



NOVA SCOTIA LANDS INC.

# Human Health and Ecological Risk Assessment Problem Formulation (Final)

Lake Enon Former Mill Site, Enon, Nova Scotia  
PID Nos. 15551369, 15340045, and 15340052





May 11, 2023

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*Human Health and Ecological Risk Assessment Problem Formulation (Final)  
Lake Enon Former Mill Site, 2412 Loch Lomond Road  
Parcel Identification Designation Numbers (PID Nos.): 15551369, 15340045, and  
15340052*

Dillon Consulting Limited (Dillon) is pleased to provide the final report for the Human Health and Ecological Risk Assessment (HHERA) Problem Formulation of the Lake Enon Former Mill property located at 2412 Loch Lomond Road in Enon, Nova Scotia, and identified by PID Nos. 155136, 15340045, and 15340052.

Should you have any questions, please do not hesitate to contact us.

Sincerely,

DILLON CONSULTING LIMITED

A handwritten signature in blue ink, appearing to read "N. Wambolt".

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Our file: 22-3723

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# Table of Contents

## Acronyms, Abbreviations, Definitions

## Executive Summary

<b>1.0</b>	<b>Introduction</b>	<b>1</b>
1.1	Structure of the Report.....	1
1.2	Objectives and Scope.....	2
<b>2.0</b>	<b>Background and Site Characterization</b>	<b>4</b>
2.1	Physical Setting.....	5
2.1.1	Water Supply/Groundwater Usage.....	5
2.1.2	Regional Geology and Topography.....	5
2.1.3	Stratigraphy.....	6
2.1.4	Climate.....	6
2.2	Land Use Considerations.....	6
2.3	Previous Investigations.....	7
2.4	Data Availability and QA/QC.....	10
2.4.1	Background Data.....	10
2.4.2	Site Data.....	10
2.4.3	Lead Bioaccessibility Data.....	11
<b>3.0</b>	<b>Human Health Risk Assessment Framework</b>	<b>12</b>
3.1	Problem Formulation.....	14
3.1.1	Site Characterization.....	15
3.1.2	Selection and Characterization of Receptors.....	15
3.1.3	Selection of Exposure Pathways and Scenarios.....	16
3.1.4	Identification of COPCs.....	17
3.1.5	Conceptual Site Model for Human Receptors.....	18
3.2	Exposure Assessment.....	18

Nova Scotia Lands Inc.

Human Health and Ecological Risk Assessment Problem Formulation (Final)

Lake Enon Former Mill Site, Enon, Nova Scotia

PID Nos. 15551369, 15340045, and 15340052

May 2023 - 22-3723



3.3	Toxicity (Hazard) Assessment .....	19
3.3.1	Toxicity Reference Values .....	19
3.4	Risk Characterization .....	20
<b>4.0</b>	<b>HHRA Problem Formulation Outcomes</b>	<b>22</b>
4.1	Site Characterization .....	22
4.2	Selection and Characterization of Receptors.....	22
4.3	Selection of Exposure Pathways and Scenarios .....	24
4.4	Identification of COPCs .....	25
4.4.1	Determining Usability of Soil Data .....	26
4.4.2	Comparison of Site Soil Data to Regulatory Human Health-Based Benchmarks .....	26
4.4.3	Results of the Human Health-Based COPC Screening of Site Soil.....	28
4.5	Conceptual Site Model.....	33
<b>5.0</b>	<b>Ecological Risk Assessment Framework</b>	<b>35</b>
5.1	ERA Goals, Approach, and Scope .....	35
5.2	ERA Steps .....	35
5.2.1	Problem Formulation .....	37
5.2.2	Exposure Assessment.....	42
5.2.3	Effects Assessment.....	42
5.2.4	Risk Characterization .....	43
<b>6.0</b>	<b>ERA Problem Formulation Outcomes</b>	<b>44</b>
6.1	Site Habitat Characterization .....	44
6.2	Regulatory Context .....	44
6.3	Selection of Site Boundaries and Reference Areas .....	45
6.4	Species at Risk (SAR) Assessment .....	45
6.5	Identification of Receptors of Concern .....	46
6.5.1	Further Considerations Regarding Potential ROCs .....	54
6.5.2	Summary of ROC Selection .....	57
6.6	Selection of Assessment and Measurement Endpoints and Lines of Evidence.....	58

6.7	Exposure Pathway Identification .....	62
6.7.1	Terrestrial Vegetation and Soil Invertebrates.....	63
6.7.2	Birds and Mammals .....	63
6.8	Identification of COPCs .....	65
6.8.1	Determining Usability of Data.....	67
6.8.2	Comparison of Site Data to Regulatory Ecological Health-Based Benchmarks .....	67
6.8.3	Soil Quality Guidelines .....	67
6.8.4	Conservativeness of Ecological Soil Quality Benchmarks .....	69
6.8.5	Results of Ecological Health-Based Soil Screening.....	69
6.8.6	Final COPCs for the ERA Problem Formulation.....	75
6.9	Conceptual Site Model for Ecological Receptors .....	75
<b>7.0</b>	<b>Summary of HHERA Problem Formulation Outcomes, Data Gaps and Next Steps</b>	<b>77</b>
<b>8.0</b>	<b>Limitations and Closure</b>	<b>79</b>
<b>9.0</b>	<b>References</b>	<b>80</b>
	<b>Figures</b>	
	Figure 3-1: Human Health Risk Assessment Framework (from Health Canada, 2010). .....	14
	Figure 4-1: Conceptual Site Model for Soils for Human Receptors for the Lake Enon Former Mill Site, Enon, Nova Scotia .....	34
	Figure 5-1: Ecological Risk Assessment Steps (from CCME, 2020; FCSAP, 2012a).....	37
	Figure 6-1: Conceptual Site Model for Soils for Ecological Receptors at the Lake Enon Former Mill Site, Enon, Nova Scotia .....	76
	<b>Tables</b>	
	Table 2-1: Summary of APECs and site conditions. Adapted from Phase I ESA (Dillon, 2022a).....	9
	Table 4-1: Summary of Parameter Assumptions for Human Receptors .....	23
	Table 4-2: Summary of Selected and Excluded Exposures Pathways for the Study Area .....	24
	Table 4-3: Human Health Screening for COPCs in Study Area Soil at Full Depth, Direct Contact Pathway .....	28
	Table 4-4: Human Health Screening for COPCs in Study Area Soil at Surface Depth, Direct Contact Pathway.....	30

Table 6-1: Ecological Receptors Selected for or Excluded from Evaluation in the ERA.....	47
Table 6-2: Estimated Ns Values for Selected Ecological Receptors at the Lake Enon Former Mill Site, Enon, Nova Scotia .....	56
Table 6-3: Receptors of Concern (ROC) Selected for Evaluation .....	57
Table 6-4: Assessment and Measurement Endpoints and Lines of Evidence for the Selected ROCs.....	58
Table 6-5: Summary of exposure pathways and routes selected for the ROCs. ....	62
Table 6-6: Ecological Screening (Soil COPC Identification) for the Lake Enon Former Mill Site.....	70
Table 6-7: Comparison of Lake Enon Former Mill Site Soil Chemistry Data for Initial COPCs to Receptor-Specific Ecological Health-Based Soil Quality Benchmarks.....	71
Table 7-1: Summary of Problem Formulation Outcomes for Lake Enon HHERA Problem Formulation of Soil.....	77

## Appendices

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A	Figures
B	Site Photographs
C	Laboratory Certificates of Analysis
D	Bioaccessibility Data
E	Human Health Screening Files
F	Ecological Health Screening Files

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



# Acronyms, Abbreviations, Definitions

AEP	Alberta Environment and Parks
APEC	Area of Potential Environmental Concern
ARBCA	Atlantic Risk-Based Corrective Action
ASTM	American Society for Testing and Materials
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
CCME	Canadian Council of Ministers of the Environment
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
CSM	Conceptual Site Model
CVOC	Chlorinated volatile organic compounds
CWQG	Canadian Water Quality Guidelines
CWS	Canada Wide Standard
DQRA <sub>CHEM</sub>	Detailed Quantitative Risk Assessment for Chemicals
ECCC	Environment and Climate Change Canada
EcoSSL	Ecological Soil Screening Levels
EQS	Environmental Quality Standards
ER	Exposure Ratio
ERA	Ecological Risk Assessment
ESA	Environmental Site Assessment
FCSAP	Federal Contaminated Sites Action Plan
HC	Health Canada
HHERA	Human Health and Ecological Risk Assessment
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient
ICMM	International Council on Mining and Metals
ILCR	Incremental Lifetime Cancer Risk
IVBA	In Vitro Bioaccessibility Testing
LMWPAH	Low Molecular Weight Polycyclic Aromatic Hydrocarbons
LOE	Lines of Evidence
m bgs	Metres below ground surface
MW	Monitoring Well
NA	Not Applicable
NGA	No Guideline Applicable
NOAEL	No Observed Adverse Effect Level
NS CSR	Nova Scotia Contaminated Sites Regulations
NS PSS	Nova Scotia Pathway Specific Standards
NSCS	Nova Scotia Contaminated Sites
NSDNRR	Nova Scotia Department of Natural Resources and Renewables
NSLI	Nova Scotia Lands, Inc.
ON MECP	Ontario Ministry of the Environment, Conservation, and Parks
PAH	Polycyclic Aromatic Hydrocarbons
PARCC	Precision, Accuracy, Representativeness, Comparability and Completeness
PCB	Polychlorinated Biphenyls

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



PHC	Petroleum Hydrocarbons
PID	Property Identification Designation Number
PPE	Personal Protective Equipment
PQRA	Preliminary Quantitative Risk Assessment
PSS	Pathway Specific Standards
QA/QC	Quality Assurance/Quality Control
RDL	Reportable Detection Limit
ROC	Receptor of Concern
RQ	Risk Quotient
RSL	Regional Screening Level
SABCS	Science Advisory Board of Contaminated Sites in British Columbia
SAR	Species At Risk
SARA	Species At Risk Act
SF	Slope Factor
SoQG	Soil Quality Guideline
SoQG <sub>E</sub>	Ecological Health-Based Soil Quality Guideline
SoQG <sub>HH</sub>	Human Health-Based Soil Quality Guideline
SSTL	Site-Specific Target Level
sVOC	Semi-Volatile Organic Compounds
TPH	Total Petroleum Hydrocarbons
TRV	Toxicological Reference Values
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compounds
WOE	Weight of Evidence

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



# Executive Summary

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Dillon Consulting Limited (Dillon) was retained by Build Nova Scotia, on behalf of the Nova Scotia Department of Natural Resources and Renewables (NSDNRR), to conduct a Human Health and Ecological Risk Assessment (HHERA) Problem Formulation for the Lake Enon Former Mill Property in Enon, Nova Scotia, herein referred to as the “site” or “subject property”.

The Lake Enon Former Mill (i.e., the site) is located in Enon, Nova Scotia along Loch Lomond Road, approximately 50 kilometers (km) southwest of Sydney in the Cape Breton Regional Municipality, and is situated adjacent to Lake Enon. The former mill site [Parcel Identification Designation Numbers (PID Nos.) 15551369, 15340045, 15340052] is owned by NSDNRR. The total property area of the site (i.e., all three PIDs) is approximately 141 ha (**Figure 1, Appendix A**). The area of the site anticipated to be impacted by historical site activities comprises a smaller, localized portion of the site consisting of twelve (12) Areas of Potential Environmental Concern (APECs) as identified in the Phase II Environmental Site Assessment (ESA). Based on sampling completed to date, the contaminated area is generally limited to the portions of the site east and west of Loch Lomond Road, which intersects the site, and along the south shoreline of Enon Lake. The study boundary (or “study area”) for the HHERA Problem Formulation encompasses approximately 46 hectares of the total area of the former mill property. The Problem Formulation study boundary, is shown in **Figure 2, Appendix A**.

A summary of the overall outcomes of the Human Health and Ecological Health Risk Assessment Problem Formulation for the study boundary in addition to data gaps and next steps is provided below.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



### Summary of Problem Formulation Outcomes for Lake Enon HHERA Problem Formulation of Soils

Receptors	Exposure Pathways	Soil COC	Data Gaps and Recommended Next Steps
<b>Human Health Risk Assessment Problem Formulation</b>			
Site visitor (all ages)	- Ingestion of outdoor soils/dusts	Lead Strontium	As COCs have been identified for both human and ecological receptors, a human and ecological health risk assessment should be completed. Other media (sediment, surface water and groundwater) should be assessed and incorporated into the HHERA where relevant.
Site excavation / remediation worker (teen adult)	- Inhalation of outdoor soils/dusts - Dermal contact with outdoor soils/ dusts - Ingestion of groundwater as drinking water	Lead Strontium	
<b>Ecological Risk Assessment Problem Formulation</b>			
Terrestrial vegetation	- Direct contact with soils - Root uptake	Copper Lead Strontium Zinc	Soils to the north west of the site (between the study boundary and the nearby Lake) have not been fully characterized. Surface soil samples should be collected within this area.
Soil invertebrates	- Direct contact with soils - Soil ingestion		
Herbivorous small mammals (surrogate: meadow vole)	- Soil ingestion - Vegetation ingestion	Cadmium Lead Strontium Zinc	Surface water and sediment samples should be collected in the adjacent unnamed lake to identify whether tailings may have spread into these areas and to identify any COPCs.
Insectivorous/ Invertevorous small mammals (surrogate: masked shrew)	- Soil ingestion - Ingestion of soil invertebrates		
Herbivorous birds (surrogate ruffed grouse)	- Soil ingestion - Vegetation ingestion		
Insectivorous/ Invertevorous birds (surrogate: American robin)	- Soil ingestion - Ingestion of invertebrates		
Carnivorous small mammals (surrogate: ermine)	- Soil ingestion - Ingestion of prey		
Amphibians	- Soil / sediment ingestion - Direct contact with soil, sediments and surface water - Ingestion of aquatic and terrestrial foods		

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



Receptors	Exposure Pathways	Soil COC	Data Gaps and Recommended Next Steps
Freshwater aquatic life	- Direct contact with sediment / surface water		<p>Contamination in site soil is not fully delineated so receptors were conservatively selected assuming contamination extended into areas of suitable habitat for receptors. Receptors and surrogate receptors should be refined following site delineation.</p> <p>Some of the site was reported to be very damp and have wetland vegetation (e.g., cattails). In addition, a brook was noted within the study boundary. A survey of these areas within the study boundary should be conducted to identify the presence of suitable habitat for amphibians and / or aquatic life receptors.</p> <p>- There is uncertainty associated with the potential presence and use of the site by SAR. Although potential presence of the common nighthawk was qualitatively discussed, a formal SAR assessment should be undertaken within a full ERA to reduce uncertainty associated with this aspect of the Problem Formulation.</p>

**Note:**  
COC = contaminant of concern



## 1.0

# Introduction

Dillon Consulting Limited (Dillon) was retained by Build Nova Scotia, on behalf of the Nova Scotia Department of Natural Resources and Renewables (NSDNRR), to conduct a Human Health and Ecological Risk Assessment (HHERA) Problem Formulation for the Lake Enon Former Mill Property in Enon, Nova Scotia, herein referred to as the “site” or “subject property” .

The Lake Enon Former Mill (i.e., the site) is located in Enon, Nova Scotia along Loch Lomond Road, approximately 50 kilometers (km) southwest of Sydney in the Cape Breton Regional Municipality, and is situated adjacent to Lake Enon. The former mill site [Parcel Identification Designation Numbers (PID Nos.) 15551369, 15340045, 15340052] is owned by NSDNRR. The total property area of the site (i.e., all three PIDs) is approximately 141 ha (**Figure 1, Appendix A**). The area of the site anticipated to be impacted by historical site activities comprises a smaller, localized portion of the site consisting of twelve (12) Areas of Potential Environmental Concern (APECs) as identified in the Phase II Environmental Site Assessment (ESA). Based on sampling completed to date, the contaminated area is generally limited to the portions of the site east and west of Loch Lomond Road, which intersects the site, and along the south shoreline of Enon Lake. The study boundary (or “study area”) for the HHERA Problem Formulation encompasses approximately 46 hectares of the total area of the former mill property. The Problem Formulation study boundary, is shown in **Figure 2, Appendix A**.

The findings presented in this report are based on information and analytical data obtained from the Phase I and II Environmental Site Assessments (ESAs) and supplemental assessments (Dillon, 2022a, Dillon, 2022b and Dillon, 2023, respectively), other investigations, reports, and site records; information obtained during site visits; and discussions with the province and Build Nova Scotia.

## 1.1

## Structure of the Report

The current section of this report (**Section 1.0**) details the objectives and scope of the Problem Formulation. **Section 2.0** provides information related to the site background and characterization, including physical descriptions of the site, summaries of previous investigations, and site data available for the assessment. The Human Health Risk Assessment (HHRA) framework and Problem Formulation outcomes are detailed in **Section 3.0** and **Section 4.0**, respectively, and the Ecological Risk Assessment (ERA) framework and Problem Formulation outcomes are detailed in **Section 5.0** and **Section 6.0**, respectively. **Section 7.0** provides overall conclusions and recommendations from the HHERA Problem Formulation. Limitations and closure conditions are described in **Section 8.0**. References are provided in **Section 9.0** and additional information to support the Problem Formulation is provided in **Appendices A through F**.

Nova Scotia Lands Inc.

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



## Objectives and Scope

The overall study boundary for the HHERA Problem Formulation is provided in **Figure 2, Appendix A**. The study boundary generally included the following APECs identified in previous reports (Dillon, 2022b) and shown on **Figure 2, Appendix A**:

- APEC 1: Tailings Pile/Pond;
- APEC 2: Waste Rock/Dump;
- APEC 3: Processing Area;
- APEC 4: Mill/Plant Area;
- APEC 5: Waste Rock/Dump;
- APEC 6: Tailings Pile/Pond;
- APEC 7: Settling Ponds;
- APEC 8: Lake Enon (Potential Receptor);
- APEC 9: Waste Rock/Dump;
- APEC 10: Tailings Disposal Area;
- APEC 11: Tailings Disposal Area; and
- APEC 12: Former Pad Area.

This HHERA Problem Formulation focused on analytical data for site soils. Chemical concentrations in site groundwater, surface water and sediments were not considered herein. No soil samples were collected from APEC 6, APEC 7 or APEC 8. As such, these APECS have not technically been evaluated in this Problem Formulation, but will be considered when additional media are assessed and / or as part of a full HHERA.

Pending the outcomes of the Problem Formulation, it is anticipated that a site-specific HHERA will be conducted on the site. Given this, a description of the overall HHRA framework is briefly included herein along with the methods and outcomes of the Problem Formulation step.

The Problem Formulation for the site was conducted in accordance with the Nova Scotia Contaminated Sites Regulations (NS CSRs) and associated Ministerial Protocols, where relevant. Provincial guidelines were applied where possible (i.e., the Nova Scotia Pathway Specific Standards [NS PSS] for human health and Atlantic Risk-Based Corrective Action [ARBCA] guidelines for ecological health). In addition, Federal Contaminated Sites Action Plan (FCSAP), Health Canada (HC), Environment and Climate Change Canada (ECCC) guidance materials and applicable provincial and federal protocols and guidelines were also considered, where relevant (See **Section 4.4** for details of the guidelines applied).

The scope of the HHERA Problem Formulation included:

- Review site information;
- Compile relevant site and background soil data for the purpose of identify contaminants of potential concern (COPC) in site soils;

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



- Identify relevant human and ecological receptors;
- Identify relevant exposure pathways and scenarios;
- Develop a site-specific conceptual site model;
- Prepare a report presenting the outcomes of the HHERA Problem Formulation, including identified data gaps and next steps.

The site is zoned for commercial land use, and neighbouring properties are zoned for residential and commercial land use. No known potable wells are currently located on the site, nor are they reasonable anticipated to be constructed in the future. However, the surrounding properties are serviced by individual potable wells with nearest residential building located approximately 200 m north/cross gradient to the site boundary. Given neighbouring properties are zoned for residential land use, potable wells could potentially be constructed closer to the site in the future. Two grain-size samples were collected from different areas of the site during the Phase II ESA. The results indicated one sample was classified as fine-grained and one sample was classified as coarse-grained. As such, the Nova Scotia Tier 1 EQS for both fine- and coarse-grained soils have been considered. Therefore, for the purpose of the HHERA Problem Formulation the site was considered to be commercial and potable, with both fine and coarse-grained soil conditions.

The HHERA Problem Formulation evaluates current and reasonably foreseeable future exposures associated with the site, assuming future land use, existing engineering controls and site conditions remains consistent with current land use, as is anticipated.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



## 2.0 Background and Site Characterization

The Lake Enon Former Mill (i.e., the site) is located in Enon, Nova Scotia along Loch Lomond Road, approximately 50 kilometers (km) southwest of Sydney in the Cape Breton Regional Municipality, and is situated adjacent to Lake Enon. The former mill site (PID Nos. 15551369, 15340045, 15340052) is owned by NSDNRR. As reported in the Phase II ESA (Dillon, 2022b), significant deposits of celestite, the principal source of strontium, were discovered from the Lower Windsor rock group in Enon in the early 1960s. The site was developed in the mid-1960s and was operational from 1969 through 1975 or 1976 by Kaiser Celestite Mining (Kaiser). During this time, ore was reportedly sourced from an on-site pit, as well as a quarry to the north of the site. Concentrated ore was then sent to Kaiser's chemical plant in Point Edward, NS to be converted to different strontium compounds. Site photos can be found in **Appendix B**.

In 1977, the site was purchased by Yava Mines Ltd. (Yava). Between 1979 and 1981, Yava operated the milling site to process lead ore from a nearby mine. The site was then acquired by Novex Mining and Exploration (Novex). From 1983 to 1984, Novex operated the mill site to process barite ore. In 1988, Lodestone operated the mill site to process a magnetite bulk sample from Bass River. Buildings and processing equipment associated with the former mill operations were reportedly removed from the site in the mid-1990s.

The total property area of the site is approximately 141 ha (**Figure 1, Appendix A**). The area of the site anticipated to be impacted by historical site activities comprises a smaller, localized portion of the site consisting of the APECs as identified in **Section 1.2**. The contaminated area is limited to the northwest portion of the property along Lake Enon. The study boundary for the HHERA Problem Formulation has an area of approximately 46 hectares (**Figure 2, Appendix A**). Areas within the property boundaries but well outside of the study boundary have been considered as background locations.

