlots is primarily due to size and community structure (e.g., age, species). Secondly, through the CBRA public participation process, concern was raised regarding the absence and/or death of older trees in woodlots, and that the long term "overall health" of woodlots in the Study Area may be impacted by CoCs in the soil.

To address the ecological risk of overall woodlot health to soil CoCs, the ERA included an assessment of 18 woodlots in the Study Area. These woodlots (totalling 232 ha, representing 82% of the Study Area's forest cover) were compared to six woodlots in the Reference Area located east of the Study Area. For the forest health study, individual woodlots were divided into study compartments and assessed for a number of forest parameters (32 compartments in total for the 18 Study Area woodlots and 7 compartments in total for the 6 control woodlots). The methods used in the woodlot assessment are detailed in Volume II (Tab 17). The locations of the forest compartments used in the woodlot assessment are presented in Map 3 (Tab 16). The findings of the study are detailed in a separate report that is presented in its entirety in Volume IV. The following provides a summary of the study's findings.

Stand Structure

For the assessment of stand structure, the total basal area of trees in each compartment was measured and the mean basal area was calculated. The mean basal area for the Study Area's woodlots (28.3 m^2/ha) and reference woodlots (28.9 m^2/ha) were not significantly different. Based on six size classes (saplings, poles, small saw log, medium saw log, large saw log and extra large saw log), the mean basal area for the "pole" size class was greatest (by percent total basal area) for both the Study Area (41%) and reference woodlots (37%). For both Study Area and reference woodlots, polewood abundance is greater than expected. Based on an age assessment, it was determined that current polewood conditions became established between 1957 and 1972. The present dominance of polewood in the Study Area's woodlots could have resulted from a number of factors, such as removal of larger trees through logging and/or disease, resulting in better conditions of sapling growth. The reduction of grazing pressure from livestock starting in the 1960s may also have been a contributing factor for current observed abundance of polewood. In addition, a comparison of the species representing polewood indicates the species composition of the Study Area and reference woodlots are similar, with a dominance of soft maples (Red Maple and Freeman's Maple) and ashes. Based on an age estimate of the polewood present, it was determined that they became established (time of germination and sapling growth) in local woodlots starting 30 - 45 years ago. That polewood became established during this period is important as it coincides with the period of peak atmospheric deposition of CoCs from the refinery, and indicates that past and present levels of soil CoCs did not, and do not, inhibit natural forest regeneration in Port Colborne.

Similar results were obtained for mean stocking estimates (stems/ha), with no significant difference between Study Area woodlots and reference woodlots for all size classes, except for saplings. With respect to stocking, the Study Area woodlots had more than 200 stems/ha more than reference woodlots. Again, though not desirable from a silvicultural perspective for maximising harvestable wood, the abundance of saplings in the Study Area woodlots indicates that past and present levels of soil CoCs do not inhibit natural forest regeneration. The findings of this field assessment of woodlots in the Study Area are supported by the results of the dose-response experiments on seedlings as detailed above. These indicate that seed germination and seeding/sapling growth are not significantly impaired in soils where nickel concentrations are as high as 3000 mg/kg.

Species Composition

Two measures were used to determine species composition for each woodlot compartment: woody species diversity (number of trees, shrubs and vines species) and tree species composition of woodlot compartments. In the Study Area, the number of woody species per compartment ranged from a low of 8 species to a high of 26 species. For the reference woodlots, the number of woody species ranged from a low of 14 to a high of 25 species. An analysis of all compartments determined that there was no statistically significant difference in the total number of woody species between Study Area woodlots and reference woodlots.

With respect to tree species, woodlots in the Study Area had as few as 3 species to a high of 13 species, while reference woodlots had the number of tree species ranging from 6 to 14 species. For both Study Area and reference woodlots, soft maples and ashes were the dominant trees. With respect to the species composition represented by tree regeneration (seedlings/saplings), ashes, Black Cherry, soft maples and White Elm dominated the Study Area's woodlots. Blue Beech and Sugar Maple are present but to a lesser degree. Regeneration species in the reference woodlots include soft maple, Blue Beech, Sugar Maple and Beech. Tolerant shade species such as Black Cherry, ashes and elms are present but in lesser amounts.

The assessment of woody species diversity and regeneration of tree species strongly indicates that past and current levels of soil CoCs have not resulted in a significant reduction of woody species diversity within woodlots located downwind of the Refinery. These results indicate that woody species diversity in woodlots with elevated levels of soil CoCs is expected to be maintained through the future life spans of the area's woodlots. The results of the woodlot health study are consistent with the findings of the general inventory of tree and shrub species conducted in the Primary Study Area for the ERA (Section 3.8.1). It was also found that tree and shrub species that are typical to the Niagara Region are also found to occur in woodlots located in areas directly adjacent to the refinery where CoCs soil levels are the highest. It is also important to note that the study found the woodlot (O1C) that had the highest number of woody species (26) was the dune forest found along the shore of Nickel Beach located directly adjacent to the Refinery. As noted in Section 3.7, this woodlot is a significant natural feature in the Niagara Region, yet has soils with high CoC concentrations.

Woodlot Productivity

The measurements of mean maximum height, average age of trees, and mean stand diameter for woodlot compartments were used to assess woodlot productivity. These productivity parameters allow for a long-term (50+ years) assessment of potential effects of soil CoCs (as well as historic atmospheric CoCs) on general tree bio-chemical and bio-physiological process. Although an assessment of general productivity measures cannot determine specific causal effects of soil CoCs on tree productivity, a lower productivity in the Study Area woodlots (when compared to those in the Reference Area) could, as a general measure, indicate overall toxicological effects to trees and woodlots.

Results of the mean maximum height for the woodlot compartments indicate that there is no significant difference between the Study Area woodlots (24.2 m) and reference woodlots (25.5 m). Woodlots located directly adjacent to the Refinery (O1A, 1B, O1C and O2A) had mean maximum heights that were either at the average value or higher. Similarly, the mean tree diameter for woodlot compartments in the Study Area (31.4 cm) and in the Reference Area (32.8 cm) were very similar and not statistically different. The average age of the dominant canopy trees within the Study Area was 74 years, while for the reference woodlots, the average age was 90 years. For both the Study Area and Reference Area, all compartments are considered to be unevenly aged, with multiple age classes represented in the compartments. In general, the forests associated with the dunes along the Lake Erie Shore, both in the Study and Reference Areas, are the oldest aged stands, with an average age of 107 years. This older age is almost certainly a result of the absence of historical logging in these dune forests.

The above findings strongly indicate that prolonged (50+ years) exposure to both soil and atmospheric CoCs has not resulted in a significant observable reduction in the overall growth and productivity of the woodlots located downwind of the Refinery. The results of the study found that the productivity of woodlots exposed to elevated concentrations of CoCs is very similar to that of reference woodlots.

Wildlife Habitat Trees

Wildlife habitat trees are trees with cavities (woodpecker holes, natural cracks and rots) or snags (broken limbs and tops) that provide nesting, roosting and protected areas for many forest birds and mammals. In addition, downed woody debris (e.g., limbs, tree trunks, branches) promote microbial soil production and help preserve soil moisture during dry periods. Typically, wildlife habitat trees are represented by larger mature trees or older over-mature trees in a woodlot. In a healthy forest or woodlot, the Ontario Ministry of Natural Resources has identified a minimum target of 5 m^2/ha. For the study, it was determined that mean total basal area of wildlife trees for the Study Area woodlots was not significantly different from that of control woodlots and that 26 of the 31 woodlots had compartments that were above this minimum threshold. The assessment determined that the woodlots downwind of the Refinery host good wildlife habitat trees, which is an important factor in maintaining wildlife population numbers and species diversity. This assessment also indicates that the basal area of larger trees with cavities, snags or broken limbs – features which could be used to identify them as "dying trees" – is similar in both woodlots immediately downwind of the Refinery and woodlots that have not been exposed to elevated levels of either soil or atmospheric CoCs.

8.3.2.4 Summary of Effects of CoCs on Maples

Controlled experiments examining the response of maple seeds and seedlings to a range of soil CoC concentrations indicate that increased CoC concentrations up to 3000 mg/kg nickel do not negatively affect maple germination, growth or health. This was further supported with results from the analyses of leaf health from maples naturally growing in the Port Colborne area. Only the frequency of leaves attacked by galls appeared to be suppressed in trees growing in very high concentrations of nickel, yet relative leaf health did not differ across the range of nickel, copper, cobalt or arsenic concentrations.

Findings of the forest health assessment are in agreement with the controlled experiments and leaf health assessment. The assessment of 82% of the forested areas in the Study Area found that past and current soil CoCs levels have not resulted in a significant reduction of primary forest health parameters, including stand structure, species composition and woodlot productivity. The woodlot health assessment found that woodlots located nearest to the Refinery, where soil nickel levels are highest (ranging from 3,000 mg-Ni/kg to up to 33,000mg-Ni/kg) were equal to or better than other woodlots for the parameters assessed.

8.3.3 Decomposers

Earthworms were selected as indicators of the decomposer community, and were assessed using three methods: the Quotient Method outlined earlier, a dose-response experiment using mixtures of the Study Area's soils, and an evaluation of field data examining worm species richness, biomass, density and tissue CoC concentrations (the latter is discussed in Section 6.4). Results of these analyses are provided below, as well as the results of an examination of leaf litter, which can be used by inference to evaluate the decomposer community on the whole.

8.3.3.1 Earthworm Quotient Calculations

Potential risk was calculated for earthworms using the equations similar to the Quotient Method to compare TRVs, as outlined in Section 7, and the UCLM of soil CoC concentrations found within the bounds of the Study Areas and adjacent lands (Section 6.5). For this study, an earthworm's exposure was assumed to be equal to the CoC concentrations in the surrounding soil, correcting for presumed bioavailability (Section 6.5). This method of calculation is considered to be a conservative approach, since earthworms are expected to obtain some portion of their exposure from detritus, which would appear to have much lower CoC concentrations than the surrounding soils based on concentrations in maple leaf tissue (Section 6.4.3).

Four scenarios were examined: exposure to soils in clay fields, clay woodlots, organic fields and organic woodlots. Risk was calculated based on exposures derived using two methods, as discussed in Section 6.5.4.3. Tables 8-6 and 8-7 present comparisons between exposure concentrations and derived TRVs for the four scenarios. Table 8-6 includes exposures estimated using aqueous extraction for nickel, copper and cobalt, and Table 8-7 includes exposures estimated using the acid ammonium oxalate extraction.

Table 8-6 Calculated Quotient for Earthworms in the Port Colborne Area, with Exposure Estimated Using Aqueous Extraction.

CoC	TRV (ppm)	Exposure Concentration (mg/kg)				Calculated Quotient			
		Clay		Organic		Clay		Organic	
		Woodlot	Field	Woodlot	Field	Woodlot	Field	Woodlot	Field
Nickel	3000	11.4	7.6	45.6	6.1	<0.01	<0.01	0.02	<0.01
Copper	50	2.9	2.2	6.0	0.9	0.06	0.05	0.1	0.02
Cobalt	3000	0.3	0.3	3.7	0.6	<0.01	<0.01	<0.01	<0.01
Arsenic	21	12	8	83	20	0.57	0.38	**4.0**	0.95
Notes	Bold type indicates the calculated risk > 1.								

Table 8-7 Calculated Quotient for Earthworms in the Port Colborne Area, with Exposure Estimated Using Acid Ammonium Oxalate Extraction.

CoC	TRV (ppm)	Exposure Concentration (mg/kg)				Calculated Quotient			
		Clay		Organic		Clay		Organic	
		Woodlot	Field	Woodlot	Field	Woodlot	Field	Woodlot	Field
Nickel	3000	539	360	5960	792	0.2	0.1	**2**	0.3
Copper	50	180	140	1621	248	**4**	**3**	**30**	**5**
Cobalt	3000	5.4	4.5	134	23	<0.01	<0.01	0.05	0.01
Arsenic	21	12	8	83	20	0.57	0.38	**4.0**	0.95
Notes	Bold type indicates the calculated risk > 1.								

Using the aqueous extraction of nickel, copper and cobalt to estimate the exposure of earthworms to bioavailable concentrations of these CoCs, it is apparent that earthworms are not at risk in the Study Area (Table 8-6). However, using the more powerful acid ammonium oxalate extraction, exposure is estimated to be at levels higher than the TRVs, indicating potential risk due to nickel and copper concentrations. For nickel, a calculated safe total soil concentration in woodlots on organic soil is approximately 7600 mg-Ni/kg based on this conservative (over) estimate of exposure. Safe total copper concentrations would be in the range of 50-60 mg-Cu/kg, depending on the scenario. Earthworms would be placed at risk due to arsenic only in woodlots on organic soils, with a safe soil concentration being equal to 21 mg-As/kg.

TRVs for earthworms derived in laboratory settings are often based on the addition of soluble salts of chemicals to soil. For nickel, unlike the other CoCs, the TRV selected for earthworms is specific to the species of nickel found in the soils in the natural environment, namely nickel oxide, rather than a soluble form. For this reason, the adjustment for bioavailability applied to copper, cobalt and arsenic in Port Colborne soils, is less applicable to nickel.

Nickel in Port Colborne soils is expected to be somewhat less bioavailable than pure nickel oxide added to soil in a laboratory setting similar to that on which the TRV value is based; however, the amount of conservatism in this value is less clear than for the other CoCs. Since the earthworms in the nickel TRV study were exposed to nickel oxide, the bioavailability was low in both the TRV study and the Port Colborne environment. The use of bioavailability adjusted quotients is therefore not conservative. A safe value for nickel in Port Colborne soils could therefore be expected to fall somewhere between the TRV value and the total soil nickel concentration adjusted for bioavailability based on the extraction methods.

8.3.3.2 Earthworm Dose-Response Experiment

ESG International (now Stantec) performed dose-response experiments with *Eisenia andrei*, using soils taken from the Port Colborne area (see Jacques Whitford 2003a for a discussion of soil blending). Phase 1 was an examination of acute toxicity in clay and organic soils, where worms were subject to these soil types from the Reference Area and the Primary Study Area. An initial examination of chronic toxicity of Study Area soils to earthworm health was also performed as part of Phase 1. Phase 2 was chronic dilution testing, which was an observation of lethal and sublethal effects to clay and organic blended soils. Measured responses included the number and biomass of juveniles, and numbers of hatched and unhatched cocoons. Organic and clay soils taken from the Primary Study Area were diluted with uncontaminated organic and clay soils of the same soil type from the Port Colborne area, in various proportions to approximate soil CoC concentrations from the Study Area, as outlined in Volume II (Tab 10) and Table 8-8. The predicted soil CoC concentrations for the blends of clay and organic soils are listed in Table 8-8.

Table 8-8 Predicted CoC Concentrations (mg/kg) in Soil Blends for the Phase 2 Earthworm Dose-Response Experiment.

Ratio (High[1]: Reference)	Clay				Organic			
	Ni	Cu	Co	As	Ni	Cu	Co	As
0:100	52[2]	20[2]	5[2]	2.6[2]	100[2]	43[2]	6[2]	8.2[2]
5:95	482	70	11	4.3	615	120	13	10.6
12:88	1084	141	19	6.6	1336	229	24	13.9
25:75	2203	272	34	11	2675	430	43	20
50:50	4354	523	63	19.4	5250	817	80	31.8
80:20	6934	825	97	29.5	8340	1281	124	45.9
100:0	8655[2]	1026[2]	120[2]	36.2[2]	10400[2]	1590[2]	154[2]	55.3[2]

Note:
1 Soil from Primary Study Area
2 Determined through chemical analyses

The results of 14-day earthworm acute mortality tests are normally entered manually into data spreadsheets, graphed and analyzed using the Probit, the Moving Average, and the Trimmed Spearman-Karber methods of analysis (Stephen 1989). However, as there was no mortality among any of the treatments with the clay and organic soils (Volume IV, Tab 2), statistical analyses were not required.

The results of the chronic earthworm tests (both with the contaminated clay and organic soils) were analyzed by applying linear or non-linear regression procedures to the earthworm reproductive data after the data were entered into electronic spreadsheets. The analyses consisted of using a linear or four non-linear regression models (i.e., logistic, gompertz, exponential and logistic with hormesis; where c = % contaminated soil) that had been re-parameterized to include the ECx and the associated 95% confidence limits. The ECx is the effect concentration (EC) resulting in a specified percentage (x) effect; for this study, EC_{20} and EC_{50} were calculated. The residuals were examined for homogeneity of variance among treatments. If data showed heteroscedasticity among treatments, data were weighted with the inverse of the variance of each treatment (Myers 1986, Stephenson *et al.* 2000). Additionally, analyses of variance procedures were applied to the data and a two-tailed Dunnett's test was used to compare each treatment mean to the mean of the control treatment. The Dunnett's pairwise comparison test was used to determine the NOEC (no observed effect concentration) and LOEC (lowest observed effect concentration) values (SPSS 1997). Thirty-five-day adult survival data were analyzed using analysis of variance procedures followed by a two-tailed Dunnett's and a Fisher's protected Least Significant Difference pairwise comparison tests. Results from these latter analyses are presented in Volume IV (Tab 2), as the EC_{20} is the measurement endpoint of interest. All analyses were performed with SYSTAT 7.0.1 (SPSS 1997). A more detailed description of the statistical procedures used to analyze earthworm test data can be found in either Environment Canada (1998) or Stephenson *et al.* (2000).

Earthworm Dose-Response on Organic Soils

Table 8-9 provides a summary of the response of *E. andrei* to blends of organic soils. Generally, there is a decline in numbers and biomass of juveniles, and numbers of hatched cocoons (Table 8-9). Analyzed statistically, EC_{20} for organic soils is found at a value of 16-25% of contaminated soil (Table 8-10, Figure 8-8), which equates to a predicted nickel concentration of 2000-3000 mg/kg (Table 8-11).

According to the regression, the CoC concentrations at which an effect was observed at the 20% level were lowest for unhatched cocoons (Table 8-10). The number of hatched cocoons was significantly influenced by CoC concentrations with an effect observed at the 20% level occurring when nickel is at approximately 2279 mg/kg, copper is at 370 mg/kg, cobalt is at 37 mg/kg and arsenic is at 18 mg/kg. Measurements of juveniles indicate a 20% effects concentration a little higher than these values (Table 8-11).

Table 8-9 Effect of Exposure to Contaminated Organic Site Soil Diluted with Uncontaminated Organic Reference Control Soil on *Eisenia andrei* Reproduction Following 63 Days of Exposure.[1]

Concentration (% contaminated soil)	**Number of Juveniles** (± Standard Error)	**Number of Unhatched Cocoons** (± Standard Error)	**Number of Hatched Cocoons** (± Standard Error)	**Wet Mass of Juveniles (g)** (± Standard Error)	**Dry Mass of Juveniles (g)** (± Standard Error)
RS	20.40 ± 2.48	1.70 ± 0.73	3.40 ± 0.87	0.62 ± 0.10	0.13 ± 0.02
0	28.50 ± 5.94	1.70 ± 0.33	5.60 ± 1.07	0.62 ± 0.10	0.11 ± 0.02
5	23.10 ± 2.88	2.20 ± 0.66	3.60 ± 0.73	0.46 ± 0.06	0.08 ± 0.01
12	16.80 ± 2.21	1.30 ± 0.65	3.80 ± 0.49	0.57 ± 0.06	0.10 ± 0.01
25	22.20 ± 1.82	0.90 ± 0.18	4.40 ± 1.11	0.45 ± 0.05	0.08 ± 0.01
50	15.70 ± 1.81	0.90 ± 0.23	2.50 ± 0.45	0.16 ± 0.01	0.03 ± 0.00
80	7.60 ± 1.19	1.10 ± 0.41	0.90 ± 0.41	0.07 ± 0.01	0.01 ± 0.002
100	0	0.90 ± 0.55	0.40 ± 0.22	N/A	N/A

Notes
1 Values are means of ten replicates per soil treatment
RS Experimental control soil, which is a clay loam soil
N/A Data not applicable

Table 8-10 Summary of the Results of Regression Analyses of the *E. andrei* Reproduction Test Conducted with the Contaminated Organic Soil Diluted with Uncontaminated Organic Reference Control Site Soil[1].

Endpoint	**Parameter**	**Model**	**EC_{50}** (% contaminated soil)	**LCL**	**UCL**	**EC_{20}** (% contaminated soil)	**LCL**	**UCL**
Juveniles	Number	Linear	53.79	43.89	63.69	21.51	17.55	25.47
	Wet Mass	Logistic	39.12	28.72	49.53	25.72	14.31	37.12
	Dry Mass	Logistic	37.92	27.11	48.72	24.84	13.26	36.43
Cocoons	Hatched	Linear	52.87	40.39	65.36	21.15	16.15	26.14
	Unhatched	Hormesis	71.00	< 0	240.03	16.66	< 0	48.39

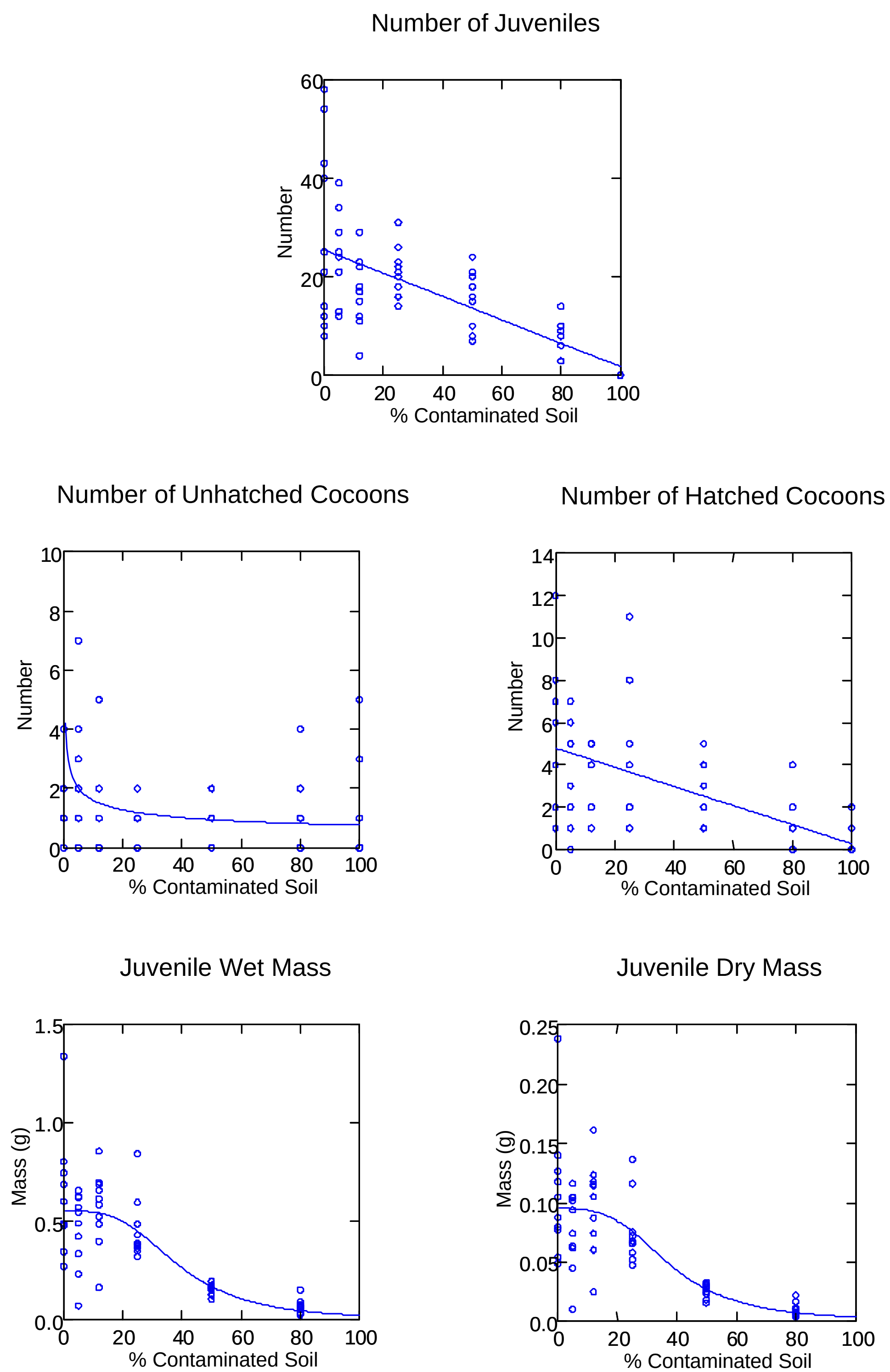
Notes
1 Values are expresses as percent of contaminated soil.
UCL Upper Confidence Limit
LCL Lower Confidence Limit

Table 8-11 Organic Soil CoC Concentrations Corresponding with EC Values Calculated Using Regression and Analyses of Variance, as above.[1]

Effects Level	Soil Nickel Concentration (mg/kg)	Soil Copper Concentration (mg/kg)	Soil Cobalt Concentration (mg/kg)	Soil Arsenic Concentration (mg/kg)
EC_{20}				
Juvenile Number	2316 (1908 – 2723)	376 (314 - 437)	38 (32 - 44)	18.3 (16.5 - 20.2)
Juvenile Biomass (wet)	2749 (1574 – 3923)	441 (264 - 617)	44 (27 - 61)	20.3 (14.9 - 25.7)
Juvenile Biomass (dry)	2659 (1466 – 3852)	427 (248 - 607)	43 (26 - 60)	19.9 (14.4 - 25.4)
Number of Hatched Cocoons	2279 (1763 – 2792)	370 (293 - 447)	37 (30 - 45)	18.2 (15.8 - 20.5)
Number of Unhatched Cocoons	1816 (100 – 5084)	301 (43 - 792)	31 (6 - 78)	16.0 (8.2 - 31)
EC_{50}				
Juvenile Number	5640 (4621 – 6660)	875 (722 - 1028)	86 (71 - 100)	33.5 (28.9 - 38.2)
Juvenile Biomass (wet)	4129 (3058 – 5202)	648 (487 - 809)	64 (49 - 79)	26.6 (21.7 - 31.5)
Juvenile Biomass (dry)	4006 (2892 – 5118)	630 (462 - 797)	62 (46 - 78)	26.1 (21 - 31.1)
Number of Hatched Cocoons	5546 (4260 – 6832)	861 (668 - 1054)	84 (66 - 103)	33.1 (27.2 - 39)
Number of Unhatched Cocoons	7413 (100 – 24823)	1141 (43 - 3756)	111 (6 - 361)	41.6 (8.2 - 121.3)

Notes
1 Numbers in brackets represent the range from lower confidence limit to upper confidence limit.
EC_{20} 20% effects level
EC_{50} 50% effects level

Figure 8-8 Results of Exposure to Contaminated Organic Site Soil Diluted with Uncontaminated Organic Reference Control Site Soil on *Eisenia andrei* Reproduction Following 63 Days of Exposure. Data were Subjected to Regression Analyses.



Earthworm Dose-Response on Clay Soils

Table 8-12 provides a summary of the response of *E. andrei* to blends of clay soils. Generally, there is a decline in numbers and biomass of juveniles, and numbers of hatched cocoons (Table 8-12). Analyzed statistically, as described above, EC_{20} for clay soils is found at a low value of 0-13% of contaminated soil (Table 8-13, Figure 8-2), which equates to a predicted nickel concentration of 80-1200 mg/kg (Table 8-14).

Table 8-12 Effect of Exposure to Contaminated Clay Site Soil Diluted with Uncontaminated Clay Reference Control Soil on *Eisenia andrei* Reproduction Following 63 Days of Exposure.[1]

Concentration (% contaminated soil)	**Number of Juveniles** (± Standard Error)	**Number of Unhatched Cocoons** (± Standard Error)	**Number of Hatched Cocoons** (± Standard Error)	**Wet Mass of Juveniles (g)** (± Standard Error)	**Dry Mass of Juveniles (g)** (± Standard Error)
RS	8.78 ± 2.00	1.11 ± 0.19	2.89 ± 0.68	0.31 ± 0.05	0.06 ± 0.01
0	7.00 ± 1.21	0.30 ± 0.15	1.00 ± 0.42	0.21 ± 0.04	0.04 ± 0.01
5	4.70 ± 1.23	0.40 ± 0.22	0.60 ± 0.34	0.09 ± 0.03	0.02 ± 0.005
12	4.80 ± 1.13	1.20 ± 0.47	0.70 ± 0.40	0.09 ± 0.02	0.02 ± 0.004
25	0.80 ± 0.55	1.00 ± 0.37	0	0.03 ± 0.01	0.01 ± 0.002
50	0.10 ± 0.10	1.00 ± 0.39	0.10 ± 0.10	0.004 ± 0.001	0.001 ± 0
80	0	0.60 ± 0.31	0	N/A	N/A
100	0.20 ± 0.13	0.60 ± 0.27	0	0.02	0.01 ± 0.003

Notes
1 Values are means of ten replicates per soil treatment
RS Experimental control soil, which is a clay loam soil
N/A Data not applicable

Table 8-13 Summary of the Results of Regression Analyses of the *E. andrei* Reproduction Test Conducted with the Contaminated Clay Soil Diluted with Uncontaminated Clay Reference Control Site Soil.[1]

Endpoint	Parameter	Model	EC_{50} (% contaminated soil)	LCL	UCL	EC_{20} (% contaminated soil)	LCL	UCL
Juveniles	Number	Gompertz	15.44	8.94	21.94	8.45	1.38	15.52
	Wet Mass	Gompertz	4.54	< 0	12.53	0.37	< 0	2.25
	Dry Mass	Gompertz	4.44	< 0	12.74	0.36	< 0	2.36
Cocoons	Hatched	Gompertz	16.73	< 0	36.99	13.01	< 0	27.70
	Unhatched	Hormesis	> 100	N/A	N/A	> 100	N/A	N/A

Notes

1 Values are expresses as percent of contaminated soil.

UCL Upper Confidence Limit

LCL Lower Confidence Limit

N/A Data not applicable

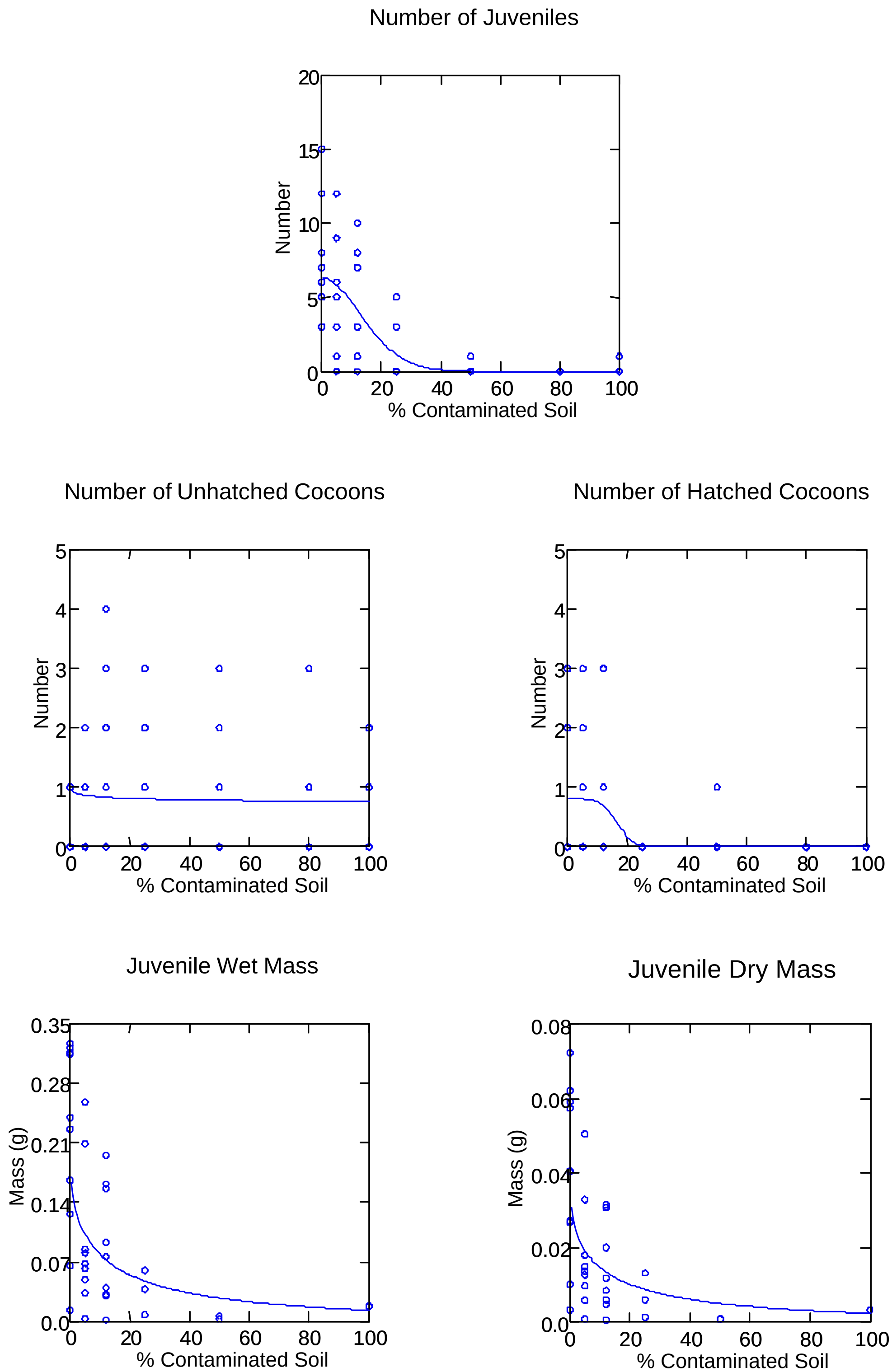
Results of the regression analysis indicate variability exists in how *E. andrei* responds to CoC concentrations in clay soil. Examining the number of unhatched cocoons, no influence of CoC concentrations was found. However, the number of hatched cocoons was significantly influenced by CoC concentrations, with an observed effect at the 20% level occurring when nickel exists at 1170 mg/kg, copper is at 150 mg/kg, cobalt is at 20 mg/kg and arsenic is at 7 mg/kg. The number of juveniles is affected at slightly lower levels (Table 8-14), but biomass is affected by CoC concentrations at much lower levels in clay soil. Biomass of juveniles is predicted to be reduced by 20% when nickel is at 84 mg/kg, copper is at 24 mg/kg, cobalt is at 5 mg/kg and arsenic is at 2.7 mg/kg. From these results, it is not known what CoC or combination of CoCs is driving this effect, or if some other factor is responsible. Certainly, it is difficult to believe that CoCs would be so much more bioavailable in these clay soils compared to the organic soils, considering the results of the chemical extractions (Section 6.5) and assessments of bioavailability (Section 6.4).

Table 8-14 Clay soil CoC Concentrations Corresponding with Values Calculated Using Regression and Analyses of Variance, as above.[1]

Effects Level	Soil Nickel Concentration (mg/kg)	Soil Copper Concentration (mg/kg)	Soil Cobalt Concentration (mg/kg)	Soil Arsenic Concentration (mg/kg)
EC_{20}				
Juvenile Number	779 (171 – 1387)	105 (34 - 176)	15 (7 - 23)	5.4 (3.1 - 7.8)
Juvenile Biomass (wet)	84 (0 – 246)	24 (0 - 43)	5 (0 - 8)	2.7 (0 - 3.4)
Juvenile Biomass (dry)	83 (0 – 255)	24 (0 - 44)	5 (0 - 8)	2.7 (0 - 3.4)
Number of Hatched Cocoons	1171 (0 – 2435)	151 (0 - 299)	20 (0 - 37)	7.0 (0 - 11.9)
Number of Unhatched Cocoons	> 8655	> 1026	> 120	> 36.2
EC_{50}				
Juvenile Number	1380 (821 – 1939)	175 (110 - 241)	23 (15 - 30)	7.8 (5.6 - 10)
Juvenile Biomass (wet)	443 (0 – 1130)	66 (0 - 146)	10 (0 - 19)	4.1 (0 - 6.8)
Juvenile Biomass (dry)	434 (0 – 1148)	65 (0 - 148)	10 (0 - 20)	4.1 (0 - 6.9)
Number of Hatched Cocoons	1491 (0 – 3234)	188 (0 - 392)	24 (0 - 48)	8.2 (0 - 15)
Number of Unhatched Cocoons	> 8655	> 1026	> 120	> 36.2

Notes
1 Numbers in brackets represent the range from lower confidence limit to upper confidence limit.
EC_{20} 20% effects level
EC_{50} 50% effects level

Figure 8-9 Results of Exposure to Contaminated Clay Site Soil Diluted with Uncontaminated Clay Reference Control Site Soils on *Eisenia andrei* Reproduction Following 63 Days of Exposure. Data were Subjected to Regression Analyses.



8.3.3.3 Earthworms in the Natural Environment

Earthworms found in the Primary and Secondary Study Areas were *Allolobophora chlorotica*, *Aporrectodea tuberculata*, *Dendrodrilus rubidus*, *Lumbricus rubellus* and *L. terrestris*. One individual of a sixth species, *Eisenia foetida*, was found at one site in the Reference Area. Most individuals were considered juvenile across the Study Area and Reference Area (>95%; Table 8-15), which indicates reproduction in local earthworms is healthy. Further data are presented in Section 6.4.5 and Volume III (Tab 1).

Table 8-15 Summary of Age Classes and Reproductive Status for Earthworms Collected for the Study Area and Reference Area During 2001.

	Study Area	Reference Area
Number of Juveniles	554	98
Number of Aclitellate Adults	17	10
Number of Clitellate Adults	7	3
Total Number of Individuals	578	108
Number of Sites Sampled	10	4
Note: Refer to Vol.III, tab 1 for a complete listing of this data.		

For earthworms, general abundance, species richness and biomass were assessed statistically, in addition to species-specific responses (Table 8-1). Generalized linear models were used to evaluate the relationships between these responses and other environmental variables (Table 8-1), the results of which are found in Volume III (Tab 3), and Tables 8-16 to 8-18. In 2001, earthworms were absent from a sample location adjacent to the Inco Refinery, which had much higher soil CoC concentrations (e.g., nickel = 18,500 mg/kg) than all other sample sites. This site was excluded from statistical analyses of the 2001 data as an outlier, but was taken into consideration in evaluating the potential effect of CoCs. Subsequent sampling at this site in 2002 resulted in small numbers of earthworms being found, including the only specimens of *D. rubidus* for the Study Area.

Species richness of earthworms was not influenced by soil type, habitat or any soil CoC concentrations (Volume III, Tab 3). However, total biomass of earthworms per sample was found to be influenced by soil type and habitat, as shown in the example results from the nickel *glm* in Table 8-16, which is representative of all four CoC *glm*s (Volume III, Tab 3). Woodlots had overall less biomass than fields on organic soils, and the reverse was true for clay soils (Figure 8-10). This pattern was also apparent in numbers of worms per sample (Table 8-16, Figure 8-11). Other predictors of total worm counts were also found to be significant, including soil type (higher in clay soils, Figure 8-11) and soil concentrations of nickel and cobalt. Contrary to what could potentially be expected based on the literature-derived TRV value of 3000 (mg/kg), no difference in worm numbers was noted as soil nickel concentrations increased from 2000 mg/kg to 5000 mg/kg (Figure 8-12). In addition, field data indicated a slight increase in earthworm numbers was associated with increasing nickel concentrations at lower levels. Similarly, worm numbers increased as cobalt increased in the soil from 10-30 mg/kg, with no change in numbers occurring at higher concentrations up to 80 mg/kg at least (Figure 8-13). Additionally, the relationship between worm numbers and soil arsenic concentration differed between soil types, although there was not an overall relationship between arsenic and worm abundance noted (Table 8-16). Worms living in clay soil began to decrease in number as arsenic increased in concentration, but worms living in organic soils did not show such a relationship (Figure 8-14).

Table 8-16 Analysis of Deviance Table. The Response Variables are Total Counts of Individuals and Total Biomass of Earthworms within Samples, Log-Transformed.[1]

		Total Biomass (CoC = Ni)		Total Count (CoC = Ni)		Total Count (CoC =Co)		Total Count (CoC = As)	
Term	**df**	**Dev**	***p***	**Dev**	***p***	**Dev**	***P***	**Dev**	***p***
Null	37	107.36		347.93		347.93		347.93	
Soil CoC[2] Concentration	1	0.85	0.56	5.10	**0.02**	6.30	**0.01**	0.43	0.51
Habitat	1	8.06	0.08	1.89	0.17	1.96	0.16	1.52	0.22
Soil Type	1	0.37	0.70	16.74	**<0.01**	17.34	**<0.01**	14.02	**<0.01**
Soil CoC[1] Concentration: Habitat (Interaction)	1	1.37	0.46	0.52	0.47	0.99	0.32	0.21	0.65
Soil CoC[1] Concentration: Soil Type (Interaction)	1	0.80	0.57	0.66	0.42	0.02	0.89	5.49	**0.02**
Habitat: Soil Type (Interaction)	1	20.85	**<0.01**	36.66	**<0.01**	39.19	**<0.01**	45.42	**<0.01**
Residual	31	75.06		286.38		282.13		280.84	

Notes

1 The models of individual counts were fit as Poisson log-link models, while the biomass models were fit as Gaussian. Bold type indicates an estimated p-value of ≤ 0.05. Further information on Analysis of Deviance is found in Volume II, Tab 18.

2 CoC relevant to the model (see header row)

Figure 8-10 Total Worm Biomass Across Habitats. Circles & solid line = clay soils, triangles & dotted line = organic soils.

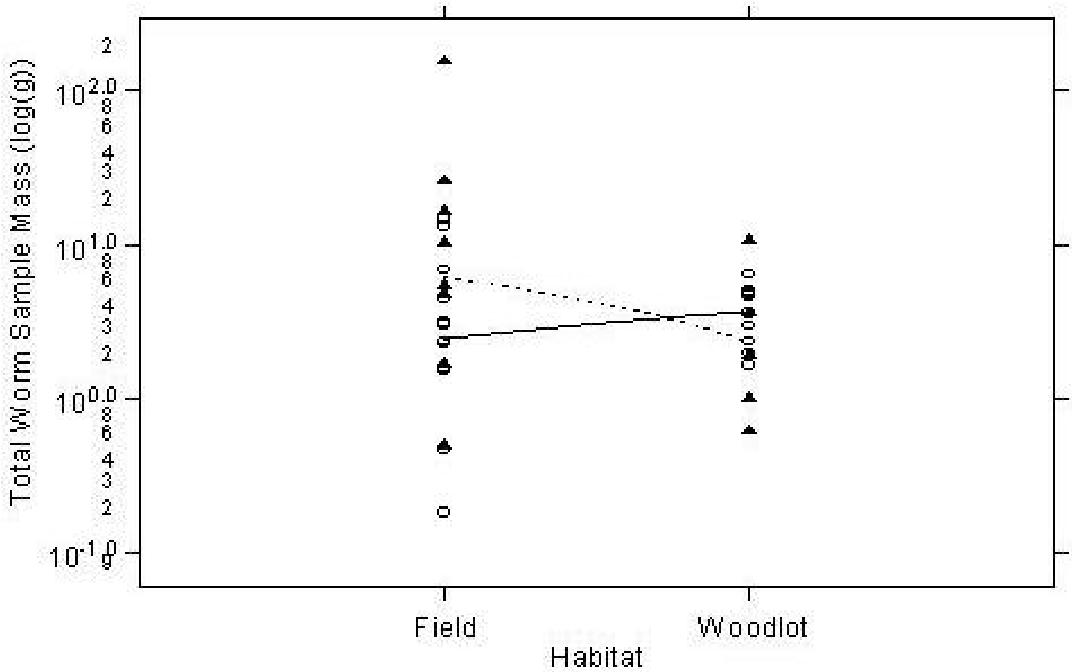


Figure 8-11 Total Worm Counts Across Habitats. Circles & solid line = clay soils, triangles & dotted line = organic soils.

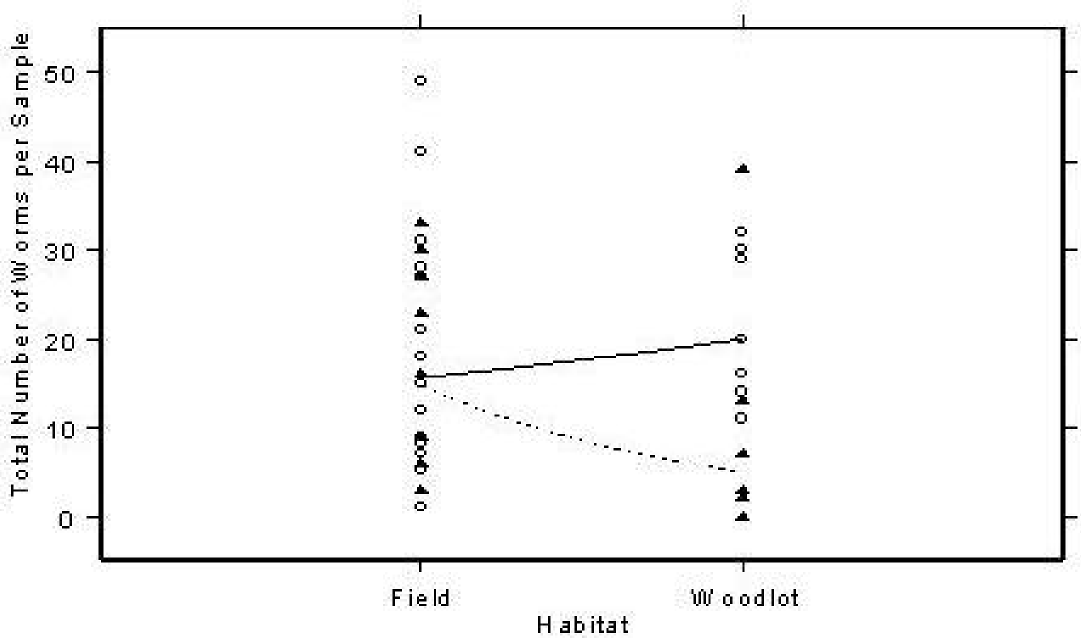


Figure 8-12 Relationship Between Total Numbers of Worms per Sample and Soil Nickel Concentration.

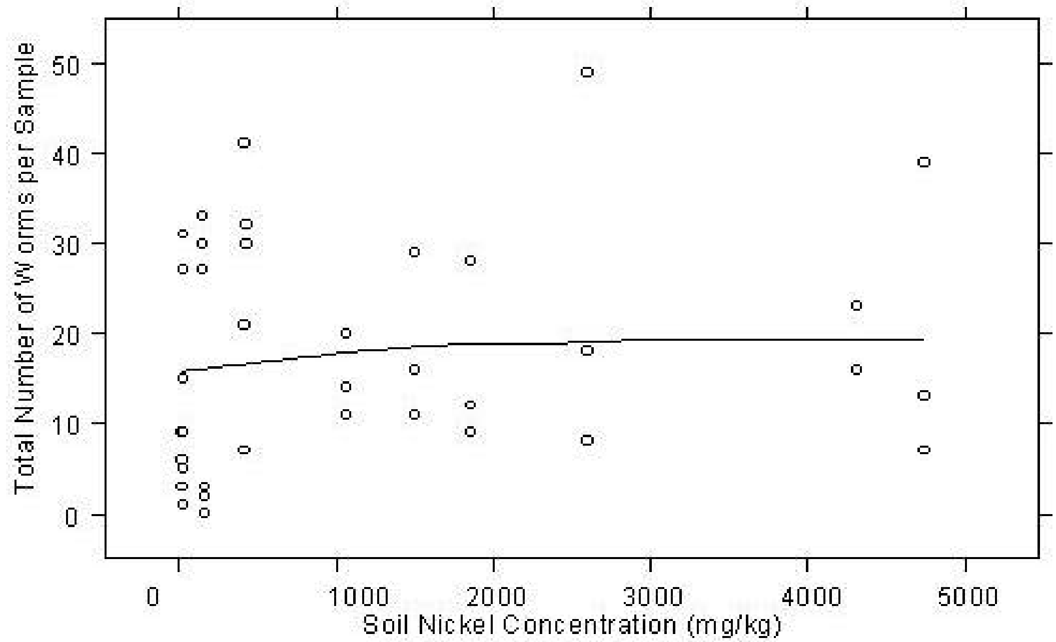


Figure 8-13 Relationship Between Total Numbers of Worms per Sample and Soil Cobalt Concentration.

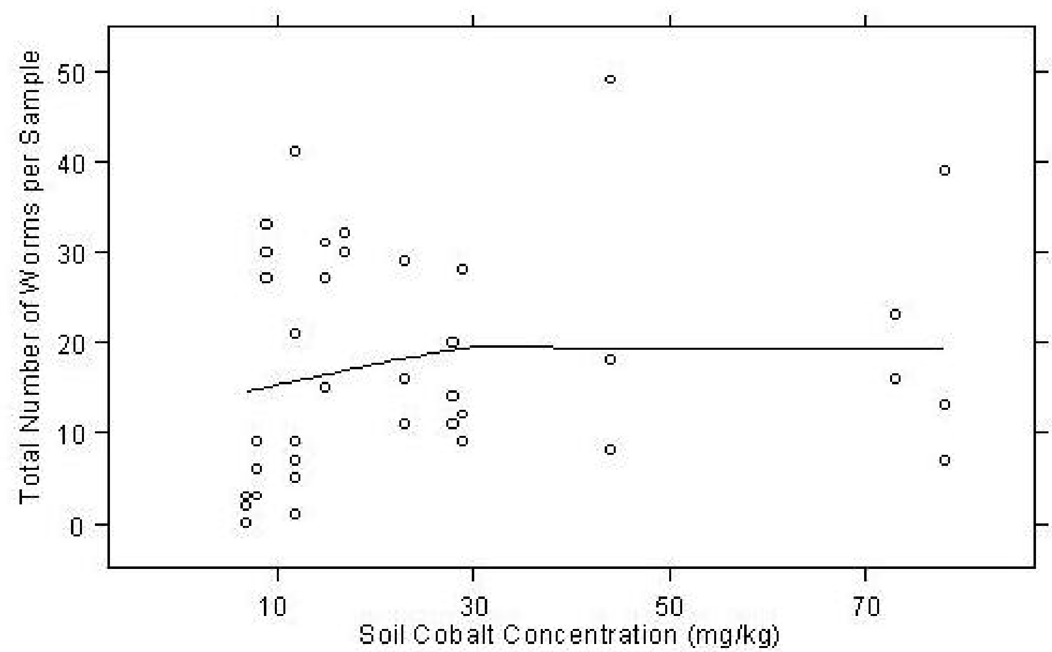
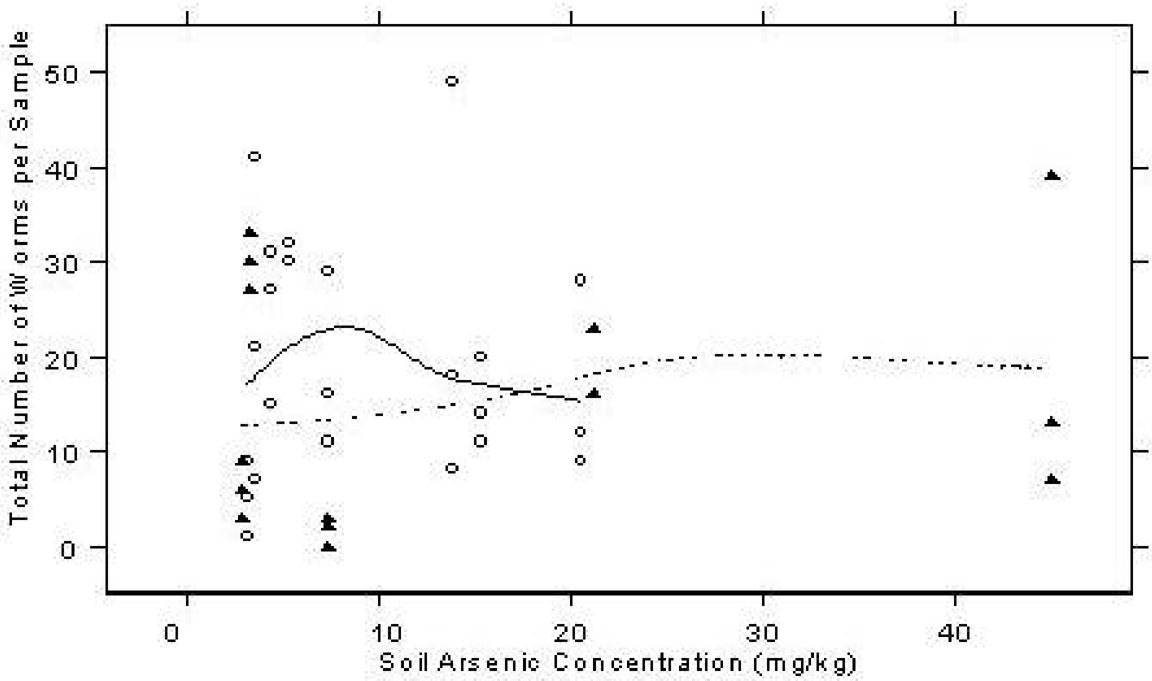


Figure 8-14 Relationship Between Total Numbers of Worms per Sample and Soil Arsenic Concentration. Circles & solid line = clay soils, triangles & dotted line = organic soils.



Three of the six earthworm species were examined separately: *Lumbricus terrestris*, *L. rubellus* and *Aporrectodea tuberculata*. Other species were sampled too infrequently to be examined separately. The incidence of *Lumbricus terrestris* was fit against soil CoC concentrations, soil type and habitat as it was found too infrequently to assess either biomass or numbers of individuals within a sample. Although no CoC was found to be linked to *L. terrestris* incidence, habitat and soil type both had an influence (Table 8-17). While habitats did not greatly differ on clay soils, fields of organic soils had many more occurrences of *L. terrestris* than any other habitat/soil combination (Figure 8-15). These habitat differences are in line with what has been reported regarding the species' biology with a preference for conditions found in field habitats (Reynolds 1977).

Figure 8-15 Incidence of *Lumbricus terrestris* in Field and Woodlot Habitats on Clay and Organic Soils. Circles & solid line = clay soils, triangles & dotted line = organic soils.

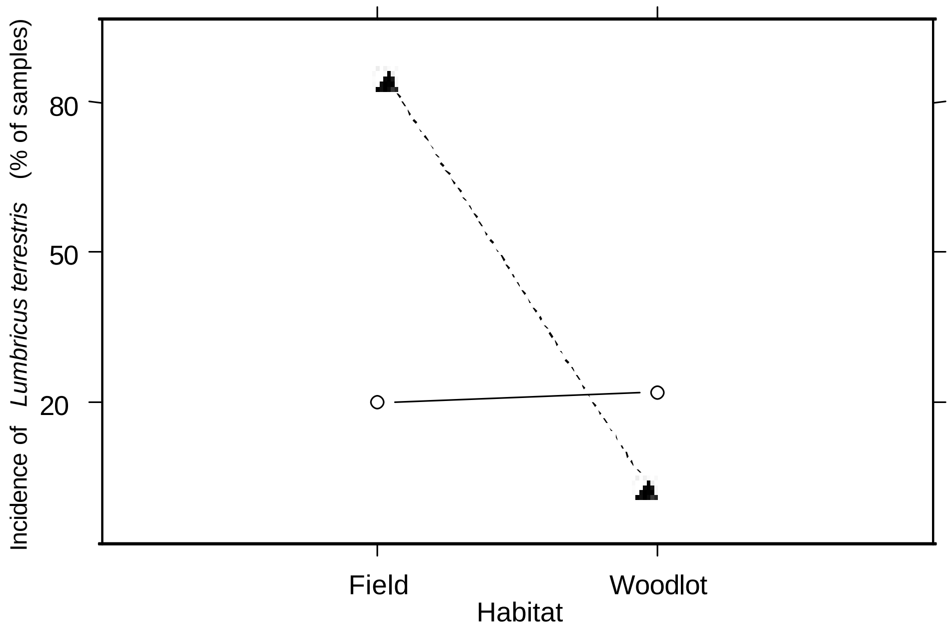


Table 8-17 Analysis of Deviance Table. The Response Variables are Incidence of *Lumbricus terrestris* (Binomial), Counts of *Lumbricus rubellus* (Poisson) and Biomass of *Lumbricus rubellus* (Gaussian), Log-transformed.

		Incidence of *L. terrestris* (CoC = Ni)		Count of *L. rubellus* (CoC = Ni)		Count of *L. rubellus* (CoC = As)		Biomass of *L. rubellus* (CoC = Co)	
Term	**df**	**Dev**	***p***	**Dev**	***p***	**Dev**	***P***	**Dev**	***p***
Null	37	47.40		370.72		370.72		278.67	
Soil CoC[1] Concentration	1	0.32	0.57	27.51	**<0.01**	24.87	**<0.01**	46.34	**<0.01**
Habitat	1	3.86	**0.05**	0.02	0.88	0.05	0.83	0.29	0.83
Soil Type	1	4.66	**0.03**	47.10	**<0.01**	46.36	**<0.01**	7.93	0.26
Soil CoC[1] Concentration: Habitat (Interaction)	1	1.97	0.16	0.70	0.40	0.06	0.81	0.24	0.84
Soil CoC[1] Concentration: Soil Type (Interaction)	1	1.63	0.20	<0.01	0.98	0.36	0.55	36.60	**0.02**
Habitat: Soil Type (Interaction)	1	12.32	**<0.01**	11.45	**<0.01**	14.26	**<0.01**	0.12	0.89
Residual	31	22.63		283.94		284.78		187.15	

Notes

1. Bold type indicates an estimated p-value of ≤ 0.05. Further information on Analysis of Deviance is found in Volume II, Tab 18.
2. CoC relevant to the model (see header row)

Both biomass and numbers of individuals of *L. rubellus* were examined using *glm*. All results are presented in Volume III (Tab 3), and some results are presented in Table 8-17 to illustrate the common patterns. Numbers of individual *L. rubellus* showed a relationship with all four CoCs and with soil type, including an interaction between habitat and soil type, as is shown for nickel in Table 8-17. Numbers of *L. rubellus* were highest in clay woodlots and lowest in organic woodlots (Figure 8-16). As is illustrated for nickel, but which is also true for copper and cobalt, numbers of *L. rubellus* increased with increases in CoC concentrations (Figure 8-17), much like what was seen in total numbers of earthworms (Figures 8-12 and 8-13). For arsenic, a difference was noted between soil types (Table 8-17). As soil arsenic concentrations increased in clay soils, numbers of *L. rubellus* increased and then levelled, whereas soil arsenic concentrations exceeding approximately 30 mg/kg in organic soils showed a decrease in *L. rubellus* numbers (Figure 8-18). Although this is based on sparse data (i.e., only one worm sample site exceeded 25 mg-As/kg), it does roughly agree with the arsenic TRV taken from the literature (Section 7).

Biomass increased with increases in soil CoC concentrations, but was not linked to any other variable (Volume III, Tab 3). For cobalt, however, there existed an interaction between soil concentrations and soil type (Table 8-18), with *L. rubellus* biomass increasing more in clay soils as cobalt concentrations increase than in organic soils (Figure 8-19).

Figure 8-16 Relationship Between Numbers of *Lumbricus rubellus* and Habitat. Circles & solid line = clay soils, triangles & dotted line = organic soils.

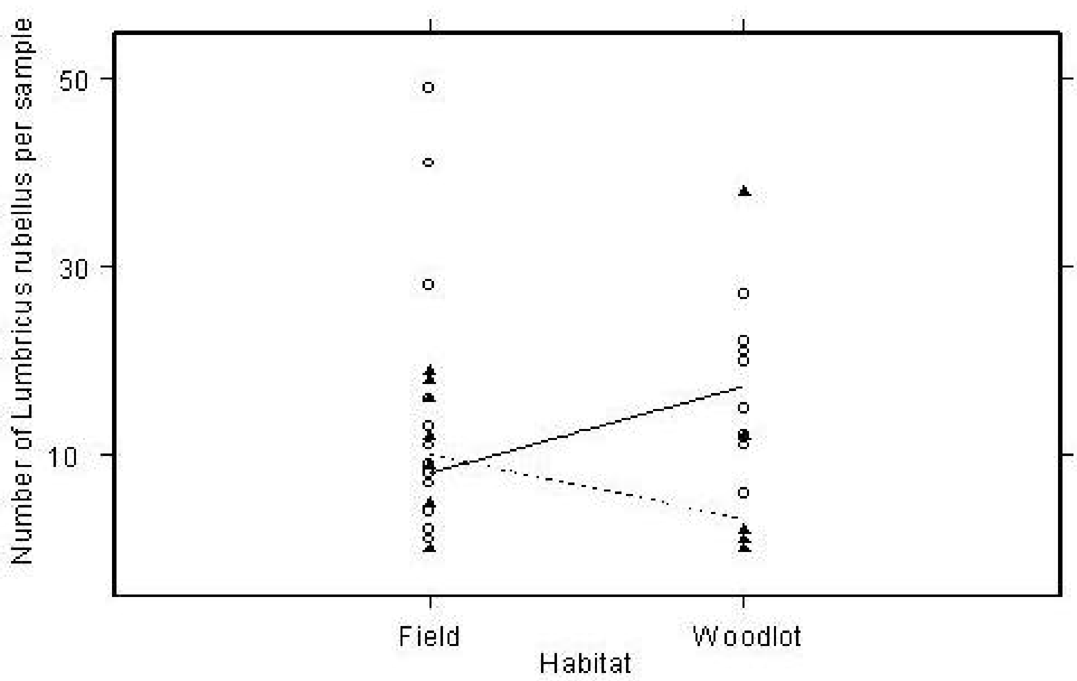


Figure 8-17 Relationship Between Numbers of *Lumbricus rubellus* and Soil Nickel Concentration.

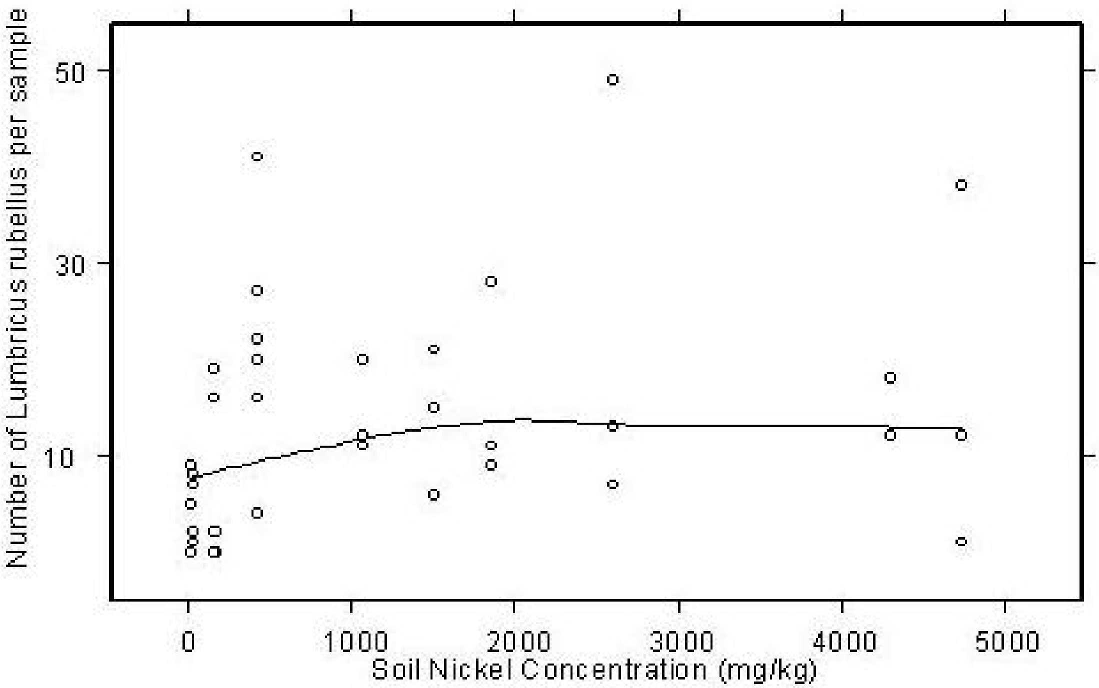


Figure 8-18 Relationship Between Numbers of *Lumbricus rubellus* and Soil Arsenic Concentration. Circles & solid line = clay soil, triangles & dotted line = organic soil.

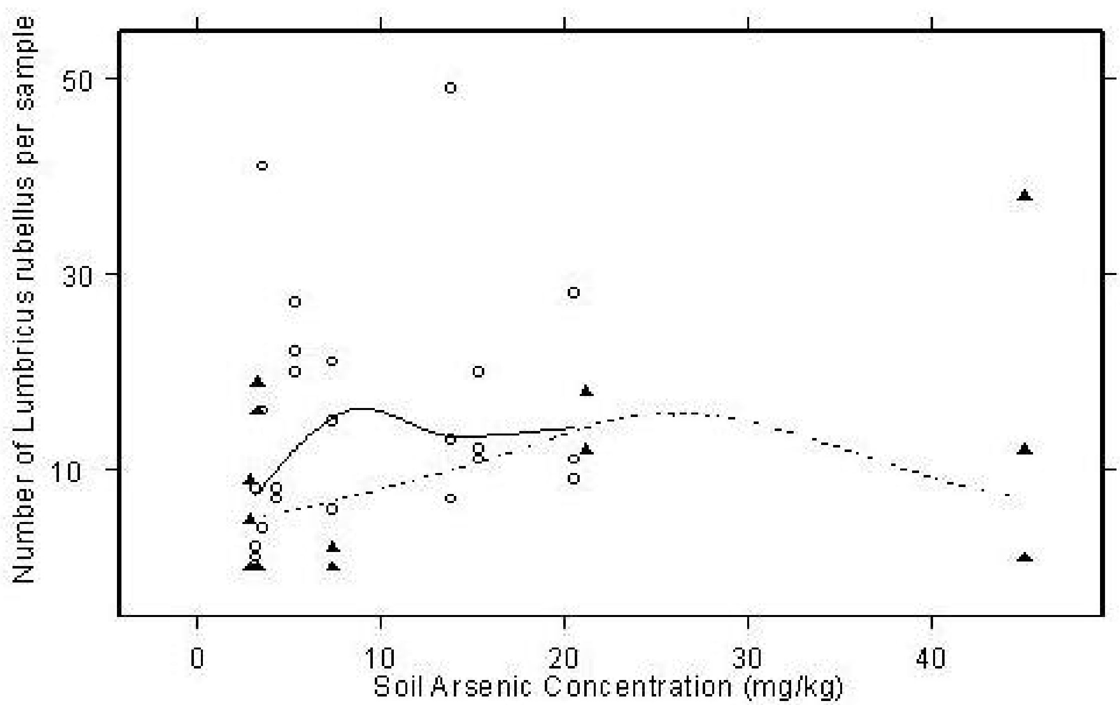
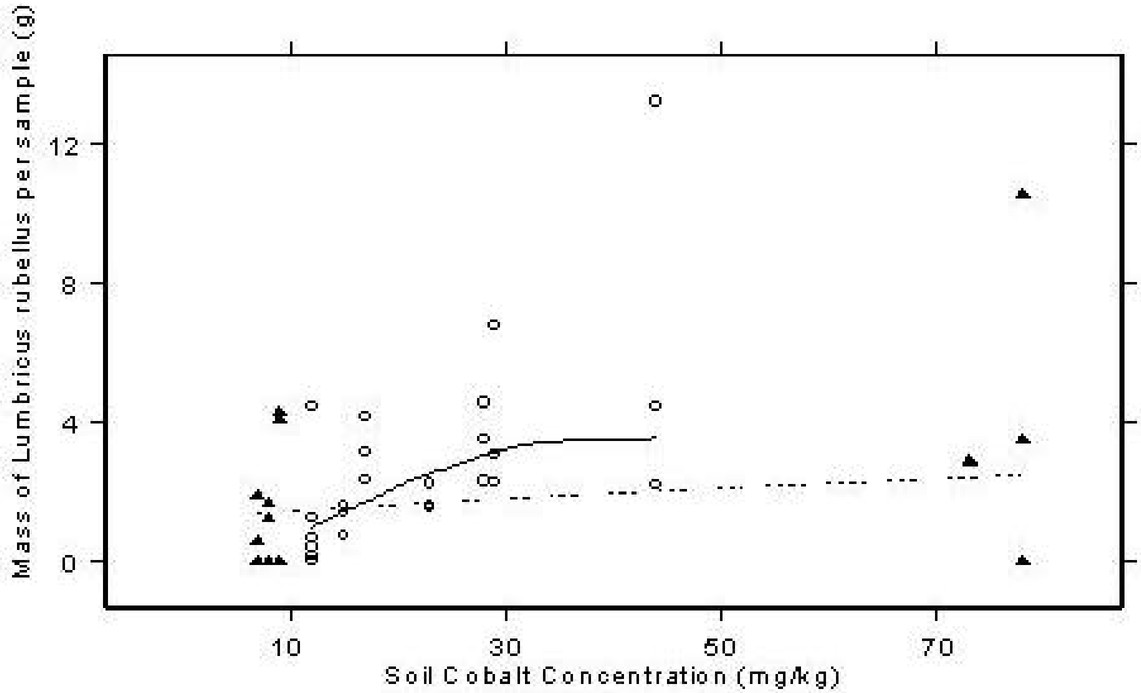


Figure 8-19 Relationship Between Biomass of *Lumbricus rubellus* and Soil Cobalt Concentration. Circles & solid line = clay soil, triangles & dotted line = organic soil.



Of the predictors fit against *A. tuberculata* biomass, only soil nickel concentration was found to be significant (Table 8-18). Unlike the other earthworms, biomass of *A. tuberculata* appears to decrease as soil nickel concentrations increase, at least up to concentrations of approximately 2000 mg/kg, after which the change in biomass is minimal as concentrations increase (Figure 8-20). No other CoC was linked to *A. tuberculata* biomass. However, all four CoCs proved to be significant predictors of *A. tuberculata* abundance, as was soil type and habitat to some extent (Table 8-18; Volume III, Tab 3). Clay woodlots hosted greater numbers of *A. tuberculata* than organic woodlots (Figure 8-21). As for the CoCs, all had generally the same relationship with *A. tuberculata* abundance. Only nickel is presented here to illustrate these relationships (Table 8-18). While nickel (and other CoCs) did not influence *A. tuberculata* numbers in areas with organic soils, increases in nickel concentrations in clay soils leads to a decrease in *A. tuberculata* abundance (Figure 8-22).

Table 8-18 Analysis of Deviance Table. The Response Variables are Counts (Poisson) and Biomass (Gaussian, log-transformed) of *Aporrectodea tuberculata*.

Term	df	Number of *A. tuberculata* (CoC = Ni) Dev	*p*	Biomass of *A. tuberculata* (CoC = Ni) Dev	*P*
Null	37	166.09		10.34	
Soil CoC[1] Concentration	1	15.00	**<0.01**	1.08	**0.05**
Habitat	1	1.21	0.27	0.08	0.57
Soil Type	1	5.00	**0.03**	0.17	0.41
Soil CoC[1] Concentration: Habitat (Interaction)	1	27.76	**<0.01**	0.06	0.62
Soil CoC[1] Concentration: Soil Type (Interaction)	1	4.57	**0.03**	0.95	0.06
Habitat: Soil Type (Interaction)	1	9.09	**<0.01**	0.29	0.29
Residual	31	103.47		7.69	

Notes
1 Bold type indicates an estimated p-value of ≤ 0.05. Further information on Analysis of Deviance is found in Volume II, Tab 18.
2 CoC relevant to the model (see header row)

Figure 8-20 Relationship Between Biomass of *Aporrectodea tuberculata* and Soil Nickel Concentration.

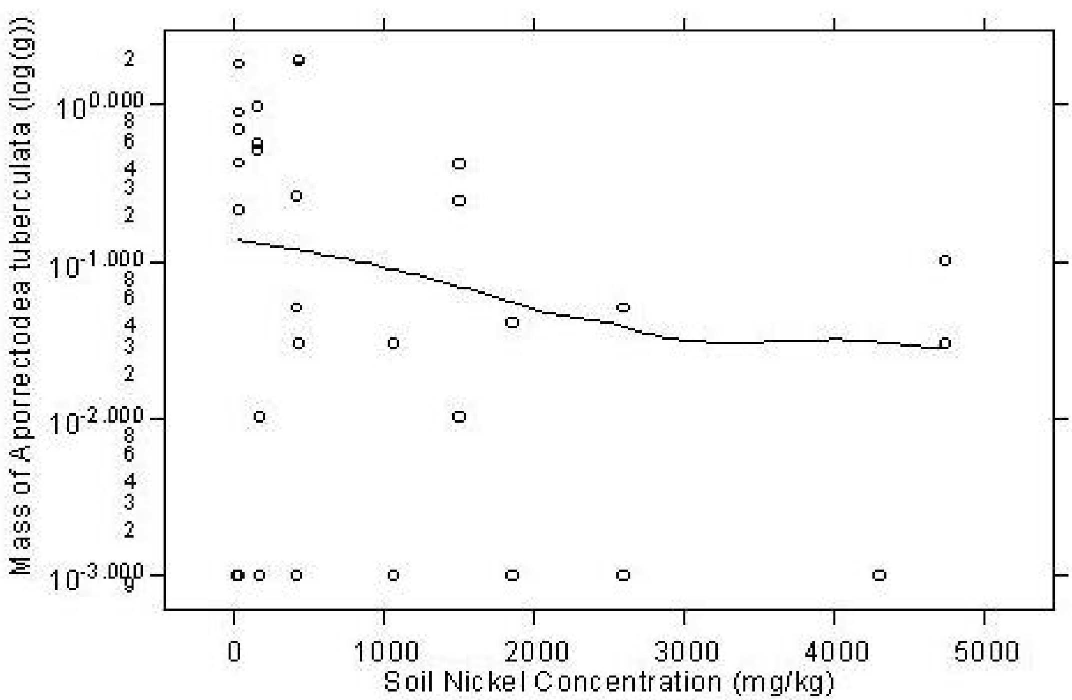


Figure 8-21 **Relationship Between Numbers of *Aporrectodea tuberculata* and Soil Type. Circles & solid line = field, triangles & dotted line = woodlots.**

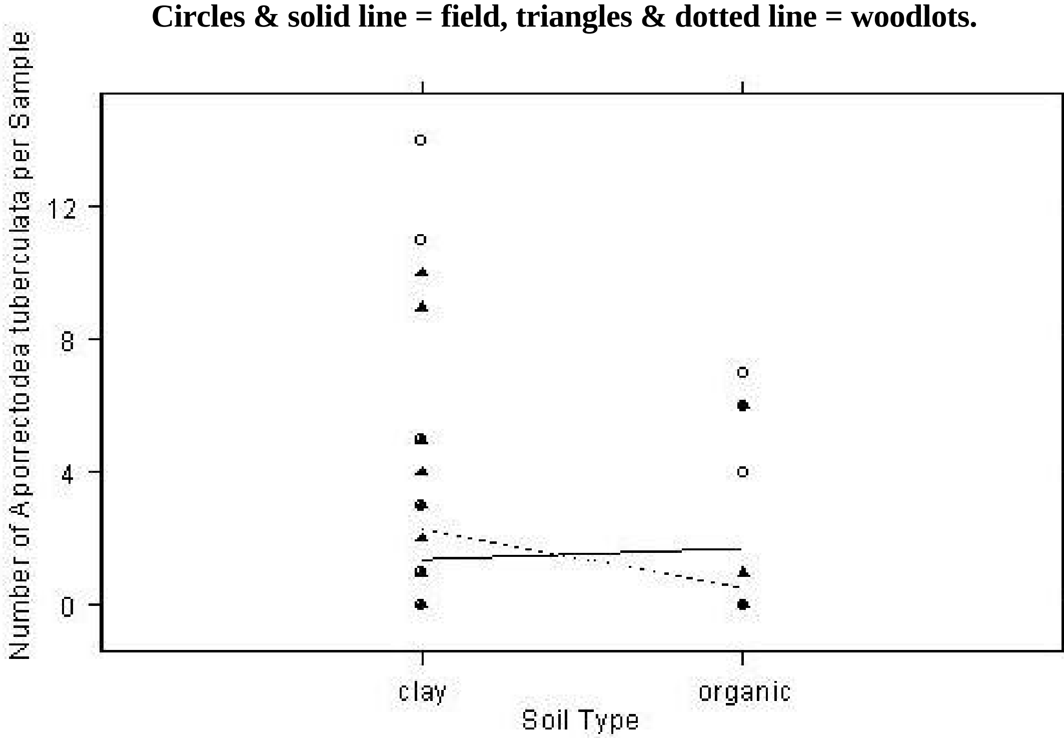
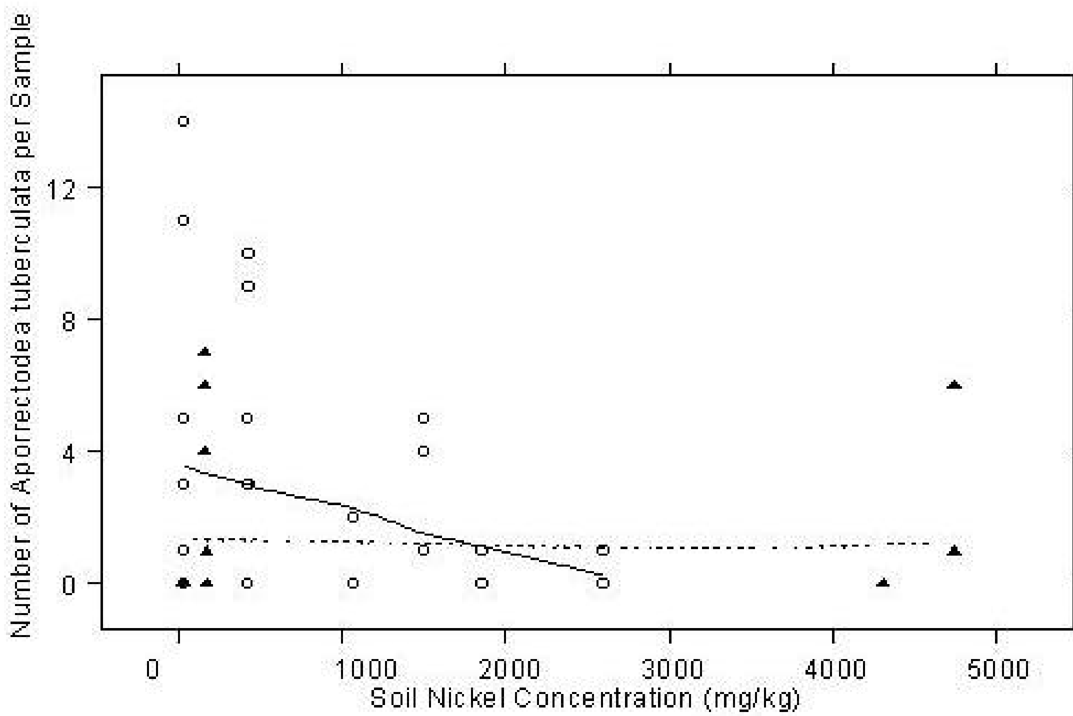


Figure 8-22 **Relationship Between Numbers of *Aporrectodea tuberculata* and Soil Nickel Concentration. Circles & solid line = field, triangles & dotted line = woodlots.**



To specifically address the absence of earthworms in 2001 at the sample site adjacent to the Inco Refinery, the site was re-sampled in June 2002 (Volume II, Tab 10). The sole purpose of this exercise was to confirm that earthworms were absent from that location. Species, abundance, age and biomass were measured at quadrants placed along a west to east transect through the Reuter Road Woodlot and Snider Road Woodlot, starting at the western edge of each woodlot. Soil samples were taken at each sampling point to better relate fine-scale soil CoC concentrations to measures of earthworm biology. Too few sites were sampled for statistical analysis, but a summary of the data collected is presented in Table 8-19.

Earthworms were found at each sample site in the Reuter Road and Snider Road Woodlots (Table 8-19). Numbers of earthworms within each woodlot increased as one moves to the east (i.e., further away from the presumed source of CoCs), but individuals were present at the western edge of each woodlot, including juveniles. At the western edge of the Reuter Road Woodlot, adjacent to the Inco Refinery, soil nickel concentrations were 21,100 mg/kg, soil copper concentrations were 3620 mg/kg, and soil arsenic concentrations were 129 mg/kg; two adults and three juveniles of two species were found at this site. Judging from these observations, it is apparent that earthworms can survive and successfully reproduce in areas with very high levels of CoCs.

