PORT COLBORNE CBRA – ECOLOGICAL RISK ASSESSMENT

CROP STUDIES

VOLUME I – MAIN REPORT
(BINDER 1 OF 3)

PROJECT NO. ONT34663

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DECEMBER, 2004

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This document presents results and findings of the Ecological Risk Assessment for the Crop Studies, a component of the Community Based Risk Assessment (CBRA) conducted in the City of Port Colborne. This report should be interpreted within the overall context, goals and scope of the CBRA conducted by Jacques Whitford Limited.

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FOREWORD

This report presents the Ecological Risk Assessment for the Crop Studies prepared by Jacques Whitford Limited for the Community Based Risk Assessment (CBRA), Port Colborne, Ontario. Following three years of field investigations and analyses of data (2000-2003), an initial draft of the report was completed in April 2003, followed by a revised draft in July 2003. Drafts were submitted to the CBRA's Public Liaison Committee (PLC) Technical Sub-Committee (TSC), Regional Niagara Public Health Unit and the Public for review and comment. In addition, the revised draft report received independent peer review from Dr. Murray McBride, Cornell University. The report presented under this cover has taken into account the comments provided by this review process of the two draft reports and, where required, comments have been addressed within this text. Specific responses to each of the peer reviewer comments are included in Volume V.

Major changes to the draft reports which are included in this final report are the reporting of phytotoxicity limits for nickel below EC_{25}, i.e. at PNEC levels. Also included are EC_{25} values for other CoCs, in particular copper, cobalt and arsenic. A section dealing with the uncertainty analyses and sensitivity analyses of the Greenhouse-derived EC_{25} values has been included. This report has been prepared for submission to the PLC and Ontario Ministry of the Environment (MOE) 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.

ACKNOWLEDGEMENT

Jacques Whitford would like to first express sincere thanks to our primary scientific advisors from the University of Guelph, Dr. Beverley Hale and Dr. Les Evans. Their expert guidance was instrumental to the ultimate success of the Crops Studies and their efforts are gratefully acknowledged.

In addition, we would like to thank Dr. Rufus Chaney, USDA, for the benefit of his experience in carrying out Crop Studies in Port Colborne and for his advice in the undertaking of our work. Appreciation is also extended to our external reviewers, in particular Dr. Murray McBride, for insightful criticism that helped to improve the interpretation of experimental results. Jacques Whitford would also like to thank both Niagara College and the University of Guelph for the use of their greenhouse facilities and knowledgeable staff.

Most importantly, we would like to thank the people of Port Colborne for participating in this process, for answering our questions and asking their own, and for providing access to the property and soils necessary in carrying out our experiments.

EXECUTIVE SUMMARY

Inco Limited (Inco) has committed itself to the community of Port Colborne (represented by the Public Liaison Committee, PLC), the City of Port Colborne (The City) and the Ontario Ministry of the Environment (MOE), to conduct a Community Based Risk Assessment (CBRA). The CBRA was conducted in the Port Colborne area for chemicals of concern (CoCs) that are elevated in soil as a result of historical emissions from Inco's refinery. The Crop Studies, which are the focus of this report, are one component of the CBRA process.

The list of CoCs comprised of arsenic, cobalt, copper and nickel. Of these elements, nickel was targeted as the primary toxicant because of its much higher soil concentrations relative to its published soil toxicity threshold (MOE, 1996).

Crop studies carried out in 2000 and 2001 consisted of several components including Field and Greenhouse Trials, as well as a Biomonitoring Study of sentinel species (goldenrod – *Solidago sp. L.)* occurring naturally in the Port Colborne area. These complementary studies were specifically designed to determine how CoCs affect crop plants growing on impacted soils, to establish acceptable levels of soil and tissue CoC concentrations that do not cause significant phytotoxic effects, and to assess the potential benefit of certain remediation strategies. The Greenhouse trials provided the primary means of establishing phytotoxicity thresholds based on plant response to elevated concentrations of CoCs in soils and also the utility of soil amendments similar to those recommended for routine farming by the Ontario Ministry of Agriculture and Food (OMAF). In contrast, the Field Trials focused on the growth of several crop species on a variety of soil types with varying concentrations of CoCs primarily to provide perspective for the Greenhouse Trials. This was also the rationale behind the Biomonitoring Study, which provided a means to compare the relationship between soil CoC concentrations and plant tissue CoC concentrations under field and greenhouse conditions.