The study area contains notable features including two settling ponds (APEC 1 and APEC 6), two infilled settling ponds (APEC 10 and APEC 11), a tailings pond (APEC 6), two waste rock piles from previous mining activities, and a concrete pad from previous mining activities) with the Loch Lomond road running through the study area. The settling ponds and tailing pond were artificially constructed for the mine, and were not originally aquatic habitat. Currently these areas do not provide habitat for aquatic receptors and no aquatic wildlife were observed onsite.

The closest ecological receptor, Lake Enon, is identified as an ecological habitat of potential concern since it is within 200 m of the site (i.e., it borders the site immediately north) (Atlantic RBCA, 2012). Lake Enon is located to the north and immediately adjacent to the study boundary and a drain pipe connects the settling ponds to the lake. To the northwest and adjacent to the study boundary is a small unnamed water body which also drains into Lake Enon was noted during the assessment activities. In addition to

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



the settling ponds, the site contains large wet areas with widespread cattail growth and water-logged soil.

Much of the study areas is covered with rock and has limited soil. There is limited vegetation in the central areas of the study areas, although trees and shrubs are noted intermittently and around the study boundary.

## 2.1 Physical Setting

### 2.1.1 Water Supply/Groundwater Usage

During the Phase II ESA field program from May 17 to 19, 2022 (Dillon, 2022b), groundwater was encountered at depths ranging from 1.16 meters below top of casing (mbtoc) (i.e., in MW3) to 5.78 mbtoc (i.e., in MW4). Based on the measured groundwater elevations, the generalized groundwater flow direction in the study area is interpreted to be convergent towards Lake Enon. There are currently no potable groundwater wells on site; however, the surrounding properties are serviced by individual potable wells with nearest residential building located approximately 200 m north/cross gradient to the site boundary.

### 2.1.2 Regional Geology and Topography

To describe the regional physiography and expected hydrogeological conditions beneath the subject property, the following documents were reviewed as part of the Phase I ESA (Dillon, 2022a):

- Stea, R.R., Conley, H., and Brown, Y. (compilers) 1992: Surficial Geology of the Province of Nova Scotia; Nova Scotia Department of Natural Resources, Map 92-3, Scale 1:500,000;
- Keppie, J.D. (compiler) 2000: Geological Map of the Province of Nova Scotia; Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Map ME 2000-1, Scale 1:500,000; and,
- S.M. Barr, C.E. White (compilers) 2017: Bedrock Geology Map of the Grand Narrows Area, NTS 11F/15, Cape Breton, Inverness, Richmond and Victoria Counties, Nova Scotia; Nova Scotia Department of Natural Resources, Map ME 2017-014, Scale 1:50,000.

The surficial geology of the subject area consists of stony till plain and drumlins. Till is stony, sandy and consists of material derived from local bedrock sources, ranging in thickness from 2 meters (m) to 20 m. Drumlin facies are siltier due to erosion and incorporation of older till units by glaciers. The regional bedrock geology of the site is mapped as variable. The Uist formation is present at the northwest portion of the site, northwest of the former pond. Between the former pond and tailings pond, the Loch Lomond formation is present. To the southeast of Enon Lake, the Enon formation is present, followed by the Grantmire formation, and then by the Chisholm Brook Plutonic Suite - mozzogranite. A small area of the Chisholm Plutonic Suite - granodiorite is present with the Loch Lomond formation on the southwest

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



portion of the site. Bedrock mapping of the area also identified occurrence of strontium on the subject property, south of Enon Lake and north of the former tailings disposal pond.

The topography of the site is flat to rolling with many surface boulders; drumlins-elongate or oval hills veneered by stony till with underlying multiple till layers. Regional topography suggests the regional shallow groundwater flow is likely west to north/northwest towards Enon Lake. Historical reports (see **Section 2.3**) noted that a portion of the site (PID No. 15340052) was leveled and graded between 1995 and 1997. It is noted that some of the historical lagoons and pits have been infilled. The characteristics of the fill material are not known. The local shallow groundwater flow direction may vary from the regional context and be influenced by backfilled areas with coarse-grained materials, which may provide a more permeable conduit for groundwater flow when compared to the lower permeability of the native soils.

### 2.1.3 Stratigraphy

Due to the nature of the site, there is significant variability in soil stratigraphy depending on the area. Additionally, the grade of the site is even more variable depending on the area within the study boundary. During the Phase II ESA it was noted that soil stratigraphy in the area generally consisted of a thin layer of organics underlain with silt and gravel with varying amounts of sand and clay, with cobbles atop bedrock. Bedrock was encountered in the background area at a depth of 3.05 meters below ground surface (m bgs).

### 2.1.4 Climate

The site is situated within the maritime boreal climate zone and is characterized by variable weather, warm summers, cold winters and moderate precipitation. Current climate conditions at the site can be characterized by examining the historical data. Climate data was taken from ClimateAtlas.ca using the historical period 1976-2005. All data is for the Cape Breton Regional Municipality which includes the Lake Enon site (ClimateAtlas.ca, 2023).

- Average annual temperature: 6.1 °C
- Coldest month: February: -5.5 °C
- Hottest month: September: 14.2 °C
- Annual average precipitation: 1394 mm
- Number of Frost Days (Days with coldest temperature below 0°C): 150.5 days
- Number of Summer Days (Days above 25°C): 13.7 days
- Dry Days (Number of days without rain or snow): 186.1 days

## 2.2 Land Use Considerations

The site is zoned for commercial land use, and neighbouring properties are zoned for residential and commercial land use. The site is currently vacant with no buildings present. A concrete pad is located on the eastern side of Loch Lomond Road. To date, soil delineation has not been achieved at the site;

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



therefore, the extent of the contamination is unknown at this time and will be addressed in future studies.

No potable wells are currently located on site; however, the surrounding properties are serviced by individual potable wells with nearest residential building located approximately 200 m north/cross gradient to the site boundary.

### 2.3 Previous Investigations

As noted in the 2022 Phase I ESA (Dillon, 2022a), the previous following reports were available for review:

- A.D. Hudgins, Milado Mines (1957) Limited Mine Drilling Report, Loch Lomond Area – Cape Breton, NS.
- Lura Corporation Limited, Milado Mines (1957) Limited Report. (1963).
- J.H. Fowler (1991) Barite, Celestite and Fluorite in Nova Scotia.
- Jacques, Whitford, and Associates Limited. (1983) Yava Mines Review, Cape Breton, NS.
- Dillon. (2018) Flooding Assessment Task 1 - Initial Assessment - Loch Lomond Road, Cape Breton
- Nova Scotia Transportation and Infrastructure Renewal (2018) Lake Enon Drainage Improvement Plan.

As noted in the 2022 Phase I ESA (Dillon, 2022a), not all reports contained information relevant to the ESA, so the following summary of relevant information was provided.

- Float (i.e. loose pieces of rock that are not connected to an outcrop) containing mineralizations of galena, sphalerite, barite, and celestite were identified on the subject property. Diamond drilling (for Milado Mines (1957) was completed on-site in 1963 to test the results of geological mapping, and previously completed geophysical surveys and geochemical testing. Three boreholes were reportedly completed on-site. Findings indicated that it was not considered feasible to undertake additional diamond drilling in the Loch Lomond Area until favorable targets were further delineated by gravity surveys.
- Kaiser operated the site from approximately 1969 to 1975 for the purposes of mining and milling celestite (a mineral consisting of strontium sulfate). The site contained several open pits, one of which was eventually used for the disposal of tailings, and a facility for milling the ore. Maps provided in this review display infrastructure including a pump, crusher building, transfer toner, concentrator, sub-station, fuel oil tank (22,700 L capacity), thickener tank, water storage tank, sewage treatment plant, and pump house. The facility also contained a laboratory and several sheds. Infrastructure was located west of Loch Lomond Road (formerly Enon Road). The former tailings pond and former settling pond are located west of this infrastructure. A process water reclaim pond was shown located between the tailings disposal pond and the two settling ponds. A seeded dump area to the east of Loch Lomond Road, opposite the former mining pit was displayed.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



- In 1979, Yava reactivated the mine until 1981, with the purpose of milling lead ore from a nearby mining site (Salmon River), located approximately 13 km northeast of the subject property. The tailings disposal pond used by Kaiser was utilized by Yava and was altered to accommodate a higher storage capacity. In 1981, Yava was placed in receivership resulting in withdrawal from the site. Yava reportedly did not conduct any stabilization or restoration of the tailings.
- Disposal of tailings was conducted between 1981 and 1983 by use of a discharge line to the east of the tailings pond. Drainage was facilitated to the northwest corner of the subject property, where slime accumulation had occurred. Soil samples were collected to complete a sieve analysis, and slime samples were collected for geotechnical characteristics analysis (i.e., water content, liquid limit, plastic limit, unconfined pressure, and remoulded pressure). The majority of the tailings surface was categorized as sand and silty sand. The northwest corner of the tailings area contained slime deposits from internal drainage. The thickness of tailings from the disposal area was determined to range from 1.52 m to 2.44 m. The water table in the tailings area was encountered at depths ranging from 0.61 m to 0.76 m.
- In 1983 until 1984, Novex Mining Exploration acquired the subject property for the purposes of milling and processing barite ore.
- In 1988, the mill facility was used by Lodestone to process magnetite bulk samples from Bass River.
- Prior to 1995, Industrial Estates Limited (IEL), a provincial government economic development company, assumed ownership of the mill site. This did not include the tailings disposal pond or part of the open flooded pit.
- Between 1995 and 1997, Kelly Rock Limited removed all on-site buildings and leveled and graded the site.
- A 2018 flooding assessment was completed by Dillon, investigating backups of water onto Loch Lomond Road during significant rainfall events. Since the closure of the site, a portion of underground piping previous used to manage stormwater on-site during mining and process operations had collapsed, contributing to this backup. Surface water samples were collected in the former tailings disposal pond, the tertiary pond, near the shore of Enon Lake, and near a road culvert on Loch Lomond Road. Samples were analyzed for aluminum, ammonia, cadmium, iron, and lead and results were compared to Canadian Water Quality Guidelines (CWQG) and Nova Scotia Contaminated Sites (NSCS) Table 3 Guidelines. Concentrations of lead in both samples collected from the tailings disposal pond exceeded the CWQG and NSCS guidelines. Concentrations of analyzed parameters in samples collected in the tertiary pond and near the shore of Enon Lake were below CWQG and NSCS. Exceedances of both criteria in all analyzed parameters, with the exception of ammonia, were observed in the surface water sample collected near the road culvert, which were attributed to significant corrosion of the culvert.
- A Phase I ESA, completed by ADI Nolan Davis in 1995, is referenced in the 2018 flooding assessment noted above; however, this report was not able to be provided to Dillon for review. The flooding assessment report (Dillon, 2018) noted that the 1995 Phase I ESA had identified the potential for polychlorinated biphenyls (PCB) related issues, and buried process reagents. Though no further

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



details were provided, it has been assumed that these issues would be in the areas of former pits/lagoons at the site.

Based on the above, the following potential or actual environmental concerns were identified:

- Mining operations with regards to celestite;
- Milling operations and associated reagent use (floatation, coagulants, flocculants, etc.) with regards to processing celestite (selenium), lead, and barium, as well as select organic compounds;
- Potential acid rock drainage;
- Potential PCB related issues; and,
- Potential buried process reagents.

**Phase I ESA (Draft), Dillon Consulting Ltd, Lake Enon Former Mill Site  
(April, 2022, Nova Scotia Lands Inc.)**

Dillon Consulting Limited (Dillon) was commissioned by Build Nova Scotia (formerly Nova Scotia Lands Inc. (NSLI)) to complete a Phase I ESA of the property, with the objective of assessing whether the site is or may be subject to actual or potential contamination. The report identified twelve areas of potential environmental concern (APEC) as well as contaminants of potential concern (COPC) for each of those APEC in various media (soil, groundwater, sediment and surface water). **Table 2-1** is adapted from the Phase I ESA (Dillon, 2022a) and offers some additional insight into the conditions surrounding each APEC. Notable observations surrounding site conditions are wet areas of soil near APECs 10 and 11, large piles of waste rock in APECs 5 and 2, and the presence of artificially-constructed settling ponds (which were not originally aquatic habitat).

**Table 2-1: Summary of APECs and site conditions. Adapted from Phase I ESA (Dillon, 2022a).**

APEC No.	APEC	Comments
1	Tailings Pile/Pond	Waste storage, aerial mapping surficial water present in this area
2	Waste Rock/Dump	Waste/tailings soils area
3	Processing Area	Processing of materials, heavy equipment storage, petroleum storage
4	Mill/Plant Area	Processing of materials, heavy equipment storage, petroleum storage
5	Waste Rock/Dump	Waste/tailings soils area
6	Tailings Pile/Pond	Waste storage, aerial mapping surficial water present in this area
7	Settling Ponds	Waste storage, aerial mapping surficial water present in this area
8	Lake Enon (Potential Receptor)	Lake Enon is identified as a potential receptor, given the nature of the site conditions, sediment and surface water quality should be evaluated
9	Waste Rock/Dump	Waste/tailings soils area
10	Tailings Disposal Area (filled in)	Waste/tailings storage, historical plans indicate a pond was previously located here

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



11	Tailings Disposal Area (filled in)	Waste/tailings soils area
12	Former Pad Area	Former pad area used for storage, waste rock pile area

**Phase II ESA, Dillon Consulting Ltd, Lake Enon Former Mill Site  
(August, 2022, Nova Scotia Lands Inc.)**

Dillon Consulting Limited (Dillon) was commissioned by Build Nova Scotia (formerly NSLI) to complete a Phase II Environmental Site Assessment (ESA) of the Lake Enon Former Mill property. The Phase II ESA included the advancement of eight boreholes, installation of seven monitoring wells, completion of twelve test pits, advanced several shallow test holes and soil, groundwater, surface water and sediment sampling. The report identified exceedances in soil and various other media, and a risk assessment was recommended.

**Supplemental ESA, Dillon Consulting Ltd, Lake Enon Former Mill Site  
(October, 2022, NLSI)**

Following the Phase II ESA, Dillon was contracted by NSLI to complete a supplemental ESA at the Lake Enon site. This supplemental ESA included: preparation of detailed site contour maps using LIDAR to support future work, installation of a new well (MW5-D), and additional groundwater and surface water and background soil samples. The report concluded with recommendations for a hydrological and sediment transport study, the completion of a benthic habitat and benthic community assessment for the lake and to complete the risk assessment.

## 2.4 Data Availability and QA/QC

### 2.4.1 Background Data

The background data selected for HHERA Problem Formulation screening purposes were compiled from the sampling program in the Phase II ESA (Dillon, 2022b) and the supplemental site investigation for the study area. In total, twelve background soil samples were analyzed for metals.

Review of the laboratory certificates of analysis on their internal quality assurance/quality control (QA/QC) metrics (i.e., method blanks, certified reference materials, spiked blanks, and matrix spikes) indicates no significant data quality issues that would affect the use of the site soil data in an ESA and HHERA.

### 2.4.2 Site Data

The data selected for the HHERA Problem Formulation were compiled from the Phase II ESA field program (Dillon, 2022b) and supplemental site investigation. Sixty-nine (69) soil samples were analyzed for metals, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), semi-volatile organic compounds (sVOCs), benzene, toluene, ethylbenzene and xylenes (BTEX) and petroleum

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



hydrocarbons (PHCs), and PCBs, with not all parameters being analyzed in all samples. Laboratory certificates of analysis for soils can be found in Appendix C.

A program to ensure quality assurance and control (QA/QC) was implemented throughout the Phase II ESA (Dillon, 2022b). The QA/QC program consisted of a number of elements:

- Collection of samples using protocols consistent with Dillon Standard Environmental Field Procedures and/or industry standards;
- Use of dedicated sampling equipment and/or adherence to established equipment cleaning protocols, where applicable;
- Use of laboratory supplied containers;
- Collection of blind field duplicates; and
- Implementation of laboratory QA/QC procedures including analysis of reference standards, laboratory blanks and replicates.

Validation criteria were established that required the analytical data to have an acceptable and documented level of precision, accuracy, representativeness, comparability and completeness (the PARCC criteria). The precision of the data for the samples collected was evaluated by calculating the Relative Percent Difference (RPD) between the original samples and its duplicate when the samples had concentrations greater than 10x the laboratory Reportable Detection Limit (RDL).

Review of the laboratory certificates of analysis on their internal quality assurance/quality control (QA/QC) metrics (i.e., method blanks, certified reference materials, spiked blanks, and matrix spikes) indicates no significant data quality issues that would affect the use of the site soil data in an ESA and HHERA.

### 2.4.3 Lead Bioaccessibility Data

Five soil samples were submitted for IVBA (in vitro bioaccessibility testing) for lead. The IVBA data will be used in the exposure assessment step of the pending HHRA (Human Health Risk Assessment) to aid in estimating the oral bioavailability of lead in soils. Results of the IVBA testing can be found in **Appendix D**.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723

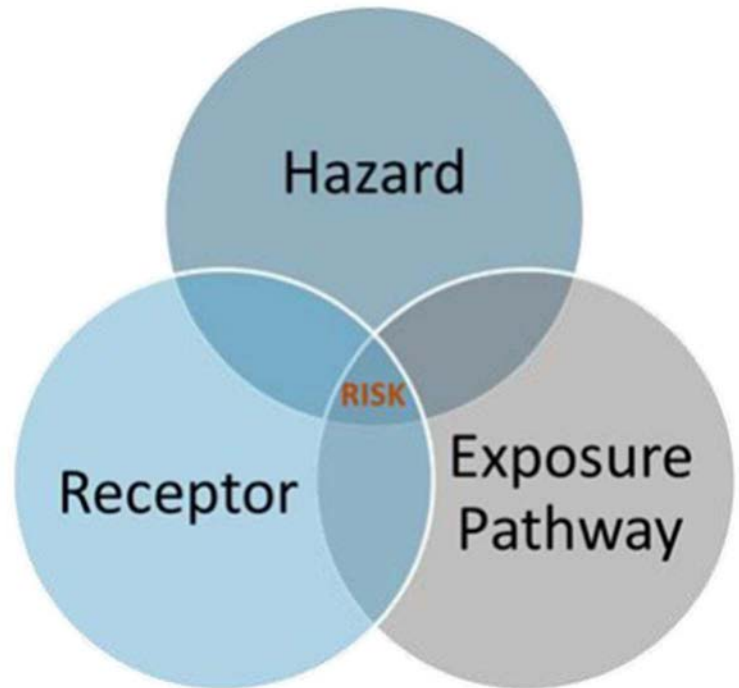


## 3.0

# Human Health Risk Assessment Framework

Risk assessment is a systematic quantitative or qualitative process for interpreting the potential adverse effects associated with an activity, situation, or an exposure. The framework and methods used for the HHRA Problem Formulation for the Lake Enon Former Mill Site are described in this section and its associated subsections.

The fundamental purpose of any HHRA Problem Formulation is to estimate or determine whether people working, living at, or visiting a given location are being exposed, or are likely to be exposed, to concentrations of chemicals that have the potential to result in adverse human health effects (i.e., toxicity). In order for a potential risk to exist, three things must be present: a contaminant of potential concern (or hazard), a receptor, and an exposure pathway that links the chemical constituent to the receptor, as presented in the graphic to the right. If one of these elements is missing, potential risk does not exist. If all three elements are present, then the degree of risk may be estimated and compared to target risk levels to identify whether or not unacceptable levels of risk are present and remedial action or risk management is required.



The HHRA Problem Formulation and other steps of the HHRA are described in this section and its associated subsections.

The HHRA Problem Formulation for Lake Enon was conducted in accordance with the following Canadian regulatory guidance documents, where applicable, as indicated in the Statement of Work:

- Federal Contaminated Site Risk Assessment in Canada. *Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA)*. Version 3.0. March 2021. Health Canada Contaminated Sites Division, Safe Environments Directorate (Health Canada, 2021a);
- Federal Contaminated Site Risk Assessment in Canada. *Toxicological Reference Values (TRVs)*. Version 3.0. March 2021. Health Canada Contaminated Sites Division, Safe Environments Directorate (Health Canada, 2021b);

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723

- Federal Contaminated Site Risk Assessment in Canada. *Overview of Health Canada Guidance Documents Related to Human Health Risk Assessment of Federal Contaminated Sites*. March 2021. Health Canada Contaminated Sites Division, Safe Environments Directorate (Health Canada, 2021c);
- Federal Contaminated Site Risk Assessment in Canada. *Part V. Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals (DQRA<sub>CHEM</sub>)*. September, 2012. Prepared by: Health Canada Contaminated Sites Division, Safe Environments Directorate (Health Canada, 2010);
- *Canada Wide Standard for Petroleum Hydrocarbons in Soil: Scientific Rationale*. Supporting Technical Document. PN 1399. ISBN 978-1-896997-77-3 PDF (Canadian Council of Ministers of the Environment [CCME], 2008); and,
- *CCME Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines* (CCME, 2006).

Where appropriate or necessary, the HHRA Problem Formulation also considered human health risk assessment guidance and procedures developed and endorsed by other regulatory agencies such as the US EPA (Environmental Protection Agency). In this HHRA Problem Formulation, the US EPA was used as a guideline source for COPC screening, consistent with Health Canada (2021a) PQRA guidance, in the absence of federal or provincial benchmarks.

The HHRA framework is shown in **Figure 3-1**, below, and the main steps are briefly described in **Sections 3.1** to **3.4**. As previously discussed, only the problem formulation step of the HHRA was conducted herein. The specific methods used to conduct the problem formulation step of the HHRA are described in **Section 3.1**, and the outcomes of this step are presented in **Section 4.0**.