Table 8-19 Earthworms Sampled During a Survey of Reuter Road and Snider Road Woodlots, June 2002.

Sample Code Ni soil concentrations (mg/kg) in parenthesis		Number of Species	Number of Adults	Number of Juveniles	Total Number of Worms	Biomass (g)
Reuter Road Woodlot	RW-H-1 (21 100)	2	2	3	5	1.06
	RW-H-2 (13 800)	1	2	0	2	0.95
	RW-H-3 (12 600)	1	0	1	1	0.05
	RW-H-4 (2 550)	1	1	9	10	1.51
	RW-H-5 (3530)	3	6	25	31	12.2
Snider Road Woodlot	SW-H-1 (2070)	2	0	4	4	0.52
	SW-H-2 (2430)	4	16	36	52	14.4
	SW-H-3 (1550)	3	1	42	43	9.53

Notes Ni soil concentrations for the above site codes are located in Vol. V, tab 25.
Earthworm data is located in Vol. III, tab 1
Stations are numbered from west to east.

8.3.3.4 Leaf Litter in the Natural Environment

Leaf litter was sampled in selected woodlots by Kilty Springs Environmental to assess the potential influence of CoCs on litter decomposition in the Port Colborne area (i.e., what is the effect of elevated CoCs on the decomposer community as a whole). Full details on the methodology and collected data of this study component are available in Volume II (Tab 11) and Volume IV (Tab 1).

The study included the selection of 21 hardwood woodlots in the area. These represented woodlots growing on clay soils and organic soils in separate zones of different CoC concentrations. Time constraints led to the use of a proxy method of assessing the rate of litter decomposition, which included collecting standing litter from 15 fixed sample points in each woodlot in late summer, 2001. The litter was separated into leafy material, twigs and fruit and dry weights were measured for each component.

The weights of standing leafy material ranged from 63.2 to 536.9 g/m^2, which is well within the normal range identified in the scientific literature (Volume IV, Tab 1). Three of the woodlots on organic soil had the highest weights of leaf litter (430- 537 g/m^2) suggesting the slowest rate of decomposition was occurring along Reuter Road where the highest CoC concentrations were present in the soil. This was especially evident where, by contrast, the smallest amounts of standing litter (211-315 g/m^2) were mostly associated with woodlots growing on organic soils with low levels of metals. On clay soils, the litter weights were intermediate to the values measured on the organic sites and showed no clear relationship between litter weight and metal concentration. Weights of twigs and fruits in the litter samples showed no statistically significant differences related to the metal level zones (Volume IV, Tab 1). Woody litter and leaf litter were typically present in nearly equal amounts averaging approximately 95% of the standing litter at the time of collection. Considerable variability existed among the amounts of litter of each type on the various woodlots.

It is expected that the single most important factor dictating how much leaf litter is on the ground is the size of the source (i.e., how many trees there are and of what size). To statistically assess whether there was a link between amount of leaf litter and soil CoC concentrations, one must first control for the size of the source. This was done by fitting into each *glm* an indicator of tree density and size, total basal area, as defined in Volume IV (Tab 1). Soil type was also included in each *glm*, and the results are presented in Table 8-20 and Volume III (Tab 3).

Table 8-20 Analysis of Deviance Table. The Response Variables are Dry Weights of Leaf Litter and Twig Litter, Log-transformed.[1]

		Dry Leaf		Twig		Fruit[2]	
Term	**df**	**Dev.**	***p***	**Dev.**	***P***	**Dev.**	***p***
Null	314	146.80		128.14		697.37	
Total tree basal area	1	22.66	**<0.01**	0.17	0.52	30.54	**<0.01**
Soil Nickel Concentration	1	28.25	**<0.01**	<0.01	0.98	82.97	**<0.01**
Soil Type	1	0.22	0.40	2.95	**<0.01**	4.26	0.13
Soil Nickel Concentration: Soil Type (Interaction)	1	0.05	0.69	0.46	0.28	8.01	**0.04**
Residual	310	95.62		124.56		571.60	

Notes
1 The models are fit as Gaussian models. Bold type indicates an estimated p-value of ≤ 0.05. Further information on Analysis of Deviance is found in Volume II, Tab 18.
2 Due to a missing value, the null degrees of freedom for fruit litter are 313, with a residual df of 309.

Table 8-20 shows that after controlling for the effect of total tree basal area, soil nickel concentration contributed to the *glm* of leaf litter dry weight. This was true for the other CoCs also (Volume III, Tab 3). As soil nickel concentrations increase, dry weight of leaf litter increases (Figure 8-23), presumably indicating that decomposition is slower. For twig litter, CoCs did not contribute to the *glm*s, but a difference between soils was noted (Table 8-20), with twig litter greater on clay soils than on organic soils (Figure 8-24). Like leaf litter, fruit litter weight was also influenced by CoC concentrations (Table 8-20; Volume III, Tab 3). Table 8-20 presents the *glm* using nickel, but all four CoCs had essentially the same relationship, which was an increase in litter weight as CoC concentrations increase (Figure 8-25). For nickel and arsenic, there also existed an interaction between soil type and CoC concentration, with litter weight increasing at lower CoC concentration more on clay soils than on organic soils (Figure 8-25).

Figure 8-23 Relationship Between Leaf Litter Dry Weight and Soil Nickel Concentration.

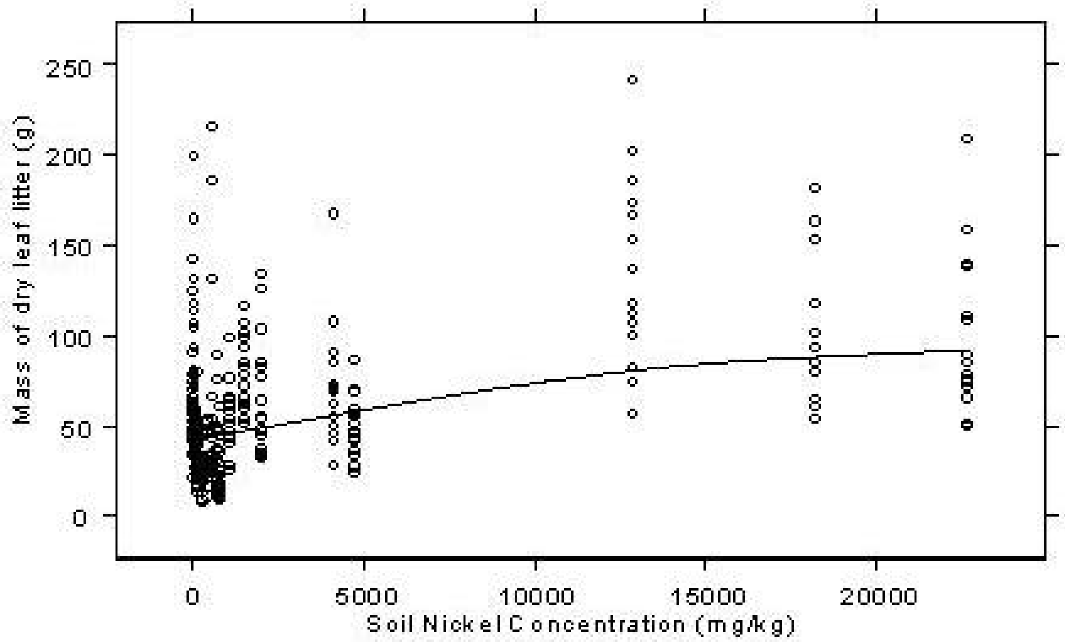


Figure 8-24 Boxplot of Twig Litter Dry Weight on Organic and Clay Soils. The Boxes Include 50% of the Data and the Whiskers Identify the Span of Data within 1.5 Times of the Inter-quartile Range.

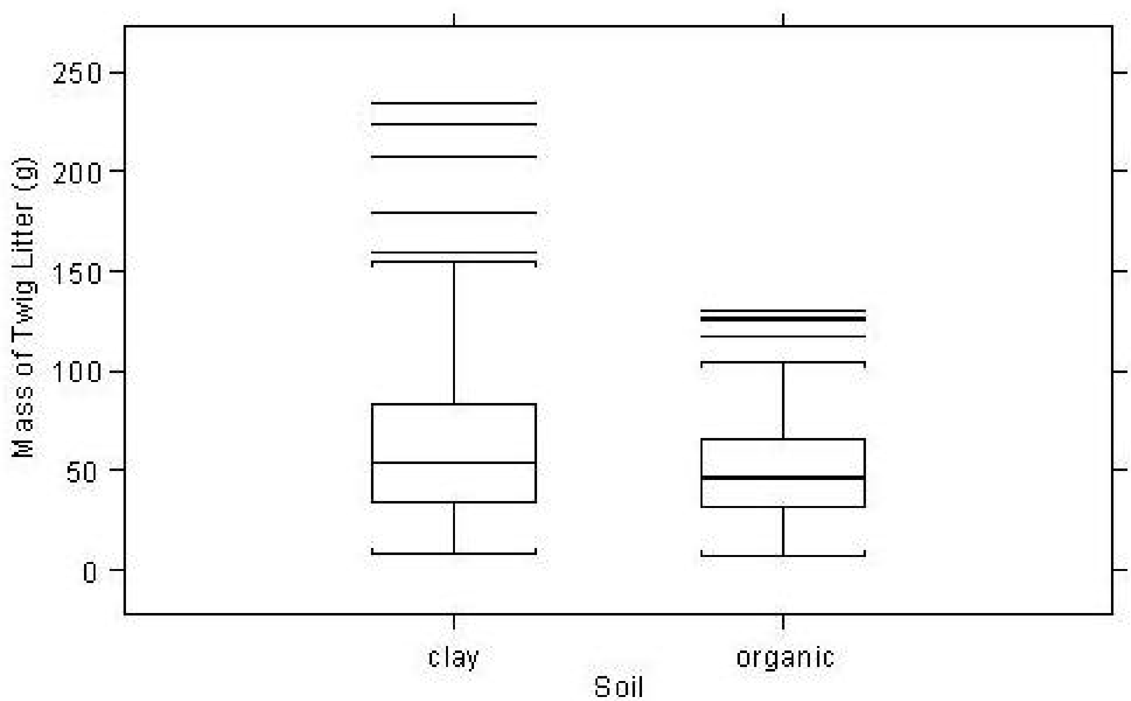
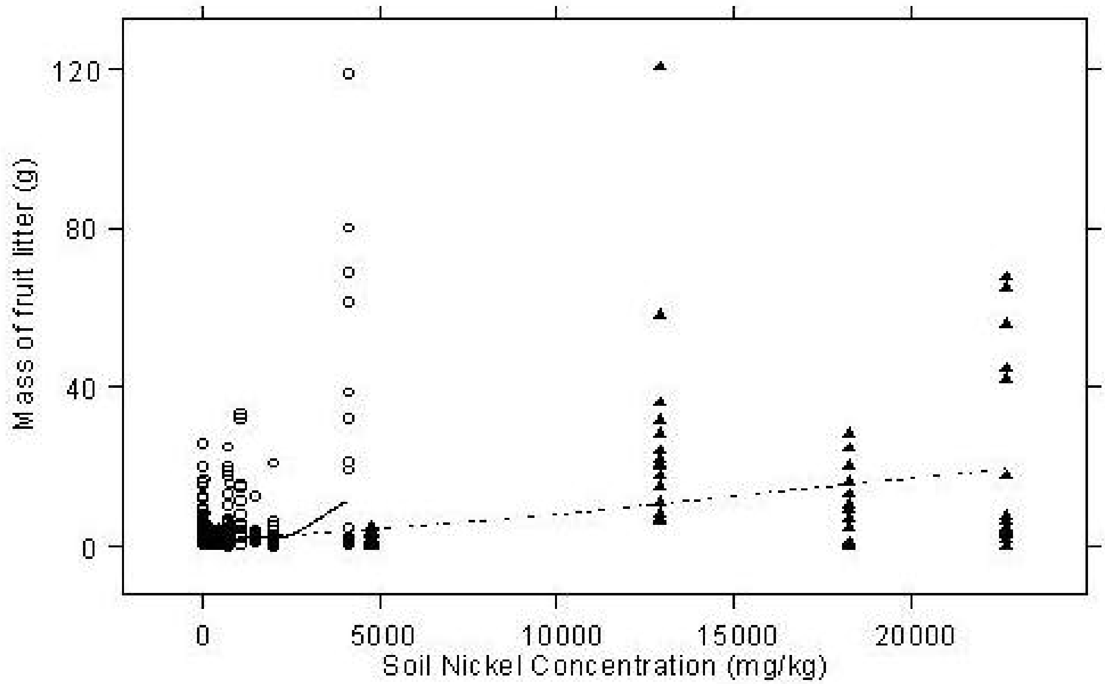


Figure 8-25 Relationship Between Fruit Litter Dry Weight and Soil Nickel Concentration. Circles & solid line = clay soils, triangles & dotted line = organic soils.



Although all four CoCs were found to be good predictors of leaf litter dry weight and fruit litter dry weight, it is likely that only nickel and copper, by virtue of their overall high concentrations, were likely to have been responsible for the slower rates of litter decomposition observed at the Reuter Road woodlots. Even though a decomposition pattern relationship with soil CoCs can be demonstrated, the total amount of decomposition that occurs in any single year at any one woodlot equals the amount of litter entering the system at that site. This conclusion is based on field observations that suggested no unusual accumulations of litter on the ground. The rates of average annual fresh litter input are essentially at equilibrium with the amount decomposing each year.

A detailed analysis of the vegetation species present in each woodlot did not provide any conclusive evidence to show alterations of the plant community that might have been related to high CoC concentrations (Volume IV, Tab 1). Tree and shrub health generally appeared to be normal at each woodlot. Mortality among trees and shrubs was in the normal range, especially if the endemic Dutch elm disease is taken into consideration. New foliage production did not show any relationship to soil CoC levels in the 2001 growing season.

8.3.3.5 Summary of Effects of CoCs on Decomposers

The quotient calculations performed for earthworms provide a conservative assessment of potential risk because the Toxicity Reference Values selected are the lowest reasonable benchmark for each CoC. Furthermore, estimating exposure using acid ammonium oxalate extraction conservatively over-estimates the likely exposure to earthworms. Conversely, exposure estimates using aqueous extraction likely underestimates the true exposure of the earthworms to nickel, copper and cobalt. Therefore the two sets of quotient calculations provide an upper and lower limit (i.e. 5900 to 46 mg/kg nickel in organic soils) to the potential risk to earthworm health imposed by soil CoCs. Based on the aqueous extraction, nickel, copper and cobalt do not pose a risk to the Study Area's earthworm population, but exposure estimated using the acid ammonium oxalate extraction suggests that nickel and copper could pose a risk in certain scenarios. Potential risk is posed by arsenic in woodlots on organic soils, assuming 100% bioavailability. Despite the variability and uncertainty associated with these results, the quotient calculations do provide worst-case scenarios and benchmarks with which one can evaluate other data analyses. Nevertheless lab studies and the field studies provide direct observation and assessment of how earthworms are potentially affected by CoCs in the Port Colborne environment.

The lab studies indicate there is no effect on survivorship in organic soils with CoCs up to 10,000 mg/kg of nickel and associated concentrations of copper, cobalt and arsenic. However, mortality of *Eisenia andrei* did occur in clay soils at a concentration of 9,000 mg/kg of nickel and associated concentrations of other CoCs. More sensitive testing by examining sublethal effects on reproduction of *E. andrei* indicates that an effect of 20% was noted at soil nickel concentrations of 1816 – 2749 mg/kg for organic soil and 83 – >8655 mg/kg for clay soils. However, other factors present in these controlled environments, including soil compaction, differences in soil moisture, and availability of natural food, may have influenced the results. These factors may have exacerbated the observed effects, especially in the trials using clay soils, and produced effect levels that were too conservative. Ground-truthing with actual field observations provides direct evidence of what was actually occurring in the natural environment and is more representative of the existing earthworm community.

Field observation and results of analyses for earthworms found in the Port Colborne area do not support the bioassay findings. Juveniles were by far the most common age group, with many individuals found at most sites, including juveniles at the site with the highest concentration of CoCs in the area. For most variables analyzed, CoCs either had no effect or were positively linked to the response; abundance, biomass and incidence increased as CoC concentrations increased. However, for one species, *Aporrectodea tuberculata*, this was not the case. As CoCs increased, measures of *A. tuberculata* abundance and biomass decreased, at least in clay soils.

Based on these three lines of investigation, it is apparent that earthworm species respond differently to soil CoC concentrations. Although some species exhibit a negative response to increased CoC concentrations, the earthworm community of the Port Colborne area appears healthy.

The overall conclusions reached from the leaf litter study suggest that the litter decomposition process might be slowed in woodlots in the zone of the highest soil concentrations of copper and nickel. While the process might be slowed in the presence of high concentrations of CoCs, the net decomposition each year is constant and there is no net accumulation of litter on the ground.

8.3.4 Birds

As representatives of the bird community, risk to Red-tailed Hawk, American Woodcock, American Robin and Red-eyed Vireo was assessed using the Quotient Method, comparing Toxicity Reference Values (Section 7) to estimated exposures (Section 6) based on site-specific CoC concentrations in soil, water and potential diet items. Where potential risk was identified (i.e., the quotient exceeded a value of 1), "safe" CoC concentrations would be calculated.

8.3.4.1 Potential Risk to Red-tailed Hawk

Potential risk of CoC exposure for the Red-tailed Hawk was estimated using the Quotient Method to compare TRVs to the derived and measured CoC concentrations in the media contacted by these birds. A Red-tailed Hawk's ADD was estimated for the four CoCs in included soil, water and diet items found within the Study Area (Section 6.5.3). As discussed in Section 6.5.1, the CoC concentrations of birds preyed upon by Red-tailed Hawks were estimated using the ADD of the three other avian VECs (American Woodcock, American Robin and Red-eyed Vireo) with appropriate BAFs for each CoC. The ADDs for the Red-tailed Hawk are presented in Section 6.5.4, and the hawk's TRVs for the four CoCs are presented in Section 7.

Four scenarios were examined for Red-tailed Hawk: fields on clay, woodlots on clay, fields on organic soils and woodlots on organic soils. Red-tailed Hawk exposure to CoCs in the Port Colborne area is minimal, and the CoCs do not pose a potential risk to this species (Table 8-21).

Table 8-21 Estimated Quotient for Red-tailed Hawks in the Port Colborne Area.

CoC	TRV (mg/kg d)	Average Daily Dose (mg/kg d)				Estimated Quotient			
		Clay		Organic		Clay		Organic	
		Woodlot	Field	Woodlot	Field	Woodlot	Field	Woodlot	Field
Nickel	83	0.5	0.47	1.01	0.5	0.01	0.01	0.01	0.01
Copper	55	0.261	0.251	0.381	0.271	<0.01	<0.01	0.01	<0.01
Cobalt	3.2	0.03	0.03	0.04	0.03	0.01	0.01	0.01	0.01
Arsenic	5.3	0.01	0.01	0.05	0.02	<0.01	<0.01	0.01	<0.01
Combined Toxicologically Independent Effects						N/A	N/A	N/A	N/A
Combined Toxicologically Similar Effects for Cobalt and Arsenic						0.01	0.01	0.02	0.01
N/A = there is no combined toxicologically independent effect as no CoC produced a value ≥ 1									

8.3.4.2 Potential Risk to American Woodcock

Potential risk of adverse effects caused by the four CoCs was estimated for American Woodcock using the Quotient Method, comparing the TRVs presented in Section 7 and the exposure to CoCs found in contacted media within the Port Colborne area, as calculated in Section 6.5.3. Four scenarios were examined for American Woodcock: fields on clay, woodlots on clay, fields on organic soils and woodlots on organic soils (Table 8-22). Based on this analysis American Woodcock exposure to CoCs in the Port Colborne area is minimal, and the CoCs do not pose a potential risk to this species.

Table 8-22 Estimated Quotient for American Woodcock Population in the Port Colborne Area.

CoC	TRV (mg/kg- day)	Average Daily Dose (mg/kg-day)				Estimated Quotient			
		Clay		Organic		Clay		Organic	
		Woodlot	Field	Woodlot	Field	Woodlot	Field	Woodlot	Field
Nickel	59	9.08	8.82	14.29	9.1	0.15	0.15	0.24	0.15
Copper	39	2.86	3.15	4.7	3.2	0.07	0.08	0.12	0.08
Cobalt	2.2	0.47	0.63	1.1	0.50	0.21	0.29	0.50	0.23
Arsenic	3.7	0.21	0.45	0.79	0.47	0.06	0.12	0.21	0.13
Combined Toxicologically Independent Effects						N/A	N/A	N/A	N/A
Combined Toxicologically Similar Effects for Cobalt and Arsenic						0.27	0.41	0.71	0.36

N/A = there is no combined toxicologically independent effect as no CoC produced a value ≥ 1

8.3.4.3 Potential Risk to American Robin

The Quotient Method was used to estimate the potential risk of adverse effects caused by the four CoCs to the American Robin in the Port Colborne area. Exposure was estimated using the models presented in Section 6.5.1, and the average daily dose for American Robins in the Port Colborne area are shown in Section 6.5.3. The TRVs are presented in Section 7. Based on available data and reference values, no CoC poses a potential risk to American Robins in the Port Colborne area (Table 8-23).

Table 8-23 Estimated Quotient for the American Robin Population in the Port Colborne Area.

CoC	TRV (mg/kg- day)	Average Daily Dose (mg/kg-day)				Estimated Quotient			
		Clay		Organic		Clay		Organic	
		Woodlot	Field	Woodlot	Field	Woodlot	Field	Woodlot	Field
Nickel	49	3.59	3.47	6.04	3.59	0.07	0.07	0.12	0.07
Copper	32	3.03	4.32	5.72	3.79	0.09	0.14	0.18	0.12
Cobalt	1.9	0.16	0.21	0.38	0.18	0.08	0.11	0.20	0.09
Arsenic	3.1	0.09	0.16	0.35	0.18	0.03	0.05	0.11	0.06
Combined Toxicologically Independent Effects						N/A	N/A	N/A	N/A
Combined Toxicologically Similar Effects for Cobalt and Arsenic						0.11	0.12	0.31	0.15
N/A = there is no combined toxicologically independent effect as no CoC produced a value > 1									

8.3.4.4 Potential Risk to Red-eyed Vireo

The potential risk to Red-eyed Vireo in the Port Colborne area was assessed using methods described above, comparing the TRV for the four CoCs with a Red-eyed Vireo's expected ADD. Although this species is a bird of forest habitat, we use Red-eyed Vireo as a representative of a suite of insectivorous songbirds, some of which are species of open areas or of both forest and field. Based on the quotient estimations, the local Red-eyed Vireo population is not at risk from exposure to observed CoC concentrations (Table 8-24).

Table 8-24 Estimated Quotient for the Red-eyed Vireo Population in the Port Colborne Area.

CoC	TRV (mg/kg-day)	Average Daily Dose (mg/kg-day)				Estimated Quotient			
		Clay		Organic		Clay		Organic	
		Woodlot	Field	Woodlot	Field	Woodlot	Field	Woodlot	Field
Nickel	37	1.25	1.18	2.65	1.25	0.03	0.03	0.07	0.03
Copper	24	2.47	4.74	6.37	3.75	0.1	0.2	0.27	0.16
Cobalt	1.4	0.04	0.04	0.07	0.04	0.03	0.03	0.05	0.03
Arsenic	2.4	0.03	0.02	0.17	0.06	0.01	0.01	0.07	0.03
Combined Toxicologically Independent Effects						N/A	N/A	N/A	N/A
Combined Toxicologically Similar Effects of Cobalt and Arsenic						0.04	0.04	0.12	0.06
N/A = there is no combined toxicologically independent effect as no CoC produced a value ≥ 1									

8.3.4.5 Summary of Potential Risk to Birds due to CoCs

Potential risk was not identified for any of the avian VECs, including a top predator, the Red-tailed Hawk. Analyses indicate that soil CoCs must be at very high concentrations for significant adverse effects to be observed in the bird populations of the Port Colborne area. Based on the above assessments that considered birds of varying body size (weight), habitat preference and diet, it is concluded that all bird populations are not at risk due to CoC exposure in the Port Colborne area.

However, American Woodcock proved to be the most sensitive bird to CoCs for woodlots on organic soils and one of the most sensitive VECs overall, as judged by the relatively higher calculated quotients. This can be attributed to the relatively high CoC concentrations found in its principal food item, earthworms. Considering the avian VECs as representative of the bird community, these results indicate that the bird community found in the Study Area is not at risk due to exposure to CoCs.

8.3.5 Mammals

For the mammalian receptors, risk was assessed using the Quotient Method, comparing Toxicity Reference Values (Section 7) to estimated exposure (Section 6) based on site-specific CoC concentrations in soil, water and potential diet items. Red Fox, Raccoon, Meadow Vole and White-tailed Deer were selected as VECs and are representative of the mammal community in the Study Area.

8.3.5.1 Potential Risk to Meadow Vole

The Quotient Method was used to evaluate the risk to Meadow Voles using a TRV for each CoC (Section 7) and estimated ADD (Section 6.5.4). This species is found almost exclusively in fields, so evaluation of exposure is limited to field habitat. Our quotient calculations show that the Meadow Vole population in the Port Colborne area is not at risk (Table 8-25).

Table 8-25 Estimated Quotient for the Meadow Vole Population in the Port Colborne Area.

CoC	TRV (mg/kg-day)	Average Daily Dose (mg/kg-day)		Estimated Quotient	
		Field Clay	Field Organic	Field Clay	Field Organic
Nickel	34	6.1	0.59	0.18	0.02
Copper	12	0.13	0.17	0.01	0.01
Cobalt	14	0.01	0.02	<0.01	<0.01
Arsenic	1.2	0.02	0.04	0.02	0.03
Combined Toxicologically Independent Effects				N/A	N/A
Combined Toxicologically Similar Effects of Cobalt and Arsenic				0.02	0.03
N/A = there is no combined toxicologically independent effect as no CoC produced a value > 1					

8.3.5.2 Potential Risk to White-tailed Deer

Risk to White-tailed Deer was assessed using the Quotient Method described above. Toxicity Reference Values are provided in Section 7 and the expected average daily dose to which a White-tailed Deer is exposed is detailed in Section 6.5.4. For this quotient estimation, one scenario is presented to reflect the home range of White-tailed Deer and its varied diet. The evaluation shows that no risk is present to the White-tailed Deer population in the Port Colborne area (Table 8-26)

Table 8-26 Estimated Quotient for the White-tailed Deer Population in the Port Colborne Area.

CoC	TRV (mg/kg day)	Average Daily Dose (mg/kg day)	Estimated Quotient
Nickel	22	0.691	0.03
Copper	7.9	0.211	0.03
Cobalt	8.8	0.01	0
Arsenic	0.8	0.01	0.01
Combined Toxicologically Independent Effects			N/A
Combined Toxicologically Similar Effects for Cobalt and Arsenic			0.01
N/A = there is no combined toxicologically independent effect as no CoC produced a value ≥ 1			

8.3.5.3 Potential Risk to Raccoon

The Quotient Method was used to assess the potential risk posed by CoC concentrations in the Port Colborne area to the Study Area's Raccoon population, using the exposures estimated in Section 6.5.4 and the TRVs presented in Section 7. The evaluation shows that the Raccoon population in the Port Colborne area is not at risk due to exposure to CoCs (Table 8-27).

8.3.5.4 Potential Risk to Red Fox

The potential risk CoCs may pose to Red Fox populations in the Port Colborne area was assessed using the Quotient Method, evaluating a Red Fox's average daily exposure (Section 6.5.4) in relation to a TRV (Section 7) for each CoC. The assessment shows that the CoCs do not pose a risk to the Red Fox population in the Port Colborne area (Table 8-28).

Table 8-27 Estimated Quotient for Raccoon Population in the Port Colborne Area.

CoC	TRV (mg/kg d)	Average Daily Dose (mg/kg d)				Estimated Quotient			
		Clay		Organic		Clay		Organic	
		Woodlot	Field	Woodlot	Field	Woodlot	Field	Woodlot	Field
Nickel	26	1.36	1.26	3.29	1.37	0.05	0.05	0.13	0.05
Copper	9.2	1.13	1.73	2.53	1.51	0.12	0.19	0.28	0.16
Cobalt	10	0.04	0.05	0.11	0.05	0	0.01	0.01	0.01
Arsenic	0.94	0.03	0.05	0.19	0.07	0.03	0.05	0.2	0.07
Combined Toxicologically Independent Effects						N/A	N/A	N/A	N/A
Combined Toxicologically Similar Effects for Cobalt and Arsenic						0.03	0.06	0.21	0.08
N/A = there is no combined toxicologically independent effect as no CoC produced a value > 1									

Table 8-28 Estimated Quotient for the Red Fox Population in the Port Colborne Area.

CoC	TRV (mg/kg-d)	Average Daily Dose (mg/kg-day)				Estimated Quotient			
		Clay		Organic		Clay		Organic	
		Woodlot	Field	Woodlot	Field	Woodlot	Field	Woodlot	Field
Nickel	26	0.735	0.705	1.355	0.735	0.03	0.03	0.05	0.03
Copper	9.1	0.582	0.632	0.812	0.622	0.06	0.07	0.09	0.07
Cobalt	10	0.041	0.041	0.051	0.041	<0.01	<0.01	0.01	<0.01
Arsenic	0.92	0.02	0.02	0.06	0.03	0.02	0.02	0.07	0.03
Combined Toxicologically Independent Effects						N/A	N/A	N/A	N/A
Combined Toxicologically Similar Effects for Cobalt and Arsenic						0.02	0.02	0.08	0.03
N/A = there is no combined toxicologically independent effect as no CoC produced a value ≥ 1									

8.3.5.5 Summary of Effects of CoCs on Mammals

The analyses performed indicate that soil CoCs must be at very high concentrations for significant adverse effects to be observed in the mammal populations of the Port Colborne area. Based on the above assessments that considered mammals of varying body size (weight), habitat preference and diet, it is concluded that all mammal populations are not at risk due to CoC exposure in the Port Colborne area.

9.0 INTEGRATION

This chapter discusses the findings of this ERA, integrating the three different lines of evidence considered in the study. This evidence is used to develop conclusions regarding the presence of potential risk to VECs caused by CoCs in the Study Area, and is discussed in more detail below.

9.1 Approach

In conducting this ecological risk assessment, the culmination of site characterization and exposure and hazard assessment resulted in the assessment of risk for a number of receptors that were identified as valued ecological components (VECs) for the CBRA. The VECs are representative of the local flora and fauna that inhabit the woodlots and fields within the Study Area. The final phase of the risk assessment process is to integrate the various lines of evidence that were developed in this study to reach conclusions regarding the existing ecological risk and to determine the safe or acceptable levels for CoCs in local Port Colborne soils. For this risk assessment, three general lines of evidence were developed that can be used for the interpretation of potential risk to the natural environment:

- Detailed field observation (qualitative) and data collection (quantitative) of the Study Area's flora, fauna and environmental media [soil, water and air];
- Controlled laboratory experiments on specific VECs using soils collected from the Study Area; and
- Quantitative risk characterization using the Quotient Method with dose exposures based on specific data collected for the Study Area.

Current ERA practice accepts and requires that, following risk estimations, a description or characterization of risk is a necessary final step. However, no standard method or widely accepted approach is identified (CCME 1997, US EPA 1998). This is due to the fact that in North America risk assessments undertaken for the natural environment vary considerably with respect to the type of data used (qualitative versus quantitative) and/or site specific values versus literature derived values. Therefore, ultimately determining unacceptable adverse ecological effects is based on the risk assessor's experience and professional judgement following an integration of all available data.

The following principles have been used as guidance for the characterization of risk to the natural environment in the Port Colborne area:

- Assessment of risk to VECs is based at the population level, with a population defined as being all the individuals of a species found to occur within the total Study Area as defined by the ERA;

- The extensive field data, both qualitative and quantitative, collected for receptors in the risk assessment is considered an important factor for the interpretation of risk, providing a real measurement of the current ecosystem in the Port Colborne area;

- The assessment of potential risk based on the Quotient Method is considered to represent the most conservative measure for the identification of potential risk;

- The use of the UCLM or maximum for environmental media and biological tissues in the exposure assessment results in a risk assessment that is considered to be conservative for a VEC's population that is found to occur throughout the Study Area; and

- The identification of safe CoC soil values and need for remediation measures is assessed using a holistic ecological risk approach at the population, community or ecosystem level.

The following section provides a discussion and description of risk for the VECs considered in this study.

9.2 Summary Discussion of Risk

The need to undertake an ERA for the natural environment found in Port Colborne, east of the Refinery, was identified as a key component of the Community Based Risk Assessment. In conducting the ERA-Natural Environment, investigations were carried out to address two key questions:

1) Are current elevated concentrations of CoCs in soils having a negative effect on existing key ecological functions of the natural environments at a level of impairment that is unacceptable?

2) Are specific species ***populations*** at risk based on their exposure to CoCs in the environments they inhabit where current soil CoC concentrations exceed MOE generic guidelines?

To address these two fundamental questions, an extensive set of qualitative and quantitative data were collected for woodlots and fields over an extensive Study Area (22 km^2), where soil concentrations of CoCs (nickel, copper, cobalt and arsenic) were known to be above current Ministry of Environment (MOE) generic guidelines, based on MOE data. Samples of soil, sediment, surface water, air and biological tissue were collected from sites throughout the Study

Area and analyzed for concentrations of CoCs. Analysis of these data clearly demonstrates that concentrations of CoCs in soil increase in a gradient moving toward the Refinery from the northeast. Additionally, this analysis showed that CoC concentrations in biological tissues were very small compared to the total CoC concentrations found in the soils, principally due to a barrier at the soil-plant interface (discussed below).

To address whether the CoCs in the environment are having an adverse effect on organisms and natural processes, field investigations, controlled experiments and calculations of potential exposure were performed for the identified VECs. The study design and data collection was undertaken so as to be able to assess potential adverse effects on biota as one moves up the food chain from primary producers in direct contact with soil CoCs (soil microfauna and plants), to primary consumers (soil invertebrates and terrestrial invertebrates) to secondary consumers (birds, mammals and amphibians) and finally to top predators in the ecosystem (birds and mammals). For an assessment of risk to woody plants (trees and shrubs) data were collected in the field and through controlled experiments. (For an assessment of risk to crops, refer to results of the ERA-Crop Studies (Jacques Whitford 2004a), which conducted both greenhouse and field experiments, were used for the ERA). Overall, the collected data provided the opportunity to use three lines of evidence to characterize the potential risk of soil CoCs to the natural environment, in the context of specific populations of animals and plants and of the whole natural system existing in the Study Area.

Generally, the study found that primary producers (plants), secondary consumers (birds, mammals, frogs/toads) and top predators (birds and mammals) are not at risk at a population level across the Study Area. The study identified, based on the lower numbers of earthworms and increased amounts of forest litter, that in the woodlots nearest the refinery on organic soils which have very high levels of CoCs are having an adverse effect on the decomposer community. However, the level of the effect on the decomposer community, and therefore the nutrient cycle in these woodlots, is not impacting long-term health or productivity of these woodlots. These conclusions are further detailed below.

Decomposers

The role of element or nutrient cycling for maintaining the long term viability of the Study Area's ecosystem was recognised as a key VEC for which potential risk was assessed. In natural systems, the decomposition process (decay) returns elements and nutrients that were incorporated into the tissues of plants and animals back to a form than can be used once again by the primary producers, generally plants. Typically, over an extended period of time [years/decades/centuries], an ecosystem such as a forest is in a steady state, where the release of elements and nutrients through decomposition fulfils the needs for growth of the flora and fauna that inhabit the system.

For woodlots, nutrient cycling is achieved by yearly decomposition and decay of forest floor litter comprised of herbaceous plants, leaves that fall and branches, twigs and ultimately trees that fall to the ground. The litter decay process is both physical and chemical and is facilitated by a variety of soil-dwelling organisms including microbes (bacteria, fungi and protozoa) and invertebrates (mites, collembola, nematodes, earthworms, millipedes, molluscs and insects). The role that specific soil fauna play in the rate of decomposition varies, but generally soil microbes are considered important, as are earthworms. For example earthworms may comprise up to 90% of the biomass of soil invertebrates and are therefore very important in the total soil fauna ecosystem (ASTM 1998).

Leaf Litter

Elevated concentrations of metals in soils have been documented to decrease rates of litter decomposition as a result of their impacts on soil fauna (Allen 2002). For example, Freedman and Hutchinson (1980) found that elevated soil levels of nickel and copper in acidic soils in the proximity to smelters inhibited litter decomposition. For the assessment of potential risk to decomposers, and ultimately the nutrient cycle, through exposure to elevated levels of CoCs, the ERA investigated the existence of potential risk to earthworms and if leaf litter decomposition is impaired in the Study Area's woodlots. The assessment of standing litter allows potential impacts of soil CoCs on the decomposer community (including microbes and invertebrates) to be indirectly assessed. Additionally, woodlot health was evaluated, comparing Study Area woodlots with representative woodlots in the Reference Area. This provided further measures on the potential influence of elevated soil CoC concentrations on nutrient cycling, as assessed using measures of woodlot health (e.g., woodlot productivity). The assessments of earthworms, litter and woodlot health are summarized below.

Earthworms

Risk to earthworms posed by CoC concentrations was evaluated using three approaches: 1) assessing potential risk using site-specific soil CoC concentrations and toxicity reference values from the literature, 2) dose-response experiments using blends of site-specific soils from the Port Colborne area to estimate EC_{20} levels, and 3) field surveys of naturally occurring earthworm populations in the Port Colborne area. These three lines of evidence produced results that are not directly supportive of one another.

Determining potential risk for earthworms using toxicity reference values, which were the lowest reasonable benchmark for each CoC taken from the literature, against soil concentrations for the CoCs was considered to be a conservative measure of risk. Assessment of potential exposure to CoCs in pore water was calculated based on exposure to CoC concentrations derived from aqueous extraction and acid ammonium oxalate extraction of nickel, copper and cobalt. Based on aqueous extraction, worms are only at a potential risk (quotient of 3.95) for arsenic in organic woodlots, at a level of 21 mg/kg. For the acid extraction, worms have a potential risk for nickel in organic woodlots at 3000 mg/kg, 50 mgCu/kg in clay and organic fields and woodlots and arsenic in organic woodlots at 21 mg/kg.

Chronic dose-response experiments using *Eisenia andrei* in clay and organic soils also found varying results. For organic soils, EC_{20} effects (juvenile biomass/numbers and hatched cocoons) were found at soil nickel values in a range of 2000 to 3000 mg/kg. For clay soils, the EC_{20} was assessed to have a range of 80 to 1200 mg-Ni/kg, although other soil properties of the clay may have negatively influenced the results. Field surveys, which included sampling earthworm populations throughout the Study Area in both soil types in field and woodlot habitats, found both adult and juvenile earthworms occurring in soils where nickel concentrations were much higher than those indicated by the conservative quotient calculations or laboratory toxicity tests. No difference in earthworm numbers was noted as soil nickel concentrations increased from 2000 to 5000 mg/kg. Throughout the Study Area, species richness of earthworms was not influenced by soil type or habitat type, or by soil CoC concentrations. Although species diversity and numbers of individual worms were reduced, both adult and juvenile worms were sampled from soils in an organic woodlot where the CoC values were very high - 21,100 mg-Ni/kg, 3620 mgCu/kg, and 129 mgAs/kg. The results of this sampling clearly indicated that successful reproduction by worms is possible even under the influence of these very high CoC concentrations. Nevertheless, samples taken along an east to west transect through the Reuter Road Woodlot showed that total numbers of worms and total biomass increase eastward with distance from the Refinery.

Wild earthworms took up CoCs in soil, although the proportion taken up varied with the CoC and soil type. Whole earthworms sampled in 2002, which included contaminated soil found in their gut contents, had CoC concentrations ranging from approximately 26% to 69% of soil CoC concentrations. When gut contents were removed (purged), earthworms had even lower concentrations of CoCs in their tissues, from approximately 39% to 60% of whole earthworm nickel concentrations, 66% to 71% of copper, 60% to 75% of cobalt and 86% to 93% of arsenic concentrations. It is apparent that bioavailability of CoCs to earthworms is below 100%, and as low as 11% on clay soils for nickel and as high as 51% for cobalt on clay soils. For copper, earthworm tissue concentrations were 20-30% of soil copper concentrations, which is less than the 44% bioavailability reported by Marinussen *et al*. (1996) for sandy loam soil but in line with the somewhat variable values reported by Peijnenburg *et al*. (1999). Peijnenburg *et al*. (1999) also reported nickel and arsenic bioavailability to *Eisenia andrei* to be roughly 22% for nickel and 20-80% for arsenic. These values approximate what was found for bioavailability in the Port Colborne area (HHRA-Jacques Whitford 2004b).

Based on the actual distribution and abundance of earthworms in the Study Area, it is clearly evident that neither estimated potential risk based on literature-based TRVs for each CoC, nor the toxicity tests for clay soils represent the actual effects, or risk, in the existing natural environment of the Study Area. Clearly, the Study Area's earthworm population as a whole is not at risk, as worm numbers and species were found to be abundant throughout the Study Area and at levels equal to or better than Reference sites. Based on field data, lethal effects on adult worms and/or their reproduction would seem to be near 20,000 mg-Ni/kg and 3,600 mg-Cu/kg. For the toxicity tests, EC_{20} effects for 2000-3000 mg-Ni/kg in organic soil is in agreement with reported effects values in the literature; however, these values were not supported by the field results of this study. The toxicity test results for clay soil are neither supported in the literature nor by the results of field sampling.

Species vary in their response, which may be partly responsible for the discrepancy between the toxicity testing using Port Colborne soils and what has been reported in the literature. This variability was noted in the field, with *Aporrectodea tuberculata* showing a negative response to increasing CoC concentrations, while two of the most common species (*Lumbricus terrestris* and *L. rubellus*) showed no adverse effect to increased CoC concentrations. Overall, the earthworm community in Port Colborne, as measured by species richness, overall abundance and overall biomass, showed no negative response to increases in soil CoC concentrations. This is taken as the ultimate assessment of risk to the earthworm community, and since increased CoC concentrations do not cause negative responses by the earthworm community overall, the ***earthworm populations*** of the Port Colborne area are not considered to be at risk due to CoC exposure. Non-lethal, chronic effect level for soil CoCs, or EC_{20}, affecting either body weight or reproduction, cannot be directly assessed based solely on the field data collected for this study.

Soil Microbes

Based on the above, if earthworms in woodlots represented the only fauna responsible for the decomposition of forest litter, then one would expect that decomposition of litter would not be impaired in the Study Area. However, soil microbes also play a role in the decomposition of litter, and metal contamination can affect the number of microbes in the soil (Duxbury 1985). Metals in soil generally affect soil microbial diversity to the point that certain genera are found less frequently, while others seem to adapt well (Arnebrandt 1987). However, loss of soil microbial diversity does not directly correlate to a reduction in the decomposition process, and microbial processes are more sensitive to elevated levels of metals in soils (Allen 2002).

Metals affect several microbial processes, such as litter decomposition, carbon mineralization, nitrogen transformations, enzyme activity and mycorrhizae activity. Responses to soil microbes have been measured based on concentrations of metal ions in soil porewater as well as concentrations in soil. Limited data on soil porewater concentrations and impacts on microbial processes are available, with assessment endpoints typically taking into consideration growth of native tree species and the efficiency of root symbionts.

As a measure of the potential effect of soil CoCs on the decomposition of litter in woodlots, standing leaf litter (as dry weight) was collected from sample stations in woodlots in the Study Area and at woodlots in the Reference Area. Weights of standing leafy material ranged from 63.2 to 53.9 g/m^2, which was considered to be well within the range of normal amounts in woodlots. The woodlots on organic soils nearest the Refinery had the highest weights of leaf litter (430-537 g/m^2), suggesting the slowest rate of decomposition was occurring along Reuter Road where soil CoC concentrations are the highest. This finding is supported by the assessment of earthworm distributions, which also found that earthworm numbers were the lowest in these woodlots for the Study Area. Analysis found that soil CoC concentrations were a good predictor of leaf and fruit litter dry weight, with litter weight increasing as concentrations of CoCs increased. Although it is likely that soil nickel and copper play the primary role, due to their very high concentrations, the results show that decomposition of litter is affected by increased concentrations of CoCs in the soil.

However, the litter study also noted no unusual accumulations of litter in woodlots, even in those woodlots adjacent to the Refinery. Increased litter (as measured by dry weight) may be correlated with increased soil CoC concentrations, but the total amount of decomposition that occurs in a year in any one woodlot equals the amount of litter entering the system. If the rate of decomposition were significantly slowed, then forest litter in woodlots would have continually accumulated over the last 40-50 years, creating a deep layer (many centimetres) of litter. This situation is not found in the Study Area, even for woodlots located nearest the Refinery.

In summary, an assessment of the potential effect of soil CoCs on decomposition and nutrient cycling in the natural environments in the Study Area found evidence that the decomposition process might be slowed in organic woodlots with the highest concentrations of CoCs (soil nickel values range from 13,000 to higher than 20,000 mg/kg). This potential effect is supported by the observation that earthworms, a known major component of the soil fauna decomposer community, were found to occur in very low numbers in these woodlots. For these organic woodlots, it is also very likely that soil microbial processes are also adversely affected by these very high concentrations of CoCs. Nevertheless, though the rate of decomposition may be slowed, current rates of decomposition are sufficient to maintain an equilibrium between fresh litter input and amount of litter decomposing each year. This assessment indicates that no significant impairment in the nutrient cycle is occurring in woodlots. This conclusion is supported by another line of evidence, namely, an assessment of overall woodlot health in the Study Area.

Woodlots

For this study, the assessment of woodlot health was undertaken using four measures: assessment of stand structure, tree species diversity, shrub species diversity and productivity. Combined, these measures can be used to assess the combined potential adverse effects of soil CoCs on nutrient cycling that translate to effects on forest structure and health. In the assessment, 82% of the Study Area's woodlot habitat was surveyed and compared to six woodlots in the Reference Area located east of the Study Area.

For the assessment of stand structure, the total basal area of trees in each compartment was measured and the mean basal area was calculated. The mean basal areas for the Study Area's woodlots (28.3 m^2/ha) and Reference woodlots (28.9 m^2/ha) were not significantly different. For woodlots in the Study Area, polewood was found in high abundance, having been established 30 to 45 years ago. In addition, a comparison of the species representing polewood indicates the species composition of the Study Area and Reference woodlots are similar, with a dominance of soft maples (Red Maple and Freeman's Maple) and ashes. That polewood became established during this period is important as it coincides with the period of peak atmospheric deposition of CoCs from the Refinery, and indicates that past and present levels of soil CoCs did not, and do not, inhibit natural forest regeneration in Port Colborne.

Similar results were obtained for mean stocking estimates (stems/ha), with no significant difference between Study Area woodlots and reference woodlots for all size classes, except for saplings. With respect to stocking, the Study Area woodlots had more than 200 stems/ha, which was more than what was found in Reference woodlots. Again, the abundance of saplings in the Study Area woodlots indicates that past and present levels of soil CoCs do not inhibit natural forest regeneration. The findings are supported by the results of the dose-response experiments on maple seedlings as detailed below.

As a measure of woodlot productivity, mean maximum height, average age of trees, and mean stand diameter for woodlot compartments were assessed. These productivity parameters allow for a long-term (50+ years) assessment of potential effects of soil CoCs on the nutrient availability in soils. If the nutrient cycle has been impaired by decades of accumulation of CoCs in the soil, then it is expected that woodlots in the Study Area would have lower overall productivity. Results of the mean maximum height for the woodlot compartments indicate that there is no significant difference between the Study Area woodlots (24.2 m) and Reference woodlots (25.5 m). Woodlots located directly adjacent to the Refinery had mean maximum heights that were either at the average value or higher. Similarly, the mean tree diameters for woodlot compartments in the Study Area (31.4 cm) and in the Reference Area (32.8 cm) were not significantly different. The average age of the dominant canopy trees within the Study Area was 74 years, while the average age in Reference woodlots was 90 years.

The above findings strongly indicate that prolonged (50+ years) exposure to both soil and atmospheric CoCs has not resulted in a significant observable reduction in the overall growth and productivity of the woodlots located downwind of the Refinery. The results of the woodlot health study found that the productivity of woodlots in the Study Area exposed to elevated concentrations of CoCs is very similar to that of Reference woodlots, and that no significant impairment of woodlot health has occurred.

A closer examination of woodlots was undertaken, which focused on the effects of CoCs on the most common tree of the Port Colborne area, and the principal component of the Study Area's woodlots: "Soft Maple", which includes Red Maple (*Acer rubrum*), Silver Maple (*A. saccharinum*) and their hybrid, Freeman's Maple (*A. rubrum* x *A. saccharinum*). Of these three trees, Freeman's Maple is the most common in the Port Colborne area, but due to the difficulty in distinguishing these taxa, the three maples were collectively referred to as Soft Maple.

Soft Maple was selected as a VEC for the ERA as it represents the primary tree occurring in the Study Area's woodlots and treed swamps, which have been identified as significant at a provincial and regional level. For example, the Soft Maple swamp located on and adjacent to the Refinery property has been evaluated as a provincially significant wetland. Therefore, the assessment of potential impacts of soil CoC concentrations on Soft Maple was identified as important to the ERA. In addition, Soft Maples have a shallow rooting system that is exposed to soil CoCs at both the soil surface and the B-horizon. Studies have also shown that Soft Maples are susceptible and sensitive to nickel toxicity symptoms (Temple and Bisessar 1981, Gunn *et al*. 1995). Due to these factors, Soft Maple was considered to be the best tree species to use for the assessment of potential impacts of CoCs on all deciduous tree species occurring in the Study

Area, including noted rare species such as the Pin Oak, Swamp White Oak, Pignut Hickory and Hop Tree. Additionally, sampling and analysis of maple tree leaves has been undertaken in the Port Colborne area for the past two decades by the Ministry of Environment, providing an opportunity to assess the change over time with respect to CoC uptake.

To assess uptake of soil CoCs into maple leaves, CoC concentration data for maple sap collected for the Human Health Risk Assessment was used for a number of trees located in a woodlot with very high soil nickel concentrations (13,000-23,000 mg/kg). Although the bioaccumulation factor for soil CoCs to sap was extremely low (0.000005 or less), indicating a strong soil-plant barrier, CoCs accumulate in the leaf tissue during the length of the growth period. However, during this growing period, data collected for this study indicate that even in areas where soil CoC concentrations are at their highest, maple trees growing in this environment do not accumulate CoCs in their leaf tissues to levels that exceed current MOE upper limit guidelines. As stated by the MOE (1993b), leaf concentrations for metals that are below the upper limit of normal are not known to be toxic. The results of this study support this conclusion. In addition, this study also supports the conclusion of Rinne (1981) who, based on a review of leaf tissue data collected during periods of atmospheric deposition and non-atmospheric deposition (during refinery shut downs), determined that elevated CoC concentrations in leaf tissue were a direct result of atmospheric deposition, rather than uptake from soils by the trees.

For plants, investigations by others into the potential effects of elevated soil metals such as nickel and copper on the flora of forests and wetlands have identified that species richness and abundance shows a decline as metal concentrations increases near a refinery (Hutchinson and Whitby 1977, Freedman and Hutchinson 1980, Gignac and Beckett 1986, Gignac 1987). Generally, these studies have shown that plant species abundance is significantly reduced near the refinery (<1km) and that effects continue up to 10 km away. General investigations undertaken for the ERA found that woodlots located nearest the Refinery had high species diversity for trees and shrubs, such that when habitat requirements and rarity of occurrence in the Niagara Region were taken into account, over 90% of tree species and 80% of shrub species were present. Detailed assessments of study plots in woodlots in the Study Area found no significant difference in species occurrence for trees, shrubs and ground flora when compared to study plots in woodlots at Reference sites. These detailed studies identified that woodlots located directly adjacent to the refinery (<500 m) had some of the highest tree species diversity, including a number of tree species that are rare in the Province.

Assessment of risk of soil CoCs to Soft Maple trees was undertaken following two lines of evidence: 1) maple seed germination and sapling growth in a controlled greenhouse setting, and 2) visual leaf health assessment of naturally occurring maple trees. Long-term health of the local area's woodlots requires the regeneration of new trees to succeed old mature trees as they die off. Generally, plants, including trees in advanced stages of maturity, are likely to be less responsive to environmental contamination than young plants (MOE 1993a). Therefore, the ability of the Study Area's woodlots to remain sustainable over time through the regeneration of new growth was assessed by conducting greenhouse experiments with locally collected maple keys.

To assess the effect of soil CoCs on maples, dose-response greenhouse trials were conducted in the summer of 2001, examining the effects of varying CoC concentrations on maple seed germination and seedling growth. For the dose-response trials, maple keys were planted in pots with clay and organic soils containing increasing concentrations of nickel (background levels, 500, 1,500, and 3,000 mg-Ni/kg), and proportionally increasing concentrations of other CoCs. This experimental design assessed the combined potential effects of existing soil CoCs on maple key germination and sapling growth. For the assessment of potential soil CoC effects, four parameters were assessed following 56 days from time of planting: maple key germination success, seedling height, number of dropped leaves and health of leaves.

Based on the results of the greenhouse trials, which included seed germination success, sapling growth and assessment of leaf health, there was no significant negative effect caused by varying soil nickel concentrations up to 3000 mg/kg, either on clay soils or on organic soils. However, the results suggest that maple keys from the Study Area responded differently than maple keys taken from the Reference Area, with Study Area plants growing better in the more contaminated soil. Whether this is due to local adaptation, as the data suggest, is unclear as the size of the source population (one tree from the Reference Area and two adjacent trees from the Study Area) prevent generalizations from being made. However, local adaptation of plants to elevated concentrations of soil metals near smelters has been documented by studies investigating recovery of natural ecosystems (e.g., Hutchinson 2000). The ability of plants to tolerate or adapt to local conditions may be important in ensuring the long-term viability of local plant communities. Based on the results of the greenhouse germination trials, a safe soil value of > 3000 mg/kg of nickel for clay and organic soils has been identified with respect to seeding and sapling growth.

For naturally occurring Soft Maple trees in the Study Area, an assessment of leaf health was undertaken as an indicator of potential toxic effects of leaf tissue CoC concentrations and potential overall reduction of plant vigour and growth. It is generally agreed that phytotoxicity in plants is the first adverse effect caused by increased phytoavailable soil nickel (Chaney 1983). Nickel phytotoxicity symptoms in plants include necrosis, chlorosis, flecking and stippling on leaves. Therefore, to assess potential effects of CoC concentrations in leaf tissue, leaves were collected from trees in the Study Area and from sites in the Reference Area. Following collection of the leaves from individual trees, a visible injury assessment was undertaken for each leaf. Each leaf was visually assessed for necrosis, chlorosis, flecking and stippling and assigned a foliar injury rating (Classes 1 through 4) (Refer to Volume II, Tab 14). In addition, the presence/absence of galls on a leaf was recorded separately.

Based on an analysis of 576 leaves collected for the study, no significant difference in leaf health class ranking was found between leaves collected in the Study Area and those collected from a Reference Area. This line of evidence indicates that the existing concentrations of CoCs in the soil do not have a significant influence on the frequency or incidence of unhealthy leaves and, therefore, tree vigour and growth. Leaves collected for the visual health assessment were also analyzed for concentrations of CoCs in the leaf tissues. Table 9-1 presents a review of the concentrations of CoCs in leaf tissue for trees in the Primary Study Area (see Section 6.4.3), where soil CoC concentrations are the highest (up to over 20,000 mg/kg for nickel). The review finds that current tissue levels are below the upper limit of normal concentrations for metals in tree foliage (MOE 1993b).

Table 9-1 Comparison of Primary Study Area Mean Maple Leaf Tissue CoC Concentrations Compared to MOE Upper Guideline Limit for Tree Foliage.

Criteria	CoCs (mg/kg)			
	Ni	Cu	Co	As
Mean CoC leaf concentration from Primary Study Area	10.2 (± 6.3)	6.56 (± 2.54)	0.31 (±0.21)	0.4 (± 0.3)
MOE Guideline Upper Limit of Normal Concentration	30	20	2.0	2.0
Notes Values in brackets are standard deviations				

Based on the findings of this study, existing soil CoC concentrations found in the Study Area do not pose an unacceptable risk to the population of maple trees, measured as both long term health of trees or a slow decrease in populations due to lack of recruitment over time. As maples have been identified as a species of tree that is sensitive to soil metals, the study also concludes that existing soil CoC levels do not pose an unacceptable risk to all trees and woody species (shrubs).

This conclusion is also supported by field observations that found tree and shrub species to be well represented in the Study Area, as well as in the Primary Study Area near the Refinery, where soil CoCs are highest.

Within the Study Area, four woodlots have been identified as significant natural features within the Regional Municipality of Niagara; Nickel Beach Wetland (predominately a Red Maple swamp located on the Refinery Site), Nickel Beach Woodlot (woodlots found directly adjacent to the Refinery, including a beach dune forest), Weaver Road Woodlot and Humberstone Swamp/Forest (predominately a Red Maple swamp). The designation of significance for these woodland areas is primarily due to the fact that they are representative larger fragments of the Carolinian deciduous forest that once covered the area and the occurrence of rare Carolinian tree species. For all these significant woodlots, Red Maple represents the dominant tree species. Based on the findings of this study which assessed the effect of soil CoCs on Red Maple trees, general woodlot health and documented high species diversity for trees and shrubs in these woodlots, it is concluded that existing levels of CoCs in the soil do not pose an unacceptable risk to these significant woodlots.

Inland Aquatic Environment

As an indicator and representative of the inland aquatic environment in the Study Area, frogs and toads were examined to determine if CoC concentrations in surface water, sediment and soil are having significant negative effects on their populations. Amphibians were examined, as they are especially sensitive to environmental contaminants due to their two-phased life histories and semi-permeable skin. For the Study Area, nine species of amphibian were recorded. Based on the known distribution of frogs and toads in the Niagara Region, all species that were expected to occur were found in the Study Area, including the nationally and provincially threatened Fowler's Toad. This species was identified as an additional VEC for which an assessment of potential risk would be performed. Results of night road surveys and day field surveys documented viable frog and toad populations occurring throughout the Study Area, even in areas nearest the Refinery.

Potential effects of a contaminant on frogs and toads vary, from increased adult and tadpole mortality, lowered hatching success of eggs, retarded growth to abnormal development, particularly during metamorphosis from tadpole to adult (Bonin *et al*. 1997). There are, however, few comprehensive field studies that have evaluated the effects of elevated levels of metals in the environment on amphibian populations (Hall and Mulhern 1984, Glooschenko *et al*. 1992). Rather, most studies are controlled laboratory toxicological tests that determine lethal effects of a specific compound on eggs and tadpoles and, in some cases, adults (Sparling *et al*. 2000).

Investigations that assess potential sub-lethal or chronic effects of a contaminant on naturally occurring populations are few and have for the most part investigated potential effects of the application of agricultural pest control chemicals (Bonin *et al*. 1997).

For the assessment of potential effects of soil CoC concentrations to amphibians in the Study Area, two lines of evidence were used, one for each stage of the life cycle – tadpoles and adults. Potential risk to tadpoles was assessed by exposure to CoCs in surface water using the Quotient Method. For the assessment of potential risk to adult frogs and toads, field data were collected to record the incidence and relative abundance of calling frogs in the Study Area. In addition, adult frogs and tadpoles were collected and tissues were analyzed for concentrations of CoCs.

Table 9-2 provides a summary of CoC concentrations in pond water, sediments and tissues for tadpoles and adult frogs (Green and Leopard Frogs) for the Primary Study Area and the Reference Area. Pond sediments show similarly low values for cobalt and arsenic in the Study and Reference Areas. However, higher concentrations of nickel and copper occur in the Study Area compared to the Reference Area (Table 9-2). These higher sediment concentrations for nickel and copper are reflected in the concentrations of these CoCs in the GI tracts of tadpoles collected from the Study Area. Similarly, concentrations of nickel and copper in the surface water are higher in the Study Area but are nevertheless only a fraction of that found in the sediment (0.06% for nickel in the Primary Study Area). For the remaining tadpole carcasses, only nickel and copper are elevated in the tadpoles collected in the Primary Study Area when compared to the Reference Area. The data suggest that only a small fraction of nickel in sediments is being absorbed via the GI tract in tadpoles (14%), while for copper a much higher percentage (45%) is being absorbed into the tissue. For nickel, tadpole tissues collected in the Primary Study Area had 12 times the concentration of tadpole tissues from the Reference Area, while tissue concentrations were only three times higher than the Reference Area for copper, and twice as high for cobalt and arsenic.

Table 9-2 Mean CoC Concentrations in Water, Sediment, and Tadpole and Frog Tissues for the Primary Study Area and Reference Area.

	Primary Study Area (ppm)				Reference Area (ppm)			
	Ni	Cu	Co	As	Ni	Cu	Co	As
Pond Water	0.159	0.179	0.0064	0.004	0.005	0.0045	0.0011	0.001
Sediment	279	65	14	4.2	30	34	8	4.6
Tadpole GI Tract	219	83.0	13.8	10.7	48.1	62.1	12.9	13.6
Tadpole Carcass	40.4	29.2	3.33	3.2	3.49	9.63	1.28	1.7
Frog GI Tract	26.9	38.8	1.48	0.9	5.61	30.2	2.30	1.1
Frog Liver	0.50	266	0.70	0.7	0.28	120	0.54	0.7
Frog Carcass	1.08	27.7	0.15	0.3	0.21	10.2	0.07	0.3

For adult frogs, concentrations of nickel and copper in tissues are higher when compared to the Reference Area (five times for nickel in carcass tissue and two times for Cu), but not for cobalt and arsenic. As was the case for tadpoles, the GI tract had the greatest concentrations of the CoCs; however, tissue values were much lower. Though tissue values are higher in the Primary Study Area when compared to the Reference Area, the data indicate that nickel, cobalt and arsenic in the GI tract are either not absorbed or are effectively excreted. For copper, liver concentrations are ten times greater than the GI tract.

Lee and Stuebing (1990) investigated heavy metal contamination of the River Toad (*Bufo juxtasper*) near a copper mine and found that Cu concentrations in the liver were abnormally high (a mean of 437.6 ppm). Goldfisher *et al*. (1970) investigated high Cu levels in the liver (10-2000 ppm) of *Bufo marinus* that did not seem to result in toxicity and determined that the toads' ability to tolerate high levels of hepatic copper can be attributed to the localization of the metal in liver lysosomes, where it is made innocuous. Therefore, high levels of hepatic copper identified for frogs in this study may not represent toxicity. In summary, based on analysis of the concentrations of CoCs in sediment, water and tissues, only exposure to nickel and copper appears to present a potential risk to frogs and tadpoles.

For tadpoles, the potential risk of CoCs in the environment was undertaken following the Quotient Method. The assessment of exposure, or dose, was based on the assumption of 100% exposure to concentrations of CoCs in the water of the breeding ponds sampled. Though exposure to CoCs via ingestion of sediment and food items (algae/detritus) is a potential exposure pathway, quantification of the daily dose that would be ingested is not possible, as no food ingestion rates or Toxicity Reference Values (TRVs) are found in the literature. In addition, for early larval stages of amphibians, such as newly hatched tadpoles, direct exposure to metal concentrations in the water is the critical mechanism driving toxicity (Sparling *et al*. 2000).

Based on a review of CoC toxicity data in the literature, two TRVs were derived based on EC_{20} and LC_{10} for arsenic and cobalt. For nickel and copper, TRVs selected were based only on EC_{20}. Literature values for LC_{10} were found to be less than background concentrations in Southern Ontario surface water (excluding the Great Lakes). When TRV values are compared to existing concentrations of CoCs in the water of breeding ponds, the estimated quotient value indicates that tadpoles are not at risk from arsenic and cobalt. However, the analysis identified that nickel and copper concentrations in pond water pose a potential risk to tadpoles with the estimated risk quotient values of 18 for nickel and 2 for copper. For this calculation, the TRV values used were not specific to the species found to occur in the Study Area (except for Fowler's Toad), but were based on a reported LC_{50} of 50 μg/l for nickel, and LC_{50} of 0.039 mg/l for copper for the larval stage of the Narrow-mouthed Toad (*Gastrophryine carolinensis*). Use of these TRVs resulted in a quotient that was greater than 1, 18 for nickel and 2 for copper, indicating a potential risk to tadpoles. For nickel based on the TRV of 0.01, and surface water values in the Study Area, it was determined that approximately 80% of the ponds sampled throughout the Study Area have nickel concentrations that may pose a risk to tadpoles.

For the provincially rare Fowler's Toad, a species-specific TRV could be derived for all the CoCs from toxicity data reported in the literature. For the Fowler's Toad, tadpoles are far less sensitive to the toxic effects of nickel and copper. For example, for nickel the calculated TRV for Fowler's Toad tadpoles was 4.4 mg/l, compared to 0.01 mg/l for the Narrow-mouthed Toad. Based on the species-specific TRV value for the Fowler's Toad, the estimated quotients for the four CoCs are significantly less than 1 (< 0.1), indicating a high level of certainty that there is no potential risk from the CoCs to tadpoles of the Fowler's Toad in the breeding ponds found in the Study Area. That current levels of CoCs in the water of breeding ponds in the Study Area do not pose a potential risk to the tadpoles of the Fowler's Toad is an important finding of the study, given the rarity of the species in Ontario.

For the assessment of potential risk of CoCs in the environment to amphibian populations, a second line of evidence was an assessment of species diversity and abundance in the Study Area, done by conducting spring breeding call road surveys. These field surveys documented six species of frogs and two species of toads occurring in relative abundance throughout the Study Area. Based on the distribution of frogs and toads in the Regional Municipality of Niagara, the species diversity within the Study Area is considered to be high. Analysis of the field data found that species richness and both incidence and relative abundance (based on calling codes) was not influenced by soil nickel concentrations. For adult Green Frog, Leopard Frog, Wood Frog and Bullfrog, potential exposure to CoCs in the environment can be expected via three pathways: ingestion of insect/invertebrates with elevated concentrations of CoCs, exposure to pond/ditch water concentrations and to a limited extent through exposure to soil. For the Spring Peeper and Chorus Frog, which are more arboreal in habit during the adult stage, the primary exposure pathway would be via ingestion of invertebrates. For the two toad species, adult exposure to soil CoCs (due to their burrowing habit) and ingestion of invertebrates would represent the primary exposure pathways. Analysis of soils, pond sediment, surface water and insect and worm tissue found that for each medium, the relative concentrations of the CoCs decreased with increased distance from the refinery. Also, analysis of CoC concentrations in the tissues of Green and Leopard Frogs collected nearest to the refinery showed elevated concentrations of nickel and copper.

Assessments of the occurrence of nickel in the environment indicate that soil nickel concentrations could be used as a marker for elevated concentrations of all the CoCs in the environment. If CoCs in the environment were having an adverse effect on frogs and toads in the Study Area, then soil CoC concentrations would seem to be a good predictor of amphibian diversity and/or abundance, if existing soil CoC concentrations were toxic to adult frogs and toads. This line of investigation was also used by Glooschenko *et al*. (1992) to determine potential effects of prolonged emissions from smelter operations on amphibian populations in the Sudbury area, where species abundance and breeding success was found to be correlated with distance from the Sudbury refinery. However, for this study analysis of the field data did not identify any trends related to soil CoC concentrations or distance from the presumed source, based on examining species richness, incidence and relative abundance throughout the Study Area. Nevertheless, based on the experience of the field biologist conducting the frog calling survey, it was noted that, although species were well represented throughout the Study Area, densities of calling adult frogs at quality breeding sites nearest the refinery were not as high as expected. This suggests that there may be some suppression in population numbers due to reduced recruitment of tadpoles to adults in areas with very high soil nickel concentration (>10,000 mg/kg). However, this study concludes that the potential risk of existing levels of CoCs in the local environment to adult frogs and toads is low.

Based on the assessment of the distribution, abundance and species diversity of frogs and toads in the Study Area, the potential risk as determined by the quotient values to tadpoles as a result of nickel and copper concentrations in pond water does not appear to be supported by general field observations or an analysis of field data. With respect to the estimated quotients for nickel and copper, the TRVs in the risk characterization represent the most conservative values found in the literature for frog and toad embryos and tadpoles. The TRVs were derived based on studies of one species, the Narrow-mouthed Toad). Sparling *et al*. (2000) noted that metal toxicity studies have been undertaken on a wide range of amphibian species, which have produced a wide range of LC_{50} values (ranging from 50 ppm nickel for *G. carolinensis* to 21,000 ppm nickel for *Xenopus laevis*). Based on the review of these studies, the authors note that the Narrow-mouthed Toad appears to be the most sensitive species for most metals. Therefore, the assessment of potential risk for the frog species of the Study Area, following the Quotient Method using the TRV values for a known sensitive species, is most certainly too conservative when compared to the observations and results of the field surveys.

As an example to illustrate the sensitivity of the TRVs used for the Narrow-mouthed Toad, the American Toad and Fowler's Toad are very closely related species that are known to successfully hybridize when one species occurs in low numbers. The ERA Quotient Method for the assessment of potential risk to the American Toad, used TRVs derived from reported studies for the Narrow-mouthed Toad (based on the conservative approach that when species specific TRVs could not be found the most sensitive TRVs for a related species would be used). However, if TRVs for the Fowler's Toad had been used for the more closely related American Toad, the estimated quotient for nickel for the American Toad would be 0.4, well below the threshold value of 1, and the potential risk to the American Toad would be considered to be low.

Based on all available information, it is concluded that the potential risk of CoCs to the Study Area's frog and toad populations is low and that no unacceptable risk is identified. Although past and current levels of nickel and copper in the area's ponds and swamps may be adversely affecting local frog populations through a small reduction in the numbers of tadpoles surviving to the adult stage, the magnitude of the potential effect appears to be equal to or below what would be seen as natural yearly variation in populations. This conclusion is based on field data identifying that long term (50+ years) exposure to nickel concentrations in surface water in ponds and swamps has not reduced the Study Area's high level of species diversity, and that viable frog populations are currently found throughout the Study Area.

Birds and Mammals

The remaining VECs considered in the ERA are birds and mammals. Extensive field inventory of the Study Area's birds and mammals found no obvious impairment in expected species diversity. For birds and mammals, both species diversity and general abundance were found to be at a level that is considered to be normal for the local area and the Region. Species that were expected to occur were indeed found in the Study Area, even for woodlots and fields that occurred closest to the Refinery where soil CoC concentrations are orders of magnitude above current generic guidelines. Field investigations identified that the current bird community in the Study Area is diverse, with 78 breeding species recorded. Population estimates of individual species, based on field observations and the extent of suitable habitat in the Study Area, indicated normal densities. Additionally, a number of regionally and provincially rare breeding bird species were recorded in the Study Area, including Tufted Titmouse and Yellow-breasted Chat. Similarly, field investigations identified that the mammalian community is typical of the Region, with twenty species recorded in the Study Area, species that inhabit both fields and woodlots in the local area.

Analysis abiotic samples (soils, sediment and surface water and biotic samples (plant and animal tissues) collected for the study found estimated exposures of birds and mammals to CoCs are low since movements of CoCs up the food chain are reduced at the soil-plant interface. Chaney (1980) has termed this the "soil-plant barrier" since certain metals will cause mortality in plants before transfer to the next trophic level has an opportunity to occur. For the local environment east of the refinery, this soil-plant barrier was found to significantly restrict the transfer of the CoCs through different trophic levels. As shown in Section 6.4, calculations of site-specific bioaccumulation factors for various biological tissues clearly show that there is a significant soil-to-plant barrier to the movement of the metals up the food chain. For example, comparisons of soil nickel concentrations to goldenrod and maple leaf tissue concentrations shows bioaccumulation factors of 0.003 and 0.0005, respectively. For arthropods and voles, the soil to tissue BAFs for nickel are 0.002 and 0.004, respectively. This indicates that even in areas where soil CoC concentrations are very high, only a small fraction of the CoCs (up to 0.4% for nickel, based on the above example) is transferred up the food chain, significantly reducing the exposure of secondary consumers to CoCs through their diet.

A review of the literature indicates that elevated dietary exposures of nickel or copper are not highly toxic to birds and mammals. For example, rats and pigs can tolerate about 200 mg/kg copper in their diet (Venugopal and Luckey 1978). Similarly, Mallard ducklings fed diets containing up to 800 mg/kg nickel showed no effect with respect to weight (Cain and Pafford 1981). Based on the analysis of the CoC concentrations in soil, water and the tissues of food items in the Study Area, the highest calculated daily doses of nickel and copper for birds were 14.3 and 4.7 mg/kg, respectively, based on results for the American Woodcock. Similarly for mammals, the highest calculated daily doses of nickel and copper were 6.1 and 0.17 mg/kg, respectively, based on results for the Meadow Vole.

Generally, both mammals and birds have efficient homeostatic mechanisms that limit the uptake of copper and nickel into tissues and have the ability to effectively excrete elevated dietary intake of these metals. The major excretion pathway for copper is the biliary system in both birds and mammals. In mammals, the majority of ingested dietary nickel is not absorbed but excreted in the faeces. For example, ingestion of elevated levels of nickel in forage by elk resulted in significant increases in faecal levels of nickel (Parker and Hamr 2001). Similarly, studies of voles have found that elevated gut concentrations of nickel reflect that of the diet, but concentrations of nickel in muscle tissue remained similar to that of animals at a control site (Cloutier *et al*. 1985).

The areas where soil concentrations of arsenic and cobalt exceed MOE generic guidelines within the Study Area are limited to within half a kilometre of the Refinery. Therefore, potential exposure of the Study Area's bird and mammal populations to elevated levels of these CoCs in the environment is significantly less than for that of nickel. For arsenic, a Lowest Observed Adverse Effect Level (LOAEL) of 1500 mg-As/kg has been reported (CEPA 1993) to result in reproductive effects (reduced litter size) in chronically exposed mice. Birds appear to be more sensitive to arsenic than mammals, particularly in the early life stages. Oral LD_{50} values for arsenic for three species of birds have been reported (CEPA 1993) for the California Quail (25 mg/kg), Mallard (185 mg/kg) and Ring-necked Pheasant (220 mg/kg). For cobalt, oral LD_{50} values for several different cobalt compounds have been determined for rats with values ranging from 91mg-(cobalt fluoride)/kg to 317 mg-(cobalt carbonate)/kg (ATSDR 2001). Guinea pigs fed 20 mg-Co/kg/day for five weeks suffered 20-25% mortality (ATSDR 2001). Based on the analysis of the CoC concentrations in soil, water and the tissues of food items, for birds the highest daily dose for arsenic was 0.79 mg/kg and for cobalt 1.1 mg/kg, based on results for the American Woodcock. For mammals, the highest daily dose for arsenic was 0.04 mg/kg and for cobalt was 0.02 mg/kg, based on results for the Meadow Vole. For both birds and mammals, excretion of arsenic and cobalt is mainly in the urine and seems to serve as a satisfactory homeostatic mechanism in preventing the accumulation of these metals (Venugopal and Luckey 1978).

Based on the above, short-term lethal effects due to exposure to the CoCs in the Study Area are not expected. Nevertheless, studies of mammals and birds that occur in areas where soil metals are elevated have documented increased concentrations of metals in various tissues (Rose and Parker 1983, Beyer *et al*. 1985, Hills and Parker 1993, Storm *et al*. 1994, Parker and Hamr 2001). However, whether these increased concentrations of metals in the tissues (muscle, liver, bone or kidney) represent a risk to the individuals or to local populations has not been assessed. Based on the results from this study, voles captured within 500 m of the Refinery had levels of nickel in liver tissues that were 2.5 times that of voles sampled in the Reference Area and had cobalt levels that were 11 times that of vole sampled in the Reference Area. However, copper and arsenic concentrations in the livers of voles captured near the Refinery were similar to that of animals in the Reference Area.

For the ERA, four species of birds and four species of mammals were identified as VECs for which an assessment of potential risk would be undertaken. Collectively, these species were selected as they represent species that occur in the Study Area and have life histories that are representative of the mammal and bird species that are known to occur in the Study Area. In addition, the species used represent primary and secondary consumers and top predators in the ecosystem with both specific and generalist dietary requirements. Taken as a whole, assessment of potential risk to these eight species is considered to represent an assessment of potential risk to all mammal and bird species that have been documented to occur in the Study Area, including the rare species of birds which have been recorded to occur.

For these species, only the Quotient Method was used to determine the potential risk posed by soil CoC concentrations. For the exposure assessment, the expected average daily dose (ADD) was calculated from data collected in the Study Area for biological tissue (grapes, insects, worms, frogs, tadpoles etc.), water and soil. Though analysis was conducted on a subset of all potential exposure pathways and dose exposures, the subset is considered realistic and representative of the existing conditions in the Study Area for the VECs considered in this assessment. For the risk characterization, the use of an extensive set of data collected from the Study Area for the determination of the ADD for each VEC significantly increases the confidence of the estimated quotients. For example, for birds it was determined that insects make up the major portion of the diet for 50% of the documented species, and that insects are a dietary item for over 80% of the bird species. To increase the confidence of the quotient calculations, insects were sampled from both fields and woodlots for analysis of tissue concentrations of the CoCs.

A summary of the findings of risk characterization for the eight VECs is provided in Table 9-3, which shows the highest estimated quotient for each CoC, drawing from all relevant scenarios. Chapters 6 and 8 present details for the estimated exposures and quotients presented in Table 9-3 below.

Table 9-3 Summary of Estimated Risk for Birds and Mammals

Receptor	Estimated Quotient for CoCs (Highest value of all soil types and habitat types)			
	Ni	Cu	Co	As
Red-tailed Hawk	0.01	0.01	0.01	0.01
American Woodcock	0.24	0.12	0.50	0.21
American Robin	0.12	0.18	0.20	0.11
Red-eyed Vireo	0.07	0.27	0.05	0.07
Meadow Vole	0.18	0.01	0.01	0.03
White-tailed Deer	0.03	0.03	0.00	0.01
Racoon	0.13	0.28	0.01	0.07
Red Fox	0.05	0.09	0.01	0.07

For a measure of the uncertainty of the Quotient Method, values which are < 0.1 are considered to represent a high certainty of no risk (US EPA 1987). The results of the quotient assessment undertaken for this study clearly indicate that the potential risk of soil CoCs to bird and mammal populations of the Study Area is indeed very low. Generally, the use of the Quotient Method can be considered to provide a conservative assessment of risk. The assessment is conservative due to the use of TRVs based on laboratory experiments, which represent conservative exposure conditions for receptors when compared to natural conditions. A hazard quotient less than one is considered to indicate that no risk to VECs is expected based on the assessment assumptions (i.e., population level assessment).

Based on the results of the risk assessment, populations of birds and mammals VECs are not considered to be at a potential risk when inhabiting areas with clay soils or organic soils associated with field or woodlot habitats. That estimated risk quotients for birds and mammals are low for an area where high levels of soil CoCs (based on the exceedance of MOE generic guidelines) occur is attributed to the fact that the movement of the four CoCs up the food chain is significantly reduced at the soil-plant interface, thereby restricting transfer of metals through different trophic levels. It is concluded that existing soil CoC levels, as found in the Study Area, do not pose an unacceptable risk to the populations of mammal and birds found in the Study Area. This conclusion is supported by field observations that noted a high number of bird and mammal species occurrences, at normal abundance levels.

9.3 Conclusion

Based on the results of the general field observations undertaken for this study, it is evident that existing CoC concentrations in the soil or other environmental media (air, water, and animal/plant tissue) do not represent a toxicity level that is lethal to local flora and fauna. No obvious absences of species or groups of species were identified, even in areas where soil levels of CoCs were orders of magnitude above current MOE generic guidelines. As a result, a qualitative risk assessment would identify the severity of effects from soil CoC concentrations on vertebrate and woody plant species populations found in the natural environment in the Study Area as very low. Quantitative assessment of the potential risks to VECs in the natural environment undertaken taken in this study support these qualitative observations.

10.0 UNCERTAINTY ANALYSIS

Risk assessment is a very powerful decision-making tool, however, there are a number of potential sensitivities and uncertainties inherent in the analysis. Generally, these sensitivities and uncertainties are addressed by making multiple conservative assumptions, or by using site-specific values in the analysis. As a result, risk assessments tend to be conservative and overstate the actual risk. Although many factors are considered in preparation of a risk analysis, analysis results are generally only sensitive to very few of these factors. The uncertainty analysis is included to demonstrate that assumptions used are conservative, or that the analysis result is not sensitive to the key assumptions.

A risk assessment containing a high degree of confidence will be based on:

i) Conditions where the problem is defined with a high level of certainty based on data and physical observations;

ii) An acceptable and reasonable level of conservatism in assumptions which will ensure that risk are overstated and not underestimated; and

iii) An appreciation of the bounds and limitations of the final result.