Dose-response relationships were established in the greenhouse experiments for crop plants exposed to varying concentrations of CoCs in soil. Data generated from the 2000 Greenhouse Trials proved unsuitable for derivation of phytotoxicity thresholds due to confounding soil variables, analytical difficulties and (in some cases) an inappropriate range in soil CoC test concentrations. Improvements were made for the 2001 Greenhouse Trials by using soil blends of the four soil types (Organic, Sand, Welland clay and Till clay) occurring in the Port Colborne area. Focus was placed on the calculation of EC_{25} values based upon soil and tissue Ni levels because of the highly correlated nature of CoC concentrations in contaminated soils. These values differed among soil types tested (Sand = 1350 mg Ni/kg; Organic > 2400 mg Ni/kg (3490 mg Ni/kg from meta-analysis); Welland Clay = 1880 mg Ni/kg; Till Clay = 1950 mg

Ni/kg), but all greatly exceeded the MOE's generic guideline of 200 mg/kg (now embodied as a regulated level in Regulation 153/04) for clean up of soils impacted with nickel.

The EC_{25} threshold representing a 25% reduction in biomass yield, was chosen specifically as a benchmark likely to be significantly different from background. The EC_{25} is used by most regulatory agencies, including the MOE, in deriving their soil generic guidelines and standards. For the purpose of comparison to the above stated EC_{25} values, calculation of an alternative threshold, the PNEC (predicted no-effects concentration - the highest dose for which there was no statistically significant decrease in biomass yield), was undertaken for soil Ni and was determined to be 750 mg Ni/kg for Sand, 2350 mg Ni/kg for Organic, 1400 mg Ni/kg Till Clay and 1650 mg Ni/kg Welland Clay.

Of the two amendments tested in the 2001 Greenhouse Trial, mushroom compost and limestone at levels recommended by OMAFRA, only limestone showed promise as a mitigative measure against toxicity in Till Clay. Limestone amendments applied to the other soil types did not have an obvious effect.

The experimental designs of the 2000 and 2001 Field Trials did not allow for direct conclusions to be drawn on soil CoC phytotoxicity thresholds. However results from these experiments were generally supportive of results from the Greenhouse Trials as plants were successfully grown in soils greatly exceeding the MOE generic soil criterion for Ni. The field crop trials also clearly showed that increasing soil pH with the addition of soil amendments most often resulted in a significant reduction in tissue Ni and Cu concentrations with all crop species. However, the effect was not uniform, nor was it beneficial at all liming levels tested for all crop species.

Results from the Biomonitoring Study showed a remarkable similarity in the relationship between plant tissue concentrations of CoCs and exposure to soil CoCs between native species growing in the field and a crop species grown in the greenhouse. Because the nature of this relationship was unchanged from field to greenhouse despite obvious differences in plant species and growth conditions, strong support is provided for the legitimacy of the toxicity thresholds as calculated.

CROP STUDIES

GENERAL TABLE OF CONTENTS

VOLUME I – MAIN REPORT

VOLUME I - APPENDICES

OTHER VOLUMES

Information to Reader: *Three binders make up this Report. Binder 1 includes the Main Report – Volume 1. Binder 2 includes the Appendices to the Main Report – Volume 1. Binder 3 includes Volumes II, III, IV, V and VI.*

GLOSSARY OF TERMS

1X – A designation for Greenhouse Trials pot tests and Field Trials containing amendments at approximately the level that would be recommended by OMAFRA for agricultural soils of the types under consideration.

2X – A designation for Year 2000 Greenhouse Trials pot tests containing amendments at approximately twice the level that would be recommended by OMAFRA for agricultural soils of the types under consideration.

Amending Agent – A material used in agriculture to amend soil. In the case of the Phytotoxicity Testing, most of the amendments used were agents which increase pH, consisting of a mixture of calcium and magnesium carbonates; in one case, organic compounds were used.

As – Symbol for the metalloid arsenic.

Beak – Beak International Inc., the PLC's consultant for the CBRA from 2000 to 2002. Beak International was purchased by Stantec in 2002. Stantec acted as the PLC's consultant till September 2004. Since September 2004, Watters Environmental Group Inc. has acted as the PLC's consultant.