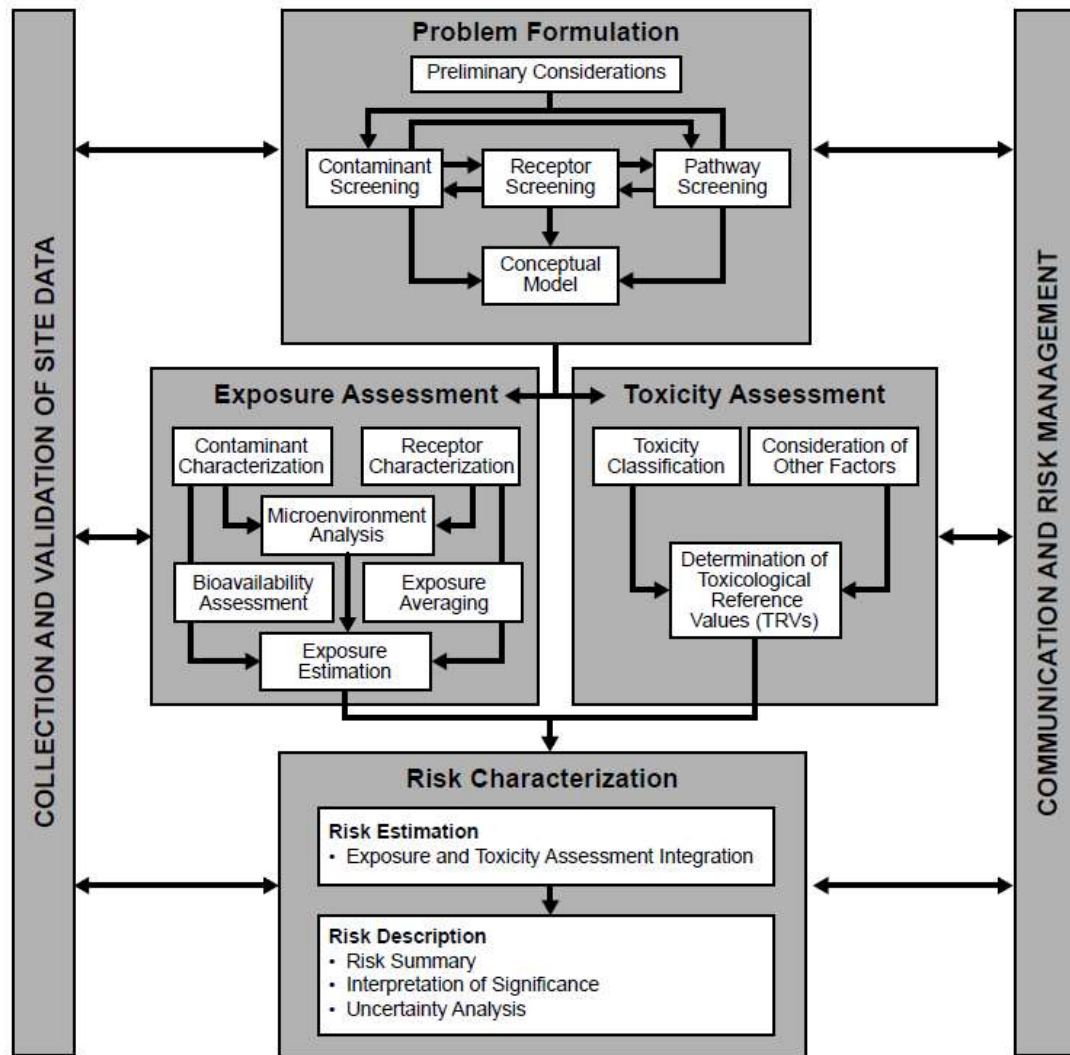


Figure 3-1: Human Health Risk Assessment Framework (from Health Canada, 2010).

### 3.1 Problem Formulation

The problem formulation step of an HHRA is an information gathering step that helps to plan and focus the risk assessment. The data gathered and evaluated in this step provides information regarding the history and layout of the subject site, possible exposure scenarios and pathways, identification of receptors of potential concern, identification of contaminants of concern, and other specific issues of concern to be addressed.

Key tasks requiring evaluation within the Problem Formulation step include the following:

- Site Characterization;
- Selection of Receptors;

Nova Scotia Lands Inc.

Human Health and Ecological Risk Assessment Problem Formulation (Final)

Lake Enon Former Mill Site, Enon, Nova Scotia

PID Nos. 15551369, 15340045, and 15340052

May 2023 - 22-3723

- Selection of Exposure Pathways and Scenarios;
- Identification of COPCs; and
- Development of a Conceptual Site Model (CSM).

### 3.1.1 Site Characterization

The site characterization step provides a description of the site including information regarding the history and layout of the site and site characteristics that are pertinent to understanding and assessing potential exposures on the site.

### 3.1.2 Selection and Characterization of Receptors

A human receptor is a hypothetical person (e.g., infant, toddler, child, adolescent, or adult) who resides, visits, or works in the area being investigated and is, or could potentially be, exposed to the chemicals identified as being of potential concern. General physical/physiological and behavioural characteristics specific to the receptor type (e.g., body weight, breathing rate, amount of soil, and food consumed) are used to determine the amount of chemical exposure received by each receptor. Due to differences in these characteristics between children and adults and between males and females, the exposures received by a female child, a male child, a female adult, or a male adult will be different. Consequently, the potential risks posed by the chemicals being evaluated will also differ depending on the receptor chosen for evaluation. While HHRA guidance in some jurisdictions continues to differentiate receptors based on gender, Health Canada HHRA guidance has moved away from distinguishing between genders for the selection of human receptors.

Since people have varying physical/physiological features, lifestyles and habits, it is not possible to evaluate all types of individuals. However, an HHRA must be sufficiently comprehensive to ensure that those receptors with the greatest potential for exposure to COPCs and/or those that have the greatest sensitivity, or potential for developing adverse effects from such exposures, are included in the evaluation. If no potential health risks are determined for relevant receptors that are considered to be either the most sensitive, or receive the greatest exposures from the site, then it can be assumed that those receptors who are either less sensitive, or who receive lower exposures, would also not be at risk.

In an HHRA, it is commonplace to select toddler receptors for the evaluation of chemicals that are not considered to be carcinogens (i.e., threshold response chemicals) or that have toxicological reference values (TRVs) available that are based on a chemical's non-carcinogenic effects. This is because toddlers typically receive greater chemical exposures, via all pathways and routes, on a relative body weight basis, when compared to other human receptor classes.

For chemicals that are considered to be carcinogens, or that have toxicity reference values (TRVs) available that are based on a chemical's carcinogenic effects, it is necessary that HHRAs evaluate such substances over an appropriate period of time, as the development of cancer is a long-term process that may take many years to manifest (i.e., latency). For this reason, a special type of hypothetical receptor

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



called a “lifetime” or “composite” receptor is evaluated when potential carcinogenic risks require consideration in a HHRA.

### 3.1.3 Selection of Exposure Pathways and Scenarios

People can come into contact with chemicals in a variety of ways, depending on their daily activities and their land use patterns. The means by which a person comes into contact with a chemical in an environmental medium are referred to as exposure pathways. The means by which a chemical enters the body from the environmental medium are referred to as exposure routes. There are three major exposure routes through which chemicals can enter the body: inhalation, ingestion, and dermal absorption through the skin. For each of these major exposure routes, there are a number of potential exposure pathways. For example:

- Inhalation of gases, vapours, and dusts/particulate material through the lungs;
- Ingestion of soils, dusts, drinking water, garden produce, local food items (e.g., fish, shellfish, game meats, wild berries/plants), grocery store-bought food items, and accidental/incidental ingestion of surface water, groundwater, and/or sediments; and
- Dermal absorption (uptake through the skin) from direct skin contact with gases/vapours, soils/dusts/sediments, water, and other materials.

The potential for adverse health effects to occur as a result of exposure to chemicals, in any medium, is directly related to the exposure pathways. If there is no possible pathway of exposure to a chemical, regardless of its toxic potency or concentration within a given medium, there is no potential for the development of adverse health effects from that chemical.

Exposure scenarios are the outcome of pathways, receptors, and COPCs at a site, and states how a human exposure to contaminants take place. The most likely exposure scenarios are selected based on the information previously presented in relation to site characterization, COPC identification and exposure pathway selection, and land use.

In general, inhalation occurs on a continuous 24-hour per day basis regardless of whether a person is on-site or off-site. Therefore, the inhalation exposure experienced by people on-site is a function of both the time spent on-site in a given day and the number of days spent on-site in a given year. Exposures of this nature are considered *time-driven*. Alternatively, exposures such as incidental ingestion or dermal contact with impacted soil (typically grouped together by the term ‘direct contact’) can only occur while a person is present on-site. In the practice of HHRA, it is commonly assumed that whether someone spends 1 minute or 24 hours at a site, their entire daily ‘dose’ of contaminant is obtained from the site. These types of exposures are considered to be *event-driven* and are a function of only the days spent on site in a given year. Unlike inhalation exposures, they do not consider the time spent on site in a given day.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



### 3.1.4 Identification of COPCs

It is common practice in HHRAs to limit the number of chemicals evaluated to those that represent the greatest potential concern to people that may be present in the area under consideration. This is done because it is often impractical in terms of time and cost to conduct a risk assessment for every chemical that has been found at measurable concentrations in a particular area. In addition, the concentrations of many chemicals associated with a particular site may be similar to chemical concentrations found naturally in the area rather than the result of predicted, current or former anthropogenic activities at the site. It is also preferable to comprehensively evaluate a smaller number of chemicals which represent the greatest potential concern, than it is to conduct a less detailed risk assessment on a larger number of chemicals that are of lesser potential concern.

This step of the HHRA identifies chemicals that have the potential to pose a risk to human health. As per Health Canada (2021a) guidance, COPCs are defined as follows:

- Chemicals for which the maximum on-site concentration exceeds appropriate human health-based environmental quality criteria (e.g., human health-based guidelines or criteria); AND
- Chemicals for which the maximum on-site concentration exceeds local or regional background concentrations; OR
- Chemicals for which no human health-based criteria or background data exist.

The identification of COPCs involved a sequential step-wise process, as follows:

1. Comparison of site soil chemistry data maxima to regulatory human health-based soil quality benchmarks and background data (see summary in Tables 4-3 and 4-4 and full datasets in Tables E-1 and E-2, Appendix E);
2. Chemicals with a maximum concentration that exceeded the applicable human health-based benchmark and were above background concentrations, were identified as initial COPCs. Chemicals for which no health-based benchmark was available were also identified as initial COPCs;
3. These initial COPCs were further evaluated by considering the frequency of detection, frequency of exceedance of site soil chemistry data over human health-based soil quality benchmarks, and/or degree of guideline exceedance; and
4. Further considerations (where/if deemed necessary and relevant), such as: essential nutrient status of certain inorganic elements, ubiquity of certain elements in soils, statistical relationships, local geology, spatial distribution patterns of soil chemical concentrations, as well as environmental fate and behaviour properties (including the potential for a substance to bioaccumulate and biomagnify), and the likely speciation (chemical forms) in site media.

The COPC identification process excluded data for the general chemistry and physical properties of soil and/or groundwater (e.g., chloride, electrical conductivity, sodium absorption ratio, etc.). While such parameters can inform on soil and water quality (where applicable), and may influence or modify the bioavailability, mobility and toxicity of certain COPCs, they are not typically considered directly in the COPC identification step of a HHRA. Also, many of these parameters lack toxicity or human health-

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



based benchmarks that media concentrations can be compared against. As such, these parameters were not considered further in the HHERA.

If site media concentrations are less than the applicable guidelines, then the likelihood of potential human health effects related to that chemical can be considered negligible. However, if site media concentrations exceed these guidelines, it does not necessarily mean that unacceptable risks exist; it is simply an indicator that further assessment is required. Guidelines are intentionally derived by regulatory agencies to be conservative and protective.

### 3.1.5 Conceptual Site Model for Human Receptors

A CSM provides a description of relevant exposure pathways for the COPCs that have the potential to contribute to human health risks for the selected receptors.

## 3.2 Exposure Assessment

The exposure assessment of an HHRA involves estimation of exposure of hypothetical human receptors to each of the COPCs. Exposure assessment involves the estimation of the amount of chemical received by individuals per unit time (i.e., the quantity of chemical and the rate at which that quantity is received). The exposure assessment evaluates and integrates available data for the chemicals, human receptors, and exposure pathways that were selected during the problem formulation step of the HHRA. The rate of exposure to chemicals, from the various environmental media being evaluated at a given site, is usually expressed as a dose, or the amount of chemical taken in per body weight per unit time (e.g.,  $\mu\text{g}$  chemical/kg body weight/day). The degree of human exposure to chemicals at a given site depends on the interactions of a number of parameters, including:

- The concentrations of chemicals in various site environmental media (e.g., air, water, soil, or foods) as determined by the quantities of chemicals entering the site's environmental media from various sources, their fate and persistence in these media, and the normal ambient, or background concentrations that may exist independent of a specific source.
- The various exposure pathways and routes for the transfer of the chemicals from the different environmental media to humans (e.g., inhalation of indoor and outdoor air, soil particles, and dusts; ingestion of food items, water, soils/dusts; skin penetration of various chemicals from water or soil/dust contact).
- The physiological, behavioural and lifestyle characteristics of human receptors that determine the actual exposures received through interactions with the various exposure pathways (e.g., respiration rate, water intake rate, food intake rate, soils/dusts intake rate, time spent at various activities and in different locations).
- The various physical, chemical, and biological factors that determine the ability of people to take chemicals into their bodies from the exposure pathways and media (e.g., bioavailability of the chemicals within soil/dust, foods, water, and air).

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



An exposure assessment can focus on one or more possible pathways. A multimedia exposure assessment approach considers total exposure of human receptors to COPCs through all possible sources or media (i.e., soil, air, dust, water, food, consumer products).

### 3.3 Toxicity (Hazard) Assessment

The toxicity (or hazard assessment) determines an exposure limit or toxicological reference value (i.e., concentration of a chemical not expected to be associated with adverse health effects) for each of the COPCs.

Toxicity is the potential for a chemical agent to produce any type of damage, permanent or temporary, to the structure or function of any part of an organism. The toxicity of a chemical depends on the amount that is taken into the organism (referred to as the “dose”) and the duration of exposure (i.e., the length of time the person or other organism is exposed to the chemical). For every chemical, there is a specific dose and duration of exposure necessary to produce a toxic effect in an organism (this is referred to as the “dose-response relationship” of a chemical). In the toxicity assessment step of a HHRA, information relating to the dose-response relationship of each COPC is evaluated (usually from laboratory animal studies and epidemiological studies of human exposure in the workplace) to determine the maximum dose to which humans can be continuously exposed that would be associated with no or very low probability of adverse health effects. These toxicity estimates are called toxicity or toxicological reference values (TRVs) (also referred to as exposure limits, the terms are analogous) and indicate an exposure that will not likely result in adverse human health effects.

#### 3.3.1 Toxicity Reference Values

TRVs are typically derived by regulatory agencies based on detailed reviews of toxicological, epidemiological, other scientific information, professional judgment, and technical oversight by a number of experienced scientists with expertise in the toxicological sciences. They are often derived to be protective of the most sensitive endpoints in individuals (e.g., organ damage, neurological effects, cancer, or reproductive effects), and large safety or uncertainty factors (i.e., 100-fold or greater) are commonly used in their estimation. These factors are often applied to exposure levels from studies where no adverse effects were observed (i.e., the NOAEL). Thus, exceedance of a TRV does not necessarily mean that adverse effects will occur; rather, it means that the safety factor beyond the no-effect exposure is somewhat reduced. Usually, exposure rates that are less than TRVs are not likely to be associated with adverse health effects, and are therefore, less likely to be of concern. As the frequency or magnitude of exposures exceeding a TRV increase, the probability of adverse health effects occurring in a human individual or population also increases. However, it should not be categorically concluded that all exposures below the TRV will be “acceptable” (unlikely to result in adverse health effects), and that all exposures above the TRV are “unacceptable” (likely to result in adverse health effects).

There are two main types of dose-response relationships that have been established for chemical agents:

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



- **Threshold Response Chemicals:** For these substances, there is a dose-response threshold below which no adverse effects would be expected to occur. This relationship is generally true for all chemicals that do not cause cancer.
- **Non-Threshold Response Chemicals:** For these types of chemicals, it is assumed there is no dose-response threshold. This means that any exposure greater than zero is assumed to cause some type of response, or damage. This relationship is typically used/assumed for carcinogens (although, some carcinogenic substances do have a well-defined threshold below which cancer does not appear to be a response to exposure). In theory, any exposure to a non-threshold substance has the potential to cause damage. As such, it is necessary to define an “acceptable” degree of risk associated with these types of exposures. This “acceptable” degree of risk is usually defined as a target cancer risk level of one-in-one hundred thousand to one-in-one million. Essentially, these numbers correspond to the dose rate that may cause an increased cancer risk in one person out of one hundred thousand people, or one person out of one million people. The acceptable or target level of carcinogenic risk is a policy rather than a scientific decision, and is set by regulatory agencies, as opposed to risk assessors. TRVs derived for non-threshold chemicals that are believed to be potential carcinogens are typically expressed as cancer slope factors or cancer potency factors [e.g., ( $\mu\text{g}/\text{kg body weight}/\text{day})^{-1}$ )], or unit risk values for environmental media [e.g., ( $\mu\text{g}/\text{m}^3$ )<sup>-1</sup>]. However, TRVs for carcinogens may also be expressed as risk-specific media concentrations or doses that are associated with a particular level of acceptable cancer risk.

Health Canada (2021a) states that for the assessment of risks posed by chemicals and substances found at federal contaminated sites in Canada, Health Canada TRVs should be employed, when available, for the characterization of potential health risks.

### 3.4 Risk Characterization

Risk characterization is the final step in a HHRA. It integrates the exposure and hazard (toxicity) assessments to provide estimate the likelihood of potential human health risk for the receptors, COPCs, exposure pathways and exposure scenarios that were evaluated. Potential risk is characterized through a comparison of the estimated or predicted COPC exposures to the selected human receptors from all exposure pathways and routes (from the Exposure Assessment) with the identified TRVs from the Hazard (Toxicity) Assessment.

For chemicals with TRVs based on threshold effects (typically non-carcinogenic effects), this comparison takes the form of a ratio calculation, and is referred to as the hazard quotient (also sometimes referred to as an exposure ratio (ER) or risk quotient (RQ)). The hazard quotient (HQ) is calculated by dividing the estimated level of exposure (based on the current site soil concentrations) by the TRV, as indicated in the following equation:

$$\text{Hazard Quotient} = \frac{\text{Estimated Exposure } (\mu\text{g}/\text{kg body weight}/\text{day})}{\text{TRV } (\mu\text{g}/\text{kg body weight}/\text{day})}$$

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



For threshold effects, if the HQ is less than or equal to 1.0, the intake of the COPC does not exceed the tolerable daily intake, and negligible health risks are expected. Conversely, if the HQ exceeds 1.0, there may be a potential risk to human health, and a more detailed assessment should be undertaken. Where not all relevant exposure media are considered, a target HQ of 0.2 is commonly used. A target HQ of 0.2 sets the upper limit of exposure from the site to be equal to or less than 20% of the tolerable daily intake for a chemical, thus (protectively) allowing 80% of the exposure to be from other sources unrelated to the site, as per Health Canada PQRA guidance (Health Canada, 2021a).

For non-threshold acting chemicals, incremental lifetime cancer risk (ILCR) is estimated as the product of the predicted exposure and the cancer slope factor (SF):

$$ILCR = \text{Slope Factor} \times \text{Exposure}$$

Health Canada considers incremental lifetime cancer risks of 1-in-100,000 ( $\leq 1E-05$ ) to 1-in-1,000,000 ( $\leq 1E-06$ ) to be “essentially negligible” (Health Canada, 2021a). The province of Nova Scotia selected EQS (environmental quality standards) and PSS (pathway specific standards) based on a risk level of 1 in 100,000. As such, ILCRs less than or equal to 1-in-100,000 ( $\leq 1E-05$ ) are considered to be acceptable for the purposes of this HHRA. Conversely, if the ILCR exceeds 1-in-100,000, there may be potentially unacceptable cancer risks to human health, and a more detailed assessment may be appropriate. The 1.0E-05 risk level has been widely accepted by federal agencies and several other provinces.

For non-threshold, non-carcinogenic chemicals (i.e., lead) a multimedia (multi-pathway) risk assessment, which considers total exposure of human receptors to COPCs through all possible sources or media, provides a more realistic assessment of potential exposures and risks. As such, the multimedia approach is deemed most acceptable when evaluating lead.

It is important to recognize that HQ and ILCR values are not absolute measures of risk, nor are they measures of actual risk; rather, they are most appropriately considered as indicators of potential human health risks which enable the following:

- Comparisons of potential adverse health effects between COPCs and between different exposure scenarios (e.g., different site-specific conditions, different site use options);
- Estimation of potential adverse health effects from exposures to mixtures of COPCs that may elicit similar effects in organs, tissues or cells (e.g., all chemicals that cause liver toxicity, or kidney toxicity, or respiratory tract cancers, or respiratory irritation effects); and,
- Simplification of HHRA results to provide clear understanding of the results, and an appreciation of their significance.

If the risk characterization results indicate potentially unacceptable risks, site-specific target levels (SSTL) can be generated as part of the risk management plan. The SSTLs provide the maximum allowable concentration at the site, based on the exposure scenario, and these values can be used to guide remediation or clean-up efforts, if warranted.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



## 4.0

## HHRA Problem Formulation Outcomes

As discussed in **Section 3.1**, the problem formulation step is an important information gathering and interpretation stage, which serves to plan and focus the approach of the HHRA. The data gathered and evaluated in this step provides information regarding the history and layout of the site, possible exposure scenarios and pathways, identification of receptors of potential concern, identification of contaminants of potential concern, and other specific areas of potential environmental concern or issues of concern to be addressed.

## 4.1

### Site Characterization

Site characterization for the study area were previously provided in **Section 2.0**. Site photos are provided in **Appendix B**.

## 4.2

### Selection and Characterization of Receptors

Based on the current and reasonable anticipated future land use identified for the study boundary, the following potential human receptors (i.e. people who may be exposed to COPCs from the site) were selected:

- Site Excavation / Remediation Worker (teen, adult)** – While there are not buildings on site and construction work is not expected to occur on site in the future; should intrusive / remediation work be conducted on the site, workers could potentially come in contact with COPCs in soils at all depths. The evaluation of potential exposures and risks to workers who may participate in site remediation work that involves soil excavation, grading, stockpiling, and other soil handling activities, at some point in the future, is beyond the scope of this Problem Formulation. Such workers are generally not evaluated in a risk assessment, but would be covered under applicable NS Health and Safety Regulations. In addition, it is recommended and expected that appropriate PPE be worn by workers when on the site, and that applicable NS occupational health and safety regulations and policies be complied with at all times. Although this receptor will not be evaluated in the future risk assessment, relevant soil data (all depths) for this receptor were screened in the problem formulation to aid in the preparation of site-specific health and safety plans. Specific exposure times for this receptor are not provided in this Problem Formulation given the large degree of uncertainty in estimating the time on site.
- Site Visitor (all ages)** –The most likely human receptor for the site are site visitors (all ages) using the land for recreational purposes (walking, hiking) and so will only be screened against surface level soil concentrations. Relevant soil data (surface soils) for this receptor were screened in the Problem Formulation and will be incorporated into the future risk assessment.