The exposure assessment conducted as part of the Port Colborne Community Based Risk Assessment was based on:

i) Well understood and generally accepted methods for ecological risk prediction;

ii) Measured values and site observations where possible; and

iii) Conservative assumptions for certain parameters, where required.

Where applicable, site-specific environmental parameters and ecological data collected from the Port Colborne area were used. The use of Port Colborne specific environmental parameters provides a greater degree of confidence in the applicability of the resulting risk value, because the concentrations determined are governed by the physical conditions of the Study Area. In general, default values are typically more conservative than field measured values and community specific parameters; therefore, the use of Port Colborne specific environmental parameters, although potentially less conservative, reflect the actual conditions present in Port Colborne.

An evaluation of the major uncertainties and their potential effect on the findings is presented in the following sections.

10.1 Uncertainties in the Problem Formulation

The conservatism and limitations on the final results of a risk assessment are dependent on the proper identification of chemicals of concern (CoC) and in the measurement of concentrations of CoCs in environmental media. The greater the number of samples, the less uncertainty exists on the overall findings of the report.

Table 10-1 Uncertainties in the Problem Formulation

Risk Analysis Study Factor/ Assumptions	Justification	Analysis Likely to Over/Under Estimate Risk?	Uncertainty Likely to Change Risk Conclusions?
Identification of CoCs	The CoCs – nickel, copper, cobalt, and arsenic - were selected early in the CBRA process, on the basis that they could be scientifically linked to the historical emissions from the Inco refinery, and were present at a community level at concentrations greater than the MOE generic effects-based guidelines.	Neutral	No
Establishing CoC Concentrations	Given that samples were collected in a targeted manner to identify areas of elevated soil CoCs, it likely represents the high end of exposure for receptors. It is possible that the average concentration of soil Ni was overestimated given the targeted approach to sampling.	Overestimate	No
Identification of the Study Area	The Study Area was identified based on soil concentrations exceeding MOE guidelines (MOE 1997). Frequency of measurements of concentrations of the CoCs in various media in the Study Area are more concentrated towards areas of higher soil concentrations of CoCs.	Neutral	No
Selection of Primary Study Area	The Primary Study Area was identified as the area where soil Ni concentrations are greater than 500 mg/kg. This area represents exposure to high concentrations of CoCs.	Neutral	No
Selection of Secondary Study Area	Secondary Study Area was identified as the moderate exposure area, where Ni soil concentrations were between 200 to 500 mg/kg.	Neutral	No

Table 10-1 Uncertainties in the Problem Formulation (cont'd)

Risk Analysis Study Factor/ Assumptions	Justification	Analysis Likely to Over/Under Estimate Risk?	Uncertainty Likely to Change Risk Conclusions?
Dividing Study Areas into Fallow/Old Fields and Woodlots	CoCs were found to concentrate in the woodlots in the Port Colborne area. This separation of areas allowed for a more meaningful determination of risk to receptors to be determined. In addition these two sub areas reflect differences in ecological habitat.	Neutral	No
Selection of the Reference Areas	Reference areas were selected by field biologist on the basis that they were outside the Study Area, concentrations of CoCs were less than the MOE guidelines for soils and were ecologically similar to habitat located within the other two Study Areas.	Neutral	No
Depth of Soil Profile Used in the Assessment	CoC concentrations analyzed in soil samples collected from the 0-5 cm horizon were included in the data sets. Concentrations of CoCs were found to generally decrease with depth in the soil profile. Therefore use of 0-5 cm soil samples is a conservative measure of the actual concentration of CoCs that would be found over the top 20 cm of the soil profile.	Overestimate	No

10.2 Uncertainties in the Ecological Site Characterization

An adequate characterization of an area's natural features, functions and values is a key component in conducting an ERA. Site characterization is required for the rational selection of both receptors and VECs on which risks are to be assessed. For this ERA the investigations into the natural environment have been extensive, and considerable site specific fieldwork was undertaken to describe the Study Areas' flora, fauna and natural features. The level of investigation undertaken to describe the Study Area's natural environment is considerably greater than that which is typically undertaken for conducting ERAs in Ontario, or Canada. Due to the level of investigations undertaken, more than sufficient information has been gathered so that an assessment of the health of the existing natural environment could be made. In addition, no information gap was identified preventing the identification of appropriate receptors or VECs for conducting this risk assessment.

Table 10-2 Uncertainties in Ecological Site Characterization

Risk Analysis Study Factor/ Assumptions	Justification	Analysis Likely to Over/Under Estimate Risk?	Uncertainty Likely to Change Risk Conclusions?
Ecological Setting Characterization	An extensive field survey of the ecological setting was undertaken by several highly trained and experience biologists. Data collected were the basis for the risk assessment to proceed to the quantitative stage.	Neutral	No
Qualitative Ecological Data Versus Quantitative Data	Although a considerable amount of quantitative ecological population data was collected across the Study Areas (e.g earthworms, and small mammals), some of the collection was qualitative in nature. Although qualitative data, such as the breeding bird survey cannot be a quantitative measure of ecological health, it does support the overall findings that the ecosystem appears to be functioning in a manner similar to other communities around the Port Colborne area.	Neutral	No
Collection of Flora	Collection of flora did not include an inventory of perennial vegetation. This was outside of the natural environment ERA and was addressed in the ERA Crop report biomonitoring study.	Neutral	No
Sufficient Level of Ecosystem Characterization to Proceed with the Analysis.	A considerable amount of ecological setting characterization was conducted that allows for risk assessment to proceed to quantitative risk characterization.	Neutral	No
Adaptation of Ecosystem to Elevated Concentrations of Soil CoCs.	It is possible that the ecosystem in the Port Colborne area has adapted over the years and changed as a result of the soil CoC concentrations. However, only the health of the current ecosystem is a question to be answered in the CBRA. It is prudent to ensure that the current ecosystem is qualitatively/quantitative healthy. Certain aspects of the ecological site characterization such as the breeding bird survey and the consideration of reference areas.	Neutral	No

10.3 Uncertainties in the Receptor Characterization

In order to ensure the conservative nature of the ERA, appropriate selection of valued ecosystem components (VECs) must occur. The selection of VECs for the CBRA was undertaken in consultation with the TSC and PLC, and was targeted at representing all trophic levels of the terrestrial ecosystem of Port Colborne. Although other species could have been selected as VECs for inclusion in this study, the number of VECs selected at each trophic level for study, ensured the conservative nature of this ERA.

Table 10-3 Uncertainties in Receptor Characterization

Risk Analysis Study Factor/ Assumptions	Justification	Analysis Likely to Over/Under Estimate Risk?	Uncertainty Likely to Change Risk Conclusions?
Receptors Selection	Although considerable effort was focused on selecting appropriate VECs, it should be noted that there are other species that could have been selected. However, those VECs selected for the ERA were chosen based on consultation with the TSC and PLC, and were selected to represent all trophic levels of the food chain.	Neutral	No
Ecological Characteristics	It is standard practice to use published literature receptor characteristics in estimating exposure. These values are best estimates of characteristics considered most applicable to the local environment. In this risk assessment, where possible, Port Colborne specific or Ontario specific receptor characteristics were used. This increases the site specificity and thus the relevance of the assessment.	Neutral	No
Carnivorous Small Mammals not Selected as a VEC	An extensive consultation process of VEC selection was undertaken with the PLC, TSC and general public. During this process shrews (or other carnivorous small mammals) were not identified by any party. Nevertheless, for the ERA, the Meadow Vole was selected as the VEC for the assessment of potential risks for a small mammal that is in close contact to the soil and is a primary consumer. In response to comments received by a peer-reviewer, an estimation of risk for Common Shrew (*Sorex cinereus*) is appended to this report.	Underestimate/ Neutral	No
Selection of Assessment Endpoints.	A sustainable level of ecological functioning was selected as the appropriate level of protection in determining a population level risk. Thus survival, reproduction, and growth were selected as endpoints for earthworms and frogs using an effects concentration of 20% (EC_{20}). Whereas for mammals and birds NOAELs (or LOAELs depending on the appropriateness available data) were selected as endpoints. EC_{20} and NOAELs or LOAELS are conservative, often laboratory based values that are designed to overestimate risk.	Overestimate	No

10.4 Uncertainties in the Data Collection Methods

The level of effort of site specific data collection undertaken for the Port Colborne ERA significantly exceeds generally accepted standards for conducting ERAs in Ontario. Often ecological risk assessments rely on the collection of a limited amount of physical and chemical data associated with soil and water samples. In order to reduce uncertainty with respect to receptor exposure to CoCs and to better reflect the site specific conditions, an extensive data collection of CoC concentrations in soil, sediment, water and biological receptors was undertaken.

Table 10-4 Uncertainties in the Data Collection Methods

Risk Analysis Study Factor/ Assumptions	Justification	Analysis Likely to Over/Under Estimate Risk?	Uncertainty Likely to Change Risk Conclusions?
	Biological Field Data Collection		
Constraints on Sampling Time	Much of the data collected in this ERA needed to be collected in an eight-month period, thus it was essential to use sampling techniques that would serve two main objectives. First, for some biological receptors (i.e., arthropods, and earthworms), it was difficult to collect enough biomass to satisfy duplicate samples for internal QA/QC and Stantec while meeting minimum sample weights for PSC. Secondly, many biological receptors could only be collected for a short period of time due to seasonality, thus affecting the number of sites that could be sampled. However, the data collection methods satisfy the need for obtaining adequate samples from a certain (though sometimes limited) number of sites, over a specified period of time.	Neutral	No
Type of Habitat Sampled	A factor that limited the outcome of data collection methods was the type of habitat that was sampled. Fields, ponds and woodlots vary in size, quality of habitat, and proximity to anthropogenic features across the sampled landscape. This fact undoubtedly contributed to a high degree of variability within the collected data. However, these factors that contributed to variability were inherently present and unavoidable. Furthermore, inclusion of covariates in statistical analyses (Jacques Whitford 2002d) can control for these limitations.	Overestimate / Neutral	No
Judgmental Targeted Sampling	Sampling of environmental media and receptors was done on a judgmental targeted basis in order to ensure representative sampling in the high and moderately impacted areas. This form of sampling tends to bias results to the elevated end of the concentration scale.	Overestimate	No

Table 10-4 Uncertainties in the Data Collection Methods (cont'd)

Risk Analysis Study Factor/ Assumptions	Justification	Analysis Likely to Over/Under Estimate Risk?	Uncertainty Likely to Change Risk Conclusions?
BAFs Determined Through Limited Soil/Receptor Pairings	BAFs calculated in the ERA were based on typically 1 to 2 composite or discreet soil samples. This may not have reflected the true range of BAFs at a local scale.	Underestimate/ Overestimate	No
Biophysical Data Collection			
Biophysical CoC Data	Samples of soil, sediment, water and air can only reflect CoC conditions at the time and at the location from which they were sampled. Therefore, CoC values from these samples are not an exact value of the exposure levels with which a biological receptor is in contact throughout its life. Rather, they are estimations of exposure. For example, an adult frog may live for several years and may not have been restricted to the location at which it was caught. The concentration of CoCs in sediment or water near the location of capture may be higher or lower than CoC levels it was exposed to throughout its life. However, given the relatively local range of arthropods, frogs, tadpoles and voles, comparing local biophysical chemical parameters of soil, water and air to these organisms is appropriate.	Neutral	No
Laboratory Analysis			
Inherent Heterogeneity of sample matricies	The heterogeneity of a sample matrix is an important consideration for elemental analysis. Typically, heterogeneous samples will result in greater variability between original and replicate samples due to differences in heterogeneous aliquots. Where heterogeneity existed in ERA samples, additional efforts were made to homogenize the samples at PSC prior to sample digestion. These samples included soils and sediment, and primarily tissues from frogs, voles and arthropods. In addition, replicate or triplicate analysis was performed, when needed, to address inherent variability.	Overestimate/ Underestimate	No
Sample Weight	Individual sample size is a factor that can reduce the accuracy of chemical analysis. When minimum sample weights were not available for digestion, estimated quantitation limits (EQLs) were consequently raised, thereby elevating detection limits. However, in many cases the concentration in the sample exceeded elevated EQLs, which made this issue inconsequential. In situations where a non-detect value ("nd") was presented, one half of the EQL value stated on the certificate of analysis was used for statistical analysis (MOE 1996). Some ERA samples, such as frog liver and gastrointestinal tract tissues, vole liver tissue, arthropod and earthworm samples, were prone to this limitation on occasion.	Neutral/ Overestimate	No

10.5 Uncertainties in the Exposure Assessment

Overall, the data collected and used in the exposure assessment are far more detailed and extensive than what is normally available for an ERA. Indeed, using site-specific CoC concentrations for environmental media and biological tissues has actually reduced uncertainty in the assessment. As a result, this assessment provides a much clearer and informed picture of the potential exposure of receptors to CoCs present in the natural environment of Port Colborne.

Table 10-5 Uncertainties in the Exposure Assessment

Risk Analysis Study Factor/ Assumptions	Justification	Analysis Likely to Over/Under Estimate Risk?	Uncertainty Likely to Change Risk Conclusions?
Surrogate Food Items	Not all of the prey items used in the ERA had measured tissue concentrations of CoCs. For these prey items, published literature uptake factors were used to calculate expected tissue body burden concentrations. Literature uptake factors did not exist for all prey items, and some types of prey (e.g., snakes, which may be eaten by Red-tailed Hawk) were thus excluded. In addition, some prey tissue concentrations were used as surrogate items representative of the entire diet of receptors. Red-tailed Hawks were modelled as consuming Meadow Voles (representative of small mammals) and three birds (American Woodcock, American Robin and Red-eyed Vireo). It is expected that Red-tailed Hawk diets may consist of many more species of small mammals and birds; however, the selected prey items (and CoC tissue concentrations) used in the ERA are considered representative surrogate food items of their entire diet. Despite the absence of a few prey items and the use of surrogate food items in the calculations, the exposure assessment is believed to be representative of actual diets of VECs in the Study Area.	Overestimate / Underestimate	No
Use of BAFs to Calculate Tissue Concentrations	Tissue CoC concentrations for birds were not measured, but were instead predicted using their calculated exposure and the most appropriate bioaccumulation factors found in the literature. Without measured values of tissue CoC concentrations, the accuracy of these predictions cannot be evaluated	Neutral	No

Table 10-5 Uncertainties in the Exposure Assessment (cont'd)

Risk Analysis Study Factor/ Assumptions	Justification	Analysis Likely to Over/Under Estimate Risk?	Uncertainty Likely to Change Risk Conclusions?
Collection of Grape as a Fruit Surrogate	Wild grapes were sampled from the edge of woodlots from both the Reference and Study areas. However, only a limited number of grapes were available at the time of collection. Given the distribution of the concentration of CoCs in grapes it is believed that they are representative of "actual" CoC concentrations. The use of wild grapes as a surrogate food for all fruit ingestion may underestimate the concentration of CoCs in other fruits, however, it was still preferred over the use of BAFs from the literature.	Underestimate/ Neutral	No
Selected Concentrations - Statistical Treatment of Datasets	In the Port Colborne study, it was deemed prudent to use the upper confidence limit of the arithmetic mean (UCLM) or the maximum value, where appropriate. It is likely that a VEC's average daily exposure to the CoCs in the Study Area would actually be considerably lower, except for non-mobile species.	Underestimate/ Overestimate	No
Selection of Exposure Pathways	Inhalation and dermal absorption are possible exposure pathways, but these are considered to be relatively minor by comparison to ingestion, and are not included as direct pathways in the ERA. Soil that adheres to fur or feathers is, for the most part, ingested by preening/licking activity and is included in the estimate of direct soil ingestion. In addition, there is little if any ecotoxicological data available for toxicity to mammals and birds in the natural environment from the inhalation route of exposure.	Neutral	No
Bioavailability / Bioaccessibility of CoCs from Soil	*In vivo* rat experiments were used to determine the oral bioavailability of nickel from three soil samples in the Port Colborne area. In addition, gastrointestinal fluid extraction *in vitro* results were used to establish the oral bioaccessibility of As, Co, and Cu from Port Colborne soils. These experiments were carried out by respected laboratories and although the findings serve to reduce the overall exposure of mammals and avian species from inadvertent soil ingestion they are based on site specific results. The validation of the GFE results against the *in vivo* rat studies for nickel provides strong evidence that bioavailability was not underestimated.	Neutral	No

10.6 Uncertainties in the Hazard Assessment

Uncertainties associated with the estimation of the toxicological effects of a chemical are inherent in the risk assessment process. For instance, when assessing the toxicity of a chemical, most values come from toxicity to laboratory animals, and not wildlife. As a result, ecotoxicologists must rely on laboratory animal studies to estimate the effect of a chemical. In addition, the availability of ecotoxicological data is often limited because of the vast number of chemicals potentially present in the environment and the high costs associated with conducting these studies. Often use of laboratory derived TRVs is the single largest contributor to conservatism in the risk assessment process.

Table 10-6 Uncertainties in the Hazard Assessment

Risk Analysis Study Factor/ Assumptions	Justification	Analysis Likely to Over/Under Estimate Risk?	Uncertainty Likely to Change Risk Conclusions?
Selection of Literature Toxicity Reference Values	TRVs were selected based on the previously discussed level of protection required for individual VECs. In some cases the LOAEL was selected and in others the NOAEL for birds and mammals. A 20% effects level was selected for earthworms and frogs. This was a result of the detailed literature review conducted to evaluate the most appropriate TRV to be used for each CoC and specific to each VEC. The protection of VECs at a population level was the driving force behind TRV selection. Although this is typically considered a conservative approach, it may not be protective of individual organisms for any given species. Values selected were the most conservative of those most relevant to the current assessment.	Overestimate / Neutral	Yes
Earthworm toxicity testing	The use of a sensitive earthworm species not found in the local environment is conservative. The impact of the disturbance of soil and mixing is unknown.	Overestimate	Yes
Derivation of TRVs	TRVs for mammals and birds are, for the most part, derived in the laboratory using soluble salts of the CoCs. This would suggest that the TRVs are a conservative measure of toxicity. However, the inclusion of site specific oral bioavailability for CoCs serves to reduce the conservative nature of the TRVs and provides a more realistic measure of potential toxicity.	Neutral	No

Table 10-6 Uncertainties in the Hazard Assessment (cont'd)

Risk Analysis Study Factor/ Assumptions	Justification	Analysis Likely to Over/Under Estimate Risk?	Uncertainty Likely to Change Risk Conclusions?
Use of Laboratory Animals to Derive TRVs	The majority of TRVs used in this assessment were derived in the laboratory using test species (e.g. rat, mice). In ERA body weight scaling factors are used to extrapolate wildlife toxicity. It is believed that many of the receptor populations in Port Colborne would have developed some tolerance to the levels of CoCs in environmental media. For example, the local evolution of metal tolerance in plants following long term exposures to soil metals has been demonstrated in the Sudbury area (Hutchinson 2000). Therefore, it is more likely that laboratory based TRVs are conservative measures of toxicity to wildlife.	Overestimate	No
Additive or Synergistic Effects of Chemical Exposures	Toxicity data is almost exclusively based on single chemicals, whereas natural exposure is almost always to a mixture of chemicals. The toxicology of chemical mixtures is very much a developing science. There is currently a great deal of uncertainty regarding chemical interactions in mixtures and the effects of mixtures on receptors. The approach of examining hazards based on single chemical exposures may over-underestimate the potential toxicity of chemicals in mixtures on receptors. See Section 7.4 (Additive and Less than Additive Effects) for further discussion.	Unknown	No

10.7 Uncertainties in Risk Characterization

The calculation of risk using the Quotient Method is based on the ADD and the TRV values for each VEC. Given the conservatism and/or site specific nature of the ADD and the TRV values for the VECs, the risks presented for the VECs are considered conservative or reflective of actual risk posed.

Table 10-7 Uncertainties in the Risk Characterization

Risk Analysis Study Factor/ Assumptions	Justification	Analysis Likely to Over/Under Estimate Risk?	Uncertainty Likely to Change Risk Conclusions?
Use of EPC of 3000 mg/kg of nickel in soil to estimate risk to maples	Greenhouse studies indicated that concentrations of up to 3000 mg/kg in soil did not affect maple germination or growth. However, concentrations of up to 30,000 mg/kg nickel have been detected in woodlot soil samples. The leaf health assessment of maple trees in woodlots containing very elevated nickel concentrations indicated that they were as healthy as other woodlots. However, on an individual receptor basis it is possible that some trees may have been impacted by the very elevated nickel concentrations.	Underestimate/ Neutral	No
Field Based Risk Characterization to Earthworms	The purpose of the CBRA was to identify potential risk to receptors on a population level. Although results of the field studies suggest that there is no potential risk to the earthworm population of the Primary Study Area as a whole, there may be isolated woodlots where earthworms may have been at potential risk from exposure to very elevated nickel concentrations. An example of this would be the Rueter Road woodlot where concentrations of nickel were as high as 20,000 mg/kg and there was a significant reduction of species richness and number of worms found. Given that these woodlots represent only a relatively small area of Port Colborne, it is unlikely to impact the overall population.	Underestimate risk to individual earthworms in a limited number of locations.	No
Use of the Quotient Method to Characterize Risk	The use of the quotient method to characterize risk to receptors is the generally accepted approach, and that adopted by CCME. Given the use of site specific data and/or conservative parameters derived in the exposure and hazard assessment the hazard quotients derived are either conservative or actual measures of potential risks for VECs at a population level.	Overestimate/ Neutral	No

10.8 Summary of Confidence in the Port Colborne ERA – Natural Environment

A considerable amount of progress has been made in advancing the science upon which ecological risk assessments are conducted; however, a number of factors, input variables, calculations and literature derived values used still in uncertainties being inherent in conducting any ecological risk assessment.

In an attempt to limit the uncertainty in the ERA, while still ensuring its desired conservative nature, Jacques Whitford has:

- Collected of a considerable amount of site specific biogeochemical data on CoC concentrations in the Port Colborne area;
- Conducted numerous laboratory studies using Port Colborne soils; and
- Conducted a rigorous review of literature values selected for use in all aspects of the ERA

The overall confidence in the risk characterization is considered high and the potential risks to valued ecosystem components in the Port Colborne area are not underestimated. The use of Port Colborne specific data, scientifically defensible and regulatory accepted data from the literature, coupled with scientifically credible sampling and analysis protocols has produced an ecological risk assessment with a high degree of confidence in its conclusions.

11.0 SUMMARY AND RECOMENDATIONS

11.1 Summary

The primary objective of this study was to conduct an ecological risk assessment to determine if historical emissions of nickel, copper, cobalt and arsenic from the Inco Port Colborne refinery and deposited in the local soil present an unacceptable risk to the natural environment. To conduct this assessment, a Study Area was identified based on the extent of lands where previously collected data showed soil nickel concentrations of 200 mg/kg or greater (i.e., exceeding the MOE generic guideline for soil nickel). Within this Study Area, an extensive sampling and inventory program was undertaken to collect qualitative and quantitative data for the natural environment.

To determine the potential exposure of the natural environment to the chemicals of concern (CoCs), samples of soil, water, air and biological tissue were collected throughout the Study Area, resulting in the collection and analysis of over 700 samples for the ERA. To characterize the natural environment, two years of field surveys were conducted to identify the species of flora and fauna and natural areas that occurred in the area. In addition, a number of detailed studies and experiments using site-specific soils were undertaken to address specific aspects of the environment and potential risk to species and ecological processes. Combined, these efforts resulted in the largest collection of site-specific data ever collected for conducting an ecological risk assessment in Canada. The collected data have allowed the study to assess potential risk to the natural environment following multiple lines of evidence;

- Qualitative field data;
- Quantitative field data;
- Controlled experiments; and
- Quantitative risk assessment (Quotient Method)

For the ERA, detailed assessment of potential risk was undertaken for 14 ecological components (VECs), including mammal and bird species, amphibians (frogs and toads), earthworms, maple trees, leaf litter and woodlots. Combined, the VECs selected were considered representative of the species and ecological processes in the local area. An assessment of potential risk to these VECs were used to determine if existing CoC soil concentrations represent a risk to the local natural environment either now and into the future.

The objective of the CBRA was to assess the risk of adverse effects, at the scale of the community, caused by soil concentrations of CoCs. For this ERA, risk was considered unacceptable if soil concentrations of CoCs are at a level so as to prevent sustainability of ***population(s)*** of flora and fauna or to prevent the sustainability of ecological functioning within the defined Study Area. Based on both qualitative and quantitative assessments, the evaluation of potential risk to the Study Area's animals, trees and shrubs and natural processes found no unacceptable risk to populations across the study area. This description of risk to the natural environment is based on analysis of an extensive series of data specific to the soils of the Port Colborne area. In addition, the study's sampling design allowed for the collection of data in areas with the highest soil concentrations of the four CoCs.

An assessment of risk to birds and mammals following the Quotient Method found that potential risk was very low. These findings were further supported by field investigations that found the Study Area to support a species diversity that is typical of the local area and region. Analysis of soils and biological tissues identified that exposure to CoCs in the environment is significantly reduced by the soil-plant barrier that prevents the movement of the CoCs up the food chain. For the bird and mammal species used in the risk assessment, the study identified that the American Woodcock is a sensitive receptor for the assessment of potential risk to soil CoCs due to its feeding habit (probing soil) and major prey item (earthworms with a high soil content). However, even for this sensitive receptor, the population of American Woodcock in the Study Area was not found to be at risk.

For the tadpoles of frogs and toads, an initial assessment of potential risk following the Quotient Method identified a potential risk to nickel and copper in the surface water of breeding ponds. However, field surveys did not support this finding, which found the Study Area to support high species diversity and typical abundance of adult frogs for the species present. This line of evidence strongly suggests that the initial assessment of potential risk based on the Quotient Method was too conservative, primarily due to the use of toxicity reference values for a species of toad that is reported in the literature to be the most sensitive to metals, but a species that is not found in the Study Area. Therefore, based on the findings of extensive field data collected for the study, the ERA concludes that existing concentrations of the CoCs in the surface water of the Study Area does not represent an unacceptable risk to the frog and toad populations.

An assessment was conducted examining the potential effects of soil CoCs on the germination and growth of Red Maple. The results of this assessment, combined with the existing diversity of trees and shrubs and an overall assessment of woodlot health, found that existing soil concentrations have not resulted in a decrease in species diversity or productivity of woodlots. This was true even for woodlots located adjacent to the Refinery were soil concentrations of the CoCs were the highest for the Study Area. Results of germination experiments and age distribution of trees in woodlots indicate that current soil concentrations of the CoCs will not adversely affect the long-term sustainability of woodlots in the local area.

The study did identify that very high soil concentrations of CoCs (>20,000 mg Ni/kg) in woodlots located directly adjacent to the Refinery site is potentially causing a local effect on earthworm abundance. Additionally, these high soil CoC concentrations may be affecting other soil decomposers, as indicated by an assessment of leaf litter decomposition. However, these localized potential effects are not found elsewhere in the Study Area and CoCs do not pose a risk to the earthworm community or the productivity of woodlots in the Study Area on the whole.

As no unacceptable risk to elements of the natural environment in the Study Area as a whole was identified, no *immediate* need to mitigate risk to the natural environment has been identified. However, consideration for long-term remediation efforts for the high soil CoC concentrations in woodlots on organic soils located adjacent to the Refinery site may be considered as the CBRA process moves forward, as discussed below.

11.2 Recommendations

Analysis of soils for the ERA generally identified that soil CoC concentrations decrease with distance from the source in a north-easterly direction. Analysis of soils in fields and woodlots found that the highest concentrations of CoCs occurred within one kilometre of the sources. In addition, within the local environment, woodlots were found to have elevated levels of CoCs in comparison to surrounding fields and agricultural lands. These elevated levels are the result of trees and leaves acting as traps for the atmospheric particulate matter that, once trapped, is transferred to the forest floor by rain and leaf fall. Over the time span of the refinery's operations, this has resulted in woodlots having higher concentrations of soil CoCs. Woodlots directly adjacent to the refinery site were found to have the highest concentrations of CoCs in the soil.

Woodlots on organic soils directly adjacent to the refinery were found to have nickel concentrations ranging between 20,000 mg/kg and 30,000 mg/kg. As a result of these high levels in these woodlots, there is the potential that there may be an adverse effect on local ecological processes or on certain individual animals living in the local area. As noted above, and detailed in Section 8, investigations into leaf litter decomposition suggested that the decomposition processes may be slowed in these woodlots due to the high levels of nickel and copper. Similarly, sampling of earthworms through these woodlots found that, although earthworms were found to occur throughout (including juveniles), abundance and species richness of earthworms was reduced in areas with the highest nickel concentrations (20,000 mg/kg). As a result of these findings, it is recommended that management measures be considered for the fields and woodlots located directly adjacent to the Refinery that have significantly elevated concentrations of nickel in the soil.

Based on the assessment of risk for the various VECs considered in this ERA, it is proposed that earthworms be considered the species used to determine "safe" soil CoC values for the purpose of assessing future management options. This recommendation is based on the following considerations:

- Earthworms, as soil-dwelling animals, have the greatest exposure to soil CoCs;
- Due to their low mobility in a the environment, local earthworm communities are at a higher potential risk in woodlots and fields with high CoC concentrations;
- Earthworms are a key component for decomposition and the nutrient cycle, a process that has been identified as potentially impaired in woodlots with high soil CoCs based on an assessment of leaf litter; and,
- A "safe" soil CoC concentration for earthworms would be protective for other flora and fauna that inhabit these areas of high soil CoCs.

11.3 Determination of "Safe" Soil CoC Values for Earthwoms

Analysis of the potential risk to earthworms in the Study Area utilized three lines of evidence: toxicity reference values (TRVs) as reported in the literature; earthworm toxicity testing using Port Colborne soils, and field sampling for earthworms within the Study Area. These are presented in more detail below.

11.3.1 "Safe" Soil Determination - Element 1 – Toxicity Reference Values

TRVs reported in the literature, based on derived 20% effect concentrations (EC_{20}) or no effect observable concentrations (NOEC) for soils CoCs, are as follows:

- Ni = 3000 mg/kg
- Cu = 50 mg/kg
- Co = 3000 mg/kg
- As = 21 mg/kg

The use of total soil CoC concentrations is conservative for estimating exposure, and exposure was instead estimated using two extraction techniques: aqueous extraction and acid ammonium oxalate extraction. Correcting for these extraction techniques, total soil CoC concentrations that would put earthworms at risk, based on these TRVs, are as follows (Table 11-1).

Table 11-1 Total Soil CoC Concentrations That Pose a Risk to Earthworms, Based on TRVs.

Soil	Ni (mg/kg)[1]	Cu (mg/kg)[2]	Co (mg/kg)[2]	As (mg/kg)
Clay	3,000 – 9,100+	50+	18,000+	21
Organic	3,000 – 7,600+	62+	4,900+	21

Note:
1 Lower value represents the Toxicity Reference Value for nickel. Upper value derived using results of acid ammonium oxalate extraction.
2 Values derived using results of acid ammonium oxalate extraction.

TRV values for earthworms derived in laboratory settings are often based on the addition of soluble salts of chemicals to soil. For nickel, unlike the other CoCs, the TRV selected for earthworms is specific to the species of nickel found in the soils in the natural environment, namely nickel oxide, rather than a soluble form. For this reason, the adjustment for bioavailability applied to copper, cobalt and arsenic in Port Colborne soils, is less applicable to nickel.

Nickel in Port Colborne soils is expected to be somewhat less bioavailable than pure nickel oxide added to soil in a laboratory setting similar to that on which the TRV value is based; however, the amount of conservatism in this value is less clear than for the other CoCs. Since the earthworms in the nickel TRV study were exposed to nickel oxide, the bioavailability was low in both the TRV study and the Port Colborne environment. The use of bioavailability adjusted quotients is therefore not conservative. A safe value for nickel in Port Colborne soils could therefore be expected to fall somewhere between the TRV value and the total soil nickel concentration adjusted for bioavailability based on the extraction methods.

11.3.2 "Safe" Soil Determination - Element 2 – Earthworm Toxicity Testing

Table 11-2 provides a summary of the results of EC_{20} toxicity testing using Port Colborne soils that were blended to create a range of CoC concentrations for clay and organic soils. A comparison of EC_{20} values based on the literature with the toxicity test EC_{20} values finds that they are not in agreement.

Table 11-2 Soil Toxicity Test CoC Concentrations in Clay and Organic Soil Resulting in an EC20.

Soil Type	EC_{20} CoC Concentrations in Test Soils (mg/kg)			
	Nickel	Copper	Cobalt	Arsenic
Clay	1170	150	20	7
Organic	2279	370	37	18

11.3.3 "Safe" Soil Determination - Element 3 – Earthworm Field Surveys

As a final indicator of potential adverse effects of soil CoCs on Port Colborne earthworms, a detailed field sampling program was undertaken for the ERA where earthworms were sampled from clay and organic soils with varying concentrations of nickel. Where the soil CoC concentrations were the found to be the highest, in woodlots on organic soils located near the Refinery, earthworms were found to be present but in smaller numbers (Table 11-3). The results from sample site RW-H5, suggest that soil nickel concentrations at 3500 mg/kg can maintain an earthworm population that is typical for the Study Area. For this soil nickel value, based on the soil sampled at the collection spot, corresponding values for the other CoCs were as follows: Cu = 550 mg/kg, Co = 50 mg/kg, As = 39 mg/kg. Based on a comparison of these concentrations with those reported in the literature to have an effect, it would appear that copper has less of an effect than would be predicted.

Table 11-3 Earthworms Collected from Woodlots in Organic Soils

Sample Code		Soil CoCs (mg/kg)				Total Number of Worms
		As	Co	Cu	Ni	
Reuter Road Woodlot	RW-H-1	129	340	3,620	21,100	5
	RW-H-2	109	181	2,520	13,800	2
	RW-H-3	81.4	190	2,020	12,600	1
	RW-H-4	23.7	43	414	2,550	10
	RW-H-5	38.7	50	550	3,530	31
Snider Road Woodlot	SW-H-1	21	41	308	2,070	4
	SW-H-2	21.7	41	321	2,430	52
	SW-H-3	21.6	32	252	1,550	43

Note: Refer to Volume V, tab 25 for soil CoC values, and Volume III, tab 1 for earthworm collection data

For clay soils, a comparison of the number of earthworms from collection sites in the Study Area is presented in Table 11-4. Although the numbers of earthworms collected at the sample sites vary, the results from sample site CS-H-5 indicate that soil nickel concentrations of 2000 mg/kg have no effect; the same numbers of earthworms were collected from soils with nickel concentrations of 125 mg/kg (below the 200 mg/kg guideline) and 2460 mg/kg. At this higher soil nickel concentration, concentrations of the other CoCs were as follows: Cu = 367 mg/kg, Co = 40 mg/kg, As = 8 mg/kg.

A comparison of earthworm abundance collected from fields on clay and organic soils shows that there is a difference in effect between soils, with clay soils supporting less worms then organic soils with similar CoC concentrations. A similar difference between clay and organic soils was noted in the toxicity testing. This may be due to differences in soil composition rather than an effect of the presence and availability of CoCs in the soil.

Table 11-4 Number of Earthworms in Fields for Sample Sites on Clay Soils with Varying CoC Concentrations.

Sample Site	Clay Soil CoCs (mg/kg)				Number of Worms
	As	Co	Cu	Ni	
CS-H-12	2.2	11	29	125	16
CS-H-11	2.8	7	30	147	4
CS-H-13	2.7	8	35	186	22
CS-H-10	2.1	8	36	203	22
CS-H-9	5.2	13	58	355	39
CS-H-7	3.2	12	66	364	15
CS-H-8	5.3	13	71	410	35
CS-H-25	8.8	14	104	420	11
CS-H-5	12.4	36	346	2000	43
CS-H-4	8	40	367	2460	14

Note: Refer to Volume V, tab 25 for soil CoC values, and Volume III, tab 1 for earthworm collection data

11.4 Conclusion

Based on a review of the three lines of evidence, Table 11-5 presents the recommended "safe" soil CoC concentrations based on effects to earthworms. "Safe" concentrations of nickel and copper are based on the results of field sampling (Section 11.3.3). No difference was noted in abundance of earthworms across the range of CoC concentration in clay soil up to approximately 2500 mg Ni/kg (Table 11-4). The "safe" value for nickel in clay soils equates to the TRV in this situation, which equals 3000 mg/kg. In the Study Area, cobalt concentrations never approached the TRVs reported in the literature, so a protective concentration is considered to be the TRV. Therefore for cobalt the literature-derived EC_{20} of 3000 mg/kg is considered appropriate for both clay and organic soils. Sampling in organic soils with arsenic as high as 129 mg/kg found juvenile worms, indicating reproduction was possible and occurring. Earthworm samples collected in organic soils with arsenic at 39 mg/kg also found typical worm numbers. Therefore, a soil value of 40 mg/kg (approximately twice the reported EC_{20} of 21 mg/kg) is identified as a conservative value. For clay soils, an arsenic value of 25 mg/kg is recommended based on the MOE's guideline for soil arsenic.

Table 11-5 "Safe" Soil CoC Concentrations for Earthworms.

Soil Type	Safe Soil CoC Concentration (mg/kg) for Earthworms			
	Ni	Cu	Co	As
Organic	3500	550	3000	40
Clay	3000	350	3000	25

It is not known which of the CoCs, or a combination of CoCs, is responsible for an observed effect in the field surveys or toxicity tests. However, for the woodlots on organic soil with very high nickel concentrations, it is assumed that nickel is the major cause of the observed effect. As a result, it is recommended that management options for these woodlots should target the reduction of soil nickel concentrations.

12.0 CITED REFERENCES

Allen, G.A., P.F.J. Eagles, and S.D. Price, 1990. Conserving Carolinian Canada, Introduction, vi-xii. University of Waterloo Press.

Allen, H.E. 2002. Bioavailability of Metals in Terrestrial Ecosystems: Importance of Partitioning for Bioavailability to Invertebrates, Microbes, and Plants. SETEC, USA.

Ambrose, A.M., P.S. Larson, J.F. Borzelleca and G.R. Hennigar., Jr. 1976. "Long-term toxicologic assessment of nickel in rats and dogs." J. Food Sci. Tech. 13:181-187.

AMEC, 2001a. Phase II Environmental Site Assessment Parcel #NP-021-B (Site #1) Vacant Lands Between Clarence & Rodney Streets Port Colborne, Ontario. Submitted to St.Lawrence Seaway Management Corporation.

AMEC, 2001b. Phase II Environmental Site Assessment Parcel #NP-022-B (Site #2) Vacant Lands Between Rodney Street & East Breakwater Port Colborne, Ontario. Submitted to St.Lawrence Seaway Management Corporation.

AMEC & Environmental Limited, 2001c. Environmental Investigation – Lorraine Bay Community Water Quality Concerns. Submitted to: Members of Lorraine Bay Community.

Anderson, T.A., Coats, J.R., Kruger, E.L, 1997. Phytoremediation of Soil and Water Contaminants. American Chemical Society, Washington, DC.

Ankley, G.T., J.E.Tietge, D.L.Defoe, K.M.Jensen, G.W.Holcombe, E.J.Durham and S.A.Diamond. 1998. Effects of ultraviolet light and methoprene on survival and development of Rana pipiens. Environmental Toxicology and Chemistry 17: 2530-2542.

Arnebrant K., E. Bååth and A. Nordgren. 1987. A. Copper tolerance of microfungi isolated from polluted and unpolluted forest soil. Mycologia 79, 890-895.

Asdell, S. A. 1946. Patterns of Mammalian Reproduction. Comstock Publishing Co., Ithaca, New York.

ASTM. 1998. Standard guide for conducting laboratory soil toxicity of bioaccumulation tests with the lumbricid earthworm Eisenia fetida. E 1676 – 97. American Society for Testing and Materials.

ATSDR. 2003. *Toxicological Profile for Nickel.* United States Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp15.html. September 2003. Draft for Public Comment.

ATSDR. 2002. *Toxicological Profile for Copper*. United States Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp132.html. September 2002. Draft for Public Comment.

ATSDR. 2001. *Toxicological Profile for Cobalt.* United States Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp33.html. September 2001. Draft for Public Comment.

ATSDR. 2000. *Toxicological Profile for Arsenic.* Prepared by Syracuse Research Corporation. United States Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp2.html. September 2000.

Azcue, J.M. and Nriagu, J.O. 1994. Arsenic: historical perspectives. Wiley, New York.

Babich, H., R.J.F Bewly and G. Stotzky. 1983. Toxicity of nickel to micoorganisms in soil: influence of some physicochemical characteristics. Environmental Pollution, 29:303-315.

Bakowsky, W.D. 1999. Natural Heritage Resources of Ontario: Vegetation Communities of Southern Ontario. Natural Heritage Information Centre, MNR, Peterborough, ON.

Banfield, A.W.F. 1977. The Mammals of Canada. University of Toronto Press, Toronto.

Bartlett, C.O. 1958. A study of some deer and forest relationships in Rondeau Provincial Park. Wildlife Series No. 7, Ontario Department of Lands and Forests.

Begon, M., J.L.Harper and C.T.Townsend. 1986. Ecology: Individuals, populations and communities. Second Edition. Blackwell Scientific Publications, Boston Massachusetts.

Behan, V.M., S.B. Hill, and D.K.M. Kevan. 1978. Effects of nitrogen fertilizers, as urea, on Acarina and other arthropods in Quebec black spruce humus. Pedobiologia 18: 249-263

Beyer, W.N., O.H. Patte, L. Sileo, D.J. Hoffman and B.M. Mulhern. 1985. Metal Contaminatin in Wildlife Living Near Two Zinc Smelters. Evironmental Pollution (Series A) 38 (1985) 63-86.

Birge, W.J., 1978. "Aquatic Toxicology of Trace Elements of Coal and Fly Ash". In: J.H. Thorp and J.W. Gibbons (Eds.), Dep. Energy Symp. Ser., Energy and Environmental Stress in Aquatic Systems, Augusta, GA 48:219-240.

Birge, W.J., Black, J.A. and A.G. Westerman. 1978. Embryo-larval bioassays on inorganic coal elements and in situ biomonitoring of coal-waste effluents. In: Samuel DF, Stauffer JR, Hocutt CH, Mason WT, editors. Surface mining and fish/wildlife needs in the eastern United States. United States Department of Interior, Fish and Wildlife Service. National Technical Information Service, Springfield, VA. PB 298 353 FWS OBS-78/81.

Birge, W.J., Black, J.A. 1979. Effects of copper on embryonic and juvenile stages of aquatic animals. In: Nriagu JO, editor. Copper in the environment. Part II. New York:Wiley. P 349-366.

Birge, W.J., J.A. Black and A.G. Westerman, 1979. "Evaluation of aquatic pollutants using fish and amphibian eggs as bioassay organisms." In: National Research Council, editor. Animals as monitors of environmental pollutants. Washington D.C.: National Academy of Sciences. P 108-118.

Birge, W.J., Black, J.A. 1980. Aquatic toxicology of nickel. In: Nriago JO, editor. Nickel in the environment. New York: Wiley. P 349-366.

Birge, W.J., Black, J.A., Westerman, A.G. 1985. Short-term fish and amphibian embryo-larval tests for determining the effects of toxicant stress on early life stages and estimating chronic values for single compounds and complex effluents. Environ toxicol Chem 4:807-821.

Bishop, C.A., K.E. Pettit, M.E. Gartshore, and D.A. Macleod. 1997. Extensive Monitoring of Anuran Populations Using Call Counts and Road Transects in Ontario (1992-1993). In Amphibians In Decline, Canadian Studies of a Global Problem, D.M. Green (eds.). pp149-160.

Bleavins, M.R. and R.J. Aulerich. 1981. "Feed consumption and food passage time in mink (Mustela vison) and European ferrets (Mustela putorius furo)." Lab. Anim. Sci., 31:268-269.

Bonin, J., M. Ouellet, J. Rodrigue and Jean-Luc DesGranges. 1997. Measuring the Health of Frogs in Agricultural Habitats Subjected to Pesticides.). In Amphibians In Decline, Canadian Studies of a Global Problem, D.M. Green (eds.). pp246-257.

Bormann, F.H., and G.E. Likens. 1979. Pattern and process in a forested ecosystem. Springer-Verlag, New York.

Bouc, K. 1997. The deer of Nebraska. NEBRASKAland Magazine, April 1997. Available online: http://www.ngpc.state.ne.us/wildlife/whtmules.html

Bricker, B, and R. Reader. 1990. The effects of woodlot size on woody species composition and richness. Pp. 75-87. In: Conserving Carolinian Canada, University of Waterloo Press.

Broadfoot, J.D., and D.R.Voigt. 1996. White-tailed Deer Migration Behaviour: A resource management perspective. STERS Technical Paper No. 5, Ontario Ministry of Natural Resources, January 1996.

Cadman, M. D., P. F. J. Eagles and F. M. Helleiner. 1987. Atlas of the Breeding Birds of Ontario. University of Waterloo Press. Waterloo, Ontario.

Cain, B.W. and E.A. Pafford. 1981. "Effects of dietary nickel on survival and growth of Mallard ducklings." Arch. Environm. Contam. Toxicol. 10:737-745.

Cameco Corporation, 1994. Screening level ecological risk assessment - McArthur River Project. Prepared by SENES Consultants Limited, SENES Oak Ridge Inc., Center for Risk Analysis and Terrestrial & Aquatic Environmental Managers Ltd. (TAEM).

CCME. 1997. A Framework for Ecological Risk Assessment: Technical Appendices. The National Contaminated Sites Remediation Program, Winnipeg. Canadian Council of Ministers of the Environment.

CCME. 1998. "Development and Application of Soil Quality Guidelines within the CCME Framework for Contaminated Site Assessment and Remediation." February 9. Canadian Council of Ministers of the Environment.

CCME. 1996. A Framework for Ecological Risk Assessment: General Guidance. CCME Subcommittee on Environmental Quality Criteria for Contaminated Sites. The National Contaminated Sites Remediation Program, Winnipeg, Manitoba. Canadian Council of Ministers of the Environment.

CCME. 1997. A Framework for Ecological Risk Assessment: Technical Appendices. CCME Subcommittee on Environmental Quality Criteria for Contaminated Sites. The National Contaminated Sites Remediation Program, Winnipeg, Manitoba. Canadian Council of Ministers of the Environment.

CCME. 2001. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health. Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment.

CEPA. 1993. *Arsenic and its Compounds.* Canadian Environmental Protection Act, Priority Substance List Assessment Report. Government of Canada, Health and Welfare Canada, Environment Canada.

CEPA. 1994. *Nickel and its Compounds.* Canadian Environmental Protection Act, Priority Substance List Assessment Report. Government of Canada, Health and Welfare Canada, Environment Canada.

Chaney R.L. 1980. Health risks associated with toxic metals in municipal sludge. In: Allen, H.E. Bioavailability of Metals in Terrestrial Ecosystems:Partitioning for Bioavailability to Invertabrates, Microbes, and Plants. SETEC, USA.

Chaney, R.L. 1983. Potential effects of waste constituents. Pp 50-76. In J.F. Parr, P.B. Marsh, and J.M. Kla (eds.) Land Treatment of Hazardous Wastes. Noyes Data Corp. Park Ridge, NJ.

Chapman, L.J. and D.F. Putnam, 1984. The Physiography of Southern Ontario, Third Edition. Ontario Geological Survey Special Volume 2. Ontario Ministry of Natural Resources.

Cimprich, D.A., F.R.Moore and M.P.Guilfoyle. 2000. Red-eyed Vireo. In The Birds of North America, No. 527. (A. Poole, P. Stettenheim, and F. Gill, editors). Philadelphia Academy of Natural Sciences, Philadelphia, PA, USA.

City of Port Colborne, 2000. Municipal Drains and Drain Areas.

Cloutier, N.R. , F.V. Clulow, T.P. Lim and N.K. Dave. 1985. Metal (Cu, Ni, Fe, Co, Zn, Pb) and Ra-226 Levels in Meadow Voles *Microtus pennsylvanicus* Living in Nickel and Uranium Mine Tailings in Ontario, Canada: Evironmental and Tissue Levels. Environm. Pollut. (Series B) 10(1985) 19-46.

Cook, F.R. 1984. Introduction to Canadian Amphibians and Reptiles. National Museums of Canada, Ottawa, Ontario.

Cooke, A.S., P.W.Greig-Smith and S.A.Jones. 1992. Consequences for vertebrate wildlife of toxic residues in earthworm prey. In: H.Becker et al. (eds.). Ecotoxicology of Earthworms, Intercept Limited, Hants, UK.

Corbet, P.S. 1998. Dragonflies: Behaviour and Ecology of Odonata. Comstock Publishing Associates, Ithaca, New York.

Corp, N., and A.J.Morgan. 1991. Accumulation of heavy metals from polluted soils by the earthworm, Lumbricus rubellus: Can laboratory exposure of 'control' worms reduce biomonitoring problems? Environmental Pollution 74: 39-52.

Crossley, D.A. and M. Witkamp 1960. The role of arthropods and microflora in breakdown of white oak litter. Pedobiologia 6: 293-303.

Cullen, W.R.., and Reimer, K.J. 1989. Arsenic speciation in the Environment: Chemical Reviews. V. 89. no. 4.p.713-764.

Danish Environmental Protection Agency. 2003. "Human Bioaccessibility of Heavy Metals and PAH from Soil." Environmental Project no. 840, Technology Programme for Soil and Groundwater Contamination. http://www.mst.dk/homepage/default.asp?Sub=http://www.mst.dk/udgiv/publications/2003/87-7972-877-4/html/kap04_eng.htm

Debon, S.J.J. and R.F. Tester. 2001. "In vitro binding of calcium, iron and zinc by non-starch polysaccharides." *Food Chemistry*. 73: 401-410.

Denholm, K.A, L.W. Schut. 2003. Field Manual for Describing Soils in Ontario, 4th Edition. Land Resources Science, University of Guelph. C. 1993. ISBN 0-88955-340-8.

Diaz, G.J., R.J. Julian and E.J. Squires, 1994. "Lesions in Broiler Chickens Following Experimental Intoxication with Cobalt." In: Avian Dis. 38:308-316.

Dickinson, C.H. 1974. Decomposition of litter in soil. In: C.H. Dickinson and G.J.F. Pugh (eds.). Biology of plant litter decomposition, Vol. 1. Academic Press, London.

Dobbyn, J. 1995. Atlas of the Mammals of Ontario. Federation of Ontario Naturalists.

Duxbury, T. 1985. Ecological aspects of heavy metal responses in microorganisms. Adv. Microb. Ecol.8: 185-235, 1985.

Doyle, P.J., D.W. Gutzman, M.I. Sheppard, S.A. Sheppard, G.A. Bird, D. Hrebenyk, 2003. " An Ecological Risk Assessment of Air Emissions of Trace Metals from Copper and Zinc Production Facilities" In: Human and Ecological Risk Assessment. 9(2).

Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten, 1997a. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants. 1997 Revision, Prepared for US Department of Energy.

Efroymson, R.A., M.E. Will, G.W. Suter II, 1997b. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: Revision 1997. United States Department of Energy, November, ES/ER/TM-126/R2.

Eisler, R. 1998. Copper Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. United States Geological Survey, Washington DC.

Ellickson, K., Meeker, R., Gallo, M., Buckley, B. and P. Lioy. Oral Bioavailability of Lead and Arsenic from a NIST Standard Reference Soil Material. Archives of Environmental Contamination and Toxicology. 40: 128-135.

Environment Canada. 1989a. American Robin. In Hinterland Who's Who. Environment Canada Document CW69-4/35-1989E.

Environment Canada. 1989b. Raccoon. In Hinterland Who's Who. Environment Canada Document CW69-4/47-1989E.

Environment Canada. 1993. Red Fox. In Hinterland Who's Who. Environment Canada Document CW69-4/5-1993E.

Environment Canada. 1998. Development of Earthworm Toxicity Tests for Assessment of Contaminated Soils. Prepared for Method Development and Application Division, Technology Development Directorate, Environment Canada, Ottawa, Ontario, 52 pp. (Appendices).

Environment Canada. 2002. Canadian Climate Normals – Port Colborne. Available online: http://www.msc-smc.ec.gc.ca/climate_normals/show_normals_e.cfm?station_id =956&prov=ON [accessed 4/17/02]

Environmental Sciences Group. 2002. Bioaccesssibility of Copper, Nickel, Cobalt and Arsenic in Soils Northeast of Inco Refinery, Port Colborne. Queen's University Analytical Services Unit, Royal Military College, Kingston, Ontario. RMC-CCE-ES-02-19.

Ernst, W.H. 1996. Bioavailability of heavy metals and decontamination of soils by plants. Ernst, Applied Geochemistry. 11: 163.

Fischer, E., and L. Koszorus. 1992. "Sublethal effects, accumulation capacities and elimination rates of As, Hg and Se in the manure worm, Eisenia fetida (Oligochaeta, Lubricidae)." Pedobiologia, 36:172-178.

Freedman, W.B., and T.C. Hutchinson. 1980. Effects of smelter pollutants on forest leaf litter decomposition near a nickel-copper smelter at Sudbury, Ontario. Can. J. Bot. 58:1722-1736.

Fritzell, E.K. 1978. Habitat use by prairie raccoons during the waterfowl breeding season. Journal of Wildlife Management 42: 118-127.

Giashuddin, M., and A. H. Cornfield. 1978. Incubation study on effects of adding vary levels of nickel (as sulphate) on nitrogen and carbon mineralization in soil. Environ. Pollut. 15:231-234.

Gibson, R.1991. Guide to the Natural History of the Niagara Region. Mammals. Lewis J.C Eds.

Gignac, L.D. 1987. Ecological Tolerance and Niche Structure of Sphagnum along a pollution Gradient Near Sudbury, Ontario, Canada. Can. J. Bot. 65:1268-1274.

Gignac, L.D. and P.J. Beckett. 1986. The effects of smelting operations on peatlands near Sudbury, Ontario, Canada. Can. J. Bot. 64:1138-1147.

Gish G.D., and R.E.Christensen. 1973. Cadmium, nickel, lead and zinc in earthworms from roadside soil. Environmental Science and Technology 7: 1060-1062.

Glooschenko, V., W.F. Wellr, P.G.R. Smith, R. Alvo, and J.H.G. Archbold. 1992. Amphibian Distribution with Respect to Pond Water Chemistry near Sudbury, Ontario. Can. J. Fish. Aquat. Sci. Vol 59(Suppl. 1): 114-121.

Godfrey, W.E. 1986. The Birds of Canada. Revised Edition. National Museum of Natural Sciences, Ottawa.

Goldfisher, S., B. Sschiller, I. Sternlieb. 1970. Copper in Hepatocyte Lysosomes of the Toad *Bufo marinus* L. Nature. 228:172-173.

Griffiths, B., and R. Bardgett. 1999. Interactions between microbe feeding invertebrates and soil microorganisms. In: Modern Soil Microbiology. J. Elsas, J. Trevors and E. Wellington (eds.). Marcel Dekker, Inc., New York.

Gunn, J. W. Keller, J. Negusanti, R. Potvin, P. Beckett, and K. Winterhalder. 1995. Ecosystem Recovery After Emission Reductions: Sudbury, Canada. Water, Air and Soil Pollution 85:1783-1788.

Hall, R, and B.M. Mulhern. 1984. Are anuran amphibians heavy metal accumulators. In Vertebrate Ecology and Sysematics. R.A. Seigel, L.E. Hunt, J.L. Kingth, L.Malaret, and N.L. Zuschlag (eds.).

Haq, A.U., T.E. Bates and Y.K. Soon. 1980. Comparison of Extractants for Plant-available for Zinc, Cadmium, Nickel and Copper in Contaminated Soils. Soil Sci. Soc. Am. J. 44:772-777.

Hartenstein, R., E.F. Neuhauser and A. Narahara, 1981. "Effects of Heavy Metal and Other Elemental Additives to Activated Sludge on Growth of Eisenia foetida." In: J.Environ.Qual. 10(3):372-376.

Heath, G.W., C.A. Edwards, and M.K. Arnold. 1964. Some methods for assessing the activity of soil animals in the breakdown of leaves. Pedobiologia 4: 80-87.

Hills, T.L. and G.H. Parker. 1993. Age and Proximity to Local Ore-Smelters as Determinants of Tissue Metal Levels in Beaver (*Castor canadensis)* of the Sudbury (Ontario) Area.Environmental Pollution 80(1993) 67-72.

Hosie, R. C. 1979. Native Trees of Canada. Fitzhenry & Whiteside Ltd. Publs.

Houlahan, J.E., C.S.Findlay, B.R.Schmidt, A.H.Meyer and S.L.Kuzmin. 2000. Quantitative evidence for global amphibian declines. Nature 404: 752-755.

Howell, J. C. 1942. Notes on the nesting habits of the American robin (Turdus migratorius L.). American Midland Naturalist 28: 529-603.

Hrudey, S.E., Weiping, C., Rousseaux, C.G. 1996. Bioavailability in Environmental Risk Assessment. CRC Lewis Publishers, New York.

Hutchinson, T.C. 2000. The evolution of metal tolerance in higher plants. Keynote address: International 25th Anniversar Conf. Heavy Metals in the Environment. Ed. J. Nriaur, Ann Arbor, August 2000. Contribution #1000 C.D.

Hutchisnson, T.C. and L.M. Whitby. 1977. The effects of Acid Rainfall and Heavy Metal Particulates on Boreal Foreset Ecosystem Near the Sudbury Smelting Region of Canada. Water, Air and Soil Pollution 7:421-438.

Hutnick, Russell J., and Harry W. Yawney. 1961. Silvical characteristics of red maple (Acer rubrum). USDA Forest Service, Station Paper 142. Northwestern Forest Experiment Station, Upper Darby, Pennsylvania.

IAEA. 1994. Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments. Technical Report No. 364. International Atomic Energy Association.

Inco Limited. 1998. Port Colborne Refinery Closure Plan Part 1 of 2. Inco Limited, Port Colborne, Ontario.

Ingstrom, M. pers, com. Mammologist, Royal Ontario Museum, Department Of Mammalogy.

Jacques Whitford. 2000a. Technical Scope of Work - Community Based Risk Assessment Plan for Port Colborne, Ontario. November 30, 2000. Jacques Whitford Environment Limited.

Jacques Whitford. 2000b. Statistical Examination of MOE/JWEL Soil Data in the Evaluation of As, Se, B and Pb as Potential CoCs. October 18, 2000. Jacques Whitford Environment Limited.

Jacques Whitford. 2001a. Potential CoC identification using soil chemical concentration data in exceedance of MOE generic guidelines. Port Colborne Community Based Risk Assessment. Draft Report, November 2001. Jacques Whitford Environment Limited.

Jacques Whitford. 2001b. Residential Well Water Sampling Program part of the Human Health Risk Assessment Port Colborne CBRA. Prepared for Inco Limited. Draft Report. Jacques Whitford Environment Limited.

Jacques Whitford. 2001c. Ecological risk assessment, natural environment part of Port Colborne CBRA. Draft Report, March 5, 2001. Jacques Whitford Environment Limited.

Jacques Whitford. 2001d. Sampling and Analysis: Quality Assurance and Quality Control Port Colborne Community Based Risk Assessment. Prepared for Inco Limited. 9 July, 2001. Jacques Whitford Environment Limited.

Jacques Whitford. 2002a. In prep. Phytotoxicity Testing. Ecological Risk Assessment, Port Colborne Community Based Risk Assessment. Jacques Whitford Environment Limited.

Jacques Whitford. 2002b. Ambient Air Monitoring in the Community Human Health Risk Assessment Input Port Colborne, Ontario. Draft Report. Submitted to Inco Limited. June 3, 2002. Jacques Whitford Environment Limited.

Jacques Whitford. 2002c. Soil Characterisation. Port Colborne Community Based Risk Assessment Port Colborne, Ontario. Draft Report. Prepared for Inco Limited. November 2002. Jacques Whitford Environment Limited.

Jacques Whitford. 2002d. Data Interpretation Protocol Ecological Risk Assessement Community Based Risk Assessment Port Colborne Ontario. Prepared for Inco Limited. July, 2002. Jacques Whitford Environment Limited.

Jacques Whitford. 2002e. Ambient Air Monitoring in the Vacinity of Farming Activities. Human Health Risk Assessment Input Port Colborne, Ontario. Jacques Whitford Environment Limited.

Jacques Whitford. 2003. Potential CoC Identification using Emission Inventories and Dispersion Modelling of Inco and Algoma Operations. Prepared for Inco Limited. March 2003. Jacques Whitford Environment Limited.

Jacques Whitford. 2004a. Ecological Risk Assessment Crop Studies. Prepared for Inco Limited. July 2003. Jacques Whitford Environment Limited.

Jacques Whitford. 2004b. Human Health Risk Assessment. Prepared for Inco Limited. July 2003. Jacques Whitford Environment Limited.

Johnson, P.T.J., K.B.Lunde, E.G.Ritchie and A.E.Launer. 1999. The effect of trematode infection on amphibian limb development and survivorship. Science 284: 802-804.

Kabata-Pendias, A. 2001. Trace Elements in Soils and Plants. Third Edition. CRC Press, New York.

Kaufmann, J.H. 1982. Raccoon and allies. In: J.A.Chapman and G.A.Feldhamer (eds.). Wild Mammals of North America: Biology, Management and Economics. Johns Hopkins University Press, Baltimore, Maryland.

Keppie, D.M., and R.M.Whiting Jr. 1994. American Woodcock (Scolopax minor). In The Birds of North America, No. 94 (A. Poole, P. Stettenheim, and F. Gill, editors). Philadelphia Academy of Natural Sciences, Philadelphia, PA, USA.

Khangarot, B.S., A. Sehgal and M.K. Bhasin. 1985a. “Man and biosphere studies on the Sikkim Himalayas. Part 5: acute toxicity of selected heavy metals on the tadpoles of Rana hexadactyla.” Acta Hydrochim. Hydrobiol. 13(2):259-263.

Khangarot, B.S., A. Sehgal and M.K. Bhasin. 1985b. “Man and biosphere studies on the Sikkim Himalayas. Part 4: Effects of Chelating Agent EDTA on the Acute Toxicity of Copper and Zinc.” Acta Hydrochim. Hydrobiol. 13(1):121-125.

Klohn-Crippen. 1996. Port Colborne Refinery. Site Characterization Study. Part B: Groundwater Characterization Study. Volume 1: Report, June 1996. (PM6543 01) Prepared for Inco Limited.

Knable, A. E. 1974. Seasonal trends in the utilization of major food groups by the red fox (Vulpes fulva) in Union County, Illinois. Transactions of the Illinois State Academy of Science 66: 113-115.

Knupp, D.M., R.B.Owen, Jr., and J.B.Diamond. 1977. Reproductive biology of the American Robin in northern Maine. Auk 94: 80-85.

Kroodsma, D.E., and J.Verner. 1997. Marsh Wren (Cistothorus palustris). In The Birds of North America, No. 308 (A. Poole, P. Stettenheim, and F. Gill, editors). Philadelphia Academy of Natural Sciences, Philadelphia, PA, USA.

Kukier, U., and R.L. Chaney. 1999. Methods for characterization of need for remediation of Ni phytotoxicity of, and for persistent remediation of, low Mn, high Ni soils at Port Colborne, Ontario. Task 1B report to INCO Ltd., Toronto, Ontario, Canada.

La Force, M. J., Fendorf, S., 2000. "Solid-phase iron characterization during common selective sequential extractions", Soil Sci. Soc. Am. J., 64, 1608-1613.

Lamb, L., G. Rhynard. 1994. Plants of Carolinian Canada. Federation of Ontario Naturalists.

Lawrence, L.K. 1953. Nesting life and behaviour of the Red-eyed Vireo. Canadian Field-Naturalist 67: 47-77.

Lee, Y.H., and R.B. Stuebing. 1990. Heavy Metal Contamination in the River Toad, Fufo juxtasper (Inger), Near a Copper Mine in East Malaysia. Bull. Environ. Contam. Toxicol. 45:272-279.

Lee, H., W. Bakowsky, J.Riley, J. Bowles, M. Puddister, P. Uhlig and S. McMurray. 1998. Ecological Land Classification for Southern Ontario. First Approximation and Its Application. Ontario Ministry of Natural Resources. SCSS Field Guide FG-02.

Levengood, J.M. and L.M. Skowron. 2001. Use of a Simulated Gizzard to Measure Bioavailability of Metals and Other Elements to Waterfowl. Ecotoxicology. 10: 299-304.

Lewis, J.C., and G. Winger. 1991. Guide to the Natural History of the Niagara Region: Birds. Lewis Publishers.

Llewellyn, L. M., and F.M.Uhler. 1952. The foods of fur animals of the Patuxent Research Refuge, Maryland. American Midland Naturalist 48: 193-203.

Lock, K. and C.R. Janssen. 2000. Effect of clay and organic matter type on the ecotoxicity of zinc and cadmium to the potworm *Enchytraeus albidus*. Chemosphere 44 (2001) 1669-1672.

Lofty, J.R. 1974. Oligochaetes. In: C.H. Dickinson and G.J.F. Pugh (Eds.) Biology of plant litter decomposition, Vol. 2. Academic Press, London. Pp 467-488.

Luttich, S.N., D.H.Rusch, E.C.Meslow and L.B.Keith. 1970. Ecology of Red-tailed Hawk predation in Alberta. Ecology 51: 190-203.

Ma, W-C. 1982. The influence of soil properties and worm related factors on the concentration of heavy metals in earthworms. Pedobiologia 24: 109-119.

Malecki, M.R., E.F. Neuhauser and R.C. Loehr. 1982. “The effect of metals on the growth and reproduction of Eisenia foetida (Oligochaeta, Lumbridicae).” Pedobiologia, 24:129-137.

Malone, C.R., and D.E. Reichle. 1973. Chemical manipulations of soil biota in a fescue meadow. Soil Biology and Biochemistry 5: 629-639.

Mandal, B.K. and K.T. Suzuki. 2002. Arsenic round the world: a review. Talanta 58 (2002) 201-235.

Marinussen, M., Van Der Zee, S. and F. Haan. 1996. Effect of Cd or Pb Addition to Cu-Contaminated Soil on Tissue Cu Accumulation in the Earthworm, Dendrobaena veneta. Ecotoxicology and Environmental Safety. 38: 309-315.

MathSoft, Inc. 1998. S-Plus 4 Guide to Statistics. Data Analysis Products Division, MathSoft, Seattle.

McCullagh, P., and J.A.Neldar. 1989. Generalized Linear Models. Second Edition. Chapman and Hall, London, UK.

McIlveen, W.D., and J.J. Negusanti. 1994. Nickel in the terrestrial environment. Science of the Total Environment 148: 109-138.

McIlveen, W.D., and D.L.McLaughlin. 1993. Field Investigation Manual. Part 1 - General Methodology. Ontario Ministry of the Environment and Energy, Report No. 014-3511-93.

McLaughlin, D. and S. Bisessar. 1994. Phytotoxicology Survey Report: International Nickel Comapy Limited, Port Colborne – 1999. Stamdards Development Branch, Phytotoxicology Section, Ontario Ministry of Environment and Energy. #SDB-003-3512-94.

Mehring, A.L., Jr., J.H. Brumbaugh, A.J. Sutherland and H.W. Titus. 1960. "The tolerance of growing chickens for dietary copper." Poultry Science, 39:713-719.

MOE. 1993. Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags and Snow. Queen's Printer for Ontartio. Ontario Ministry of Environment.

MOE. 1993a. Field Investigation Manual, Part 1 General Methodology. Phytotoxicology Section, Hazardous Contaminates Branch, Ontario Ministry of the Environment and Energy, Report Number 014-3511-93. Ontario Ministry of Environment.

MOE. 1993b. Metals in Soil and Vegetation in the Sudbury Area.- Table H-2, From, MOE "Upper Limit of Normal" Contaminant Guidelines for Phytotoxicology Samples. Report Number ARB-138-88-Phyto, ISBN 0-7729-5143-8. Ontario Ministry of Environment.

MOE. 1994. Provincial Water Quality Objectives. Water Management Policies, Guidelines. July 1994, Reprinted February 1999. Ontario Ministry of Environment.

MOE. 1996. Guidance on Sampling and Analytical Methods for Use at Contaminated Sites in Ontario. June 1996. Ontario Ministry of Environment.

MOE. 1996. Guidance on Site Specific Risk Assessment for Use at Contaminated Sites in Ontario. MOE, Standards Development Branch, May 1996. Ontario Ministry of Environment.

MOE. 1997. Guideline for Use at Contaminated Sites In Ontario. Ontario Ministry of the Environment. February 1997. Ontario Ministry of Environment.

MOE. 2000a. Phytotoxicity Soil Investigation: Inco – Port Colborne (1998). January 2000. Ontario Ministry of Environment.

MOE. 2000b. Phytotoxicity Soil Investigation: Inco – Port Colborne (1999). Ecological Standards and Toxicology Section, Standards Development Branch, Ontario Ministry of the Environment. Report No. SDB-032-3511-2000. July 2000. Ontario Ministry of Environment.

MOE. 2000c. Soil Contamination in Port Colborne Woodlots: 2000. Ontario Ministry of the Environment. February 2000. #SDB-012-3511-2001. Ontario Ministry of Environment.

Mollenhauer, H.H., D.E. Corrier and D.E. Clark, 1985. "Effects of dietary cobalt on testicular structure." Virchows Arch B Cell Pathol Incl Mol Pathol 49:241-248.

Morgan, J.E., and A.J.Morgan. 1990. The distribution of cadmium, copper, lead, zinc and calcium in the tissues of the earthworm Lumbricus rubellus sampled from one uncontaminated and four polluted soils. Oecologia 84: 559-566.

MRI. 2002. Determination of the Relative Absorbed Fraction of Nickel in Port Colborne Soil Following Single Oral Administration to Rats. Prepared for Inco Limited and Jacques Whitford Environment Ltd.. Midwest Research Institute.

Myers, R.H. 1986. Classical and Modern Regression with Applications. Prindle, Weber and Schmidt Publishers, Massachusetts.

Napier, B. 1988. GENII - The Hanford Environmental Radiation Dosimetry Software System. PNL-6584, Pacific Northwest Laboratory, Richland, Washington.

NHIC. 2002. Natural Areas, Species List and Provincial S-Ranking on OMNR Web Site: http://www.mnr.gov.on.ca/MNR/nhic/queries/lists.html. Natural Heritage Information Centre.

NRC. 2003. *Bioavailability of Contaminants in Soils and Sediments, Processes, Tools and Applications*. Committee on Bioavailability of Contaminants in soils and Sediments, Water Science and Technology Board, Division on Earth and Life Studies, National Research Council, The National Academies Press, Washington, DC.

Oldham, M.J., 1999. Rare Vascular Plants: Data Base of the Natural Heritage Resources Of Ontario. Ontario Ministry of Natural Resources.

Ollson, C.A. 2003. *Arsenic Risk Assessments: The Importance of Bioavailability*. Doctoral Thesis, Royal Military College of Canada. October 2003.

OMAFRA. 1998. Soil Fertility Handbook. Ontario Ministry of Agriculture, Food and Rural Affairs. Publication 611.

Ontario Breeding Bird Atlas. 2002. Online: http://www.birdsontario.org/atlas/atlasmain.html

ORNL. 1992. *Toxicity Summary for Copper*. Chemical Hazard Evaluation and Communication Group, Biochemical and Environmental Information Analysis Section, Health and Safety Research Division, Oak Ridge, Tennessee. Prepared for Oak Ridge Reservation Environmental Restoration Program. Oak Ridge National Laboratory.

ORNL. 1995. *Toxicity Summary For Nickel Compounds*. Chemical Hazard Evaluation and Communication Group, Biochemical and Environmental Information Analysis Section, Health and Safety Research Division, Oak Ridge, Tennessee. Prepared for Oak Ridge Reservation Environmental Restoration Program. Oak Ridge National Laboratory

Ouellet, M., J.Bonin, J.Rodrigue, J.L.DesGranges and S.Lair. 1997. Hindlimb deformities (ectromelia, ectrodactyly) in free-living anurans from agricultural habitats. Journal of Wildlife Disease 33: 95-104.

Parker, G.H. and J. Hamr. 2001. Metal Levels in Body Tissues, Forage and Fecal Pellets of Elk (*Cervus elaphus)* Living Near the Ore Smelters at Sudbury, Ontario. Environmental Pollution 113 (2001) 347-355.

Peck, G.K., and R.D.James. 1983. Breeding Birds of Ontario Nidiology and Distribution, Volume 1: Non-passerines. Royal Ontario Museum, Toronto.

Peck, G.K., and R.D.James. 1987. Breeding Birds of Ontario Nidiology and Distribution, Volume 2: Passerines. Royal Ontario Museum, Toronto.

Peijnenburg, W., Baerselman, R., Groot, A., Jager, T., Posthuma, L., and R. Van Veen. 1999. Relating Environmental Availability to Bioavailability: Soil-Type-Dependent Metal Accumulation in the Oligochaete *Eisenia andrei*. Ecotoxicology and Environmental Safety. 44: 294-310.

Perala, D.A., and E. Sucoff. 1965. Diagnosing potassium symptoms in American elm, silver maple, Russian olive, hackberry, and box elder. Forest Science 11: 347-352.

Petersen, L.R. 1979. Ecology of Great Horned Owls and Red-tailed Hawks in southeastern Wisconsin. Wisconsin Department of Natural Resources Technical Bulletin Number 111.

Pongratz, R., 1998: Arsenic Speciation in Environmental Samples of Contaminated Soil. Sci. Tot Environ., 224, 133-141.

Preston, C.R., and R.D.Beane. 1993. Red-tailed Hawk (Buteo jamaicensis). In The Birds of North America, No. 52 (A. Poole, P. Stettenheim, and F. Gill, editors). Philadelphia Academy of Natural Sciences, Philadelphia, PA, USA.

Reichle, D.E. 1977. The role of soil invertebrates in nutrient cycling. In: U. Lohm and T. Persson (eds.) Soil organisms as components of ecosystems. Ecological Bulletin 25: 145-154.

Reynolds, J.W. 1977. The Earthworms (Lumbricidae and Sparganophilidae) of Ontario. Life Sciences Miscellaneous Publications, Royal Ontario Museum, Toronto.

Rinne, R.J. 1981. Phytotoxicology Surveys Conducted in the Vicinity of the Inco Nickel Refinery, Port Colborne – 1979, 1980. Phytotoxicology Section, Air Resources Branch, Ministry of the Environment.

Rinne, R.J. 1989. Phytotoxicology Assessment Surveys In The Vicinity of INCO LTD, Port Colborne – 1985, 1986. Phytotoxicology Section, Air Resources Branch, Ministry of the Environment.

RMON. 1980. Environmentally Sensitive Areas. Department of Geography, Brock Universtiy, St. Chatharines. Regional Municipality of Niagara.

Rose, G.A. and G.H. Parker. 1983. Metal Content of Body Tissue, Diet Items, and Dung of Ruffed Grouse Near the Copper-Nickel Smelters at Sudbury, Ont. Can. J. Zool. Vol. 61:505-511.

Ruby, M.V., A. Davis, R. Schoof, S. Eberle, and C.M. Sellstone. 1996. “Estimation of Lead and Arsenic Bioavailability Using a Physiologically Based Extraction Test.” *Environ. Sci. Technol.* 30, 422-430.

Sallabanks, R., and F.C.James. 1999. American Robin (Turdus migratorius). In The Birds of North America, No. 462 (A. Poole, P. Stettenheim, and F. Gill, editors). Philadelphia Academy of Natural Sciences, Philadelphia, PA, USA.

Sample, B.E. and C.A. Arenal. 1999. "Allometric Models for Interspecies Extrapolation of Wildlife Toxicity Data." Bull. Environ. Contam. Toxicol. 62:653-663.

Sample, B.E., M.S.Aplin, R.A.Efroymson, G.W.Suter II, and C.J.E.Welsh. 1997. Methods and tools for estimation of the exposure of terrestrial wildlife to contaminants. Prepared for the United States Department of Energy, Environmental Sciences Division Publication 4650.

Sample, B.E., D.M. Opresko and G.W. Suter, II. 1996. Toxicological benchmarks for wildlife: 1996 revision. Prepared for the United States Department of Energy by Oak Ridge National Laboratory.

Sanderson, G.C. 1987. Raccoon. In: Novak, M., J.Baker, M.Obbard and B.Malloch, (eds.) Wild Furbearer Management and Conservation in North America. Ministry of Natural Resources, Toronto, Ontario.

Schowalter, T.D. 2000. Insect Ecology: An Ecosystem Approach. Academic Press, New York.

Schroeder, H.A. and M. Mitchener. 1971. "Toxic effects of trace elements on the reproduction of mice and rats." Arch. Environ. Health., 23:102-106.

SENES, 2001. Risk Assessment of Selected Contaminants at Former Sarnia Fiberglas Canada Inc. Insulation Manufacturing Site. Prepared for Legder Environmental Services Limited, April. SENES Consultants Ltd.

Sepik, G.F., and E.L.Derleth. 1993. Habitat use, home range size, and patterns of moves in the American Woodcock in Maine. In: J.R.Longcore and G.F.Sepik (eds.). Proceedings of the Eighth Woodcock Symposium. Biological Report 16, United States Fish and Wildlife Service, Washington, DC.

Smith, M.L. 1975. Phytotoxicology Surveys Conducted in the Vicinity of the International Nickel Company, Port Colborne Ontario, 1967-1974. Phytotoxicology Section, Air Resources Branch, Ministry of the Environment.

Soper, J.H., M.L. Heimburger. 1994. Shrubs of Ontario. The Royal Ontario Museum, Queens Park, Toronto, Canada.

Southern, W.E. 1958. Nesting of the Red-eyed Vireo in the Douglas Lake region, Michigan. Jack-Pine Warbler 36: 105-130, 185-207.

Sparling, D.W., G.Linder, C. A. Bishop. 2000. Exotoxicology of Amphibians and Reptiles. Society of Environmental Toxicology and Chemistry (SETAC).

Sparling, D.W. and P. Lowe. 1995. Metal Concentrations of Tadpoles in Experimental Ponds. Environmental Pollution. 91: 149-159.

SPSS Inc. 1997. SYSTAT 7.0.1. for Windows. 7/97, Standard Version. Chicago, Illinois, USA.

Spurgeon, D.J., and S.P.Hopkin. 1996. Risk assessment of the threat of secondary poisoning by metals to predators of earthworms in the vicinity of a primary smelting works. The Science of the Total Environment 187: 167-183.

Stephen, C.E. 1989. Software to Calculate LC50 Values with Confidence Intervals using Probit, Moving Averages, and Spearman-Karber Procedures. Modified by R.G. Clements and M.C. Harraass. United States Environmental Protection Agency, Duluth, Minnesota.

Stephenson, G.L., Koper, N., Atkinson, G.F., Solomon, K.R. and Scroggins, R.P. 2000. Use of nonlinear regression techniques for describing concentration-response relationships for plant species exposed to contaminated site soil. Environmental Toxicology and Chemistry 19(12):229-242.

Stone, R.P. and S.W. Johnson. 1997. Survival, Growth, and Bioaccumulation of Heavy Metals by Juvenile Tanner Crabs (Chionoecetes bairdi) Held on Weathered Mine Tailings. Bulletin of Environmental Contamination Toxicology. 58: 830-837.

Storm, G.L., G.J. Fosmier, and E.D. Bellis. 1994. Heavy Metals in the Environmet: Persistance of Metals in Soil and Selected Vertebrates in the Vicinity of the Palmerton Zine Smelters. J. Environ. Qual. 23:508-514.

Suter, G.W., C.L. Tsao, 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota. 1996 Revision, Prepared for US Department of Energy.

Sylvia, D.M., J.J.Fuhrmann, P.G.Hartel and D.Zuberer. (eds.) 1998. Principles and Applications of Soil Microbiology. Prentice Hall, Upper Saddle River, New Jersey.

Temple, P.J. 1976. Phytotoxicology Surveys Conducted in the Vicinity of the International Nickel Company, Port Colborne-1975. Phytotoxicology Section, Air Resources Branch, Ministry of the Environment.

Temple, P.J and S. Bisessar, 1981. Uptake and Toxicity of Nickel and Other Metals in Crops Grown on Soils Contaminated by a Nickel Refinery. Journal of Plant Nutrition 3(1-4): 473-482.

USDA. 2001. National soil surveys handbook. Natural Resources Conservation Services. Revisions of July 2001. Available online at http://www.statlab.iastate.edu/

United States Department of the Interior. 1998. *Copper Hazards to Fish, Wildlife, and Invertebrates 1998: A Synoptic Review.* Biological Science Report, USGS/BRD/BSR – 1997-0002. United States Geological Survey; Patuxent Wildlife Research Center.