Bioavailability – The fraction of a total chemical that can interact with a biological target (e.g., a plant or animal).

Biomass Yield – The total amount of aboveground plant tissue of a crop harvested. Not to be confused with the yield of marketable products (seeds, cobs, fruit) normally associated with the yield of marketable produce.

Biomonitoring Study – The testing involving wild plants found in the Port Colborne area carried out as part of the Phytotoxicity Testing during the summer and autumn of Year 2001. Information about the Biomonitoring Study is presented in Volume V.

C – A designation for Control soils.

C3, C4 – Designations for methods of carbon fixation in plants.

Calcareous – A term that describes soil containing sufficient reactive carbonate such that when one adds cold 3N HCl, a "fizz" of released CO_2 is observed. In this report, calcareous refers to soil amended with a quantity of lime intended to raise pH to 7.6 or higher. It must be noted that this pH target level was approached but never achieved due to the buffering characteristics of the soils used.

CBRA – Community Based Risk Assessment for the Port Colborne area.

CCME – Canadian Council of Ministers of the Environment.

City – The City of Port Colborne.

Clay Till Soil – A shallow clay soil collected for the Greenhouse Trials representative of soils in the Port Colborne area, mapped primarily as the Farmington or Alluvial series or commonly identified locally as a "light clay loam" soil. The origin of this soil is from glacial till.

Co – Symbol for the metal element cobalt.

CO_2 – Carbon dioxide.

CoCs – Chemicals of concern, identified for the CBRA, including nickel, copper, and cobalt during the Year 2000 Greenhouse Trials and nickel, copper, cobalt and arsenic during the Year 2001 Greenhouse Trials.

Control soil – A soil collected at a location remote from and upwind of the Refinery in an area not expected to have had any historical emissions of CoCs from the Refinery. Control soils show only background levels of CoCs and are designated C.

Cu – Symbol for the metal element copper.

Dicots – Plants that have two cotyledons (leaf structures) per seed.

Dose-response testing – A method of determining the impact of CoCs on the growth of plants.

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, Effective Concentration – A point on a regression-generated dose-response plot above the threshold toxicity concentration.

EC_{25} – The effective dose concentration at which there is a 25% reduction in response (*e.g.* growth). In this report, the EC25 refers to tissue or total soil CoC concentration in mg CoC/kg at which vegetative biomass growth is reduced by 25%. .

ERA – Ecological Risk Assessment, as defined in the TSOW.

Field Trials – The testing carried out during the summers and autumns of Year 2000 and Year 2001 at field test locations in the vicinity of the Refinery in the Port Colborne area.

GPS – Global Positioning System. Refers to a method for accurately determining locations on the surface of the earth using electronic triangulation using satellites.

Greenhouse Trials – The testing carried out during the summers and autumns of Year 2000 and Year 2001 under greenhouse settings at Niagara College (Year 2000) and the University of Guelph (Year 2001). Information about the Greenhouse Trails is presented in Volume III.

H – High. A designation for test soils used with the Year 2000 Greenhouse Trials targeted to contain high levels of CoCs (1,250 – 3,500 mg Ni/kg).

HCl – Hydrochloric acid.

Heavy Clay Soil – A clay soil collected for the Greenhouse Trials or grown on in the Field Trials representative of soils in the Port Colborne area, mapped primarily as the Welland series or commonly identified locally as a "heavy clay" soil. The origin of this soil is glacio-lacustrine.

HHRA – Human Health Risk Assessment, as defined in the TSOW.

ICP – Inductively Coupled Plasma Atomic Emission Spectrometry. An analytical technique used for the detection of trace elements in environmental samples.

Inco – Inco Limited, CBRA proponent.

Jacques Whitford – Jacques Whitford Limited, consultant to Inco.

L – Low; A designation for test soils used with the Year 2000 Greenhouse Trials targeted to contain low total concentrations of CoCs (~200 - 500 mg Ni/kg).

Liming agent – An amending agent such as limestone (calcium carbonate), dolomitic limestone (a mixture of calcium and magnesium carbonates), slaked lime, or some other similar calcium–based material used in agriculture to increase soil pH.

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.