Key parameters and assumptions for the receptors evaluated in the Problem Formulation for the study area are described in **Table 4-1**, below:

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



**Table 4-1: Summary of Parameter Assumptions for Human Receptors**

<b>Parameter</b>	<b>Value</b>	<b>Reference</b>
Body Weight (kg)	Infant: 8.2 Toddler: 16.5 Child: 32.9 Teen: 59.7 Adult: 70.7	Health Canada, 2021a
Inhalation Rate (m <sup>3</sup> /day)	Infant: 2.2 Toddler: 8.3 Child: 14.5 Teen: 15.6 Adult: 16.6	Health Canada, 2021a
Soil Ingestion (mg/day)	Infant: 20 Toddler: 80 Child: 20 Teen: 20 Adult: 20	Health Canada, 2021a
Hand Surface area (m <sup>2</sup> )	Infant: 0.032 Toddler: 0.043 Child: 0.059 Teen: 0.08 Adult: 0.089	Health Canada, 2021a
Skin surface area (upper and lower arms) (m <sup>2</sup> )	Infant: 0.055 Toddler: 0.089 Child: 0.148 Teen: 0.223 Adult: 0.25	Health Canada, 2021a
Hand Soil adherence factor (kg/cm <sup>2</sup> -event)	Infant: 1 x 10 <sup>-7</sup> Toddler: 1 x 10 <sup>-7</sup> Child: 1 x 10 <sup>-7</sup> Teen: 1 x 10 <sup>-7</sup> Adult: 1 x 10 <sup>-7</sup>	Health Canada, 2021a
Outdoor dust level from soil (µg/m <sup>3</sup> )	0.76	Health Canada, 2021a
Time spent on site	<i>Outdoor site visitor: 2 hours/day, 2 days/week, for 6 months/year (May to October)</i> For oral and dermal pathways, exposures are considered event driven, and as such, the hour/day term does not apply in the risk modelling.	Assumed

## 4.3

## Selection of Exposure Pathways and Scenarios

Based on the information previously presented in relation to site characterization, COPC identification and exposure pathway selection, and assuming that the commercial land use will be applicable in the future, the exposure scenarios selected were as follows:

- **Outdoor Site Visitor Scenario:** This scenario assumes that adult receptors would periodically visit the Subject Property. It was assumed that outdoor site visitors would be present on the Site for 2-hours/per day, for 2 days per week for 6 months of the year and exposed to surface soil only.

While there are currently no potable groundwater wells on site and the nearest residential property that serviced by groundwater is approximately 200 m away, some properties closer to the site are zoned as residential so that potable wells could potentially be constructed at these locations in the future. With respect to the ingestion groundwater pathway, it is conservatively assumed that a site visitor could consume groundwater in the wells near the site, but not on the site while visiting the site. Given the proximity of potable groundwater wells to the site and the potential for other potable wells off-site, the groundwater on-site has conservatively been assumed to be potable for screening purposes. Since actual groundwater data have been collected from the site, the soil data evaluated herein, were not screened for the soil to potable groundwater pathway given the large uncertainty in these guidelines. The ingestion of groundwater will be considered in the future HHRA using available site groundwater data.

Given the site's current and likely future land use pattern as commercial, the most likely and relevant human exposure pathways/routes are as follows:

- Inhalation of outdoor soils / dusts
- Ingestion of outdoor soils / dusts
- Dermal contact with outdoor soils / dusts
- Ingestion of groundwater (as potable drinking water)

A number of other potential exposure pathways for human receptors were considered, but were ultimately excluded, as briefly summarized in **Table 4-2**, below. HHRAs commonly exclude pathways that are not relevant to the site under investigation or that lack sufficient data to enable their evaluation with a reasonable degree of confidence and/or accuracy.

**Table 4-2: Summary of Selected and Excluded Exposures Pathways for the Study Area**

Pathway	Selected or Excluded?	Rationale
Inhalation of outdoor soils/dusts	Selected	COPCs have been identified in soils on-site. People may be exposed to COPC in surface soils while on-site.
Dermal Contact with outdoor soils/dusts	Selected	
Ingestion of outdoor soils/dusts	Selected	

Nova Scotia Lands Inc.

Human Health and Ecological Risk Assessment Problem Formulation (Final)

Lake Enon Former Mill Site, Enon, Nova Scotia

PID Nos. 15551369, 15340045, and 15340052

May 2023 - 22-3723



Pathway	Selected or Excluded?	Rationale
Groundwater ingestion (as drinking water)	Selected	There are no potable groundwater wells on site and wells are not anticipated to be constructed on site in the near future. However, given the presence of potable wells in the vicinity of the Study Boundary, consumption of groundwater was conservatively selected as an exposure pathway.
Dermal contact with groundwater.	Excluded	Dermal contact with site groundwater is not expected to occur. If dermal contact with groundwater did occur, it would be transient and of short duration in nature, such that exposure to substances present in groundwater would be negligible.
Inhalation of vapours in indoor air.	Excluded	There are no habitable or occupied buildings are present within the study area; therefore, people will not be within an indoor environment. The construction of buildings on site is not anticipated to occur in the future.
Indoor dust ingestion, dermal contact and ingestion.	Excluded	
Ingestion and dermal contact of surface water / sediments	Excluded	While there is surface water present in the study area within the former settling ponds and tailings pond, this water would not be expected to be used for drinking. If someone fell into the water, exposures to surface water and sediments did occur, they would be short lived and infrequent and unlikely to result in significant exposure. Similarly, it is not expected that potential human receptors would come in contact with sediment and they are unlikely to spend a significant amount of time in the water. Therefore, ingestion of and dermal contact with surface water and sediments are considered negligible exposure pathways and were excluded.
Ingestion of country foods	Excluded	While most of the former mine site is heavily vegetated, most of the land within the study boundary contains very little vegetation and is unlikely to be used for gathering berries. Hunting would also not be expected to occur in the area. Therefore, this pathway was excluded.

## 4.4

## Identification of COPCs

The goal of COPC selection is to identify those chemicals measured in site media that may pose a potential risk to human health. Based on the site characterization information, the anticipated future land use of the site, and consideration of the physical-chemical and environmental fate and behaviour

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



properties of the chemicals present in site media, the main human exposure media of concern is soil. Only site soils were evaluated in the current assessment. Other media, including surface water, groundwater, and sediment should be considered further as part of the HHRA.

Soil data used in the screening are discussed in **Section 4.4.1** and assessment standards against which site data were compared are discussed in **Section 4.4.2**. Details regarding the COPC identification process are presented in **Section 3.1.4**. Analytical data used in the COPC screening along with applicable benchmarks and background data are provided in **Appendix E**. The COPC screening results are discussed in the following sections.

#### 4.4.1 Determining Usability of Soil Data

For HHRA, surface soils can be represented by soil depths ranging from 0.05 m bgs to 1.5 m bgs; however, the soil depth that is considered to contribute the greatest to incidental soil exposures via direct contact is typically the top 5 cm to 10 cm (provided the soils are not tilled, excavated, subjected to gardening) (Health Canada, 2021a).

For the screening of direct soil contact pathways, it is assumed that a soil depth <0.3 m bgs represents surface soil that is biologically accessible for humans (i.e. soil at depths greater than 0.3 m bgs are generally not available for direct contact or ingestions from human health). Therefore, soil samples with depths of <0.3 m bgs were used to identify COPCs in soil. Soil depths were provided as a range (e.g., 0.0-1.0 m bgs, 0.3 to 0.6 m bgs), so the depth range which encompassed the 0.3 m bgs depth was included. By using this approach, all soils samples up to a depth of 0.3 m bgs were included as surface soils. The exception to this was screening of direct soil contact for the site excavation / remediation worker who was assumed to be potentially exposed to site soils at all sample depths.

#### 4.4.2 Comparison of Site Soil Data to Regulatory Human Health-Based Benchmarks

Part of the COPC identification process involved comparing Site soil data to available benchmarks that are protective of human health. Maximum measured soil chemical concentrations were compared to applicable regulatory benchmarks that were derived specifically for the protection of human health as per Health Canada (2012) guidance (see **Appendix E**).

The specific human health-based soil quality benchmarks that were considered in the COPC identification process are presented below. As the study area is located on Nova Scotia land, NS CSR guidelines apply and the NS PSS for commercial soils were preferentially used.

It is important to recognize that all human health-based benchmarks are derived by their respective regulatory agencies to be intentionally conservative and protective. Thus, exceedance of these benchmarks does not imply there is a risk of adverse health effects; rather, it suggests that further evaluation of those chemicals is warranted.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



Given the available soil chemistry information that is available for the study area, and considering the operable exposure pathways that were selected for the human health risk evaluation, soil quality benchmarks that were developed to be protective of direct soil contact exposure pathways (ingestion, dermal contact, and soil/dust inhalation), were considered to be the most relevant and applicable for use.

The study area is currently considered as having a commercial land use, which was assumed not to change in the future and as such, commercial land use guidelines were used in the human health screening. If there are differences between current and future land use and conditions, the results and conclusions of the risk assessments will need to be examined to determine if additional assessment/re-evaluation is required.

Nova Scotia assumes an acceptable target cancer risk level of 1 in 100,000 (1E-5), similar to most federal departments and several other provinces.

The specific guideline sources used in the COPC screening are discussed below.

#### Human Health-Based Soil Quality Guidelines

##### **Nova Scotia Pathway Specific Standards (NS PSS)**

The Nova Scotia Tier II PSS for Soil – Commercial land use protective of direct soil contact / ingestion were selected for the COPC screening. The PSS are benchmarks developed by source agencies and departments outside of Nova Scotia such as the CCME soil quality guidelines (SoQGs) developed for the protection of human health (SoQG<sub>HH</sub>); Alberta Environment and Parks (AEP) guidelines for human health – direct soil contact; Ontario Ministry of the Environment, Conservation and Parks [MECP] soil component values; US EPA Regional Screening Levels [RSLs]). The primary guidelines adopted by NSDNRR, and thus applied herein, are provided below. Guidelines for commercial land use and coarse-grained soils were preferentially sourced from all jurisdictions, where applicable. The specific source of the guideline used in the COPC screening are identified in the human health screening tables (**Tables E-1 and E-2, Appendix E**).

##### Canadian Council of Ministers of the Environment (CCME)

CCME soil quality guidelines developed for the protection of human health (SQG<sub>HH</sub>), commercial land use (coarse soils), were preferentially applied. The direct soil contact guidelines were selected. Where the CCME soil guidelines defer to the older CCME (1991) soil remediation criteria (which are not identified as being either human or ecological health-based), the benchmarks from the next preferred jurisdiction were selected rather than using the outdated CCME (1991) value(s), where possible. If no other guideline was available from another jurisdiction, the CCME (1991) value was used. The most up to date CCME guidelines were selected from on the online CCME summary tables and associated fact sheets (<http://st-ts.ccme.ca/en/index.html>; searched February, 2022).

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



**Alberta Environment and Parks (AEP, 2019)**

The direct soil contact, human health-based soil guidelines for commercial land use and coarse-grained soils were applied. These AEP guidelines are developed in a very similar manner to, and are protective of, the same ecological receptor types as the CCME SQG<sub>E</sub>. Details on soil guideline basis and derivation are provided in AEP (2019).

**Ontario Ministry of the Environment, Conservation, and Parks (MECP, 2011)**

The MECP human health-based soil component values for soil contact (i.e., soil component values for S1 Risk) were applied. The specific soil component values that were used are from Table 3 in MECP (2011), for conditions of non-potable water, institutional land use, and coarse-textured soils. The derivation of these values is described in MECP (2011).

**US Environmental Protection Agency Regional Screening Levels (RSL)(2022)**

The US EPA RSLs for residential soil (Summary Table; November, 2022) were applied. RSLs are divided by 5 for non-carcinogens to be consistent with CCME SoQGs, which typically assume a soil allocation factor or target hazard quotient (HQ) of 0.2 in their derivation (RSLs assume a HQ of 1.0). Details on the basis and derivation of these benchmarks is provided at <https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables>.

## 4.4.3

**Results of the Human Health-Based COPC Screening of Site Soil**

Two separate COPC screening were conducted with site soils (one using soils at all depths relevant for the site excavation / remediation worker, and one using only surface soils relevant for the site visitor). The comparison of the maximum measured concentrations of chemicals in the site soil at all depths to the selected SQG<sub>HH</sub> are presented in **Table 4-3** and the comparison of maximum measured concentrations of chemicals in site surface soil to the selected SQG<sub>HH</sub> are presented in **Table 4-4**. Additional details are provided in **Tables E-1 and E-2, Appendix E. Figures 4 and 5, Appendix A** show the locations of the human health guideline exceedances for the Lake Enon site.

**Table 4-3: Human Health Screening for COPCs in Study Area Soil at Full Depth, Direct Contact Pathway**

Chemical	Maximum Measured Concentration (mg/kg)	Background Maximum Concentration (mg/kg)	Human Health Screening Level (mg/kg)	Exceeds Guideline and Background? (Y/N) <sup>e</sup>
Aluminium	17,000	38,000	15,400 <sup>d</sup>	N
Antimony	<2	<2	7.5 <sup>c</sup>	N
Arsenic	15	6.2	31 <sup>a</sup>	N
Barium	1,100	540	10,000 <sup>a</sup>	N
Beryllium	2	1.6	110 <sup>a</sup>	N

Nova Scotia Lands Inc.

Human Health and Ecological Risk Assessment Problem Formulation (Final)

Lake Enon Former Mill Site, Enon, Nova Scotia

PID Nos. 15551369, 15340045, and 15340052

May 2023 - 22-3723



Chemical	Maximum Measured Concentration (mg/kg)	Background Maximum Concentration (mg/kg)	Human Health Screening Level (mg/kg)	Exceeds Guideline and Background? (Y/N) <sup>e</sup>
Bismuth	2.9	<2.0	NGA	NA
Boron	<50	<50	4300 <sup>c</sup>	N
Cadmium	21	2.6	49 <sup>a</sup>	N
Chromium (Total, III+VI)	34	21	630 <sup>a</sup>	N
<b>Cobalt</b>	<b>270</b>	<b>10</b>	<b>22</b> <sup>c</sup>	<b>Y</b>
Copper	120	29	4,000 <sup>a</sup>	N
<b>Iron</b>	<b>100,000</b>	<b>31,000</b>	<b>11,000</b> <sup>d</sup>	<b>Y</b>
<b>Lead</b>	<b>30,000</b>	<b>160</b>	<b>260</b> <sup>a</sup>	<b>Y</b>
<b>Manganese</b>	<b>6,900</b>	<b>5,000</b>	<b>360</b> <sup>d</sup>	<b>Y</b>
Mercury	0.35	0.56	24 <sup>a</sup>	N
Molybdenum	5.9	2.6	110 <sup>c</sup>	N
Nickel	69	16	310 <sup>a</sup>	N
Selenium	2.3	14	125 <sup>a</sup>	N
Rubidium	18	29	NGA	NA
Lithium	29	41	32 <sup>d</sup>	N
Silver	4.3	1.3	77 <sup>c</sup>	N
<b>Strontium</b>	<b>27,000</b>	<b>470</b>	<b>9,400</b> <sup>d</sup>	<b>Y</b>
Thallium	0.52	0.42	1 <sup>a, e</sup>	N
Tin	5.5	1.6	9,400 <sup>d</sup>	N
Uranium	11	3.9	33 <sup>a</sup>	N
<b>Vanadium</b>	<b>57</b>	<b>40</b>	<b>39</b> <sup>c</sup>	<b>Y</b>
Zinc	3,600	340	16,000 <sup>a</sup>	N

**Notes**

NGA = no guideline available; NA = not applicable; Y = yes; N = no

**Bold** values indicate exceedances over the guideline and background.

*Italicized* values indicate exceedances over the guideline, but not background.

- Guideline is from CCME Factsheets. SQG<sup>HH</sup> (soil quality guideline human health); commercial land use; lower of direct contact pathways; coarse soils; 10<sup>-5</sup> risk level (1 in 100,000) where applicable.
- Alberta Environment Protection (2019) - Surface soil remediation guideline for Commercial/Industrial land use for direct contact pathway; Human; coarse grained soils.
- MECP (2011) Table 2 Soil Components - Full Depth, Non-Potable Water - Institutional land use; Coarse soils - Soil contact (human); S1 Risk soil component.
- US EPA Regional Screening Level (RSL) - Resident Soil RSL November, 2022; lowest of ingestion, dermal and inhalation pathways; divided by 5 to adjust for soil pathway only as per Health Canada, 2021.
- If guideline and the maximum background concentration was exceeded, but the samples were generally within the range of background, the chemical was not carried forward as an initial COPC.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



**Table 4-4: Human Health Screening for COPCs in Study Area Soil at Surface Depth, Direct Contact Pathway**

Chemical	Maximum Measured Concentration (mg/kg)	Background Maximum Concentration (mg/kg)	Human Health Screening Level (mg/kg)	Exceeds Guideline and Background? (Y/N) <sup>e</sup>
Aluminium	17,000	38,000	15,400 <sup>d</sup>	N
Antimony	<2	<2	7.5 <sup>c</sup>	N
Arsenic	14	6.2	31 <sup>a</sup>	N
Barium	1,100	540	10,000 <sup>a, f</sup>	N
Beryllium	2	1.6	110 <sup>a, f</sup>	N
Bismuth	2.9	<2.0	NGA <sup>f</sup>	NA
Boron	<50	<50	4,300 <sup>c</sup>	N
Cadmium	12	2.6	49 <sup>a</sup>	N
Chromium (Total, III+VI)	34	21	630 <sup>a, f</sup>	N
<b>Cobalt</b>	<b>270</b>	<b>10</b>	<b>22</b> <sup>c, f</sup>	<b>Y</b>
Copper	120	29	4,000 <sup>a, f</sup>	N
<b>Iron</b>	<b>100,000</b>	<b>31,000</b>	<b>11,000</b> <sup>d, f</sup>	<b>Y*</b>
<b>Lead</b>	<b>30,000</b>	<b>160</b>	<b>260</b> <sup>a</sup>	<b>Y</b>
<b>Manganese</b>	<b>6,900</b>	<b>5,000</b>	<b>360</b> <sup>d, f</sup>	<b>Y*</b>
Mercury	0.35	0.56	24 <sup>a</sup>	N
Molybdenum	4	2.6	110 <sup>c, f</sup>	N
Nickel	69	16	310 <sup>a, f</sup>	N
Selenium	2.3	14	125 <sup>a</sup>	N
Rubidium	18	29	NGA	NA
Lithium	29	41	32 <sup>d, f</sup>	N
Silver	2.5	1.3	77 <sup>c, f</sup>	N
<b>Strontium</b>	<b>27,000</b>	<b>470</b>	<b>9,400</b> <sup>d, f</sup>	<b>Y</b>
Thallium	0.52	0.42	1 <sup>a, e, f</sup>	N
Tin	1.4	1.6	9,400 <sup>d</sup>	N
Uranium	11	3.9	33 <sup>a, f</sup>	N
<b>Vanadium</b>	<b>57</b>	<b>40</b>	<b>39</b> <sup>c, f</sup>	<b>Y</b>
Zinc	1,500	340	16,000 <sup>a, f</sup>	N

**Notes**

<sup>a</sup> Guideline is from CCME Factsheets. SQG<sup>HH</sup> (soil quality guideline human health); commercial land use; lower of direct contact pathways; coarse soils; 10<sup>-5</sup> risk level (1 in 100,000) where applicable.

<sup>b</sup> Alberta Environment Protection (2019) - Surface soil remediation guideline for Commercial/Industrial land use for direct contact pathway; Human; coarse grained soils.

<sup>c</sup> MECP (2011) Table 2 Soil Components - Full Depth, Non-Potable Water - Institutional land use; Coarse soils - Soil contact (human); S1 Risk soil component.

<sup>d</sup> US EPA Regional Screening Level (RSL) - Resident Soil RSL November, 2022; lowest of ingestion, dermal and inhalation pathways; divided by 5 to adjust for soil pathway only as per Health Canada, 2021.

<sup>e</sup> If guideline and the maximum background concentration was exceeded, but the samples were generally within the range of background, the chemical was not carried forward as an initial COPC.

Nova Scotia Lands Inc.

Human Health and Ecological Risk Assessment Problem Formulation (Final)

Lake Enon Former Mill Site, Enon, Nova Scotia

PID Nos. 15551369, 15340045, and 15340052

May 2023 - 22-3723



<sup>f</sup>The depths of the soil samples were generally provided as a range (e.g., 0.0-1.0 m bgs, 0.3 to 0.6 m bgs), so all samples having a depth range which encompassed the 0.3 m bgs depth were included in the surface soil screening. By using this approach, all soils samples up to a depth of 0.3 m bgs were included as surface soils; however, the exact depth of the maximum concentration unknown due to the range of sample depth.

NGA = no guidelines available; NA = not applicable; Y = yes; N = no

**Bold** values indicate exceedance over the guideline and background.

*Italicized* values indicate exceedance over the guideline, but not background.

Chemicals that were not detected in any of the analyzed soil samples and were not associated with current and historical activities at the site, were excluded from further assessment. For metals antimony and boron were not detected in soil samples and were excluded from further assessment. A check was conducted to confirm that chemicals that were not detected in any of the soil samples had detection limits that were greater than applicable benchmarks.

Although only metals were to be assessed under the current scope of work, soil data were also available for the following contaminant groups: PAHs, PHCs, VOCs, sVOCs, phenolics. Analytes in these contaminant groups were all non-detect with the exception of the analytes listed below, which were detected at low frequency and below their applicable human health-based guideline, where available.