United States Department of the Interior. 1998. *Nickel Hazards to Fish, Wildlife, and Invertebrates 1998: A Synoptic Review.* Biological Science Report, USGS/BRD/BSR – 1997-0002. United States Geological Survey; Patuxent Wildlife Research Center.

US EPA. 1986. *Guidance for the Health Risk Assessment of Chemical Mixtures.* Washington D.C., United States Environmental Protection Agency. United States Environmental Protection Agency.

US EPA. 1987. Technical Resource Document for variances from the secondary containment requirement of hazardous waste tank systems. Vol. 2I: Risk-based variance. US EPA, Washington, DC. United States Environmental Protection Agency.

US EPA. 1993. Wildlife Exposure Factors Handbook. EPA600-R-93-187. Office of Research and Development. United States Environmental Protection Agency.

US EPA. 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. Interim Final. June 1997. United States Environmental Protection Agency.

US EPA. 1998. Guidelines for Ecological Risk Assessment. EPA/630/R-95/0002F. US EPA, Washington, DC. United States Environmental Protection Agency.

US EPA. 1999. Screening level ecological risk assessment protocol for hazardous waste combustion facilities. EPA530-D-99-001C. United States Environmental Protection Agency.

US EPA. 2000. Supplementary Guidance for the Health Risk Assessment of Chemical Mixtures. Washington D.C., United States Environmental Protection Agency. United States Environmental Protection Agency.

US EPA. 2002. ECOTOX. Ecotoxicology Database. United States Environmental Protection Agency.

US FWS. 1964. Pesticide-wildlife studies, 1963: a review of Fish and Wildlife Service investigations during the calendar year. FWS Circular 199. United States Fish and Wildlife Service.

Varga, S., and G.Allen. 1990. County/Regional Municipality Vascular Plant Floras for the Carolinian Zone of Canada. In: Conserving Carolinian Canada, University of Waterloo Press. pages 129-153.

Venugopal, B. and T.D. Luckey. 1978. Metal Toxicity in Mammals, Volume 2. Chemical Toxicity of Metals and Metalloids. Plimum Press.

Vockeroth, J.R. 1992. The Flower Flies of the Subfamily Syrphinae of Canada, Alaska and Greenland - Diptera: Syrphidae. The Insects and Arachnids of Canada - Part 14. Agriculture Canada, Ottawa.

Vogt, R.C. 1981. Natural History and Ecology of Amphibians and Reptiles in Wisconsin. Milwaukee Public Museum, Milwaukee, Wisconsin. 205pp.

Voigt, D.R. 1987. Red Fox. In: Novak, M., J.Baker, M.Obbard and B.Malloch, (eds.) Wild Furbearer Management and Conservation in North America. Ministry of Natural Resources, Toronto, Ontario.

Voigt, D.R., and R.L.Tine. 1980. Strategies for analyzing radio tracking data. Pp. 387-404 In C.J.Amlaner, Jr., and D.W.Macdonald (eds.). A Handbook on Biotelemetry and Radio Tracking. Pergamon Press, Oxford, UK.

Weitzman, S., and R.J. Hutnik. 1965. Silver maple (Acer saccharinum L.). In: H.A.Fowells (comp.). Silvics of forest trees in the United States. United States Department of Agriculture, Agriculture Handbook 271. Washington, DC.

Weller, W. F. and M. J. Oldham (Eds.). 1986. Ontario Herpetofaunal Summary. Published by Ontario Field Herpetologists.

Wheelwright, N.T. 1986. The diet of American robins: an analysis of United States Biological Survey records. Auk 103: 710-725.

Wiken, E.B. 1986. Terrestrial Ecozones of Canada. Ecological Land Classification, Series No. 19. Environment Canada. Hull, Quebec. 26pp. + map.

Wise, D.H. 1993. Spiders in Ecological Webs. Cambridge University Press, Cambridge, Massachusetts.

Yagi, A. 2002. Ontario Ministry of Natural Resources. Niagara Region Biologist.

APPENDIX A

JACQUES WHITFORD RESPONSE TO INDEPENDENT THIRD PARTY PEER REVIEW COMMENTS

Port Colborne Community Based Risk Assessment

Ecological Risk Assessment – Natural Environment

Peer Review of Draft Report – July 2003

Introduction

As part of a Community Based Risk Assessment (CBRA) initiated by Inco Limited to address potential impacts resulting from historical emissions from a former nickel refining in Port Colborne, Jacques Whitford (JW) completed an Ecological Risk Assessment (ERA) for the natural environment of Port Colborne. Following completion of two years of fieldwork and analysis of data, JW prepared a draft ERA report in July 2003. Following the CBRA process, this draft report was presented to the City of Port Colborne through the Public Liaison Committee (PLC) for public review and comment. In addition, to this public review, an independent third party peer eview of the draft report was undertaken by a CHM2Hill.

Following the review, CHM2Hill prepared a report detailing their comments on the draft ERA report. This review report was provided to Inco, JW, and the City of Port Colborne (the PLC). This Appendix prepared by JW combines the comments presented in CHM2Hill's peer review report, with JW's response to those comments. Following completing JW's response to CHM2Hill comments, JW's responses were forwarded to CHM2Hill for final review and comment. Following this review, CHM2Hill prepared a second report that identified whether JW's responses had either addressed their comment in full, party addressed their comment, or had not addressed their comment. JW's responses to this second review is also provided in full in this Appendix.

The format of the appendix is to present CHM2Hill's questions and comments in their entirety as with JW's response in bold following each question, statement or comment. CHM2Hill comments that question specific results or methods of assessments have been fully addressed in this Appendix and/or in the report under this cover.

Peer Review of Community Based Risk Assessment
Final Report on Environmental Risk Assessment
Port Colborne, Ontario

Rank	Number	Section	Page	Paragraph	Comment
General Comments:					
	1	---	---	---	It is apparent that great effort was spent to thoroughly assess the risk to the natural environment associated with historical emissions from the Inco refinery. The report generally provides a complete and clear description of study area and detailed ecological site characterization. Overall, the ERA is well-organized and well-researched; however, there are places where the review identified issues that may materially affect the findings of the ERA and risk to certain receptors may have been under estimated. We have also identified issues where transparency of the ERA could be improved. These issues are addressed in subsequent general comments, with greater detail provided (including identification of report sections) under specific comments. **Comments provided by CHM2HILL have been reviewed by JW in full. For the completion of the final report, the vast majority of the specific A category comments have been addressed and incorporated into the report. For B and C category comments, following JW's review, a number of these where also incorporated into the final report. However, for many of the B and C category comments, clarification and discussion is only provided within this Appendix. Finally, many of the C level comments pertaining to how changes to the report structure and/or presentation of the data could improve the overall transparency of the ERA, where reasonable, have been incorporated into the final report. However, incorporation of all the C comments would require considerable effort to change the document and this was not undertaken.**
A	2	---	---	---	This assessment contains an extensive amount of site-specific biological data. These data are invaluable, and permit a more accurate evaluation of exposure as experienced by resident biota. The utility of these data should be greatly strengthened by presenting the concentrations of CoCs in soil, sediment and water associated with the areas where all biota were collected so that we can understand how representative of maximum CoC exposure the biota data are. A table showing the range in Ni concentrations (as a surrogate for all CoCs) associated with stations from which biota were sampled in all areas would be particularly helpful. **Tables in the report that present CoC concentrations in tissues will be restructured to also present the range and mean of Ni concentrations in soil, sediment and water. In addition footnotes will be provided to direct the reader to the specific location of the raw data sets presented in Volume V of the report. (e.g. P. 6-21, table 6-3)**

Rank	Number	Section	Page	Paragraph	Comment
A	3	---	---	---	The manner in which exposure of the VECs is evaluated should reflect how these receptors experience their environment. Plants and invertebrates are immobile (or functionally so). They do not experience average CoC concentrations; rather they experience concentrations at each individual point. As a consequence, exposure for plants and invertebrates should be evaluated on a point-by-point basis. This would better represent the spatial distribution of exposure and potential risk within the study area. Because of their mobility, birds and mammals experience mean CoC concentrations. All species however do not experience mean CoC concentrations over the same spatial area. While it is appropriate to evaluate wide-ranging receptors (i.e., white-tailed deer, red fox, and red-tailed hawk) over the entire study area, receptors with smaller home/foraging ranges should be analyzed on a smaller scale to better represent the spatial distribution of exposure and potential risk. Exposure estimation can also be enhanced by considering the relative use of different types of habitats by different receptors. **As required by the CBRA process, JW's approach for the characterization of risk to Valued Ecological Components (VECs) were presented on numerous occasions to the Public Liaison Committee (PLC), the Technical Subcommittee (TSC), and the general public for their review and comment. Specific approaches to the analysis of the data for the determination of risk was presented in full in a document entitled "An Approach To Data Interpretation" (see Tab 18 of Volume 2). Through this review/comment process it was agreed that the characterization of risk for each selected VEC was to be a community-based risk assessment, rather than for specific properties, examining risk at a population level for an identified VEC with a VEC's population defined as those individuals living within the Study Area. In addition, exposure assessment was to be based on the population level (not individuals at a specific location) using a calculated UCLM (or maximum where sample sizes were fewer than 10) for various environmental media that were sampled and analyzed for CoCs.** **This was the study design and approach agreed to by all stakeholders for the CBRA. However, to address the above comment, JW will provide a separate uncertainty assessment in the final report that will assess potential risk to subpopulations of less mobile VECs located within the Study Area. This analysis is now presented in Section 11 in the report.**

Rank	Number	Section	Page	Paragraph	Comment
A	4	---	---	---	Four significant natural features were identified within the Study Area. Because of their significance, it would be appropriate to specifically determine whether they have been affected. Some discussion should be provided on why this assessment was not conducted or additional evaluation could be included to address risks to VECs that may occur in these areas. **The four significant natural areas are woodlots and Red Maple swamps that have been identified due to the rarity of woodlots/forest habitat in the Regional Municipality of Niagara (a.k.a., Niagara Region). As a result of the ERA's assessment of the potential risk to woodlots and maple trees in the Study Area, the ERA has fully addressed potential risk to these significant features. However, JW will provide additional assessments specific to these areas in Section 9.0 of the report. (P. 9-13, para. 2)**
A	5	---	---	---	Uncertainties are a critical component of all risk evaluations. In the current assessment, uncertainties, limitations, and data gaps are discussed in each section as they relate to the specific discussion. A comprehensive analysis of uncertainties would be helpful at the end of the assessment to integrate all of these earlier statements and discuss how the uncertainties with the data, assumptions, and approaches employed affect the final risk conclusions. **Agreed, JW will prepare a separate and detailed uncertainty/limitations section to the report. (Section 10)**

Rank	Number	Section	Page	Paragraph	Comment
A	6	---	---	---	Several issues of concern were identified for the amphibian risk characterization. These include the TRV selection, the spatial and temporal representativeness of the samples, high sediment concentrations, and the weight given to roadside call surveys in the risk characterization. We recommend consideration of the following issues: *Fowler's Toad:* Alternative surface water TRVs are recommended for the risk characterization (see attached Table 8). These are the most recent TRVs presented in the literature, and supersede those used in the risk assessment. Since the authors (Birge et al., 2000) present LC10s and LC50s, rather than calculating an LC20 from the LC50 (this relationship also does not appear linear), a low (LC10) and high (LC50) toxicity value can be used to produce low and high hazard quotients. **TRVs for toads (American/Fowler's) will be reviewed and hazard quotients re-evaluated. (P. 7-13, Section 7.3 and Vol. III, tab 4)** *Other Amphibians:* Alternative surface water TRVs are also recommended for the risk characterization for other amphibians (see attached Table 9). Using northern leopard frog TRVs (a species found on-site with a similar sensitivity to the CoCs as the narrow-mouthed toad), nickel concentrations exceeded low and high risk TRVs. Copper concentrations exceed the low, but not high, risk TRVs. Therefore, risks from nickel in surface water are considered probable, and risks from copper are possible. **TRVs for frogs will be reviewed and hazard quotients re-evaluated. (P. 7-13, Section 7.3 and Vol. III, tab 4)**
B	7	---	---	---	Although uncertainties are generally acknowledged, it is often concluded that the approach used would overestimate risk. In many cases, this is not substantiated and the confidence in the approach appears to be overstated. Often times, it can only be said that the uncertainty would either under- or overestimate risk, and a conclusion of overestimation should only be made when there is strong evidence to support this statement. Also, the ERA approach is repeatedly referred to as a very conservative approach with very conservative assumptions. However, this is not entirely the case as the ERA uses site-specific data including bioavailability and measured tissue concentrations for prey items, less conservatism is employed than with ERAs that use conservative literature values or assumptions (e.g., 100% bioavailability). This ERA, therefore, likely reflects more accurate exposure, but is not highly conservative. Examples are provided below in the specific comments. **Report comments regarding the confidence and conservatism of the assessment will be reviewed in full.**

Rank	Number	Section	Page	Paragraph	Comment
B	8	---	---	---	It is evident that the TRV literature was reviewed and that certain studies were excluded and not presented; however, the justification for exclusion is often not clear. Presentation of all available studies accompanied by the rationale for inclusion or exclusion (this could be in tabular form) in the TRV development would increase the transparency of the TRV selection process. Additionally, the data for studies that are presented in tabular form are often vague, and more information is needed to understand the merits of the study. Examples are given below in the specific comments. **Justification for the TRV selected will be expanded upon. (Vol. III, tab 4)**
B	9	---	---	---	Overall, the statistical analysis description should provide more details on how the analysis was actually carried out, either in the report or in a statistical analysis appendix. The report (see Section 6.4.2, p. 6-15) refers the reader to Appendix C for a more detailed Generalized Linear Models (*glms)* analysis but Appendix C does not really provide any further detail. **Vol. III, tab 10, will be reviewed and, where required, additional text will be provided to further detail the statistical analysis undertaken for the ERA.**
B	10	---	---	---	The authors also discuss the use of the link function in general terms but do not show how they used it in the study or give any justification for its use. Link functions are typically used to relate a linear predictor to the mean response as shown in the following equation: $X'_{i}b = g(m_{l})$ Where g is the link function, X is the matrix of linear predictors, and β is the matrix of coefficients. The link function used in the study was the logit function and the type of estimation was a logistic regression. The authors do not expressly state this in the report and should do so either in Appendix C or Section 6.4.2 of Vol. I. **This will be addressed in Vol. III, tab 10.**
B	11	---	---	---	The conceptual site model (CSM) for CoC deposition, secondary sources, soil transformations, and transport mechanisms is not well defined and reduces the ability of the reader to follow and understand the assessment. Basic information for the CoCs should include identification/discussion of sources; speciation, fate, and transport; bioavailability and bioaccumulation; in addition to a complete toxicological profile. All contaminant migration pathways should be evaluated and documented. Much of this information is included in various sections of the report, but because it is not integrated into a unified CSM, the inter-relationships of the various components are obscured. **Much of the detailed background information regarding COC sources/deposition, speciation etc. is provided in separate reports prepared by JW for the CBRA. For the full review of the CBRA, the Ministry of the Environment (MOE), the review and approval agency for the CBRA, will have all documentation for their review. In addition the reader will be clearly directed to the supporting documents in the report. (P. 1-14, para. 1, line 2)**

Rank	Number	Section	Page	Paragraph	Comment
B	12	---	---	---	There is a limited characterization of CoC deposition, that examined the filtering effect of the woodlots. However, those results could have been more clearly and convincingly represented with data (using Ni as the indicator CoC) showing the concentration changes as one moves from the windward to the lee side of woodlots using appropriate graphics. Presumably, the trend could be shown for representative woodlot groups (i.e., within high, moderate, and low impact areas). Statistical separation of means could also be used to quantify the strength of the conclusion. **A full analysis of the deposition of CoCs in woodlots in the Study Area was undertaken as suggested above by the MOE in 2000. The MOE report detailing the findings is referenced, but the details of the findings are not repeated in full in the ERA report. Again, for the full review of the CBRA, the MOE, the review and approval agency for the CBRA, will have all documentation for their review.**
B	13	---	---	---	The ERA does not fully support the decision taken to not assess soil background conditions for the CoCs. It may be that there were discussions amongst the stakeholders during planning that determined the approach to be acceptable. In the interest of having a transparent document, the reasons not to assess background conditions needs to be documented in the ERA. **Correct, for the ERA, soil background conditions for the CoCs in the Niagara Region, or Ontario, were not assessed in detail. For the study, all CoC soil values below current MOE generic effects-based guidelines (MOE Table 'A' generic guidelines, 1997) were considered be "safe" soil values with respect to potential risk to flora and fauna. As a result, areas where CoC soil values were below the generic effects-based guideline were considered to represent control or reference sites against which potential effects to elevated soil CoCs concentrations in the Study Area could be assessed.**
C	14	---	---	---	Although many tables of data are presented in the report it is very difficult to discern what actually represents the complete data set used for the assessment. Subsets of data are extracted and used in different sections to illustrate different issues. Comprehension of the analysis would be greatly enhanced if a summary of the complete analytical chemistry data set were presented along with information as to what it represented and sources of the data. **Tables in the report that present CoC concentrations in tissues will be restructured to also present the range and mean of Ni concentrations in soil, sediment and water. In addition footnotes will be provided to direct the reader to the specific location of the raw data sets presented in Volume V of the report. (e.g. P. 6-21, table 6-3)**
C	15	---	---	---	There are frequent inconsistencies among sections of text, such as sequence of discussing VECs, etc. It would be preferable to use similar text and a consistent order of listing/discussing VECs (such as in the order of plants, decomposers [or the first two could be reversed], amphibians, birds, and mammals. For example, compare the order of subsections in Sections 3.8, 4.3, 6.5, and 8.3. **These inconsistencies will be reviewed.**

Rank	Number	Section	Page	Paragraph	Comment
C	16	---	---	---	Organizational suggestions: Section 1.3 could be combined with 1.3 to "CBR Process and Participants" to avoid the single subhead under 1.3.1; 1.4 and 1.4.8 have same title, so it would be preferable to change one of them; title for 2.0 should be Problem Formulation and Identification of CoCs (to be consistent with listings of topics elsewhere (e.g., page 1-9); subheads under 2.0 would more appropriately be 2.1 Historical Overview and 2.2 Chemical/Physical Site Characterization (with remaining subheads) to complement the Ecological Site Characterization in Section 3.0. **These organizational suggestions will be reviewed and changes made where considered appropriate**.
C	17	---	---	---	The report would benefit from editing to correct errors of wording (e.g. incorrect usage of affect vs. effect, missing words, unclear wording), agreement of subject and verbs (plural vs. singular), punctuation, hyphenation, and similar editorial matters. In addition, several sections have single subheads (with no second subhead at the same level) that could be deleted. **Final editorial reviews will be undertaken.**
C	18	---	---	---	Typically an ERA presents calculations of risks and may describe them as high or low, but does not make the risk management decision as to acceptability. Determinations of acceptability should be deferred to regulatory agencies. **Agreed, sections that make statements regarding the *acceptability* of soil CoC values will be restated. (P. 1-18, para. 1, line 3)**
C	19	---	---	---	There are many places in the text where the citations for numbers or statements of fact are not provided. It is important that this information be provided so that the sources of the information can be reviewed as needed. In some cases, several sources are identified in the beginning of the section; however, these sources should be cited as appropriate within the text, so the reader is not forced to search through several large documents to locate the information. **Citations for statements and facts will be reviewed.**
C	20	--	--	--	A quality check of all calculations performed in the risk assessment was performed (see Tables 1 through 7). In general, the quantitative component of risk assessment appears to be well done. Although discrepancies were noted in the checked calculations, these were largely attributed to differences in rounding, and would have little or no impact on risk characterization. Errors that were observed were also minor, but are included in the specific comments below. However, please note that the number of significant digits, rather than the number of decimal places, should be consistent within the document. **For the calculations, the number of significant digits reported will be reviewed for consistency.**

Rank	Number	Section	Page	Paragraph	Comment
C	21	---	---	---	The rationale for the stratification of soil types is not well defined. More information should be provided about the basic soil mapping information upon which the soil groupings were made and the terms used for grouping the soils. A table summarizing the basic soil characteristics of each soil mapping unit in the impact area would be useful for documenting the basis upon which the soil groupings were made and would allow the reader to understand something about the range of soil characteristics in the project area. **For the CBRA, detailed soils analysis and mapping was undertaken and presented in a separate report "Soil Characterization" in Volume IV of the Crop Studies Report. As stated previously, in JW response to comment 11 above, for the full review of the CBRA, the MOE, the review and approval agency for the CBRA, will have all documentation for their review.**

Rank	Number	Section	Page	Paragraph	Comment
Specific Comments:					
B	1	Executive Summary and relevant section in the main text	iv	1	Wording here is unclear. First sentence of the text is better on p. 2-3, but the meaning of "community level" and "scientific linkage" should be explained in both places. **This will be reviewed and addressed where appropriate. However, for the final report the structure and content of the executive summary has been revised significantly.**
B	2	Executive Summary and relevant section in the main text	iv	Last	Here and elsewhere there's inconsistency about where the area is located (should say the Study Area is east of city, northeast of refinery). **This will be reviewed and addressed where appropriate. However, for the final report the structure and content of the executive summary has been revised significantly.**

Rank	Number	Section	Page	Paragraph	Comment
B	3	Executive Summary and relevant section in the main text	iv	Table	For soil concentrations, milligrams of contaminant/kilograms of soil (or mg/kg) is preferable to parts per million (ppm). The table indicates that the area exceeding the guideline for nickel (26.3 km^2) is different from that indicated on page vi, middle of first full paragraph, which says 18.6 km^2. It may be that the difference is accounted for by the two separate areas where surface soils exceed 200 ppm (shown on Figure 1-4), but, this is not clear in the text. **For soil concentrations mg/kg will be used instead of ppm where appropriate.** **Area values presented in the report will be reviewed. The following is provided to explain the various values reported.** **The area where soil nickel exceeds MOE guidelines varies depending on the soil data set used. For example, the MOE presented a total area 18.6 km^2 based on soil data collected in 1998 and 1999. Then, with the addition of new soil data collected in 2000, the MOE presented a total area of 29 km^2 For the CBRA, additional soil data was collected and the isoplethes generated from this full data set produced a value of 26.4 km^2 . The value of 26.4 km^2 is the value used for the CBRA.** **However, as final note, for the ERA, the identification of a Study Area for the purpose of data collection and risk assessment was based on the MOE soil data base for lands east of the Welland Canal, excluding residential and commercial areas and the refinery site. This resulted in a ERA Study Area of approximately 22 km^2** It would also be desirable to indicate the number of soil samples that were used to assess the moderate impact areas for each of the CoCs on this table. A supporting figure (in the ES and the main text) showing the distribution of sampling points within the contaminant isopleths would also give a sense of the adequacy of soil sampling within the high and moderate impact zones (and outside of the moderate impact zone, as well.) **Full analysis and mapping of soil data points are provided in a separate report prepared for the CBRA, "Potential CoC Identification Using Soil Chemical Concentration Data in Exceedence of MOE Generic Guidelines" (JW 2001). As stated previously, for the full review of the CBRA, the MOE, the review and approval agency for the CBRA, will have all documentation for their review. In addition the reader will be clearly directed to the supporting documents in the report.**
B	4	Executive Summary and relevant section in the main text	v	3 (list)	It would be preferable to revise #1 to be like it is on p. 1-9. **This change will be made. (P. iv, Section ES 1.2)**

Rank	Number	Section	Page	Paragraph	Comment
B	6	Executive Summary and relevant section in the main text	v	4	The paragraph states that more than 700 samples were used to limit uncertainty. However, the ERA does not demonstrate that the number of samples was adequate to explain the variability among the samples for a given confidence level. Some statistical analyses (i.e., a minimum sample size or power analyses) would go a long way toward supporting this. **The referenced paragraph is intended to convey that a multitude of samples were collected and analysed, representing the large spatial scope of the ERA and the variability of the various biological and environmental media therein. Sampling multiple media across the Study Area rather than relying solely on values derived from the literature or on very few site-specific data reduced uncertainty. No quantitative comparison between sites or populations was made, and no null hypothesis was formally tested, thus there is no need for a power analysis. However, Jacques Whitford acknowledges that certain sets of data are small, limited in scope, and have higher uncertainty which is addressed in the treatment of the data sets as described in Section 10.**
B	7	Executive Summary and relevant section in the main text	vi	1	Third sentence indicates that the primary focus of the ERA was to determine potential risk to terrestrial natural environment. It seems that the aquatic environment should also be mentioned. If not, please explain why aquatic environments and receptors were not also considered in this design. **A statement regarding the aquatic environment will be included in the Executive Summary (P. vii, para. 2). However, the exclusion of the aquatic environment is addressed in full in the main body of the report. (P. 2-26, Section 2.1.7)** Should be 1998-1999? **Yes.** As noted in Item 3, fifth sentence says the study area is 18.6 km^2. Please clarify the study areas and the basis upon which they are defined. **See above.** Last sentence. The use of the terms 'clay soils and organic soils' is vague and should be explained more clearly, as should the basis of the soil groupings. **This level of detail, in JW's opinion, is not appropriate for an executive summary.**
B	8	Executive Summary and relevant section in the main text	vi	Table	Secondary Study Area should be (200-500 ppm Ni). **Yes.**

Rank	Number	Section	Page	Paragraph	Comment
C	9	Executive Summary and relevant section in the main text	viii	1	Use of maple "key" does not seem necessary; if the word is retained, please put in Glossary. **The use of "key" and "seed" will be reviewed.**
B	10	Executive Summary and relevant section in the main text	viii	Table	'Woodlot litter' is not a decomposer and 'Woodlots' are not plants. Please revise grouped headers to accurately reflect the VECs in the group. **This table is no longer provided in the executive summary Rather than generating new group headings, JW suggests the following:** **Woodlot litter (decomposition by invertebrates/bacteria/fungi)** **Woodlots (Tree species)** **(P. xvi, table ES-6)**
B	11	Executive Summary and relevant section in the main text	viii	2	It seems the wording of habitat as predictor of exposure to CoCs is reversed of what it should be (i.e., why would one want to predict CoCs on the basis of habitat?). **Habitat is more appropriately considered a modifier. However, the type of habitat in which a receptor is found was thought to possibly affect its uptake of CoCs, due to differences in such things as the local environment and diet. In this case, the paragraph is stating that knowledge of the habitat type is not useful, generally, in predicting the uptake of CoCs. In this sense, the paragraph remains unchanged.**
B	12	Executive Summary and relevant section in the main text	ix	2	BAFs approaching 1 (i.e., As in sediment) do not seem to indicate a "clear barrier" to movement of CoCs. Because the concentration in surface soil (<5 cm) may not be relevant for evaluating uptake from soil by deeper-rooting maple trees, information should be provided for Ni in soil > 5 cm. **See discussion below for comment 41.**
A	13	Executive Summary and relevant section in the main text	ix	3	Why were TRVs not used for evaluating toxicity to plants to provide that line of evidence? **See discussion below for comment 172.**
B	14	Executive Summary and relevant section in the main text	x	1	Here and throughout the document, ADD is often used as though it applies to all receptors, but it applies only to birds and mammals; please expand/explain more clearly for other VECs. **Reference to ADD had been removed from the executive summary. The use of ADD in others sections of the report will be reviewed and addressed where appropriate.**

Rank	Number	Section	Page	Paragraph	Comment
C	15	Executive Summary and relevant section in the main text	x	First in Risk Char.	For which terrestrial invertebrates in addition to soil invertebrates were effects evaluated? **Text for risk characterization in the executive summary has been revised (P. xxii, Section ES 7).**
B	16	Executive Summary and relevant section in the main text	xi	2	Conclusions of no significant influence of CoCs for tree leaf damage or woodlot health studies should be supported with a statement about the relative sensitivity of these studies to detect such an influence. **As detailed in Section 1.4.1, injury to maple leaves has been used by the MOE to assess potential adverse affects of soil nickel in the Port Colborne area. With respect to the woodlot health study, JW is unaware of studies being undertaken of similar scope to assess potential adverse affects of soil CoCs on woodlot health. However, impacts of soil metals on plant growth in general is well documented in the literature and is addressed in full in the Crop Studies being conducted as part of the CBRA.**
B	17	Executive Summary and relevant section in the main text	xi-xiii	All	The sequence of receptor headings here is generally good, but suggest reversing amphibians and decomposers; then be consistent throughout the document with use of this sequence in discussing the VECs. Among birds and mammals here and table on p. xiv, suggest putting species in taxonomic or trophic-level order and using that throughout. **This will be reviewed and addressed where appropriate. (P. xxii, Section ES 1.7)**
B	18	1.4.1	1-8	3	Please state whether maple leaves were washed before analysis. **The leaves were washed, this will be stated. (P.1-10, para 2, line 5)**
B	19	1.4.1	1-8	1	Last sentence indicates that the area where soil nickel exceeds MOE Guidelines increased from 19 km^2 to 29 km^2. The table in the Executive Summary says 26.3 km^2. Please clarify which is the correct value. **The correct value as shown in the MOE 2000b document is 29 km^2. The value of 26.3 km^2 (now re-calculated at 26.4 km^2) is reflective of all area exceeding 200 ppm nickel based on MOE and JW data sets combined for this CBRA.**
B	20	1.4.1	1-8	3	Cobalt (9-19 ppm) is a range not an average concentration. **This will be corrected and stated as a range. (P. 1-10, para 2, line 5)**
B	21	1.4.1	1-8	4	Please explain what is meant by 're-entertainment of contaminated soil.' **Re-entrainment refers to re-suspension of soil particles into the air. This will be inserted into the text. (P. 1-10, para 3, line 17)**

Rank	Number	Section	Page	Paragraph	Comment
B	22	1.4.1	1-8	4	Reference: Rinne (1989) is out of order in the reference section. **This will be corrected. (P. 12-17)**
B	23	1.4.3.1	1-10	---	The summary should also include conclusions about crop uptake of CoCs, not just phytotoxicity. **Based on additional comments regarding potential risk to plants provided below, it is clear that the report has not fully explained that the ERA was conducted under two component studies; ERA-Natural Environment and ERA-Crop Studies. To address this, Figure 1-3 has been revised to more clearly show that the crop studies lies within the ERA. Due to the complexity of the ERA reports, neither report provides summaries of the findings of the other component studies. However, potential risk to plants as a result of elevated levels of CoCs in Port Colborne soils is fully addressed in the ERA-Crop Studies Report. The results of the ERA-Crop Studies have direct applicability to native plants growing in a natural environment in the Study Area. For the CBRA, the MOE, the review and approval agency for the CBRA, will have all documentation for their review.`**
A	24	1.4.6	1-15	Last	Is the first sentence true or mis-worded? ("The primary objective of the ERA is to establish that . . . present an unacceptable risk . . .?"[emphasis added]). Alternatively, this could be stated as a testable hypothesis with an alternative hypothesis for comparison. **The sentence was miss worded and will be revised as follows:** **"The primary objective of the ERA is to determine if historical emissions of CoCs from the refinery and deposited……Port Colborne area." (P. 1-18, para 1, line 1)**
A	25	1.4.6	1-15	Last	What constitutes 'safe' or 'acceptable' levels needs to be defined so that it is clear when CoC levels are adequately low. **The following text will be included in this section.** **"Ultimately, the Regulatory Authority, the Ministry of the Environment, will determine what constitutes safe or acceptable levels. However, for this ERA, an unacceptable risk is defined as an estimated risk linked to the occurrence of soil concentrations of CoCs, as a result of historical emissions from the refinery, that prevents sustainable *population(s)* of flora and fauna or ecological functions within the defined study area." (P. 1-18, para 1, line 3)**
A	26	1.4.7	1-16	5th bullet	Please define 'unacceptable' **See above.**

Rank	Number	Section	Page	Paragraph	Comment
C	27	1.4.7	1-16	1	Last two sentences indicate that nearshore environment in Lake Erie was not part of the ERA and was shown to not have adverse effects from stack emissions (based on Beak and Klohn-Crippen 1997). It is not clear if those nearshore environment studies evaluated the effects of stormwater and sediment discharges. If so, then please state it. **The last sentence will be re-worded as follows:** **"Studies of the ecological effects of the long term operation of the refinery on the nearshore…." (P. 1-20, para 1, line 10)**
B	28	1.4.8	1-17	2	Here and throughout the report. The text, tables, and figures refer to the Study Area (whole area evaluated), the Primary Study Area (Ni>500 ppm) and the Secondary Study Area (Ni 200-500 ppm). To prevent confusion, please consider retaining 'Study Area' when describing the whole area assessed and renaming Primary and Secondary areas to be 'Focus Areas' as opposed to 'Study Areas'. **The terms "Study Area", "Primary Study Area" and "Secondary Study Area" has been presented to the Public, PLC, and TSC throughout the CBRA process. Therefore, JW does not believe it would be appropriate to change terms at this point. (P. 1-21, para 3, line 1)**
B	29	1.4.8	1-17	4	Text here is not consistent with para. 2 on this page, which apparently limits the Study Area to areas east of the Welland Canal. Please clarify. **This will be reviewed and addressed where appropriate. (Section 1.4.7 and 1.4.8)**

Rank	Number	Section	Page	Paragraph	Comment
A	30	1.4.8	1-18	Top of page	This assumption is faulty. OTR_{98} values from MOE (1993) and Table F values from MOE (1997) were compared to soil CoC values reported in Tables 2-5 and 2-6. CoC concentrations in all field soil samples from the Reference Area are within acceptable background range, as are concentrations of As, Co, and Cu from the reference woodlot. However, Ni concentrations from the reference woodlot exceed (almost by a factor of 2) the accepted background concentrations. This indicates that the Reference Area is likely to have been affected by the Port Colborne operations (or some other source) and is therefore not truly independent. The strength of conclusions based on these comparisons is therefore significantly weakened. The impact of this discrepancy should be addressed in an uncertainty section and throughout the report as needed. **Table F presents the Ontario Typical Range soil concentrations for various chemical compounds. For example, the value for nickel is 43 ppm. However, this value does not represent the level that, if exceeded, would represent a condition where a potential adverse effect on biota can be expected to occur. For the ERA, soil background conditions for the CoCs in the Niagara Region were not assessed in detail. For the study, all CoC soil values below current MOE generic effects-based guidelines (MOE 'A' generic guidelines, 1997) were considered to be "safe" soil values with respect to potential risk to flora and fauna. As a result, areas where CoC soil values were below the generic effects-based guideline were considered to represent control or reference sites against which potential effects from elevated soil CoCs concentrations in the Study Area could be assessed.**

Rank	Number	Section	Page	Paragraph	Comment
A	31	1.4.8	1-18	First Full	It would seem more appropriate to evaluate exposures and risks separately for the Primary and Secondary Study Areas, especially for relatively sedentary or immobile VECs. **As required by the CBRA process, JW's approach for the characterization of risk to Valued Ecological Components (VECs) were presented on numerous occasions to the Public Liaison Committee (PLC), the Technical Subcommittee (TSC), and the general public for their review and comment. Specific approaches to the analysis of the data for the determination of risk were presented in full in a document entitled "An Approach To Data Interpretation" (see Tab 18, Volume II). Through this review/comment process it was agreed that the characterization of risk for each selected VEC was to be a community-based risk assessment, rather than for specific properties, examining risk at a population level for an identified VEC with a VEC's population defined as those individuals living within the Study Area. In addition, exposure assessment was to be based on the population level (not individuals at a specific location) using a calculated UCLM (or maximum for small sample sizes) for various environmental media that were sampled and analyzed for CoCs.** **As this was the approach agreed to by all stakeholders for the CBRA, significant changes to the study design and approach are not possible at this time. However, to address the above comment, JW will provide a separate uncertainty assessment in the final report that will assess potential risk to subpopulations of less mobile VECs located within the Study Area. This analysis will be presented in a separate uncertainty section in the report.**

Rank	Number	Section	Page	Paragraph	Comment
A	32	1.4.8	1-18	5 bullets at bottom of page	All of these should be defined – what constitutes a woodlot or field? What were the characteristics of clay vs. organic soil? **Woodlots and fields will be defined in this section following the Ecological Land Classification for Southern Ontario (Lee et al. 1998) as follows:** **"For the purpose of this study, woodlots and field are defined as follows:** • **Woodlots are natural forested habitats where trees (woody species greater than 6m in height) cover 60% or more of an area.** • **Fields are lands where cover by woody species (trees and shrubs) is 25% or less, including agricultural lands that are either actively cultivated or fallow.** **"For the purpose of this study, organic and clay soils will be defined following the Field Manual for Describing Soils in Ontario as follows:** • **Clay soils are mineral soils where soil particles of <0.002 mm diameter represent 30% of the soil. This would include soils identified as Heavy Clay and Shallow Clay and Clay Loam soils.** • **Clay Loam soils are soils where soil particles of <0.002 mm diameter range between 20 and 40% of the soil.** • **Organic soils are soils of 40 cm or more depth with 30% or more organic matter, or 17% or more organic carbon. (P.1-23, para 4, line 1)**
C	33	1.4.8	1-19	Fig. 1-4	In the Legend, 'Topographic Features' should be either 'Map Features' or 'Development Features'. Please clarify if the clay and organic soil groupings are appropriate for urban areas of Port Colborne, and that these lands are not better characterized as Urban and Built-Up lands more typically used when native soils have limiting properties for development. Please note that these same comments apply to Figures 2-2, 2-3, 2-4, and 2-5. **Topographic Features will be changed to Map Features.** **The clay and organic groupings extended into urban areas of Port Colborne are presented to show native soils beneath fill materials used in the built up areas. (P. 1-25, Fig. 1-4)**
B	34	1.4.8	1-20	1	Last sentence. Please clarify what minimal sample size or other condition determined when it was not possible to calculate a UCLM. **A minimum sample size of 10 was considered the criterion for calculating an Upper Confidence Limit for the Mean (UCLM), as stated later in the document (Page 6-32). This sentence will now read "Where sample sizes were too small (N<10) to calculate…." (P. 26, para 4, line 5)**

Rank	Number	Section	Page	Paragraph	Comment
A	35	1.4.8	1-20	2	How were populations defined? Were analyses actually performed at the population-level or were they simply assumed to represent population-levels? Please clarify. **Population will be defined in the second paragraph on page 1-18 as follows:** **"Although Primary and Secondary Study Areas were identified to ensure that field data collection was structured and data were representative of the areas where soil CoC concentrations were high to moderate, characterization of risk to VECs was based on potential exposures to a VEC's population. For the purpose of this ERA, a VEC's population is defined as all individuals of a species (plant or animal) that inhabit or occur within the entire Study Area (i.e., both Primary and Secondary Study Areas). Separate risk characterization was not undertaken for sub-populations represented by the Primary and Secondary Study Areas, or other specific areas within the Study Area." (P. 21, para 5, line 1)**
C	36	2.1.3	2-4	1	It is unclear that the soils were not originally mapped as shown, but were rather grouped as shown for the ERA. Please clarify the basis of the soil groupings and provide the basic soil mapping information to support the soil groupings. The end of this paragraph would be a good location to define the characteristics of these soil types. **As noted in the text, additional details on soils are provided in Section 3.4. For the CBRA, detailed soils analysis and mapping was undertaken and presented in a separate report "Soil Characterization" in Volume IV of the Crop Studies Report. As stated previously, for the full review of the CBRA, the MOE, the review and approval agency for the CBRA, will have all documentation for their review.**
C	37	2.1.3.1	2-4	2 – 1st sentence	Recommend deletion ('The distribution….') as it is repeated in a better way in the 2nd sentence. **The first sentence will be removed. (P. 2-4, para 3, line 1)**
B	38	2.1.3.1	2-4	Last	Please provide information also for woodlots. **Information regarding soil CoCs in woodlots is presented later in this section.**
B	39	2.1.3.1	2-9	1	The CoC distribution with depth in soil is not clearly explained and is difficult to judge. Please describe the rationale for location of test pits and clarify the results of the depth distribution assessment. This is of particular interest in the woodlots, where deeper-rooted plants grow. (a table or graph would be useful.) **See response to comment 41 below.**

Rank	Number	Section	Page	Paragraph	Comment
C	40	2.1.3.1	2-9	1	Text states that highest CoCs on the refinery site in undisturbed clay soil are found at the 5 to 10 cm depth, whereas CoCs in all organic soils and clay soils outside the site are relatively constant and evenly distributed from 0 to 20 cm. It would be good to present a table or figure that describes/depicts this distribution as support for choosing the 0 to 5 cm depth. This could be done in this section or in an appendix. Including the data also adds transparency because the reader can see the depth distribution of the soil data. **See response to comment 41 below.**
B	41	2.1.3.1	2-9	1 – lines 9-13	The 5 cm depth limit seems too shallow. 20 cm would be a more defendable depth to evaluate. Concentrations drop off below this depth. Also, virtually all plants and earthworms will use soils at depths >5 cm. Additional discussion is needed to justify the limitation to 5 cm. **As is noted by a number of the comments above, the reviewer has identified that the report has not provided detailed information or data for the Study Area's soils. The report does provide data on soils that have been summarized from a Soil Characterization report prepared by JW for the CBRA. Initially, this soils report was attached as an appendix report in the first draft of ERA-Natural Environment Report. However, the ERA has been conducted under two major component studies, the Natural Environment and Crop Studies. Following the completion of the first draft of the ERA-Natural Environment Report, it was determined that, given the importance of soil characterization in relation to crops, the detailed soils report was better placed as Volume IV in the Crop Studies Report. As stated previously, for the full review of the CBRA, the MOE, the review and approval agency for the CBRA, will have all documentation for their review.** **With respect to the use of CoC concentrations in the 0-5 cm soil profile for the assessment of exposure, an additional table will be inserted as part of the discussion presented in this paragraph (P. 2-11, Table 2-2). The information in this table is based on test pit analysis as detailed in the Soils Characterization Report.** **As stated, results of the test pit analysis determined that CoCs are primarily restricted to the upper regions of the soil profile (0-20 cm) for both clay and organic soils. Data in the new table will show that for organic soils, the concentrations of the CoCs remain evenly distributed through the first 0-15 cm. Therefore, using the 0-5 cm concentration values for organic soil is clearly representative of the potential exposures of VECs to CoCs in the environment.** **For clay soils, data in the table will show that for all CoCs the values are lower at the 10-15 cm depth when compared to either the 0-5 or 5-10 depth. Therefore using CoC values at the 10-15 cm or at 20 cm is not justifiable. Comparing the CoC values for 0-5 cm and 0-10 cm finds that the values are very similar, particularly given the range of the values. For the risk assessment, bird and mammal VECs are primarily exposed to the surface soil as part of their food chain exposure pathway, that is, ingestion of surface soils. Given that, 1) soil CoC values are less at the 10-15 cm or 20 cm depth, 2) the primary area of exposure is at**

Rank	Number	Section	Page	Paragraph	Comment
					surface for the majority of the VECs, and, 3) there is no significant difference in CoC values between 0-5 and 5-10 cm, JW remains confident that the 0-5 cm soil depth values for the CoCs is valid and justifiable for this ERA. **With respect to worms and plants, which inhabit soils at greater depth than 0-5 cm, given that CoC values decrease with soil depth starting at 15 cm, the use of CoC values from the 0-5 cm depth provides a higher and more conservative exposure than actually experienced by worms and the rooting zone of plants in deeper soil.**
A	42	2.1.3.1	2-9	Tab. 2-2	Table shows area of land with soil CoCs that exceed MOE guidance. This includes residential land west of Welland Canal. Are there natural lands west of Welland Canal that exceed 200 ppm Ni? Figure 2-2 shows nickel concentrations greater than 200 ppm in what appears to be woodlots and fields (per Figure 2-6) west of Welland Canal. **For the ERA-Natural Environment, the Study Area, as defined, is considered to contain natural areas and soils that are representative of the Port Colborne area. Therefore, the identification of risk to species or habitats within the Study Area as a result of the exceedence of a specific soil value for a CoC can be considered valid for other areas within the local Port Colborne area (provided the occurrence of the CoC in the soil meets the criteria for the identification of a CoC for the CBRA).**
B	43	2.1.3.1	2-10	Table 2-3	Please indicate how close the sample points are to one another to provide a way to judge comparability. Are these the only paired sample locations in the study? **The reviewer should refer to Map 1 for a spatial assessment of sample points.**
B	44	2.1.3.1	2-10	1	'Figure 2-6 shows CoC concentrations in selected woodlot…' Why were these data used and why are data not presented for all sampled woodlots? Are there more? **The term "selected" was used since every woodlot in the study area was not sampled by the MOE and JW. Figure 2-6 includes all data that were collected in woodlots of the study area by the MOE and JW. The word "selected" will be removed from the title. (P. 2-4, para 3, line 1)**

Rank	Number	Section	Page	Paragraph	Comment
B	45	2.1.3.1	2-10	Table 2-4	It would be good to present more summary statistics for each media type than just the n, mean and standard deviation. Tables 2-4, 2-5, 2-9, 2-10, and 2-11 should also include the number detects, frequency of detection (%), minimum, median, maximum, 90th percentile, and UCLM values so the reader can better understand the distribution of the data. Tables in Section 6 that show concentrations in prey items (e.g., Table 6-3 and 6-4) present more statistics, but also should include those listed above. Also consider possibility of showing these data graphically – field and forest (mean bar w/ standard deviations) paired by analyses and grouped by area. **JW believes that presentation of the Mean, SD and N is sufficient statistical information. The data are presented to provide the reader with a general understanding of the distributions of the CoCs in the environment. These data are not presented to provide information as to how exposure was assessed in Section 6.0 or risk characterized in section 8.0.**
B	46	2.1.3.1	2-10	Tables 2-4 and 2-5	Sample sizes for soil seem small for size of area. With all of the data available (see Appendix B) why not use all data? **Table 2-4 now includes all available data for open spaces (Vol. III, tab 9), excluding values which were obtained from commercial or residential areas as these areas are not part of the Study Area, as defined for the ERA (see Map 1). (P. 2-12, Table 2-4)**
C	47	2.1.3.1	2-11	Figure 2-6	Please indicate the date of the aerial photograph **The date of the photograph is shown below the Niagara Region logo, but will also be placed under map parameters. (P. 2-13, Figure 2-6)**
B	48	2.1.3.1	2-12	Table 2-6	This table would support the 4th sentence of 1st paragraph better if there were a column that identified the relative position (e.g., leading edge, center, downwind edge) within the woodlot. **The relative position of the sample location has been added to the Table. (P. 2-14, Table 2-6)**
C	49	2.1.3.1	2-12	---	Section heading 2.1.3.1 Leaching Characteristics should be numbered 2.1.3.2. Note that this material does not really belong here – It would be better if the methods were presented in Section 5.3.1 and results in Section 6. **Section numbering will be changed. JW is of the opinion for the Problem Formulation section of the report that a discussion of the availability of the CoCs to the environment is appropriate. (P. 2-15, Heading 2.13.2)**
C	50	2.1.3.1	2-13	1	Please indicate if reference is Jacques Whitford 2003a, b, or c **The reference is Jacques Whitford 2003a. (P. 2-15, para 2, line 1)**

Rank	Number	Section	Page	Paragraph	Comment
B	51	2.1.3.1	2-13	2	References are needed for statement that DTPA extraction has been correlated with soil nutrient and metals bioavailability and that strontium nitrate extraction correlates with shoot nickel concentrations **The reference will be added. (P.2-15, para 3, line 8)**
B	52	2.1.3.1	2-13	2 – last 2 sentences	How does this discussion relate to bioavailability? This is a very strong destructive extraction that does not have much in common with general biological digestion. Need to provide a reference to support. **JW agrees that this is a very strong extraction method, and is described as a "particularly aggressive extraction method" in the report. The first full paragraph on the following page clearly identifies that the aqueous extraction method is the closest representation to the natural environment. The results of the various extractions have been provided for the reader to gain an understanding of how various extraction methods result in different values. (P. 2-16, para 2, line 1)**
B	53	2.1.3.1	2-13 and 2-14	Tables 2-7 and 2-8	Show N (number of samples) for the listed values. How many areas do these numbers represent? Also, what are the percentages relative to? Total analyses? What method? Were extractions all done on splits of the same sample? More detail is needed to fully understand these data. Bar graphs would be more effective in presenting the comparisons. The last 2 columns should be reversed to be consistent with text. It would be helpful to also have the total concentration of each CoC in the samples that were extracted. **Full details are provided in the Crop Studies Report, as referenced.**
B	54	2.1.3.1	2-14	1 – last sentence	Statement is not really true – heavy rains and snowmelt will have no effect on *bioavailability*. The form of the CoCs is unaffected. Location as to where the CoCs are concentrated could, however, change to lower soil horizons – thus potentially making them less available for biota to contact. **When considering the conditions in the Study Area, the aqueous extraction results should be considered the closest representation of the existing conditions, with water from rain and snow melt dissolving some amount of CoC and potentially increasing its bioavailability.**

Rank	Number	Section	Page	Paragraph	Comment
A	55	2.1.4	2-15	1	It would be helpful to know the rationale for the location of sediment samples. **A detailed sampling of aquatic sediment was not part of the scope of work for the ERA. Sediment samples were only collected for assessment of the movements of CoCs from sediment to adult frogs and tadpoles. As for the determination of the location of the sediment samples, this was dictated by location of ponds from which tadpoles were collected. The location of ponds at which tadpoles were collected was dictated by 1) where the ponds occurred (Primary/Secondary Study Area), 2) that tadpoles were in the pond, and 3) that the pond could be sampled (i.e., water depth).** **The following sentence will be added following the first sentence of the paragraph:** **"For the study, sediment samples were only collected from ponds and ditches from which tadpoles were collected." (p. 2-17, Para 3, Line 1)**
A	56	2.1.4	2-15	Table 2-9	Is this the complete data set for sediment in the Study Area? It seems small. Summarizing TOC and pH of sediment would be useful here too (would also be a help for soils). **Yes, see comment above.** The values for the Primary Study Area do not match those presented in the raw data for frog pond sediment. Six samples (five plus a duplicate) are listed for the Primary Study Area and, subsequently, the mean concentrations are different than those presented in Table 2-9 for all CoCs. It appears that sample F-H-3 and the replicate for this sample were removed from the calculations, but no reason is given for this deletion. There are no discrepancies for the Secondary and Reference Areas. **A total of six samples (five samples and one duplicate) from the Primary Study Area was submitted for chemical analysis. The laboratory then performed two replicate analyses on F-H-1 and F-H-3, yielding a total of 8 analytical results for the original six samples. Data from F-H-3 were not included in the data set as it was determined that it was inappropriately sampled, as summarized in Volume V. Thus, six values for each of the CoCs was appropriately averaged, yielding the results shown in Table 2-9. A footnote will be added to Table 2-9, explaining the omission of F-H-3. (P. 2-16, Table 2-9)**
C	57	2.1.5	2-15	2	First bullet should note 'discrete areas of ' peat, sand, gravel, and shallow groundwater. **This change will be made. (P. 2-18, para 3, line 3)**
B	58	2.1.5	2-16	2	Klohn-Crippen (2000) is missing in Cited References. Please check all those mentioned in text. **This reference has been removed from the report.**

Rank	Number	Section	Page	Paragraph	Comment
B	59	2.1.5	2-16	5	Please consider how contaminants may move from known source areas, by release and transport mechanisms, and how those processes affect exposure to aquatic organisms (or other VECs). **As noted in the text, the studies on ground water found that the occurrence of the CoCs in the ground water was not due to local air deposition. Therefore, as identified in the CBRA scope work, potential risk of CoCs in ground water as a result of other refinery operations on the refinery site is not within the scope of the CBRA. In addition, assessment of risk to the aquatic environment (Lake Erie/Welland Canal) is also outside the scope of the CBRA.**
C	60	2.1.5	2-20	1	Please state whether the CoCs were detected in any resident wells. **Findings of well water testing can be found in full in the CBRA HHRA report. However the sentence will be reworded as follows:** **"Results of the testing of 172 well samples found that CoCs were present in well water, but at levels that were below all applicable MOE guidelines (Jacques Whitford 2001b)." (P. 2-20, para 4, line 3)**
C	61	2.1.5	2-20	2	First sentence states that regional contamination of groundwater is not present but 2 paragraphs earlier the report indicates that groundwater contamination has occurred. **Ground water contamination at the regional aquifer level has not occurred. Only local site-specific ground water contamination has been documented for the refinery site. The refinery site and its potential adverse effects are outside the scope of the CBRA.**
C	62	2.1.6	2-20	1	Are the agricultural lands irrigated? **No, they are not irrigated.**
B	63	2.1.6	2-20	2	Some of the farm ponds could contain fish such as bass and bluegill. Was this assessed or eliminated? **Yes, some farm ponds do contain smallmouth bass, bluegill and yellow perch. Potential risk to fish in these artificial systems was not undertaken. The assessment of the aquatic environment was outside the scope of the CBRA.**
B	64	2.1.6	2-20	2 – 2^{nd} to last sentence	Although fish may not be a concern, text should acknowledge that sediment-associated aquatic insects and crayfish would make use of these sites and may be affected or serve as exposure pathways to other biota. **As noted above, the assessment of the aquatic environment was outside the scope of the CBRA.**

Rank	Number	Section	Page	Paragraph	Comment
B	65	2.1.6	2-21	1 and Table 2-10	Numbers do not agree – Text states there were samples from 37 locations but only 32 are listed in Table 2-10. **This has been reviewed. The 32 samples shown in the table are correct. The 37 samples referred to in the text have been changed to 32. (P. 2-23, para 3, line 1)**
B	66	2.1.6	2-21	2	Please provide also the water hardness, if available. There is an inconsistency between text and Figure 2-10; is it S2 or S3? **The text should read S3. This has been changed. (P. 2-24, para 1, line 6)**
B	67	2.1.6	2-21	2	Sample locations S1 and S3 appear closer to the refinery than S20. **S3 and S20 were used since the objective is to illustrate the contrast between surface water in woodlots and fields. Both S1 and S3 are closer to the refinery but were sampled in woodlots.**
B	68	2.1.6	2-21	2 and Table 2-10	It may be beneficial to evaluate risk to amphibians by habitat, if there are differences in surface water concentrations in woodlots and fields. In general, the Primary and Secondary Study Areas do not seem to be useful for predicting surface water concentrations, except in close proximity to the Inco facilities, and modification by other factors, such as habitat, surface flow, or groundwater hydrology, seems likely. **To clarify, risk was not evaluated separately for the Primary and Secondary Study Area. However, surface water samples were taken from multiple sites across the Study Area, and there appears to be a difference in nickel concentrations measured in forest pools and field pools, as seen in Figure 2-10. Values for surface water in fields and woodlots will be used to estimate the exposure of amphibians in each of these habitats within the Study Area.**
B	69	2.1.6	2-23	1 – last sentence	Statement is made that CoCs in surface water can be *predicted* by soil CoCs. Was a model developed? If not, use the term *approximated* instead. **The term approximated will be used rather than predicted. (P. 2-24, para 2, line 11)**
B	70	2.1.6	2-23	Fig. 2-11	It is unclear how the sample locations relate to distance from the refinery. **Samples are not related to the distance from the refinery, but rather as one moves from the headwaters of the watershed to mouth of the drain at Lake Erie. As noted above, for a spatial assessment of sample locations the reader should consult Map 1 in the back of the report**

Rank	Number	Section	Page	Paragraph	Comment
B	71	2.1.8	2-25	4	Where are the sample locations, J5 and J7? Please clarify how total CoCs were calculated. **It is understood that the reviewer does not have the report referenced in Section 2.1.8. However, the second sentence in Section 2.1.8 refers the reader to the Jacques Whitford (2002b) report for the locations of J5 and J7. An explanation of how total CoCs were calculated is also in this report.**
A	72	3.2	3-3	1	Though it is true that trees and shrubs are longer lived and may therefore be exposed over a longer duration, perennial herbaceous vegetation (e.g., forbs and grasses) would have shallower roots and may be exposed to the greatest concentrations of CoCs in surface (0 to 5 cm) soils. **True, but the following paragraph will also be added to further explain why JW did not inventory non-woody vascular plants.** **"For the Study Area, it was determined that investigations into the species richness of non-woody vascular plants in the Study Area would not be helpful in assessing potential adverse effects of elevated levels of soil CoCs on plants, due to four factors. First and foremost, investigations of the fields and woodlots found that significant disturbance to their natural state had occurred due to historic agricultural use of the lands for growing crops and pasturing of cattle in both fields and woodlots. Combined, tilling of the land and pasturing of cattle can significantly reduce the occurrence of native flora that could be expected to occur in a local area. Second, clay soils are the dominant soil type for the Study Area. Due to the nature of clay soils, years with lower than average rainfall quickly dry the soil to almost drought conditions and years with greater than average rainfall result in prolonged standing water. Under these conditions, the occurrence of many non-wood plant species, or their local abundance, can fluctuate greatly from year to year or from decade to decade. Third, due to the poor drainage of the area's soil, significant effort has been undertaken in the past to drain the lands for agriculture through the construction of an extensive municipal drain and ditch system throughout the Study Area. This historic draining activity has significantly altered the floristic composition of the Study Area's forested swamps, which now have much more upland plant species than true wetland species. As a final consideration, generally in any one local area where natural habitats cover a landscape, the number of vascular plant species that occur is highly dependant on local micro-habitat conditions (soil type, soil moisture, terrain, groundwater influence, past land use, etc.), and comparisons of species richness between one local area to another is very difficult. Due to the inherent variability of plant species richness between sites, comparisons between sites cannot provide the resolution required for separating natural occurring effects and adverse effects directly due to elevated levels of the CoCs in the Study Area's soils. Such a comparison method could only identify catastrophic effects of soil CoCs on vascular plants." (P. 3-3, para 2, line 1)**

Rank	Number	Section	Page	Paragraph	Comment
B	73	3.2	3-3	3	Please clarify limitations of the databases (i.e., they may document known occurrences but absence of records does not indicate species absence). **The following sentence will be added to the end of the paragraph.** **"Nevertheless, the potential for rare species of flora and fauna to occur in the Study Area that had not been documented in existing data bases was recognized and therefore extensive field investigations were undertaken over a two year period." (P. 3-4, para 2, line 5)**
B	74	3.3	3-3	1 – last sentence	Were any of the 40% of the 550 rare plants with southern Ontario distributions within the Study or Reference Areas? Please clarify. **Yes, see Section 3.8.1.**
C	75	3.4	3-4	---	Uniform information for each of the soil types should be presented. Suggestion is to provide a table or appendix that shows each series in the study area with relevant soil unit properties. The series should be grouped according to the study groups (i.e., heavy clay, shallow clay, clay loam, etc.). **Such detailed summary tables are provided in the Soil Characterization Report. The text for each soil type identified in the report will be reviewed so that Total Carbon and pH is recorded for each type.**
C	76	3.4.1	3-5	1	The phrase 'poorly drained in general' is vague. Are they all poorly drained or range from ?? to poorly drained? What is the parent material for clay soils? Is it the varved clays? **They are poorly drained. The term "in general" will be removed. (P. 3-5, para 4, line 4)**
C	77	3.4.2	3-5	1	Please include the pH range for shallow clay soils as was done for the other soil types. **pH range will be included. (P.3-8, para 1, line 4)**
C	78	3.4.3	3-5	1	Imperfectly drained is a vague term. Is it poorly to very poorly drained? **They are poorly drained. (P. 3-8, para 1, line 5)**
C	79	3.4.3	3-5	1	Please include the range for organic matter content for clay loam soils as was done for the other soil types. **Organic matter ranges will be included. (P. 3-8, para 2, line 6)**

Rank	Number	Section	Page	Paragraph	Comment
B	80	3.4.4	3-7	1	Organic soils are also known to be acidic. This should be considered in light of how it could affect mobility of the CoCs (i.e., fate and transport assessments). **The higher mobility of the CoCs with the decreasing pH of organic soils was considered by using soil CoC values based on % extraction using the DTPA method rather than the aqueous method values.**
C	81	3.4.5	3-7	1	Imperfectly drained term is vague. If poorly drained sandy soils occur, there must be some restrictive layer present (e.g., shallow bedrock contact or clay lenses). Please clarify the soil conditions for this group. **They are well drained. (P. 3-8, para 4, line 2)**
A	82	3.5	3-8	Table 3-1	Four significant natural features were identified within the Study Area. Please describe the rationale for not evaluating potential effects in the Waver Road Woodlot and the Humberstone Swamp/Forest. **See response to comment number 4 above.**
B	83	3.7	3-12	2 and 3	Can locations of these plant communities be shown in a figure? Do they correspond with the Nickel Beach Wetland and Woodlot from Table 3-1? From this description, additional attention to these areas to determine whether they have been affected would seem to be warranted. **Yes, these significant communities are found in the Nickel Beach Wetland and Nickel Beach Woodlot. The text will include the following:** **First paragraph in Section 3.7** **"For the lands in the immediate vicinity of the Inco Refinery, the dune upland forest and sand dune communities are considered to represent significant natural areas (see Nickel Beach Woodlot in Section 3.5)."** **Last paragraph in Section 3.7** **"In addition to the dune communities, the mature Red Maple swamp on the Inco site that is part of the provincially significant wetland may be considered a significant feature, as mature swamp forest is rare in the region (see Nickel Beach Wetland in Section 3.5)." (P. 3-13, para 3, line 1)**
A	84	3.8.1	3-12	---	Only trees and shrubs are discussed in the Flora section. Though these are important to the area, it would be helpful if this section could describe all relevant vegetation in the Study Area, including grasses and forbs that are important food sources for bird and mammal receptors. This is especially important given the conclusions in the second paragraph of page 3-32. **See response to comment 72 above and 112 below**

Rank	Number	Section	Page	Paragraph	Comment
B	85	3.8.1	3-14	Table 3-3	This table would be more useful if it indicated any special-status species. For example, the table could use boldface for any provincially rare species and explain in footnotes **The text in this section specifically identifies the rare tree species that are in the table.**
B	86	3.8.2	3-16	1 – 2nd to last sentence	Need to clarify if the statement refers to 90% of all *species* or all *individuals* were counted. **This will be re-worded as follows:** **"…more than 90% of the bird species that breed annually…." (P. 3-17, para 3, line 6)**
B	87	3.8.2	3-16	Table 3-5	Please state the basis upon which the identification was made (e.g., observed, bird song, etc.). Define all special terms used in the table (e.g., generalist, successional) in footnotes. Suggest sorting species by habitat type first then by feeding guilds. **Footnote regarding the basis for bird identification will be added to the table. (P. 3-18, Table 3-5)**
B	88	3.8.2	3-17	Table 3-5	The diet for the red-eyed vireo is described as invertebrates in this table, but the exposure calculation includes wild grapes. This species is only in the Study Area for 3 or 4 months during the breeding season and is unlikely to be foraging on plant matter at this time. Additionally, fruit such as grapes generally ripen in August or later in the summer into early fall. The red-eyed vireo leaves the area in August and would only consume grapes, if at all, for a small fraction of the time spent in the area. Finally, the red-eyed vireo is supposed to represent the 50% of breeding birds that feed "almost entirely on insects and spiders" (from page 3-21 middle of the 1st paragraph). **Fruit, as represented by the wild grape, will be removed from the diet of the Red-eyed Vireo for the exposure calculation. The diet will be based on invertebrates only.**
B	89	3.8.3	3-23	Table 3-8	Also suggest using boldface for provincially rare or special-status species. **There are no mammals in the Study Area that are considered to be rare or of special status.**

Rank	Number	Section	Page	Paragraph	Comment
B	90	3.8.3	3-23	Table 3-8	Table 3-8 indicates that the common shrew was recorded in the study area. Shrews are insectivorous and have close association with soil; therefore, are likely to be the most highly exposed small mammals at a site. **Early in the CBRA process it was recognized that the selection of VECs for the ERA was important, as it was not possible to characterize the risk to all species of fauna and flora found to occur in the Study Area. As a result, the selection of VECs for the ERA was a fully open process, with presentations by JW and comments and suggestions provided to JW by the PLC, TSC and the general public. Therefore the addition of new VECs into the CBRA process at this time is not possible.** **Nevertheless, for the ERA, the Meadow Vole was selected as the VEC for the assessment of potential risk for a small mammal that is in close contact to the soil and a primary consumer.**
C	91	3.8.3	3-24	2	A reference for the anticipated trapping success values (10-15%) is needed. **A reference will be provided. (P. 3-28, para 2, line 7)**
B	92	3.8.4	3-27	Last paragraph	Quantitative analyses of these data would have been beneficial and would have strengthened the discussion. Are data available with which such an analysis could be performed? **Quantitative data (i.e., number of adult male frogs along lakeshore) is not available.**
B	93	3.8.4.1	3-27	last	Were spring surveys also conducted in the reference area for comparison? If yes, statistical comparisons would strengthen this information. **No, reference areas were not surveyed for the study. The survey was designed so that a comparison could be made between the Primary Study Area with high soil CoCs and the Secondary Study Area where soil CoCs were moderate to low. Therefore a difference in frog abundance and species richness between these two study areas could be more directly linked to the potential effects of elevated levels of CoCs in the environment. If, during the initial stages of the survey, the results had shown an overall lack of frogs and toads in the Study Area, then surveys of reference sites would have been undertaken to enable a comparison of general frog abundance and species.**
B	94	3.8.4.1	3-28	1	This information is very useful; please provide more details about this evaluation. How were egg and tadpole numbers estimated? **The number of tadpoles in the pond was a general estimate, based on the counting of the number of tadpoles in an area of the pond surface (approximately 30x30 cm) and then extrapolating this information for the entire pond.**

Rank	Number	Section	Page	Paragraph	Comment
A	95	3.10	3-31	1	There are extensive site-specific data available for the study area; however, the ERA should acknowledge that uncertainties still exist within the field data. It is true that a qualitative assessment of the health of the existing natural environment is possible given the available site-specific field data. However, the lack of sufficient data for a quantitative analysis for all receptors makes determination of the true health of the environment uncertain. For example, a diversity of avian species were observed breeding within the study area during site-specific surveys; however, studies to determine the breeding success of these species were not conducted. It is therefore, unclear whether these breeding pairs add individuals to the population (i.e., are a source) or whether nests fail and the area acts as a sink to populations. Thus, high diversity is considered a positive ecosystem asset, but uncertainty associated with the lack of the breeding success data produce uncertainty about the health of the environment. **See comment 96 below.**

Rank	Number	Section	Page	Paragraph	Comment
A	96	3.11	3-32	2	Although the statements made at the beginning of this paragraph are correct, it must be emphasized (and described in the uncertainties) that the data were *qualitative* in nature. They do not permit a *quantitative* determination of the presence/absence nor magnitude of effects. Statements that the site appears to be unaffected are poorly supported by the data (aside from concluding that catastrophic effects are not occurring, the data are silent on the issue of whether there are or are not effects). The site has been exposed to elevated levels of metals for numerous years. A degree of adaptation by the natural community to this contaminant is expected to have occurred. Effects, if present, are likely to be of a more subtle nature, requiring well designed, statistical ecology studies to differentiate affected from unaffected areas. Taxonomic inventories of resident biota are extremely valuable. However, they do not provide sufficient rigor to judge the presence or absence of effects. Some discussion of the relative strength or power of the methods employed to discern effects if present needs to be presented to allow readers to accurately judge conclusions that are based on these data. It should also be noted or acknowledged that flora are represented only by trees and shrubs. **JW agrees that the presence of breeding pairs of birds does not directly equate to successful breeding. This statement would be true even for a landscape where no elevated levels of CoCs occur. In southern Ontario, many woodlots are in fact sinks for breeding birds, hosting individuals that do not contribute to the fecundity of the overall population. In addition, JW agrees that taxonomic inventories can only speak to a qualitative assessment of risk, and not quantitative assessment of risk (that is why we have undertaken sections 6 through 9). However, JW is of the opinion, which is clearly supported in the literature, that specific species (birds/mammals) only breed in areas that meet their specific life cycle and ecological niche requirements. As a result, areas with poor habitat diversity, or poor quality habitats, generally support a low diversity of breeding birds or mammals. Conversely, areas that have high species diversity of birds and mammals can generally be considered to support healthy diverse ecosystems and quality habitats as well. In this sense it can be stated that based on species richness (birds, mammals, trees, shrubs, frogs), the overall ecosystems in the Study Area are not *significantly impaired* and that adverse effects of CoCs in the soil on specific species populations in the Study Area are probably at a low level.**
B	97	4.2	4-3	First and Last	The first paragraph appropriately describes the raccoon as a "generalist omnivore", whereas the last paragraph incorrectly says it is a "top predator". **The Raccoon will be consistently identified as a generalist omnivore. (P. 4-4, para 2, line 3)**

Rank	Number	Section	Page	Paragraph	Comment
B	98	4.2	4-3	Table 4-1	Table 4-1 and associated text outline the receptors selected for the ERA. As indicated in another specific comment, a mammal that has a small home range and is highly exposed to CoCs through association with soil and bioaccumulation via the food chain (e.g., common shrew) was not selected. Therefore, potential risk to carnivorous small mammals is not represented in the ERA. **See JW's response to comment 90 above.**
A	99	4.2	4-4	last	The text in paragraph states that NOAELs or LOAELs are used as more conservative alternatives to EC_{20} values. NOAELs are likely to be more sensitive than EC_{20}s; LOAELs however may not be. Please clarify. **This paragraph has been rewritten as follows:** **"Assessment endpoints may be based on individual or population responses. Individual responses may include survival, growth, reproduction, behaviour or histopathology (e.g., lesions, tumours, etc.). Population responses may include changes in size of a population through a combination of birth, death, emigration and immigration. Individual responses may also change the overall population characteristics. Some research has found that measures of individual responses are not as sensitive as measures of population responses (CCME 1997).** **"CCME and US EPA recommend the selection of ecological endpoints based on the goals and the sought level of protection of the environment. In the current assessment, the objective is to determine ecological risk at a population level. A sustainable level of ecological functioning was selected as the most appropriate level of protection in determining a population level risk. Based on this, survival, reproduction and growth were selected (see Chapter 1) as the assessment endpoints for individual species of mammals and birds, where a literature-based hazard assessment was conducted. The US EPA (1997) reported that at a 40% mortality effects level, a population is likely to be unable to sustain itself. Up to a 20% effects level of a less severe nature (i.e., EC20) was determined to be an adequate level of protection for survival of the species.** **"The 20% effects level or less has been referenced as a No Observable Effects Concentration (NOEC) in plants, soil and litter invertebrates and heterotrophic processes (Efroymson, et al., 1997a; Efroymson, et al., 1997b) because of difficulties identifying effects below this level. For slower reproducing species with less dense populations, such as larger mammals, a 20% decrease in population may not be acceptable. For these types of populations, a Lowest Observable Effects Level (LOAEL) or a No Observable Effects Level (NOAEL) is considered a more appropriate endpoint."**

Rank	Number	Section	Page	Paragraph	Comment
B	100	4.2	4-5	Table 4-2	The table has incomplete entries (e.g., exposure media for Fowler's toad – see text on p. 4-9), extra entries (e.g., adult survival was not evaluated for frogs/toads, per text on p. 4-8), the raccoon is erroneously listed as a "top predator", and the terrestrial VECs are listed in jumbled order. **Table 4-2 will be revised (P. 4-6, Table 4-2). For Fowler's Toad and Frogs/American Toad, as primary consumers the Exposure Assumed to Occur Via is "surface water". For Frogs/American Toad, adults as secondary consumers, a risk was not calculated using TRV values, but rather risk assessed by conducting statistical analysis of field data on the occurrence and abundance of breeding adult male frogs and toads in the Study Area. This is stated in the Measurement Endpoint column. The following additional text in the last paragraph on page 4-8 will be added to clarify that field data were used to assess risk to adult frogs and toads:** **"…on CoC effects on the adult life stage. For adult frogs and toads, potential effects of CoCs in soil, sediment, water and food were assessed indirectly by analysis of field data (calling surveys of males) that was used to document species occurrence, general abundance and distribution in the Study Area." (P. 4-11, para. 3, line 7)**
A	101	4.2	4-5	Table 4-2	Please explain in the text why assessment endpoints for birds and mammals differ (if this is intentional). Generally, survival, reproduction, and growth are considered endpoints for population-level effects in each bird and mammal species and it is not clear why all three are not included for each bird and mammal. **Table 4-2 has been changed so that for birds and mammals the Assessment Endpoints are survival, reproduction and growth. Text has also been added in the report, see response to comment 99 above. (P. 4-6, Table 4-2)**
A	102	4.2	4-5	Table 4-2	It is important that the assessment endpoints relate back to the study objectives (page 1-16). One of the objectives is to determine ecological risk at the population level. The relationship between the assessment endpoints and the stated objective of evaluating population-level risks should be described in text related to the table (perhaps a final paragraph on p. 4.4). **See response to comment 99 above.**
B	103	4.3.4.1	4-9	All	There are no citations for the life-history information provided for meadow voles. This is also true for the first paragraph under the white-tailed deer life-history account (Section 4.3.4.2, page 4-9). Citations appear to be appropriately provided in the other parts of this section. **Appropriate references will be cited within the Meadow Vole and White-tailed Deer sections (4.3.4.1 and 4.3.4.2). (P. 4-12, para 2, line 9)**

Rank	Number	Section	Page	Paragraph	Comment
B	104	4.4	4-14	2	This section acknowledges uncertainties and data gaps with respect to receptor life-histories, but should conclude the 2nd paragraph with a statement of the impact of these uncertainties on the risk conclusions. Because there is no way to determine the degree of accuracy of the literature values used, a sentence such as the following should be added: "These differences may result in either an over- or under-estimation of risk." **For the final report, subsections headings "uncertainties, limitations and gaps" as presented in Section 4.4 of the draft report will be addressed in a separate section (Section 10). In this new section, uncertainties and limitations will be assessed for over/under estimation of risk and whether it is likely to change the risk assessment conclusions.**
A	105	5.1	5-1	2	Details on the 'Reference Area' are needed. How were the areas selected? What is their land-use history? What ecological communities exist on them? How large are they? How similar to the study area are they? Without these details it is hard to interpret the utility of the reference data. **Discussion on criteria for data collection locations will be added to Section 5.2. No rigorous selection criteria process was established for the selection of reference areas. Generally the selection of reference sites was based on the judgment of JW biologists that the reference areas were similar to sites in the Study Area. Nevertheless for the selection of reference sites a number of basic general parameters had to be met, including; site located as near the Study Area as possible (i.e., within 10-20 km); soil nickel less than 200 ppm; site located within a few kilometers of the Lake Erie shoreline; site located in a local agricultural setting; soils that were either organic or clay; woodlots of the same general size with similar tree species composition (Red Maple, Red Oak); and fields of the same general size that were fallow and dominated by field weed species. (P. 5-2, para 4, line 1)**
A	106	5.2	5-2	Whole section	We need to know the concentrations of CoCs in soil, sediment and water associated with the areas where all biota were collected so that we can understand how representative of maximum CoC exposure the biota data are. A table showing the range in Ni concentrations (as a surrogate for all CoCs) associated with stations from which biota were sampled in all areas would be particularly helpful. If biota were not collected in association with the maximum CoC concentrations, conclusions based on these data may not accurately reflect risk at the site. **The range of soil Nickel will be added, where appropriate to the tables in this section.**
C	107	5.2	5-2	Table 5-1	It would be very helpful to list out how each sample was handled and what each was analyzed for. **Details on how samples were collected, handled and the types of analysis undertaken are provided in full in the data collection protocols in Volume II of the report. A footnote will be added to the table to direct the reader to Volume II. (P. 5-4, Table 5-1)**

Rank	Number	Section	Page	Paragraph	Comment
B	108	5.3.1	5-4	2	How were sampling locations selected? Was it strictly judgmental (OK if it was, but should state this)? Clarification is needed. Text implies that duplicate field samples were collected by Stantec for QA/QC. These are useful for inter-laboratory comparisons, but were field duplicates also collected by Jacques Whitford for intra-laboratory comparisons? Please clarify in the text. For all analytical discussions in Section 5.3, the field QA/QC samples included and frequency should be described (e.g., MS/MSD at 10% frequency). **Text regarding the selection of sample sites will be inserted at the end of Section 5.2. As was stated for the selection of reference sites for comment 105 above, no rigorous selection criteria process was established for the selection of sample sites. Generally the selection of sample sites was based on the judgment of JW biologists that sample areas were similar based on a number of general parameters that had to be met, including; site located in Primary or Secondary Study Areas; varying soil nickel concentrations (high to moderate); soils that were either organic or clay; woodlots of the same general size with similar tree species composition (Red Maple, Red Oak); and fields of the same general size that were fallow and dominated by field weed species.** **With respect to QA/QC, the last sentence in the second paragraph of section 5.3.1 states that JW also collected duplicate samples in the field. This section will be further clarified to include the frequency of QA/QC samples.** **(P. 5-3, para 1, line 1) and (P. 5-6, para 3, line 2)**
B	109	5.3.1	5-5	Table 5-3	Goldenrod sampling is not listed in this table, but BAFs are shown in Section 6. Please include. It would be helpful to break the number of stations sampled down by study area. Do the 17 sample stations for maple sap apply to both soil depths? If so, please clarify. Table should be modified to make it clear how sampling was performed. From soil protocol in Volume II it is clear that soil samples consisted of composites of cores at each location (station). The specifics of this sampling are not very clear in this table. **Goldenrods have been added to the table. The number of stations sampled will be divided into study areas. JW does not feel it is necessary to provide the specifics of soil sampling in this table. This level of detail is addressed in the protocols in Volume II. (P. 5-7, Table 5-3)**

Rank	Number	Section	Page	Paragraph	Comment
B	110	5.3.4	5-7	Table 5-6	Only 1 composite sample (i.e., soil from around 1 tree) was collected for the maple leaf study. Therefore, the BAF for soil to maple leaf was developed based on only 1 tree, presumably using soil from <5cm depth. This results in very limited data for this relationship and should be discussed in the uncertainties here and in Section 6. Similarly, the vole BAF is based on only 2 composite soil samples. Again, this is very limited and the soil-to-vole BAF values calculated may not be representative of the full range of values. **The limitations mentioned above will be added to the uncertainties and limitations section.** Goldenrod sampling is not listed in this table, but BAFs are shown in Section 6. Please include. **Goldenrods will be added to the table. (P. 5-9, Table 5-6)**
A	111	5.3.5	5-8	1st full – 1st sentence	The statement is only correct at the individual level. At the plant population level, which is the level of ecological organization that is the stated goal for this assessment, spatial variability of CoCs in soil could be important. **For the final report, text in this section will be removed from Section 5.0 and presented in table form in a new Section 10 that deals specifically with uncertainties and limitations.** **However, the following presents JW's comment:** **"For individual plants, variability of exposure to CoCs due to distribution of soil CoCs in the Study Area is not a concern. However individual long-lived specimens, such as a tree, may have been exposed to a range of CoCs in soil, water, and air that varied over time. For a population of a plant species within the Study Area, exposure to soil CoCs varies based on the proximity of individual plants to the refinery, resulting in a population being exposed to a range of soil CoC values. To capture this range of exposure, the complete soil data set was used as an estimation of exposure. However, exact values of exposure to individual plants or sub-populations was not undertaken and is identified as a limitation, which could result in either an under- or over-representation of exposure to a plant's population, depending on the location of a sub-population, or individual plant and the soil CoC concentration at the growth site. (P. 10-1, Heading 10.0)**

Rank	Number	Section	Page	Paragraph	Comment
B	112	5.3.5	5-8	2nd full	This paragraph discusses the use of surface (0-5 cm) soils. The last sentence indicates that herbaceous plants such as goldenrod may have deeper roots, but a significant portion of their rooting zone is in the surface soils. What about trees? BAFs were developed for maple leaves, sap and seeds; therefore, need to address the concept that trees are likely not exposed to the highest concentrations at the soil surface. This is of concern because risk to plants was only assessed for trees. **For a general discussion of the use of the 0-5 cm soil CoC values see JW's response to comment 41 above. With respect to the exposure of tree roots to soil CoCs, it is important to note that one of the reasons why the Red Maple was selected is because this tree has a very shallow rooting system due to its adaptation to seasonally flooded swamps and high water table where soils have full water saturation conditions. As a result, much of the tree's root system is found in the shallow, near-surface soil zone (water saturated soils are deficient in oxygen and therefore a common adaptation of a wetland tree species such as Red Maple is to maintain a very shallow rooting system near the soil surface to obtain oxygen).** **With respect to the statement, "this is of concern because risk to plants was only assessed for trees" - for the ERA, this statement is not true. As noted above, the ERA was conducted under two major study components, the ERA-Natural Environment, and ERA-Crop Studies. The crop studies for the ERA assessed the risk of CoCs in Port Colborne soils for the most sensitive species, oats, under controlled greenhouse conditions for various soil types. As stated previously, for the full review of the CBRA, the MOE, the review and approval agency for the CBRA, will have all documentation for their review. (P. 5-12, para 4, line 2)**
C	113	5.4.7	5-11	1	It is unclear whether the duplicate samples discussed in this section are field duplicates or laboratory duplicates. Please clarify. **This section has been clarified.**
B	114	6.0	6-1	1	Last sentence states that exposure is evaluated for 11 VECs, but Table 4-1 identifies 14 VECs; please clarify that the 11 VECs are the animals identified as VECs. **Table 4-1 identifies for which 11 VECs exposure is estimated. They are: earthworms, tadpoles, Fowler's Toad, Meadow Vole, Raccoon, Red Fox, White-tailed Deer, Red-tailed Hawk, American Woodcock, American Robin and Red-eyed Vireo.**

Rank	Number	Section	Page	Paragraph	Comment
B	115	6.1	6-1		Please expand the text to indicate that estimation of risk was based on exposure concentration for some receptors (e.g., amphibians) or the average daily dose (for birds and mammals). Although this is eventually explained in Section 8.22 (p. 8-2), it should be stated clearly throughout the report. **The fourth sentence has been modified to read as follows:** **"Pathways were identified, and empirical data were used to estimate each receptor's exposure to each CoC, either as an exposure concentration (for earthworms, tadpoles and Fowler's Toad) or as an average daily dose (for birds and mammals)." (P. 6-1, para 2, line 6)**
B	116	6.3	6-3	Fig. 6-2	Wild grapes should not be included in the red-eyed vireo diet. Also, remove grapes from the vireo diet reported in text on page 6-8, 1st paragraph, line 8. **Wild grapes will be removed as an exposure pathway for the Red-eyed Vireo. (P. 6-3, Fig. 6-2)**
B	117	6.3	6-6	Figure 6-5	Please include arrows indicating complete pathways from arthropods to amphibians. **An arrow from arthropod to adult frog will be added to the figure. (P. 6-6, Fig. 6-5)**
B	118	6.3.4	6-7		Exposure of receptors such as plants also occurs through direct contact with contaminated soils. Last sentence of the paragraph probably should say that tadpoles are exposed to CoCs in the sediment and water as well as their food, but only risk resulting from exposure through water is evaluated. **The following will be added to the start of the paragraph.** **"For receptors that are in direct contact with soil, such as plants and earthworms, exposure to CoCs occurs through contact with soils and soil porewater concentrations of CoCs. Additional exposure of earthworms to CoCs is also assumed to occur through ingestion of surface soils and CoCs in food (i.e., leaf litter). Earthworms are included in Figures 6-2 and 6-4, and are assumed to receive all of their exposure by ingestion of, and dermal contact with, soil. However, there is no existing literature that allows for a calculated assessment of risk to earthworms as a direct result of exposure through the ingestion of the CoCs in food or soil."** **The last sentence of the paragraph will be re-written as follows:** **"Exposure to CoCs for adult frogs and tadpoles is through water and sediment of the ponds they inhabit, and through the ingestion of food (plants, algae, insects and sediment). However, there is no existing literature that allows for a calculated assessment of risk to adult frogs and tadpoles as a result of exposure through the ingestion of the CoCs in food or sediment. Therefore, only risk resulting from exposure through water can be evaluated." (P. 6-7, para 4, line 1)**

Rank	Number	Section	Page	Paragraph	Comment
B	119	6.4.1	6-9	Whole section	This section would be better if it related uptake in the various areas by trophic group to indicate where accumulation and risk is greatest. Relatively small transfer rates can be of great significance if high concentrations exist in the source medium. **JW believes that the figures and text provided in this section provide the reader with an adequate overview of the bioaccumulation of CoCs through the food chain and various trophic groups.**
B	120	6.4.1	6-10	2 – last sentence	More description of the weighting analyses performed and presented in Volume III would be helpful. **JW believes it is sufficient to direct those readers who require more details on the analysis to Volume III, Tab 3.**
B	121	6.4.1	6-10 to 6-13	Figures 6-6, 6-7, 6-8, and 6-9	Although these are only examples, the samples used to calculate the BAFs should be clearly stated. For surface water, in particular, the sample concentrations used were difficult to discern. Additional detail should be provided as to how these BAFs were developed. **Sediment and animal samples used to calculate BAFs are shown in the text. Surface water samples used to calculate these BAFs will be added to the text.** The average sediment concentrations do not match those presented in the raw data tables for the samples indicated in Figure 6-6. **The numbers do not match since sediment collected from F-H-3 was sampled incorrectly and therefore was omitted from the data set. This is indicated on the summary page in Tab 27, Volume V. The BAFs shown in Figure 6-6 have been updated.** Note that average BAFs calculated by averaging BAFs calculated on paired samples individually are more representative of bioaccumulation than is using average sediment and tadpole concentrations. For nickel in sediment and tadpoles, for example, the mean BAF obtained from individual pairs of samples is more than double that obtained by using mean sediment and mean tissue (2.2 versus 0.7). **Average BAFs shown in Figures 6-6 through 6-9 were calculated by averaging BAFs derived from paired samples, as suggested above. Using this correct method for sediment and tadpoles in the Secondary Study Area yields a value of 0.7 for Ni, as shown in Figure 6-7. We are unsure as to how a value of 2.2 was derived using the method suggested above. (P. 6-11, Fig. 6-6)**
					Note. Comment 122 was missing in the Original CHM2HILL document.