LOESS – Locally weighted polynomial regression. This is a method of showing trends in the data (Y-variable) as one moves across the range of the explanatory variable (X-variable). A least squares regression line is fit for each point using a subset of the data that surrounds it, giving more weight to data points near the point in question; hence, “locally weighted”. This method is used to show general trends in data within the Biomonitoring Study Report (Volume I, Part 5).

M – Medium; A designation for test soils used with the Year 2000 Greenhouse Trials targeted to contain medium total concentrations of CoCs medium (500 – 1,250 mg Ni/kg).

Meta-analysis – The statistical analysis of a large collection of analytical results from individual studies for the purpose of integrating the findings.

MOE – The Ontario Ministry of the Environment.

Ni – Symbol for the metal element nickel.

OMAFRA – The Ontario Ministry of Agriculture, Food and Rural Affairs. Also referred to as OMAF.

Organic Soil – An organic soil collected for the Greenhouse Trials representative of soils in the Port Colborne area, mapped primarily as the Quarry series or commonly identified locally as “muck” or organic soil.

Phytoavailability – Bioavailability of an element or chemical compound to plants.

Phytoremediation – That form of bioremediation where the inactivation, transformation, degradation and/or removal of contaminants from a medium (e.g., a soil) is caused, mediated and/or assisted by plants.

Phytostabilization – A form of phytoremediation involving the conversion to less toxic forms and/or the decrease in bioavailability of metal in soils, thereby inhibiting/preventing their take up by groundwater or plants and/or their entry into food chains.

Phytotoxicity – Toxicity towards plants.

PLC – The Public Liaison Committee of the City of Port Colborne CBRA.

PNEC – The predicted no-effects concentration is the highest dose at which there is no statistically significant difference in response from that observed at zero dose. In this report, the PNEC is the highest soil CoC measured in mg CoC/kg at which plant vegetative growth is not different from that observed in background soil.

Port Colborne area – The City of Port Colborne and the rural regions around it 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).

Precision – The degree of variability of an obtained result determined by repeated analyses of the same sample through all of the steps from sample preparation to the final obtained result.

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.

Purpuresence – The exhibiting of a purple-colored border on the leaves of plants or purple coloring on other parts, possibly due to phosphorus deficiency.

Refinery – The Inco facility at Port Colborne, Ontario.

Sand – A sand soil collected for the Greenhouse Trials or used in the Field Trials representative of soils in the Port Colborne area mapped primarily as the undifferentiated beach-scarp complex or commonly identified locally as "sand" or sandy soil.

SEM – Scanning Electron Microscopy.

Sequential extraction – An analytical procedure by which soil samples are extracted with a series of progressively more aggressive extractants to estimate the distribution and association of CoCs among different mineral and organic fractions within the soil.

Sequential test – A group of greenhouse tests that are carried out at two or more soil CoC concentrations. In the case of the Year 2000 Greenhouse Trials, the sequence used was C, L, M, H, and sometimes V. In the case of the Year 2001 Greenhouse Trials, the sequence used was the target soil CoC concentrations for the Blends: C, 500 mg Ni/kg, 750 mg Ni/kg, 1000 mg Ni/kg, 2000 mg Ni/kg, 3000 mg Ni/kg and sometimes V.

Soils Studies – Soil testing involving soils and sites for soils in the Port Colborne area carried out as part of the Phytotoxicity Testing during the summers and autumns of Year 2000 and Year 2001. Information about the Soils Studies is presented in Volume II.

SSRA – Site Specific Risk Assessment.

Stantec – Stantec Consulting, the PLC's consultant for the CBRA from 2002 to September 2004.

TC, Threshold Toxicity Concentration – The point on a dose-response plot where the continuous line at a unit response (e.g., relative yield) intersects with the regression-generated curve for effective concentrations where phytotoxicity impacts are occurring.

TSOW – Technical Scope of Work, as referenced in Section 7 of this document.

U – A designation for Year 2000 and Year 2001 Greenhouse Trials for pot tests involving unamended soils.

V – Very High. A designation for most contaminated soils in Year 2000 Greenhouse Trials targeted to contain very high total concentrations of CoCs (> 3,500 mg Ni/kg). Also the designation for the Highly-Contaminated soils for the Year 2001 Greenhouse Trials.

VEC – Valued Ecological Component, a species, population or process identified for conducting Risk Assessment.