#### Fluoranthene

- Frequency of detection: 1/23 samples
- Guideline (MECP, 2011): 7.8 mg/kg
- Maximum observed concentration: 0.06 mg/kg

#### 1- and 2-Methylnaphthalene

- Frequency of detection: 4/23 samples
- Guideline (MECP, 2011)<sup>a</sup>: 72 mg/kg
- Maximum observed concentration: 0.1 mg/kg

#### Modified TPH

- Frequency of detection: 5/23 samples
- Guideline (NS PSS, 2021)<sup>b</sup>: 13,000 mg/kg
- Maximum observed concentration: 2,600 mg/kg

#### Phenanthrene

- Frequency of detection: 2/23 samples
- Guideline (NS PSS, 2021)<sup>c</sup>: 37,000 mg/kg
- Maximum observed concentration: 0.031 mg/kg

#### PHC F2 (>C10-C16)

- Frequency of detection: 1/13 samples
- Guideline (CWS, 2008): (10,000 mg/kg)
- Maximum observed concentration: 17 mg/kg

#### PHC F3 (>C16-C34)

- Frequency of detection: 1/13 samples
- Guideline (CWS, 2008): (23,000 mg/kg)
- Maximum observed concentration: 950 mg/kg

#### PHC F4 (>C34-C50)

- Frequency of detection: 1/13 samples
- Guideline (CWS, 2008): (30,000 mg/kg)
- Maximum observed concentration: 510 mg/kg

<sup>a</sup>No guideline is available for 1- or 2-methylnaphthalene as individual compounds; the guideline presented is for the sum of 1 & 2-methylnaphthalene, and the maximum concentration presented is the sum of the maximum concentration of each. Frequency of detection is based on considering the two as one compound.

<sup>b</sup>The lowest available guideline for mTPH (fuel) was applied.

<sup>c</sup>No guideline is available for phenanthrene; however, given that its structure is similar to anthracene (both 3 rings), the anthracene guideline was applied.

Substances with a maximum concentration which exceeded the applicable guideline are shown in **Table 4-3** and **Table 4-4**. These chemicals were also compared to the maximum background soil concentration.

All aluminum samples that exceeded the guideline in all soil depth and in surface soils (**Tables 4-3** and **4-4**, respectively) were below the maximum local background concentration of 38000 mg/kg. For this reason, aluminium was considered to be background related and not carried forward as an initial COPC.

Iron exceeded the applicable guideline in 52 of 62 full depth samples and 45 of 54 surface soil samples, by up to 9.1-fold. The maximum background concentration for the site was 31,000 mg/kg. The background maximum was only exceeded in one sample (TP-22) by approximately 3-fold, and the remaining samples were all within the background range. The maximum site iron concentration exceeded the Highland Soil Zone iron concentration of 52,000 by less than 2-fold. Given the high background concentration and infrequency of exceedance of the background maximum, iron was considered to be background related and not carried forward for further consideration.

Manganese exceeded the applicable guideline in 61 of 62 of full depth samples and 53 of 54 surface soil samples by up to 19-fold. The maximum background concentration for the site was 5000 mg/kg. The background maximum was only exceeded in three samples (TP-27, TP2 and MW5 SS1), and the remaining samples were all within the background range. Given the high background concentration and infrequency of exceedance of the background maximum, manganese was not carried forward for further as an initial COPC.

Based on the number of samples that exceeded the guideline (provided in brackets) and consideration of the local background data, the following chemicals were selected as initial contaminants of concern (COPCs) for both full depth and surface soils:

**Initial COPCs – Direct Soil Contact: full depth of soil**

- Cobalt (1 of 62)
- Lead (44 of 73)
- Strontium (12 of 62)
- Vanadium (2 of 62)

**Initial COPCs – Direct Soil Contact: surface soil**

- Cobalt (1 of 54)
- Lead (40 of 65)
- Strontium (11 of 54)
- Vanadium (1 of 54)

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



### Further Examination of Initial COPCs

Cobalt exceeded the applicable guideline in 1 of 62 full depth samples and 1 of 54 surface soil samples by 12.2-fold (TP22). The remaining samples were below the guideline and maximum background concentration of 10 mg/kg. Given the infrequency of exceedance, cobalt was not carried forward for further consideration.

Lead exceeded the applicable guideline in 44 of 73 full depth samples and 40 of 65 surface samples, by as much as 115-fold. The background maximum for lead was 160 mg/kg. Given the frequency and degree of exceedance, lead was carried forward for further consideration.

Strontium exceeded the applicable guideline in 12 of 62 full depth samples and 11 of 54 surface soil samples by up to 2.9-fold. Given the frequency and degree of exceedance, strontium was carried forward for further examination.

Vanadium exceeded the applicable guidelines in 2 of 62 samples and 1 of 54 samples by less than 1.1-fold. The site maximum for the background was 40 mg/kg. Given the elevated background concentration of vanadium and the exceedance being slightly over the guideline, vanadium was not carried forward for further consideration.

Based on the available data, COPC identification steps and considerations described above, the following COPCs were carried forward as final COPCs for the Site Excavation / Remediation Worker:

#### Final COPCs – Direct Soil Contact (Full Depth)

- Lead
- Strontium

Based on the available data, COPC identification steps and considerations described above, the following COPCs were carried forward as final COPCs for the Site Visitor:

#### Final COPCs – Direct Soil Contact (Surface Soils)

- Lead
- Strontium

## 4.5

### Conceptual Site Model

The HHRA Problem Formulation CSM is presented in **Figure 4-1**. The CSM provides a simplified representation of potential exposure pathways and routes that link the identified COPCs in Subject Property environmental media to the human receptors of interest.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

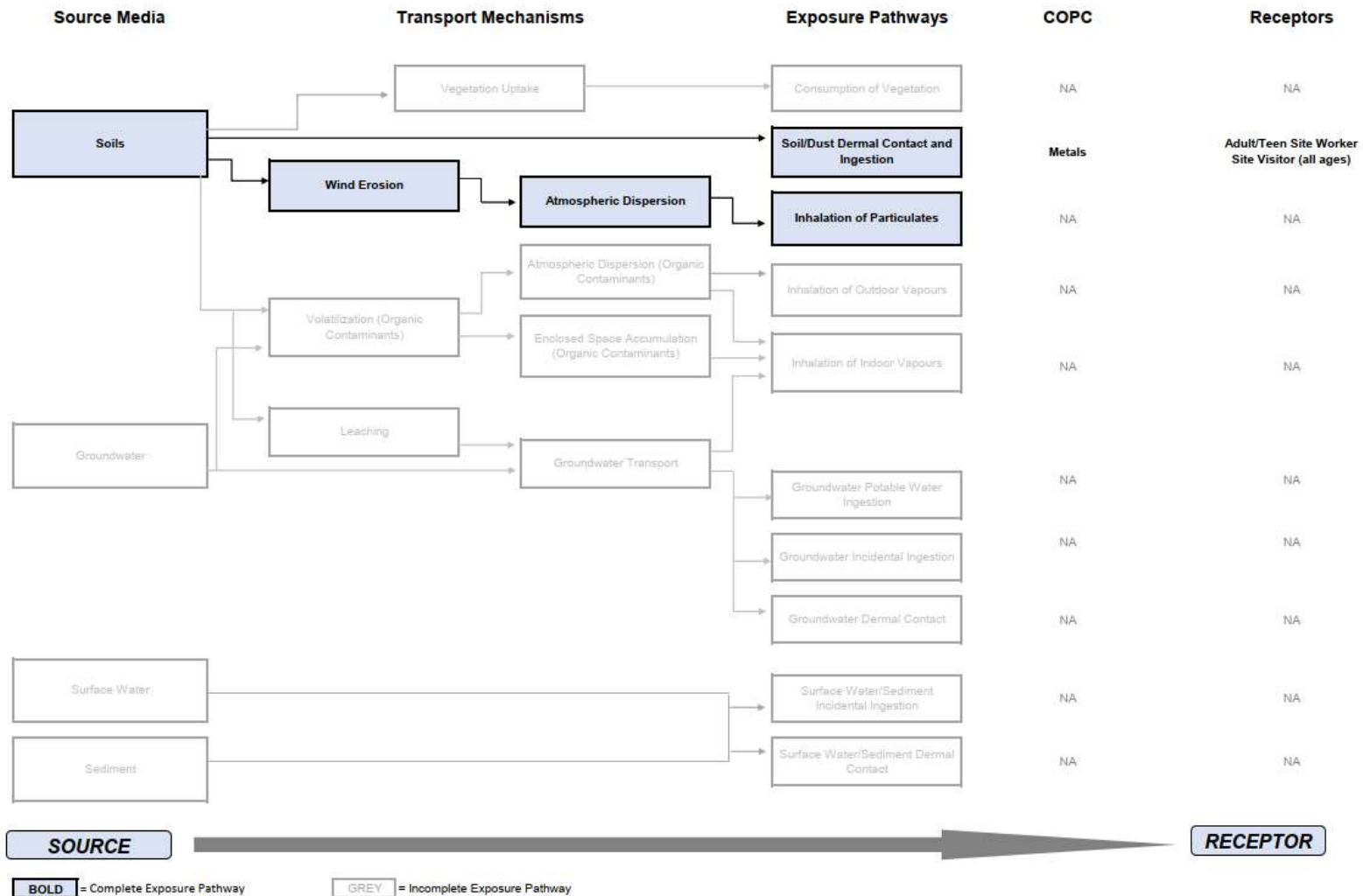
*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



Figure 4-1: Conceptual Site Model for Soils for Human Receptors for the Lake Enon Former Mill Site, Enon, Nova Scotia



## 5.0

## Ecological Risk Assessment Framework

An Ecological Risk Assessment (ERA) evaluates potential effects on non-human (ecological) organisms, populations or communities in response to human-induced stressors. The framework and methods used for the ERA Problem Formulation component, as well as other components of an ERA for the Lake Enon Former Mill Site should it be completed in the future, are described in this section and its associated subsections.

## 5.1

### ERA Goals, Approach, and Scope

In many ERA frameworks, it is common to establish management and assessment goals for the ERA of a given site. The FCSAP ERA guidance (FCSAP, 2012a) defines a site management goal as the “overall planning objective for a site”, which provides a statement about the “desired condition of an ecosystem, or its components, within the context of current or future site use.” The site management goal for this ERA Problem Formulation was to determine whether or not soils at the Lake Enon Former Mill Site warrant risk management for the protection of ecological receptors that may occur on, or utilize the properties. The assessment goal for an ERA relates to the management goal. In the current ERA Problem Formulation, the assessment goal was to determine if there are potential ecological risks associated with current conditions at the site, and if so, determine what (if any) management or remedial action is needed to reduce environmental risks and liabilities.

The scope of this ERA Problem Formulation is limited to the terrestrial (i.e., soil) at the site. The scope of the Problem Formulation is also limited by the chemistry data that are currently available for the on-site media. The Problem Formulation does not evaluate or consider potential exposures and risks to ecological receptors that may occur on adjacent properties other than the site, nor does it consider the adjacent freshwater water bodies that could potentially be influenced by the current and historical activities at the site. Although the current scope of this study is limited to the Problem Formulation component of the ERA for soils only, the framework and associated methodologies for each step of a full ERA is provided below for context in the event that the Problem Formulation is incorporated into a full risk assessment in the future.

## 5.2

### ERA Steps

The Problem Formulation for the site was conducted in accordance with the NS CSRs and associated Ministerial Protocols, where relevant. In addition, the current ERA Problem Formulation considered widely accepted ecological risk assessment frameworks, methodologies and guidance published and endorsed by Environment Canada (e.g., CCME, 2020; the FCSAP ERA Guidance Document [2012a], and the US EPA [i.e., U.S. EPA, 1998]). Where necessary, consideration was also given to ERA guidance from other agencies and jurisdictions in Canada and internationally.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

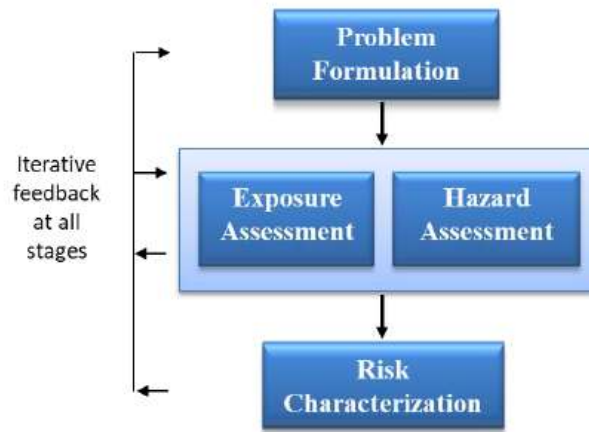
May 2023 - 22-3723



ERAs can involve various levels of detail, complexity and level of effort. The initial ERA framework developed by Environment Canada (CCME, 1996) reflected this in its tiered approach, where each successive tier is sequentially more detailed than the previous one, with assessment characteristics ranging from a simple, qualitative and literature-based approach for the first tier (often termed Screening Level Assessment) to complex, predictive and field-based approaches for the second and third tiers (often termed Preliminary Quantitative and Detailed Quantitative Assessments, respectively). While moving from one tier to the next increases the complexity and effort of the ERA, this is typically only required if the results of the previous tier indicate that a more complex and detailed assessment is warranted. The more recent ERA guidance endorsed by Environment Canada for use on federally contaminated sites (i.e., CCME, 2020; FCSAP, 2012a) does not categorize ERAs according to scope or level of detail/effort (e.g., screening-level versus detailed quantitative). Rather, this recent ERA guidance suggests that the level of detail and effort for an ERA is dependent on many factors and is often site- and assessment-specific. This guidance also recognizes that the level of detail and effort in an ERA may involve a combination of qualitative screening level and quantitative approaches, depending on the chemicals and receptors that are selected for assessment, as well as spatial and temporal factors or boundaries that are associated with the ERA.

In general, if the use of conservative assumptions related to both chemical exposure and toxicity to ecological receptors (as would be commonplace in an initial tier of an ERA) indicates a low potential for ecological risks, there is typically a high degree of confidence in this finding, such that areas and/or receptors with a low risk potential may be excluded from further investigation. However, in situations where the initial tier of an ERA indicates an elevated potential for ecological risk, or identifies key data gaps that preclude the completion of an ERA, further data collection is typically required and/or more detailed ERA approaches are typically applied (i.e., those that are less conservative but more realistic or site-specific).

The specific steps used to conduct an ERA are based on CCME (2020) and FCSAP (2012a) guidance as illustrated on **Figure 5-1**.



**Figure 5-1: Ecological Risk Assessment Steps (from CCME, 2020; FCSAP, 2012a)**

Each step of an ERA is briefly described in the following sections.

### 5.2.1 Problem Formulation

The problem formulation step of an ERA is analogous to that described above for the HHRA and acts as an information-gathering and interpretation stage, which serves to plan and focus the approach of the ERA on the most critical aspects of the site being evaluated. The outcomes of the problem formulation step form the basis of the approach taken in the ERA. These outcomes can also help identify key data gaps that may limit aspects of the ERA, and/or lead to developing sampling and analytical plan development, and determine whether or not there is a need to further evaluate certain areas of a site, receptor types, exposure pathways, and/or site-related chemicals.

There are several elements or tasks that typically comprise the problem formulation step in an ERA, including:

- Site characterization and review of existing site information;
- Review regulatory context;
- Establish the objectives, goals, and level of effort of the ERA;
- Selection of study boundary and reference areas;
- Identify receptors of concern;
- Identify assessment and measurement endpoints;
- Develop lines of evidence (LOE);
- Identify exposure pathways;
- Identify COCs; and
- Develop a CSM for the ERA.

Additional details of some of the steps of the problem formulation are provided in the following sections.

## 5.2.1.1

### Identification of Receptors of Concern

A receptor of concern (ROC) is any non-human individual, species, population, community, habitat or ecosystem that is potentially exposed to COCs (FCSAP, 2012a). Consideration of potential ROCs for an ERA is site-specific and must reflect an understanding of the specific ecological attributes of the site being investigated. For example, sites that offer limited or no habitat or food resources for ecological receptors likely do not merit an ERA study. Identification of ROCs is not limited to those that only occur on the site of interest, but also considers receptors that may utilize the site for foraging, breeding, nesting, resting and other aspects of their life history.

For an ERA, it is neither practical nor necessary to assess each and every species that may potentially occupy or utilize a site. Instead, it is common practice to identify a selected subset of species as the ROCs for the assessment. There are many considerations when identifying ROCs for an ERA, which include the following:

- General site characteristics (e.g., surface coverings, habitat types present, observed species) as determined from environmental site investigations;
- Representation from the various trophic levels, habitats, and feeding guilds that are appropriate for the site;
- Behavioural and physiological characteristics that would increase or decrease the potential for chemical exposure (e.g., diet and habitat preferences, feeding behaviour, home/foraging /breeding ranges, mobility, or body weights); for example, species that are highly omnivorous are rarely selected as receptors in an ERA as it is much more difficult (due to high variability and uncertainty) to estimate the exposure such species may incur from food items, relative to species that are primarily in one feeding guild, such as herbivore, granivore, insectivore / invertevore, or carnivore;
- Habitat quality, suitability, and preferences for receptors that may occur on or utilize a site (e.g., does the site meet habitat requirements or preferences for receptors of interest?);
- Likely percentage of time spent within potentially impacted areas of a site and fraction of diet obtained from within these areas;
- Whether species of interest are resident biota or migratory (and other seasonal factors, such as species that may hibernate);
- The availability of biological data describing receptor characteristics, life history and behaviour;
- The physical-chemical, environmental fate/behaviour, and toxicological properties of COCs (such as persistence and potential to bioaccumulate and/or biomagnify in terrestrial and/or aquatic food webs; known sensitivity of certain wildlife species to certain chemicals);
- Availability of reliable ecotoxicological data for the receptor or receptor group;
- Availability of appropriate measurement endpoints for the ROC;
- Availability of regional and local habitat surveys or species inventories;

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



- Potential or documented presence of species that are at risk (e.g., listed as rare or endangered), or have some similar status within provincial jurisdictions);
- Socioeconomic considerations (e.g., commercial importance of a species, level of value to humans; recognized as a pest or vermin);
- Availability of information from local experts and residents of the area or surrounding properties;
- Potential presence of domestic animals (e.g., livestock, cats, dogs); domestic animals may have different protection goals or biological endpoints of interest than wildlife, and the presence of domestic animals may serve as key ecological stressors for wildlife species that may occur on a given site;
- A site visit to visually confirm habitat types, exposure pathways, and the potential for certain wildlife species to occur on or utilize the site; and
- Professional judgement.

The key outcome of the ROC identification step is the consideration of relevant receptor types that could potentially be included in the ERA, along with rationale or justification for why certain receptor types are included or excluded from the ERA. This is often presented as a tabular or matrix format. Ideally, the ROCs selected for an ERA will be those that occur on the site (or would be expected to utilize the site on a regular basis), have a high exposure potential to COPCs in site media, and/or have a known sensitivity to one or more COPCs. When the selected ROCs meet these general conditions, the likelihood for the occurrence of adverse effects in less exposed or less sensitive receptors would be lower than for the assessed receptors.

The level of biological organization at which a ROC is evaluated in an ERA is an important concept that links closely with ecological protection goals for the ROCs. For lower trophic levels, such as vegetation and soil and sediment invertebrates and pelagic aquatic life (e.g., fish, invertebrates), the level of biological organization that is evaluated in an ERA is generally community level (FCSAP, 2012a; Suter et al., 2000). The community level is also considered the relevant level of biological organization when a receptor group has limited ecotoxicity data available (e.g., amphibians and reptiles). For higher trophic level receptors (such as birds and mammals), the ROCs are usually evaluated at the population level of biological organization. The individual organism level of biological organization is typically evaluated in an ERA only if the ROCs are rare, threatened, or endangered species (FCSAP, 2012a; Suter et al., 2000). Thus, for most ROCs that are assessed at contaminated sites, the relevant level of biological organization is either community or population. The ecological protection goals for ROCs are the same in that the goal of an ERA is to protect most ROCs at the population or community level (unless there is evidence that the ROCs being evaluated are rare, threatened or endangered, or listed as “species at risk” under SARA). As such, in most contaminated site ERAs, the focus is not on protecting individual organisms or even groups of individuals (such as breeding pairs) that may occur on, or utilize a site. Rather, the ecological protection goal is focused on maintenance of local populations of the ROC (or its surrogate), or maintenance of community ecological structure and function.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



## 5.2.1.2

**Selection of Assessment and Measurement Endpoints and Lines of Evidence**

An assessment endpoint is defined as an explicit expression of what is to be protected, defined by an ecological entity (i.e., receptor or receptor group) and by a characteristic (Suter, 1989; US EPA, 1998; FCSAP, 2012a). The characteristic is a specific attribute or property for the receptor that is important to protect, and which is potentially at risk (e.g., abundance, survival). As noted previously, the ecological entity (or receptor) can be defined at different levels of biological organization. An assessment endpoint must include a receptor (or receptor group) and a specific property or attribute of that receptor (FCSAP, 2012a). Assessment endpoints are quite similar to protection goals with the only notable difference being that the former describes the environmental attribute of interest, whereas the latter articulates the desired state of that attribute (FCSAP, 2012a). It is common practice in ERA that assessment endpoints do not express a direction or desired state (such as: increased, decreased, healthy, or sustainable).

Assessment endpoints may or may not be directly measurable (US EPA, 1998). For example, the abundance of song birds may be assessed directly if avian surveys have been conducted, but would have to be assessed indirectly if survey outcomes are not available. If assessment endpoints are not directly measurable (which is not uncommon due to practical reasons), then other measures, called “measurement endpoints”, may be used to evaluate the risk related to the assessment endpoints.

A measurement endpoint is considered to be any measure of exposure or effects for a ROC or any measure of change in the attribute of an assessment endpoint (FCSAP, 2012a). Measurement endpoints form the LOE that are used to estimate risks in an ERA. Measurement endpoints and LOEs are developed at the same time. Similar definitions of measurement endpoints have been provided by others. For example, Suter II (1990) defined measurement endpoints as responses to a chemical stressor that can be measured and quantified. CCME (1996) defines measurement endpoints as “the effects on an ecological component that can be measured and described in some quantitative fashion.”

A key consideration in the selection of measurement endpoints is how well a given measurement endpoint represents an assessment endpoint, and its ecological relevance. The greater the strength of association between the measurement and assessment endpoint, the greater the weight that is given to that measurement endpoint in the overall ERA, so long as the measurement endpoint is considered ecologically relevant.