Rank	Number	Section	Page	Paragraph	Comment
A	123	6.4.1	6-11	1	Note that the BAFs calculated for CoCs in sediment and tadpoles are sufficient (0.7-1.7) to indicate significant bioaccumulation. Please re-phrase the last sentence that states, "Indeed, BAFs for sediment to tadpoles are small, indicating little or no accumulation of CoCs through ingestion of sediment." Although the BAFs are significantly lower than the BAFs for surface water, this statement is contradicted by the high levels of copper observed in frog livers. **This sentence has been revised. Text has been added to point out levels of copper in frog livers. (P. 6-10, para 4, line 1)**
B	124	6.4.1	6-11	2 – 1st sentence	This statement is only true for herbivores. **Not true, though herbivores are the primary consumers directly eating the plants that have taken up CoCs from the soils, secondary consumers and top predators are nevertheless exposed to CoCs that come from plants via the primary consumer in the food chain.**
B	125	6.4.2	6-15	4	There is reference to ANOVA (Analysis of Variance) tables being provided but in the results shown in Tables 8-16, 8-17, 8-18, 8-20 in Section 8 of Vol. I, and in Tables C2, C4, and C6 through C9 are for Analysis of Deviance for the *glms.* The authors should point out the differences between Analysis of Deviance and ANOVA and explain why they are using the Analysis of Deviance approach instead of the usual ANOVA approach. The use of the Analysis of Deviance is related to the regression analysis used – in this case the logistic regression. The authors should be more explicit about what analysis was actually done. **When one performs an Analysis of Variance on a generalised linear model, the result is an analysis of deviance. In our experience, this is the norm for glms, and allows one to assess the fit of a model and the contributions of predictors. Reference in this paragraph to ANOVA will be changed to Analysis of Deviance. (P. 6-17, para 4, line 6)**
B	126	6.4.3.1	6-17	1	Statistical analyses should be performed to support statement that CoC concentrations are higher in the study area. The basis for the <30% absorption of CoCs statement should be provided. **The low sample size for tadpoles prevents a meaningful statistical analysis of difference between treatments. However, ANOVA was performed comparing reference samples with those from the Study Area, for each frog tissue and CoC. The results of these analyses, which show significant differences between samples for nickel for all tissues and significant differences for copper and cobalt for certain tissues, will be reported in the text. The <30% absorption was based on a comparison of GI tract CoC concentrations to the those of the remaining carcass. (P. 6-20, para 1, line 2)**

Rank	Number	Section	Page	Paragraph	Comment
C	127	6.4.3.1	6-18 and 6-19	Tables 6-3 and 6-4	A reference to Volume III Table 8 should be added **A reference to Volume III will be placed as a footnote to each table. (P. 6-21, Table 6-3)**
B	128	6.4.3.2	6-19	Table 6-4	The total body nickel concentrations (mean, max, standard deviation, and UCLM) for both the Study and Reference Areas do not correspond with the values presented in the raw data and the summarized data in Volume III, Appendix 6. **A computing error was made when total body nickel was calculated for a short series of samples. This has been corrected and all other calculations of composite body CoC concentrations have been checked. (P. 6-22, Table 6-4)**
B	129	6.4.3.2	6-20	Table 6-5	The maple leaf reference data shown for nickel are the data for arsenic, and the data for copper are the data for cobalt, and vice-versa. **These numbers will be corrected.** The number of maple sap samples in the Study Area (15) does not match the number presented in the raw data (18; raw data). **The extra three samples in the raw data set are samples of syrup that were submitted from local residents and analyzed in the laboratory under the same chain of custody. Values for syrup were not used in the ERA. (P. 6-23, Table 6-5)**
B	130	6.4.3.3	6-20	1	Grapes are said to have a limited distribution in the Study Area. How does this impact accessibility to wildlife receptors, particularly those with a small home range (i.e., robins)? If grapes were not available in areas with the highest CoC concentrations, then they may not be representing exposure to robins eating fruits that are available in these areas. This should be discussed in the uncertainties at a minimum, and further justification for the use of the grape tissue in the exposure calculations would improve Section 6.4.3.3. **CoC concentrations of grapes used in exposure calculations were derived from measured CoC concentrations of three samples from the Primary Study Area and four samples from the Secondary Study Area. As a wild fruit found in the Study Area, it is a real example of what American Robins and other frugivores may be eating in the Port Colborne area. The limited sample size of these grape COC data will be discussed in the uncertainties section.**
B	131	6.4.3.4	6-21	Table 6-7	Are these data for non-purged worms? If so, the title or a footnote should make this clear. **These data are for non-purged worms, and a footnote will be added to the table. (P. 6-25, Table 6-7)**

Rank	Number	Section	Page	Paragraph	Comment
B	132	6.4.3.4	6-22	Table 6-8	Are these data for non-purged worms? If so, the title or a footnote should make this clear. **These data are for non-purged worms, and a footnote will be added to the table. (P6-26, Table 6-8)**
B	133	6.4.3.4	6-23	3	Please provide a reference giving guidance to the approach to use the ratio of purged to non-purged concentrations. An alternate approach would be to use the purged concentrations, as it would fully eliminate including additional soil ingestion in the exposure estimation. **Due to the small number of samples where earthworms were purged, it was thought that a better approach was to use the ratio of purged: non-purged earthworm CoC concentrations and apply that to the whole data set. This has resulted in overall higher CoC concentrations, which we believe is a more conservative approach, yet is more realistic than using non-purged earthworm CoC concentrations without a modifying factor applied. (P. 6-28, para 2, line 4)**
B	134	6.4.3.4	6-24	Table 6-10	Please indicate if these tissue concentrations are in wet weight or dry weight, as they are the values used for exposure estimates, and must be known when calculating with ingestion rates based on wet or dry weights. **As noted on Page 5-8, all CoC concentrations presented in this report are in dry weight.**
B	135	6.4.3.5	6-24	1	Additional detail on the problems with analyses of grasshoppers is needed so that the potential effects on data usability (if any) can be judged. **Additional detail will be provided through the addition of the following text, which replaces the third sentence of this paragraph.** **"The homogenisation of grasshopper samples prior to subsampling was problematic. Specifically, the grinding of the grasshopper tissue was incomplete and left parts of the exoskeleton intact or partially intact. Although the digestion process allowed for complete homogenisation of each subsample, each subsample was not representative of the whole sample. To address this problem, the entire grasshopper sample for each site was digested and analysed through multiple subsamples, and the resulting CoC concentrations for each subsample were averaged."**
C	136	6.4.3.5	6-25	1 and Table 6-11	Was the sampling effort equal for all tax in all areas or are these biomass values normalized by sampling effort? Please clarify. **The sampling design for arthropods was not based on ensuring equal effort for all taxa (i.e., different sampling methods for various taxa). However the sampling methods that were used were standardized with respect to effort, and equal amount of effort was expended at each sample site. As a result, comparisons can be made between sites or areas, but not necessarily between taxa.**

Rank	Number	Section	Page	Paragraph	Comment
B	137	6.4.3.5	6-25	Table 6-12	The copper concentrations in woodlot arthropods (mean, max, standard deviation, and UCLM) for the Study Area does not correspond with the values presented in the raw data and the summarized data in Volume III Appendix 6. A reference to Volume III Table 8 should be added. **The values in Table 6-12 were checked and found to be correct. Please note that this table combines both insect and spider samples. A footnote to direct the reader to Volume III will be added. (P. 6-30, Table 6-12)**
B	138	6.4.3.6	6-26	Table 6-13	A reference to Volume III Table 8 should be added. **A footnote to direct the reader to Volume III will be added. (P. 6-13, Table 6-13)**
B	139	6.4.4	6-27	Whole section	As currently written, this section does not summarize the results of the preceding text. **Indeed, Section 6.4.4 provides concluding remarks rather than a summary of the preceding text. A paragraph summarising Section 6.4 will be added to the end of 6.4.4.**
A	140	6.5.1	6-27	Eqn. 6-1	It is inappropriate to sum inhalation exposure with exposure of ingested soil, water and food. The units may be comparable, but the mechanisms of gastric absorption differ dramatically from pulmonary absorption. Toxicity values also differ for inhalation and dietary exposure. We recommend that inhalation exposure and risk be evaluated independently. **JW agrees that the mechanisms of gastric absorption and pulmonary absorption are different, and therefore the potential exposure and risk as a result of inhalation of CoCs should be removed from the equation. However, conducting separate risk assessments for inhalation of CoCs by the selected VECs is not possible as there is little to no toxicity data, or literature benchmarks with respect to risk calculations for the selected VECs. Data collected for ambient air for the HHRA (see Table 2-11), found that though concentrations of the CoCs are elevated in the Study Area, the values are very low and below current MOE guidelines. Therefore, for the ERA, the potential risk to VECs as a result of the inhalation of CoCs will be considered to be negligible when compared to the exposure and risk associated with the ingestion of CoCs. As a result, an assessment of potential risk associated with inhalation exposure to CoCs for the selected VECs will not be included. The text and calculations in the report will be revisited to address the removal of the air exposure pathway. The data present in Section 2 will remain, and referenced in text detailing why inhalation exposure has not been assessed.**
B	141	6.5.1	6-28	Eqn. 6-2	Suggest adding a *w* subscript to 'C' and 'NIR' to denote water concentrations and ingestion. NIR should have units of L/kg/d. **The equation and units will be modified to reflect the above comment. (P. 6-34, Equation 6-2)**

Rank	Number	Section	Page	Paragraph	Comment
B	142	6.5.1	6-28	Eqn. 6-3	The normalized, wet weight food ingestion rate is used in this calculation; however, the food concentration is in dry weight units. The food ingestion and food concentration should both be either wet weight or dry weight. Suggest adding an *f* subscript to 'NIR' to denote food ingestion. **The equation will be modified to reflect the above comment, which will take into account the moisture content of each food item. (P. 6-34, Equation 6-3)**
B	143	6.5.1	6-28	Eqn. 6-4	Suggest adding an s subscript to 'C' and 'NIR' to denote soil concentrations and ingestion. BAF term is already used (for bioaccumulation factor). Suggest using a different acronym (BF?). Suggest changing form of model to be consistent with Eqns 6-2 and 6-3: $ADD_{soil} = C_s * FS * NIR_s * FR * BF$ **The above suggestions will be incorporated, including the change of BAF to BF. (P. 6-35, Equation 6-4)**
B	144	6.5.1	6-29	Eqn. 6-5	Suggest adding an a subscript to 'C' and 'NIR' to denote air concentrations and inhalation. Suggest changing form of model to be consistent with Eqns 6-2 and 6-3: $ADD_{air} = C_a * FR * FIR_a$ Note FIR_a has units of m^3/kg/d. **As per JW'S response to comment 140 above, risk associated with the inhalation of CoCs will not be undertaken and this equation will be removed. (P. 6-35, Equation 6-5)**

Rank	Number	Section	Page	Paragraph	Comment
A	145	6.5.1	6-29	Eqn. 6-6	The units resulting from this calculation are not correct. Dose (mg/kg/d) multiplied by body weight (kg) yields a bird concentration in mg/d instead of mg/kg. Also, multiplying the daily oral exposure by a BAF would not represent the concentration of CoCs accumulated in avian tissue over time. In addition, there is a large degree of uncertainty associated with this approach for obtaining concentrations in avian tissue (a compounding of the uncertainty from each step). We recommend pooling all site-specific measured data from other vertebrates (small mammals, tadpoles, frogs) and use these data to approximate birds. There will still be significant uncertainty, but you will be relying on measured site-specific relationships as opposed to multiplying uncertainty from literature-based biota transfers. **Bioaccumulation factors have the unit of d/kg, which, when multiplied by dose (mg/kg-d) and body weight (kg), leads to the resulting concentration of mg/kg. Although this does not represent the CoC concentrations that may accumulate over time, if any indeed accumulate, it is an estimate of their tissue concentration. Limitations of this approach are discussed in Section 6.6,and will be a part of the uncertainties section.** **We disagree with the suggested approach of pooling data for species such as tadpoles and frogs or even small mammals in estimating concentrations in birds. The potential exposures and hence potential flesh concentrations in these species are very different from birds and we don't consider these to give a reasonable approximation of exposures to birds. In the estimate of doses to red foxes and red-tailed hawks, an average concentration based on those calculated for the three other bird species assessed was used. These bird species include woodcock which is a species at the extreme end of the range of characteristics that may maximize exposures and including this species in the averaging is thus expected to be conservative and should not lead to an underestimation of exposures to hawks and foxes. The dietary intakes for predators are based on the expected portion of birds, mammals and frogs in the diet and changing these to portions to exclude birds from the diet is not justified based on what these species are known to consume.**
B	146	6.5.2	6-30	2 – 2nd sentence	Please report what the assumed site use was (or reference the section/table where it is reported). **The affected area is the Study Area. In this paragraph, mention of the "affected area" will be changed to the "Study Area". (P. 6-36, para 1, line 3)**

Rank	Number	Section	Page	Paragraph	Comment
A	147	6.5.3	6-31	Table 6-15	Not all VECs are listed – frogs, Fowler's Toad, and plants (maples and woodlots) are missing. How was exposure for these VECs evaluated? Note that although clay and organic soils affect bioavailability and accumulation, many receptors (esp. the birds and mammals) will experience exposure across these soils groups – few (if any) will experience exposure within a single soil group. Tadpoles (plus frogs and the toad) would be better evaluated on the basis of individual water bodies as opposed to a site-wide basis. Evaluation of risks to earthworms would be improved if risk were evaluated on a point-by-point basis (clay and organic soil would be useful here) with risks summarized as the frequency with which a exposure to a given CoC being the measure of risk (the pt by pt evaluation within waterbodies would also be an improvement for the amphibians). It is unclear why deer would be evaluated on a site-wide basis and not fox, raccoon, and hawk also – all species that could travel and be exposed over the entire area should be evaluated similarly. Exposure and risk evaluations for the remaining VECs (vole, vireo, robin, and woodcock) should focus on areas that contain habitat for these species – fields for voles (as suggested in the table), woodlots only for the vireo (they are a forest bird), fields and woodlot edges for the robin, and wetlands, wet fields for the woodcock. **Exposure was not calculated for adult frogs and plants, so these VECs were excluded. Fowler's Toad was excluded because the exposure assessment and risk characterisation for this special species was undertaken in a different manner (i.e., based on a specific site for this federally Threatened species, warranting special circumstances).** **JW's approach was to examine the potential risk to the overall populations of VECs found in the Study Area, not to individual sites. JW is interested in examining how habitat (woodlot vs. field) and soil type (clay vs. organic) could modify exposure to CoCs, and used VECs that were identified as part of the CBRA process to represent not just themselves but also other species that share similarities in life history and biology. Red-eyed Vireo represents itself and other insectivorous birds. Although it is a species that nests in deciduous woodlots and does not forage in open field, other insectivorous birds forage in open fields, and the scenarios pertaining to field habitat for this species, though artificial, are maintained to account for the potential exposure of those field species. Contrary to your statements above, American Robins use both open field habitat and forest, including interiors of woodlots, as do American Woodcocks, and JW maintains the four scenarios for those two species. JW acknowledges that species are mobile and will use different soil types and habitats, but the simplified, conservative approach employed for this ERA allows for specific assessment and recommendations for habitats and soil types.**

Rank	Number	Section	Page	Paragraph	Comment
B	148	6.5.3	6-33	Table 6-16	Soil woodlot/clay number of samples (N) should be 41, not 121. Frog tissue number of samples should be 49, not 44 **Presented sample sizes will be amended. (P. 6-39, Table 6-16)**
B	149	6.5.3	6-35	Table 6-17	Frog tissue nickel and copper concentrations do not match those presented in Table 6-4. **As noted above, a simple error was made in computing total body concentrations for a series of frog samples. This has been corrected and the correct values will be presented in both Table 6-4 and 6-17.** Please indicate if the surface water sample concentrations are dissolved or total concentrations. Sampling methods (Volume II, Table 1) state that samples were field filtered, but this should also be stated in the data table in Volume 1 because a comparison to TRVs for amphibians should be based on dissolved concentrations, whereas surface water ingestion by birds and mammals is of total concentrations. **Surface water sample concentrations are total concentrations, which provides a conservative estimate of the CoC concentrations to which tadpoles are exposed. (P. 6-41, Table 6-17)**
B	150	6.5.3	6-35	Table 6-17	Please state in the table title that these values are for the overall scenario. Also, it would be good to refer to Table 6-16 or indicate on this table which values are UCLM and which are max. **These suggestions will be incorporated. (P.6-41, Table 6-17)**
B	151	6.5.3	6-36	Table 6-18	Concentrations of copper in arthropods do not match those presented in the raw data. Footnote 2 should be clarified – what is meant by data pooled across scenarios? **As noted above, concentrations combine both insect and spider samples. Maximum values will be used instead of UCLMs, due to small sample size. Values for each scenario will be provided in the table, which will eliminate the need for Footnote 2 (which indicated that for nickel and cobalt, UCLMs based on the entire dataset were presented, combining both soil types and habitats).**

Rank	Number	Section	Page	Paragraph	Comment
C	152	6.5.3	6-36	2	Please provide a reference giving guidance to use Stage 2 concentrations preferentially over Stage 1 concentrations, or research demonstrating that metals are not absorbed in the stomach. Otherwise, an average of Stage 1 and Stage 2 concentrations may be more appropriate. **This paragraph has been replaced with the following expanded discussion:** **The application of a single stage (*i.e.* stomach) extraction using glycine has previously been validated for arsenic, and was considered appropriate for application as both pH and glycine were previously found not to change the bioaccessibility of arsenic from soils (Ruby et al., 1996; Ollson, 2003). However, no such validation has been made for nickel, copper and cobalt, therefore selection of the methodology adopted must be made based upon an understanding of the physiological conditions in mammals. Gastrointestinal absorption is known to occur primarily in the intestinal phase (NRC, 2003) and is absorbed by passive paracellular transport, by passive, transcellular diffusion or by active, transcellular transport fitting into a transport system already present (Danish EPA). This suggests that the application of an intestinal equivalent bioavailability (*i.e.* Stage 2) would best mimic the physiological conditions of metal absorption in mammals. With respect to glycine, results of the *in vitro* study suggest that the addition of glycine significantly increases the bioaccessibility of nickel, copper, and cobalt in the stage 2 extraction. The degree of increase ranges from a factor of 2 to 20 depending on the CoC and the soil type. The increase suggests that in the neutralized solution, glycine is bonding with the nickel, copper, and cobalt in the soil to increase the bioaccessible fraction. This is consistent with previous literature findings at which a measurable interaction between divalent cations and polysaccharides compounds were observed (Debon and Tester, 2001). A comparison of the *in vitro* and *in vivo* results for nickel indicate that the bioavailability is similar to the stage 2, without glycine, bioaccessibility. Given copper, and cobalt behaves similar to nickel in the presence of glycine, stage 2 without glycine bioaccessibility were adopted. The bioaccessibility values adopted are presented in Table 6-19.** **Danish Environmental Protection Agency. 2003. "Human Bioaccessibility of Heavy Metals and PAH from Soil." Environmental Project no. 840, Technology Programme for Soil and Groundwater Contamination.** http://www.mst.dk/homepage/default.asp?Sub=http://www.mst.dk/udgiv/publications/2003/87-7972-877-4/html/kap04_eng.htm **Debon, S.J.J. and R.F. Tester. 2001. "In vitro binding of calcium, iron and zinc by non-starch polysaccharides." *Food Chemistry*. 73: 401-410.** **NRC. 2003. *Bioavailability of Contaminants in Soils and Sediments, Processes, Tools and Applications.* Committee on Bioavailability of Contaminants in soils and Sediments, Water Science and Technology Board, Division on Earth and Life Studies, National Research Council, The National Academies Press, Washington, DC.** **Ollson, C.A. 2003. *Arsenic Risk Assessments: The Importance of Bioavailability*. Doctoral**

Rank	Number	Section	Page	Paragraph	Comment
					Thesis, Royal Military College of Canada. October 2003. **Ruby, M.V., A. Davis, R. Schoof, S. Eberle, and C.M. Sellstone. 1996. "Estimation of Lead and Arsenic Bioavailability Using a Physiologically Based Extraction Test." *Environ. Sci. Technol.* 30, 422-430. (P. 6-42, para 2, line 6)**
C	153	6.5.3	6-36	2	Third sentence. Please provide the reference to support the use of the Stage 2 extraction based on the rationale that it best represents intestinal concentrations. **See response to comment number 152.**
B	154	6.5.4.2	6-38	5	Please include a discussion on the representativeness of a single sample used to assess risk to the Fowler's toad. Considerable uncertainty may be associated with this assessment because of the potential for spatial and temporal variation in concentration. It may also be beneficial to include the conditions on the sample collection date (August 1, 2001). **There was only one pond sampled, as this was the only breeding pond found in the Study Area for the Fowler's Toad. Perhaps the use of the phrase "major breeding pond" was misleading, suggesting that were other ponds, but the one sampled was the major or primary breeding pond. This was not the case. As there was only one breeding pond, the assessment of risk to tadpoles of the Fowler's Toad population in the Study Area can only be based on the concentrations of the CoCs found in the water and sediment of that pond. The first sentence in the paragraph will be rewritten as follows:** **Frog surveys conducted during the study identified only one breeding pond to occur in the Study Area for the Fowler's Toad.** **(Page 6-42, Table 6-22)**
B	155	6.5.4.3	6-40	Tables 6-22 and 6-23	The exposure concentrations from the two extraction techniques do not match those presented in Tables 2-7 and 2-8. **Tables 2-7 and 2-8 present mean percentages rather than concentrations, and correction factors applied to the soil UCLMs were maximums rather than means (as described in the preceding text of this section). However, values presented in Table 6-22 and 6-23 will be checked and corrected as needed.**
B	156	6.5.4.3	6-40	Table 6-22 and Table 6-23 to 31.	Please either footnote in table or provide in text reference to exposure calculation tables in Vol. III. **A footnote will be added to each table referring the reader to Volume III. (P. 6-47, Table 22)**

Rank	Number	Section	Page	Paragraph	Comment
B	157	6.5.4.3	6-40	3	Please include an explanation as to why the DTPA extraction results were not used for soil invertebrate exposure concentrations. As stated in Section 2.1.3.1, this method is a highly successful predictive technique. These results may provide the most accurate exposure estimate. **Due to the uncertainty associated with this correction, JW opted for providing maximum and minimum bounds for the concentrations available to earthworms (i.e., using aqueous extraction and acid ammonium oxalate extraction).**
B	158	6.5.4.4	6-41	Table 6-24	Average Daily Dose/Organic/Woodlot/Cobalt is listed as 7.59 mg/kg/d in Volume III, Appendix 6 **Based on modifications to the exposure calculations, all calculated Average Daily Doses will be amended, and values will be consistent throughout the report. (P. 6-48, Table 6-24)**
B	159	6.6	6-45	1	Please acknowledge that risk may be either over- or under-estimated from use of literature-derived life-history parameters and surrogate diets. **This will be included in the paragraph.**
B	160	6.6	6-45	2	The total ADD should not be considered a "very conservative estimate of a VEC's actual exposure" because site-specific bioavailability and prey concentrations were utilized. Very conservative estimates are those using 100 percent bioavailability. Instead, the ADD is likely to be a more accurate representation of actual exposure because site-specific data are used. However, limitations with these site-specific data (e.g., small sample size for determining soil-to-maple leaf BAFs) may over- or under-estimate risk. Please be careful not to overstate the confidence in the approach used. Additionally, because exposure was based on large spatial aggregates of the data, it is likely that underestimation of risk may be occurring in localized areas of elevated concentrations. Individuals that live in these areas are likely to experience exposure and risks in excess of the 'average' for the population as a whole. **The statements regarding the results being very conservative and the actual daily exposures as likely being considerably lower have been removed from the report.** **With respect to the potential risk to individuals in specific locations, as detailed above the study design and objective was to conduct the assessment of risk for the population of a VEC for the Study Area as a whole. The uncertainties associated with individuals or sub-population for specific areas within the Study Area will be addressed in a separate uncertainties section.**

Rank	Number	Section	Page	Paragraph	Comment
B	161	6.6	6-46	1	Lines 6-7. This states that exposure ingestion rates are considered to be a "conservative, upper-end estimate of organism exposure to CoCs." The food ingestion rates are either literature-derived or calculated using generic food ingestion rate models, so they may over- or under-estimate risk. Consequently, the statement that the ingestion rates are conservative upper-end values should be removed. **This will be included in the paragraph.**
B	162	6.6	6-46	2	Literature BAFs for birds are said to be conservative estimates. Again, please avoid overstating the conservative nature of the exposure calculation. A good attempt was made to calculate a realistic approximation of exposure. However, there are no perfect data and the uncertainties of the site-specific and literature inputs to the exposure model may result in over- or under-estimation of exposure and risk. **This will be included in the paragraph.**
B	163	6.6	6-46	3	Suggest removing the text following the comma in the last sentence of the paragraph for the reasons described in the previous comment. **This suggestion is accepted and the paragraph will be amended.**
C	164	7.1	7-1 and 7-2	---	Although the primary sources of information for the section are listed, this does not preclude listing citations within the text of Sections 7.1.1 to 7.1.4. It is very difficult to verify information in these sections when the sources are not provided. **Section 7.1.1 through 7.1.4 are provided as a general overview of the literature regarding effect concentrations of the CoCs. Specific reference for each reported value have been purposely omitted to make these sections more readable. For a reviewer that is interested in conducting his/her own review of literature, the primary references have been provided.**
B	165	7.1	7-1	Last	The ATSDR toxicological profiles for arsenic, copper, and nickel (as well as other references listed in these bullets but not already included) should be added to the Cited References. The ATSDR profile for cobalt is listed there twice (p. 10-1 and 10-2); one should be deleted. In addition, the copper and nickel reviews should be replaced by the "published" version of those agency reports (Eisler, R. 2000. *Handbook of Chemical Risk Assessment: Health Hazards to Humans, Plants, and Animals, Vol. 1*, Lewis Publishers, Boca Raton, Florida). (That reference also provides information on arsenic and some details of the citations of the synoptic review reports are not accurate.) **The references have been updated; items duplicated in the text or referenced have been removed, missing references have been added. (P. 7-1, para 2, line 1)**

Rank	Number	Section	Page	Paragraph	Comment
B	166	7.2	7-10	2	Please indicate here that the NOAEL was chosen as the TRV in cases where the LOAEL was based on significant mortality. Though this rationale is not clearly stated in Vol. III, it appears that this was the justification for selecting NOAELs. **The reviewer is correct. This has been added to this section. (P. 7-15, para 2, line 3)**
B	167	7.2	7-10	3	EC50 should be LC50. Also, the equation given for calculating an EC20 from an LC50 is not correct. Efroymson et al. 1997a and 1997b say to divide the LC50 by 5 to get an EC20. It is unclear why the LC50 is multiplied by 2 and then divided by 5 in Equation 7-1. **These points have been corrected in the report. (P. 7-15, Equation 7-1)**
B	168	7.2	7-10	4	Please indicate that Equation 7-2 is used to scale the test species LOAEL to a wildlife receptor LOAEL based on body weight. This scaling is actually done for birds and mammals, but a scaling factor of 1 (as recommended in Sample et al. 1996) was used for birds as compared to a scaling factor of 0.75 for mammals. This should be discussed in the text. It may be clear to show the equation as follows: $LOAEL_w = LOAEL_t(BW_t/BW_w)^{(1-0.75)}$ Please note that more recent scaling factors for birds and mammals (1.2 and 0.94, respectively) have been developed (Sample and Arenal, 1999). **The equation has been revised as indicated above and discussion regarding birds added. (P. 7-15, Equation 7-2)**

Rank	Number	Section	Page	Paragraph	Comment
B	169	7.2	7-12	Table 7-1	Please explain in test endpoint description why NOAEL was chosen over LOAELs in some cases (e.g., Cain and Pafford, 1981). **A rationale for each selected value explaining why each NOAEL or LOAEL was selected has been added. In instances where NOAELs were selected, these are considered the most conservative.** **For nickel toxicity to mammals, the LOAEL based on decreased body weight was selected. A NOAEL was determined at 50% of the LOAEL. Since the observed affect is not severe and since the values for the NOAEL and the LOAEL are close, the LOAEL was selected as reasonable for use in this study.** **For cobalt exposure to birds, a LOAEL was identified at 21 mg/kg-day. No NOAEL was identified in the literature. The LOAEL was based on reduced growth. Since no NOAEL was identified and since the LOAEL was not related to a severe affect, this value was selected as appropriate for use in this study.** **For cobalt toxicity to mammals, a LOAEL was identified for histological changes in rats. Although a somewhat lower NOAEL was estimated for cobalt chloride exposure to rats, the histological changes endpoint are considered non severe and the LOAEL based on these was thus considered appropriate for use in this study.** **An explanation for the arsenic LOAEL value selected for mammals is already provided.** Birds, As. The test species for the USFWS (1964) study should be the mallard instead of the brown-headed cowbird. **This has been corrected in the text.** Please footnote the mammalian receptors to indicate that the TRVs were scaled using equation 7-2 and a scaling factor of 0.75. **The footnote has been added.** Other comments on specific TRVs are included in comments for Table 4 of Vol. III. **See responses to Table 4 comments. (P. 7-28, Table 7-2)**
C	170	7.3	---	---	In the discussions of the bioavailability of each CoC (Sections 7.3.1 to 7.3.4) please include the range of site-specific pH values for comparison since the availability of CoCs is closely tied to pH. Also, site-specific CEC values should be included, if available, in the 2^{nd} full paragraph under Section 7.3.4 and a description of how these CEC values relate to bioavailability should be included. **Site specific pH values will be added to sections 7.3.1 to 7.3.4. Site specific CEC values are not available. A discussion of how CEC values relate to bioavailability will be added to this section.**

Rank	Number	Section	Page	Paragraph	Comment
B	171	7.5	7-20	1 partial	The conclusion that TRVs are considered to be "very conservative measures of toxicity" is not justified by the preceding sentence. It can be stated that the use of soluble forms of the metals in toxicity tests may result in an overestimate of risk. However, it should also be noted that the use of site-specific bioavailability data in the exposure calculation reduces this uncertainty because only the available portion of the total measured media values are incorporated. It is not known whether the test species to wildlife species extrapolation model over- or under-estimates risk. It would be appropriate to separate the uncertainty analysis for the toxicity tests and the extrapolation as the degree of uncertainty differs for each. **Agreed. Uncertainty will be discussed for individual factors and each factor will be identified as to whether it may lead to an over or underestimation of risks. (P. 7-11, para 2, line 1)**
A	172	8.1	8-1		This paragraph should include the explanation for evaluation of media-based exposure concentrations as well as the average daily dose for birds and mammals. Is there an explanation for excluding the line of evidence for plant TRVs (soil toxicity to plants); can the rationale be provided, please? **The third sentence will now read as follows:** **"The second analysis is an empirical evaluation of the presumed risk to which a VEC is subject, based on a calculated average daily dose (calculated using site-specific data and parameter estimates based on other published studies) or an estimated exposure concentration (see Section 6), and toxicity reference values (TRVs) taken from published studies (see Section 7)."** **With respect to excluding the line of evidence for plant TRVs and soil toxicity to plants, JW provides the following. First as stated above to comments pertaining to risk to plants, for the CBRA, the ERA-Crop Studies represents the CBRA study for the assessment of risk for plants exposed to CoCs found in specific Port Colborne soils. The Crop Studies was specifically undertaken as it was recognized that literature-based TRVs for plants are generally very conservative (due to experimental design) and would not be representative of existing conditions in the Port Colborne area. Therefore, for the ERA-Natural Environment, a review of plant TRVs as presented in the literature was not considered appropriate.**
B	173	8.2.2	8-2	First	Please correct the first sentence; it is not true for all other VECs listed in Table 4-1 (i.e., plants, woodlots, etc.) **The first sentence of this section is correct. The wording of the sentence is as follows: "For the VECs <u>denoted</u> in Table 4-1,….", not "…listed…." Those VECs denoted with a "c" in Table 4-1 are the VECs for which the Quotient Method (or similar approach) was used.**

Rank	Number	Section	Page	Paragraph	Comment
B	174	8.2.4	8-4		It is not clear why the “safe” concentrations were not just “back-calculated” by setting the risk quotient to a value of 1. **JW has shown that as soil CoC concentrations decrease, CoC concentrations in organisms within the environment (e.g., plants, earthworms) decrease. After first assessing whether there was a risk to the VEC, JW followed the procedure outlined in Section 8.2.4 to derive “safe” concentrations. This involved setting the risk quotient to a value of 1, but decreasing doses due to soil, food and water proportionally (not just soil itself) to arrive at that risk quotient value.**
B	175	8.2.4	8-4	2	Please change ADD_{pot} to ADD_{tot} **This will be changed. (P. 8-62, Equation 8-2)**
B	176	8.3.1.2	8-7	First	Please provide rationale/explanation for not considering the absence of leopard frogs in the Study Area. **Leopard frogs were not absent from the Study Area; see discussion in Section 3.8.4. However, due to the difficulty of hearing the calls of the Northern Leopard Frog while conducting night road calling surveys, the analysis of frog calling data indicated a sporadic distribution for the species. This sporadic distribution was not verified by other field surveys, with adult Northern Leopard frogs being found in abundance throughout the Study Area.**
B	177	8.3.1.3	8-9	1	Please provide a reference that documents the successful survival of tadpoles and emergence of young adults from the breeding pond. **The sentence will be reworded as follows:** **“………and is not supported by this studies field observation (see Section 3.8.4.1) that documented………” (P. 8-9, para 2, line 8)**

Rank	Number	Section	Page	Paragraph	Comment
A	178	8.3.1.4	8-9	3 full	Text says based on literature and site-specific information on CoC concentrations in water, sediment and beach sand, CoCs do not appear to pose unacceptable risk. This is true for water, but no comparisons to literature benchmarks for sediment and beach sand were available. It would be more accurate to summarize results as follows: Remove sediment and beach sand from the sentence. Insert the sentence "Due to the lack of toxicity data for evaluation of CoCs in sediment and beach sand, these pathways could not be evaluated. However, observations of Fowler's Toad population, including…." **The paragraph will be reworded as follows:** **"……Based on available information in the literature and site-specific CoC concentrations collected for water of the breeding pond, existing concentrations of CoCs in surface water do not pose a risk to tadpoles. Due to the lack of toxicity data for an evaluation of potential adverse effects of CoCs in pond sediments on tadpoles, and sand for adult toads, risk for these pathways could not be assessed. However, observations of Fowler's Toad populations…." (P. 8-10, para 2, line 2)**
A	179	8.3.2.1	8-10	1	Soils used in the maple experiments only go to 3000 mg/kg nickel. Because this is far below the maximum values at the site (>20,000 mg/kg nickel), results of these tests should be applied with caution. Please identify the uncertainties associated with all the site-specific bioassays described in Section 8. It would be a good idea to present literature-based TRVs for plants for comparison to the NOECs derived from the bioassays. **Uncertainties and limitations associated with the maple experiments and other bioassays such as earthworm tox tests will be detailed in a separate uncertainty section in the report.** **Literature-based TRVs for plants are discussed in detail in the Crop Studies Report.**
B	180	8.3.2.1	8-13 and followin g	Figs	The symbols used in many of the figures are not discernable, which makes it difficult to determine which data points represent which sample types. For many of the figures depicting the results of the bioassays and field surveys (maples and decomposers), the lines drawn onto the figures do not appear to represent the data; often, there is not an apparent pattern to the data from which to draw a line. Figure 8-8, and 8-9 are exceptions. Most graphs in these figures show definite response patterns in the data. **The figures will be improved so as to make them clearer to the reader. The lines are locally weighted regression lines, with spans of 0.9. This is explained in Vol. III, tab 10, but will be also included at the beginning of this section. Additionally, the use of these lines as indicators of relationships and trends, rather than as predictive lines that can be used to model responses, will be discussed. (P. 8-13, Fig. 8-1)**

Rank	Number	Section	Page	Paragraph	Comment
B	181	8.3.3.1	8-21	Last	Correcting the CoC concentration in soil for presumed bioavailability greatly reduces the conservativeness of the risk assessment; the text seems inaccurate in referring to this as a very conservative approach. **Since earthworms are mobile creatures that obtain some portion of their exposure from detritus and not soil, JW still considers this approach to be conservative. However, JW concedes that the qualifier "very" can be omitted. (P. 8-22, para 1, line 5)**
B	182	8.3.3.1	8-22	Table 8-6	Calculated Risk/Clay/Field/Copper should be 0.044, and not 0.05. **Based on modifications to the exposure calculations, all calculated Average Daily Doses and Risk Quotients will be amended, and values will be consistent throughout the report. (P. 8-22, Table 8-6)**
B	183	8.3.3.1	8-22	Table 8-7	Calculated Risk/Organic/Field/Copper should be 4.96 and not 4.95 Calculated Risk/Organic/Woodlot/Cobalt should be 0.04 and not 0.05 **Based on modifications to the exposure calculations, all calculated Average Daily Doses and Risk Quotients will be amended, and values will be consistent throughout the report. (P. 8-23, Table 8-7)**
B	184	8.3.3.3	8-32, 8-36, 8-40, 8-44	Tables 8-16, 8-17, 8-18, 8-20	Please provide a footnote explanation (even if it is a reference to a section or a page) in the tables showing the Analysis of Deviance results. These are Tables 8-16, 8-17, 8-18, 8-20 in Section 8 of Vol. I, and C2, C3, C4, and C6 through C9 in Appendix C. **A footnote will be added. (P. 8-16, Table 8-16)**
B	185	8.3.3.5	8-47	2	Please list other factors that may have exacerbated the toxicity observed in the earthworm bioassays. **The fourth sentence in this paragraph is replaced by the following:** **"However, other factors present in these controlled environments, including soil compaction, differences in soil moisture, and availability of natural food, may have influenced the results." (P. 8-49, para 2, line 7)**
B	186	8.3.3.5	8-47	3	As stated in the last sentence of the last paragraph, the field observations were intended to refute or support the bioassay line-of-evidence. The field observations also have some degree of uncertainty associated with them, and should not be considered as the definitive condition that is actually occurring throughout the Study Area. Please change the first sentence of this paragraph from, "Field observation and results of analyses for earthworm found in the Port Colborne area indicate something different is actually occurring," to " "Field observation and results of analyses for earthworm found in the Port Colborne area do not support the bioassay findings." **Suggestion will be incorporated. (P. 8-50, para 2, line 1)**

Rank	Number	Section	Page	Paragraph	Comment
B	187	8.3.4.2	8-49 and 8-50	Paragraph 1 and Table 8-22	Average Daily Dose/Organic/Woodlot/Cobalt is listed as 7.59 mg/kg/d in Volume III, Appendix 6. Using the value listed for cobalt (6.02 mg/kg/d) Calculated Risk/Organic/Woodlot/Cobalt should be 0.29, and, therefore, Calculated Risk/Organic/Woodlot/Combined Toxicologically Similar Effects for Cobalt and Arsenic should then be 0.97. Since this value is less than 1, the discussion on the implications of this value being ≥1 in last paragraph of the preceding page is no longer necessary. **Based on modifications to the exposure calculations, all calculated Average Daily Doses and Risk Quotients will be amended, and values will be consistent throughout the report. (P.8-52, Table 8-22)**
					Note. Comment 188 was missing in the Original CHM2HILL document.
B	189	8.3.4.3	8-51	Table 8-23	Calculated Risk/Clay/Woodlot/Combined Toxicologically Similar Effects for Cobalt and Arsenic should be 0.14, and not 0.014. Calculated Risk/Clay/Field/Combined Toxicologically Similar Effects for Cobalt and Arsenic should be 0.24, and not 0.024. Calculated Risk/Organic/Field/Combined Toxicologically Similar Effects for Cobalt and Arsenic should be 0.23, and not 0.33 **Based on modifications to the exposure calculations, all calculated Average Daily Doses and Risk Quotients will be amended, and values will be consistent throughout the report. (P. 8-53, Table 8-23)**
B	190	9.2	9-13	Table 9-2	The pond water concentrations listed for the Reference Area do not match those presented Table 6-17 and Table 6-20. Although these values are listed for comparison only, the presentation of values should be consistent or alternate sources should be listed/referenced. **Pond water concentrations for Table 6-17 and Table 6-20 will be reviewed and revised as necessary. (P. 9-15, Table 9-2)**
B	191	9.2	9-19	Table 9-3	The Calculated Risk Quotient for CoCs/Cobalt/American Woodcock should be 0.29 or 0.36. **Based on modifications to the exposure calculations, all calculated Average Daily Doses and Risk Quotients will be amended, and values will be consistent throughout the report**
C	192	Appendix C	C-4, C-5, C-13, C-16, C19, C23, C27	Tables C2- through C9	The authors also need to provide a footnote explanation (even if it is a reference to a section or a page) in the tables showing the Analysis of Deviance results. These are Tables C2, C3, C4, C5, C6, C7, C8 and C9 in Appendix C. **As noted above, a footnote will be added.**

Rank	Number	Section	Page	Paragraph	Comment
B	193	Volume II General Note	I	4	Figures 1-1 and 1-2 were not found at the back of this volume as indicated. **The figures are the same figures that are at the back of the report (Volume 1) which were included in the copy of Volume 1 sent to CHM2HILL. However, when notified by CHM2HILL of the absence of the figures in their copy of Volume II, additional copies of the figures were sent by JW.**
C	194	Volume II General Note	--	--	This document outlines the QA/QC procedures for the ERA data collection. However, there is no explanation of how the QA/QC procedure tracks any problems with data that do not meet the QA/QC requirements. It is suggested that the ERA present all raw data with the corresponding analytical and/or validation qualifiers so that data quality can be readily determined by readers. **In Volume V (Tabs 1 through 24) there is a QA/QC report that indicates calculated percent differences between replicates, duplicates and SRMs. Justification of why the data were either included or excluded from the data sets is also provided in this report. The "Quality assurance and quality control protocol for data of the ecological risk assessment CBRA" in Volume II, Tab 3, explains the validation qualifiers that were used to assess the quality of the data.**
C	195	Volume II Tab1; Sec 4	3	---	There are no samples to assure that matrix effects are not present (such as matrix spike/matrix spike duplicates). These samples are collected in the field for a subset (usually 5%) of all tested matrices and may also be considered as an analytical QA/QC procedure. **Travel blanks and blank spikes were taken into the field and analyzed with all samples as part of the QA/QC process. Analytical results of these blanks are presented in the raw data sheets in Volume V, Tabs 25 through 47. Percent differences between these blanks and expected values are presented in the QA/QC report in Volume V, Tabs 1 through 24. Further, Section 4.2 of Tab 1 in Volume II has been changed to indicate that duplicate samples accounted for 10% of all samples to provide an estimate of variability. Process blanks, process % recovery, and matrix spike results were done as part of the laboratories QA/QC. The results for these analyses are shown in the raw data set in Volume V, Tabs 25 through 47.**
C	196	Volume II Tab1, Sec8	10	---	The laboratory QA/QC process stated which QC information is completed for the analyses but does not explain how the results of the QC process are linked to the data (i.e., data quality flags for data which do not meet all QA/QC requirements). This report needs to clearly present acceptability/non-acceptability criteria for each measurement and state how data that do not meet the criteria are handled. **This report will be clarified to provide a detailed description of the qualifiers used to determine the quality of data and how data not meeting criteria were handled.**

Rank	Number	Section	Page	Paragraph	Comment
C	197	Volume II Tab1, Sec9	10	---	Similar to the item above, there is no explanation how data that do not meet the QA/QC requirements are handled. **A sentence has been added to Volume II, Tab 1, Section 9, to explain how data not meeting QA/QC requirements were handled. The handling of data is addressed in the "QA/QC protocol for data of the ERA CBRA", which is located in Volume II, Tab 3. The results are shown in Volume V, Tabs 1 through 24.**
C	198	Volume II Tab1, Sec10	11	---	Similar to item above, it is unclear how qualified data (i.e., not meeting QA/QC requirements) is tracked in a way that allows the reader to judge the quality of any particular result. **This point will be clarified.**
B	199	Volume II Tab4 Sec3	2	---	It is stated that soil/sediment samples were collected in the 'general location' of where biological samples were collected. Determination of accurate bioaccumulation relationships depend on good associations between the abiotic sources and biota. The term 'general location' needs to be more clearly defined. **This sentence has been changed in Volume II, Tab 4, Section 3. The term 'general location' has been changed to 'soil/sediment samples were collected from the same woodlot/field/water body where biological specimens were collected'.**
A	200	Volume II, Table 8. Section 4	3	1	Please provide a description of how sample locations were selected within the Study Area, which includes rationale for sampling locations outside of the Primary and Secondary Study Areas. **Selection of sample locations will be clarified in the Report (Volume 1). See JW's response to comments 105 and 108.**
C	201	Volume III Tab2	---	---	**Maple Dose Response Experimental Data**. Suggestion is to provide footnotes to explain the basic test performed and how site soils were diluted or spiked for the test. To avoid confusion, column headings Class 1 through Class 4 should be defined or use the term 'Leaf Rating #", as shown on the reverse page. **JW agrees with this suggestion.**
C	202	Volume III Tab3	---	---	**Statistical Output**. Suggestion is to organize data so the results of specific tests can be found more easily. This could be done by separating results of different types of tests with different color flysheets, or numbering pages and providing a list of the results with page numbers at the beginning of the attachment. **JW agrees with this suggestion.**

Rank	Number	Section	Page	Paragraph	Comment
B	203	Volume III, Table 4, A4.2	2	2	Line 8. Nickel sulphate is said to make up 20% or less of the total nickel at the site. Although this is not dominant, it is not insignificant as implied. This suggests that the TRV should include studies using this form of nickel. **If the LOEC for nickel sulphate (500 ppm) is considered and a TRV derived from this value, since this nickel species makes up 20% or less of the soil nickel, this could be estimated at 500/0.2 or 2,500 ppm. This is not substantially different from the TRV of 3,000 ppm derived for oxidic nickel. Further discussion of this will be added to the text.**
B	204	Volume III, Table 4, A4.2	4	---	Mammals. More recently (USEPA IRIS reference dose for chronic oral exposure to nickel), the two year feeding study by Ambrose et al. (1976) has been determined to be more reliable than the three-generation study. Based on the two-year study and the rat study reported in ABC (1986) a chronic NOAEL of 5 mg/kg/d and a chronic LOAEL of 50 mg/kg/d were developed. **The Springborn (2000) two generation rat study developed a NOAEL of 10 mg/kg-day. The one generation Springborn (2000) study established a LOAEL of 30 mg/kg-day based on reproductive effects. The nickel TRV will be replaced with the LOAEL from the Springborn study.**
B	205	Volume III, Table 4, A4.3	7	1	Mammals. The description for the Aulerich et al. (1982) study is inaccurate. It should be stated that there were 4 dose levels (25, 50, 100, and 200 ppm). Kit mortality at the 25 ppm was less than controls, but at the 50 ppm and 100 ppm dose was greater than controls. There was a 19 percent mortality rate at 50 ppm, this is approximately a 20 percent effect and should be indicated as the LOAEL instead of the NOAEL as described. Also, the copper in the base feed is presented in dry weight and must be converted to wet weight before addition to the supplemental copper concentration. These two factors would lower the selected copper TRV for mammals. Also, in the 2nd to last sentence, it is said that the NOAELs and LOAELs from this study are similar to those based on other studies, but the other studies are not presented for evaluation. **The discussion for the other dose groups will be added. We disagree that a 20% (or 19%) effect was seen in the 50 ppm dose group. Since 12% mortality was seen in the control group, at best this is a 7% increase and is thus within the range of natural variability. The weight basis of the feed will be reviewed and adjusted if appropriate. Additional studies will be presented for comparison.**

Rank	Number	Section	Page	Paragraph	Comment
B	206	Volume III, Table 4, A4.4	10	2	Birds. It says there are no other suitable studies, but there are other studies (e.g., Southern and Baker 1981) that are very similar to Diaz et al. (1994). Ten papers were identified for TRV development in the Cobalt Eco-SSL document (USEPA 2003). However, it should be noted that none of the studies available are of chronic duration, including Diaz et al. (1994); All are considered subchronic. The application of a subchronic to chronic uncertainty factor of 10 may therefore be appropriate. **Discussion of the results of subchronic studies will be added to the text; however, the chronic study is considered the most appropriate provided conflicting results are not seen.**
B	207	Volume III, Table 4, A4.4	11	1	Mammals. The studies listed do not have endpoints that are readily applicable to population effects in mammalian receptors. Domingo et al. (1985) investigates the effects of cobalt on reproduction in rats. This is a more appropriate endpoint. The LOAEL from this study is 12 mg/kg/d based on decreased pup growth. **Agreed. Appropriate revisions will be made.**
B	208	Volume III, Table 4, A4.5	12	1	Earthworms. Line 4. The reference to Sample et al. (1996) should be changed to Efroymson et al. (1997b). Also, this reference is not listed in the reference section. The value comes from the benchmarks for soil invertebrates document, cited as Efroymson et al. (1997b) in the main text. **The reference will be corrected.**
B	209	Volume III, Table 4, A4.5	13	3	TRV calculation is incorrect. Should be 8 ug/L based on equation A4-1. Efroymson et al. (1997a and 1997b) recommend dividing an LC50 by 5 to get an EC20 (see comment 39). **Agreed. The calculation will be corrected.**
B	210	Volume III, Table 4, A4.5	14	2	Birds. Line 3. Change date in citation from USFWS 1996 to USFWS 1964. **The reference will be corrected.**
B	211	Volume III, Table 4, A4.5	14	Tab. 10	Include Stanley et al. (1994). **The additional data will be added.**

Rank	Number	Section	Page	Paragraph	Comment
B	212	Volume III, Table 4, A4.5	15	1	Lines 3 and 4. NOAELs and LOAELs should be in mg As/kg/day units. **The units for As will be corrected.** Line 10. Sample et al. (1996) did not conclude that the LOAEL was appropriate for the current study. Please rephrase as follows: "Sample et al. (1996) also report lethal… other mammals; therefore, the LOAEL of 1.26 mg As/kg/d selected …" **The wording will be revised as indicated.**
B	213	Volume III, Table 4, general comments	---	---	It would increase the transparency of the TRV selection parameter if all studies reviewed were included (at least in tabular form) with a rationale for inclusion or exclusion in the TRV development. For example, three studies presented in Efroymson et al. (1997b) for nickel exposure to earthworms were not included in Table 1 or associated text, but there is no explanation for this. These data should be presented in Table 1 and then the rationale for the TRV selection should be explained. Also, it would be helpful if more information (e.g., expand the endpoint description or add a new column) was included in the tables presenting summaries of the available data. Please indicate in the text values used for the "adjustments" for relative bioavailability in the bird and mammals sections (e.g., Line 4 of 1st paragraph on page 4). Also, it is not clear in the text whether the adjustment is made to the TRV or to the exposure calculation. Please indicate that the adjustment is made to the exposure calculation. **The additional information requested will be added to expand the appendix and improve clarity.**

Rank	Number	Section	Page	Paragraph	Comment
B	214	Volume III, Table 5	deer	---	White-tailed deer. Diet composition does not add up to 100%. Calculations in Table 6 use a proportion of 33% for maple leaves, not 17% as reported here. The fraction of soil (FS) value says assumed as per guidance in Sample et al. (1996). There is no such guidance in this document. Rather the value for white-tailed deer was assumed to be similar to that reported for mule deer in Sample and Suter (1994) The FR value is made on the assumption of snow cover. Need to explain why snow cover of only 1 cm would impact soil ingestion. No source for this assumption is given. This could underestimate exposure. Smith (1991) reports that body weights for w-t deer in the northern US and southern Canada are 90 to 135 kg for males and 20 to 40 % less for females. This would be a higher average than the value used (56.5 kg) which is the reported overall average for North America. Silva and Downing (1995) present a mean for males and females in New Brunswick of 74.8 kg. **JW agrees with these comments and amendments will be made to the text and the calculations.**
B	215	Volume III, Table 5	fox	---	Red Fox. Include name of study from USEPA (1993) used to develop surrogate diet. It looks like the diet reported by Knable (1974) was used, but frogs are not part of this diet or any other diet listed. Frogs are also not identified as dietary items in the Environment Canada (1993) fact sheet. Why were frogs included? **Frogs were identified as dietary items based on Banfield (1974).**
B	216	Volume III, Table 5	hawk	---	Red-tailed Hawk. NIR for diet exposure – it is not clear whether this is a wet weight or dry weight value. Preston and Beane (1993) report that 12% of the body weight (median of summer and winter) is ingested by r-t hawks or 0.147 kg/kg/d wet weight. Need rationale for FS in soil exposure. For example, the minimum soil ingestion across all species reported in USEPA (1993) was 2 %; therefore, it was assumed that the r-t hawks have a soil ingestion rate of 0.02. IR for soil exposure – why calculate this from equation when literature value available. Convert assuming a moisture content for small mammals (see Sample et al., 1996). **Parameter estimates for Red-tailed Hawk will be examined and amended as needed, with rationale provided.**
B	217	Volume III, Table 5	Meadow Vole	Soil Exposure	The IR is listed as 0.00896 kg/d in Volume III Table 6 for ADD Soil exposure calculations. **This table shows the wrong units (kg/day instead of g/day).**

Rank	Number	Section	Page	Paragraph	Comment
B	218	Volume III, Table 5	raccoon	---	Raccoon. Please indicate the study used to develop the surrogate diet and outline the dietary items that were excluded (e.g., reptiles, fish..). NIR for diet exposure was estimated using equation 3-7 in USEPA (1993) and is a dry weight value. No conversion to wet weight was made. However, as noted in Section 6, this should be a dry weight ingestion rate for use with dry weight tissue concentrations in prey items. Need to explain rationale and provide supporting reference for FR value in soil exposure (as for w-t deer). BW value was reported for southern latitudes (Environment Canada 1989b). Not sure if this meant southern latitudes in Canada or across the range of the species. My guess is that it is for the range of the species and raccoons in Ontario are more likely to be 6-8 kg (7 kg average) as reported for northern latitudes. IR for air exposure reduced to 1.65 m^3/d using if a body weight of 4.0 used. **Rationale will be provided for the Raccoon's diet and other exposure parameters.**
B	219	Volume III, Table 5	robin	---	American Robin. It would be good to indicate the body weight used in parameter calculations (e.g., NIR) if different from the body weight value listed in the table. Though it is recommended that these values be re-calculated from the models (provided in USEPA 1993 and in Sample et al., 1996) using the body weight selected for use in the exposure model. *This applies to all receptors*. Indicated that the NIR for diet exposure is based on observed ingestion of 1.4 kg of food every two weeks is for nestlings. The FS for soil exposure is not provided in USEPA 1993. You will need to use a rationale for developing the value used. Sample and Suter (1994) have used a value of 0.021 based on the following rationale: "No value for American robin available. Though a value is available for another avian species that consume earthworms (10.4% for American woodcock; Beyer et al. 1994 [also in USEPA 1993]), the woodcock diet is >60 to 99% earthworms, whereas the robin diet is <20% earthworms. Therefore, soil ingestion value represents the woodcock soil ingestion proportioned to the percent of earthworms in the robin diet." The IR value for air exposure should be 0.06 m^3/d using equation 3-19 in USEPA (1993).). This would reduce risk as this rate is lower than that used in the ERA.. Also, the inhalation equation is for non-passerine birds, therefore, it should be noted in the uncertainties in Section 6 that the metabolic rate (and thus respiration rate) of passerines tend to be higher than for other birds such that use of this equation likely underestimates exposure to robins from air (also true for vireo). **American Robin parameter estimates will be re-assessed and amended as needed, supported by JW's rationale.**

Rank	Number	Section	Page	Paragraph	Comment
B	220	Volume III, Table 5	vireo	--	Red-eyed Vireo. NIR for water exposure was not estimated by USEPA (1993), but was estimated using Equations 3-15 and 3-16 from USEPA (1993). As stated earlier in these comments, wild grapes (or other fruit) are unlikely to be a significant part of the vireo diet because they are only present in the study area during the breeding season. Diet should be 100 percent arthropods. NIR for diet exposure. Looks like a wet weight was estimated using Equation 3-4 in USEPA (1993) to get a dry weight and then converting to a wet weight. Please provide the values used for this conversion (i.e., what moisture content was assumed). As with robin, need rationale for FS value selected as this species is not included in USEPA (1993). The IR value for air exposure should be 0.02 m^3/d using equation 3-19 in USEPA (1993). This would reduce risk as this rate is lower than that used in the ERA. Please add the BW in the air exposure section as with other receptors for consistency. As with the woodcock, please indicate here that the water exposure pathway was not evaluated because this species is expected to derive it's water the diet or from water on leaves (as stated in Section 5 text). Also, please provide associated references. **Red-eyed Vireo parameter estimates will be re-assessed and amended as needed, supported by JW's rationale. Water was not considered a pathway for Red-wyed Vireo.**
B	221	Volume III, Table 5	vole	---	Meadow vole. Please indicate whether the diet composition is averaged across all seasons. The IR value under soil exposure is expressed in the incorrect unites. It should be 0.008876 kg/day. (Note: the correct value was used in the calculations in Section 6.) Also, please include the moisture content (mc) used for the dry weight conversion to IR under soil exposure. As described we were unable to check this calculation. *This applies to all receptors*. **Meadow Vole parameter estimates will be re-assessed and amended as needed, supported by JW's rationale.**
B	222	Volume III, Table 5	White-tailed Deer	Diet Exposure	DF_k for Maple leaves should be 33% and not 17% **Agreed, as noted above.**

Rank	Number	Section	Page	Paragraph	Comment
B	223	Volume III, Table 5	wood-cock	---	American Woodcock. The IR value for air exposure should be 0.12 m^3/d using equation 3-19 in USEPA (1993). This would reduce risk as this rate is lower than that used in the ERA. Text in Section 5 indicates that the water exposure pathway is not evaluated because woodcocks get all their water from the diet and are not known to drink water. This with the associated source should be indicated here as it currently appears that water exposure was calculated. **American Woodcock parameter estimates will be re-assessed and amended as needed, supported by JW's rationale. Water was not included as a pathway for American Woodcock.**
B	224	Volume III, Table 5, general comments	---	---	NIR for diet exposure should be presented on a dry weight basis for use in the exposure calculation because the concentrations for prey items are reported on a dry weight basis*. This applies to all receptors.* **Agreed.**
B	225	Volume III, Table 6	2	---	The final risk calculation should be 0.28, instead of 0.25. **Based on modifications to the exposure calculations, all calculated Average Daily Doses and Risk Quotients will be amended, and values will be consistent throughout the report.**
B	226	Volume III, Table 6	America n Robin Total Risk	Table	ADD/Woodlot on organic soils/Nickel should be 21.59 mg/kg/d, not 21.61 mg/kg/d **Based on modifications to the exposure calculations, all calculated Average Daily Doses and Risk Quotients will be amended, and values will be consistent throughout the report.**
B	227	Volume III, Table 6	Exampl e Calculat ion Page 2	3	The reference to Table 6-31 should be to Table 6-17. The calculated risk in the example equals 0.28, not 0.25 **Based on modifications to the exposure calculations, all calculated Average Daily Doses and Risk Quotients will be amended, and values will be consistent throughout the report.**
B	228	Volume III, Table 6	Tables	--	It is recommended that exposure concentrations, particularly for air (ADD Air), be changed from 0 mg/kg/d to the lowest level of confidence, such as ≤0.01 mg/kg/d. **Inhalation of air is excluded as a pathway, as discussed above.**

Rank	Number	Section	Page	Paragraph	Comment
A	229	Volume III, Table 6, general comments	---	---	When individual ADD was very small, it was misleading to present the value as "zeros". The magnitude of the dose depends on the level of the toxicity reference value. This is particularly true for the ADD for air which was often <0.01 and was presented as being 0. Even reporting this as 0.00 indicates to the reader that there was a value, but it is very low a lone 0 suggests that there is no exposure. Although this issue was replete in the entire dose and risk calculations, none of the risk calculations that were QA'd were significantly impacted such that hazard quotient values were changed. For all future revisions, it is advisable to present small ADDs in scientific notation or as <0.01. Calculations are rounded arbitrarily to various significant figures. There is no discernable pattern for presenting calculated values in terms of a consistent significant figures. As a result, the QA'd values may deviate from the values presented in the report, although the differences are only in the thousandth, and occasionally, the hundredth place. Values should be rounded to the least precise values. Because of the uncertainty remain in many of the input parameters, the result should probably be presented in two significant figures, at best. Values that appear to be erroneous because of rounding errors are not provided because it does not impact the risk conclusion. See issue regarding the calculation of body concentrations for avian prey using dose calculations. This approach is questionable, and possible errors identified in the equation will impact exposure estimates for the red fox and the white-tailed deer. **Presentation of results will take into consideration the above comments.**
C	230	Volume III Tab7	---	---	**Soil Data Used to Calculate UCLMs**. Suggestion is to better document information sources and define the units of measurement. Any cryptic or abbreviated information should be defined in footnotes. It would also be useful to provide a footnote to explain where the soil data were collected (i.e., surface soils or other) and provide a collection date for data. **JW will endeavour to be as clear as possible with measurements and abbreviations, which is helped by this concise and constructive review.**
B	231	Volume III, Table 7	raccoon	---	Raccoon calculations: the copper concentration in oat seeds in woodlots (clay soil) should be 6.8 mg/kg, not 6.7. This did not impact the ADD diet value. The food fraction (FR) should be 6.2% for oat seeds instead of 6.4%. This did not impact the ADD diet value **Based on modifications to the exposure calculations, all calculated Average Daily Doses and Risk Quotients will be amended, and values will be consistent throughout the report.**

Rank	Number	Section	Page	Paragraph	Comment
B	232	Volume III, Table 8	Total Frog CoC Concent rations	Table	H-1-E concentrations are not the same as those listed in the raw data sheets. Sample “H-2-I” should be “H-2-E” Total Ni/C-5-B should be 0.14, not 0.02 **This was the result of a simple computing error, as discussed above.**
B	233	Volume III, Table 8	Total Tadpole Concent rations	T-H-3	Please note that the weight of the GI (2.062 g) is high relative to the total weight (2.351 g). Please double-check these weights. Note that moisture contents (mc) are as percentages, and in previous tables they are reported as proportions. Please be consistent. Total Ni/T-H-3 should be 145 mg/kg, not 143.47 mg/kg Total Cu/T-H-3 should be 76.2 mg/kg, not 75.18 mg/kg Total Co/T-H-3 should be 11.83 mg/kg, not 11.63 mg/kg Total Ni/V-H-5-2 should be 23.15 mg/kg, not 23.04 mg/kg. **Values will be double-checked, but the weight of the GI tract is indeed a very large proportion of the tadpole’s total weight. Especially when small, tadpoles can be described as mobile GI tracts.**

CHM2Hill Comments to JW Response			JW's Response
Rank	**Number**	**Issue**	
General Comments:			
B	11	The text should be revised to indicate the documents and sections of the report where the information may be found. In addition, one single unified CSM should be developed that documents the multiple interrelationships at the site.	**A figure displaying the multiple interrelationships at the site. A summary of CoCs, exposure pathways modeled, exposure pathways measured, and VECs selected will be provided as a separate section of the report (including the figure mentioned above), bringing together all of the components of the CSM (P. xiv and P.2-28).**
C	14	The response (which is the same as that for Comment 2) does not address the question. The issue is that the report does not provide a clear view of the full dataset on which the CBRA is based. Different subsets of data are extracted and used to support different arguments. Without a summary of what constitutes the complete master dataset, the validity of these comparisons cannot be evaluated.	**A summary for each sample matrix chemically analysed is provided in each section of Volume V along with the master data sheets. Based on our professional judgment for the ERA, it was not always appropriate to use the full data set for a particular data set (ie surface water). In this case, a subset of the data was used for calculating risk or for illustration purposes in Volume 1. In these situations, references to the samples used are provided against the data presented. This enables the reader to see the data used, and compare this data to the overall master data set presented in Vol. V. (Vol. V)**
C	21	Although the MOE may have documents that include all necessary information, it is very important that adequate details be provi ded within each report to allow a complete review. The report should summarize the key information and reference the documents where more details may be located.	**JW is of the opinion that section 2.1.3.1 "Distribution of CoCs in Soils" does provide a sufficient level of detail. However, to direct the reader to the reports from which the data in this section was summarised, the following will be added at the start of the section.** **"The following provides a summary of the distribution of CoCs in soils in the local Port Colborne area. For a detailed assessment, the following reports should be consulted, "Potential CoC identification Using Soil Chemical Concentration Data in Exceedance of MOE Generic Guidelines" (JW 2001a) and "Soil Characterisation. Port Colborne Community Based Risk Assessment" (JW 2002c)."(P.2-4, Sec. 2.1.3.1, first para.)**

CHM2Hill Comments to JW Response			JW's Response
Rank	**Number**	**Issue**	
General Comments:			
Specific Comments:			
B	3	The report needs to contain adequate documentation to allow any reader to understand what analyses were conducted on which data. Although the MOE may have documents that include all necessary information, it is very important that adequate details be provided.	**A map showing the distribution of soil sampling points will be provided with a footnote directing the reader to the corresponding analytical data for these points that was used to generate the isopleths (Vol. III, tab 9).**
B	12	The response to Comment 41 addresses the soil depth question. The BAF comment is not addressed, however.	**BAFs are no longer discussed in the Executive Summary. Section 6.4.1 has been expanded to address BAFs. (P. 6-10)**
B	23	Because the results of the ERA-Crop Studies has direct relevance to the evaluation of risks to native plants, it is essential that results from this study be integrated into the evaluation of native plants in this report. An alternative would be to remove native plants entirely from this report and add them to the Crop Studies report. In addition, the report needs to contain adequate documentation to allow any reader to understand what analyses were conducted on which data. Although the MOE may have documents that include all necessary information, it is very important that adequate details be provided within each report to allow a complete review. The report should summarize the key information and reference the documents where more details may be located.	**As stated in our initial response, JW agrees that the results of the ERA-Crop Studies have direct relevance to the evaluation of risk to plants that occur in the natural environment. However, given the complexity and breadth of the ERA-Crop Studies Reports, sumarisation of this study in the ERA-Natural Environment Report to a level that would provide sufficient detail is not possible. Therefore, for the CBRA, the assessment of risk to natural growing plants, and need for site remediation, will be addressed and integrated in the CBRA Integration Report. The Integration Report will summarise the results of the three CBRA study reports, the HHRA, ERA-Natural Environment, and ERA-Crop Studies.** **For the ERA-Natural Environment, the following will be added to section 1.4.3 Components of this ERA** **"For the ERA, the results of the Crop Studies will be used to assess the potential risk of elevated levels of soil CoCs on non-woody vascular plants that occur in the natural environment. This assessment will be undertaken during the integration phase of the CBRA, and will be detailed in the Integration Report." (P. 1-11, section 1.4.3)**

CHM2Hill Comments to JW Response			JW's Response
Rank	**Number**	**Issue**	
General Comments:			
C	36	The report needs to contain adequate documentation to allow any reader to understand what analyses were conducted on which data. Although MOE may have documents that include all necessary information, it is very important that adequate details be provided.	**JW is of the opinion that combined sections 2.1.3 and 3.4 do provide adequate detail for the soils of the study area. To insure that the reader is directed to key supporting documents to the ERA-Natural Environment, the following will be added in Section 1.4.4 Outline of the ERA – Natural Environment Report** **"For a comprehensive technical review of the ERA – Natural Environment, the reader should consult all five volumes of this report. In addition, in conjunction with the five volumes of this report, two other reports are identified as required for a detailed technical review, these include "Potential CoC identification Using Soil Chemical Concentration Data in Exceedance of MOE Generic Guidelines" (JW 2001a) and "Soil Characterisation. Port Colborne Community Based Risk Assessment" (JW 2002c). (P. 1-14, para. 1, line 1)**
B	39	The table and text described in the response to Comment 41 will summarize the data concerning concentration variation over depth. Additional discussion concerning how locations for test pits were selected is needed.	**See response to 36 above.**
B	43	These distances should be reported in the text or as a footnote to the table.	**Distances between woodlots and adjacent fields will be added as a column in the table (P. 2-12, table 2-4).**
B	45	Additional summary statistics are recommended. Presenting means and standard deviations implies that the data are normally distributed and it is highly unlikely that these data are. They are more likely to be lognormally distributed. Minimum and maximum concentrations and frequency of detection data should be provided to provide the most complete description of these data.	**Minimums and maximums have been added to tables where appropriate (E.g. P. 2-14, table 2-5). However other summary statistics for the tables referenced were considered to be not required.**

CHM2Hill Comments to JW Response			JW's Response
Rank	**Number**	**Issue**	
General Comments:			
B	54	Bioavailability represents the potential that biota will be able to access and remove an analyte from (in this case) a soil matrix. Bioavailability is a function of the form of a chemical and attributes of the matrix. Neither of these are affected by rain or snowmelt. The simplest solution to this issue is to delete the text: '...and potentially increasing bioavailability.'	**This sentence will now state "When considering conditions in the Study Area, the aqueous extraction is the closest representation of potential conditions where heavy rains or snowmelt would leach CoCs from the soil, thereby mobilizing CoCs." (P. 1-17, line 2)**
B	64	Although the aquatic environment may not be within the scope of the CBRA, it's contributions to the terrestrial receptors cannot simply be ignored. Amphibians use these sites and raccoons forage from them. Some reference should be included to indicate these linkages and relationships. In addition, because these aquatic-to-terrestrial pathways are specifically excluded, they should be noted in the Uncertainty section.	**We agree, and included certain components of the aquatic environment within the ecological risk assessment where they have a link to the terrestrial environment, such as the input of potential exposure to CoC concentrations in surface water and amphibian tissues. We will add the following text to this paragraph:** **"Additionally, CoCs may be ingested by certain receptors through the capture and predation of aquatic invertebrates not sampled as part of this CBRA." (P. 2-23, para. 2, line 6)**
B	70	A note describing these spatial relationships should be included in the text, with a reference to Map 1. The current description is not sufficient.	**Spatial relationships between water samples will be discussed in the text, with a reference to Map 1. (P. 2-25, table 2-10)**

CHM2Hill Comments to JW Response			JW's Response
Rank	**Number**	**Issue**	
General Comments:			
A	72	The response to this comment provides several reasons why any effort to evaluate potential effects on herbaceous plants would be unable to discern an effect. It does not however address the issue of whether or not herbaceous plants would or could actually be affected. In our opinion, data probably could have been collected that may have displayed and effect (if one was present). The plant community need not be native nor undisturbed to be affected by contamination. We recognize however that at this stage of the assessment, additional field data are unlikely to be collected. Therefore, in addition to inclusion of the proposed text, we recommend adding text in the Uncertainty section to indicate that the herbaceous plant community is potentially more highly exposed that the tree community and that data are lacking to support or refute the presence of effects on the herbaceous plant community.	**As noted in JW's response to 23 above, for the ERA, the results of the Crop Studies will be used to assess the potential risk of elevated levels of soil CoCs on non-woody vascular plants that occur in the natural environment. This assessment will be undertaken during the integration phase of the CBRA.**
B	73	Result of the two-year field survey for rare species of flora and fauna need to be included.	**The following will be added to this section.** **"Nevertheless, the potential for rare species of flora and fauna to occur in the Study Area that had not been documented in existing data bases was recognized and therefore extensive field investigations were undertaken over a two year period. These field investigations identified the occurrence of provincially rare bird, amphibian and tree species within the study area." (P. 3-4, para. 1, line 4)**
C	75	Reference for the Soil Characterization Report needs to be included in the text as does a brief summary of the requested data.	**The reference for the soils report is provided, Jacques Whitford 2002c, in the first paragraph of section 3.4. As discussed in our responses to soil issues above, JW is of the opinion that directing the reader to the soils report for detailed information is more appropriate than providing a summarisation of a detailed data set. (P. 3-5)**

CHM2Hill Comments to JW Response			JW's Response
Rank	**Number**	**Issue**	
General Comments:			
A	84	We recognize that the evaluation of risks to plants is addressed in another report. However, to be complete and thorough, we recommend that the report be referenced and the key findings need to be presented and discussed in relation to the findings for woodlots and maples trees. Otherwise, only a partial evaluation of the ecological risks to plants is presented.	**See response JW's response to 23 above.**
B	90	We recognize that the public decision process places limitations on the analysis. Nevertheless, because meadow voles are not among the most highly exposed small mammal receptors, some text should be added to the Uncertainty section that indicates the risks to omnivorous and insectivorous small mammals may be under-represented.	**We disagree that meadow voles are not among the most highly exposed small mammals receptors, but do agree that shrews have the potential to receive greater CoC exposure. We will discuss this in the Uncertainty section. Furthermore, we have calculated the risk to Common Shrew (Sorex cinereus) and have presented the cal culation as an addendum at the end of this Appendix. The calculation shows that shrews are not at risk through exposure to CoCs.**
B	92	see comment 100 - the responses are contradictory	**Our previous answer is not contradictory with what we presented in response to Comment 100. We do not have data pertaining to measured abundance of adult frogs along the lakeshore. We have data on relative abundance, assessed qualitatively using standard protocol, on calling frogs throughout much of the study area.**
B	94	However, information regarding the method of estimation should be included as part of the tadpole evaluation.	**Estimation method will be inserted in text. (P. 3-32, para. 2, line 2)**
A	95	See comment 96 below.	**See comment 96 below. In addition, comment on the uncertainties associated with the breeding bird survey will be specifically discussed in the uncertainty analysis.**

CHM2Hill Comments to JW Response			JW's Response
Rank	**Number**	**Issue**	
General Comments:			
A	96	We continue to believe that the data are insufficient to make the strong conclusions proposed. We recommend that the text be limited to factual statements that are clearly supported by the data. To that end we recommend the deletion of two sentences from the second paragraph of Section 3.11: - the 2nd sentence ('In this respect, the area with elevated soil soil CoCs....'), and - the final sentence ('Based on these findings, it would appear that...')	**JW agrees, these two sentences will be removed from the text. (P. 3-36, para. 2 and 3)**
B	98	We recognize that the public decision process places limitations on the analysis. Nevertheless, because meadow voles are not among the most highly exposed small mammal receptors, some text should be added to the Uncertainty section that indicates the risks to omnivorous and insectivorous small mammals may be under-represented.	**See our response to Comment 90.**

CHM2Hill Comments to JW Response			JW's Response
Rank	**Number**	**Issue**	
General Comments:			
A	99	This statement is acceptable As a point of clarification, in USEPA (1997) the reference to a 40% mortality effect is presented as an example of a potentially unacceptable level of effect, not as a definitive statement that this level of effect is unacceptable. USEPA (1997) does not discuss whether a 20% level of a less severe effect is acceptable. If that level is chosen for this assessment, that is OK - it simply needs to be stated something like: 'For the purposes of this assessment, up to a 20% effects level of a less severe nature (DEFINE WHICH EFFECTS - GROWTH, REPRODUCTIVE IMPAIRMENT, ETC.) were assumed to be an adequate level of protection...' A better justification for the 20% effect level is presented in Suter et al. (2000), pages 40-41. Finally, although the statement a 20% effect level may not be suitable for some species is correct, LOAELs and NOAELs are not equivalent alternatives. Whereas EC20s or ED20s are derived by does-response curve fitting and represent precise levels of effects, LOAELs and NOAELs are derived by hypothesis texting statistics and do not. A NOAEL is the highest dose that did not differ statistically from the controls and the LOAEL is the lowest dose that did differ statistically. The level of effects associated with the LOAEL is therefore undefined and is a function of the quality of the study design. Large sample sizes may show LOAELs with low levels of effects; small sample sizes would generally have high levels of effects. For this reason, the final sentence of the proposed revision should refer only to NOAELs.	**The text will be reworded as indicated. The final sentence will be worded as follows:** **"For these types of populations, an effect level at or near the No Observable Effects Level (NOAEL) is considered a more appropriate endpoint." (P. 4-8, para. 2, line 3)**

CHM2Hill Comments to JW Response			JW's Response
Rank	**Number**	**Issue**	
General Comments:			
B	100	The response to this comment is inconsistent with the response given to Comment 92, in which it was stated that no statistical analyses were performed on the abundance of adult amphibians. Clarification of these responses should be provided.	**As stated in our response to Comment 92, measured quantitative data on the abundance of adult frogs were not collected, although calling frog surveys were conducted throughout the study area. These qualitative data were statistically analysed.**
A	102	The response to comment 99 does not address this issue. Inclusion of specific text that relates the selected assessment endpoints back to the stated study objectives is highly recommended to allow readers to judge the appropriateness of measures against the goals of the assessment.	**The following paragraph will be added:** **"The measurement endpoints shown in Table 4-2 were selected to achieve the study objective of determining ecological risk at a population level. For frogs, survival of tadpoles described with a 20% effects level was selected as appropriate since the tadpole is a particular sensitive life stage. Adult survival and abundance at a 20% effects level was selected as the lowest directly measurable population response for both adult frogs and earthworms. For forest-specific effects, the 20% effects level was again selected as the lowest directly measurable risk at a population level. For mammals and birds, a NOAEL (or the LOAEL if at or near the NOAEL) was selected as a measure of the study objective since this no or lowest observable effect level is considered indicative of not having populations effects."(P. 4-8, para. 3)**
B	119	We disagree. Bioaccumulation is a nonlinear process and varies in accordance with changes in concentration. Although the pathways presented are generally appropriate, the emphasis for this section would be much improved had it identified the areas where the accumulation and risk is greatest.	**This section will be expanded upon to highlight the areas where transfer from one trophic level to the next is greatest. (P. 6-13, para. 1, last line)**
B	124	We disagree. Although exposure pathways for some secondary consumers and top predators pass through plants, all do not. For example, consumers of earthworms do not have a plant pathway. We recommend a revision: 'One of the key pathways…'	**We accept the recommended revision to the sentence. (P. 6-13, para. 2, line 1)**

CHM2Hill Comments to JW Response			JW's Response
Rank	**Number**	**Issue**	
General Comments:			
B	130	Although field samples are invaluable in ERAs, given the limited distribution of grapes, the dose estimates may not be representative of VECs in the Study Area. This needs to be discussed in the Uncertainty section.	**Discussion of this source of uncertainty will be added. (P. 10-9, table 10-5)**
A	145	We disagree. BAFs are derived by dividing a concentration in tissue (mg/kg) by a concentration in soil (mg/kg), resulting in a unitless value. There is no time component in a BAF. Therefore the approach used is incorrect. We concur that the use of other vertebrates to approximate concentrations in birds is not accurate. However, the uncertainty associated with these site-specific data is less than that associated with current approach employed in the assessment. We reiterate our strong recommendation to use other site-specific vertebrate data to approximate birds, accompanied by a discussion about uncertainties in the Uncertainty section.	**The nomenclature will be corrected to indicate that these are transfer factors with the units of d/kg, not BAFs. (P. 6-35, equation 6-5) A reference for the corrected equation/nomenclature/units will be provided. (P. 6-36, table 6-14)**

CHM2Hill Comments to JW Response			JW's Response
Rank	**Number**	**Issue**	
General Comments:			
A	147	The response generally addresses the spatial and habitat scope issues. To add clarity to the report, this material should be included in the text. The comments concerning risk to earthworms and the inconsistency between the evaluation for deer, raccoon and hawk however, were not addressed.	**This material will be added to the text.** **For earthworms, a recommended target concentration protective of local (point) earthworm populations will be recommended. This will allow identification of local areas where earthworms may be at an increased risk. Conclusions regarding risk to earthworms will be appropriately amended. This will be used to augment the study-wide population risk evaluation, answering the question of risk at specific points. (see Section 11)** **The greater mobility of White-tailed Deer in the Study Area (as per information from the MNR), their frequent use of different habitats on a daily basis and their regular forage on both field plants and forest plant led to the difference in evaluation methods.**
A	172	In the case of the risk evaluation for plants, it is important to link the results of the two assessments. Plants are a critical component of the natural environment. We recommend that text be added acknowledging this, stating that they were evaluated in detail in the Crop Studies report, and summarizing the key conclusions in this report	**See JW's response to 23 above.**
B	174	Decrease in biota concentration as soil concentration of CoC decreases is accounted for by the bioaccumulation factor, thus it would be incorrect to account for the decrease by proportionally adjusting the concentration in biotic and abiotic media.	**This would be true if bioaccumulation factors were used, which they were for Red-tailed Hawk and Red Fox. However, with the exception of the hawk and fox, only field data of diet items were inputted into exposure calculations. As a result, the relationship between soil and biotic CoC concentrations is incorporated within the derivation of "safe" concentrations.**

CHM2Hill Comments to JW Response			JW's Response
Rank	**Number**	**Issue**	
General Comments:			
A	179	Literature-based TRVs from the crop-studies report should be compared to the NOECs for the site-specific bioassays to provide an insight into the sensitivity of maples and the protectiveness of these tests for other plant species.	**Final assessment of potential risk to plants including trees will be undertaken using results of the crops studies and the ERA for the natural environment in the development of the integration report as part of the CBRA process. In addition the ERA natural environment report has identified that woodlots with soil nickel greater than 3500 mg/kg nickel for organic and 3000 mg/kg for clay soils should be considered for risk management. (see Section 11)**
B	203	This response is only true if there is no toxicity associated with the other forms of nickel that are present. If there is toxicity with these other forms (which is likely) they will drive down the overall toxicity value. In addition, because 2500 is 17% lower than 3000, we would argue that this is a substantial difference. Regardless, some discussion should be included to indicate whether the spatial distributions of the nickel compounds are similar. If they are similar, then the pooled approach suggested is acceptible. If they are not the same and nickel sulfate is the dominant form in some areas, then an effort should be made to apply toxicity values that represent the form in each area. Whichever situation exists, this issue needs to be described in detail in the Uncertainties section.	**Further review of the speciation of nickel in soils pertinent to the natural environment indicate that it's almost exclusively in oxidic forms. The original TRV of 3,000 ppm nickel is thus considered appropriate. Further discussion of speciation results will be added to the text. (Vol. III, tab 4)**
B	206	Because chronic studies are considered most appropriate and because none of the papers including Diaz et al. (1994) are chronic, application of a subchronic to chronic uncertainty factor of 10 may be appropriate to extrapolate from subchronic to chronic exposure will be necessary.	**This change has been made. (Vol. III, tab 4)**

CHM2Hill Comments to JW Response			JW's Response
Rank	**Number**	**Issue**	
General Comments:			
B	221	Need to re-assess all receptors for the dry weight conversion to IR under soil exposure.	**This has been done. (Vol. III, tab 4)**

Common Shrew
Total Risk

Scenario	CoC	ADD (mg/kg d)	TRV (mg/kg d)	Risk
Woodlot on clay soils	Nickel	7.26	39	0.19
	Copper	3.12	14	0.22
	Cobalt	0.39	17	0.02
	Arsenic	0.18	1.4	0.13
Woodlot on organic soils	Nickel	8.76	39	0.22
	Copper	5.07	14	0.36
	Cobalt	0.85	17	0.05
	Arsenic	0.47	1.4	0.34
Field on clay soils	Nickel	7.19	39	0.18
	Copper	4.11	14	0.29
	Cobalt	0.52	17	0.03
	Arsenic	0.36	1.4	0.26
Field on organic soils	Nickel	7.27	39	0.19
	Copper	3.76	14	0.27
	Cobalt	0.41	17	0.02
	Arsenic	0.35	1.4	0.25

Common Shrew
ADD Water

CoC	Concentration (mg/l)	Total Fraction	NIR (kg/kg d)		ADD (mg/kg d)
Nickel	0.178	1	0.223		0.04
Copper	0.018	1	0.223		0
Cobalt	0.006	1	0.223		0
Arsenic	0.005	1	0.223		0

Common Shrew
ADD Diet

Scenario	CoC	Food	Concentration (mg/kg)	Food Fraction	Total Fraction	Ingestion Rate (kg/d - dw)	Body Weight (kg)		ADD (mg/kg d)
Woodlot on clay soils	Nickel	grapes	1.6	0.131	1	0.000378	0.0045		7
		earthworms	180	0.4345					
		arthropods	12.4	0.4345					
	Copper	grapes	12	0.131	1	0.000378	0.0045		3.1
		earthworms	52	0.4345					
		arthropods	29.6	0.4345					
	Cobalt	grapes	0.03	0.131	1	0.000378	0.0045		0.39
		earthworms	10.1	0.4345					
		arthropods	0.46	0.4345					
	Arsenic	grapes	0.1	0.131	1	0.000378	0.0045		0.17
		earthworms	4.2	0.4345					
		arthropods	0.3	0.4345					
Woodlot on organic soils	Nickel	grapes	1.6	0.131	1	0.000378	0.0045		7
		earthworms	180	0.4345					
		arthropods	12.4	0.4345					
	Copper	grapes	12	0.131	1	0.000378	0.0045		4.7
		earthworms	52	0.4345					
		arthropods	72.6	0.4345					
	Cobalt	grapes	0.03	0.131	1	0.000378	0.0045		0.82
		earthworms	21.9	0.4345					
		arthropods	0.46	0.4345					
	Arsenic	grapes	0.1	0.131	1	0.000378	0.0045		0.36
		earthworms	8.9	0.4345					
		arthropods	0.8	0.4345					
Field on clay soils	Nickel	grapes	1.6	0.131	1	0.000378	0.0045		7
		earthworms	180	0.4345					
		arthropods	12.4	0.4345					
	Copper	grapes	12	0.131	1	0.000378	0.0045		4.1
		earthworms	52	0.4345					
		arthropods	57	0.4345					
	Cobalt	grapes	0.03	0.131	1	0.000378	0.0045		0.52
		earthworms	13.7	0.4345					
		arthropods	0.46	0.4345					
	Arsenic	grapes	0.1	0.131	1	0.000378	0.0045		0.36
		earthworms	9.6	0.4345					
		arthropods	0.3	0.4345					
Field on organic soils	Nickel	grapes	1.6	0.131	1	0.000378	0.0045		7
		earthworms	180	0.4345					
		arthropods	12.4	0.4345					
	Copper	grapes	12	0.131	1	0.000378	0.0045		3.7
		earthworms	52	0.4345					
		arthropods	44.6	0.4345					
	Cobalt	grapes	0.03	0.131	1	0.000378	0.0045		0.4
		earthworms	10.6	0.4345					
		arthropods	0.46	0.4345					
	Arsenic	grapes	0.1	0.131	1	0.000378	0.0045		0.32
		earthworms	8.2	0.4345					
		arthropods	0.5	0.4345					

Common Shrew
ADD Soil

Scenario	**CoC**	**Concentration (mg/kg)**	**Soil Fraction (kg/kg dw)**	**Ingestion Rate (kg/d)**	**Food Fraction**	**Body Weight (kg)**	**ADD (mg/kg d)**	**Bioaccessible Ratio**	**Bioaccessible ADD (mg/kg d)**
Woodlot on clay soils	Nickel	1630	0.021	0.000378	1	0.0045	2.88	0.078	0.22
	Copper	180	0.021	0.000378	1	0.0045	0.3	0.058	0.02
	Cobalt	33	0.021	0.000378	1	0.0045	0.06	0.043	0
	Arsenic	12	0.021	0.000378	1	0.0045	0.02	0.27	0.01
Woodlot on organic soils	Nickel	15200	0.021	0.000378	1	0.0045	26.81	0.064	1.72
	Copper	2020	0.021	0.000378	1	0.0045	3.56	0.105	0.37
	Cobalt	219	0.021	0.000378	1	0.0045	0.39	0.083	0.03
	Arsenic	83	0.021	0.000378	1	0.0045	0.15	0.74	0.11
Field on clay soils	Nickel	1090	0.021	0.000378	1	0.0045	1.92	0.078	0.15
	Copper	140	0.021	0.000378	1	0.0045	0.25	0.058	0.01
	Cobalt	27	0.021	0.000378	1	0.0045	0.05	0.043	0
	Arsenic	8	0.021	0.000378	1	0.0045	0.01	0.27	0
Field on organic soils	Nickel	2020	0.021	0.000378	1	0.0045	3.56	0.064	0.23
	Copper	308	0.021	0.000378	1	0.0045	0.54	0.105	0.06
	Cobalt	37	0.021	0.000378	1	0.0045	0.07	0.083	0.01
	Arsenic	20	0.021	0.000378	1	0.0045	0.04	0.74	0.03

APPENDIX B

JACQUES WHITFORD RESPONSE TO PUBLIC COMMENTS

Port Colborne Community Based Risk Assessment

Ecological Risk Assessment – Natural Environment

Public Review of Draft Report – July 2003

Introduction

As part of a Community Based Risk Assessment (CBRA) initiated by Inco Limited to address potential impacts resulting from historical emissions from a former nickel refining in Port Colborne, Jacques Whitford (JW) completed an Ecological Risk Assessment (ERA) for the natural environment of Port Colborne. Following completion of two years of fieldwork and analysis of data, JW prepared draft ERA report in July 2003. Following the CBRA process, copies of the report was presented to the City of Port Colborne (PLC) and the public for review and comment.

The public review comment period was concluded in June 2004. During this review period, the PLC received to formal written response for the public. This Appendix prepared by JW combines the comments of the individual's review comments, with JW's response to those comments.

The format of the appendix is to present the individual questions and comments in their entirety, with JW's response in bold following each question, statement or comment.
Comments that question specific results or methods of assessments have been fully addressed in this Appendix and/or in the report under this cover.

The following comments were provided by Ms Ellen Smith, 91 Rodney St., Port Colborne, ON L3K 1A4. Ms Smith's comments are presented in full with Jacques Whitford's response, in bold, following each comment.

Comments, questions or concerns on Jacques Whitford's Draft Natural Environment Report dated July 2003:

Volume 1:

Executive Summary:

- pg iii - (first para.) - clarification - CBRA process was initiated in January 2000 not May 2000.

The Executive Summary no longer includes this information on timeline.

- pg iv - (last para.) - clarification - Where was the high level of "33,000 ppm nickel found within 500 m to the Refinery site"?

This high level was found in the woodlots along Reuter Road, just east of the Refinery site.

- pg xi - (2nd para.) - clarification - What is the "MOE current upper limit of normal concentrations for metals in tree foliage"? Where is this value located in the literature?

The current MOE upper limit of normal concentrations for metals in tree foliage is presented in Table 9-1 of the report reviewed.

The reference, which is provided in the report in Section 9.0 is as follows, (MOE 1993) Table H-2, in MOE "Upper Limit of Normal" Contaminant Guidelines for Phytoxicology Samples. Report Number ARB-138-88-Phyto, ISBN 0-7729-5143-8.

- pg xi - (plants section) - comment - First stated that no significant negative effect was found for varying soil nickel concentrations **up to 3000** mg/kg of nickel, then reviewed leaf tissue for trees in an area with soil nickel levels of **over 20,000** mg/kg and found levels to be **below MOE standards**, then concluded section by saying that existing soil CoC levels "**do not pose an unacceptable risk** to maple trees". Confusing paragraphs. Could it be that the woodlots and trees themselves have become accustomed to the level of CoC's that they have been growing in, therefore not much of a difference would be noted??

While it is perhaps true that long-term exposure to CoCs has resulted in local genetic adaptations in maple trees, or other vegetation, this adaptation would in theory reduce the trees risk to CoCs. If this is the case, this adaptation further supports the observations and conclusions that the trees in the local area are not exposed to an unacceptable risk with respect to the long-term viability of their populations within the Study Area.

- pg xii - (first 2 paras.) - comment - First stated that approximately 60% of the ponds sampled have nickel concentrations that would put tadpoles potentially at risk. Then it is stated in next paragraph that frog and toad species were not influenced by soil nickel concentrations, but "that there may be some suppression in population numbers". Yet, "it is concluded that the potential risk of soil CoCs to maintaining frog and toad populations in the Study Area is low." What is the acceptable level of risk to this population?

Ultimately, the Regulatory Authority, the Ministry of the Environment, will determine what constitutes safe or acceptable levels. However, for the ERA, an unacceptable risk is defined as an estimated risk linked to the occurrence of soil concentrations of CoCs, as a result of historical

emissions from the Refinery, that prevents sustainable population(s) of flora and fauna or ecological functions within the defined Study Area.

- pg xii - (Decomposers) - clarification - How could reproduction occur in very high nickel concentrations of 20,000 ppm Ni when, "a significant reduction in species richness and number of worms found" is stated at these levels? Wouldn't a **significant reduction in** # of worms found reflect the reproduction #'s? Yet, once again, it is concluded that the earthworm community of Port Colborne is not at risk due to exposure to CoC's in the soil. Is there scientific literature that states how many worms should be found, depending on species, soil types, etc?

For areas with very high soil levels of Nickel, young worms were found, indicating that even at these high levels, reproduction (though reduced) was possible. The report has been revised to indicate that earthworms may be at risk in localized areas of high CoC concentrations (Chapter 11).

The results of all data collected for earthworms found that existing concentrations of soil CoCs did not prevent long term sustainable worm populations to occur for the Study Area.

There is no set number of worms that should be found under "normal" conditions. The number of worms in natural soils varies from site to site (even in the same woodlots) due to a number of natural, site-specific factors.

- pg xiii - (Birds and Mammals) - clarification - First paragraph, last sentence...."assessment of potential risk to these **eight species** is considered to represent an assessment of potential risk to **all mammal and bird species** that have been documented to occur in the Study Area. How could only eight species be compared to the many other species that live in the area? What about the species that weren't included in this study, like pets, that would have an impact on the whole Study Area, and the species that were included that wouldn't have an impact on the whole Study Area like the Fowler's Toad? The only breeding ground for this rare species of toad is along the lakeshore, which is not part of the Study. Area (as per Ron Huizer, PLC meeting Dec 5,2002).

No ERA can assess the risk to all species that occur in a study area. Current ERA practice is to assess risk to representative species found in various trophic levels and habitats represented in the local environment. This ERA has followed this approach. The selected VECs are considered representative of all species but their assessment is not intended to imply that an assessment to all species was undertaken.

The Fowler's Toad breeding pond is found along the lakeshore east of the Refinery on Cassaday Point. Though the pond is just outside the Ni 200 mg/kg (because it is on the beach) the site is nevertheless considered within the Study Area as defined by Jacques Whitford for the ERA.

For the CBRA's ERA, it was clearly identified early in the process at PLC meetings that pets would not be considered VECs with respect to the natural environment as they are not natural fauna of the Niagara Region. However, risk was assessed for a number of VECs that are representative of mammals of various sizes (body weight) and that eat various food items. The results of the risk

assessment to these naturally occurring mammals can be used to appromimate a level of risk assessment to pets such as dogs and cats. The mammals assessed in the ERA such as Raccoon and Red Fox are similar to pets such as cats and dogs with respect to body weight and potential foods that could be eaten when pets are out of doors. For the ERA the calculated Risk Quotients for Fox and Raccoon are very low, indicating that the potential risk is very low. Given that pets are less exposed to CoCs in their diets (most pets eat foods purchased in stores) and spend, in general, less time out of doors, it seems reasonable to assume that a pet's exposure and hence risk to CoCs would be lower than that for mammals in the wild.

- pg xxviii - (List of reports for the CBRA) - question - Would Jacques Whitford be accommodating and supply the writer with a copy of the last nine (9) reports listed?

Copies of these reports have been provided to the PLC.

<u>Section 1:</u>

- pg 1-8 - (4th para.) - comment - "70% of the nickel attributed to direct emissions", doesn't make sense if the plant was shut down all those times.

The estimate of 70% of nickel due to air emissions was made by comparing the data collected during the plant shutdown during the six-week period in 1978, against previously collected data when the plant was in operation. In this way the contribution of nickel in maple leaves from the air, rather than uptake from soil, could be determined.

<u>Section 2:</u>

- pg 2-2 and 2-3 - comment - Chemicals of Concern by definition still haven't been finalized. This issue is still up for discussion and therefore shouldn't be excluding certain chemicals, metals, elements, which could be classified as CoC's.

Based on analysis of soils and criteria developed for determining what would be considered CoCs for the CBRA, four CoCs (nickel, copper, cobalt and arsenic) have been identified to date. Therefore the risk to the natural environment as a result of elevated soils levels of these four CoCs has been investigated for the CBRA.

- pg 2-16 - (last para) - comment - Confusing conclusions of the Klohn Crippen reports regarding groundwater. How could "the contamination of local groundwater" be "restricted to the Refinery Site", yet it also states that the "movement of the contaminant plume is directly west-southwest to the Welland Canal and south to Lake Erie"??

Analysis of ground water undertaken by the Klohn Crippen study, and sampling of wells undertaken for the CBRA (see comment below) clearly indicated that contamination of ground water over a large area (i.e. the area of the natural environment where soil nickel exceeds 200 ppm) as a result of historic emission from the Refinery has not occurred.

Groundwater contamination with CoCs is locally present in shallow bedrock beneath the Refinery site and extends offsite westward toward the Welland Canal. This groundwater contamination

migration is being controlled and recovered by wells on Inco property. The recovered contaminated groundwater is treated at Inco's onsite water treatment plant. The presence of the localized bedrock groundwater contamination does not represent an exposure pathway to elements of the terrestrial environment in the ERA Study Area.

- pg 2-20 - (1st para.) - clarification - States that 100 wells were sampled by Jacques Whitford (2001b), at a PLC meeting it was stated that approximately 300+ wells were sampled, (PLC meeting Feb 20,2003 pg 2). Which number is correct?

There are more than 300 properties located in the rural area on the East side of Port Colborne within the Study Area. A review of available MOE water well records for this area indicates there are hundreds of water wells registered and documented. Some of these wells may have been historically active, but are not currently used. The exact number of drinking water wells that are currently in use in the Port Colborne area is not available. Considering the scope of the project, the number of properties involved, as well as the assumption that not all the wells would be active, a decision was reached that at least one in three homes would be surveyed. Based on this rationale, approximately 100 water wells were sampled, covering areas of potential concern where there are elevated soil concentrations of CoCs exceeding generic soil guidelines.

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pg 2-20 - (2nd para.) - clarification - "....regional contamination of groundwater by CoC's is not present and is not expected to occur". How is that possible considering all the studies that Klohn-Crippen has done in the past? If there are no CoC's present in the groundwater, why then is Inco using purge well systems to capture the CoC's in the groundwater?? How could groundwater discharged to the natural environment **not** be considered a pathway for ecological exposures? What about the groundwater that plants and trees take up through their roots? These are routes of exposure to the natural environment and groundwater is a major source and should be assessed further in the ERA study.

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The wording of this paragraph may be misleading and clarification is provided. The intent was not to imply that groundwater contamination does not exist, but to indicate that the contamination is contained within a limited area and has not migrated to wells throughout the region. The purge wells serve to contain the contamination and prevent it from spreading. Plants and trees have root systems within the surface soils which is where they take up water from. The MOE have defined surface soil as the top 1.5 m of soil. This can be considered the likely extent of the root zone, a factor that the MOE would have considered in developing this definition. Groundwater in the Study Area roughly ranges from 3 to 6 m below the ground surface, and is mostly within the bedrock which does not provide nutrients for trees. Roots would not be inclined to grow at this depth. Since the contamination is localized, contained and below the root zone depth, no significant pathways of ecological exposure were identified for evaluation of groundwater (P. 2-20, para. 5).

- pg 2-24 - (last para) - clarification - Sediment testing east of Nickel Beach showed 150 ppm, 193 ppm and 25 ppm for nickel because it might be affected by treatment plant effluent?? Compared to the lowest effect level of 17 ppm nickel established by the MOE, that would mean that these results are way over the guidelines. Where does the treatment plant effluent go once it enters the lake? Does it evaporate? Is this the same effluent that has failed numerous times under the MISA program?

The information presented in this paragraph was provided to show that elevated levels of CoCs in the lake sediment in the local area are influenced by the discharge of the treatment plant effluent, and not by the Refinery's historic air emissions. The purpose of the CBRA as stated in Section 1.2 of the report is as follows- "The CBRA was conducted for chemicals of concern (CoCs-Nickel, Copper, Cobalt, and Arsenic) in the Port Colborne area that have elevated concentrations in soil as a result of historical emissions from the Inco Refinery". Therefore, the effects of the past/current operations of the water treatment plant are not within the mandate of the CBRA.

- pg 2-25 - (first half of pg) - clarification - How is it possible to conclude that "no adverse impacts on fish nor inverebrate populations" therefore "an assessment of environmental risk from CoC's to the nearshore aquatic environment of Lake Erie was not undertaken for the CBRA", when in the first paragraph, last sentence states, " The study concluded that localised sediment metal contamination was causing CoC accumulation in fish tissue in Gravelly Bay"???

There are two points to clarify here. First, with respect to the sentence "The study concluded that localized sediment metal contamination was causing CoC accumulation in fish tissue in Gravelly Bay", this statement is in error. Based on the results presented in the Beak-Klohn Crippen report the sentence should state " The study concluded that localized sediment metal contamination was *not* causing CoC accumulation in fish tissue in Gravelly Bay". This incorrect statement in the draft report has been pointed out by other reviewers as well and is revised in the final report (P. 2-26, para. 2).

Second, as detailed in this section, a number of factors were identified that make the assessment of the risk to the aquatic environment (Lake Erie near shore) outside of the scope of the CBRA. The purpose of the CBRA as stated in Section 1.2 of the report is as follows- "The CBRA was conducted for chemicals of concern (CoCs-Nickel, Copper, Cobalt, and Arsenic) in the Port Colborne area that have elevated concentrations in soil as a result of historical emissions from the Inco Refinery". As there are a significant number of potential sources for CoCs in the near shore aquatic environment, as identified in this section, the aquatic environment of Lake Erie is not within the mandate of the CBRA.

Section 3:

- pg 3-32 - (2nd para.) - clarification - What does "no observable dramatic negative effects of high soil CoC concentrations on flora and fauna" mean? What constitutes a dramatic effect? What constitutes a negative effect?

In this summary section, the statement "no observable dramatic negative effects of high soil CoC concentrations on flora and fauna" means that based on field investigations, the diversity (and numbers) of birds, mammals, frogs, trees, shrubs, etc, is typical for the Port Colborne area and Niagara Region. This finding is contrary to general public opinion that many species of birds and mammals are no longer seen in the area, opinions that have been expressed by the public attending various PLC meetings and reported in local newspapers.

This section is a summary of the qualitative assessment of the natural environment and potential risk to soil CoCs. Therefore the statement is "visual negative effects". In this respect "visual negative effects" would be an obvious absence of species which should be in the area, or a very low number of species or individuals, or degraded woodlots (stunted growth of plants and trees, high number of dead trees, lack of species diversity etc) and natural areas. This type of dramatic obvious effect was not seen in the Study Area, and is not supported by the inventories of flora and fauna collected for the ERA.

Section 4:

- pg 4-1- (Criteria for VEC Selection) - question - If rare and significant species were identified in the Study Area and detailed data collection was not considered appropriate because of low population density, then why is so much emphasis being put on the Fowler's Toad habitat and existance as a means of proving there is nothing affecting the natural environment?

Fortunately, the Fowler's Toad was a rare species for which good data sets could be collected. This is because this species is easy to survey for (calling males during the breeding season) and breeding success could be determined, both visually and by sampling CoC concentrations in water for risk calculations, as there was only one breeding pond in the Study Area. This was not the case for other rare species, such as birds, which are represented by only one or two pairs, for which direct monitoring of breeding success would be very difficult, if not impossible. Second, there was no particular "emphasis" placed on the risk assessment for the Fowler's Toad with respect to the effects of CoCs on the natural environment. The ERA also conducted risk assessment for other toad and frog species, as well as birds, mammals, worms, maple trees, etc.

- Referring to page 4-4, Jacques Whitford states that the VEC's chosen can "be considered <u>representative</u> of the species and ecological processess in the <u>vicinity of Port Colborne</u>". "The VEC's selected here are <u>'classic' species</u> typically used in ERA and thus <u>provide a level of standardization</u> to the study." The Fowler's Toad is **not representative** of all of Port Colborne as it lives and breeds in only a small, localized area and is not found anywhere else. The toad is **not a classic species**, it is a **rare** species.

The reference statement has been removed (P.4-4, para. 2, line 7).

- pg 4-5 - (Table 4-2) - clarification - Should there not be a distinct measurement endpoint for the list of VEC's? What would the differences be between a LOAEL and a NOAEL for the mammals listed?

The LOAEL and NOAEL for each selected TRV study (where both are available) have been documented in Volume III, Tab 4. Also described in this section is why any LOAELs selected are considered more appropriate or relevant than available NOAELs. In some cases NOAELs were selected where the LOAEL was not considered appropriate. Each was selected based on the assessment endpoint and the suitability of the selected value to address that endpoint.

- pg 4-9 - (1st para) - comment - Again, referring to the Fowler's Toad and it's habitat, one breeding pond within the Study Area and entire lifecycle occurs within 700m of the lakeshore, how can this species be representative of the whole Study Area? The toad is designated as "Threatened", so how can this be a classic species typically used in ERA's? This breeding pond is located within Inco's Refinery Site boundaries, so therefore isn't even in the "Study Area" by definition of Jacques Whitford.

The breeding pond is not located within the boundary of the Inco Refinery site; it is located further east along the lakeshore and within the Study Area as defined by Jacques Whitford (see response to comment above). The reference to the selected VECs being classic species, etc., has been modified (P.4-5, para. 2, line 3).

Section 5:

- pg 5-1- (Data Collection Protocols) - clarification - Which detailed field protocols were reviewed and accepted by the TSC and PLC prior to collection of field data?? Were changes to these protocols made during the course of collecting data? And if so, were the changes documented, reviewed, and accepted by the TSC and the PLC?

All draft data collection protocols were reviewed by the PLC's consultant, Stantec. Comments provided by Stantec on draft documents where addressed in the final protocol documents, which were forwarded to Stantec for final review. In addition, protocols were also reviewed at TSC meetings and commented on at PLC meetings. In some cases, some minor changes were made in the field with respect to number of samples collected, how and where. However, during the collection of field data a PLC representative (Stantec) was present to ensure that the data collection methods and data collected would provide meaningful data for the ERA.

- pg 5-3 - (Table 5-2) - clarification - Note 2 in chart states that Stantec was provided with a full data set of the Meadow Voles biological specimens. Why? When? Wouldn't the rest of the data sets be provided to Stantec for QA/QC functions?

With respect to QA/QC of biological data collected for the ERA, the following was undertaken:

1) **When possible, duplicate samples representing 20% of the samples collected by Jacques Whitford were specifically collected for Stantec so that they could conduct their own analysis of the samples;**
2) **When the collection of an additional 20% of sample was not possible, as was the case with the Meadow Voles, then results of the analysis undertaken at the laboratory were sent directly to Stantec as well as Jacques Whitford;**
3) **For qualitative data, for example frog call surveys and bird surveys and worm surveys, a representative of Stantec was present during the data collection; and**
4) **All raw data collected for the ERA is presented in Volume 5 of the ERA-Natural Environment Report.**

- pg 5-5 - (Table 5-3) - questions - In the Leaf Litter Study, tent caterpillars are included in column titled, "Studies for which soils used". When did tent caterpillars become included in this study? Same question in regards to the Field Corn Sampling program, when did it become included in this study?

First, it should be understood that soils data (that is the concentration of the CoCs in the soil) collected for the Leaf Litter Study, was used in the assessment of other receptors as listed in the column "Studies for Which Soils Used". That is, soil was not re-sampled during the collection of other data sets as the collection site was the same as that for the leaf litter study. Second, the collection of wild grapes, tent caterpillars and field corn was undertaken at the request of the PLC consultant, Stantec, as it was considered that the collection of this data were important for the assessment of risk to specific VEC's. Jacques Whitford agreed with Stantec and the data were collected. The specific date for the collection of these samples is found in Volume 5 of the ERA report.

- pg 5-5 - (CoC's in Surface Water) - clarification - Why were different numbers of stations used for surface water samples. Wouldn't it be more comparable to use the same number of stations in each area? Where were the locations for these sample sites? Should it not be referenced to a map or other location in the study?

All sample site locations are provided on a large map (Map 1) located at the back of the report, this will be clearly stated in the beginning of Section 5.0 in the final report. The number of sample sites and their location was based on a number of criteria, such as soil type (clay-organic), habitat type (field-woodlot) and occurrence in the Primary and Secondary Study Areas. These criteria lead to different numbers of samples for the various data sets collected. Nevertheless, the data sets are considered by Jacques Whitford to be representative of the Study Area as a whole, as well as Reference Areas.

- pg 5-8 - (3rd para) - comment - I disagree that "the 0-5cm soil zone represents a significant portion of the plants rooting zone for most herbaceous vascular plants." I also disagree with the statement that "surface soils represent the primary exposure zone for the majority of receptors for which risk is assessed." For example, a robin can dig deeper than 5 cm to obtain a worm, meadow voles burrow, deer dig the ground with their hooves trying to locate food in the winter, raccoons will also dig to obtain some of their food, and plant roots inevitably go further than 5 cm into the soil.

Analysis of CoC concentrations in soil profiles in a test pit program conducted for the CBRA identified that for both clay and organic soils the 0-5 cm surface soil reflect the higher concentrations of CoCs in the local area soils. Therefore, use of soil CoC concentrations in the 0-5 cm zone is considered to represent a conservative approach for the risk assessment. This exploration will be inserted into the report in place of the referenced statements.

- pg 5-9 - (Laboratory QA/QC) - clarification - How were the SMR's chosen for vegetation and animal tissue? Is this a standard laboratory practice to use these species? Was this detailed in the protocols prior to data collection?

The SMR's used were identified as the appropriate standards by the laboratory. Use of these SMR's was identified in the Laboratory Protocol for Analysis of Biological Tissues (Tab 2, Volume II).

Section 6:

- pg 6-11 - (Figure 6-7) - question - In which zones are the 3 ponds located? There is nothing stating this in the written discussion of BAF's.

Text on page 6-10, second paragraph, identifies the ponds of Figure 6-7 as TM1, TM2 and TM3. The location of these sample sites is provided on MAP 1.

- pg 6-17 - (2nd para) - clarification - If the statement, "This analysis shows that soil and habitat type are generally poor predictors for determining the relationship between CoC concentrations in soils and a biological receptor's exposure to CoC's", then why was the study initiated? Is not the soil concentrations and risk exposure for the different species in association with the CoC's the purpose of doing a risk assessment?

Prior to conducting the ERA, it was not known whether there was a difference in the bioavailability of CoCs between clay and organic soils. That is, due to the chemical nature of the soils, clay and organic soils with the same concentration of a CoC could have shown significantly different uptake of CoCs by VEC's. Therefore a "safe soil value" for clay soil, would not have been the same as a "safe soil value" for organic soils. The same rationale applies to different habitat types - fields vs woodlots. This is why data were collected based on soil type and habitat type.

- pg 6-18 - (Table 6-3) - question - Why were only 2 composite samples taken from the Reference Area compared to 6 samples from the Study area? Would it not be more comparable to have the same number of samples in each area?

No, as the soils in the Reference Area do not have the range (gradient) of soil CoCs as that of the Study Area.

- pg 6-18 - (Maple Tissue) - question - Why were there limited maple seeds taken from the Study Area and the Reference Area? Maple trees have an abundant supply of seeds, are easily obtainable and maple trees are the main focus of that part of the study.

Collecting maple keys from a large number of individual trees could have confounded the results of the experiment, showing different results due to variation in seed genetics rather than the effects of CoCs in soils.

- pg 6-20 - (Wild Grape Tissue) - question - Were changes in the data collection protocols made to include grapes that were encountered during the field data collection?

Yes. Also see comment above regarding including wild grapes in the data set.

- pg 6-21 - (Earthworm Tissue) - clarification - This paragraph is very confusing and tables are referenced but don't explain why they are there. Table 6-7 is titled, ".....sampled in 2001 and 2002" but there is no division in the chart to show the two different years.

The data provided in Table 6-7 and 6-8 is pooled data for worms collected both in 2001 and 2002. Table 6-7 shows the CoC concentrations for all worms collected (2001 and 2002) for the Study Area and Reference Area. Table 6-8 presents CoC concentrations for all worms collected for the Study Area, but is broken down by soil type (clay-organic) and habitat type (field and woodlot).

Text regarding Table 6-12 and 6-13 is not correct, as it should reference Table 6-9 and 6-10. Table 6-9 details the average number of worms collected from organic and clay soils, and the concentrations of CoCs in worms compared to the CoC concentrations of the soil from which they were collected. The last table in this section, Table 6-10 presents a comparison of CoC concentrations in Non-purged worms (soil still in gut), to Purged worms (no soil in gut). This table shows that much of the CoC concentrations in worms as presented in Tables 6-7, 6-8, and 6-9 is due to CoCs in the soil in the gut, rather than in the tissue of the worms.

The paragraph on page 6-21 has been re-written so that the correct tables are referenced (P.6-24, para. 2, line 3).

- pg 6-23 - (Table 6-9) -comment - This chart should have been in same format as other charts throughout the report. This chart is difficult to understand.

The table is different as it shows three data sets, 1) average number of worms collected by soil type, 2) CoC concentrations in worms, and 3) the CoC concentrations in the soils from which the worms were collected. The other tables only present data on concentrations of CoCs in worms.

- pg 6-23 - (last para) - clarification - Please explain what this paragraph says.

For earthworms, there are two sources of CoCs to which an animal that eats worms (a Robin for example) can be exposed: the CoCs in the soil in the gut of the worm (which directly reflects the concentrations of CoCs in the soils in which the worm lives because worms eat soil), and the concentration of CoCs in the worms tissues (which reflects the accumulation of CoCs in the worm). For the Robin, once it eats a worm, the amount of CoCs it absorbs from the soil in the worm's gut is different from the CoCs it absorbs from the worm's tissue. The CoCs in the worm tissue move more readily into the Robin than do the CoCs in the soil from the worm's gut. Therefore, the question addressed here is, for a whole worm eaten by a Robin, what fraction of the CoC exposure is from the CoCs in worm tissue and what fraction of CoCs is from the worm's gut soil.

- pg 6-35 - (Table 6-17) - question - Are these numbers average or mean numbers or where did they come from?

The values in this table reflect the summary statistics of each medium, as shown in the previous table (Table 6-16) and explained on page 6-34. Further clarification will be placed as a footnote to this table (P.6-41, Table 6-17).

- pg 6-36 - (1st para) - comment - Has Environmental Science Group done any additional studies or reports for Inco regarding the Refinery here in Port Colborne either in the past or present? Isn't ESG also doing work on the Sudbury Soils Study?

ESG is a different company from Environmental Science Group. Jacques Whitford is unaware of any other studies conducted by the Environmental Science Group on behalf of Inco. ESG conducted worm toxicity testing for the current study and is currently conducting work in Sudbury also.

<u>Section 7:</u>

- Have not read this section as it is beyond my knowledge of scientific issues.

A response from Jacques Whitford is not required.

<u>Section 8:</u>

- Have not read this section as it is also beyond my knowledge of scientific issues.

A response from Jacques Whitford is not required.

<u>Section 9:</u>

- pg 9-1 - (Approach) - clarification - Second paragraph states that "following risk estimations, a description or characterisation of risk is a necessary final step, however no standard method or widely accepted approach is identified" What does this statement mean? That data and information can be collected and analysed and put into a report but there are not any rules as to what to do with the outcomes? Doesn't make sense.

Standard methods do exist for quantitative characterization of risks; however, much of the data collected in this evaluation (and in many others) is qualitative in manner. General guidelines for methodology in conducting risk assessments do exist and are followed; however, the statement was intended to indicate that there are many instances when the qualitative data must be assessed using professional judgment and experience.

- pg 9-1 - (bullet points after above paragraph) - question - First bullet states that the risk to VEC's is based at the population level defined as being within the TOTAL Study Area. First of all, was data collected for population comparisons, and secondly, some species in this study are not found TOTALLY in the Study Area. For example, where is the reference community for the Fowler's Toad? Is there such a place other than the lakeshore (primary area) where the Fowler's Toad lives for comparison?

For the first point, no population studies (number of individuals) were undertaken for the ERA. However, data were collected to assess the exposure of a VEC's population occurring in the Study

Area. This is what is meant by an assessment of risk to a population as defined for the ERA. This is different than assessing risk to an individual found in a specific area.

For the second point, for the risk assessment, a VEC's population is considered to always inhabit the Study Area and be exposed to soil CoCs. This is considered a conservative approach for some species.

- pg 9-2 - (Summary Discussion of Risk) - clarification - The first paragraph under this heading states, "the need to undertake an ERA for the natural environment found in Port Colborne east of the Refinery was identified as a key component of the Community Based Risk Assessment". I believe since the conception of the CBRA in 2000, the main understanding of the stakeholders involved were under the impression that the whole city of Port Colborne was included in the process, not certain areas. Is this still the understanding or has the definition of "community" changed yet again?

Authors of the ERA-Natural Environment are aware that for the CBRA the term "community" has been interpreted to mean different things for various studies and by different groups of people. However, it is stressed here that the study was structured so that the findings of ERA-Natural Environment are applicable to *all natural environments* wherever current soil values for nickel exceed 200 ppm in the Port Colborne area.

Section 10:

- pgs 10-1 to 10-19 (Cited References) - question - Could the following list of documents be made available to the reader as these would be helpful in the understanding of the ERA report?

For the list of documents identified by the reviewer, it is recommended that the PLC Chair be contacted to follow the appropriate avenues for acquiring these documents. It is noted here that a number of the documents were already public documents at the time of this review and in the possession of the PLC (noted with * by Jacques Whitford below), or are provided as an appendix in the ERA-Natural Environment Report, Human Health Risk Assessment Report and ERA Crop Studies Report (Noted with ** by Jacques Whitford below). Jacques Whitford is not at liberty to reproduce copyrighted material. USEPA documents can be obtained by contacting the USEPA. Other literature may be ordered through library services.

- *********Environmental Sciences Group. 2002. Bioaccessibility of Copper, Nickel, Cobalt and Arsenic in Soils Northeast of Inco Refinery, Port Colborne. Queen's University Analytical Services Unit, Royal Military College, Kingston, Ont. RMC-CCE-ES-02-19.*
- ********Jacques Whitford. 2000b. Statistical Examination of MOE/Jacques Whitford Soil Data in the Evaluation of As, Se, B and Pb as Potential CoCs. October 18,2000.*
- *********Jacques Whitford. 2001b. Residential Well Water Sampling Program part of the Human Health Risk Assessment Port Colborne CBRA. Prepared for Inco Limited. Draft Report.*
- ********Jacques Whitford. 2001c. Ecological risk assessment, natural environment part of Port Colborne CBRA. Draft report, March 5, 2001.*
- ********Jacques Whitford. 2001d. Sampling and Analysis: Quality Assurance and Quality Control Port*

Colborne Community Based Risk Assessment. Prepared for Inco Limited. 9 July 2001.

- ***Jacques Whitford. 2002a. In prep. Phytotoxicity Testing. Ecological Risk Assessment, Port Colborne Community Based Risk Assessment.*
- ***Jacques Whitford. 2002b. Ambient Air Monitoring in the Community Human Health Risk Assessment Input Port Colborne, Ontario. Draft Report. Submitted to Inco Limited. June 3,2002.*
- ***Jacques Whitford. 2002c. Soil Characterisation. Port Colborne Community Based Risk Assessment Port Colborne, Ontario. Draft Report. Prepared for Inco Limited. November 2002.*
- ** and **Jacques Whitford. 2002d. Data Interpretation Protocol Ecological Risk Assessment Community Based Risk Assessment Port Colborne Ontario. Prepared for Inco Limited. July 2002.*
- ***Jacques Whitford. 2002e. Ambient Air Monitoring in the Vacinity of Farming Activities. Human Health Risk Assessment Input Port Colborne, Ontario.*
- ***Jacques Whitford. 2003a. Ecological Risk Assessment Crop Studies. Prepared for Inco Limited. July 2003.*
- ***Jacques Whitford. 2003b. Human Health Risk Assessment. Prepared for Inco Limited. July 2003*
- *Klohn-Crippen. 1996. Final Report- Port Colborne Refinery- Groundwater Characterization Study. Prepared for Inco Limited.*
- *Kukier, U., and R.L. Chaney.1999. Methods for characterization of need for remediation of Ni phytotoxicity of, and for persistent remediation of, low Mn, high Ni soils at Port Colborne, Ontario. Task 1B report to INCO Ltd. Toronto, Ontario, Canada.*
- *Lee, H., W. Bakowsky, J.Riley, J. Bowles, M.Puddister, P. Uhlig and S. McMurray. 1998. Ecological Land Classification for Southern Ontario. First Approximation and Its Application. Ontario Ministry of Natural Resources. SCSS Field Guide FG-02.*
- *McIlveen, W.D. and D.L. McLaughlin. 1993. Field Investigation Manual. Part 1 - General Methodology. Ontario Ministry of the Environment and Energy, Report No. 014-3511-93*
- ***Midwest Research Institute (MRI). 2002. Determination of the Relative Absorbed Fraction of Nickel in Port Colborne Soil Following Single Oral Administration to Rats. Prepared for Inco Limited and Jacques Whitford.*
- *Regional Municipality of Niagara (RMON) 1980. Environmentally Sensitive Areas. Department of Geography. Brock University, St. Catharines.*
- *Temple, P.J. and S. Bisessar, 1981. Uptake and Toxicity of Nickel and Other Metals in Crops Grown on Soils Contamintated by a Nickel Refinery. Journal of Plant Nutrition 3(1-4):473-482.*
- *U.S. Environmental Protection Agency (USEPA). 1998. Guidelines for Ecological Risk Assessment. EPA/630/R-95/0002F. US EPA, Washington, DC.*

Volume 2: Field Data Collection and Analysis Protocols:

- pg i - (Introduction) - comment - In the first paragraph of the Introduction there is a misleading sentence about the approval of protocols. It is stated in the report that, "...to insure an open public process, prior to conducting field data collection for the Ecological Risk Assessment (ERA), draft protocols were developed by Jacques Whitford Environmental Limited for review by the Technical Subcommittee (TSC) and approval by the Public Liaison Committee (PLC)." In the CBRA process, protocols were reviewed and approved by the TSC, then brought to the PLC for review, not approval. The Terms of Reference for the PLC states that they can only make recommendations and are a communication tool between the public, Inco and the MOE.

Correct, the PLC did not have approval powers. Text will be changed to…"for review by the Technical Subcommittee (TSC) and Public Liaison Committee (PLC)" (P. i, para. 1, line 5).

Tab 1

- pg 1 - comment - Under the section, Sampling Methods QA/QC, the first bullet point refers to "clean latex gloves worn by the Jacques Whitford technicians during sampling and were changed before each new sample was collected." On various occasions while samples were taken from my property, surrounding properties, or instances where I happened to be observing samples being taken elsewhere, latex gloves were not always worn. If they had been they certainly weren't changed between when new samples were collected.

For the ERA-natural environment, during the collection of field data, when required, latex gloves were used and changed between samples. This field sampling was also supervised by Stantec who served to ensure that the protocols were followed appropriately.

- pg 14 - Appendix B, Standard Reference Material, C of A, - clarification - Was Phillips supplied with the results of the SRMs? On page 2 of 8 from the C of A for Spinach Leaves, under the heading, "Notice and Warnings to Users", it is stated that, "digestion of the SRM in nitric and perchloric acids was found to be incomplete, with a small residue of siliceous material remaining." Did or would this affect the analysis in any way?

Yes Philips did know the concentrations in the SRMs, otherwise they could not have undertaken an internal QA/QC check. Philips compares their SRM results with certified expected results of the SRM to make sure their lab is reporting analytical results in the expected range.

The notice and warnings to users was a consideration for the analysis of arsenic content. However, arsenic results obtained for the spinach SRM were within the expected range. Therefore, further digestion using hydrofluoric acid was not required to achieve total dissolution. If adequate dissolution of the SRM was not achieved using nitric acid, values for arsenic would have been lower than the expected results.

Tab 2:

- pg 1 - (Introduction) - question - First paragraph, last sentence states, " Chemical analysis of these samples provides data that will assist in dertermining the uptake of chemicals of concern (COC's) by various animals and plants from three media in the environment of Port Colborne (soils, sediment and water)" Shouldn't air be added to this statement? If not, explain why ambient air wouldn't affect biological tissues of plants and animals.

First, measurements of ambient air CoC concentrations in the Port Colborne rural areas were undertaken under the Human Health Risk Assessment (HHRA) program. These HHRA data were used in Section 2.1.8 of the draft ERA report reviewed by this reviewer.

Second, based on comments from other technical reviews of the draft ERA Report, due to the different nature of air CoC exposure and uptake in the lungs (rather than food ingestion and uptake by the gut), and the fact that TRV values for the VECs for the inhalation of CoCs are not available from scientific literature, the risk from ambient air levels cannot be assessed. However, it is noted in Section 2.1.8 that CoC ambient air concentrations as measured for the CBRA are within MOE guidelines.

- pg 25 - (Rabbit Meat Samples) - clarification - How many meat samples were submitted to PSC for analysis? How many rabbits were captured for the ERA study?

Two Cotton Tail Rabbits were collected from woodlots located directly adjacent to the Refinery along Reuter Road. For each rabbit, meat tissue from the hind leg and liver tissue was sent for analysis for CoCs.

- pg 30 - (Summary of Method) - question/comment - The statement, "Composite earthworm samples were pulverized in the glass jar using a **hand held domestic mixer**." Would there not be cross contamination from the metal blades of a domestic mixer? This discussion was had many times at past TSC meetings while discussing these protocols and Dr. Neibor stated he was concerned about cross-contamination from metal utensils.

The QA/QC procedures of the laboratory addressed the potential for cross-contamination during the preparation and analysis of samples. The potential for such cross contamination was indeed a concern for some sampling programs where concentrations of metals in specific types of samples were expected to be low. This is not the case for earthworms.

- pg 32 - (Composite Caterpillar Samples) - Same comment as previous bullet.
- pg 35 - (Maple Leaf Samples) - Same comment as previous bullet.
- pg 42 - (4.16.3 Sample Preparation) - question - How were the kernels of corn removed from the cobs? Was it manually or by some type of utensil? What type of "grinding apparatus" was used "to achieve a visually homogeneous mixture". Was there any possibility of cross contamination by using a "grinding apparatus"?

The QA/QC procedures of the laboratory addressed the potential for contamination during the preparation and analysis of samples. System blanks were run through the equipment used to prepare and analyze samples to make sure "cross contamination" was not occurring. Corn kernels were removed by hand.

Tab 3:

- pg 2 - (QA/QC laboratory duplicate, replicate and triplicate analysis) - clarification - Why is a percent difference of less than 70% acceptable for soils between duplicate and replicate samples yet for all other matrixes, "a percent difference of less than 30 % was considered acceptable"? What was the essence of the telephone conversation between Jacques Whitford and Jim Bishop in 2002 that makes these differences acceptable?

Soils are inherently more heterogeneous than many other types of sample matrixes. This means that thorough mixing and digestion of two aliquots taken from the same sample of soil can result in significant variation. Other matrixes such as tissue samples are more homogenous and therefore yield more consistent results between replicates. Discussion with the PLC's consultant and review of the 1996 MOE document "Guidance on Sampling and Analytical Methods for Use at Contaminated Sites in Ontario" resulted in the aforementioned percentage differences being used.

Tab 5:

- pg 1- (General Study Approach) - comment - The last sentence on this page states that, "sample collection was undertaken from April through to August of 2001". If this was the case, then sample collection was done prior to protocols being reviewed and approved?

The protocol for this field program was reviewed and commented on by the TSC and presented to the PLC prior to the collection of field data. During the PLC presentation, a request to include the Rodney Street area was made by the PLC. This request was subsequently included into the field program to accommodate the PLC. Finally the PLC did not have approval powers regarding data collection protocols.

- pg 3 - (Quality Assurance/Quality Control) - question- First sentence refers to " a representative of the Public Liaison Committee (PLC) provided third party verification in the field program during the collection of the water samples". Who was the representative of the PLC who provided this verification? And it is not clear how many sets of samples were taken in the field collection of water samples and by whom?

Collection of field data was undertaken by staff of Jacques Whitford. At all times the collection of field data was overseen by staff of Stantec, who represented the PLC in the field. One sample of surface water was collected at each sampling location by Jacques Whitford. At some locations a duplicate sample was also collected by Stantec staff. Stantec staff collected duplicate samples representing 20% or more of the total number of sampling stations.

Tab 6:

- pg 1- (Objectives) - clarification - Item #2 under the heading Objectives states that one of the primary objectives of the 2001 frog survey was, "to establish the breeding status of nationally rare, provincially rare and locally rare species that could potentially occur in the Study Area". Wouldn't this be outside of the scope for the CBRA process? Not relevant but useful infromation none the less. For example, the Fowler's Toad breeding ground is along the lakeshore which is not part of the Study Area. (See additional comments below).

Establishing the occurrence and distribution of species (any kind) in a study area is part of any ERA that is being conducted. With respect to the Fowler's Toad, the breeding site is located along the lakeshore within the Study Area (see response to comment above).

- pg 4 - question - Referring to two survey stations undertaken west of the Refinery site, at the intersection of Rodney and Welland Sts. and the intersection of Rodney and Davis St. Wouldn't these locations be out of the Study Area? Previously in the ERA document it is stated that residential areas weren't included as they didn't reflect the natural environment and also these locations would be consistant with the definition of industrial lands, also not reflective of the natural environment.

Yes, the above statements are correct. However, the Rodney Street area survey stations were included at the specific request of the PLC (See above comment regarding Protocol review process).

- pg 4 & 5 - (Rare Species Survey) - It is stated that field surveys were conducted in 2000 by Jacques Whitford as part of the ERA site characterization, and the location of potential habitats for the nationally, provincially "threatened" Fowler's Toad. This happened before protocols were approved? Also stated on page 5 is the **focus location of the survey...."on the backshore areas of Nickel Beach [on the Inco Refinery Site] ....." This is not within the Study Area as defined by Jacques Whitford.**

The data collected in 2000 was for the purpose of background data collection to provide focus for the collection of data for the ERA. Data collected in 2000 was not specifically used for the purpose of risk assessment. Specific data collection for the purpose of conducting the risk assessment was undertaken in 2001 and 2002, following the development and review of Protocols.

The backshore areas of Nickel Beach are in fact within the Study Area as defined by Jacques Whitford (See Map 1). Investigations in 2000 identified the potential for Fowler's Toad breeding to occur along the lakeshore in the local area, including the Nickel Beach area adjacent to the Inco Refinery. For the 2001 frog survey, the entire lakeshore from Pinecrest Road to Nickel Beach was surveyed for the potential occurrence of the Fowler's Toad. These surveys found one breeding pond to occur in the Study Area as defined by Jacques Whitford (see response to comment above).

- pg 5 - (Quality Assurance/Quality Control) - comment & question - For easier language flow, wouldn't it be better stated, "For quality assurance, a representative from Beak/Stantec, the PLC'c consultant, was present during the surveys." Question- Where is the sound recording of the call and photos of the breeding pond that the PLC's consultant undertook? Should they not be included in this report as well as the ONHIC data base?

The recordings are in the possession of Beak/Stantec. Pictures and information regarding the Fowler's Toad were forwarded to the NHIC.

- pg 6 - (References) - question - Would Jacques Whitford please provide a copy of this reference document, *Jacques Whitford 2001. Ecological Risk Assessment, Natural Environment, Part of the Port Colborne CBRA, Draft Report. Prepared by Jacques Whitford Environmental Limited, Markham, Ontario.*

A copy of this Report has been provided by Jacques Whitford to the PLC.

- pg 7 - (Amphibian Survey Field Data Collection Sheet) - comment - The two signatures of who was involved in the frog calling survey should be, Jacques Whitford Recorder and Stantec Recorder, not PLC Recorder?

For the CBRA/ERA Stantec Staff are representatives of the PLC during field data collection.

<u>Tab 7:</u>

- pg 2 - (Survey Approach) - comment - At the bottom of the page, lists where the surveys conducted in 2000 and 2001 were performed, including Transects 1 to 5. These first five transects for the bird survey are **all on Inco property**, which again are **not part of the Study Area as defined by Jacques Whitford**.

It is true that some transects were in fact on Inco property, however, all transects were undertaken in the Study Area for the ERA as defined by Jacques Whitford. Not all Inco properties in the local area have been excluded from the Study Area, for example Inco property east of Reuter Road are lands that were sampled for the ERA. Only Inco lands identified as being part of the Refinery site proper were excluded (See Map 1).

- pg 3 - (Continuation of Survey Approach) - comment - At the end of the bullet points describing the location of bird surveys, a sentence directs the reader to "(Figure 1-1) at the back of this Volume", yet there is no Figure 1-1 or sample location map.

This was an oversight, as Fig 1-1 should have been provided in Volume II. However, Map 1 in Volume I is the same map.

Tab 9:

- pg 3 - (Amendments) - clarification - This paragraph doesn't make sense. Were the soils amended or not for the greenhouse experiments?

For the ERA, the Red Maple greenhouse experiments did use amended soils with respect to pH adjustment, using a mixture of reagent grade calcium carbonate and magnesium carbonate to raise the clay soils close to a pH of 7.0 and the organic soils close to a pH of 6.5.

For the Crop Studies, amended soils are with reagent grade, amorphous calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) at the same ratio as found in dolomitic limestone. For the Crop Studies each soil type at each CoC concentration level was subjected to one of three limestone amendment treatments: 0, 1X and 2X Ontario Ministry of Agriculture and Rural Affairs (OMAFRA) recommendations for Port Colborne soils.

- pg 4 - (Key Collection and Planting) - clarification -First paragraph also refers the reader to "Figure 1-1 and 1-2 at the back of this Volume for the sample site locations) which is not in this volume. Comment - Why were Maple keys only collected from one tree in the Study Area?

Collecting maple keys from a large number of individual trees could have confounded the results of the experiment, showing different results due to variation in seed genetics rather than the effects of CoCs in soils.

- pg 4 - (Key Collection and Planting) - clarification - Second paragraph states that surface soil was collected from location within the site, mixed and a sub-sample used for chemical analysis. Sediment sampling followed the soil sampling protocols developed by Jacques Whitford for the CBRA. Shouldn't this last sentence be "**Soil sampling** followed the soil sampling protocols....." ?

Yes, you are correct.

- pg 6 - (Physical and Chemical Analyses) - clarification - Bullet #3 states, "Metal analysis (Ni, Cu,Co) by ICP-MS (See Jacques Whitford, 2001d). Shouldn't these samples be analysed by a full metal scan?

All samples were analyzed for 17 metals, arsenic and selenium. The text will be changed.

- pg 7 - (Quality Assurance/Quality Control) - comment - It seems, according to the wording of this paragraph, that the QA/QC carried out for this survey "conformed to Jacques Whitford's QA/QC protocols under the company's ISO 9001 registration." How is this different from the QA/QC process that stated throughout the ERA report? Comment - During an earlier TSC meeting regarding this greenhouse experiment, a PLC member stated that they would like to tour the greenhouse to observe the process. Did this ever occur?

All greenhouse procedures were monitored by Stantec staff, representing the PLC. PLC members did tour the greenhouse, but this was for the ERA-Crop Studies component.

Tab 10:

- pg 1 - (Introduction) - clarification - First sentence of third paragraph states that "19 species of worms have been recorded (Reynolds 1977)". Are there any more recent studies?

No there are no more recent studies regarding the earthworms of Ontario. In addition it is noted here that Dr. Reynolds was part of the field team. Dr. Reynolds is the author of the Earthworms of Ontario (1977).

- pg 3 - clarification - First paragraph stated that, "Though *Eisenia andrei* does not occur naturally in the fields and woodlots in and around the Inco Port Colborne Refinery, surrogate test species are commonly used in both aquatic and terrestrial toxicity testing." Where is the literature or reference documents to back this statement?

This statement was based on information provided by ESG, who regularly conduct these types of tests. Details are provided in the reference Environment Canada, 1998. Development of Earthworm Toxicity Tests for Assessment of Contaminated Soils.

- pg 3 - (Experimental Concept and Design) - clarification - Second paragraph states that the soils collected and processed for the crop greenhouse experiments were also used for the earthworm studies. "In summary, following the collection of the four test soils, their pH was adjusted with a mixture of reagent grade calcium carbonate and magnesium carbonate to raise the clay soils close to a pH of 7.0 and the organic soils close to a pH of 6.5". There is nothing stated in the objectives of this study that refers to "amended soils" as used in this experiment. What is the justification for amending the soils?

Soils were only amended to adjust pH so that a difference in soil pH could be eliminated as a confounding factor in the dose response experiment. Soil pH has a direct influence on the mobility of CoCs in soils. For the Crop Studies, amended soils are with reagent grade, amorphous calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) at the same ratio as found in dolomitic limestone. For the Crop Studies each soil type at each CoC concentration level was subjected to one of three limestone amendment treatments: 0, 1X and 2X amendment levels obtained following Ontario Ministry of Agriculture and Rural Affairs (OMAFRA) recommended procedures.

- pg 5 - (Continuation of Phase II - Chronic Testing) - clarification - On page 5, the paragraphs below the charts indicate that Phase II "experiment design was the same as that conducted for Phase I". There are a couple differences in the descriptions of Phase I and II mainly: *(I)* "Jars/soil were maintained throughout at 20C and continuous fluorescent illumination (24h)" *(II)"*Jars/soil were illuminated with a fixed dail photoperiod, 16 h light and 8 h dark." *(I)* Doesn't state whether the worms were fed or not. *(II)* "Worms in each test unit were fed an identical quanity of food on days 0, 14, 28 and 42 (Environment Canada 2001)"

For Phase I, worms were fed as per *Biological Test Methods. Tests for Toxicity to soil to earthworms (Eisenia andrei, Eisenia fetida, or Lumbricus terrestris)*, (Environment Canada. 2001).

- pg 5 - (last paragraph) - There are 3 statistical endpoints mentioned in this paragraph, NOAEC, LOAEC and the levels of contamination that result in a 20 or 50 % reduction in survival and reproduction of earthworms. Explain what the differences are for each endpoint, why 3 different endpoints are being investigated and why there is a difference of 20 to 50% survival and reproduction rate.

The No Observable Adverse Effect Concentration, is the level where there is still no effect seen. The Lowest Observable Adverse Effect Concentration is the level of CoC concentrations where some effect is noted. The 20% and 50% survival end points are standard end point measures used to determine the level of soil toxicity.

- pg 6 - (Study Area and Control Site Assessment) - clarification - Point #3 states, "Two woodlots and two fields per area." Should this not include, "*....two fields per area of contamination* ?

Jacques Whitford believes it is clear as presented.

- pg 6 - (Second paragraph) -grammar/spelling - Second sentence should read, "For one woodlot located along Reuter Road, worm samples were collected from five stations, *moving* west to east through the woodlot. In the second woodlot, *located* east of Snider Road, worm samples were collected from three *stations*. " -clarification -Was the second woodlot samples collected the same way as the first one? If not then it should be stated why not.

Yes, in the second woodlot samples were collected moving west to east through the woodlot.

- pg 6 - (Third paragraph) - grammar/spelling - "In addition to the woodlot *surveys* ....." - Question - Where were the samples collected that were in addition to the woodlot surveys?

The text refers the reader to Figures 1-1 and 1-2 for the sample site locations. It is understood based on previous comments that these maps were not in the reviewer's copies.

- pg 7 - (first paragraph) - question - Where are the Figures 1-1 and 1-2 (sample location maps) that is reportedly at the back of this volume?\

See response to above comments.

- pg 7 - (Earthworm Sampling Method) - question - Last paragraph, last sentence states, "The identification and classification of earthworms into age classes was undertaken by Dr. John W. Reynolds". Who is Dr. Reynolds and was this breakdown into age classes part of the current sampling method?

Dr. John W. Reynolds is Ontario's leading earthworm expert and author of the Earthworms of Ontario. The age classification system used is a standard aging method used in earthworm studies.

- pg 8 - grammar/spelling - First sentence at top of page, "For the year 2001 field program and 2002 woodlot *surveys* , following the sorting of samples....."

Yes, you are correct.

- pg 9 - (Soil Sampling and Analysis) - comment - First paragraph states, " For both fields and woodlots, surface (0-5cm) soil cores were collected". Wouldn't it be fair to say that worms would be more exposed by soils that are deeper than 5 cms?

Worms are exposed to a range of soil CoC concentrations as they move up and down the soil profile through the seasons and throughout their life cycle. However, the use of the 0-5 cm soil CoC concentrations is the most conservative measure for the risk assessment (see response to the above comment regarding the use of the 0-5 cm soil values).

- pg 9 - (Treatment of Data) - question - Where is the report that details the procedures for the statistical analysis of the data?

The report is Tab 18 in Volume II.

- pg 9 - (Quality Assurance/Quality Control) - grammar/spelling - Second sentence, "For the field program, representatives of the Public Liaison Committee's (PLC's) consultant *were be* (?) allowed to monitor field collection of speciment and *may* (?) take a fraction of duplicate samples (20%) for analyses." Second paragraph - "For the laboratory toxicity studies, representatives of the PLC's consultant *were be* (?) allowed to monitor the field collection of soils and blending of soils used for the study."

Text should read as follows "For the field program, representatives of the Public Liaison Committee's (PLC's) consultant monitored field collection of specimens and to take a fraction of duplicate samples (20%) for analyses."

- pg 10 - (References) - Would the authors please supply the following:
- *Jacques Whitford 2001a. Soil Sampling Protocol, Year 2001 - Greenhouse & Field Trials. Port Colborne Community Based Risk Assessment, May 25,2001.*
- *Jacques Whitford 2002a. Animal Tissue Laboratory Analysis Protocol. Ecological Risk Assessment & Health Risk Assessment, Port Colborne Community Based Risk Assessment, March 2002.*

Copies of these reports have been provided to the PLC.

Tab 11:

- pg 1 - (Introduction) - comment - First paragraph references several studies done on the concept of element cycling in the natural environment which are dated, 1979,1954 and 1973. Are there not any newer versions or studies which could be used?

Basic investigations into element cycling in the environment have a long history and the basic principles have been understood for many decades. The references are provided as overview background documents to the subject.

- pg 4 - (Table 1 - Numbers of Sample Collection Woodlots) - clarification - In the chart listed as Table 1, the Study Area column states different concentration levels than that previously mentioned for the Natural Environment Study. Is there a reason for this?

In general for the ERA, two Study Areas were identified, the Primary Study Area (>500 mg/kg Ni) and Secondary Study Area (500 to 200 mg/Kg Ni). However, for the leaf litter study to ensure effects could be detected by comparing results of samples, it was determined that Heavy (over 2000 mg/kg) and Moderate (200-2000 mg/kg) would be used for the sample site selection process.

- pg 5 - (first paragraph) - grammar/spelling - Second sentence, "Open areas used were of sufficient distance to avoid the immediate and direct influence *of tree* trunks, tree roots, shrubs, large fallen branches or poison ivy."

Yes, you are correct.

- pg 5 - (Sample Sorting) - clarification - Last part of paragraph states, " A single large elm at Site 8 had lost a significant portion of its current year's foliage, in part due to the late date of sample collection (September 13,2001). These leaves were not included in the weighed samples." Why wouldn't these leaves be included, they were part of the leaf litter regardless of when they fell from the tree.

The goal of the leaf litter study was to assess the amount of the previous year's leaf litter that remained prior to the start of the new fall drop of leaves. Therefore, in this situation, the newly dropped leaves were removed so as not to confound the study results for this site.

- pg 6 - (Woody Species Inventory) - grammar/spelling - Second last sentence of paragraph, " The *percentage of* dead branches in the crown was estimated...."

Yes, you are correct.

Tab 12:

- pg 1 - (Introduction) - clarification - The first paragraph states, "Insects may accumulate Chemicals of Concern (CoCs) in their tissues, but no values are available for use in the Ecological Risk Assessment (ERA)" Does this mean that there are no studies or scientific literature available regarding insects and CoC's? That statement is hard to believe.

Yes, there are some studies that report tissue concentrations of the CoCs in various insects, however, the vast majority of these studies do not indicate the soil CoC concentrations from which the insects were collected. Therefore, site specific data for the CoCs in soils and insects in the Port Colborne area were required.

- pg 2 - (Collection Methods) - comment - The two paragraphs under the sub heading, "Sweep Net", should be combined or one eliminated as they both say the same thing.

The second paragraph details sampling methods specific for woodlots.

- pg 3 - (Post Field and Laboratory Preparation of Specimans) - grammar/spelling - Second paragraph, second sentence, "Following sorting of the insects in each sample, the sub-samples represented by the insect orders were *weighed* and then the sub-samples...."

Yes, you are correct.

- pg 4 - (Insect Chemical Analysis) - grammar/spelling - First paragraph, second sentence, "Samples were analyzed for *(by?)* Inductively Coupled Plasma (ICP).....",".....and appropriate controls and blanks *were to be* used."

No change required. ICPMS is the methodology used to analyse samples. Samples are chemically analysed for metals by or using ICP.

<u>Tab 13:</u>

- pg 2 - (First paragraph) - question - This comment has been made a number of times regarding "sample site location maps at the back of this volume". There is nothing here indicating where the samples sites are.

See above comments dealing with this issue.

- pg 2 - (Field and Laboratory Preparation of Specimens) - comment - If a bird or mammal was eating these wild grapes in their local habitat, they wouldn't be washing the soil and dust off.

Agreed. As part of the risk calculations, incidental ingestion of soil from foods was accounted for. See equation 6-4 in Chapter 6.

Tab 14:

- pg 1 - comment - Shouldn't this protocol be named, "Soft Maple Leaf Collection and Analysis Protocol"

As noted in the protocol, Soft Maple and Red Maple are used interchangeably.

- pg 1 - (Introduction) - grammar/spelling - First paragraph, second to last sentence, "Of these species, the hybrid Freeman's Maple is *the most common* species in the Port Colborne area.

Yes, you are correct.

- pg 3 - (Field Collection Schedule) - clarification - Were leaf samples collected in September 2000 before protocols were developed, reviewed and approved?

No, leaf samples were collected in late August of 2001.

Tab 15:

- pg 1 - (Introduction) - grammar/spelling - First paragraph, second sentence, "They avoid forest and woodlots, where the deer mouse *Peromyscus* spp is *the most common* rodent."

No grammar or spelling to be corrected.

- pg 3 - (Preparation of Specimens) - grammar/spelling - Second paragraph, third sentence, "Sample bags were not *to* be reused during the trapping process and all bags and used cloths were placed in a sealed container prior to destruction".

Yes, you are correct.

- pg 4 - (Field Collection Schedule) - grammar/spelling - First paragraph, first sentence, "Vole populations *in* Ontario are typically at their highest in the fall".

No grammar or spelling to be corrected.

- pg 5 - (References) - clarification - *Environment Canada. 1998. Pulp and Paper Technical Guidance for Aquatic Environmental Effects Monitoring. EEM/1998/1, April 1998.* What is this report used for in this protocol for the collection of meadow voles?

This reference has been removed as it is not cited in the text.

- pg 5 - (References) - grammar/spelling - *Jacques Whitford. 2001a. Ecological Risk Assessment, Natural Environment, Part of Port Colborne CBRA.* Prepared *for Inco Limited, Toronto, Ontario, (March 2001)*

Yes, you are correct.

Tab 16:

- pg 2 - (Identification of Study Area) - clarification - Last paragraph states, " An historical assessment was also undertaken using aerial photographs from as early as 1934 from the Brock University Aerial Photo Library, Inco archives and the Regional Municipality of Niagara." Please clarify what "Inco Archives" refer to as it has been stated at numerous public meetings that Inco didn't have any older records of what went on at the plant.

Inco Archives, refers to old photographs of the Refinery site that are found in the Inco offices on the site. This is not a reference to old operations documents.

- pg 8 - (Analysis) - grammar/spelling - First sentence, "Following the collection fo the field data similar ELC classified compartments were pooled together, summarized *and* by compartment and by parameter." (Remove and)

Yes, you are correct.

- pg 8 - (Quality Assurance/Quality Control) - question - "Representatives of the Public Liaison Committee's (PLC's) consultant were allowed to monitor field collection of data." Does this mean that Stantec didn't take 20% duplicate samples for QA/QC?

For the woodlot health assessment study, samples were not collected for analysis, only field data was recorded. Therefore Stantec did not take 20% duplicate samples, but Stantec staff did accompany the forester in the field during the data collection for a number of forest stands. The forester did take tree cores to assess age. The cores were later sent for analysis. As Stantec did not take duplicate cores, the results of the analysis were sent directly to Stantec by the laboratory.

- pg 10 - (Appendix A Map) - question - Control sites 1,2 and 4 are shown on this map, where is control site #3? This map is dated December 19,2001 before protocols were established, reviewed or approved??

For the Map provided in Appendix A, Site #3 lies off of the Map, to the east. However, the location of Site #3 is shown on the map in Appendix B. The process for protocol development and review began in April 2001. The woodlot health assessment study protocol was reviewed and commented on by Stantec and the TSC a number of times.

- pg 11 - (Appendix B Map) - comment - This map is very limited in showing where the actual woodlots are. A better map could have been used and would have been more helpful to the reader.

Details regarding the locations of woodlots is provided in the study report in Volume IV.

Tab 17:

- pg 1 - (Introduction) - grammar/spelling - First paragraph, second sentence, "As part of the ERA - Natural Environment, Chemicals of Concer (CoCs) values of corn kernels harvested from the field *trial* crop were to be used to determine dose exposure for risk assessments for deer and raccoons within the Study Area." Same spelling mistake in last sentence of that paragraph.

Grammar corrected.

- pg 1 - (Introduction) - clarification - Corn crops were grown and tested to determine dose exposures for assessments to deer and raccoons within the Study Area. When were raccoons added in the list of species to be studied?

Raccoon were identified as a mammal VEC early on in the process. The list of VECs that would be used in the ERA was presented to the public at a number of PLC meetings during the CBRA process.

- pg 1 - (Methodology) - clarification - If no corn samples were collected in the Primary Study Area and no corn fields were found growing on organic soils, how can CoC comparisons be made in this study?

The inability of being able to sample corn on clay soils in the primary study area is identified as a limitation for the assessment of overall exposure to VECs due to diet. However, as no corn is growing on organic soils, this is not a limitation.

- pg 3 - (Sample Preparation and Analysis) - clarification - First sentence states, "Cobs of corn were husked within seven hours of being collected." Why seven hours? Is there a specific reason for this time limit??

There is nothing special about "7 hours", it is just presented so that it is clear that the corn kernels were processed as quickly as possible.

- pg 3 - (Quality Assurance/Quality Control) - clarification - Why were the PLC's consultants only allowed to monitor the field collection and not take 20% of the samples for QA/QC purposes?

The PLC consultants could have collected a 20% duplicate sample. They chose not to. This question is better directed to the PLC consultant, Stantec.

Tab 18:

- pg 6 - (Table 3) - question - What year were the air quality data collected? It should be stated somewhere in the chart or the notes following.

Air data was collected in August and September of 2001.

- pg 7 - (Biological Materials) - clarification - The biological materials that are asteriked state that the data will be provided in the ERA Crop Studies, so why would they be mentioned in this list and not mentioned anywhere else in this report?

These biological materials are listed in Volume I of the ERA-Natural Environment Report, for example see Table 6-17.

- pg 18 - (General Exposure Calculations) - question - In the paragraph before Table 7, what is air-to-flesh TF and why would it be substituted for ingestion TF when ingestion should be looked at?

This section of the text is explaining that the transfer of inhaled CoCs to the blood and tissue of a bird or mammal via the lungs, is not well studied for the CoCs. Therefore, no specific literature transfer factor could be used. For the first draft, it was determined that as a conservative estimate, the transfer factors for ingestion would also be used for inhalation. However, technical review of the draft report has indicated that due to the significant difference between inhalation of CoCs and ingestion of CoCs, this approach is not appropriate. As a result, the assessment for CoCs in air was not carried forward in the final report. It is also noted that all CoCs measured in ambient air in Port Colborne were within MOE guidelines; hence, it is expected that VEC exposure via inhalation to CoCs would be a minimal exposure pathway.

- pg 19 - (Employed CoC Concentrations) - clarification - Last paragraph, first sentence, "To aid in interpreting risk in different components of the landscape, and to focus any future remediation efforts, exposure assessment and risk characterisation will be undertaken for <u>five scenarios</u>:...." Last sentence of paragraph states, "Soil and food chemical data representing each of these <u>four scenarios</u> will be pooled into subsets,....." Why the difference between five and four scenarios?

The first scenario is "overall study area" which does not require data to be pooled into subsets. The use of subsets of data apply to only four scenarios based on 2 soil types and 2 habitat types.

- pg 40 - clarification - "Protocol Prepared By: Mr. Ron Huizer and Mr. Matt Holder, Jacques Whitford. Protocol Reviewed By: Mr. Eric Veska, Jacques Whitford" Shouldn't this be reviewed by Stantec personnal?

The protocol was reviewed by Stantec personnel. This has been added to the text (P.40).

<u>Volume 3: Supporting Data:</u>

<u>Tab 1:</u>

- Field Data for Surface Water - clarification - Is this the depth at which the sample was taken or how deep the water was? Did this depth include sediment sampling?

The depth presented is the total depth of the water at the sampling point. Samples were collected, where possible in the middle of the standing water column.

These data are not for sediment sampling.

- Amphibian Survey Field Data - clarification - According to this chart, the Fowler's Toad was only heard at one station (#12) one time? How does this qualify for a representative species for the Study Area?

The data presented in the table are the results of the Road Survey. This survey did record the occurrence of the Fowler's Toad at one station. In addition to the Road Survey, the lakeshore was also surveyed on foot to specifically locate breeding sites.

The need to assess risk for the Fowler's Toad has been detailed above in response to other questions regarding this species.

- 2002 Earthworm Sampling Field Data - clarification - What does the column, "Average Value" refer to?

Two samples of earthworms were collected for several sites in the "2002 Earthworm Sampling Fields Data". For sample sites where samples were collected in both Quadrat 1 and Quadrat 2, the "Average Value" is calculated by taking the average number of worms between the two quadrats. For those sites where samples were only collected in Quadrat 1, no average value was calculated. A change will be made and "N/A" will be listed in the column "Average Value" in this case.

Tab 2:

- The chart labelled, "Ecotoxicity testing - Jacques Whitford: Phase 2 Chronic *E.andrei* test,set up date: February 7,2002, obviously shows that there were reproduction problems in this phase of testing.

Agreed and this is discussed in the report.

- Adult 35 day reproduction on clay chart, set up date February 5,2002 - What does the "soil" column refer to? It should be stated what it represents.

The soil column shows the % of the soil mixture for the test. RS is the experimental soil which was used as a control soil for the test. For others, for example, soil-50, is a soil mixture that is 50% control soil with no CoCs and 50% soil with CoCs.

Tab 4:

- pg 2 - clarification - The first paragraph references a study by Malecki et al. (1982), is this the most recent study to establish a NOEC? NOEC for nickel and nickel oxide is the same?

NOECs have been established for many nickel species in many soil types. The Malecki et al 1982 study was not selected because it is the most recent, but because it was considered the most relevant. In subsequent reviews, this value was replaced with a slightly lower value for nickel

sulphate, based on the fraction of the nickel in soil that is of this nickel species. This section has been revised to document additional (including more recent) studies reviewed.

Tab 6:

- pg 2 - clarification - Last paragraph on that page doesn't make sense.

Since no risk is estimated for the Robin population in the study area, an estimation of “safe” soil concentrations of the CoCs for robins is not considered necessary and has not been undertaken.

Volume 4: Consultant's Report:

Tab 1:

- When was it discussed and approved that Jacques Whitford would retain outside consultants to do some of the parts of the ERA Natural Environment Report?

Use of outside consultants was made public at PLC meetings. At these meetings it was requested that the CVs of the sub-consultants be provided. These CVs were provided by Jacques Whitford to the PLC.