FCSAP (2012a) defines LOE as any pairing of exposure and effects measures (or measurement endpoints) that provide evidence for the evaluation of a specific assessment endpoint. It is not uncommon for a LOE to involve the use of more than one measurement endpoint.

Essentially, measurement endpoints are tools, and LOEs are the way that these tools are used and applied in the ERA. LOEs are directly related to both measurement endpoints and assessment endpoints.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



Four main categories of LOE are described in FCSAP (2012a), as follows:

- **Site-specific toxicological evidence** – Considers measurement endpoints related to studies of test organism exposures to contaminated site media under controlled conditions;
- **Indirect toxicology evidence** – Considers toxicological information obtained from other sites, or the literature, assuming that the concentration-response relationships between sites are similar;
- **Site-specific biological evidence** – Considers direct assessment of the site biological conditions; and
- **Indirect biological evidence** – Considers indirect assessment of biology, through extrapolation of knowledge obtained at other sites and from the literature.

### 5.2.1.3 Exposure Pathway Identification

If there are no possible exposure pathways that link ROC to COC that are present in site media, there can be no potential for adverse effects from those chemicals. Therefore, it is important for any ERA to identify the major exposure pathways (means by which an ecological receptor comes into contact with a chemical in an environmental medium) and exposure routes (the means by which a chemical enters the body from the environmental medium) for each of the selected/identified ROCs.

### 5.2.1.4 Identification of COPCs

The goal of COC selection is to identify those chemicals measured in site/property media that may pose a potential risk to ecological health.

It is common practice in ERAs to limit the number of chemicals evaluated to those that represent the greatest potential concern to ecological receptors that may be present in the area under consideration. This is done because it is often impractical in terms of time and cost to conduct a risk assessment for every chemical that has been found at measurable concentrations in a particular area. In addition, the concentrations of many chemicals associated with a particular site may be similar to chemical concentrations found naturally in the area rather than the result of predicted, current or former anthropogenic activities at the site. It is also preferable to comprehensively evaluate a smaller number of chemicals that represent the greatest potential concern, than it is to conduct a less detailed risk assessment on a larger number of chemicals that are of lesser potential concern.

In the context of an ERA, the COC selection process is designed such that if no health risks are predicted for the chemicals evaluated, then no health risks would be expected for any of the chemicals not included in the initial evaluation (e.g., those that are present at lower concentrations in site media, those that have a lower toxic potency, those that are emitted/released at lower rates, etc.). If a large degree of risk is predicted for those chemicals initially evaluated, then additional chemicals (from the list that was not evaluated) can be added back into the ERA for evaluation, if deemed necessary. Thus, the COC selection process is iterative, and is designed to reasonably ensure that no contaminants of potential concern are overlooked.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



### 5.2.1.5 Conceptual Site Model for Ecological Receptors

The ERA CSM for ecological receptors provides a simplified representation of potential exposure pathways and routes that link the identified COCs in site environmental media to the ecological receptors of interest.

### 5.2.2 Exposure Assessment

The exposure assessment step of an ERA involves estimating the amount (quantity) of chemicals that are received by ecological receptors.

Exposure can be calculated using quantitative approaches (e.g., where exposures for a specific receptor are estimated using models and a variety of receptor input parameters), or can be assessed qualitatively (e.g., where exposures are assumed to equal measured concentrations in environmental media). The latter method likely overestimates potential exposure as it ignores an organisms' natural barriers to chemical uptake (i.e., bioavailability considerations), and biochemical transformation processes that may occur within cells, tissues and organs, which may reduce the actual dose that reaches a target site within an organism.

The degree of exposure of ecological receptors to chemicals in the environment depends on the interactions of a number of parameters, including:

- The concentration of chemicals in various environmental media (e.g., water, soil, food) as determined by the quantities of chemicals entering the environment from various sources, their persistence in these media, and the normal ambient, or background concentrations that exist independent of a specific source.
- The various exposure pathways for the transfer of the chemicals from the different environmental media to ecological receptors (e.g., inhalation of soil particles and dusts; ingestion of food items, water, soils/dusts).
- The physiological and behavioural characteristics of ecological receptors that determine the actual exposures through interactions with the various pathways (e.g., rates of respiration, water intake, food intake, soils/dusts intake, energy utilization).
- The various physical, chemical, and biological factors that determine the ability of the ecological receptors to take the chemicals into their bodies from the exposure pathways (e.g., bioavailability of the chemicals from soil/dust particles, foods, water and air).

### 5.2.3 Effects Assessment

The effects assessment (also commonly referred to as the hazard or toxicity assessment) step of ERA evaluates the potential for chemical exposure to elicit an adverse effect, or a toxic response, in the ROCs. The toxicity of a chemical depends on the amount taken into an organism or its tissues and the duration of the exposure (i.e., the length of time the receptor is exposed to the chemical). Analogous to the HHRA and humans, for every chemical, there is an exposure level or dose, and a duration of

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



exposure, which is necessary to produce a toxic effect in the ROCs (this is referred to as the exposure–response or dose-response relationship). TRVs can be expressed in different ways depending on the COC (and its properties), and the receptor or receptor group. Many TRVs are expressed as a dose (e.g., mg/kg body weight/day) and are commonly used to evaluate risks to mammalian and avian receptors via ingestion-based exposure pathways (and occasionally dermal and inhalation-based pathways).

It is important to recognize that when/if ecological TRVs are exceeded by estimated exposures, it does not necessarily imply that there is a risk of adverse ecological effects. Rather, it suggests that further evaluation or consideration of additional lines of evidence may be warranted before reaching final conclusions on the potential for ecological risk.

#### 5.2.4 Risk Characterization

In an ERA, the risk characterization step is the process by which the probability of adverse ecological effects (based on the information obtained from the exposure and effects assessments for each LOE), is integrated and interpreted in the context of the overall potential for ecological risk (FCSAP, 2012a). The risk characterization step also serves to translate the complex scientific information that comprises the previous steps of the ERA process into a format that is useful, unambiguous and understandable for risk managers. Another key element of risk characterization in an ERA is to acknowledge, evaluate, and/or discuss the major strengths, limitations, conservative assumptions and uncertainties arising from the information used to estimate exposure and potential risk to the ROCs (FCSAP, 2012a; CCME, 1996).

The risk characterization of ROCs in the ERA utilized a simple qualitative weight of evidence (WOE) approach. FCSAP (2012a) defines a WOE approach as “any process used to aggregate information from different lines of scientific evidence to render a conclusion regarding the probability and magnitude of harm.” This definition encompasses a wide range of potential techniques and practices, ranging from those that are qualitative, and/or based on professional judgment, to those that involve complex quantitative and/or statistical methods. The type of WOE approach used generally reflects the scale/scope, the level of effort, and the numbers and types of LOE considered in the ERA. Irrespective of how the WOE approach is conducted, key principles are transparency, clarity, consistency, and reasonableness (FCSAP, 2012a).

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



## 6.0

## ERA Problem Formulation Outcomes

The Lake Enon Former Mill Site Problem Formulation outcomes are provided in the following sections.

## 6.1

### Site Habitat Characterization

Site characterization information specifically relevant for the ERA are provided below, while additional aspects of the site's history and site characterization have been previously presented in **Section 2.0** of this report. Photos of the site and the surrounding ecological habitat can be found in **Appendix B**.

While the former mine property is approximately 141 ha, the study boundary focuses on a total area of approximately 46 ha within the former mine site. As described in the Phase II ESA (Dillon, 2022), the study boundary is generally covered with rock and limited soil. There is limited vegetation in central areas of the study boundary, although trees and shrubs are noted intermittently and around the study boundary. Given that most of the study area is essentially a deforested, empty gravel area, it likely offers little productive ecological habitat. Areas of the former mill property but outside of the study boundary are generally heavily forested .

The site is located immediately adjacent to Lake Enon, which is identified as an ecological habitat of potential concern since it is within 200 m of the site (Atlantic RBCA, 2012). Lake Enon is a potential ecological receptor due to the potential for surface water runoff and groundwater flow to carry contaminants into the lake, and the potential transportation of soil dusts into the lake via wind and precipitation. Although the current Problem Formulation was limited in scope to terrestrial media on site (i.e., soil), further investigations into Lake Enon as an ecological receptor are recommended and discussed in **Section 7**.

There are no freshwater bodies on the site that can support aquatic life and no aquatic life were observed while onsite. The scope of the current ERA is limited to terrestrial media (i.e., soil) on site, and therefore other environmental media were not considered; however, this is considered to be a data gap and should be assessed in the future as discussed in **Section 6.11**. No wildlife was observed during the field program. The site plan is illustrated in **Figure 2 (Appendix A)**. Photos of the site are provided in **Appendix B**.

## 6.2

### Regulatory Context

With respect to the regulatory context for the ERA Problem Formulation, the site is located on land owned by the NSDNRR, and as the NS PSS for commercial soils were preferentially applied . The PSS are benchmarks developed by source agencies and departments outside of Nova Scotia such as the CCME, AEP and MECP . Where no NS PSS was identified, other provincial or federal regulatory benchmarks

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



were used, where available. In the absence of Canadian guidelines, the US EPA EcoSSL (ecological soil screening levels) were applied.

For a number of regulatory jurisdictions, ecological soil quality benchmarks have been derived for specific receptor types such as terrestrial vegetation, soil invertebrates, mammals and birds. In these cases, the lowest benchmark provided was selected for COPC identification purposes.

The site and surrounding land may provide some habitat for resident and transitory wildlife and limited native fauna; however, the site provides limited habitat for ecological receptors as it mostly consists of deforested land and gravel areas (Dillon, 2022b). Based on this, and the reasonably anticipated future site uses, the most appropriate land use for selecting applicable guidelines for the ERA was determined to be commercial. As such, the COPC screening was conducted using commercial guidelines for ecological health.

### 6.3 Selection of Site Boundaries and Reference Areas

The spatial boundary for the current ERA is the northern, southern, and western property boundary and the study area boundary along the southeastern portion of the property (i.e., approximately 46 ha; see **Figure 2, Appendix A**).

As part of the Phase II ESA (Dillon, 2022b), forty-one (41) soil samples, including three (3) blind duplicate samples, were collected at depths ranging from 0 to 3.05 m and submitted for metals analysis, including free cyanide, total cyanide, and mercury. Due to the size of the study area (i.e., approximately 46 hectares), multiple potential areas of contamination (i.e., 12 APECs and surrounding areas), and limited surface soil data at the time, Dillon personnel collected an additional forty-four (44) soil samples as part of supplemental ESA that were also used in the Problem Formulation, including three (3) blind field duplicates (0 to 3 m depth) through a supplemental site investigations over multiple days in October and December, 2022. In addition, thirteen (13) background (reference) soil samples, including one blind field duplicate (0 to 0.25 m depth) were collected and analyzed for metals at locations adjacent to, but outside of, the study boundary and expected area of potential impact between the Phase II ESA and the supplemental site investigation. Sample locations are presented on **Figure 3 (Appendix A)**. Site photographs are presented in **Appendix B**.

### 6.4 Species at Risk (SAR) Assessment

A Species at Risk (SAR) assessment was not completed under the current scope; however, NSDNRR provided some information on potential SAR which was considered herein .

The common nighthawk (*Chordeiles minor*), listed as Special Concern under Schedule 1, is known to inhabit the area in the vicinity of the site (Government of Canada, 2021) and areas within and adjacent to the site have been identified by NSDNRR as potential nighthawk nesting habitat. Common

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



Nighthawks are known to nest in open and vegetation-free habitats between early June and late July and lay their eggs on the ground (Government of Canada, 2021; Maritime Breeding Atlas, 2022). Some examples of nesting habitat are dunes, beaches, recently harvested forests, burnt-over areas, logged areas, rocky outcrops, rocky barrens, grasslands, and marshes (Government of Canada, 2021). During the 2022 field program, accommodations were made by Dillon to avoid the nesting period of the common nighthawk in Region C3 (all of Cape Breton) that ends in late August.

Although portions of the site comprise potential habitat for the common nighthawk, this species feeds on flying insects so their exposure to site contamination would be expected to be limited given the available habitat, food resources, and typical home range of this species (up to 259 ha; Ng, 2009). However, there is uncertainty associated with other potential SAR species on or near the site; therefore, a SAR assessment is recommended to support a future risk assessment for the site, particularly in the wet marsh-like areas of the site.

## 6.5 Identification of Receptors of Concern

The selection of ROC considers site characteristics in addition to the size. While the total area of the property is approximately 141 ha, the study boundary is approximately 46 ha, and there is little habitat for ecological receptors within the study boundary. The study boundary is shown on **Figure 2 (Appendix A)**. Given that soil contamination on the site has not been fully delineated, there is some uncertainty in how far the contamination extends into areas that may have suitable habitat for ecological receptors. As such, receptors were conservatively selected assuming there is suitable habitat in the vicinity of the contamination. These receptors can be refined once the site is further delineated.

To identify ROCs for the site, a number of information sources were reviewed and considered including:

- Previous environmental reports (e.g., Dillon 2022a and 2022b as well as historical reports);
- FCSAP (2012b) Ecological Risk Assessment Guidance Module C: Standardization of Wildlife Receptor Characteristics. This document suggests a number of candidate receptors for Canadian federally owned sites;
- Specific guidance related to spatial and habitat quality considerations for ERA (i.e., ASTM, 2014; 2016); and
- Information gathered during fieldwork on the site and obtained through on-line searches regarding wildlife species that would be expected to be within the study boundary.

The ecological receptors and receptor groups that were considered for selection as receptors for the ERA Problem Formulation, along with rationale for their inclusion/exclusion are provided in **Table 6-1**. Among the rationale for inclusion or exclusion of ecological receptors is the presence or absence of operable exposure pathways by which receptors could come into contact with COPCs in soil. While the selection of exposure pathways is typically its own item within the Problem Formulation step of ERA, it is only conducted for ROCs that have been deemed to merit inclusion in the ERA. Furthermore, receptor and exposure pathway selection are linked processes that influence each other and it is commonplace

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



for exposure pathway considerations to be a factor in deciding whether or not certain ecological receptors should be selected for evaluation in an ERA.

Surrogate receptor species are also provided in **Table 6-1**, where relevant. As noted in FCSAP (2012a), surrogate receptor species are used to represent particular feeding guilds or ecological niches, and are selected based on many of the same considerations used to identify ecological ROCs (as noted above).

**Table 6-1: Ecological Receptors Selected for or Excluded from Evaluation in the ERA**

Receptor Groups	Include/ Exclude	Surrogate Species for Receptor Group (if included)	Rationale for Inclusion/Exclusion
Terrestrial Vegetation	Include	Not applicable; assessed at the community level	Terrestrial vegetation has been observed on the site during fieldwork conducted in 2022 (see <b>Appendix B: Site Photos</b> ). COPCs in soil may enter vegetation via root uptake and potentially via the pathway of volatilization from soil and subsequent foliar uptake of vapour phase COPCs. Terrestrial vegetation on the site may be consumed by herbivorous wildlife. Terrestrial vegetation is not mobile and most species have limited strategies to avoid root contact with contaminated soil. Thus, these organisms have a high exposure potential to COPCs in soil and were selected as ROC.
Soil Invertebrates	Include	Not applicable; assessed at the community level	Soil invertebrates would be expected to inhabit the site based on physical characteristics. Soil invertebrates (such as earthworms and arthropods) have a key role in soil development and nutrient cycling and are a major food item for many wildlife species. Soil invertebrates are in constant direct contact with soil, are largely immobile, and some species directly consume soil. Thus, these organisms have a high exposure potential to COPCs in soil.
Herbivorous Small Mammals	Include	Meadow vole ( <i>Microtus pennsylvanicus</i> )	Small herbivorous mammals such as the snowshoe hare and woodchucks are some of the herbivorous mammals that are found in Nova Scotia and could possibly be found on the site (Government of Nova Scotia, 2021). Herbivorous small mammals have a high potential to be exposed to COPCs in soil due to burrowing behaviour, ground-foraging of vegetation and seeds, and generally small home ranges.  The site is large relative to the home and foraging range sizes of small mammal herbivores, such that the entire home/foraging ranges could occur within the study area boundaries (e.g., meadow vole – 0.0069 ha to 0.348 ha;

Nova Scotia Lands Inc.

Human Health and Ecological Risk Assessment Problem Formulation (Final)

Lake Enon Former Mill Site, Enon, Nova Scotia

PID Nos. 15551369, 15340045, and 15340052

May 2023 - 22-3723



Receptor Groups	Include/ Exclude	Surrogate Species for Receptor Group (if included)	Rationale for Inclusion/Exclusion
			<p>snowshoe hare – 1.6 ha; FCSAP, 2012b). Small herbivorous mammals could be exposed to COPCs via the consumption of vegetation and incidental soil ingestion. As such, this receptor group was selected as a ROC.</p> <p>The meadow vole was selected as the surrogate species for this receptor group as it occurs in Nova Scotia and would have relatively high exposures due to its small home range.</p>
Insectivorous or Invertevorous Small Mammals	Include	Masked shrew ( <i>Sorex cinereus</i> )	<p>Insectivorous/invertevorous small mammals such as the star-nosed mole and the deer mouse are some of the insectivorous/invertevorous mammals that are found in Nova Scotia and could possibly be in the area (Government of Nova Scotia, 2021). Insectivorous/invertevorous small mammals have a high potential to be exposed to COCs in soil due to their burrowing behaviour, consumption of soil dwelling organisms (soil invertebrates) and generally small home ranges. The site is large relative to the home and foraging range sizes of small mammal insectivores/invertevores, such that entire home/foraging ranges could occur within the assessment boundaries. While much of the habitat that makes up the APECs and immediate surrounding areas would not be considered suitable (e.g., extremely wet areas, piles of waste rock, concrete pad), there are areas that would be suitable habitat for insectivorous small mammals and the site would provide food resources for some of these receptors.</p> <p>Insectivorous and invertevorous small mammals such as the masked shrew are found in Nova Scotia (NatureServe, 2023). As such, this receptor group was included as a ROC.</p>
Herbivorous Birds	Include	Ruffed Grouse ( <i>Bonasa umbellus</i> )	<p>Herbivorous birds such as the ruffed grouse and spruce grouse have been reported to occur in Nova Scotia (Nova Scotia Bird Society, 2023). While herbivorous birds tend to have moderately large home/foraging ranges, the size of the site encompasses the home/foraging range sizes, some areas of the site could contain habitat and food resources for herbivorous birds. This, it is possible that herbivorous birds occur/forage on the site where they would be exposed to COPCs via the consumption of vegetation and incidental soil ingestion.</p> <p>The ruffed grouse was selected as a surrogate for this</p>

Nova Scotia Lands Inc.

Human Health and Ecological Risk Assessment Problem Formulation (Final)

Lake Enon Former Mill Site, Enon, Nova Scotia

PID Nos. 15551369, 15340045, and 15340052

May 2023 - 22-3723



Receptor Groups	Include/ Exclude	Surrogate Species for Receptor Group (if included)	Rationale for Inclusion/Exclusion
			receptor group given that it occurs in Nova Scotia (NatureServe, 2023).
<b>Insectivorous/ Invertevorous Birds</b>	<b>Include</b>	<b>American Robin (<i>Turdus migratorius</i>)</b>	<p>Insectivorous/invertevorous birds have a high potential to be exposed to COPCs in contaminated soils due to their typical ground foraging behaviour in relation to the consumption of soil dwelling organisms (soil invertebrates) and generally small home/foraging ranges. The site is large relative to the home and foraging range sizes of most small bird insectivores/invertevores, however there is limited habitat and food resources within the study boundary. Although there is limited habitat and food resources for these receptors, it is likely they could forage in some parts of the site. Therefore insectivorous/invertevorous birds were selected for assessment.</p> <p>The American robin was selected as a surrogate for this receptor group as it has been reported to occur across Nova Scotia (Natural Resources and Renewables, 2023; online).</p>
<b>Carnivorous Small Mammals</b>	<b>Include</b>	<b>Ermine (<i>Mustela erminea</i>)</b>	<p>Carnivorous small mammals, such as red fox and ermines, could occur on site and be potentially exposed to COCs via the ingestion of prey items that occur or forage on the site, and via incidental soil ingestion from the site. Prey items on the site would consist primarily of herbivorous small mammals and birds. The site is within the same size range as the home and foraging range sizes of most small bird insectivores/invertevores; however, there is limited habitat within the study area given much of it is gravel and tailings with little vegetation. The extent of contamination on the site has not been fully delineated. As such, the areas of impact could extend further into areas with more suitable habitat and more plentiful food resources. As such, carnivorous small mammals were conservatively assumed to occur/forage on the site, where they could be exposed to COPCs via the consumption of small mammals and soil (incidentally), and were selected as receptors.</p> <p>The ermine was selected as a surrogate species for this receptor group as it has been reported to occur in Nova Scotia (Natural Resources and Renewables, 2023; online).</p>

Nova Scotia Lands Inc.

Human Health and Ecological Risk Assessment Problem Formulation (Final)

Lake Enon Former Mill Site, Enon, Nova Scotia

PID Nos. 15551369, 15340045, and 15340052

May 2023 - 22-3723



Receptor Groups	Include/ Exclude	Surrogate Species for Receptor Group (if included)	Rationale for Inclusion/Exclusion
Freshwater Pelagic and Benthic Aquatic Life	Include (not evaluated under current project scope)	Not applicable (to be assessed as a community)	No freshwater aquatic habitat is present on the site. However, Lake Enon is adjacent to the site and what appeared to be mine tailings were noted within the lake. It is assumed pelagic and benthic freshwater life could be present in Lake Enon and could be exposed to contaminants that originated from the site. Freshwater aquatic life is carried forward as a receptor. However, given the current scope of work was to address exposures via soil, aquatic receptors were included as ROC, but not evaluated in the current problem formulation. These receptors can be further evaluated as part of an ERA for the site. In addition, when sediment samples were being collected as part of the Phase II ESA (Dillon, 2022); some samples appeared to be tailings and no sediment was located. There is uncertainty in aquatic habitat in the vicinity of the site. As such, a benthic habitat assessment should be conducted to determine if benthic species are expected to be present in areas potentially impacted by the site. If benthic habitat is noted, a benthic community assessment could aid in identifying if the health of the benthic communities in Lake Enon close to the site are different from those that are further away.
Amphibians	Include (not evaluated under current project scope)	Not applicable (to be assessed as a community)	Amphibians are commonly regarded as being among the more highly exposed and sensitive receptors to contaminants in environmental media, due to various aspects of their life history, dietary preferences, and physiology. Parts of the site are more marsh like and could potentially offer habitat to amphibian species. Amphibians can also be exposed via potentially impacted sediments or surface waters in Lake Enon. Amphibians were therefore carried forward as a receptor. However, given the current scope of work was to address exposures via soil only, amphibians were included as ROC, but not evaluated in the current problem formulation. These receptors can be further evaluated as part of an ERA for the site. Given uncertainty in potential habitat for these receptors, a habitat survey of potential amphibian habitat should be conducted.