Volume 5: Laboratory and Analytical Data & QA/QC:

- Where is the Quality Assurance/Quality Control data that Beak (Stantec) analysed?

This question should be directed to Stantec, the PLC’s consultant.

Conclusion:

Given the scientifics of this study and report findings and although not as knowledgeable as others who might have read this first part of the Natural Environment report for the Community Based Risk Assessment being carried out in Port Colborne, I do have to comment on the difficulty I had in following the flow of this report. For example, there were Tables and Figures referenced in the reading, yet the reader had to flip many pages to find the corresponding chart, or not find it at all. I would also have to comment on the general statement that Jacques Whitford makes that the natural environment is not at risk because of the concentrations of chemicals of concern in the soil, but once the reader reads the report and sees the data, this is not the case. There are conflicting statements made about what is at risk and more importantly why. There also has been too much emphasis put on a specific species of rare toad that is found on Inco's property, supposedly not included in the Study Area, with no real proof that it even exists to the extent that the authors of this report make. While other species, including domestic animals, should have been looked into because of their habitat in the Study Area and close relationship to the CoC's they are exposed to day to day.

The report will be reviewed for flow and table and figure references. Conclusions will be significantly revised to more clearly and accurately summarize the results and conclusions and the basis for these. Other comments have been addressed in previous responses.

The following comments were provided by Ms Diana Wiggins, resident of Port Colborne, ON L3K 1A4. Ms Wiggins comments are presented in full with Jacques Whitford's response, in bold, following each comment.

June 15, 2004

Volume I

Forward pg i 2nd para

"Following this wider review process, a final report will be prepared for submission to the Ontario Ministry of Environment for review and approval."

> *Since this statement has been written the process has been changed to allow for additional public comments once JWEL has addressed all comments submitted.*

The forward of the Final Draft will reflect the current CBRA process.

Executive Summary

pg v

"700 samples from various biological and environment media, including soil, water, air and biological tissue."

> *MOE did sampling in Rodney Street area for soil alone and collected far more data. How are 700 samples from four media considered extensive and how confident are we that all media is covered sufficiently with this testing?*

The samples identified were specific to the ERA. All soil data collected by the MOE in the study area was used, but was not identified in this statement. If we were to also identify this data set (which we did use), the total number of samples used for the ERA would be much higher. Independent third part review of the draft ERA report identified that the data set collected for the risk assessment was extensive and comprehensive.

> *Data Interpretation Protocol should have been completed prior to Lab analysis. This could bias the results as it was done out of turn.*

Interpretation of the all the data collected for the ERA, both quantitative and qualitative, is not directly linked to the lab analysis of the samples collected for the study and did not bias the findings of the study.

> *Farm stock and pets – How will they be looked at?*

At the initiation of the CBRA process, it was stated that the ERA-Natural Environment would not specifically look at pets or live livestock, as they are not part of the natural environment. However, a number of the mammals species used in the ERA are representative of pets and livestock and the results of the risk assessment for these species can be used to assess potential risk to pets and livestock.

Sand Dunes are part of the Natural Environment, therefore cannot be ignored!

The sand dunes were not ignored in the ERA. The dune forest was assessed in the woodlot study, and data was collected for the Fowler's Toad that inhabits the dune-lake shore environment.

EC 20 is not an acceptable risk.

As detailed in the report, the use of an EC20 is a reasonable conservative approach to the assessment of risk to the VEC's used in the ERA and follows standard accepted methods for conducting ecological risk assessment.

Scope of Work and General Design
pg vi
"the study focus would be on natural environment and human influenced environments such as residential yards, parks, playgrounds or schoolyards would not be considered as part of the natural environment"

The reviewer here provides no comment to the above statement from the report. Therefore JW cannot respond without understanding the reviewer's intentions for providing this statement.

Site Characterization
pg vii para 1
"Only small pockets of historically cut and logged woodlots remain. In this respect, the lands east of the refinery are typical for the region, with only highly altered and significantly fragmented natural landscape remaining."

With the above statements it makes no sense that the area that is highly impacted by the CoC's west of the plant be excluded from this ERA. As well the Lake is the only body of water that is natural.

Though it is not clear how the reviewer's comments relate to the quoted text, for the ERA-Natural Environment, the lands east of the refinery were identified as the area with the highest soil concentrations for the identified Chemicals of Concern (nickel, copper, cobalt and arsenic) and represent the greatest extent where soil values exceeded MOE generic guidelines. In addition, results of the ERA are applicable to the natural environment west of the canal where CoC values exceed generic guidelines.

With respect to the exclusion of the aquatic environment of lake Erie, the purpose of the CBRA was to assess the potential risk of CoCs in the local soils. Therefore, the aquatic environment of Lake Erie, where no soils are found, was not considered to part of the study area for the ERA. However, the shoreline along the lake, where soils do occur, was included in the ERA.

para 2

"provincially rare fowler's Toad, a species which is limited to shoreline dune habitats along the north shore of Lake Erie."

> *There is no indication that you studied the Fowler's Toad elsewhere in the natural environment for comparison. However it is noted that you studied them in the Natural Environment you said you were not going to look at in this area i.e. along the shoreline.*

A comparison approach was not used in the risk assessment for any of the bird, mammal or amphibian VECs used in the ERA. However, a comparison approach was used in the woodlot study and leaf litter study.

With respect to including the shoreline in the study area, see JW's response to the comment above.

Plants

pg xi para 1

"maple seed germination and sapling growth in controlled greenhouse study"

> *Were the seeds and saplings from the area or were they introduced?*

For the greenhouse study, two sets of maple seeds (keys) were used, seeds from trees growing in the study area near the refinery, and seeds collected from a control site located north of Port Colborne.

para 1 Greenhouse study only used up to 3,000 ppm nickel.

> *Why was only 3,000 ppm used and what would happen above that?*
> *3rd para. No mention of regrowth or newly introduced trees.*

Soils with up to 3000 ppm nickel were used in the greenhouse study as the soils used where those collected and prepared for use in the ERA-Crops Study which had soils up to this level of nickel concentrations. The potential risk to trees where soil nickel exceed 3000 ppm nickel was addressed in the woodlot study which studied woodlots directly adjacent to the refinery which had the highest soil nickel values.

With respect to "newly introduced trees", the use of control site seeds in the greenhouse experiment addressed this.

pg xii

Scientifically, you determine that 60% of ponds sampled through out the study area have nickel concentrations that would put tadpoles potentially at risk. However when you do frog and toad calls you say you got enough of a response.

> *How can you say that calling a frog would take precedence over the scientific work that was completed to determine that the ponds are putting tadpoles at risk?*
> *Can you guarantee that this clearly indicates the protection of the fish in ponds, snakes, hawks and others for future generations in this area?*

The assessment of risk to the frogs and toads found to occur in the study area was based on two lines of evidence, 1) field observations of species diversity and abundance, and 2) conducting a risk assessment following the risk quotient method where toxicity references values (TRVs) reported in the literature were compared to concentration of the CoCs in pond water in the study area. Generally, using TRVs reported in the literature can be considered a conservative approach, which may or may not reflect what is found to occur under natural conditions. Therefore, as was the case for all VECs studied, field observations were used to determine if calculated risks were consistent with what was found to occur in the study area. In this case, field observations found high species diversity and viable frog and toad populations throughout the study area, indicating that the assessment of risk based on reported TRVs was too conservative. Conversely, if the risk calculation had indicated no risk, but field observations had documented few species and low numbers of frogs and toads, then the results of the risk assessment using the TRVs would have been identified as not reflective of the risk as identified by field observations.

With regard to the other points raised, assessment of risk to fish in ponds was not undertaken, as fish placed in made ponds was not identified as a VEC, as these ponds do not support naturally occurring fish populations.

Also, for the ERA, the Red-tailed Hawk was identified as a VEC and was not identified to be at risk. Snakes were not identified as a VEC for this study.

Decomposers

For an assessment of risk to the soil decomposer fauna, earthworms were studied in the field and in controlled toxicity tests.

> *For the controlled toxicity tests please also refer to comments under Volume II Tab 10 Earthworm Toxicity Tests. What published TRV's were used and are they of type of worm that is found here in Port Colborne rather than the species used in this report? Again please refer to comments under Volume II Tab 10 regarding analysis, Purging of Earthworms.*

***E. andrei* is used in standard toxicity testing as this species can be cultured to grow in the laboratory. Species of worms found in the Port Colborne area have not been successfully raised in laboratories for the purpose of conducting soil toxicity testing. The literature used for the TRVs used in the risk assessment is referenced in the report. In addition, it was recognized that literature reported TRVs may not be specific to both the soils and the worm species found to occur in the local Port Colborne area. This is why an extensive field data collection program was undertaken so that field data could be used to verify the literature based calculated risk.**

Tab 1 1.4.7 Scope of Work

para 1 Live stock and pets are not included in this SOW.

Live stock should be considered in the Crop Studies if not in the Natural Environment as some people grow their crops specifically for Live Stock as well, some use parts of the crops for Live Stock. Pets need to be included in one of these reports as they too are an important part of this community.

See JWs response to comments above regarding livestock and pets.

If a garden is considered as human influenced, what is agriculture land considered?

The assessment of risk to crops was fully addressed in the ERA-Crop Studies. Gardens were not considered natural environments as they occur in residential areas, which are not considered natural areas. However, it was recognized that in a rural environment, agricultural fields are part of the natural environment for many species of fauna. Therefore, data regarding CoCs in soils and crops in agricultural fields was collected for the ERA-Natural Environment.

para 1 Lake Erie "only natural occurring body of water in Study Area."

As you state in your report Lake Erie is the only natural occurring body of water in the "Study Area." Since this is a fact that this report is acknowledging…you can not just leave this area alone and not test the sediments, water and fish.

See JWs response above (pg vii para 1).

1.4.8
pg 18
Clarify the second paragraph starting with "Although Primary and Secondary Study Areas……"

This paragraph has been revised based on comments by other reviewers.

pg 20 2.1.6 Hydrological Parameters

Wignell drain indicates elevated CoC levels directly east of the Refinery; however, this is more a function of proximity to the Refinery and not downstream accumulation.

I thought the CBRA process was to look at elevated levels of CoC's. The fact that the proximity to the Refinery alone should be enough to say we have to look at Lake Erie.

See JWs response above (pg vii para 1).

2.1.7 Lake Erie Nearshore
pg 24
Due to the close proximity of the Refinery to the shore of Lake Erie, there is the potential that CoCs may have accumulated in the nearshore lake sediments. Therefore, the presence of CoCs in the lake sediments could represent potentially harmful environmental effects on the local aquatic biota associated with Gravelly Bay and Lorraine Bay.

Because there is the potential that the CoC's may have accumulated in the lake (again the only natural body of water in the Study Area), this just can not be ignored. Again the statement that there could be" potentially harmful environmental effects on the local aquatic biota associated with Gravelly Bay and Lorraine Bay" CoC's in the lake must be addressed. The fowler's toad lives on the lakeshore and in the Sand Dunes. This species is classified as threatened under the Species at Risk Act (SARA) and therefore it's environmentally significant. Under the messages of the Ministers for SARA it states "Protecting habitat-the places where species live, where they reproduce, where they feed -is essential." Their breeding sites are in shallow areas of permanent water bodies. Therefore this would be along the shore line of Lake Erie in Port Colborne. As this area lies in the Study area, there are only two choices here. Choice one is you need to create protocols and procedures under the CBRA and do the lake sediment testing, water testing, and all further environmental testing in order to protect the fowler's toad. Choice two is release the document Beak-Klohn-Crippen report that you refer to in this NE report for public comment. The fowler's toad environment needs to be addressed and it MUST be part of the CBRA process as it is a threatened species and protected under the SARA. You simply can't just say you are going to omit this area.

As stated previously above, the purpose of the CBRA was to assess the potential risk of CoCs in the local soils. Therefore, the aquatic environment of Lake Erie, where no soils are found, was not considered to part of the study area for the ERA. However, the shoreline along the lake, where soils do occur, was included in the ERA. In addition, the Fowler's Toad was identified as an important species in the local environment, and the potential risk of current levels of CoCs within the shoreline environment was assessed in detail.

Potential sources of CoCs that are independent of historic air emissions include – Dishcarge from the refinery's effluent treatment plant to Gravelly Bay east of the Welland Canal; discharge of impacted groundwater from beneath the refinery lands to the lake nearshore; and, Run off from historical filling and industrial activities along the shoreline, including a slag pit created by the former Algoma Steel south of its operation.

As the above three scenarios are still under the mandate of the MOE, and where necessary we will need to contact the Fisheries and Oceans Dept. any discharge leaving the site MUST be looked at. So again by saying to simply omit this area because there is another report (Beak-Klohn-Crippen 1997) is irresponsible. By deleting the mention of this report does not address the issue at hand. This leaves too many unanswered questions. The sand dunes are also a sensitive area and must be looked at.

The objective of the CBRA was to assess potential risk of elevated levels of CoC's in local soils due to historic air emission from the refinery. As a result potential risk from other sources of in the aquatic environment was not within the scope of the CBRA.

Volume II

Tab 10 EARTHWORM TOXICITY TESTS AND FIELD SAMPLING PROTOCOL

1. pg 1

"population densities are reported to range from 831 worms/m2 in pastureland to 32 worms/m2 in forest soils."

> *In your protocols however you collected in "an area of approximately 0.5 x 0.5 m." How can you compare the two when the field collection was smaller in area than the "reported population density?"*

By multiplying the numbers found for 0.25m^2 by four.

3 pg 3

"Though Eisenia andrei does not occur naturally in the fields and woodlots in and around the Inco Port Colborne Refinery,"

> Choosing this type of worm is wrong on a few different levels. As you state this worm is not naturally occurring in the fields of Port Colborne. This worm feeds on organic materials only. The results clearly indicate that this species feeds readily on this medium, and is able to select and digest organic particles from the artificial soil (Jager et al 2003). E. andrei is not a typically soil dwelling organism as it prefers accumulations of organic matter such as rotting vegetation and compost heaps as a habitat (Sims & Gerard 1985.) Soil type, does influence the feeding behaviour of E. andrei and therefore the uptake of contaminants from the soil (Roel H.L.J Fleuren et al, 2002). This species is therefore not an obvious choice for bioassays with field soils (Edwards & Coulson 1992). For these reasons it could explain why you do not find this variety in Port Colborne. Using this species for your toxicity testing is inappropriate.

For the use of *E. andrei* for toxicity testing see JWs comment above. E. andrei may occur in the area, however, for the study the collection of worms was undertaken for fields and woodlots. Compost piles, the preferred habitat for the species were not sampled.

3.2 Phase I – Acute Testing

"soil was air-dried and sieved using a mesh size of 4 or 9mm,"

> *Which were used 4 or 9mm?*

Both.

4.3 Purging of Earthworm

pg 8

Your study says "worms were left in the bran to purge existing soils in the gut"

> *If you remove the soils from the gut it will give you an inaccurate result. Did you test the bran after the purging? Doing the whole body doesn't give you an accurate result either as the soils and vegetation is retained primarily in the gut. The crop content (representative of ingesta) and the gut content from the last 1 cm of the posterior gut (representative of egesta) were collected by dissection (Roel H.L.J. Fleuren et al, 2002). This former statement appears to be*

the norm when testing on worms. Explain why you chose to analyze the entire worm and purge existing soils in the gut.

For the study worms were looked at for two reasons. First worms are common food item for a number of the VECs that were looked at for the risk assessment. Second worms were also a VEC. By comparing the total concentration of the CoCs in whole worm (soil in gut) to purged worms (no soil in gut) one could determine exposure to a VEC that eats worms based on the fraction of CoCs in worm tissue and fraction of CoCs in soils in the worms gut. For the risk assessment CoCs in worm tissue was considered completely bio available. A fraction of the CoCs in the soil in the worms gut was considered bio available based on the results of CoC absorption from soils by rats.

Tab 11 Leaf Litter Decomposition Study Protocol

pg 1.

"Factors that disrupt decomposition ultimately influence the rate of natural processes." "Loss in weight of the litter over time is used as the indicator of decomposition rate. Because the decomposition rate is not rapid and involves sequential steps in the breakdown of the different types of material, as well as a variety of different types of microbes...etc…such studies often require two years or more to complete. Because of time constraints the current situation does not allow for a detailed investigation"

> *By saying in a protocol from November 02, that the time constraint doesn't allow a proper study is not acceptable. We are now in 2004 and the study could have been completed. There is no reason why this study should not be done as the remediation of lands will take many years. If you started a proper study now it may be completed by the time we get to the HHRA and the Integration Report. Nitrogen, potassium amongst others are important nutrients in the ecosystem. The woodlots highly depend on the nutrients to balance the natural system. It is important to test the nitrogen levels as well as other nutrients in order to be accurate in the Woodlot study.*

The extended time frame for the CBRA for completing the ERA could not be anticipated at the initiation of the study. However, the results of the leaf litter study as conducted for the ERA in conjunction with the woodlot study do provide sufficient information to conduct the ERA.

Tab 18

1.1 Scope of this CBRA

pg 1. 1st para.

"For the ERA, current impacts to the natural environment resulting from historical emissions of CoCs from the Inco Refinery in Port Colborne will be assessed.

> *This should say "For the ERA, current and potential future impacts to the natural environment" (This could put a different prospective on the peer reviewers remarks.)*

The conclusions of the ERA do assess future impacts.

pg 3

The primary objective of the ERA-Natural Environment is to develop the weight of evidence that emissions of CoCs from the Refinery are having effects and will continue to present undue risk to the natural environment of Port Colborne.

> *This is basically impossible to do if part of the natural environment is being ignored….i.e. Lake Erie and the Sand Dunes. What is going to be done to meet the objective of the ERA-Natural Environment?*

The ERA-Natural Environment was undertaken for CoCs in soils and the sand dunes forests were considered.

pg 5 Table 1

QA\QC is missing from this chart.

The purpose of this table was to present a summary of the data collected. For QA/QC, for the collection of the data sets the review should refer to the protocols for the collection of each specific data set.

pg 10 Figure 2 Exposure Assessment

Frog exposure Calculation not done…..why?

Exposure calculation where not undertaken for adult frogs as there are no Toxicity Reference Values (TRVs) for skin exposure to frogs for the CoCs in the literature.

5.4 2nd para
pg 15

"All analysis will be preformed by an independent consultant (ESG International)"

ESG is not independent of Inco.

To the best of JW's knowledge, at the time when the tests were conducted, ESG International was independent of Inco.

5.5.2 para 3
pg 19

"In certain cases where CoC concentrations of food items are unknown and can not be estimated (such as crayfish as part of a Raccoon's diet), then either a suitable food item where the CoC concentration is known will be used as a surrogate, or the food item will be excluded and the percent composition recalculated."

6.6 Uncertainties – Does not appear to tell us what was done. Was it omitted or was there a surrogate? If omitted I have to go back to the Beak-Klon Krippon Report. Crayfish in this area live in the Lake and are bottom feeders. This is necessary to have this information. If a surrogate was used how was it used? Was the fact that crayfish are bottom feeders in the Lake dealt with? How was it dealt with if the levels of CoCs in the sediment are unknown?

The uncertainty associated with food items from the aquatic environment will be address in a new limitations and uncertainty section.

5.5.3 para 1
pg 19
"Site-specific CoC concentrations will be used to calculate the exposure a receptor receives from food items and surrounding media when occupying the affected area."

The Laboratory protocols state that vegetation was washed with distilled water prior to analyzing. I don't believe that a deer (and others) will wash its food prior to eating it or crawling in it.

The fraction of soils in the diet of a VEC was included as part of the daily dose for the purpose of exposure assessment.

The area you have studied has been affected by human activity, i.e. farmland. I don't understand why urban areas were not considered. All VEC;s should and could be found West of the plant and East of the canal. Please explain this rationale much clearer.

JW's position is that urban areas are more altered than rural areas and do not support the populations of flora and fauna that are found to occur in the local area. Nevertheless, the study area as identified, did contain soils with levels of CoCs that were fully representative of the local area, be it rural, urban, or east or west of the refinery.

Volume III
Tab 1 Earthworm Sampling Fields Data

The following are listed under Primary Area but according to Map 1 they are in the Secondary Area: CW-H10, CW-H-11, CW-H-12, CW-H-13, CW-H-25 and WW-H-30. CW-H-24 is out of the study area completely.

Sample locations shown on Map 1 are correct. The heading "Primary Area" in Volume III will be changed to "Study Area". As for CW-H-24, this site location is considered to represent the study area based on soil CoCs in this location. MOE contours were used as a sampling guideline only.

Tab 7 Soil Data Used to Calculate UCLMS
I was unable to find on map 1 where soil samples were taken from with the sample number. Verbal answer on this would be sufficient.

A map will be added to Volume III, Tab 7 showing the location of soil sample locations.

Map 1 Sample Site Locations

There is no indication that corn in Primary Study area was used. Did you use the corn from the field plot? If so why is it not marked on the map.

No corn was sampled from the primary study area. Corn data was obtained from the Crops Study which shows the location of the crops.

Frog surveys 1,2,3,10,12,13 and 29 are outside both primary and secondary study are. Why is this on the map and did you use the results as part of this report? If so why?

Due to the difficulty of pinning down the exact location of a frog call, the frog survey was designed to determine whether frog calling abundance and species diversity changes with distance from the Inco Refinery. Study Area has no bearing on the Frog survey.

Tadpoles 7-M-3 and T-M-2 are outside Primary and Secondary Study area. Why is this on the map and did you use the results as part of this report? If so why?
Water sampling S7, S12 and S30 are outside Primary and Secondary Study area. Why is this on the map and did you use the results as part of this report? If so why?
Earthworm CW-H-24 is outside Primary and Secondary Study area. Why is this on the map and did you use the results as part of this report? If so why?
Frog sample F-M-2 is outside Primary and Secondary Study area. Why is this on the map and did you use the results as part of this report? If so why?
Maple Leaf L-M-4 on map shows to be in Primary Study area but appears to have the coding of Secondary Study area.

MOE contour line were used at the beginning of the study to generally structure the sampling program for this ERA into a Primary, Secondary and Control Area. However, for the purposes of the ERA, the MOE contours by no means restricted sample collections within these lines. What is important here is the soil concentrations where the organisms were collected. Since a soil CoC gradient occurs across the landscape, organisms collected just outside the secondary area may have been exposed to similar CoC levels to organisms just inside the secondary area. In some situations, to obtain a robust sample set, areas just outside the secondary area were considered secondary study area samples based on the soil CoC concentrations.

Volume IV Woodlot Health Assessment Study
pg 2 para 2
Compartment age was measured by using an increment borer to produce a wood core which was visually analyzed to determine age by counting rings.

> *Before this study got underway during a PLC meeting it was requested that the forester dealing with this issue be capable of coring the trees. We were told that there wasn't anyone that was known to be able to do this. As the coring had to be done to identify the age of the tree anyway were these sent to a lab for analyzing? If not, why? If so where are the results? Either they are capable of coring or not. I am making it a request now that the coring of trees be redone and sent to have it analyzed if this has not yet been done.*

JW is unaware of any comment regarding the inability to find someone capable of coring trees. Core samples were taken by the forester. Analytical results of these cores are located in Volume V, Tab 43.

Map 3 Ecological Land Classification

> *Woodlot C1A is outside study area. Did you use this in this report and if so why?*
> *Woodlot 17C is outside study area. Did you use this in this report and if so why?*

See the above comment.

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APPENDIX C

JACQUES WHITFORD
RESPONSE TO STANTEC COMMENTS

Port Colborne Community Based Risk Assessment

Ecological Risk Assessment – Natural Environment

Review of Initial Draft Report – January 2003

Introduction

As part of a Community Based Risk Assessment (CBRA) initiated by Inco Limited to address potential impacts resulting from historical emissions from a former nickel refining in Port Colborne, Jacques Whitford (JW) completed an Ecological Risk Assessment (ERA) for the natural environment of Port Colborne. Following completion of two years of fieldwork and analysis of data, JW prepared an initial draft ERA report in January 2003. Following the CBRA process, a copy of the report was presented to the City of Port Colborne's consultant, Stantec Consulting Ltd. (Stantec, formerly Beak International Incorporated) for review and comment.

Following their review, Stantec prepared a report in April 2003 detailing their and comments on the initial draft ERA report. This review report was provided to Inco, JW, and the City of Port Colborne (the PLC). This Appendix prepared by JW combines the comments of the Stantec's review report, with JW's response to those comments.

The format of the appendix is to present Stantec's questions and comments in their entirety as stated in their April 7, 2003 report (starting with Part 1 – page 5) with JW's response in bold following each question, statement or comment. Some of Stantec's comments were helpful editorial suggestions, or state that a particular section of the draft report needed clarification. In these cases, JW's comments are simple responses, indicating that changes have been made to the text of the report. For comments or questions made by Stantec that are of a technical nature, or where the study's design, methods and/or approach are questioned, a detailed response is provided by JW. In this way, reviewers can clearly follow the review and comment process, understand the depth of Stantec's review and how JW has responded within the final ERA report.

Stantec comments that question specific results or methods of assessments have been fully addressed in this Appendix and/or in the report under this cover.

Part 1 Review of the Port Colborne ERA – Natural Environment

Section 1.0 – Introduction	JWEL advise that the primary question that the ERA addresses is "Are the natural ecosystems in the vicinity of Port Colborne affected by the historical emissions from the Inco smelter?" However, if the ecosystems are affected, the next logical question would be "how extensive are the impacts and what can be done to remediate them?" **Section 1.4 Study Objectives provides a clear statement of the primary objectives of the ERA and addresses the above questions (Section 1.4).** Stantec has additional questions that we believe should be considered: ➢ Are there any species missing that should be present, based on habitat and other ecological conditions? ➢ Are there any species that are very low in numbers that can't be explained? **For the above two points, the question of determining species absence or low numbers in any local landscape is very difficult given the level of investigation that would be required (time period of study; assessment of natural population dynamics including emigration and migration; requirements for detailed comparative assessment of a number of local areas in a region; and so on). Given all the potential confounding factors, and time constraints for completing this study, detailed analysis of this type was not considered appropriate for the CBRA ERA.** **No one local area in Ontario will be found to support all potential species that occur in its region, even under pristine conditions. Therefore conducting fieldwork and analysis for missing species or determining if low numbers occur for a species was not considered useful to this study. However, as detailed in Section 3.8 Flora and Fauna, the study did conduct sufficient field investigations so that large-scale effects of soil CoCs on local flora and fauna (species absence/numbers) would have been identified (Section 3.8).** ➢ Did the ERA include the natural environment within the urban area (i.e., did it include potential impacts on domestic animals, squirrels, etc.)? **Section 1.4.7 Scope of Work, clearly details what the ERA considered to be the natural environment with respect to this study. It clearly states that parks, playgrounds, farm stock and pets were not considered to be receptors for the ERA. Squirrels occurring in natural woodlots could have been considered to represent a mammal receptor or VEC for the study; however, they were not included. Rather, fox, raccoon, white-tailed deer and vole were identified as mammal receptors for the ERA (Section 1.4.7).**

Page 1-7, Third Paragraph	The first sentence states that no ERA has been conducted for the Port Colborne lands prior to these studies. The second sentence then describes how the MOE has conducted assessments of maple in the area through the 1970s and 1980s and found injury symptoms in maple leaves. The subsequent paragraphs describe MOE investigations and conclusions that would certainly indicate that an assessment of risk had been undertaken. **This statement is true, prior to this study no ERA had been conducted for lands in the local Port Colborne area. As this section details, some studies were conducted by the Ministry of the Environment (MOE) on some species to assess potential effects of CoCs on trees; however, characterization of risk was not undertaken by the MOE for any species in the local Port Colborne area. Ecological Risk Assessments are a standardized process that includes site characterization, receptor characterization, exposure assessment, hazard assessment and finally, risk characterization. A review of the previous studies indicate that some limited level of exposure and hazard assessment had been conducted over a number years, however no risk assessment was conducted. During the course of this study, the MOE was asked by JW if any ERAs had been conducted on lands or specific properties in the Port Colborne area, and their response was, and is, "no" (P. 1-10).**
Section 1.3 – ERA Process Page 1-12	States"… limited existing data and uncertainty in exposure assessments often limits the sole use of using a probabilistic method for completing an ERA." The sentence is unclear. If JWEL are trying to say that sometimes there are insufficient data to support use of a probabilistic method, then the section should be rewritten. **The references to probabilistic assessment methods have been removed since these techniques are not used in this assessment (P. 1-11)**
Section 1.4 - Study Objectives	The reader would like to know the extent of the natural environment within the Study Area and to which part of CBRA this study applies; this has not been done and is a major omission. **This section details the study objectives, and the next Section 1.5 Scope of Work defines what is the natural environment for the purpose of this study. JW believes that sections 1.1, 1.1.2 and 3.1 provide the reader with detailed information as to which part of the CBRA process the ERA applies.** **However, as stated on page 1-14, the general study area for the ERA is "the lands east of the Welland Canal, in and around the Inco Port Colborne Refinery, where soil nickel concentrations are greater than 200 mg/kg, as mapped by the MOE (2000a,b)." Data on the natural environment were collected from within this area and in reference areas to the east and west of the study area. As stated later in the report, only lands outside of the urban setting of Port Colborne are relevant to the scope of this ERA. Samples collected from crop fields, unused or fallow fields, woodlots and areas of standing water were used as part of the ERA. More detail has been provided both in the text of the report and mapping to clarify the spatial extent of this ERA (P. 1-20)** Such a map would also show the agricultural lands to which the phytotoxicity study applies and the boundaries of the residential areas to which the HHRA study applies. **Although this comment appears to be a disjointed thought, it seems that the reviewer is under the impression that the ERA-Natural Environment and the Crops Phytotoxicity Study and Human Health Risk Assessment (HHRA) have divided up the lands around Port Colborne into separate parcels for separate study. This approach**

	would, of course, be absurd, as each study must define its own study area, which will often overlap with any or all of the other study areas. In general, the CBRA study area extends over all soils in the Port Colborne area where CoCs exceed MOE generic criteria. The results of the various ERA and HHRA work apply to all human receptors and flora/fauna within this area. Later in the report, there is discussion of the areas of different habitats and the relative proportion of these areas within the Study Area. However, examination of Figure 1.1 shows the Study Areas enclosing large areas of residential and industrial lands. Have these been included in the calculations of the relative amounts of natural areas? **Figure 1.1 has been corrected so that the study area within the 200 mg/kg Ni contour is clearly defined and shows that the major residential areas and the industrial lands of the Inco Refinery proper and areas east of the Welland Canal are not included in the study area. In addition, text in Section 1.6 provides a more detailed description of what is considered to be the study area for the purpose of the ERA (Vol. 1, Map 1).** The 200 ppm Ni isopleth in Figure 1.1. extends across the Welland Canal and into west Port Colborne. There are also other 200 ppm isopleths in the northwest and in the northeast of Figure 1.1. Are these areas bounded by these isopleths also included in the ERA Natural Environment? **See above.**
CROP PHYTOTOXICITY VS. NATURAL ENVIRONMENT AREAS	There are two parts of the ERA, one dealing with crops and the other dealing with the natural environment. JWEL does not appear to have described or shown on a map, the lands to which these different sets of studies apply. It would seem logical that the arable lands would be mapped as they would represent the part of the study area to which phytotoxicity experiments and results apply, and the natural grasslands, woodlots and water bodies would constitute the natural environment. **See above.** There is no mapping of water bodies or indication that they exist based on the Ecological Land Classification (ELC) of the Study Area. If important features and habitat types were clearly mapped then the calculation of the areas impacted by different levels of CoC would be much clearer and plans for mitigation where necessary could be more focused. **Water bodies (mostly cow ponds) are shown on the ELC map, Map 3. With respect to other habitats, Map 3 presents the natural habitats in the study area. Areas in the natural environment where risk from CoCs has been identified and that could be considered for mitigation are addressed in Section 9.0 of the report.** The clear mapping of the natural areas by general habitat type at the outset showing woodlots, old fields, meadows, ponds and water courses would considerably assist the reader in understanding the very irregular distribution of sampling points for some of the plants and animals (Figure 1.1.). It would also help define the area to which the ERA Natural Environment applies. Later on reference is made to "the Study Area's ponds and drains" (page 3-19) but the ponds are not mapped nor included in the ELC classification. **See above.**

	JWEL specifies “only the terrestrial environment has been identified for the screening of ecological conditions and potential effects of CoCs”. However, later on in the report JWEL describes the importance of water bodies for the breeding of frogs, the collection of water and sediment samples as well as the collection of tadpoles and frogs for the purpose of the ERA. This inconsistency should be addressed. **The potential impacts of CoCs in surface water for inland water bodies (cow ponds and municipal drains) that the ERA addressed has been expanded on in the report (P.1-20)**.
ACCESSIBILITY OF SITES FOR SAMPLING	There is no reference about accessibility to sites for the purpose of sampling. Because JWEL staff was not given permission to visit numbers of properties this has an effect on the distribution of the sampling sites. This should be mentioned in the reports as it explains at least some of the irregularity in the distribution of sampling stations. **While it is true that permission to gain access to lands to collect samples was not provided by some landowners, this was not considered to represent a limitation to the study. If this had been identified as problem for the completeness of the study, this sampling limitation would have been identified is sections 5.2.2 and 5.3.4 and Section 10.0 of the report.** **With respect to the statement “as it explains at least some of the irregularity in the distribution of sampling stations”, JW does not share Stantec’s opinion that there is an irregularity in the sampling locations. For the study, sampling sites were identified based on a set of predetermined criteria (located in the secondary and primary study area based on soil Ni concentrations, organic and clay soils, and woodlots and fields). As the study area is heterogenic with respect to these criteria, the resulting sampling pattern appears to be “irregular” when mapped. Though a visually regular sampling pattern gives one an innate feeling that the data set is good, and that an irregular data collection pattern means bad data, there is no scientific bases for this line of reasoning, as the two are not linked**.
Section 1.6 - General Study Design and Approach	The Study Area for the ERA Natural Environment is based upon MOE data and isopleths and has been divided up into three zones: a Primary Study Area (>500 ppm nickel), a Secondary Study Area (200-500 ppm nickel) and a Reference Study Area in which soils have less than 200 ppm Nickel. The soil values plotted by MOE show several additional Ni concentration isopleths and plot the sampling points, including those outside the 200 ppm Ni zone; this provides a level of confidence in the results (MOE 2000a). A subsequent MOE report (MOE 2000b), investigates the soil concentrations in woodlots and notes the much higher value of CoCs in woodlots. **Maps 1 and 3 show the 200 mg/kg and 500 mg/lg Nickel isopleths based on MOE soils data as is referenced in the report. For these maps only these contours are provided as they are relevant as to how at the start of the study a sampling program could be set in place. For the final report, Vol. III, Tab 9 provides all data (including MOE) used for the production of isolines for the CBRA. In addition, Figure 2-6 has been added and shows CoC values for woodlots. Data used for Figure 2-6 is also provided in Vol. III, Tab 9.** JWEL makes reference to “major” CoCs. Which are these? Are there “minor” CoCs? **There are only CoCs, and this has been corrected in the report text (Section 1.4.8).**

	JWEL suggests that "to focus any future remediation efforts, exposure and risk characterization were undertaken for five scenarios: overall Study Area, woodlots on organic soils, woodlots on clay soils, fields on organic soils and fields on clay soils." (Volume 1 page 1-15). The extent of these habitats in the different Study Areas is not shown. **There are no different Study Areas; there is only one as defined in the report. Within this Study Area, the assessment of risks was undertaken for the scenarios as noted. For the report, both a soils map (Figure 3-1) and habitat map (Figure 3-2) are presented.**
Section 1.6, Page 1-14	Primary and Secondary Areas: It is not clear why these areas have been defined (to ensure that field data collection was structured so that data sets were representative of areas where soil CoCs were high to moderate?). Was the sampling effort stratified to ensure coverage of these two levels of contamination? In any case, the risk characterization was apparently performed for a "population that occurred within the entire Study Area". On pp. 1-15, we learn that this means an individual exposed to the UCLM (Upper Confidence Limit For The Mean) for the Study Area. Depending on home range, individuals may experience CoC concentrations much greater than study area average. A risk assessment must consider the range of impacts on individuals, even if the population is of primary interest, because the population is comprised of individuals. **The Primary and Secondary Study Areas were identified within the ERA's Study Area to structure the sampling so as to collect representative samples from areas with both high and moderate soil concentrations of CoCs. Sampling was aimed at providing a representation of each of these areas, but sampling structure was constrained by the spatial distribution of landscape elements (e.g., the location of standing water). Further discussion on the constraints to sampling has been expanded upon in the report.** **This ERA is examining the risk to the population of the identified VECs, with the population defined as those individuals living within the Study Area. Since this is a community-based risk assessment, and not a site-specific risk assessment, we believe this is appropriate. For this ERA, we are interested in the potential risk to the population overall.** **For highly mobile species such as birds and mammals, the home range may be large compared to the spatial extent of the high concentrations and use of the UCLMs to evaluate exposures is considered a reasonable maximum approach for protection of such individuals as well as the population.**
Section 1.6, Page 1-15	We are told here that UCLMs are conservative estimates of concentration, i.e., close to the highest values found in the Study Area. A UCLM can only approach the maximum when: (a) sample size is very small, or (b) the distribution is very "non-normal". However, we are not shown maximum values by which to verify the stated conservatism. In any case, Table 6-32 shows that the UCLM values used were not conservative in some instances. **Summary statistics, showing the mean, range, standard error, standard deviation and UCLMs, have been added for the data sets collected and used for the ERA. This information, in table format, is accompanied by text discussing the conservatism in the methods (Section 6).**

Section 1.6, Page 1-16	We are told here that a LOAEL (Lowest Observable Adverse Effects Level) benchmark was used to assess doses to mammals and birds, and then we are told that, for large mammals such as deer, a LOAEL was considered more appropriate than an EC20 (Effects Concentration Where 20% Of The Shows An Effect). This is confusing since EC20 was not used for any mammal or bird. **The paragraph and section in question has been amended to make it clearer why we chose to use LOAELs and NOAELs for mammals and birds instead of EC_{20}s (P. 1-26).**
AVERAGING OF WOODLOT AND FIELD CoC LEVELS	The MOE demonstrated that woodlots act as a trap for CoCs and that CoC values for woodlots were higher than surrounding fields (MOE 2000). Because potential remediation will likely be very different for different land uses, i.e. woodlots vs. pasture vs. arable fields, and because there does not appear to be a separation of the soil CoC data for these different land use types, one cannot determine from the data presented what should be the concentration isopleths for CoCs. This averaging of soil CoC values for different land use types will result in an incorrect evaluation of which lands need remediation, and the woodlots should be separated from the other data **The report has been reviewed so that Figures 2-2 through 2-5 present isopleths for CoC soil concentration values (0-5 cm depth) for soil samples collected by MOE previously and by JW during this study from open field/pasture/arable fields habitats. Woodlot soil CoC values (0-5 cm depth) are not included in the data set for the generation of the isopleths. Soil CoC values for sampled woodlots are presented in Figure 2-6.**
CONFIRMATION OF CoC CONCENTRATION ISOPLETHS	A major premise of the ERA is the pattern of distribution of CoCs that is based on the MOE soil sampling in the Port Colborne area and the several isopleths created for CoCs (MOE 2000). The MOE used a regular grid of sampling stations to produce the isopleths. JWEL does not appear to have consolidated the data used from the test pit sampling and the ERA soil sampling to either confirm the MOE isopleths as a form of QA/QC or to provide revised isopleths. A map showing the soil sampling stations used by JWEL and the results of the surface 0-5 cm samples at each site for each of the CoCs would probably remedy this situation. **See above.** This distribution of CoCs demonstrated by the various isopleths has a significant bearing on the lands that will need to be remediated. It is therefore extremely important that great care is taken in drawing them. The use of an irregular pattern of sampling sites as illustrated in Drawing No. 4, Volume 4, will easily distort a standard GIS plotting of isopleths. **See above.** The tables providing values of CoCs in fields and woods have very high standard deviations (SDs); the range of values should be provided. Perhaps part of the reason for the high SDs is the allocation of sites to incorrect Study Areas. A revision of the boundaries and more accurate mapping would improve the confidence. For instance, in Table 2-5 the SD for Ni in the Primary Study Area (9041) is greater than the mean value (8926). Also in the Secondary Study Area the mean value for Ni is 797 ppm (n = 16), which is higher than the upper limit for the Secondary Study Area, which suggests that the boundaries should be revised. **As noted earlier, additional summary statistics has been provided for data.**

To repeat, as stated in the text, the Primary and Secondary Study Areas are based on MOE data and do not reflect additional data collected by Jacques Whitford. These Study Areas were defined only to provide structure to the sampling program. High standard deviations are not due to allocation of sites to "incorrect" Study Areas, although the values presented by Jacques Whitford indicate that knowledge of the distribution of CoC concentrations in the Port Colborne area has improved with the additional data collected during the CBRA. Instead, the standard deviations indicate that the area is highly heterogeneous.

The Primary Study Area has >500 ppm nickel, the Secondary Study Area 200-500 ppm nickel and Reference Study Areas <200 ppm nickel. The results of JWEL soil studies (Figure 2.3 Volume 1: Volume IV Drawing No 8) do not show a 500 ppm isopleth. It would be helpful to the reader if the reason for this could be explained, or if a 500 ppm isopleth was provided.

Mapping has been revised to provide further detail on the distribution of CoC concentrations in the landscape, which includes the mapping of the following isopleths: 200, 500, 1000, 2000, and 4000 mg/kg for Ni (Figure 2-2).

There is a general concern on the way isopleths have been charted. For example, the separate 200 ppm isopleth around the Welland Canal in Figure 2.3 could well be a result of the irregular distribution of the sampling sites, or the local distribution of AMEC sampling sites. Should they be connected to the major 200 ppm isopleth?

See above.

The very high levels of Ni recorded (20,000-30,000 ppm) (Volume 1, page 2-25) do not appear to have been plotted on a map as was done by the MOE (2000). The reason for this should be explained, as the very high levels will certainly skew results if distributed over many hectares. While copper, cobalt and arsenic have intermediate isopleth contours plotted (Figures 2.4-2.6), this was not done for nickel; why? This is again referred to in Section 2.1.10 where the point is made that within one kilometre of the smelter, the nickel concentrations are two orders of magnitude greater than the MOE guidelines.

See above.

JWEL indicates in Tables 2-5 and 2-6 that there is a very large variance in nickel concentrations both within an individual woodlot (Table 2-6) and between a number of woodlots (Table 2-5). It is certainly not clear how JWEL has used this information in the revision of isopleths. If the woodlot data is so much higher than the open field data, and if woodlots are relatively scarce in the natural environment, why they have included this data in creating the isopleths in Figure 2-3?

See above.

In discussion of the vegetation of the Study Area (Section 3.8.1), the emphasis is placed on woody vegetation in terms of the survey work. Page 3-15 states "The vast majority of the tree and shrub species were found to be growing on lands directly adjacent to the Inco refinery in areas where existing soil concentrations of CoCs are the highest (3,000- 5,000+ ppm Ni)." Given that JWEL has recorded levels of Ni of 20,000 – 30,000 ppm in woodlands east of Reuter Road, it seems unusual that the value 5,000+ ppm Ni is used. This is

	particularly unusual considering that the Hop Tree Dune Woodland, adjacent Upland Dune Woodland and the Red Maple Swamp, is described as being particularly significant in the Region. **The range of Ni values in the text has been re-assessed.** A revision of the Study Areas based on the JWEL findings should be undertaken, showing the original Study Areas and revised 200 and 500 ppm isopleths, and also 1,000, 2,000 and 5,000 ppm Ni isopleths. **It is noted here that the reviewer has mistakenly combined two concepts. First, the term *Study Area* refers to the area that was identified for the purpose of sample collection and general description of the local area's natural environment. As the Study Area had to be identified early in the CBRA process, the exiting MOE soil data set was used, and the 200 ppm Ni isopleth, as well as other parameters as detailed, was used to define the Study Area *for the purpose of sample collection and natural environment assessment.* The second concept is the area of land where soil levels of Ni exceed the current MOE guideline of 200 ppm. This area is found in Figure 2-2 of the report and represents all soil data collected for the local area, both MOE data and data collected during the CBRA. This map has been updated as detailed above. However, Figure 2-2 is not the Study Area for the ERA. All lands where soil Ni is greater than 200 ppm Ni have never been referred to as the Study Area with respect to the determination of risk for the ERA. Therefore, there is no change to the Study Area for the ERA as a result of new soil data and no revision is required**.
Section 2.1.4 - Distribution of CoCs in Soils	The first paragraph describes how the soil CoC concentrations sampled in the top 20 cm are similar for both the organic and clay soils. The next paragraph states that the MOE, AMEC and JWEL data are combined to produce Figure 2.3. Can we therefore assume that JWEL has mixed the soil values from the top 20 cm with those of the top 5 cm for the purpose of creating this figure? **No, this assumption is not correct. It is clearly indicated in the legend of all the figures where soil CoC values are shown as isopleths that the data is based on 0-5 cm surface soil data.**
	JWEL describes at some length the different concentrations of CoCs in the surface layers of the soil and concludes that while the higher levels of CoCs are in the 5-15cm layer of clay soils, "the 0-5 cm horizon is considered to represent the area of primary interaction of soil CoCs with most biological receptors." Considering that for the ERA the primary producers are considered to be maple trees and herbaceous vegetation (grasses), (goldenrod was examined as part of the phytotoxicity studies), JWEL should recognize that the majority of contact with CoCs is below the 5 cm level. Even earthworms spend much of their lives below the 5 cm layer. **As stated in the text, for clay and organic soils, the CoCs are primarily distributed throughout the top 20 cm of the surface soil. The report does not conclude that CoCs have higher levels in the 5-15 cm depth layer of surface soils. The report clearly states that CoCs are higher in the 5-15 cm for undisturbed clay soils, and that for all other soils, (both disturbed and undisturbed organic soils and disturbed clay soils) that the CoCs are at the same concentration throughout the 0-20 cm surface soils. Data collected from three undisturbed clay sites outside of the study area on the Inco Refinery property show that slightly higher concentrations are found in the 5-10 cm horizon than in other horizons at those locations, which was the basis for our earlier**

	statements. However, based on data collected from test pits in the study area, outside of the Inco Refinery site, the greatest concentrations of CoCs are typically found in the 0-5 cm horizon. This supports our statement that using CoC concentrations from the 0-5 cm horizon is reasonable for estimating exposure of the receptors to CoCs. **With respect to using soil CoC concentration values based on the 0-5 cm soil depth, JW remains confident that CoC values of the surface soils represent the primary exposure zone for the vast majority of the receptors for which risk is assessed. For the risk assessment, birds and mammals are only exposed to surface soil as part of their food chain exposure pathway to the CoCs (Meadow Vole, White-tailed Deer, Raccoon, Red Fox, Red-tailed Hawk, American Robin, American Woodcock and Red-eyed Vireo). While it is true that plant roots will move down and past the 0-5 cm soil depth, the 0-5 cm zone nevertheless represents a significant portion of the plants rooting zoning for most herbaceous vascular plants, such as goldenrod. For maple trees, the greenhouse experiments were based on fully mixed soils that were put into the pots up to a concentration of 3000 ppm Ni. In this case, the seeds and young trees were exposed continually to a range of CoC concentrations that are above what would be found in the typical rooting zone of maple trees in the local area east of the refinery. In this respect, for maple trees, the greenhouse exposure experiments are more conservative than what is found in the natural environment in the Port Colborne area.** **Given the above, the use of CoC concentrations in the 0-5 cm surface soils is considered to be the appropriate method for assessing the ecological risk of soil CoCs to the Port Colborne environment.**
Section 2.1.4, Page 2-6	We are told here that As is unrelated to other CoCs. This is not correct, as JWEL's Re-evaluation of Lead report shows that As is correlated with Co, Cu and Ni, not to mention Pb. **This line has been removed from the ERA report, as this ratio is not directly relevant to the ERA as the assessments were based on full analysis of specific soil samples.**
Section 2.1.4, Page 2-6, Second Paragraph	Soil concentrations for 0-5 cm were used in the assessment. Clearly some species of interest are exposed to somewhat deeper soils (e.g., earthworms, trees). How does the 0-5 cm zone compare to the 5-20 cm zone with respect to CoCs? **See above for a detailed discussion on this point.**
Section 2.1.4, Table 2-3	Is a comparison of Soil Nickel Concentrations in woodlots and adjacent fields at various distances from the Inco Refinery. There is an indication that a woodlot within 1 km of the refinery has Ni at 33,000 ppm nickel. It is referenced as (A3-0-5); there is no such point on Figure 1.1 or Figure 2.3. The adjacent field is indicated as having a 1,860 ppm Ni (I-H-3) and is situated on the east side of Reuter Road. **Maple Sap tree codes (e.g. A3), have been added to the existing site locations map (Map 1).** It seems curious that no soil samples were taken from the woodlot/swamp on the west side of Reuter Road as this has been identified by JWEL as a significant wetland and ESA. As such, it would presumably have higher levels of CoCs and therefore the plants and animals that occupy these lands may be exposed to even higher levels and be at risk. It is a serious omission if the soils in this area were not sampled.

	The environmental management of the lands associated with the Inco Refinery proper is to be undertaken through a closure plan pursuant to the Ontario Mining Act and are therefore outside the CBRA process. This has been expanded upon in Section 1.6 in the report. However, some samples were taken from lands just inside the refinery fence to capture specific sampling criteria, i.e. high CoC clay fields. As for the ESA lands on organic soil within the fenced refinery property, as detailed in Map 1, large number of samples were collected just east of Reuter Road in the ESA to make sure the ERA addressed those concerns raised by the reviewer.
SOIL TYPE AND LEACHING RATES **Section 2.1.4, Page 2-14**	The discussion of leaching rates and soil CoCs needs to be reconsidered. The main point is the assertion that water associated with leaching would be relatively neutral (pH~ 7). However, rainwater in southwestern Ontario and the drip flow through trees with leaf exudates etc. would be likely much more acidic (pH values of 5 or less are commonly reported for rain in Southern Ontario - this is 100 times more acidic than a pH of 7). Also the presence of humates (salts of humic acids) in the surface soils would tend to acidify water and complex various metals to some extent, and thus water will not be buffered by the underlying limestone until it reaches deeper soil horizons. If JWEL has data that refutes the lower pH in rain and exudates/foliage water, they should provide it. Otherwise their discussion to appears to be based on false assumptions. **This section has been clarified (P. 2-14).**
ASSESSMENT ENDPOINTS	JWEL states that "The assessment endpoints were based on population responses." It is not clear how this will be achieved given the type of sampling that was undertaken for the majority of taxa as population estimation was not included in the methodology. The following paragraph does not help clarify this matter and should be rewritten to express clearly how JWEL can undertake this assessment when they have not examined species at the population level. More discussion on the rationale for selection of endpoints would help the reader to draw a conclusion as to whether they are appropriate. **The reviewer is confusing assessment endpoints with measurement endpoints. Please see Chapter 4 (Volume 1) of the report for an explanation of how these differ.**
Section 3.0 - Ecological Site Characterization	The sequence of information is rather confusing in this section. Normally one describes the more general attributes of an area at the regional level before going into details about a specific site or study area. Therefore Section 3.3 should be introduced prior to the identification of the Study Area. **Sections 3.1 and 3.2 generally detail methodologies used and do not present data on the ecological characterization of the study area; this is first introduced in Section 3.3. In this sense, Section 3.0 does start off with detailing the more general attributes of the Niagara Region, starting with Section 3.3 (P. 3-4).** The use of the Ecological Land Classification (ELC) was only undertaken after repeated requests by Stantec (BEAK) to have a map of the area showing the various plant communities. Unfortunately the study area is not described in a way that will be useful to the general reader, or in a way that will assist in the overall risk characterization. **The reviewer is correct that during the study that JW could not understand why Stantec considered the use of the Ontario Ecological Land Classification (ELC) system as being critical or important to the ERA as a whole. And we still don't. We believe Stantec is in fact correct in stating that using the ELC does not assist in conducting the overall risk characterization for the ERA. The ELC is simply an Ontario Ministry of Natural Resources approved standardized method for describing natural vegetation**

	communities in Southern Ontario. There is nothing special about this descriptive methodology that is useful in, or has direct applicability in, conducting an ecological risk assessment. The use of ELC is most appropriate in conducting land use planning or watershed studies. For an ERA, conducting an ELC mapping exercise is not an MOE ERA guideline or requirement. Clear maps of the major study areas, habitats and soil CoC levels should be provided. **Maps are provided which show soil type distribution (Figure 3-1) and vegetation communities (Figure 3-3). It is JW's opinion that these maps are clear.** In the ELC classification of the Study Area, which presumably is the area bounded by the MOE 200 ppm Ni isopleth, 81% of the area is associated with human uses (Table 3.2) and issues of CoC impacts will be covered under the HHRA and the phytotoxicity studies. This leaves only 19% of the Study Area to be the subject of this study, is this correct? This has a major bearing on the way in which JWEL has undertaken the studies and will determine the level of risk because the soil CoC values in agricultural soils are mixed and are generally lower on average than those occurring in the woodlots and old fields. **For the study, two habitat types are identified, woodlots and fields. Woodlots represent about 15% of the Study Area, the rest are fields in various stage of use (agricultural) or regeneration. For soil samples collected by the MOE, all field types were sampled. These values were used to calculate UCLMs for the ERA. For biological samples, fields with natural habitats, fallow fields (dominated by weeds) and old fields (fields with grass/weeds and shrubs and young trees) were used, as these natural areas, rather than crop fields, represent the habitats where the VECs could be expected live out their entire life cycles.**
Section 3.2, Page 3-2, Second Paragraph	The last sentence states "For the study, no attempt was made to document the Study Area's arthropods or other invertebrates." This is incorrect since JWEL undertook field insect collections, tent caterpillar collections and earthworm collections. **Our intent is clarified with the revised sentence stating, "Arthropods are considered a food item for exposure assessment for this ERA, and no attempt was made to evaluate diversity or abundance of insects or spiders in the Study Area." (P. 3-35)**
Section 3.2, Page 3-6, First paragraph	The last sentence states "The wetland areas have been identified as provincially significant due to the presence of rare flora and fauna, and due to the rarity and importance of Great Lakes coastal wetlands." However, the wetlands identified in Figure 3-1, except for possibly Empire Beach Backshore Forest/Wetland (11), would not be considered to be Great Lakes coastal wetlands. **The classification is bases on the Ministry of Natural Resources Ontario Wetlands Evaluation System. This evaluation system is the only accepted method by the Ontario government for the evaluation of wetlands and the assessment of a wetlands provincial significance. In the Ontario wetlands evaluation system the importance of Great Lakes coastal wetlands is clearly identified in a separate section of the evaluation system. In this section, Great Lakes coastal wetlands are defined as follows: 1) any wetland that is on the Great Lakes, and 2) any other wetland on a tributary (or water course) above a Great Lake, that lies either wholly, or in part, downstream of a line located 2 km upstream of the 1:100 year floodline…" In short any wetland with a surface water connection to a Great Lake, such as Lake Erie, that lies within 2 km of the shoreline is considered by the Province of Ontario to be a Great Lakes Coastal wetland. Therefore**

	the wetlands that lie 2km north of the Lake Eire shore in the study area are in fact Great Lakes Coastal wetlands (P.3-13).
Section 3.8.2 - Birds Table 3-5 - Breeding Birds Recorded in the Study Area	There is no reference provided as to how the estimated numbers of breeding pairs in the study area were derived. Is it based on home ranges from the literature and the area of the lands within the 200 ppm Ni isopleth or is it just a guess? The reason this is relevant is that JWEL states that it is undertaking a risk assessment at the population level (page 9-1 "Assessment of risk to receptors and/or communities is based at the population level, with a population defined as being within the total Study Area and is defined by the 200 mg/kg soil nickel concentration contour;") **Breeding pair estimates were based on a combination of the availability of habitat, breeding territorial requirements of each species and occurrence of the species as noted during surveys conducted by the field biologists over two breeding seasons for the study area. This information has been added as a footnote in the Table 3-5 (P.3-18).** **It is unclear to JW as to why Stantec has identified the study's estimates of breeding pairs for birds as being particularly relevant to the risk assessment when compared to other receptors used in the risk assessment. For the ERA, the "population" assessment is based on how the exposure assessment was undertaken for the study area, that is, how well a population is represented within the study area. Risk assessment was not based on a 20% effects on actual numbers within an estimated population for any receptor, including birds.**
Section 3.10 - Uncertainties, Limitations and Gaps Section 3.10, Page 3-26	The statement "Also detailed comparative diversity studies (e.g. Control Woodlots s. Study Area Woodlots) could not be undertaken." does not seem to reflect the reality that such studies were in fact undertaken and are described in the Trees Unlimited Report (Volume IV, Tab 3 Table 8) in which the mean woody species diversity is compared between the Primary Study Area and the Control Study Area. This table indicates that there are 16.6 ±1.07 woody species in the Primary Study Area and 19.7 ±1.82 species in the Control Study Area. **This sentence has been re-written to address that for trees and shrubs, a control versus. study area comparison was undertaken. In addition, for the litter study an assessment of ground flora at sample stations was also undertaken.**
Section 3.9 - Significant Wildlife Habitat	While the gull and tern colonies were outside the described Study Area, the colonies at Port Colborne have been designated an Important Bird Area (IBA) and should be mentioned as such. Also Ring-billed Gull forage on fields, consuming large numbers of worms and other invertebrates and so the statement in Section 3.9 (page 3-26) is incorrect. **This section has been revised to note the occurrence of the IBA. We agree, some adult gulls do feed in the fields in the study area during the breeding season, but not frequently. During the breeding season (May through mid July) the vast majority of breeding gulls at this colony forage along the lake shore, the Welland Canal and inland waters, and not on inland fields in the local Port Colborne area. Over 50,000 breeding pairs of gulls occur on the colony. Through a two-year study, typically only small flocks of less than 200 birds were noted to feed/loaf in the fields east of the refinery. If the fields east of the refinery were important feeding areas during the colonies breeding season, flocks of thousands to tens of thousands of gulls would have been common during the breeding season. Clearly this is not the case. Finally, gulls could have been selected as a receptor for this study but they were not. Rather, common bird species typical of the natural forests and old fields of the study area were selected as being more relevant to the study.**

Section 4.0 – Receptor Characteristics **Section 4.2, Page 4-3**	It is unusual to refer to herbivores such as voles and deer as "secondary consumers". Should they not be primary consumers? See also Table 4-2. **Correct. They are primary consumers and this has been corrected (P.4-5).**
Section 4.2, Page 4-4	We are told that a 20% effects level was adopted for all measurement endpoints. However, LOAEL's were also used, as indicated in Table 4-2. **The lowest effects level that can generally be measured is often considered to be a 20% effects level. This is therefore not a contradiction.**
Section 4.3.6, Page 4-14	Red-tailed Hawk. JWEL say first of all the Red-tailed hawk is common across much of forested North America and then goes on to say that they prefer open habitat with elevated perches; there is an inconsistency here which should be resolved. **There is no inconsistency. Red-tailed Hawks are common across much of *forested* North America, in a broad sense, not *forests* of North America. Yet they prefer open habitat within these forested regions. However, to make it clearer, the statement has been revised to say that they are common across much of North America (P.4-17).**
Section 4.4 - Uncertainties, Limitations and Gaps Page 4-14, Second paragraph	It is stated that... "There is a lack of data with regards to specific characteristics, lifestyle and feeding habits of the selected receptors for the Port Colborne area." This is not true, there is a considerable amount of information about the receptors chosen; this sentence is not helpful and is typical of many such unsubstantiated statements throughout the report. **A discussion of uncertainties and limitations is now presented in Chapter 10.** **With regard to the statement made by Stantec that "this sentence…is typical of many such unsubstantiated statements throughout the report"- it is hoped that each such statement has been duly identified by Stantec for JW's review and comment. If they are not, such a sweeping unsubstantiated statement by Stantec is inappropriate.**
OVERLAP OF PHYTOTOXICITY AND ECOLOGICAL STUDIES	There should be some clarification of how observations and studies between these two studies overlap. These relate specifically to the Maple Sap, the Biomonitoring (goldenrod), The Fish and Game and the Corn sampling. There is also an overlap in the soil sampling from these studies and differences in methodology. For instance, Biomonitoring sites are shown in Figure 1.1 but not discussed in the early part of Volume 1. Later on in Section 6, tables and references are to goldenrods, but no methodology has been referred to for goldenrod. Is JWEL referring to several species of goldenrod, or did they sample just one, in which case the noun is goldenrod. **Clarification has been provided in Section 5 under this specific heading (Section 5.1.2). However, this clarification is not required in Section 4, as none of these samples (maple sap, fish, game, corn, goldenrod/goldenrods) are considered receptors of VECs for this study. Table 4-1 has been revised to remove any confusion (P.4-4).**

Section 5.0 - Data Collection Methods **SAMPLING AND COLLECTION PROTOCOLS**	Generally the sampling and collection protocols were undertaken in a competent and professional manner. However, in many cases the protocols were not prepared sufficiently ahead of the sampling program to allow for an opportunity to suggest changes prior to the fieldwork being undertaken. In many cases, numerous drafts of the protocols were made to take into account comments by the reviewers and practical difficulties experienced in the field. In general the protocols reflect what was actually already undertaken, prior to the acceptance of the protocols. **JW takes issue with the statement that "in many cases the protocols were not prepared sufficiently ahead of the sampling program to allow for an opportunity to suggest changes prior to the field work being undertaken". It is true that the project schedule as determined by the CBRA representatives (of which Stantec was a party) did put significant pressures on both JW and Stantec staff to develop and review protocols to conduct the fieldwork. However, at no time was fieldwork undertaken without a first draft protocol having been developed by JW, review by Stantec, and comments received back to JW from Stantec prior to conducting the fieldwork.** **In addition, during the field collection program, Stantec staff were in the field with JW staff at all times and discussions and suggestions by Stantec were always taken into account before samples were collected. Therefore, yes, final protocols reflect what actually was undertaken in the field, as they should for the record. During the study, if Stantec field staff had strongly disagreed with a sampling protocol or how samples were being collected in the field, they did have the opportunity and authority, to reject the data, and initiate re-sampling.**
Section 5.1 – General Study Design for Site Specific Data Collection	The last paragraph describes that soil type and habitat type were taken into consideration for the collection of data. It would seem reasonable that JWEL would include a figure showing the sampling sites in relation to these habitats and soil types as this is not easy to see in Figure 1.1. **Maps showing soil distribution (Figure 3-1, soil types) and habitats are provided (Figure 3-2, significant natural features and Figure 1-4, fields and woodlots). The sample location map does show areas of field and woodlot (Map 1). Trying to overlay a soil layer on this map resulted in less clarification.**
Section 5.2 - Biological Field Data Table 5-1	is rather confusing as it includes two kinds of data, survey data and also specimen collecting data. It is not clear that the specimen collection data includes both the number of specimens and the number of total samples which may include many specimens. This should be clarified. Also Goldenrod is indicated and there is no previous reference to this part of the plant toxicity study. One would have expected that this table would relate back to the previous paragraph which described how the sampling was related to soil type and habitat, yet the frequency of collecting here is not included. The statement that specimens shipped to PSC (Philip Analytical Services Inc.) for elemental analysis of the four CoCs is incorrect, as specimens were analyzed for 24 elements including the CoCs and other [non-CBRA] chemicals of concern to the community, including lead. **This has been corrected (P. 5-4).**

Section 5.3.1 - CoCs in Soils and Sediments	Soil samples were not collected at every location where biological samples were collected. The use of sweeping statements that are not true is unfortunate. If the statement was rephrased to state that the general areas where biological samples were collected also had soil samples collected and analyzed, the issue would be clarified. This is necessary because soil samples were not repeated for the earthworms where soil was analyzed when the maple sap was collected. **The issue has been clarified as suggested above (P. 5-6).** In fact a map showing soil and sediment sampling sites would be appropriate and this would clarify Table 5-3. Maps for surface water sampling and air sampling locations could also follow. **Map 1 indicates in the legend where sediment and soil samples where taken. Air sampling locations can be found in the HHRA.**
Section 5.3.4 – Uncertainties, Limitations and Gaps	There is a statement that CoC values in the surface soil to 5 cm depth are sampled because this is the region where CoC levels are highest. There is no reference to the soil studies earlier on in the text to corroborate this. With general leaching over the years one would expect the higher levels to be lower down in the soil horizons, so the concluding sentence appears to be unfounded. **JW is confused by the comment, "There is no reference to the soil studies...", as based on other comments made above it clear that the reviewer has read Section 2.1.4 which details the distribution of CoCs in the soils of the study area. Uncertainties and limitations are discussed in Section 10.**
Section 5.4, Figure 5.1	Describes a "Homogenizating" technique in second box; the proper term used in the methods section (Volume II) is "Homogenization" and this describes digestion at 90-950C not 900C. **Correction made (P.5-10).**
Section 5.4.7, Page 5-9:	The formula given for "percentage difference" is applicable for evaluation of precision based on replicate samples or analyses. However, percentage differences were also calculated using Standard Reference Methods (SRMs) to reflect accuracy of the analysis. A different formula would presumably be used for SRMs, and should be stated. **This section has been clarified. The same formula for calculating percent difference between expected and observed is the same as calculating percent difference between "test 1" and "test 2" (P. 5-13).**
Section 6.0 - Exposure Assessment **Section 6.1**	The last sentence states… "Wherever possible, we used site-specific values of CoC concentrations from media, and assessed if CoCs accumulate within the trophic web." It is not clear as to how this assessment was actually undertaken. Soil would not be considered a landscape element in the same way as forest cover. This section needs to be rewritten. **This section has been modified to clarify our intent (P. 6-1).**

Figures 6-1 to 6-4	of exposure pathways do not show tadpoles, yet in Section 6.3.4 "Exposure to CoCs for tadpoles is assessed for both water and sediment." Is this an omission? JWEL goes on in Section 6.4.2.1 to discuss tadpole tissue, but its relevance to the food webs previously explained is not expressed. **A figure showing exposure pathways to tadpoles has been added (P. 6-2).**
Section 6.4 - Assessment of Bioavailability	It would be useful if JWEL provided some baseline values of the normal concentrations of copper, cobalt, arsenic and nickel in various animal and plant tissues. These substances are normally present in the environment, and copper is important in enzyme systems so it would seem relevant that the normal levels in animal and plant tissues would be discussed. **We consider biota collected from the reference study area to reflect the concentrations of CoCs normally found in organisms of the Niagara region. CoC values observed in biota of the reference area are baseline values.**
	Some of this information is in Section 7. It would be more appropriate to discuss the distribution and abundance of the CoC elements in the environment before discussing their bioavailability. **It is included in the Hazard Assessment (Section 7.0).** In the first paragraph of Section 6.4 JWEL state that "Linkage between CoC concentrations in tissue and those of the surrounding soil, sediment or water are presented, if statistical analysis indicates that such links exist." Does this statement actually reflect the author's intent? Statistical analysis is not what is used to indicate linkage; knowledge of feeding behaviour might be. **This section has been modified and rearranged to make it clearer to the reader. Many of the details of the statistical analysis are now provided in Volume 3, tab 10.** For the analysis of amphibian tissues, the variance seems so high that the value of drawing lines on the relationship graphs is questionable. There does not seem to be any discussion of this variance, reasons for it etc.; the report is incomplete without such a discussion. **Presumably, the reviewer is confused over the variance presented in a table showing standard deviations for each of the Study and Reference areas. This variance is at least partly heterogeneity in CoC concentrations found in the environmental media. These standard deviations do not account for variability attributable to such factors as CoC concentrations in site-specific environmental media and the potential influence of soil type, which may explain much of this variability. Section 6.4.2 explores these potential influences on tissue CoC concentrations.** In the discussion of the relation of tadpole CoC levels to that of the surrounding water, why would JWEL assume that there should be high levels of CoCs after 20 years of water being flushed through the system? This should be considered in the report. **Firstly, no assumption was made in this regard. Secondly, what "flushing through the system" occurs in the dugout cattle ponds found within the Study Area?**

Section 6.4.1, Page 6-8	States: "…. first-order interactions between the predictors were fit against each response …." The language here is awkward and confusing. Does this mean that interactions were included in the model and tested for significance? **Yes.**
Section 6.4.2.1, Page 6-9	In discussion of tadpoles uptaking Ni and Cu from sediment, the statement is made that "soil type does not influence uptake of these metals" There is no obvious connection between sediment and soil type that JWEL has made, let alone a suggestion that the sediment in different ponds is different. Furthermore, published literature contradicts this statement. **This was an exploration of what possible influence surrounding soil type may have on CoC uptake, making no *a priori* assumptions. It was believed reasonable to explore this, since it is intuitive that sediment would be partly composed of soil matter from surrounding fields that had been washed into the ponds.**
Table 6-8, Page 6-11	It is not clear what N represents in this table. Is it the number of overall locations in the Study Areas or the number of quadrants sampled? **Although the comment seems to be mis-referenced, we believe the questions refer to Tables 6-3 to 6-13 (Tables in P. 6-21 to 6-31).** **n refers to the number of sample locations in each of the Study and Reference Areas.** Table 6-9 legend does not seem to refer to the table contents as neither Primary nor Secondary Study Areas appear in either the column or row headings. **The title of Table 6-9 indeed refers to the table contents. This is now Table 6-8.** The discussion of the effects of purging worms versus analyzing them whole is dismissed in three lines. Yet there is substantial evidence that a considerable part of the CoC in the worm analyses is in the gut soil. What is the relevance of the number of worms per sample? Why have the Primary and Secondary Area worms been combined in Table 6-11? Does the table refer to whole or to purged worms? **The difference between purged and non-purged earthworms is discussed in Section 6.4.3.4 (P. 6-25). For completeness, the numbers of earthworms per sample was provided. The Primary and Secondary Study Areas are combined because of the sampling structure used during 2001. This sampling structure was not used for the 2002 earthworm sampling. The table to which the reviewer refers provides data on whole earthworms.**

Section 6.4.2.2, Page 6-14	In this section regarding frog tissue, the contention is made that frogs do not bioaccumulate CoCs. The data does not appear to support this. Mean concentrations of Ni in the carcass of frogs in the primary area is 1.08, secondary area is 0.48, and in the reference area it is 0.21. When one looks at the Figures 6-13 to 6-28 the relevance of lines on relationship graphs seems obscure. Why not use simple plots? When one plots the mean values of a CoC in animal tissue against the mean values of the soil CoC, a reasonably good linear relationship is seen with increasing levels in the soil resulting in increased levels in animal tissues. This simple plot provides a compelling indication that for many of the sample types analyzed, there actually is a relationship between soil CoC levels and the concentrations of CoCs in test species. **The plots and results of the statistical analysis we presented show that there is a relationship between CoC concentrations in tissue and environmental media (sediment and water). And we say as much. However, we were attempting to convey that our evidence suggests that frogs are not *concentrating* CoCs in tissues outside of the liver. We have made the discussion of these data clearer (P. 6-13).**
Section 6.4.6, Page 6-38	In discussing meadow vole tissue, there seems to be a belief that the presence of any of the four CoCs in tissues is related to the Inco refinery. Copper is an important catalyst in animal enzyme systems and animals are able to retain or excrete these elements as required (see Volume 1, Section 7.3.3). Therefore, one would expect that an element such as copper would be regulated and levels would be independent of surrounding levels, whereas an element such as Ni which is not an integral part of enzyme systems nor a part or analogue of structural elements, would reflect surrounding levels. There is a major lack of understanding of physiology and potential alternative explanations in the JWEL report; these need to be considered. **Here, we are interested in the potential influence of environmental CoC concentrations on tissue CoC concentrations, and are focussed on the presence or absence of a relationship between those CoC concentrations found in soil vs. two types of tissue samples: liver and remaining carcass. Discussion regarding the normal availability of CoCs, such as copper, in the environment and in animals and plants is found in Chapter 7 – Hazard Assessment.**
Section 6.4.6, Page 6-38	The statement that Ni and Cu concentrations in soil significantly contributed to the concentrations in vole tissue is contradicted by Table 6- 15 which shows Ni and Co contributing. **The statement has been corrected; copper was not found to contribute significantly (P. 6-31).**

Section 6.4.7.2, Page 6-43	states "However, arthropod copper concentrations appear to be influenced by soil type and habitat, as shown in Figure 6-50, where arthropods in woodlots have lower copper concentrations than arthropods in fields, and lower copper concentrations in areas with organic soil than in areas of clay soil." JWEL does not seem to recognize that they are comparing very different classes of arthropods (spiders in woodlots and grasshoppers in fields) whose physiology and enzyme systems and structure are likely to be very different, which would lead to different levels of copper and other metals in their tissues, regardless of the amount of copper in the soils. **Jacques Whitford is well aware of the difference between arachnids and insects. In woodlots, spiders and insects were of roughly equal biomass, but insects comprised a larger proportion of the arthropod biomass sampled from fields. Regardless of the composition of the arthropod samples, these animals were sampled for the purpose of determining CoC concentrations in potential prey of selected VECs. This statistical analysis indicated that copper concentrations in arthropod tissue were lower in woodlots than in fields, regardless of the taxonomic make-up of the sample. As a result, copper may be more available to arthropod-eating receptors in fields than in woodlots, given a particular soil copper concentration.**
Section 6.4.8 - Bioconcentration Factors	The authors conclude on the basis of some widely variable analytical results that "It is apparent there exists a barrier at the soil – plant interface which prevents significant uptake of CoCs into above ground biomass and ultimately into the food chain (Tables 6- 23 through 6-25)." **This statement is true. It has been clarified and referenced in the section (P.6-13).** None of the sampling, which the authors have undertaken, could lead them to this conclusion as they have not investigated pathways and barriers. If the CoCs are not mobile in the soil, i.e. not in solution, they cannot pass the root hair membranes. They could be mobile and be excreted through stomata as with other exudates and so return to the soil. CoCs may be taken into animals and either pass through (the purged earthworms demonstrate this may occur) or they could be taken into tissues and be subsequently excreted. JWEL has not undertaken the necessary experiments to suggest these conclusions. **The bioconcentration factors in this section simply indicate that concentrations of CoCs present in soils are greater than those identified in the biota sampled. Regardless of the mechanisms that may be acting to uptake, exclude or excrete CoCs in various biota, JWEL can conclude that CoCs are not bioconcentrating. Rather, there is a dramatic reduction of CoCs in biological tissues when compared to soils and sediments. Thus, only a small fraction of the CoCs present in biophysical data are available for uptake at higher trophic levels.**

Page 6-48	There is the suggestion that there is a bioconcentration from soil to sap, to leaves, to insects. There is no reason to suppose there is any concentration to insects [the insects (Class Insecta) referred to are in fact spiders (Class Arachnida). Spiders are carnivorous and do not consume leaves]. The underlying biology of these systems has not been analysed prior to JWEL making these assertions. **Not true. Clearly, arthropods have not bioconcentrated CoCs when compared to soils. However, arthropods do contain more CoCs when compared to leaves. These results estimate that herbaceous feeding by insects and carnivorous feeding by some spiders (on insects) has resulted in an increase of CoCs on the whole in arthropods when compared to maple leaves but a dramatic reduction in CoCs when compared to soils. There is no attempt or need to explain the transfer between insects and spiders in the composite sample of arthropods.**
	It is not clear why some organisms are sometimes considered as receptors by JWEL, and sometimes not. For instance, Table 4-1 provides a list of Receptors and Sources of Data for Hazard Assessment which includes frogs and maples. These taxa do not appear in Table 6-30 Exposure scenarios calculated for each receptor. In neither table is goldenrod mentioned; yet it appears frequently in the text, please clarify. **The terms "receptor" and "VEC" are synonymous, but we have clarified our terminology throughout the report, and modified tables where appropriate. Essentially, VECs are receptors that have been selected for this ERA to assess risk to the natural environment. Risk is assessed using the Quotient Method, using statistical analysis of empirical laboratory toxicological data, and using statistical analysis of empirical field data.**
Table 6-31	In this table it is not clear how the "averaged" values for CoCs were derived for the Study Area. The area defined in the legend is different from the previously defined Study Area which was bounded by the MOE 200 ppm Ni isopleth. How are the values averaged for the new area? **The values used to calculate average daily dose of selected VECs, as outlined in the text, are more explicitly explained within this section (Section 6.0).**
Table 6-32	There is a similar concern as to how the values are derived since the actual areas of the habitats contributing to these values are not described. **See above.**
Table 6-1 (and other such tables)	Where concentrations in tissue are reported, the weight basis should always be stated. **As stated in Chapter 5, all results of chemical analysis for biological and bio-physical matrixes are reported by PSC and presented in this report as dry weight values (mg/kg).**
Section 6.4.8, Page 6-47	Bioconcentration Factors (BCFs). The weight basis of the BCFs should be stated. Are they for fresh weight tissue and dry weight soil or sediment? **See above.**

Section 6.4.8, Page 6-47, 48	It is not clear how the BCFs shown for frogs, tadpoles and voles are related to the various tissues of these organisms that were analyzed, e.g., liver, gut, remainder. Are the BCFs for certain tissues or for some composite representation of the whole organism? If the latter, what was the assumed tissue composition of the organism? **The values for various organisms are for the entire organism. Therefore, frog values were calculated by factoring in weights and concentrations in the liver and GI tract analyzed separately. This has been clarified in the section. Data for these calculations are presented in Volume III, tab 8.**
Section 6.4.8, Pages 6-48 and 6-49	Are the “insects” in these BCF tables the “arthropods” that are used in the risk calculations? **Yes, the values used for BAFs (bioaccumulation factors) are composite samples of arthropods.**
Section 6.4.8	Why are no soil: tissue BCFs shown here for earthworms? **A diagram showing BAFs for earthworms has been added to this section (P. 6-16).**
Section 6.4.9, Page. 6-50	The statement that As in soil, sediment or water does not predict biological exposures is too broad, since relationships have been shown at least for frog, maple leaf and earthworms. **Perhaps our statement is too broad. The text is clarified to state, “Increasing concentrations of arsenic in soil, sediment and water do not appear to be reliable predictors of increased exposures to biological receptors, with a few exceptions.” (P. 6-19)**
SECTION 6.5 – Exposure Magnitude, Frequency and Duration	
Section 6.5.1, Page 6-52, Equation 6-3	The units shown for Ck (concentration in food) are stated incorrectly. Presumably they should be mg/kg? On a fresh weight basis? **This is a typo. The units should be mg/kg dw (P. 6-35).**
Section 6.5.1, Page 6-53	Ingestion transfer factors used for inhalation transfer “as a conservative approximation”. It is not clear that this is conservative. The ratio of lung: blood and gut: blood absorption has been determined for humans (ICRP66), and has been used to estimate inhalation transfer factors for animals. The ratios of inhalation to ingestion transfer factors are both above and below 1.0, depending on the metal and the lung clearance assumptions. **The word "conservative" has been removed. Based on previous experience, inhalation is expected to be a very minor contributor to total body burden of the CoCs and the approximation is therefore considered reasonable for use in this assessment. The uncertainty in this approximation is not expected to have a significant impact on the uncertainty in the estimated exposures (P. 6-33).**

Section 6.5.3, Page 6-55	The rationale for using "overall" exposure values rather than habitat-specific values is unclear. It is reasonable for deer, since an individual will use both habitats, but tadpoles are not so mobile. **"Overall" exposure values for tadpoles indicate that exposure was assessed for tadpoles using water samples from the whole Study Area, not subsets of the Study Area (P. 3-37).**
Section 6.5.3, Page 6-55	The term "one-sided" confidence limit is unusual and confusing. Does this mean "upper" confidence limit? A test of hypothesis can be "one-sided" but a confidence interval has two sides, i.e., it extends above and below the mean. Was the appropriate (two-sided) t value used? **The Upper Confidence Limit for the Mean was calculated.**
Section 6.5.3, Page 6-56	Should the reference to wild "grapefruits" read wild "grapes"? **Yes, this typo (missing space) has been corrected.**
Section 6.5.3, Page 6-56	The rationale for UCLMs from pooled data does not make sense. While uptake factors may be similar across soil types and habitats (e.g., for Ni and Cu for earthworms), the CoC concentrations clearly are not. The UCLM concentrations used here are far below the concentrations found in most of the Primary and Secondary study areas, e.g., 213 µg/g Ni in soil assumed, vs. Mean of 8,926 and 2,415 µg/g in Primary Area woodlots and fields, or Mean of 797 and 214 in Secondary Area woodlots and fields. **No mention of uptake factors is found in this section. What is stated is "..., neither soil type nor habitat significantly influenced the uptake of nickel and copper in earthworms...." The CoC concentration of 213 mg/Kd Ni shown in the associated table is for earthworms.**
Section 6.5.3, Page 6-57	The bioavailability or bioaccessibility values have been derived from rat experiments (for Ni) or from extractions mimicking gut action (Cu, Co, As). Both are legitimate approaches. However, any adjustment in the risk calculation should be for relative bioavailability, i.e., how much less available were the metals in these soils as compared to the metals in the toxicity tests behind the benchmark values. It cannot simply be assumed that bioavailability was 100% in the toxicity test, as appears to have been done here. The evidence as to bioavailability in the toxicity test should be presented and discussed. **The reviewer is mistaken. The relative bioavailability of nickel in Port Colborne soils compared to nickel sulphate hexahydrate was determined in the in vivo study. This relative bioavailability was used in the ERA, as opposed to the stated 100% bioavailabilty in the toxicity test. Since the TRVs in the natural environment report are based on nickel sulphate hexahydrate, this relative bioavailability is directly applicable. Furthermore, the results of the in vivo study for nickel were used to bench mark the in vitro study results so that the bioaccessibility determined for copper, cobalt, and arsenic would be a conservative estimate of the relative bioavailability for these compounds. The results of bioaccessibility testing have been previously validated for arsenic and lead and their use in this assessment as an estimate of relative bioavailability is considered appropriate. A detailed review of the studies validating the in vitro method is provided in the MOE (2002) Rodney Street Report. Ruby et al. (1996) reported that the use of a physiologically based extraction test (i.e., in vitro extraction) would over predict the bioavailability by 2 to 11% depending on the animal model used. Both the in vivo and in vitro study will be presented in detail in**