Receptor Groups	Include/ Exclude	Surrogate Species for Receptor Group (if included)	Rationale for Inclusion/Exclusion
Reptiles	Exclude		<p>Terrestrial reptile species could potentially be on the site. Reptiles are commonly regarded as being among the more highly exposed and sensitive receptors to contaminants in environmental media, due to various aspects of their life history, dietary preferences, and physiology. However, the availability of reliable or relevant toxicity data for these receptors is essentially non-existent at this time for most substances. This paucity of suitable toxicity data precludes the assessment of reptiles in most ERA studies. As such, reptiles were not included for assessment.</p>
Soil Microorganisms	Exclude		<p>While soil microorganisms play key roles in nutrient cycling within soils (as they are primary consumers of organic matter and convert soil nutrients into forms that are available for uptake by plants and higher trophic level organisms), their inclusion as ROCs in an ERA is problematic, even though there are some soil quality benchmarks utilize nutrient cycling parameters as the biological endpoints.</p> <p>There is high spatial and temporal variability in soils with respect to microbial community composition and tolerance to most contaminants. Reliable toxicity data are extremely limited and exposure-response relationships are unclear for most contaminants, especially those that can be utilized by certain microbial species as energy sources, or terminal electron receptors in respiration. There are limited tools and approaches that reliably determine microbial exposure and responses to chemical stressors.</p> <p>The ecological relevance of microbial responses to contaminants is questionable, given the often high rates of functional redundancy in soil microbial communities. Basic understanding of microbial community structure and function in soils is limited. Given these considerations, soil microorganisms were excluded as ROCs.</p>

Receptor Groups	Include/ Exclude	Surrogate Species for Receptor Group (if included)	Rationale for Inclusion/Exclusion
Herbivorous Large Mammals	Exclude		<p>Herbivorous large mammals such as deer and moose could occur within the site, but would not be anticipated to occur within the study boundary to any large degree due to the limited habitat and food resources within the APECs. Given the large home range of large herbivorous mammals (e.g., white-tailed deer home range of 30 ha; moose home range of 460 ha; FCSAP, 2012), and their large body weights (relative to other herbivores), the exposure potential to COPCs for these receptors is likely limited, especially given that the site has minimal vegetation in some areas.</p> <p>While exposure routes for this receptor group were not selected for evaluation (i.e., direct soil contact / soil ingestion and vegetation ingestion), the evaluation of these pathways for small mammal herbivores adequately captures potential worst case COPC exposures for large mammals. Small mammals have much smaller body weights and home/foraging range sizes than large mammals and would therefore incur much higher exposures and potential risks to site COPCs.</p>
Carnivorous Large Mammals	Exclude		<p>While large carnivorous mammals occur in Nova Scotia, and possibly within the vicinity of the site, the amount of time they would spend within the study boundary would be expected to be limited. Large carnivorous mammals have large home ranges: for example, the coyote (home range reported to be approximately 2000 ha in Nova Scotia) and the bobcat (home range 100 ha to 10,000 ha) (NatureServe Explorer, 2023). While these species could be exposed to site chemicals via ingestion of prey from the site, given the limited food resources within the study boundary, the large home ranges and body weights of carnivorous large mammals, their exposure potential to COPCs in media and biota at the site are likely very limited. As such, carnivorous large mammals were excluded as ROCs.</p>

Receptor Groups	Include/ Exclude	Surrogate Species for Receptor Group (if included)	Rationale for Inclusion/Exclusion
Carnivorous Birds	Exclude		Carnivorous birds may be exposed to COPCs via the ingestion of prey items that occur or forage on the site, and incidental soil ingestion. The prey items on the site would consist primarily of herbivorous and/or insectivorous/ inverteverous small mammals (and birds). However, the exposure potential to COPCs in site media and biota is very limited given the lack of habitat and food resources within the study boundary, in addition to the very large home/foraging range sizes which are considerably larger than the site. As such, carnivorous birds were excluded as ROCs.
Marine Pelagic and Benthic Aquatic Life	Exclude		Marine surface water and aquatic receptors are not located on or near the site; thus, this receptor group was excluded as ROCs.
Waterfowl and Piscivorous Wildlife (bird and mammal piscivores)	Exclude		No waterfowl or piscivores were observed on the site during the Phase II assessment (Dillon, 2022). The site does not offer food resources or habitat that would enable or encourage the presence of these avian receptors on the site. As such, this receptor group was excluded as ROCs.
Species at Risk (or other rare, threatened or endangered species)	Exclude		<p>As discussed in <b>Section 6.4</b>, a SAR assessment was not conducted for the site under the current scope of work. Although the likely home ranges of potential mammal and bird SAR species and the expected diets of those species, potential chemical exposures to SAR on the site are expected to be low. In addition, there is limited habitat available on the site for these receptor groups.</p> <p>As such, SAR were excluded as ROC in the current assessment; however, it is recommended that a SAR assessment is conducted for the site in the future to reduce the uncertainty associated with SAR use of the site.</p>

**Note:**

Receptors to be refined once contamination on the site is delineated.

### 6.5.1 Further Considerations Regarding Potential ROCs

Further considerations regarding potential ROCs for the site are briefly described and discussed in the following subsections.

#### Size of Site and Potential Habitat

The spatial scale of impacts at a given contaminated site can be useful in determining if potentially significant exposure conditions exist for ecological receptors, and for determining if risk estimates are ecologically significant (US EPA, 1997; 1998; 1994; ASTM, 2014; MCP, 1996). Ideally, spatial scale issues are discussed at the onset of the ERA process. This can allow small sized sites that may not require ERA, to be excluded early in the ERA process, such that resources are not needlessly allocated to the assessment of these sites. ASTM (2014) states that the space or size of a contaminated site is directly related to the potential for ecological receptors to be exposed. Consideration of spatial scale can help focus an ERA on the issues or receptors of greatest ecological relevance, and/or provide a basis for determining that an ERA for a given site is not necessary for some or all receptors of interest. Similarly, the FCSAP (2012a) guidance identifies home range size, habitat suitability, and off-site habitat characteristics as factors that can affect the degree of exposures to Site receptors.

ASTM (2014) suggests that for terrestrial environments (or sites), ecological habitat areas of less than two acres (equivalent to approximately 0.81 ha) are commonly considered too small to require an ERA, so long as there are no site-specific issues of special concern. While it is noted that sites of < 2 acres may contain foraging or breeding areas for individual small mammals, birds, and herpetofauna (amphibians and reptiles), this spatial scale does not usually support local populations of such wildlife species; and these sites would not require an ERA in most cases. Vegetation and soil invertebrates are typically excluded from this criterion, as there can be populations or communities of these receptors on sites < 2 acres in size, as long as the habitat and soil conditions are suitable. ASTM (2014) also notes that site coverings and surface features (such as foundations, pavement, gravel, concrete, fences, walls) are important to account for, as they limit the size of the habitat and foraging areas for various receptors. The site has a total area of roughly approximately 46 ha which is above the ASTM (2014) spatial criterion of 0.81 ha, indicating the site may be large enough support local populations of mammalian and avian receptors. This, however, does not consider the available habitat and food resources on the site, which are rather limited in many areas (i.e., within and surrounding APECs) as much of the study boundary is covered with rock and has limited soil, and there is limited vegetation in the central areas of the site although trees and shrubs are noted intermittently and around the site boundary. In addition, in some areas of the site there is the presence of extremely wet ground wherein mostly aquatic plants (such as cattails) grow (see **Section 2.1**).

#### Consideration of Habitat Quality and Habitat Preferences

ASTM (2016) provides guidance on using habitat quality and preference information as a means of determining if an ERA of a site is warranted. This guidance defines “habitat” as the combination of physical (landscape) and biological features preferred by a particular species. ASTM (2016) states that

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



consideration of landscape features to characterize habitat quality can enhance the ecological relevance of an ERA, and avoid conducting ERAs on sites or in areas where wildlife species would be absent (or limited) because of a lack of suitable habitat. ASTM (2016) further notes that even if the habitat is determined to be suitable for certain ecological receptors, other factors such as limited food resources, predation, or human disturbances may override the apparent habitat quality for a given receptor, such that its exposure to contaminants in site media and biota would be minimal. Because the foraging behaviour/time and occurrence of receptors on a site is directly related to habitat suitability, the exposure potential to contaminants in site media is also directly related to the suitability of the site's habitat for a given receptor. ERAs should only be conducted for sites where ecological receptors occur, or would likely occur. If receptors are not present, or are unlikely to be present because of poor habitat quality or suitability, then an ERA of those receptors is not warranted.

Other habitat-related considerations suggested by ASTM (2016) include the following:

- Consider the size of the site relative to receptor home/foraging/breeding range requirements; and
- Consider the site habitat quality relative to habitat quality on adjacent or surrounding sites. If a site's habitat quality is approximately equal to that of the site surroundings, the proportion of time that an animal will spend on the site will likely be proportional to the surrounding sites, and bounded by the size of the animal's home range. If the habitat on the site is of lower or higher quality than the surrounding sites, then an animal is likely to spend proportionally less or more of its time on the site.

To further explore these concepts in relation to the site, information was sourced on habitat preferences, and home, foraging, and breeding range size for the selected ROCs. Review of habitat preferences for these ROCs shows that the site has some conditions and ecological features that are consistent with their preferred habitat types (e.g., forested areas and open grassy fields); however, many areas of the site likely associated with the most contamination (i.e., within and immediately surrounding APECs) provide little to no suitable habitat for ROC due to the presence of waste rock piles and/or exposed rock, no vegetation. Thus, it can be concluded that the site offers some suitable habitat conditions for various common mammal and avian receptors. As such, it is possible that local populations of these receptors could utilize the site for foraging, nesting, breeding, and other activities. This conclusion is generally supported by conducting  $N_s$  calculations for these receptors (where  $N_s$  is the number of individuals of a given receptor species that are likely to inhabit any habitat subdivision on a site), as presented in ASTM (2016). The  $N_s$  calculation is similar to the common Area Use Factor (AUF) calculation that is sometimes used in ERAs. One form of this calculation is as follows (some alternate means of determining  $N_s$  are also provided in ASTM, 2016).

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



$$N_s = \frac{A_s}{HR_s}$$

**Where:**

- $N_s$  = the number of individuals likely to inhabit the habitat subdivision on a site and incur potential exposures to COPCs from site media.
- $A_s$  = the area of the habitat subdivision (or portions of the site with potential habitat or foraging areas). In this case, the habitat subdivision of interest is vegetated areas of the site which were assumed to be the area of the entire site of approximately 46 ha.
- $HR_s$  = the approximate home/foraging range size of the receptor (ha); based on literature regarding lowest reported home range sizes.

To examine whether the site could support populations of the mammalian ROC being examined,  $N_s$  values were calculated for the ROC in addition to other typical avian and mammalian species evaluated in ERA.  $N_s$  calculations for the receptors selected as ROC are presented below (**Table 6-2**). For all receptor species, the smallest identified  $HR_s$  value was taken from the FCSAP ERA guidance documentation (i.e., FCSAP, 2012b) or other resources if no FCSAP value was available. The  $A_s$  value used was approximately 46 ha which is the entire area within the study boundary.

**Table 6-2: Estimated  $N_s$  Values for Selected Ecological Receptors at the Lake Enon Former Mill Site, Enon, Nova Scotia**

Receptor	$A_s$	$HR_s$	$N_s$
Meadow vole	46	0.348 ha	132
Masked shrew		0.6 ha	77
Ruffed grouse		1 ha	46
Ermine		1 ha	46
Snowshoe hare		1.6 ha	29
White-tailed deer		30 ha	2
Black bear		300 ha	<1

**Notes:**

Home ranges from FCSAP, 2012b unless otherwise noted. The smallest home ranges provided were used for the  $N_s$  calculation with the exception of the meadow vole. The lowest home range for the meadow vole of 0.0069 ha would apply only if the habitat quality and food resources are exceptional, which they would not be on the site due to limited habitat and food resources. As such, the home range of 0.348 ha (FCSAP, 2012b) was used.

<sup>1</sup>Home range from NatureServe Explorer (<https://explorer.natureserve.org/>)

While there is no set  $N_s$  value that represents the presence of a population for each receptor, the  $N_s$  values in **Table 6-2** suggest that a few individuals to potentially populations of receptors with smaller home ranges may occur on site. The  $N_s$  scores were calculated based on the total area of the site within the study boundary which is approximately 46 ha. If the areas of limited habitat and food resources

available on the site are considered (e.g., within and immediately surrounding APECs), the  $N_s$  scores for each receptor would be lower, and thus these estimations are considered to be conservative. While the  $N_s$  calculation is not without uncertainty and does not account for literature reports of actual measured population density and territoriality considerations, it provides a reasonable and often conservative indication of the numbers of individual organisms that may be expected to use a habitat subdivision on a given site. For the Lake Enon Former Mill Site, these  $N_s$  values would be considered conservative given the limited habitat/food resources on the site. As such, it would be unrealistic to assume that ROC presence and foraging occurs extensively on the site, but not on the various adjacent areas that have equally suitable (or better) habitat conditions and food availability. For example, the site consists of areas with little to no terrestrial vegetation (e.g., rocks piles and tailings ponds) whereas adjacent areas to the site are mostly forested with more preferable vegetation for the ROC selected herein.

There is nothing to distinguish the site from other areas as offering unique or preferred habitat or food resources for any known ecological receptor population or community. In fact, areas outside of the study boundary would offer better habitat and food resources than the habitat within the study boundary. The calculated  $N_s$  scores support that the use of the site by mammalian and avian receptors could potentially include populations. However, the  $N_s$  scores were calculated based on the total site area and did not exclude areas within the study boundary where there is no available habitat and / or limited food resources. Given much of the study boundary is covered with rock and has limited soil, and limited vegetation and other food resources, it is unlikely that populations could be supported within the study boundary. While it is unlikely that populations can be supported within the study boundary, given the site has not yet been fully delineated, better habitat exists outside the study boundary, the selected receptors were conservatively carried forward further in the problem formulation.

### 6.5.2 Summary of ROC Selection

Based on the ROC selection procedure and related considerations described in the preceding sections, the receptors/receptor groups in **Table 6-3** were identified as ROCs that warranted further evaluation in the ERA Problem Formulation.

**Table 6-3: Receptors of Concern (ROC) Selected for Evaluation**

ROC	Surrogate	Comment
Terrestrial vegetation	NA	Assessed at the community level
Soil invertebrates	NA	Assessed at the community level
Herbivorous small mammals	Meadow vole	Assessed at the population level
Insectivorous/Invertevorous small mammals	Masked shrew	Assessed at the population level
Herbivorous birds	Ruffed grouse	Assessed at the population level
Insectivorous/Invertevorous birds	American Robin	Assessed at the population level

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



ROC	Surrogate	Comment
Carnivorous small mammals	Ermine	Assessed at the population level
Amphibians	NA	Not assessed herein, but to be considered in a full ERA
Freshwater aquatic life	NA	Not assessed herein, but to be considered in a full ERA

**Notes:**

NA = not applicable

## 6.6

## Selection of Assessment and Measurement Endpoints and Lines of Evidence

Specific assessment and measurement endpoints and LOE were identified for the ROC that were selected for evaluation in the ERA Problem Formulation, presented in **Table 6-4**:

**Table 6-4: Assessment and Measurement Endpoints and Lines of Evidence for the Selected ROCs**

Receptor of Concern (ROC)	Assessment Endpoint	Measurement Endpoints	Lines of Evidence (LOE)
Terrestrial vegetation	Survival, growth, and reproduction of vegetation communities	<p>Concentrations of chemicals in site soil and reference areas.</p> <p>Vegetation health-based soil quality benchmarks.</p> <p>Qualitative site survey of vegetation types and apparent health and similarity to surrounding sites.</p>	<p>Outcomes of the comparison of site soil chemical concentrations to vegetation health-based soil quality benchmarks and reference areas.</p> <p>Comparison of vegetation on site to vegetation present in the surrounding area.</p> <p>Outcomes of visual vegetation observations.</p>
Soil invertebrates	Survival and reproduction of soil invertebrate communities	<p>Concentrations of chemicals in site soil and reference areas.</p> <p>Soil invertebrate health-based soil quality benchmarks.</p>	Outcomes of the comparison of site soil chemical concentrations to soil invertebrate health-based soil quality benchmarks and reference areas.

Nova Scotia Lands Inc.

Human Health and Ecological Risk Assessment Problem Formulation (Final)

Lake Enon Former Mill Site, Enon, Nova Scotia

PID Nos. 15551369, 15340045, and 15340052

May 2023 - 22-3723



Receptor of Concern (ROC)	Assessment Endpoint	Measurement Endpoints	Lines of Evidence (LOE)
<p>Herbivorous small mammals (surrogate: meadow vole)</p>	<p>Survival, growth, reproduction, and abundance of populations</p>	<p>Concentrations of chemicals in site soils and reference areas.</p> <p>Mammalian health-based soil quality benchmarks.</p> <p>Modeled exposure and risk estimates for COCs in food items and soil.</p> <p>Applicable mammalian toxicity reference values (TRVs).</p> <p>Spatial size and habitat quality/preference considerations for the site.</p> <p>N<sub>s</sub> (the number of individuals of a given receptor species that are likely to inhabit any habitat subdivision on a site) values estimated for the site.</p>	<p>Outcomes of the comparison of site soil chemical concentrations to mammalian health-based soil quality benchmarks.</p> <p>Comparisons between estimated COC exposures and TRVs (i.e., ecological hazard quotients).</p> <p>Comparison of site spatial size to ASTM spatial criteria for ERA; comparison of receptor habitat preferences to site habitat conditions and habitat quality.</p> <p>Interpretation of N<sub>s</sub> values with respect to likelihood for populations or individuals to utilize or occur on the site.</p>
<p>Insectivorous or invertevorous small mammals (surrogate: masked shrew)</p>	<p>Survival, growth, reproduction, and abundance of populations</p>	<p>Concentrations of chemicals in site soils and reference areas.</p> <p>Mammalian health-based soil quality benchmarks.</p> <p>Modeled exposure and risk estimates for COCs in food items and soil.</p> <p>Applicable mammalian toxicity reference values (TRVs).</p> <p>Spatial size and habitat quality/preference considerations for the site.</p> <p>N<sub>s</sub> (the number of individuals of a given receptor species that are likely to inhabit any habitat subdivision on a site) values estimated for the site.</p>	<p>Outcomes of the comparison of site soil chemical concentrations to mammalian health-based soil quality benchmarks.</p> <p>Comparisons between estimated COC exposures and TRVs (i.e., ecological hazard quotients).</p> <p>Comparison of site spatial size to ASTM spatial criteria for ERA; comparison of receptor habitat preferences to site habitat conditions and habitat quality.</p> <p>Interpretation of N<sub>s</sub> values with respect to likelihood for populations or individuals to utilize or occur on the site.</p>



Receptor of Concern (ROC)	Assessment Endpoint	Measurement Endpoints	Lines of Evidence (LOE)
Herbivorous birds (surrogate: ruffed grouse)	Survival, growth, reproduction, and abundance of populations	<p>Concentrations of chemicals in site soils and reference areas. Avian health-based soil quality benchmarks. Modeled exposure and risk estimates for COCs in food items and soil.</p> <p>Applicable avian toxicity reference values (TRVs).</p> <p>Spatial size and habitat quality/preference considerations for the site.</p> <p><math>N_s</math> (the number of individuals of a given receptor species that are likely to inhabit any habitat subdivision on a site) values estimated for the site.</p>	<p>Outcomes of the comparison of site soil chemical concentrations to avian health-based soil quality benchmarks.</p> <p>Comparisons between estimated COC exposures and TRVs (i.e., ecological hazard quotients).</p> <p>Comparison of site spatial size to ASTM spatial criteria for ERA; comparison of receptor habitat preferences to site habitat conditions and habitat quality.</p> <p>Interpretation of <math>N_s</math> values with respect to likelihood for populations or individuals to utilize or occur on the site.</p>
Insectivorous or invertevorous birds (surrogate: American robin)	Survival, growth, reproduction, and abundance of populations	<p>Concentrations of chemicals in site soils and reference areas. Avian health-based soil quality benchmarks. Modeled exposure and risk estimates for COCs in food items and soil.</p> <p>Applicable avian toxicity reference values (TRVs).</p> <p>Spatial size and habitat quality/preference considerations for the site.</p> <p><math>N_s</math> (the number of individuals of a given receptor species that are likely to inhabit any habitat subdivision on a site) values estimated for the site.</p>	<p>Outcomes of the comparison of site soil chemical concentrations to avian health-based soil quality benchmarks.</p> <p>Comparisons between estimated COC exposures and TRVs (i.e., ecological hazard quotients).</p> <p>Comparison of site spatial size to ASTM spatial criteria for ERA; comparison of receptor habitat preferences to site habitat conditions and habitat quality.</p> <p>Interpretation of <math>N_s</math> values with respect to likelihood for populations or individuals to utilize or occur on the site.</p>

Receptor of Concern (ROC)	Assessment Endpoint	Measurement Endpoints	Lines of Evidence (LOE)
Carnivorous small mammals (surrogate: ermine)	Survival, growth, reproduction, and abundance of populations	<p>Concentrations of chemicals in site soils and reference areas. Mammalian health-based soil quality benchmarks. Modeled exposure and risk estimates for COCs in food items and soil.</p> <p>Applicable mammalian toxicity reference values (TRVs).</p> <p>Spatial size and habitat quality/preference considerations for the site.</p> <p><math>N_s</math> (the number of individuals of a given receptor species that are likely to inhabit any habitat subdivision on a site) values estimated for the site.</p>	<p>Outcomes of the comparison of site soil chemical concentrations to mammalian health-based soil quality benchmarks.</p> <p>Comparisons between estimated COC exposures and TRVs (i.e., ecological hazard quotients).</p> <p>Comparison of site spatial size to ASTM spatial criteria for ERA; comparison of receptor habitat preferences to site habitat conditions and habitat quality.</p> <p>Interpretation of <math>N_s</math> values with respect to likelihood for populations or individuals to utilize or occur on the site.</p>
Freshwater Aquatic Life *	Survival, growth, reproduction, and abundance of populations.	<p>Concentrations of chemicals in Site sediment and surface water.</p> <p>Freshwater aquatic life health-based groundwater quality benchmarks.</p>	<p>Outcomes of the comparison of Site sediment and surface water to freshwater aquatic life health-based groundwater benchmarks.</p>
Amphibians *	Survival, growth, reproduction, and abundance of populations.	<p>Concentrations of chemicals in Site surface water and sediments.</p> <p>Amphibian toxicity data. Spatial size and habitat quality/preference considerations for the subject property.</p>	<p>Comparison of amphibian toxicity data to site concentrations.</p> <p>Comparison spatial size and habitat quality to surrounding areas, comparison of receptor habitat preferences to subject property habitat conditions and habitat quality.</p>

**Notes:**

In the ERA context, the definition of a “population” can vary, and as such, very few ERA guidance documents define this term. FCSAP (2012a) states the following “From a pure biology perspective, an ecological population is defined as a group of organisms of a single species that interbreed and share a common habitat.” From a risk assessment perspective, however, this definition is too broad. Setting numerical limits on the number of individuals that comprise a population is inherently difficult and would vary greatly depending on the receptor species and its life history characteristics.