	Appendix 6 of the human health risk assessment report. **The summary presented in the human health risk assessment report indicates close to 100% bioavailability of arsenic in drinking water and 60 to 70% for arsenic in food. The arsenic TRVs are based on dietary intake. Relative bioavailabilites and bioaccessibilities estimated from other studies are similar to or lower than predicted in the current study. Given this similarity, the high absorption of dietary arsenic, and the literature validating this method, the estimated bioaccessibility is considered appropriate.** **For cobalt, the TRVs for birds are based on soluble cobalt chloride. For mammals, they are based on dietary cobalt. The literature suggests that cobalt, if in inorganic form in soils may be significantly less bioavailable than cobalt from dietary intake and could indicate a relative bioavailability in the order of 0.3% (Christensen et al., 1993) could be appropriate for cobalt oxide or other inorganic forms of cobalt. The estimated bioaccessibility is therefore considered appropriate.** **TRVs for copper are based on dietary copper. It has been reported (IOM 2001) that the bioavailability of copper to humans is over 50% at daily intakes. Absorption of copper is influenced by many factors. Since the absorption of dietary copper is high, direct use of the estimated bioaccessibility is considered appropriate.** **Christensen, JM, OM Poulsen, M Thomsen. Int Arch Occup Environ Health. 1993, 65:233-240.** **Institute of Medicine (IOM), 2001. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. National Academy Press, Washington, D.C.** **Ontario Ministry of Environment (MOE), 2002. Soil Investigation and Human Health Risk Assessment for the Rodney Street Community, Port Colborne.** **Ruby, M.V.; Davis, A.; Schoof, R.; Eberle, S.; Sellstone, C.M. Environ. Sci. Technol. 1996, 30, 422-430**.
Section 6.5.4	While doses are given for four scenarios (2 soils x 2 habitats), it is not clear what media concentrations were used to calculate them. Table 6-32 gives soil, worm and arthropod concentrations for the four scenarios. Were all other media concentrations taken from Table 6-31? Or were media concentrations that are not shown used in the dose calculations? **The first paragraph of this section, which states that only an overall value was derived for each data set, except for earthworms, arthropods and soils.**
Section 7.0 - Hazard Assessment Parts 7.1 – 7.2	are well written, clear and a delight to read after some of the previous sections. However, they would be improved by inclusion of references in relation to the specific values and examples cited. **The references for all the reported values are taken from the reports identified at the start of Section 7.1. The reader should read these documents if a detailed review is required.**

Section 7.1.1 - Arsenic	This section has errors, such as the statement “Arsenic typically occurs at a concentration of 2 µg/L for surface water and 50 µg/L for groundwater”. This “typical” value is ten times the Canadian Water Quality Guideline for Aquatic Life (CWQG) 5 µg/L for arsenic. According to CWQG, values above 1 µg/L are unusual (Canadian Environmental Quality Guidelines, 2000). Are the other values in Section 7.0 reliable or are they similarly off the mark? **The numbers are right, but the sentence should have read and now does as follows - “Arsenic typically occurs at a concentration of <2 ug/l in surface water and <50 ug/l in groundwater.” (P.7-2)**
Section 7.1.3 - Copper	“Canadian Water Quality Guidelines”, 1996, states, “dissolved total copper levels in Canadian surface waters rarely exceed 5 µg/L”. This indicates the JWEL value of “1 to 8 µg/L” needs revision. **In the referenced document –Copper Hazards to Fish, Wildlife, and Invertebrates 1998, Table 2 - Copper Concentrations in Selected Abiotic Materials, shows that, based on the literature, waters for lakes and rivers in Canada have copper concentrations in the range of from 1 to 8 µg/l. Note that this is a range, so in fact no revision is required here, regardless of the statement made in the water quality guidelines.**
Section 7.2, Page 7-9	“…. Measures of individual responses are not as sensitive as measures of population responses.” Regardless of who said this, the statement requires explanation. A contaminant cannot directly affect a population except by affecting its individuals. Perhaps the statement refers to the possibility of indirect effects? As written, it is misleading. **The statement is accurate as written. It is not misleading as written in the report, but is misleading if taken out of context as in this comment. The sentence fragment as stated here has a different meaning than the manner in which it was written. The available body of research does indeed indicate, as stated by the Canadian Council of Ministers of the Environment (CCME), that some research has found that population response measurements may be more sensitive than individual response measurements. For instance, more than 20% of a population may emigrate from an impacted area before an observable individual effect can be distinguished.**
Section 7.3 – Bioavailability of CoCs	While the various states of arsenic and cobalt are discussed there is no mention of the forms in which copper exists, cuprous and cupric, why is this? **A discussion of different copper species and their potential bioavailability have been added to the discussion (P. 7-12).**

Section 7.3.1 - Arsenic	The Canadian Water Quality Guidelines (1986) state "Arsenic ranks as the 53rd element in abundance in the earth's crust". This is somewhat different from JWEL's rank of 20th. One wonders where JWEL's information came from; revisions are suggested. **This has been reviewed (P. 7-10).** The last sentence of the first paragraph (page 7-15) suggests that copper is tightly bound to organic and mineral matter causing it to be less bioavailable, yet earlier on in Section 7.1.3, copper is described as being an essential dietary element for the normal growth and metabolism of all living organisms; please resolve this contradiction. **How is this a contradiction? Essential dietary elements are not by default readily bioavailable. This is why multivitamins contain trace amounts of compounds containing elements such as Ni and Cu, since these elements can be deficient in human and animal diets. Jacques Whitford's comments about copper being essential in the diet and growth of all living organisms and that the bioavailability of copper is reduced by the presence of organic and mineral matter are true.**
Table 7-1	A soil Ni NOEC for earthworms is given as 3,000 mg/kg, based on no reduction of body weight. However, Effroymson *et al.* (1997) give a benchmark of 200 mg/kg for toxicity of Ni to earthworms, based on reduced cocoon production. What is the rationale for selection of the higher value? **The rationale for this is outlined in Volume 3, Tab 4. After later review of this material, the Stantec comment was revised as follows.** Nickel Benchmark for Earthworms. I had questioned why a NOEC of 3,000 mg/kg was used in preference to the Effroymson et al. (1997) LOEC of 200 mg/kg. The rationale indicates a preference for metallic or oxide values rather than soluble salt values, given a predominance of metallic or oxide forms in the study area. The value of 3,000 was estimated from a study of metallic Ni. An NOEC of 500 mg/kg is cited for Ni administered as a sulphate salt, and it is noted that Ni sulphates are <20% of total Ni in the study area. Based on this, we could estimate an LOEC of 2,500 mg/kg as total Ni, not far from the value of 3,000 which was used. Thus, the benchmark used was reasonable. I note that the JWEL dose-response study produced an EC20 for reproduction around 2,200 mg/kg. **No further response is required.**

Table 7-1	The Effroymson benchmarks for earthworms are cited as estimated EC20 's (Effects Concentration Where 20% Of The Population Shows An Effect). In fact, they are 10th percentile values of the LOEC data set. A LOEC is defined by Effroymson as a response >20%. **The derivation of these values is outlined in Volume 3, Tab 4. After later review of this material, the Stantec comment was revised as follows.** Cobalt and Arsenic Benchmarks for Tadpoles. I had questioned the use of an acute exposure study (96-h LC50 for Rana hexadactyla tadpoles; Khangarot et al., 1985) to estimate a chronic value, when a chronic study (7-day LC50 for Gastrophryne carolinensis embryos and larvae; Birge et al., 1979, 1987) was available. I had also questioned the estimation procedure, which seems to lack an acute:chronic adjustment factor. The rationale in Volume III does not resolve the questions in my view. The estimation procedure (LC50 x 2/5) follows Effroymson et al. (1997) who used it for terrestrial invertebrate studies when there was excessive mortality (50%). Their interest was in sublethal endpoints (growth, reproduction) and chronic exposure (minimum test duration was 6 days). Their adjustment factor was used in cases where mortality prevented measurement of a sublethal response, and corresponds to the ratio between 50% and 20% response in typical dose response curves. Thus, it estimates a level at which minimal mortality (but sublethal effects) can be expected. It is applied to a chronic test result, and does not encompass an acute:chronic (short-term:long-term) adjustment. Acute:chronic ratios (ACRs) have been well established in aquatic toxicity testing for standard test species. For tests of arsenic on fishes, they range from about 5 to 28. A 96-h test is considered to be acute, even if performed on fry. An embryo/larval test is considered to be chronic since it encompasses all the sensitive life stages. The definitions and ACRs are not well established for frogs. The essential question is whether a 96-h LC50 for tadpoles can be considered chronic. If it is acute, an ACR adjustment is appropriate, and the adjustment factor that has been used (2.5) is not sufficient. The authors of this ERA consider the 96-h LC50 for tadpoles to be chronic, and thus avoid an acute:chronic adjustment. This is non-conservative, and I believe questionable. There would be no controversy if the Birge et al. values were used as benchmarks, since these are clearly chronic values. No rationale has been given for not using the Birge et al. values for Gastrophryne carolinensis as general tadpole benchmarks. Indeed, they have been used as benchmarks for Fowler's toad for Co and As when data specific to Fowler's toad were unavailable. The two species are unrelated, belonging to different families, so there is no taxonomic reason to consider the Gastrophryne data representative for Fowler's toad but not for other frog species. In summary, I would have used the Birge et al. benchmarks as general tadpole values for Co and As, and don't see a convincing rationale for rejecting them. If you have questions regarding these comments, feel free to call and discuss. **The Birge et al. chronic values have been substituted in the assessment (Table 7-2).**

Table 7-1	The frog (tadpole) benchmarks for Co and As are given as 7 mg/L and 0.1 mg/L, estimated from acute toxicity test results for *Rana hexadactyla* (acute LC50 x 0.4). The usual acute: chronic adjustment factor of 0.1 has been omitted. Moreover, Birge *et al.* (1979) give chronic test results for *Gastrophryne carolinensis* exposed to Co and As, as cited in Table 8-4 (7-day embryo-larval test). These data should have been used for Co and As, giving a benchmark similar to the Ni and Cu values. **The derivation of these values is outlined in Volume 3, Tab 4. After later review of this material, the Stantec comment was revised as shown above. See the response given above.**
Section 7.4, Page 7-16	The assumption of this assessment is that the four metals do not share any common modes of action, and therefore do not have additive effects. This assumption is non-conservative. Certainly, the effects observed in test organisms are similar. The U.S. EPA (1998) notes that additivity is a reasonable assumption, given that additivity or near additivity is commonly observed, and advises caution about assuming independence. If non-additivity is to be assumed, the independent modes of action should be described by way of a rationale. **The citation indicated could not be found. US EPA recommendations on this topic have been added to the assessment report. In fact a number of combined effects were evaluated as such, litter, earthworms, frogs, maples and woodlot health. Additional discussion of and evaluation of combined effects on mammals and birds has been added.**
Section 8.3 - Risk Characterization Section 8.3.1, Page 8-5	If TRVs from the Birge *et al.* tadpole tests are used for Co and As, the risk quotients for Co and As are 0.3 and 0.25, respectively. **See comment given previously to Table 7-1 (Current report Table 7-2).**
Section 8.3.1.2	The logic in this section is not clear as Frog Calls were sampled at regular intervals irrespective of there being any water bodies within the sampling area. The relationships were done to soil CoC levels rather than to water or sediment CoC levels and concentration zones of 0-1,000, 1,001-2,000 and >2,000 ppm Ni were used. We would not be surprised that the parameters considered could not be demonstrated to influence the distribution of frogs. This line of enquiry should have been screened out and dismissed. **Since the focus of this assessment is CoC levels in soils, the approach is considered appropriate. To determine the outcome before the data is collected is not considered a sound scientific approach. The approach taken is considered valid and did yield valuable information on the prevalence of frogs in the study area.**
Table 8-4, Page 8-7	Is it appropriate to use the species-specific TRVs from the Fowler's Toad toxicity tests for Ni and Cu, and the Narrow Mouth Toad values for Co and As where Fowler's Toad data were not available? **Yes, more specific (and thus more relevant) values are always considered appropriate when they are available and of suitable quality.**

Section 8.3.2.1, Page 8-10	Another dubious assertion is made "since earthworms are expected to obtain some portion of their exposure from detritus, which would have much lower CoC concentrations than the surrounding soils as judged by those concentrations in maple leaf tissues". There are two points that should be made here. First, the CoCs in leaf tissue may be much more bioavailable than those in the soil since CoCs have passed through cell membranes and been translocated to leaf tissue. Second, earthworm intestinal enzymes have evolved to break down leaf litter material to obtain nutrients from them, whereas they have not evolved enzyme systems to break down soil particles. Therefore, it would be likely that the earthworm extracts considerably more of the CoCs from leaf litter than from the soil. **The assertion has been removed (P. 8-22).**
Section 8.3.2.2, Page 8-11	The listing of dose-response models used is helpful; however, the non-sequitur "c = % contaminated soil" is meaningless since no equation involving "c" has been given. **For these experiments, "c" was equal to the % of contaminated soil in the blend as shown in subsequent tables. ECx were calculated using these values rather than actual CoC concentrations of the soils.**
Table 8-8, Page 8-12	Can the "Number of Unhatched Cocoons" be interpreted as cocoon production, i.e., scored prior to the time for hatching? The other interpretation would be that these are non-viable cocoons. The language should be clarified. **The nomenclature as presented in the report is common to earthworm toxicity studie**s.
Section 8.3.2.2, Page 8-13	If the 100% contaminated soil is 10,400 mg/kg Ni (Table 8- 7), then an EC20 concentration of 21.15% contaminated soil should be 2,718 mg/kg. However, the text cites a 20% effect at 2,279 mg/kg Ni. Similarly, the concentrations of Cu, Co and As stated in text do not quite match what one would calculate from Table 8-7. Could this be explained or rectified? Section 8.3.2.2, Page. 8-17 has the same issue. **The estimated value of 2,279 mg-Ni/kg was calculated by summing 0.2115*10,400 (the contribution of the contaminated soil) and 0.7885*100 (the contribution of the background soil). A similar method was used throughout.**
Section 8.3.3.2, Table 8-21	The ANOVA table refers to a "Treatment". There has been no mention of what this treatment is. Could it be described? **"Treatment" refers to the structure of the sampling design, which should be accounted for in the analysis to avoid potential pseudoreplication.**
Section 8.3.2.3, Page 8-46	The statement that CoCs do not affect maple germination or growth should be qualified. According to Table 8-20, and Figures 8-19 and 8-20, there is a Ni effect when seeds are from the Reference Area. This shows as a significant interaction in Table 8-20. **Soil nickel concentration is not related to overall germination success, seedling height or leaf health. When one examines the difference in response exhibited in planted seeds taken from a tree in the Reference Area and seeds taken from several trees in the Primary Study Area, an interaction is present. For example, germination success of the Reference Seeds appears to decrease as soil nickel concentrations increase, yet germination success increases with nickel concentrations with seeds from the Primary Study Area. The small sample size and lack of substantial replication of source seeds limit the results of this analysis, but the general observation that no overall effect of soil nickel concentrations is correct.**

Section 8.3.2.3 - Earthworms	The results of the earthworm sampling are very interesting. However one is left somewhat confused with no explanations of why the majority of worms collected were juveniles, nor why adults were collected in areas of some of the highest concentrations of CoCs. One would have expected after the brief discussion of the laboratory results and the field results, that the report would provide conclusions regarding the probable adaptability of local earthworm populations to high soil CoC levels, or an alternate plausible explanation. **Speculation on whether local adaptation is occurring or whether these species are predisposed to be tolerant of high CoC concentrations is not warranted in this section. However, this speculation is briefly discussed in Chapter 9.**
Section 9.0 - Integration	In this part of the report, the task JWEL has to undertake is to demonstrate that there is integration between this study and the other studies conducted under the CBRA. This has only been done in part **The purpose of this section is clearly stated in the introduction, in that all of lines of evidence for receptors that were analyzed in the ERA are to be considered in describing the risk to a receptor. There was never any intent to integrate "other studies conducted under the CBRA" into the ERA except to the degree that data are useful to the risk assessment. That this would be the case is a misconception on the part of the Stantec reviewer. In addition, that this type of integration, which is between the ERA and other CBRA studies, would not occur should have been clearly evident to the Stantec reviewer as Stantec had previously reviewed and discussed with JW the document detailing data analysis and integration for the ERA (see Volume II –Tab 14).** While JWEL may consider its analysis of receptors is complete, there does not seem to be a consideration that the receptors such as American Robin, Woodcock, White-tailed Deer may spend as much time in the agricultural or suburban landscape as they do in the natural environment landscape. The integration of other studies may in fact indicate that there is less ecological risk than that suggested by JWEL due to lower soil CoC levels in open country compared to woodlots. Therefore the proportion of foods consumed by American Robin or White-tailed Deer grown on less contaminated soils may be lower than suggested. This may well remove Woodcock as a species at risk **As has been stated before, the approach of this ERA for the description of risk was to use site specific data from natural environments in the study area, namely woodlots and fallow/old fields for biological samples, and all fields in general for soil data. Therefore, though the use of CoC values in various media from agricultural lands, suburban lands or residential areas could result in an overall lower exposure to receptors, this study's approach has been to take the conservative approach and base the risk assessment on the existing exposures to CoCs in the natural habitats and environments of the receptors.** This report does not provide evidence that CoC levels in sampled organisms were compared with those reported in the literature and with the expected values based on modelling and bioaccumulation assumptions. It would seem that this would provide a good means of checking the validity of JWEL's data and assumptions. This approach might on occasion raise questions where the results obtained by JWEL differ from the values in the literature, or may suggest that there are errors in the JWEL data. As it stands, there is no internal assessment of the value of the JWEL data.

	Based on review of the literature, it became clear that "normal background" concentrations of CoCs in organisms or tissues vary considerably. More confounding is the fact that much of the data is referenced as "distance from refinery" and existing soil concentrations from sample locations are not provided so one cannot determime bioaccumulation from the data. Similarly, in any one area across North America, normal background soil CoCs concentrations vary also, so again a direct comparison of Port Colborne data to data in the literature would only be suggestive at best. The study, however, has data from local control sites that are presented throughout the report that a reviewer can consult to assess what are normal levels of CoCs in tissue or other media in the local area. **Media sampled (tissue, air, water, etc) samples were collected from local control (background) sites, and at sample points where soil CoC concentrations varied from high to low in the study area. These site specific data sets are presented for each media analyzed in the study. A quick review of the data presented in the tables and figures presented in Section 6.0 shows the trends with respect to bioconcentration in tissues that are specific for the study area. Outliers in the data sets could therefore easily be questioned during the QA/QC process. The sampling program has been structured to provide real site specific data, and by sampling from control to high provides a means of checking for errors in the data sets used in the exposure and risk assessments. A comparison to literature values is not relevant when site specific data is used in an ERA.** The last bullet on page 9-1 states that collection of data concentrated in areas closest to the Inco refinery with highest concentrations of soil CoCs and that risk is conservative as a result. JWEL previously described how it sampled evenly in primary and secondary study areas, as it is described in various protocols. Also the areas closest to the Inco refinery are west of Reuter Road and few samples were collected from this area. JWEL must explain how they averaged numbers and why. **This bullet has been re-written as follows: That the use of the UCLM for biophysical and biological media in the exposure assessment results in a risk assessment that is considered to be conservative for a receptors population in the study area (P. 9-2).**
Page 9-3	It is not clear that the use of the term "bioconcentration" should be applied in the soil nickel to animal tissue concentration, for the following reasons: a) The form of CoC in the soil is not given and it may be inert and immobile. b) Bioconcentration relates to movement from organism to another; if it never gets into the plant because of immobility, then the lack of its presence in a consumer. **a)Bioaccumulation factors (BAFs) are commonly used in ERA's to yield soil-biota transfer of metals. BAFs calculated in this ERA indicate that bioconcentration is not occurring in organisms when compared to soil CoCs. However, the term bioaccumulation has been used in place of bioconcentration since it is understood that metals generally do not bioconcentrate in organisms. Rather, bioaccumulation can be related to BAFs (P. 9-19).** **b) the point being made here is unclear.**

Section 9.2, Page 9-3	The safe soil concentration for American Woodcock on organic soils in woodlots is given here as 14,000 ppm. However, a value of 10,000 ppm was stated in Chapter 8 (p. 8-50). The discrepancy should be resolved. **This has been corrected (Safe soil concentrations are located in Section 11).**
Section 9.2, Page 9-4	JWEL describes the worm as a tube of soil. However, JWEL demonstrates in the purged versus unpurged worms that 35-75% of the CoCs are actually in the worm tissue, not in the gut soil. If one removes the amount of Ni that is naturally in earthworms, which is given by the values from worms from reference areas (approx. 15 ppm Ni), and the calculations, one sees that worms from the organic soil areas have approximately 70% more nickel in their tissues than from the reference areas. One can hardly consider this as equivalent to a tube of soil. **This metaphor was used to indicate that American Woodcock's ingest proportionally more soil than other birds, aided by the fact that they principally eat earthworms, which tend to have a lot of soil in their gut. This metaphor has been removed.**
Section 9.3, Page 9-4	Again, the statement that seed germination and sapling growth is unaffected by Ni should be qualified. Effects were observed when using Reference Area seed. There may be pollution-induced tolerance in the Study Areas. **This text is expanded, including the potential for local adaptation (P. 9-11).**
Section 9.3, Page 9-4	Maple Trees. The assessment also included maple sap analysis, tree increment cores and nutrient flow through the litter study. Why are these studies not mentioned here? There are a number of studies JWEL undertook that resulted in a considerable amount of data which turned out to be either irrelevant or shed nothing on the assessment. JWEL should comment on these studies and provide their reasons for excluding them from the final report. **The collection of maple sap was undertaken for the Human Health Risk Assessment, owing to the fact that local residents indicated that they tap local trees and make their own syrup. The CoC concentration for sap provided in Tables 6-5. The use of data sets for the ERA that were primarily collected for the HHRA or Crops Studies has been detailed in full in Section 5.0.** **With respect to tree increment cores, the cores were collected so that this information could *possibly* be used to correlate impacts on trees and woodlots with CoC accumulation in the wood tissue. However this level of analysis was found to be not necessary, nor possible. The reviewer should note that the collection of tree cores is not found in the data collection protocol for the woodlot health assessment. However, as this data was collected for the CBRA, it is presented in Volume V in the raw data sets.**
Section 9.3, Page 9-4, Last Paragraph, 4th line	Should be less than <3,000mg/kg Ni, not >. **Correction has been made (P. 9-11).**
Page 9-5, Second Paragraph	The first sentence is unclear; does JWEL mean decrease in populations rather than increase? **Yes it should be decrease rather than increase, this has been corrected (P. 9-12).**

Section 9.5, Page 9-6	This section discusses how the calculated risk to earthworms is conservative, but neglects to mention that the calculated risk was high at all sites for Cu, and in woodlots with organic soils, high for Ni and As. This section is supposed to be integrating lines of evidence, not ignoring certain lines of evidence. **This text has been revised (P. 9-4).**
Section 9.5, Page 9-7	The EC20 concentrations for organic soils are presented. The same results for clay soils are dismissed as variable. The EC20 concentrations were lower in clay soil for four out of five endpoints, consistent with the greater uptake in clay soils. The "integration" in this section seems to be rather selective. The "integration" of earthworm results could be as follows: Potential effects were indicated in the risk calculations, in the toxicity testing, and in the field data, although only for one species in the field. **This section has been revised (P. 9-4 to 9-6).**
Section, Page 9-7, First paragraph, last sentence	"Assuming 100% bioavailability for the calculation of risk is highly conservative given these numbers, and is unlikely to have direct bearing on what is actually happening in the natural environment." This sentence is incorrect on two points: a) First, JWEL has demonstrated with the purged earthworms that up to approximately 70% of the nickel in earthworms may be in the worm tissues and thus is presumably bioavailable to any predator, and b) The assumption that this might not have a direct bearing on what was happening in the natural environment is baseless and unsupportable. **This statement is taken out of context. We are stating that 100% bioavailability of soil CoCs to the worm, not of CoCs in the worm to a predator, is highly conservative.**
	Why in Figure 9-1 is only the woodlot on the east side of Reuter Road shown – what is wrong with the habitat on the west side of the road for woodcock? Stantec, certainly observed woodcock there, along with JWEL on one of the field surveys. **For the CBRA, the lands associated with the Inco Refinery closure plan boundaries are excluded, as site closure requirements including rehabilitation or remediation are determined under separate legislative requirements pursuant to the Mining Act of Ontario. This has been detailed further in Section 1 Scope of Work In addition, a review of the data and re-calculation of risk for the American Woodcock finds that this VEC is not at risk for each CoC. Therefore Figure 9-1, is not required.**
Section 9.4 - Amphibians	Stantec does not believe that combining data on tadpoles and frogs will clarify any analysis, because the environmental media which the two life stages occupy are very different, as are their diets. **JW does not understand this objection. The question that is being addressed here is "has historical accumulation of CoCs in the local area's soils resulted in a risk to the local frog populations". Based on JW's understanding of amphibian biology, tadpoles do become adult frogs, so a risk to tadpole populations is the same as a risk to adult frog populations. If one does not find tadpoles in an environment, one can assume that adults will be rare. Conversely, if one hears many adults calling during the breeding season, one can conclude that tadpoles are surviving long enough to grow into adults. So one can combine these two data sets.** Regarding the exposure of tadpoles to CoCs, Stantec suggests that algae (the food ingested) would provide the logical pathway, as food is used in the majority of other pathways for

	animals proposed by JWEL; this should be clarified. **For aquatic organisms, such as tadpoles, standard ERA practice is to assess risk-based exposure on the water concentration of the CoC in question. There have been no studies that provide TRV values for tadpoles based on CoC concentrations in algae or any other ingested food items. Therefore food pathway exposure risk assessment is not possible for tadpoles.**
Section 9.5 - Earthworms	In the first paragraph of this section JWEL state "When gut contents were removed, earthworms had even lower concentrations of CoCs in their tissues, from approximately 39% to 97% of whole earthworm CoC concentrations." This is very confusing, as JWEL is referring to different CoCs in different soil types. This creates a confusing set of variables that obscures the very point JWEL tries to make. This section requires rewriting. **The statement to which the reviewer is referring is a summary of the data using a range, without going into the details we had presented in earlier sections within Chapter 6. However, we can understand that a little more information repeated here may be useful to the reader, and have expanded this discussion.**
	Conclusions from the earthworm toxicity suggest a range of response of two orders of magnitude (83 mg/kg to >8,655 mg/kg Ni). Stantec is not sure that this is usual in a controlled laboratory experiment and would like to see this properly explained. It is not reasonable to assume this level of variance and to be so dismissive of the results;- JWEL states "The results of the clay trials are so variable and so out of line with what is found in the literature, the validity of the results is called into question." Either the experiments were poorly conceived and/or carried out, or there were errors somewhere in the process. A proper explanation is required. **Gladys Stephenson of Stantec (formerly ESG International), who conducted these experiments, comments:** **"The data are variable but not as bad as the statement suggests. The response of multiple endpoints can be variable because toxicity is soil dependent, chemical dependent, species dependent and endpoint dependent. Variation is to be expected when you have combinations of these things along with mixture toxicity. The variation among endpoints can be high because one parameter can reflect direct effects (e.g., those directly related to the mode of toxic action) and other parameters can reflect indirect effects (a subsequent effect). The individual reviewer has selected an endpoint that is generally variable and, as such, not a required measurement endpoint for this test, especially when the actual numbers are low. The number of cocoons (hatched, unhatched, total) are enumerated but success of separation of cocoons from soil is highly dependent on the experience of the sorter (i.e., picker-dependent) and therefore not a reliable metric on its own. A cocoon is about 2 x 4 mm in width and length, respectively, on average. The colour of the matrix in which the worms are found determines to a large extent the colour of the cocoon. Therefore, in black chernozems the cocoons are very dark and difficult to see. It is also difficult to physically separate them from the soil if the clay content is moderate to high. In the one test (ISO test) where the endpoint is the # of cocoons, the soils are sieved through very fine sieves using much water to isolate the cocoons. The measurement endpoints in the EC test method are juvenile numbers and dry mass. Reporting the cocoon numbers is optional.**

	"Despite the problems with enumerating cocoons, in some tests where there are on average 10 cocoons per test unit, with a distribution between hatched and unhatched, the metric can be quite useful. In this test the average production is between 1 and 3, which is quite low and indicates to me that reproduction for *E. andrei* was less than optimal in these soils. The LOAEC is unbounded. The interpretation of the data as presented in the report is appropriate and I have no problems with the conclusion drawn other than the obvious that you have pointed out and that is you have no idea what the causal chemical is because you are dealing with mixtures and you are simply reporting the chemical levels in the soil at which a significant effect might have occurred. The other metrics are not as variable as the cocoon metric, however, the variability remains high ... Although I do not have the data yet, I have a suspicion that there is a seasonal effect on optimal reproduction even in laboratory cultures for standard soils and methods. The experiments were not poorly conceived or carried out. They follow a soon to be standardized approach to soil assessment and the methods being recommended by Environment Canada." **When asked whether other qualities of the soil could be influencing the result, Stephenson further comments:** **"My understanding from experience (and it is not well documented) dictates that the critical variables are bulk density, clay content, clay mineralogy, pH, and organic matter content. To complicate things, there is autocorrelation among the variables. My experience is that soils with high bulk density (e.g., heavy soils) with high clay and low organic matter content, compact easily when moist, and it is a relatively "hostile" environment for earthworms. It makes burrowing and feeding difficult and challenging for a worm. Chemically, I suspect the nature of the clay content itself can present challenges; however, I do not know of any paper where this has been investigated. ... In answer to your question, when performing the toxicity tests using the methodologies recommended by the existing protocols (test methods), it is difficult (i.e., almost impossible) to separate the effects attributable to only the CoCs and those attributable to the physical-chemical characteristics of the soil itself. The exposure gradient is established using different proportions of the control soil and the contaminated soil, therefore the physico-chemical characteristics are also present in different proportions. The control soils (experimental control soil for culture health and the reference soil control) presents the physico-chemical characteristics at one "level" only in the absence of the CoCs. Because the biological effects that are measured are the result or integration of the combined effects of CoC and soil physico-chemical characteristics and interactions can by additive, synergistic, and antagonistic, it is difficult to separate these factors unless you specifically design spiking tests to address them. The comparison of the two experimental controls will tell you if the conditions in the reference soil are "optimal" relative to the experimental control which is assumed to present optimal conditions. In answer to your question, I support the position that the soil themselves can play a role in the observed effects but to quantify the degree to which it might affect or influence the result, experiments would have to be designed and a lot of testing completed before an answer could be given.**

Page 9-7 last paragraph	It is stated… "while two of the most common species (*Lumbricus terrestris* and *L. rubellus*) showed either no response or a positive response to increased CoC concentrations. Overall, the earthworm community in Port Colborne, as measured by species richness, overall abundance and overall biomass, showed no negative response to increases in soil CoC concentrations." During the field work JWEL noted the paucity of earthworms in the Reuter Road woodlots relative to other woodlots and this was confirmed by the Stantec sampling results. The levels of the CoCs in tissues were also markedly higher in those worms collected from these areas (Table 6-3). The toxicity experiments showed a drop in cocoon formation and hatching with high levels of CoCs. Therefore, to suggest that there was no negative response in not substantiated by the evidence provided by JWEL in either their fieldwork or experiments. **As measured by species richness, overall abundance and overall biomass, the Study Area's earthworm community showed no negative response to increases in soil CoC concentrations, based on statistical analysis. These are not the only measures of earthworm health, but they are measures we deem to be the most important. This text is expanded upon in this section (P. 9-5).**
	Other inconsistencies are illustrated in Table 6-8 and 6-9. JWEL shows that the mean levels of Ni in earthworms are higher in the primary study area than the secondary than in the reference areas. They then compare nickel levels in different soil types and there is no major difference between clay and organic soils. Yet the nickel levels in earthworms from woodlots and fields are very similar 245 ppm (woodlots) to 264 ppm (fields) when JWEL has previously described how woodlots have much higher CoC levels than the surrounding fields; this requires an explanation. The differences in CoC concentrations between purged and non-purged worms in Table 6-13 also needs explanation. **Although this comment should have been presented in a Stance's review of section 6, rather than here in Section 9, the sections to which the above comments refer have been revised (Section 6).**
Section 9.6 - Woodlot Health Assessment	In the opening paragraph, JWEL undertakes a synthesis of several studies (woodlot health, leaf litter decomposition, maple leaf health) while not including all the woodlot studies (maple sap and wood increment cores). Why is there a partial selection of studies **See above reply (Section 9.3, page 9-4) regarding maple sap and wood increment cores.** JWEL suggests that the studies mentioned "can be used to assess the potential adverse effects of soil CoCs on an ecosystem level." This is not correct. If one was to undertake an ecosystem level approach, one might expect to see results from earthworm, insect and avifauna studies as well as studies related to the trees. The Forestry Consultants point out in their report that factors such as selective logging and drainage have had major impacts on forest stands. They also conclude that the presence of a large cohort of young trees in many stands indicates good regeneration. **JW agrees that an ecosystem is complex with countless interdependent connections and pathways. However, for the assessment of woodlot heath, i.e. the trees in the forest, we believe that the lines of evidence that were assessed are, when looked at collectively, the key components of the woodlot ecosystem at the large scale. Other measures of a forest ecosystem, such as its bird and mammal communities do not related to woodlot heath as directly as the lines of evidence that we assessed.** The Forestry Consultants refer to the woodlots within the whole Study Area (Primary and

	Secondary Study Areas) as being within the Primary Study Area (PSA) (Trees Unlimited Report Vol. IV, Page 1). JWEL should strive to have consistency between the different consultants' reports. **Agreed, but JW does not believe that this point is relevant to the findings of these studies or the ERA.**
Page 9-8	Leaf litter results "found that increasing soil CoCs were likely resulting in slower rates of decomposition, particularly for woodlots on organic soils nearest the refinery." If one examines the results of the amount of leaf litter collected from heavy organic (Volume IV, Leaf Litter Study Page 67) one sees that for sites 16,17,18 and 19, the first three values are High (536.9, 399.9 and 410.5 and the last, low 197) compared to low organic for sites 20, 21, 22 and 23 in the Secondary Study Area with low values (127.2, 126.0, 181.3 and 117.3, respectively): the units are not given in the table, but one assumes grams, not pounds or kilograms. If one examines the locations of sites 16, 17, and 18, (Figure 4) they appear to be more or less contiguous, i.e. the woodlots on the east side of Reuter Road. Site 19 is close by, within one or two hundred metres. Therefore, by taking three samples from a high woodlot and only one from a much lower woodlot that is still within the high zone, one skews the results (averages) significantly. To then conclude that CoCs might affect decomposition rates based on the larger amounts of litter present at some sites seem tenuous at best. The author (W. D. McIlveen) does conclude that current rates of decomposition are at equilibrium, so that there is no impairment of woodlots nutrient cycling occurring. It is unfortunate that the figures reproduced in these reports such as Figure 4, Volume IV, are almost impossible to read, especially the numbers, which will deter most readers from checking the content. For comparison, compare with Map 1 Regional Sampling locations for phytotoxicity study (MOE 2000) that is clear and easy to read. Figure 4 should be produced in a clear and legible form. **Units in table were grams per square meter on an oven-dry basis and this has been added.** **The author of the study, Mr. W.D. Mcllveen, provides the following comments:** **With respect to the geographic distribution of the sample plots, it should be understood that the areas sampled represent each and all of the available forested sites on organic soils in the zone designated as having high metal concentrations. Within the constraints of the geographic distribution of the existing woodlots, attempts were made to locate the sampling points to cover as large an area as possible within the designated sample zone. The distance of Plot 19 is approximately 670 meters to the east of the other three plots. The most southerly plot along the Reuter Road group (Plot 16) is approximately 570 meters from Plot 18, the most northerly of the group.** **While it cannot be disputed that the Sites 16, 17 and 18 represent a chain of wooded sites along Reuter Road, it must also be understood that Site 19 would also be contiguous with the other three had the intervening land not been cleared for agriculture. Any possible bias incorporated into the data mean calculations by the geographic distribution of the available sampling points (i.e. higher soil metal concentrations were found along Reuter Road because these three sites are closest to the refinery) actually would tend towards a worst-case scenario thus maintaining a more conservative interpretation. The reviewer's comment and concern might have had more validity if the situation had been the reverse, where the greater proportion of the sample sites were located in the area with lower metal concentrations. In most**

	cases, the interpretations of the data were based on data from individual plots and not on zone averages. The reference to the results of the greenhouse phytotoxicity studies does not provide a reference, and as the results have not been provided, it is impossible to verify this statement. **JW is confused by this statement. The results of the greenhouse studies for Maple trials are provided in this section. Dose-response Experiments with Maple.**
Second paragraph, last sentence	The Leaf Litter Study appears to have been carried out diligently by the sub-contractor. However, the relevance of its findings is questionable. As the author states in the early part of the report (Page 1 last paragraph, "time constraints imposed by the current situation would not allow for a detailed investigation using the normal procedures. Instead a proxy method of assessing the rate of decomposition was used." A number of unproven assumptions are made and no bibliographic references to this are made in spite of exhaustive citations for the majority of the report. One can only conclude that this is not a normally used method, and thus may be of little value to the ERA. **As part of the CBRA process, JW provided data collection and interpretation protocols to Stantec prior to conducting fieldwork. Therefore, Stantec was well aware of the methodology that was proposed for the leaf litter study. The purpose of the protocol review process was to insure that Stantec as the PLC's consultant would insure that studies for the ERA were appropriate and would provide meaningful data. JW therefore considers the last statement in the above paragraph to be unwarranted since Stantec is very aware of the rational for the leaf litter study.** **The author of the study, Mr. W.D. Mcllveen, provides the following response:** **The report does mention in several instances that the methods applied in the study were not the preferred method for assessing the rates of litter decomposition. The preferred methods would not have provided the required analytical results until at least the fall of 2003 (following a minimum two-year field exposure period starting at the date of normal leaf fall of 2001) during which the litter decomposition process could have been tracked. The project requirements simply did not allow the required time frame to utilize this approach. Instead, the only available option was to collect data that might reflect the cumulative effects of historic influence of accumulated soil metals on the preceding years of litter decomposition.** **There are only three possible influences of the elevated metal concentrations on the leaf litter decomposition process. These are namely an acceleration of the rate, no measurable effect, or a slowing down of the process in the presence of metals. Simple logic would dictate that these three possible effects would lead respectively to lower amounts of litter, the same amounts of litter, or larger quantities of litter remaining on the surface of the ground at any given time. These were the possible outcomes that were being evaluated from the field studies conducted across the soil metal gradient at Port Colborne. These three possible outcomes can hardly be viewed as assumptions, let alone "unproven" ones. The relevant scientific literature in this area tends to focus almost entirely on the negative effects of a specific factor (i.e. metals). If the decomposition process is slowed by such factors, at any given time, more litter will remain on site than on a normal or unaffected site. Such a differential will be maintained at least until 100% decomposition of the litter subjected to the slower process has been achieved (theoretical maximum). For example, for a given increment**

	in fallen litter, the normal rate of decomposition may require 400 days to be completed while the slower decomposition at a site with elevated metals may require 450 days to be completed. After 450 days there will be no differential since all litter would be gone but in the meantime, new litter would have fallen. The scientific literature does not specifically identify situations where large or excessive amounts of litter would accumulate on the ground in the presence of metals or other chemicals hence no specific literature report could be cited. Most literature reports, however, do show that more litter is retained in litterbags in the presence of metals, etc. at the conclusion of the testing, therefore it is logical to conclude that more litter would be present by virtue of the slower decomposition rate in the presence of any toxic chemicals. **We are unaware of situations specifically where the approach used in the present study has been applied in equivalent environmental study situations. The techniques used are simple variants on methods used elsewhere where it was necessary to obtain measurements of the amounts of standing litter for other types of ecological studies. The method for obtaining measurements of standing litter should not be considered contentious in anyway. Although the approach used lacks certain of the experimental control that would have been provided by using leaf litter bags to complete the assessment of litter decomposition, it may in some ways be superior in that it integrates the *in situ* effects of all of the local environmental factors including metals levels on the decomposition rates without the physical constraints imposed by employing litterbags. The comment that the approach used was "not a normally used method" is accurate, however, we cannot agree that "it may be of little value to the ERA" simply because the technique has not been applied directly in the past. The approach used in the present study may not have been used elsewhere because there was not a political imperative in those studies to deliver a report in such a short time frame. Had the appropriate time been allotted, the study approach would have recommended that a combination of three methods be applied. (The other two would have entailed field-testing of the litter decomposition rates using litter bags mentioned above at each field site over two years and secondly bringing soil columns from each field situation into controlled environmental conditions and following the decomposition process over the columns in those controlled conditions over 2 years). There may be alternative methods but these would likely have involved specialized analytical equipment, radioactive tracers, etc.** **Regardless of any arguments about the merits of the approach, several facts remain. These are that the leaf litter input rates into the system were same regardless of the soil metals level at the site and that substantially more leaf litter was found on the organic soil sites nearest the smelter where the highest metal levels were found in the soil. While this does lead to the conclusion that a decreased rate of decomposition occurs where high concentrations of metal were also present, it is not possible to prove that the metals were responsible, either directly or indirectly, for that change. (By contrast, had the litter quantities on the ground been the same in both high and low soil metal situations, then it would have been possible to conclude there was no effect of the metals on the decomposition process). In the evaluation of the results, it was conservatively assumed that the metals were indeed responsible for the observed slower rate of litter decomposition in the earlier stages of the process; however, the process appeared to have reached a state of equilibrium where the total annual decomposition equalled the total annual input of leaf litter although the process may have extended over a longer period.**

Section 9.6, Page 9-8	The statement that maple germination is unaffected by Ni up to 3,000 mg/kg should be qualified. Effects were seen using Reference Area seed. **As mentioned earlier in response to Chapter 8 comments, this section has been revised.**
OTHER ASSESSMENTS	There is no discussion as to the assessment of risk to insects (field or woodlot); the reason for this omission should be provided. **Insects (and spiders) were not identified as a VEC for which risk would be assessed in the ERA. Insect and spider samples were collected to provide site-specific data for food pathway exposure to receptors for which risk assessed. Clarification regarding insects in Table 4-1 has been made.**
Section 9.7 - Safe Soil Values	The statements in these two paragraphs are all embracing and should be moderated **This section has been reviewed and expanded upon.**
	JWEL does conclude that the safe soil value is approximately 14,000 ppm Ni in woodlots. There is no map showing the 14,000 ppm Ni isopleth for the Study Area; this should be done. **This statement is irrelevant as a review of the data and correction of an error shows that the American Woodcock population in the Study Area is not at risk.**
	Again, the safe soil value for Woodcock was 10,000 ppm in Chapter 8 and has become 14,000 ppm here. **See above.**
Section 9.8 - Safe Inland Surface Water Values	The value of this paragraph is not clear as the location of surface waters with a nickel value of 0.02 ppm has not been provided. Why is there a need to modify the statement "a safe nickel level of 0.02 ppm is identified" with the disclaimer "this value for surface water is considered to be very conservative"? If it is true, provide the rationale. **JW has re-assessed the appropriateness of presenting this section in the ERA Report, and has not presented safe water values since this is not within the scope of the CBRA.**
Section 9.9 - Site Remediation Requirements	JWEL has not defined what the goals and objectives of various stakeholders are, and this should be clarified for the reader. When the goals and objectives have been described, then one can assess whether they are currently met based on the results of the various studies carried out by JWEL. If for instance, the goals and objectives were to ensure that woodlot health was normal and that there was no evidence of impaired form (tree health and species diversity) or function (leaf litter study), then one could conclude that the stakeholders' objectives were currently met and there was no need for remediation. If no alternative remedial options are discussed, then it is impossible to choose one should remediation be required. It does not appear that JWEL has discussed the options at any stage in this report; this is a serious omission. The last paragraph of only two sentences provides the only mention in the report of potential remediation methods. This is a major deficiency that needs to be corrected. **As a first point, as noted above the Woodcock is not at risk. Therefore, the ERA concludes that no risk has been identified for the flora and fauna population that occur east of the refinery. Therefor the determination of a "safe soil value" is not required and the report concludes that no immediate remediation requirements are identified. JW agrees that at this stage of the CBRA process that insufficient consultation with**

	the various stakeholders has occurred. Regarding ERA findings JW has removed the discussion of remediation from the report. Remediation requirements and options will be addressed in a separate report to be prepared for the CBRA. Overall the integration/conclusions section is very disappointing and weak, considering the major effort which obviously went into these studies. This section should undertake a review, synthesis and analysis to provide the key points of the report, its strengths (original data) and weaknesses (skewed sampling sites) and from this draw reasonable conclusions, supported by reference to the scientific literature. Stantec considers that given the major effort, which went into the ERA study, a significantly more substantive conclusions section should be written. **Based on all the previous comments provided by the Stantec, JW has assessed where Section 9.0 needs to be expanded upon. However, JW does not believe that a detailed ecological treatise is required here. Section 9 should summarize the characterization of risk, not provide a detail of dissertation of the ecology of the Port Colborne area's natural environments.** **With respect to the statement "and from this draw reasonable conclusions, supported by reference to the scientific literature", JW is unaware of any other studies to be found in the literature that have assessed the risk to the flora and fauna of the Port Colborne area as a result of exposure to the four CoCs in the site specific soils addressed in this ERA.**
Editorial Comments	There is a major lack of editorial control throughout the documents submitted. These range from minor typographical errors to ambiguous sentence structure to errors and omissions. All of this makes it very difficult to unravel what JWEL is trying to say. A few examples are as follows: The location of the Inco Port Colborne Refinery is described on page 1-6, and the reader is referred to Figure 1-1 to identify its location; it is not shown and identified on Figure 1-1. **The location of the Inco refinery has been highlighted all relevant Maps in the document.**
Page 2-21	The first paragraph is very confusing: "A relationship between nickel in surface water and soil nickel exists where on average higher nickel values in surface water occur on soil/sediment closer to the Inco refinery. As the sampling identified the occurrence of CoCs in inland surface water, in surface water may pose a potential risk to certain receptors and will contribute to the calculated risk for those receptors." **This has been clarified (P. 2-21).**
	When one tries to identify the sampling sites for water on Figure 1.1, the purple colour and legend is very difficult to find and read. This problem needs to be corrected. **This has been corrected (Map 1).**
Section 2.1.10 - Summary	In the second sentence of this paragraph, tissue of vegetation is included as one of the environmental media. It was not considered earlier as an environmental medium. Explain. **This has been clarified. Environmental media include only water, soil, air and sediment (Section 2).**

Section 3.2 - Assessment Methods for Site Characterization	This section lists the primary objectives of the site characterization in bullet point. Characterize the primary soil types in the Study Area Characterize the flora and fauna communities; Conduct ecological land classification (ELC) for the Study Area; Identify important ecological/wildlife functions and attributes; and Identify any rare or significant species. It would be expected that the following section would then elaborate on those points as they are the primary objectives. However the following headings are: General Ecological Setting Known Significant Natural Features Soil Types Ecological Land Classification Significant Communities Flora and Fauna Significant Wildlife Habitat Uncertainties, Limitations and Gaps Our major concern is that in terms of logical progression, the text does not follow the outline proposed. When one reads the text, there are numerous questions left in the reader's mind, including: **This is a point of style rather than on substance. JW believes that Section 3.0 presents all the data required for the reader to gain a solid understanding of the sites ecological setting.**
Page 3-2	starts with the opening sentence "For flora, an inventory of all vascular plants was not undertaken for this study." It would be appropriate to delete this sentence as it does not help the reader. **JW disagrees. We believe it is important to point out that a inventory of all vascular plants was not undertaken and that the primary focus of field investigations was for woody vegetation.**
Figure 3-1	Illustrates two features that are shown as Wainfleet Marsh (8) and Humberstone Marsh (4), yet these are referred to as Humberstone Swamp/Forest and Wainfleet Bog in Table 3-1. There is no explanation as to the difference in terminology. Given that the Study purports to have undertaken an ELC of the Study Area, one would expect a consistency in terminology. **JW has reviewed Table 3-1 and Figure 3-1 and has found that areas 4 and 8 are identified with the same name.** **The reviewer should be aware that the common names for these natural areas has absolutely nothing to do with undertaking an ELC. The names given to these natural areas are based on various reports and studies, see footnote in Table 3-1. Various reports give different names to the same natural area. However, even given that, it appears that the reviewer is referring to the topographic map labelling these wetland features. JW has no control over how the Surveys and Mapping Branch of the Department of Energy, Mines and Resources labels maps of the topographic map series (scale 1:50,000). It is recommended that in order to clarify this matter, that Stantec notify the Department of Energy, Mines and Resources to inform them that labelling of natural areas for topographic maps in Ontario should follow ELC methodology.**
Section 4.2, Page 4-2	The word to be used for animals that inhabit both terrestrial and aquatic environments is amphibious, not "terrestrial aquatic" **This has been changed.**

Page 4-6	The Second Paragraph is very confusing with several ideas mixed up and the relevance of "stationary" soft maples is not clear. References such as RNON 1980 (page 3-10) and Barlett 1958 (page 4-10) are not in the reference section. These are just two examples. All references should be checked. **This paragraph has been reviewed and a reference check undertaken (Section 12).**
Section 5.3.4 - Uncertainties, Limitations and Gaps Second paragraph, First Sentence	"For sedentary specimens, such as maples, wild grapes, goldenrods, and crops, exposure to CoCs from a different location is not of concern." This is a very curious sentence. Why not just say "For plants **This change has been made (Section 11).**
Page 6-37, Table 6-13	There are no numbers in brackets in the table as is suggested in the legend. **This has been reviewed and changes have been made where appropriate (Section 6).**
Page 6-55	In the section on CoC concentrations, reference is made to the levels found in fields. Most people associate fields with active management (arable) and it might be best to refer to them as either old fields, pastures or some other description which clarifies the meaning. This is necessary because the levels of CoCs in the surface 5 cm of arable fields are very different from those of old fields. **We are assessing risk to VECs that use all fields in the Study Area, whether tilled or not.**

PART 2 REVIEW OF LABORATORY QA/QC ASPECTS OF THE ERA – NATURAL ENVIRONMENT	
1.0 Volume II of the ERA - "Laboratory Protocol for Analysis of Biological Tissues" and Associated QA/QC,Soil/Sediment, And Surface Water Protocols "Final Draft – November 2002"	
1.1 Introduction	The protocols describe the methods, apparatus, reagents, and laboratory procedures to be followed in order to provide accurate analyses of 24 elements including the Chemicals of Concern (CoCs). Review of the most recent JWEL draft (November 2002) indicated that it is comprehensive and detailed, but it is also riddled with incomprehensible statements, poorly written and has serious fundamental errors. Because there are so many mistakes – well into the hundreds – it is more efficient to simply note them on the Draft itself, rather than attempt to list each one in a separate document. An annotated Draft has been provided to JWEL for their consideration. The major concern is that some of the mistakes, and their large number, are indicative of an overall lack of quality assurance/quality control (QA/QC) **on the report itself**. Other errors in the report suggest a lack of understanding of some of most fundamental aspects of QC/QC for environmental sampling and analysis; these are commented upon in further detail. **It's QA/QC not QC/QC**
1.2 Lack of QA/QC on the Draft Report Itself	As noted above, the protocols described the methods, apparatus, reagents, and laboratory procedures to be followed in order to provide accurate analyses of 24 elements including the CoCs. The individual procedures discuss QA/QC, but there is clearly a considerable lack of QA/QC and editorial control on the Draft Report itself. Obviously, even for a relatively straightforward description of lab procedures repeated generally verbatim for each different sample type, a few typos, grammatical errors and minor technical errors might be expected. But when the errors add up to hundreds of typos, grammatical mistakes, and technical errors, it is clear that proper editing, proof-reading and editing was not undertaken. One would expect that careful proof-reading would be the first step in providing QA/QC for a report dealing with QA/QC. This is mentioned only because it might help explain the lack of understanding of basic QA/QC that

	becomes apparent throughout JWEL's Draft Report. **It is noted here, that for the CBRA process initial drafts of protocols were provided to Stantec for review and comment as the technical advisor to the PLC. While JW takes responsibility for typos and grammatical errors, it is not clear to JW as to why Stantec would only wait until now to identify technical errors. The identification of technical errors in protocols developed by JW for the CBRA was the purpose of the PLC review process. In this respect, it appears that Stantec has not full filled its role and responsibilities to the PLC.**
1.3 Confusion and Errors Relating to QA/QC in the Draft Report and Accompanying Documents	
1.3.1 Duplicates and Replicates	
1.3.1.1 Confusion Between Variability And Accuracy	The Draft Report (DR) refers to QA/QC in each of the individual protocols, and is accompanied by another draft, "Quality Assurance and Quality Control Protocol for Data of the Ecological Risk Assessment ("QA/QC Protocol")". The latter draft, in the Introduction, states "Quality assurance and quality control (QA/QC) is (sic) essential in order to assess variability between samples collected in the field (duplicate samples), aliquots (replicate samples) analyzed in the laboratory, and to compare analytical results of Standard Reference Material (SRM's) with certified expected values. Under "Objectives" it states "The purpose of a Quality Assurance and Quality Control (QA/QC) procedure was to screen replicate, duplicate and SRM data prior to use in the ERA so that only accurate analytical results contributed to the Ecological Risk Assessment (ERA)". Taken together, these statements would indicate that JWEL are under the mistaken impression that variability between field samples and between aliquots "analyzed in the laboratory" will somehow help to screen data so that only "accurate" results will be used in the ERA. This is incorrect, because measures of variability only determine precision, not accuracy. This is a very fundamental premise of QA/QC, and misunderstanding the difference between accuracy and precision, and the manner in which each is determined, is a serious shortcoming that is repeated throughout the DR. **This confusion has been addressed in the documents.**

1.3.1.2 Confusion Over Definitions	The definitions of "replicate" and "duplicate" in the QA/QC Protocol are wrong. The authors indicate that duplicate samples are "samples collected in the field" while replicate samples are "aliquots … analyzed in the laboratory". Again, this indicates a serious misunderstanding of basic QA/QC principles. As is made clear in definitive texts such as "Standard Methods for the Examination of Water and Wastewater", 20th Edition (1998) and L.H. Keith's "Environmental Sampling and Analysis" (1991), a replicate is a repeated operation occurring within an analytical operation and a duplicate is the smallest number of replicates that can be performed. In everyday application this means that one may have duplicates and/or replicates for samples (i.e., two or more samples taken at the exact same location and time) as well as for analyses (i.e., two or more measurements made on the same sample). The Report differentiates between replicates and duplicates improperly, and defines them incorrectly. **Clarification: the definitions of replicate and duplicate are understood. However, in the context of this ERA, these terms are merely two codes that refer to two different procedures, regardless of how they are defined elsewhere. The term "replicate" has been assigned by PSC when two or more portions of the same sample are taken, prepared, and analyzed by PSC. The term "duplicate" was assigned by Jacques Whitford and Stantec to designate the second of two physically different samples collected in virtually the same location in the field. The protocol has been updated to make this more clear (Vol. II, tab 3).**
1.3.2 QA/QC, Duplicates and Replicates	The DR provides detailed instructions on reagents, apparatus, sample preparation and other steps on the road to analysis, for a number of different sample types, ranging from tadpoles to wood cores. QA/QC is commented upon in most of these individual protocols. For example, in 3.1 "Composite Tadpole Samples", under "Sample Preparation" the fourth step is "A sub-sample of the homogenous mixture was set aside for moisture determination and, if possible, a separate sub-sample for QA/QC (duplicate analysis)". The same wording is used in 3.2.5 for "Composite Tadpole GI Tract Sample" (p. 7). Duplicate analysis is not the same thing as QA/QC, so the phrase "QA/QC (duplicate analysis)" is inexact and not rigorous, but at least it indicates that every sample of tadpole and tadpole GI tract composites has a sub-sample for duplicate testing. **The latter two statements have been clarified, and step four now reads "A sub-sample of the mixture was set**

	aside for moisture determination and, if enough sample was available, a separate sub-sample for replicate analysis" (Vol. II, tab 2). This is not the case for other, similar samples according to the protocols. For individual Frog Carcass Samples (Section 3.3), only 25% of the samples have a replicate subsample, and here there are three subsamples. Why? What criteria were used to develop different approaches to measure variability for these samples? **This point was discussed on 6 February, 2003 at Stantec and has been addressed in the protocol (Vol. II, tab 2) .** For "Frog Liver and GI Tract Samples", there is no mention whatsoever of duplicate samples or replicate samples. These inconsistencies in the very limited QA/QC described (i.e., duplicate testing or replicate testing or neither) is found throughout the remaining individual protocols, and is not acceptable in a collection of analytical protocols. If there are differences in the procedures to measure precision or variability, the rationale should be clearly stated. **A statement has been added to explain that replicate analysis was not performed due to small sample size (Vol. II, tab 2).**
1.3.3 Duplicates, Replicates and Variability	
1.3.3.1 Confusion As To What Is Measured By Analyzing Replicates	Throughout the DR, the individual protocols show a lack of understanding of what is measured by performing duplicate or replicate analyses. For example, on p. 10 under 3.3.8 Sample Digestion, the protocol states: "This procedure was done in triplicate on 25% of homogenate frog samples, to provide a measure of homogenate variability". In fact, the procedure measures total analytical variability, and there will be no way of differentiating whether, or how much, the homogenate or the analytical procedure contributed to the overall variability. Again, the report is incorrect and indicates a misunderstanding of precisely what is being determined by performing replicate analyses. **The statement now reads: "This procedure was done in triplicate on 25% of homogenate frog samples, to provide a measure of homogenate and analytical variability" (Vol. II, tab 2).**

1.3.3.2 Confusion As To What Is Measured	A similar error appears on p. 14, where the protocol states "Homogenate was separated into a maximum of five sub-samples (three replicate samples for 25% of the voles to provide a measure of variability due to the homogenization process, …". Clearly this protocol will only allow the measurement of all contributions to variability, whether from homogenization, storage, contamination from containers, reagents, lab equipment and so on, as well as that due to the analytical method itself. This misrepresentation or misunderstanding of what is being measured is repeated elsewhere throughout the ensuing protocols; the specific locations are marked in the attached annotated copy of the DR. **Wording has been changed to reflect that variability between a sample and its replicate can be an artifact of many factors including the ones mentioned above (Vol. II, tab 2).**
1.3.4 Arbitrary QA/QC Decisions	As noted above, the DR has an inconsistent approach to taking duplicate or replicate sub-samples (100% of samples having duplicates, 25% having triplicates, some having no replicates). **Decisions on the number of replicate analyses for different matrixes were decided upon prior to analysis with input from PSC and Stantec. Adequate justification has been provided in the protocol as to why different replication was necessary for different matrixes, making these decisions reasonable and not arbitrary (Vol. II, tab 2).** On page 23 (Section 3.8 Deer Samples) the DR states: "Homogenate was separated into sub-samples (one for analysis, one sample when necessary for 10% replicate analysis on all deer meat samples submitted, and one archive sample)". Accordingly, we now have a new approach (10% replicates) that is inconsistent with the previously inconsistent approach to replicates. Even more incomprehensible is the phrase "when necessary". How would the analyst know when, or if, it was necessary? How would the necessity be determined? How would it show up in the final lab certificate of analysis? Why is any of this necessary for deer meat, where paucity of samples is not likely to be an issue? **Wording has been altered to clarify statements referred to in the above paragraph (Vol. II, tab 2) .** Once again, while there may be a rationale for the inconsistent approaches to duplicate and replicate sampling in the DR, by not providing such a rationale the

	report will continue to appear inexact, uninstructed, and unrigorous.
1.4 Analytical Methods	It is recommended that since the analytical methods constitute a new section, the section currently numbered 3.17 should be a stand-alone new section, i.e., "4.0 Analytical Methods". **This has been corrected (Vol. II, tab 2).**
1.4.1 Summary	The summary of the analytical methods (p. 49) is poorly written and incomplete. There is no summary at all of how the results for the analytes are actually measured, or of how, or if, the equipment is calibrated. The existing summary contains considerable detailed but essentially useless information while not summarizing the basic operating principles of the method. In addition, the method referenced (U.S. EPA 6020) is not the method in the "References" (p. 52). The "References" section provides U.S. EPA 846 3010A, which was not used or otherwise referred to in the DR. **This section has been changed a second time despite previous comments from Stantec that insisted that more technical and detailed information be provided. Since Stantec now considers this information "useless", it has been removed. The current section adequately describes analytical methods and instrumentation for the purposes of this protocol. Future concerns can be addressed by viewing the referenced document. The reference in the References has been updated (Vol. II, tab 2).**
1.4.2 Detection Limit Criteria	The section "Method Detection Limit Criteria" does not deal with method detection limit criteria, and should be changed to reflect the topic actually dealt with. **Section now reads "Estimated Quantitation Limits" (Vol. II, tab 2).**

1.5 "Discussion"	
Section 4.1	indicates that for replicate analyses on a sample, the mean was reported, "providing QA/QC was met". It is not clear what the requirements would have to be for QA/QC to be met. The report does not indicate criteria or which data did not meet the requirement. **Clarification on this matter has been provided (Vol. II, tab 2).**
Section 4.2,	"Rejection of Data", says "it was anticipated that data variance would be reasonably low since all lab procedures in this protocol would ensure homogenous digests". This is a presumptuous and incorrect statement, since the procedures in the protocol might, at best, minimize variance (and some of the protocols would not likely even do that), but the procedures would not ensure homogenous "digests". Also "digests" should read "digestates". **The contents of this section are now discussed in the section "Replicate Analysis" (Vol. II, tab 2).**
1.5.1 QA/QC	Regarding Standard Reference Materials, the DR states "Agreement was within 30% of the range stated for the certified material". Is 30% acceptable? For all parameters measured? According to whom? (References should be provided, if the DR statement is correct.) **Yes, 30 % is the acceptable value for all parameters according to "Guidance Manual on Sampling, Analysis, and Data Management for Contaminated Sites, as noted in the QA/QC protocol. A difference of 30 % was also agreed to by Stantec early in the CBRA process (2000).**
	Also, the two SRM numbers in the text (SRM 1577a and SRM 1566) do not correspond to the SRM numbers in Appendix A "Standard Reference Material". **This has been corrected (Vol. II, tab 2,).**
	Finally, the discussion of SRMs, matrix and other spikes, and replicate analysis would be much more compelling if the Report simply provided a table which showed the actual number of SRMs, spikes, and duplicates that were run, and include the following: a) SRMs – the match of measured values to certified values, by parameters, as a percentage; b) Spikes - the number of matrix spikes and the number of samples for which there were not spikes, and those sample values considered "unsubstantiated"; - overall spike and matrix spike recovery by parameters, as a percentage; and c) Replicate Analysis - the number of replicate tests, the degree of agreement by parameter, and the number and identity of rejected values. It is realized

	that summaries of SRMs, duplicates and spikes are provided in Tables 1 through 78 of Volume V, but a combined overview of overall SRM, spike and replicate testing would help to indicate the precision and accuracy of the database. An example of such a summary, for SRMs, is provided in "3.0 Stantec Review of Quality Assurance and Quality Control for the Port Colborne CBRA" (Section 3.0 of this review), see Table 1 "SRM Comparison by Sample Type", and Table 2 "SRM Comparison by CoC". **Stantec has clearly stated in Section 5.7 of this review, that on the whole, data analyzed and presented in this ERA is of excellent quality. The additional summarizing mentioned in the above paragraph is not necessary.**
1.6 Reagent Quality	Throughout the DR, each protocol reiterates that all reagents had impurity levels less than the detection limits. No data is provided to substantiate this statement; data will be Required for the statement to be accepted. **PSC is accredited by CAEAL and SCC. As such, there is an expectation and belief that PSC are using the reagents and equipment that they say they are. Jacques Whitford does not believe that there is a need to provide data for the reagents used during sample preparation in the laboratory of PSC.**

2.0 Volume III of the ERA - Review of "Quality Assurance and Quality Control for Field Sampling and Laboratory Procedures", November 2002	
2.1 Status of Review	This document describes field and lab procedures to be applied to samples taken for the Port Colborne Community Based Risk Assessment (CBRA). This November 2002 draft incorporates most of the revisions provided by Beak International Incorporated (now "Stantec") following review of the original May 23, 2001 JWEL document. Accordingly, the definitions of various blanks, spiked blanks, and other QA/QC terms are generally acceptable. However, enough technical and grammatical errors remained to warrant a further review of the current draft in January 2003, an edited copy of which was left with JWEL following a meeting between them and Stantec on February 6, 2003. It is assumed that the errors will be corrected based on the edits and suggestions provided at that time. **All comments and edits have been taken into consideration.**
2.2 Concerns and Shortcomings	
2.2.1 Lack of Editorial Control	The report appeared to not have been edited or otherwise checked for accuracy prior to release of the November 2002 draft. Numerous (several dozen) errors were noted, ranging from sloppy ("the mixture is sample is allowed to sit …") to comical ("Once received, PSC washed the samples …").
2.2.2 Technical Errors	The ongoing confusion between accuracy and precision remains as part of the QA/QC protocol. This is compounded by related misinformation such as the advice that SRMs provide "an added check on the variability related to an analytical procedure". Such incorrect advice in a QA/QC protocol is not acceptable; it is assumed that the final draft will address the technical and grammatical errors.

2.3 Laboratory Status	In order to ensure that the lab understood the intent of the protocols, and that the lab was adhering to the protocols, Stantec conducted several teleconferences and a meeting with lab technical and management staff. The lab indicated that they had actually written many of the protocols for individual sampling types. As a result of the meeting and discussions with lab staff, the Stantec reviewer is satisfied that the lab followed their normal internal QA/QC procedures as well as the protocols in this draft. **PSC outlined laboratory procedures and sample preparation for many of the matrix types analyzed. This information was requested from PSC and incorporated into the framework of the protocol to ensure that the "Laboratory Protocol for Analysis of Biological Tissues" depicted the procedures followed at PSC.**
3.0 Volume IV of the ERA- Review of QA/QC Aspects of Philip Analytical Services Data (PSC)	A review was made of the PSC (Philip Analytical Services Inc.) data set. This data indicates that the following QA/QC procedures were generally applied for metals and other testing, except for pH and specific conductance: replicate analysis – review of data shows acceptable agreement between replicates; lab process blanks – review indicates acceptable performance; spiked samples (for metals) – review of spike sample data indicates acceptable performance; and Standard Reference Material (SRM) – SRM data indicates acceptable analytical performance for applicable metals and other parameters.
3.1 Conclusions	The lab is certified and accredited by CAEAL and SCC. The QA/QC on the soil testing is adequate and it indicates that the lab data is likely of good quality.
4.0 Volume IV of the ERA – Review of QA/QC Aspects of the "Bioaccessibility" Report	
4.1 Overview	Included in Appendix 4 is a report on Bioacessibility of Copper, Nickel, Cobalt and Arsenic in soils NE of Inco Refinery, Port Colborne. It does not appear to be referenced in other reports of the ERA and would more properly be regarded as an issue for the Human Health Risk Assessment (HHRA). Regardless of the placement of the report, the laboratory that conducted the audited work is not certified by SCC or CEAC for such testing. The use of an unaccredited lab for Port Colborne CBRA soil testing is a serious shortcoming. **The laboratory conducting the test <u>is</u> accredited by CAEAL. The appendix has been moved to the Human Health Risk Assessment report.**

4.2 Method Review	
Section 2.1	Soils were dried at 70°C for 48 hours. This is not consistent with the drying method used elsewhere in the ERA, which indicate that the PSC (Philip Analytical Services Inc.) dried soils at 30-35°C overnight. Soils were sieved to obtain <250 µm fractions. It may be possible that this approach could bias the sample by removing a portion that could be ingested by a receptor. **The soils were dried more aggressively. The end result is the same, namely dry soils. The <250 µm fraction is an appropriate standard for use in bioavailability and bioaccessibility testing.**
Section 2.2	Only four metals are considered: nickel, cobalt, copper and arsenic. The samples were analyzed by ICP-AES, which could have provided useful data for at least a dozen other metals. Were other metals (especially lead) actually determined but not reported? Is this data going to be provided to the partner of the CBRA? **No. The full report is provided.**
4.3 "QA/QC"	The results of replicate testing in the "Bioaccessibility Report" indicates serious imprecision for each of the metals tested (all results in mg/L): **Organic 1A Duplicate Difference As 0.08 0.25 3-fold Organic 1B Duplicate Difference Cu 0.87 0.68 28% Organic 2A Duplicate Difference Co 0.59 0.99 68% Ni 39.9 76.7 92%** While the replicate analysis of "Fill" appears to provide acceptable results, it matters little since replicate testing of actual Port Colborne soils indicates unacceptable precision. **Although duplicate soil samples were used, different amounts were used and the extract would be expected to be different as seen here. The reviewer' denotation of the samples as duplicates is incorrect. When the analysis is performed on an appropriate mass basis rather than the inappropriate concentration basis used by the reviewer, the results can be seen to be within acceptable margins.**

4.4 Conclusions	The lab appears to be inexperienced in the analysis of total and glycine-extracted metals. This is acknowledged by the lab with its statement "As this technique is still in the early stages of development, the results should be interpreted cautiously". The lack of acceptable replicate analytical performance on Port Colborne soils, and the lack of accreditation for the lab would indicate that this data is not acceptable for environmental or human health risk assessment. **The laboratory's statement is considered appropriate and demonstrates their understanding and appreciation of the limitations of the technique. As stated previously, the laboratory is accredited by CAEAL.**
5.0 Volume V of the ERA - Review of Quality Assurance and Quality Control for the Port Colborne CBRA	
5.1 Introduction	This review is specifically for the analytical data report on biomaterials in Volume V "Ecological Risk Assessment, Natural Environment, Community Based Risk Assessment, Port Colborne, Ontario", November 2002, prepared by Jacques Whitford Environmental Limited (JWEL), entitled "Laboratory and Analytical Data and Quality Assurance/Quality Control". This review follows a detailed review of the "Laboratory Protocol for Analysis of Biological Tissues", Volume II "Field Data Collection and Analysis Protocols", which constituted pages 1-53 of Volume II of the ERA Report. The comments from this review, and of "Quality Assurance and Quality Control for Field Sampling and Laboratory Procedures" (see 1.0, this report), were provided to JWEL at a meeting on February 6, 2003 (Attachments A and B). The lab protocols describe how the samples were prepared and analyzed in the lab; the lab data provides the analytical results themselves. This review covers the QA/QC related to these analytical results, reported in Volume V.

5.2 Scope of QA/QC Data Review	The review was carried out by examining the actual analytical data and comparing the QA/QC data to the appropriate parts of the protocols and procedures mentioned in 1.0 “Introduction”. Much of the QA/QC data was understandable and rationalized by this preliminary review; specific points of confusion were clarified by telephone calls with JWEL and the lab, PSC (Philip Analytical Services Inc.). The Stantec review team met with JWEL on February 6, 2003 to discuss questions and concerns, and with PSC (Philip Analytical Services Inc.) on February 25, 2003 to obtain information regarding some remaining technical concerns. The conclusion reached after the above activities were carried out was that there was a good understanding and adequate information to complete the review of the QA/QC data for the ERA.
5.3 QA/QC Indicators	The usual indicators of laboratory QA/QC on a specific project are those discussed in the JWEL report “Laboratory Protocol for Analysis of Biological Tissues”, November 2002: - Standard Reference Materials (SRM) - Matrix Spikes - Spikes - Replicate Testing. In addition, a proficient lab will routinely carry out the QA/QC procedures outlined in MOE’s 1996 guideline “MOE Guidance on Sampling and Analytical Methods for Use at Contaminated Sites in Ontario”, as follows: Pre-run QC: - labware and reagent blanks; - instrument setup standard; - reference standard to validate in-house standards; and - instrument detection limits (IDLs) and detector linearity curves (minimum of 5- point calibration). In-run QC: - baseline drift blanks; - standards; and - instrument checks. Run QC - method recovery blanks; - method blanks; - in-house matrix check materials; - duplicates (minimum of one set per run of 30 samples). As mentioned in the MOE (1996) guidance document, a duplicate sample is defined as a second aliquot from the same sample container; - surrogates (added prior to organic extraction); - spiked samples, if applicable; - certified standard reference materials (SRMs) to validate method recovery; and - Method Detection Limits (MDLs) for each parameter. With respect to the procedures in the MOE guidance document, PAS routinely carry out all of the requirements as part of their ongoing internal QA/QC program, and they have the records to demonstrate this. Senior Stantec staff reviewed much of this information with senior PAS staff, and are satisfied that the lab is adhering to the MOE requirements as a minimum standard of performance; they also perform numerous other QA/QC tests to maintain their accreditation with agencies such as CAEAL, State of New York, and other U.S. and Canadian organizations. The only aspects of the MOE guidance that were not routinely carried out were as follows: - 5-point calibration

	for ICP-Es detector linearity curves, because the ICP-Es technique is linear over a very large analytical range and does not require 5- point calibration; and - surrogates were not analyzed because they are only required for organic testing, and as all of the ERA testing was for inorganics, surrogate testing was not applicable. The next three sections deal with the lab's performance on the Port Colborne ERA testing: - SRMs - Matrix Spikes - Spikes - Replicate Testing.
5.4 Standard Reference Materials (SRMs)	SRMs are materials analyzed by a lab in conjunction with actual samples, in order to estimate analytical bias. These are homogenous materials whose composition is certified by a central agency, after the material has been analyzed by a large number of laboratories using a number of different analytical techniques. In the case of the ERA, the lab (PAS) analyzed two SRMs whose make-up was similar to that of the subject samples. The two SRMs were bovine liver and oyster tissue, each of which is certified by the National Institute of Standards and Technology (NIST) to contain specific, published levels of 18 or more parameters including many metals of interest in the ERA study. PAS performs SRM testing on all of its tissue testing samples, including and in addition to those reported in Volume V. The lab uses the data to maintain Control Charts for overall laboratory QA/QC monitoring. A review of their Control Charts for nickel, copper and lead indicated that the lab is performing consistent, accurate data on these samples. With respect to the Port Colborne ERA testing, JWEL arranged for SRM testing in addition to that described above, for virtually every sample submission of tissue samples. The lab data compared to the SRM values were typically within 90% of the certified value, for nickel, arsenic, cobalt, copper, and lead, as well as for numerous other metals. In many cases the lab data is in 98% or better agreement with the certified values. The following tables show the % agreement between the lab's analytical values and the NIST certified values for various metals. Table 1 at the end of this report summarizes the SRM tables for CoCs at the front of Volume V of JWEL's ERA report, and because these tables did not include lead, Table 2 (also at the end of this report) was prepared by Stantec to show the percent agreement for lead as well as other CoCs. These tables are appended at the end of this document.

5.4.1 SRM Data Gaps	As noted above, the focus of this review was on QA/QC related to the analysis of biomaterials collected as part of the Port Colborne ERA. However, the QA/QC associated with analysis of related materials such as soil and/or water from certain areas where biological material had been taken, was also reviewed. The review determined the following: 1) SRMs appear not to have been analyzed for soil and water samples. On the other hand, soil samples often had "certified" samples and "spikes" for QA/QC, and water samples were accompanied by spiked travel blanks, and the reported values for Ni, Co, Cu and Pb were within an acceptable range of the prepared spike values. 2)Vegetation samples appear to have scant SRM analyses. For several types of vegetation samples, no SRMs were analyzed, even though acceptable SRMs exist for such purposes. The Port Colborne ERA sample types for which no SRMs appear to have been determined were: - corn kernels - maple keys - leaves - tree cores Several other groups of biomaterials had no SRMs for QA/QC purposes, including maple sap, maple syrup, spinach, leaves, grasshoppers and spiders. Worms had one set of SRMs; at least one set per batch submission would ideally have been reported, which would have resulted in at least three sets of SRMs.
5.5 Spikes and Matrix Spikes	PSC (Philip Analytical Services Inc.) performed spikes and matrix spikes with every ERA sample set. Matrix spikes involve the addition of a known concentration of an analyte to a sample, so that subsequent analysis for the analyte will indicate bias related to sample preparation and analysis. A spiked sample involves the addition of a known amount of an analyte to a digested, prepared sample. Subsequent analysis of the "spiked" sample indicates bias due to the analytical procedure. Typically, analysis of spiked samples and of matrix spikes helps the analyst determine whether the sample itself, or the chemicals used to prepare it, either enhances, suppresses or otherwise interferes with the measurement of the analyte. Review of the PAS "Certificate of Quality Control" shows that analysis of matrix and process spike samples yielded acceptable results for every parameter, including the chemicals of concern. The Certificates of Quality Control are located in Tabs 2-24 of Volume V, "Laboratory and Analytical Data and Quality Assurance and Quality Control", November 2002.

5.6 Replicate Analyses	Replicate analysis of a sample means that two or more portions of the same sample are taken, prepared, and analyzed. Comparison of the results provides an estimate of the precision, or variability, of the measurements. In much environmental work, the acceptable limit of variability for biomaterials is ±50%. For soil testing the limits are often higher than ±50%. In the case of the Port Colborne ERA study, the acceptable limit was tighter at ±30%. The ERA report, Volume V, "Laboratory and Analytical Data and Quality Assurance and Quality Control", November 2002, provides a thorough listing of all replicate testing in Tables 1 through 47, pages 1 to 19. The data shows the following: Arsenic levels are too low to be assessed. Most data is "not detectable", which indicates it is either absent or if present is below the detection limit of the analytical equipment. For all tissue types with the exception of one earthworm duplicate test, the copper and cobalt values are well within the 30% limit, and many are within 5%. For nickel, there are three examples of the variability being higher than 30%, in the analysis of frog samples. These higher variabilities were likely caused by the presence of skin and bone matter, which made complete homogenization of samples a difficult, if not impossible task. For all other tissues (voles, vole liver, insects, frog liver, etc.) the Ni variability was under the 30% limit and was often within 5%.
5.7 Conclusions	The QA/QC for the lab analysis of the Port Colborne ERA samples is among the most extensive of any environmental analyses we have reviewed, and it is also of superior quality compared to most environmental testing. In the ERA sample analyses, more QA/QC testing was performed than is usually the case, and the results of the testing indicated that the database is generally precise and accurate. Some specific conclusions: The ERA database had significant QA/QC applied to it. The QA/QC data generally demonstrates good agreement between replicate samples, little evidence of matrix interference, and acceptable recovery of matrix spikes. Analysis of SRMs for the metals of concern shows that agreement between certified values and observed values is good to excellent. SRMs do not exist for some sample types, and for these as well as for certain other samples, no SRMs were analyzed. The laboratory further confirmed that the ERA project followed established laboratory sample preparation and analytical protocols. The laboratory stated that the ERA project was distinguishable from virtually all other analytical projects because of its large QA/QC component. Given the above, it is this reviewer's opinion that the QA/QC for the Port Colborne ERA is extensive and that the QA/QC data demonstrates

	that the ERA data set is of good quality. This means that the data on which the ERA will be based is of good quality. It must be cautioned that this does not automatically mean that the assessment of the data or the conclusions reached in the ERA are acceptable; other reviews by Stantec will comment on these assessments and conclusions.