\* Receptor not evaluated in the current problem formulation as it was outside the scope of the assessment.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



The abundance of a species could be affected directly (i.e., as a result of direct toxicity of COCs on survival, growth or reproduction), or indirectly (e.g., as a result of decreased habitat suitability or reduced prey/food abundance) as a result of toxicity to food or prey items and other site activities that may affect habitat and presence of food resources. This ERA Problem Formulation focuses on potential health effects as a result of direct chemical exposures.

## 6.7 Exposure Pathway Identification

For the ROCs selected for evaluation in the current ERA Problem Formulation, the following information on exposure pathways applies. Exposure pathways and routes for each receptor group are summarized in **Table 6-5**.

**Table 6-5: Summary of exposure pathways and routes selected for the ROCs.**

Receptor Group	Surrogate	Exposure Pathway and Route
Terrestrial vegetation	NA	<ul style="list-style-type: none"> <li>• Direct contact with soils</li> <li>• Root uptake</li> </ul>
Soil invertebrates	NA	<ul style="list-style-type: none"> <li>• Direct soil ingestion</li> <li>• Direct contact with dermal coverings or integument</li> </ul>
Herbivorous small mammals	Meadow vole	<ul style="list-style-type: none"> <li>• Soil ingestion</li> <li>• Vegetation ingestion</li> </ul>
Insectivorous or invertevorous small mammals	Masked shrew	<ul style="list-style-type: none"> <li>• Soil ingestion</li> <li>• Ingestion of soil invertebrates</li> </ul>
Herbivorous birds	Ruffed grouse	<ul style="list-style-type: none"> <li>• Soil ingestion</li> <li>• Vegetation ingestion</li> </ul>
Insectivorous or invertivores birds	American robin	<ul style="list-style-type: none"> <li>• Soil ingestion</li> <li>• Ingestion of soil invertebrates</li> </ul>
Carnivorous small mammals	Ermine	<ul style="list-style-type: none"> <li>• Soil ingestion</li> <li>• Ingestion of prey</li> </ul>
Freshwater Aquatic Life*	NA	<ul style="list-style-type: none"> <li>• Direct contact with sediment</li> <li>• Direct contact with surface water</li> </ul>
Amphibians *	NA	<ul style="list-style-type: none"> <li>• Soil and sediment ingestion</li> <li>• Direct contact with soil, sediments and surface water</li> <li>• Ingestion of aquatic and terrestrial foods</li> </ul>

**Notes:**

\* Receptor not evaluated in the current problem formulation as it was outside the scope of the assessment. Exposures pathways included for future reference.

NA = not applicable.

### 6.7.1 Terrestrial Vegetation and Soil Invertebrates

- Exposure of terrestrial plants to chemicals in soil is controlled by the root distribution in the soil profile, physicochemical characteristics of the soil (which determines the forms of the chemicals and their phytoavailability) and by interactions of the chemicals of interest with other chemicals present in soil (Suter II, 2007).
- Exposure of soil invertebrates to chemicals in soil is determined by depth of burrowing, the rate, and quantity of soil material ingested, activity patterns, soil physical-chemical characteristics, and interactions of the chemicals of interest with other chemicals in soil (Suter II, 2007).
- The main exposure pathways and routes evaluated for terrestrial vegetation and soil invertebrates included were direct soil contact pathways, which include direct contact with the dermal coverings or integument of invertebrates, direct soil ingestion by invertebrates, and root uptake by plants.

### 6.7.2 Birds and Mammals

- For avian and mammalian receptors, it is common ERA practice to evaluate only those pathways that relate to the oral route of exposure (such as consumption of food/prey items, drinking water ingestion, incidental soil, and sediment ingestion). Not only is the oral route the most commonly assessed exposure route in ERAs by far, but it is also almost always the dominant route that drives site-specific exposures and risks to ecological receptors at most sites.
- Dermal and inhalation exposure pathways rarely require evaluation in ERAs (FCSAP, 2012a, SABCS, 2008; U.S. EPA, 2003). This is considered to be the case in the current ERA Problem Formulation as well, given that the ROC have fur that would limit dermal contact of the COPC with skin, and given that the potential for significant soil/dust resuspension in local ambient air is low at the site for much of the year due to snow cover or frozen ground in the winter.
- For the current Problem Formulation, it was assumed that herbivorous small mammalian ROC are exposed to COCs in site soil via direct soil contact (soil ingestion) as well as the ingestion of vegetation.
- For many small mammals, and many birds, it is common not to consume water from surface water bodies, but rather, to obtain the majority of their water requirements from puddles or droplets on vegetation surfaces, as well as from the consumption of food. Many small mammals and many bird species obtain their water requirements from consumed food items, wherein their physiological water needs are met via the metabolism of ingested food. For the small mammals and birds expected to be on the site, surface water ingestion would not be expected to be a pathway of concern.
- The main exposure pathways and routes evaluated for herbivorous small mammals and birds were soil ingestion and ingestion of vegetation;
- The main exposure pathways and routes evaluated for insectivorous/invertevorous small mammals and birds were soil ingestion and ingestion of soil invertebrates; and
- The main exposure pathways and routes evaluated for carnivorous mammals were soil ingestion and ingestion of prey.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



**Freshwater Aquatic Life:**

The main routes and pathways by which these receptors may be potentially exposed to COPCs would include: direct contact of gills and other respiratory surfaces with water and sediments, sediment and water ingestion (including sediment pore water for benthos), and ingestion of aquatic prey species and other food items (i.e., detritus, plants, phytoplankton, zooplankton, macroinvertebrate fauna, and fish can all be food items for aquatic organisms depending on the number of trophic levels and aquatic food web structure). Sediment ingestion and pore water ingestion is more prevalent for bottom-dwelling or bottom-feeding species (Schoof, 2003). Aquatic plants are typically exposed to chemicals through root uptake of substances present in sediments and sediment pore water, and surface water uptake. For benthic species, the relative importance of whole (or bulk) sediment versus pore water exposures depends on the individual species, and their feeding and burrowing behaviour. For example, pore water exposure may be insignificant to invertebrates that ingest sediment particles, but may be an important exposure pathway for benthic organisms that burrow, and/or obtain their food by filter feeding.

**Amphibians:**

Amphibians have a complex life history and can live in either aquatic or terrestrial habitats depending on life stage. As such, the evaluation of exposure pathways for amphibians is complicated. Generally, during embryo and larval life stages, amphibian exposures are primarily aquatic, while during juvenile and adult stages, exposures are primarily terrestrial. The main exposure pathways associated with life stages in the terrestrial areas of the Site would include soil ingestion and direct contact and ingestion of terrestrial foods, while exposures in aquatic areas would include direct contact with sediment and surface water, incidental ingestion of soil/sediments and ingestion of aquatic foods.

With respect to the assessment and measurement endpoints and LOEs noted in **Table 6-5** and the exposure pathways and routes selected for the ROC, there were some inherent conservative assumptions within the ERA Problem Formulation that must be acknowledged. It is assumed that the ROC forage entirely in areas of the site that contain impacted soils and that their diet consists entirely of food from within the study boundary. While these are typical assumptions for an ERA of a contaminated site, they are considered highly unrealistic and conservative, particularly given the limited habitat and food resources on the site.

In summary, the following exposure pathways and routes were assessed for the selected ROCs.

- Terrestrial vegetation: direct contact with soils; root uptake.
- Soil invertebrates: direct contact with dermal coverings or integument; direct soil ingestion.
- Herbivorous small mammals (meadow vole): soil ingestion, vegetation ingestion.
- Insectivorous or invertevorous small mammals (masked shrew): soil ingestion and ingestion of soil invertebrates.
- Herbivorous birds (ruffed grouse): soil ingestion, vegetation ingestion.
- Insectivorous or invertevorous birds (American robin): soil ingestion, ingestion of invertebrates.
- Carnivorous small mammals (ermine): soil ingestion, ingestion of prey.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



- Freshwater aquatic life: direct contact with sediment / surface water.
- Amphibians: soil/sediment ingestion, direct contact with soil, sediments and surface water; ingestion of aquatic and terrestrial foods.

## 6.8 Identification of COPCs

Similar to the COC identification process for the HHRA, the identification of COCs for the ERA Problem Formulation also involved a sequential process, as follows. Details regarding the COC identification process for the Problem Formulation (including the soil quality data and statistics, benchmarks that were used, COC screening table and screening outcomes) are provided in the following sections. For the current Problem Formulation, COCs were only screened in site soils. Other relevant media should be screened for COCs as part of the ERA.

1. Comparison of the maximum measured concentrations of contaminants in site soil to applicable regulatory ecological health-based benchmarks and available background data;
2. Chemicals with a maximum concentration that exceeded the applicable ecological health-based benchmark and were above background concentrations, were identified as initial COPCs;
3. These initial COPCs were further evaluated by determining the frequency, magnitude, and spatial extent of relevant media exceedances from the site above the applicable receptor-specific ecological health-based benchmarks, where available. For mobile receptors (e.g., mammals and birds), the initial COPCs were further screened against a 90th percentile soil concentrations as per FCSAP (2012a); and
4. Further considerations (where/if deemed necessary and relevant), such as:
  - Essential nutrient status of certain inorganic elements;
  - Ubiquity of elements in soil, water or sediments;
  - Statistical relationships;
  - Local geology;
  - Spatial distribution of soil chemical concentrations;
  - Fate and behaviour properties (including potential to bioaccumulation and biomagnification); and
  - Speciation of chemicals in site media.
5. Final COCs are selected considering all other above, where relevant.

Soils would be the predominant source of exposures to terrestrial vegetation, soil invertebrates, herbivorous small mammals and birds, insectivorous/invertevorous small mammals and birds, and carnivorous mammals. For freshwater aquatic life, groundwater, surface water and sediments would be the predominant exposures sources. Given the current Problem Formulation focussed on contaminants in surface soils only, groundwater, surface water and sediments were not screened for COCs.

COC identification in site soils was guided by the following considerations:

- Substances that were non-detectable (below RDLs) in site soils were excluded from further consideration unless the RDL was above the applicable benchmark value.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



- All site soil data were considered, including field duplicate samples.
- Soil concentrations of analytes were assumed to be accessible for ecological receptor exposure regardless of location.
- The more conservative of coarse or fine-grained soil benchmarks were used based on the particle size analysis (Dillon, 2022).
- Chemicals having a maximum concentration which exceeded the applicable ecological benchmark value and available background data were retained for further assessment as COPCs. It is a general assumption in all risk assessment studies that there is a low to negligible likelihood for potential adverse effects when maximum media chemical concentrations are below such benchmarks. Media chemistry data that meets these conditions are typically considered to require no further evaluation or action.
- Chemicals without soil quality benchmarks were carried forward for further discussion.

The COC identification processes used are consistent with site and risk assessment procedures and help to distinguish natural occurring concentrations from those that have been influenced by anthropogenic activities.

It should also be recognized that published regulatory benchmarks are generic values, with no consideration given to site-specific populations/communities or media conditions that influence bioavailability. Also, they are developed by regulatory agencies to be intentionally conservative and protective. Exceedance of these values does not necessarily imply there is a risk of adverse effects; rather, it suggests that further evaluation is warranted (such as further ecological risk assessment or data collection).

The specific human health-based soil quality benchmarks that were considered in the COPC identification process are presented below. As the study area is located on land owned by Nova Scotia land, NS CSR guidelines apply and the NS PSS for commercial soils were preferentially used. The PSS were developed by source agencies and departments outside of Nova Scotia such as the CCME, AEP and MECP. Where no NS PSS was identified, other provincial or federal regulatory benchmarks were used, where available. In the absence of Canadian guidelines, the US EPA EcoSSL (ecological soil screening levels) were applied.

The benchmarks and background data that were applied in the screening are provided in the sections below and in **Appendix F**. Soil analytical data can be found in the screening tables therein, and laboratory certifications of analysis can be found in **Appendix C**.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



### 6.8.1 Determining Usability of Data

FCSAP (2012) states that all data in the top 1.5 m of soil should be considered relevant for screening COPCs for an ERA. However, soil depths greater than 0.3 m bgs are generally considered not to be available for direct contact or ingestion from ecological receptors (Anderson et al., 2010; Suter et al., 2000; Suter, 2007). Given some of the soils were wet and on ground that was marsh-like, it was assumed soil exposures could occur at deeper depths. As such, all soil samples collected within the top 1.5 m were screened against direct contact soil guidelines. Sample locations are presented on **Figure 3 (Appendix A)**. Site photographs are presented in **Appendix B**. All soil data used in the current assessment are presented in **Appendix F**.

### 6.8.2 Comparison of Site Data to Regulatory Ecological Health-Based Benchmarks

With respect to the regulatory context for the ERA Problem Formulation, the site is located on land owned by the NSDNRR, and as such the NS CSR guidelines apply. Atlantic RBCA has released Tier I EQS and Tier II PSS for soil, groundwater, surface water and sediment for use in the Atlantic Provinces. While the ecological health-based PSS for commercial soils were not found on the NS CSR website, these values have been adopted by the province. The PSS were developed by source agencies and departments outside of Nova Scotia such as the CCME, AEP and MECP. Where no NS PSS was identified, other provincial or federal regulatory benchmarks were used, where available. In the absence of Canadian guidelines, the US EPA EcoSSL (ecological soil screening levels) were applied. As previously noted, since the site is zoned as commercial, commercial land use guidelines were selected for screening purposes for the ERA.

For a number of regulatory jurisdictions, ecological soil quality benchmarks have been derived for specific receptor types such as terrestrial vegetation, soil invertebrates, mammals and birds. In these cases, the lowest benchmark provided was selected for COC identification purposes.

The specific regulatory ecological health-based soil quality benchmarks that were used to identify COPCs in site soil are briefly described below. Based on soil grain size data (Dillon, 2022), the site was considered to have coarse and fine-grained soils and as such, soil data were compared to the lower of coarse- and fine-grained soil guidelines, where applicable.

### 6.8.3 Soil Quality Guidelines

The specific source of the guideline used in the COPC screening are identified in the ecological health screening tables (**Tables F-1, Appendix F**).

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



## Ecological Health-Based Soil Quality Guidelines

### Atlantic-Based Corrective Action (ARBCA)

Atlantic RBCA Tier II PSS for soil for commercial land use, the lower of the soil contact and soil and food ingestion PSS were applied. These standards were selected for use in the Atlantic Provinces. Links to these PSS are provided on the NS CSR website. Except for petroleum hydrocarbons and select chlorinated volatile organic compounds (CVOCs), the ARBCA EQS/PSS values are adopted values that have been derived by CCME and other regulatory authorities in Canadian or international jurisdictions. For contaminants other than PHCs and CVOCs, the general hierarchy used to select EQS/PSS is outlined in the Environmental Quality Standards Rationale and Guidance Document (2021). The primary guidelines adopted by ARBCA, and thus applied herein, are provided below. Guidelines for commercial land use and coarse-grained soils were preferentially sourced from all jurisdictions, where applicable. The specific source of the guideline used in the COPC screening are identified in the ecological health screening tables (**Tables F-1, Appendix F**).

### Canadian Council of Ministers of the Environment (CCME)

Per ARBCA, the CCME Canadian soil quality guidelines developed for the protection of ecological health (SQG<sub>E</sub>), commercial land use (coarse soils), were preferentially applied. The lowest of the ecological soil contact or soil and food ingestion guidelines were used. Where the CCME soil guidelines defer to the older CCME (1991) soil remediation criteria (which are not identified as being either human or ecological health-based), the benchmarks from the next preferred jurisdiction were selected rather than using the outdated CCME (1991) value(s), where possible. If no other guideline was available from another jurisdiction, the CCME (1991) value was used. The most up to date CCME guidelines were selected from on the online CCME summary tables and associated fact sheets (<http://st-ts.ccme.ca/en/index.html>; searched February, 2022).

### Alberta Environment and Parks (AEP, 2019)

The lower of the direct soil contact, livestock soil and food ingestion, and wildlife soil and food ingestion ecological health-based soil guidelines for commercial land use and coarse-grained soils were applied. These AEP guidelines are developed in a very similar manner to, and are protective of, the same ecological receptor types as the CCME SQG<sub>E</sub>. Details on soil guideline basis and derivation are provided in AEP (2019).

### Ontario Ministry of the Environment, Conservation, and Parks (MECP, 2011)

The lowest of the relevant MECP ecological health-based soil component values (i.e., soil component values for plants and soil organisms, soil component values for mammals, and birds) were applied. The specific soil component values that were used are from Table 3 in MECP (2011), for conditions of non-potable water, institutional land use, and coarse-textured soils. The derivation of these values is described in MECP (2011).

### **Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



## 6.8.4

**Conservativeness of Ecological Soil Quality Benchmarks**

It is important to recognize that generic screening levels (such as the ecological health-based soil quality benchmarks noted above) are typically derived to be intentionally conservative and protective. Exceedances of these screening levels do not imply there is a risk of adverse ecological effects; rather, it suggests that further evaluation of those chemicals may be warranted. This is especially true for metals, many of which have essential nutritional and physiological roles in terrestrial biota. When interpreting screening level exceedances, it is also important to consider the body of literature regarding acclimation and adaptation of terrestrial organisms to metals and other substances in soil and/or food items. For example, it is well established that populations chronically exposed to metals often show an enhanced tolerance relative to populations with no, or lower exposure (Kapustka et al., 2004). This increased tolerance can be due to either acclimation (shifting of tolerance within the genetically defined limit of the organism) or adaptation (modification of the limits of an organism through changes in heritable genetic material) (ICMM, 2007). Increased metal/metalloid tolerance has been documented for many species of terrestrial and aquatic plants, animals, and microbes. For the most part, acclimation and/or adaptation have been demonstrated primarily at the population level, but studies of pollution-induced community tolerance have also documented these phenomena at the community level at various metals-contaminated sites. Acclimation and adaptation to metals is described further in Kapustka et al., (2004), ICMM (2007), Chapman (2008), and Newman and Clements (2008).

## 6.8.5

**Results of Ecological Health-Based Soil Screening**

Site soil screening results are provided in **Table 6-6**, and discussed in the following sections. Details of the ecological screening for site soil are provided in **Tables F-1 (Appendix F)** and **Table 6-7. Figures 6 and 7 (Appendix A)** show the locations of guideline exceedances for metals in soil. Results of the soil screening were used to identify COCs for terrestrial vegetation, soil invertebrates, and mammalian and avian ROC.

Chemicals that were not detected in any of the analyzed soil samples and were not associated with current and historical activities at the site, were excluded from further assessment. For metals antimony and boron were not detected in soil samples and were excluded from further assessment.

Although only metals were to be assessed under the current scope of work, soil data were also available for the following contaminant groups: PAHs, PHCs, VOCs, sVOCs, phenolics. Analytes in these contaminant groups were all non-detect with the exception of the analytes listed below, which were detected at low frequency and below their applicable ecological health-based guideline, where available. For completeness, the RDL for parameters with concentrations < the RDL were cross-referenced with the appropriate ecological-health based guideline, and all RDLs were below the applicable guideline; therefore, none of the non-detected parameters would screen on in the ERA Problem Formulation.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



Table 6-6: Ecological Screening (Soil COPC Identification) for the Lake Enon Former Mill Site

Chemical	Ecological Soil Quality Benchmark (mg/kg)	Maximum Background Concentration (mg/kg)	Maximum Measured Concentration (mg/kg)	Exceeds Guideline and Background? (Y/N)
<b>Metals</b>				
Aluminium	NGA <sup>d</sup>	38000	17000	N
Arsenic	26 <sup>a</sup>	6.2	15	N
Barium	2000 <sup>b</sup>	540	1100	N
Beryllium	8 <sup>b</sup>	1.6	2	N
Bismuth	NGA <sup>d</sup>	<2.0	2.9	N
<b>Cadmium</b>	<b>1.9</b> <sup>c</sup>	<b>2.6</b>	<b>21</b>	<b>Y</b>
Chromium (Total, III+VI)	87 <sup>a</sup>	21	34	N
<b>Cobalt</b>	<b>180</b> <sup>c</sup>	<b>10</b>	<b>270</b>	<b>Y</b>
<b>Copper</b>	<b>91</b> <sup>a</sup>	<b>29</b>	<b>120</b>	<b>Y</b>
Iron	NGA <sup>d</sup>	31,000	100000	N
<b>Lead</b>	<b>32</b> <sup>c</sup>	<b>160</b>	<b>30000</b>	<b>Y</b>
Manganese	NGA <sup>d</sup>	5000	6900	N
Mercury	20 <sup>c</sup>	0.56	0.35	N
Molybdenum	40 <sup>b</sup>	2.6	5.9	N
Nickel	89 <sup>a</sup>	16	69	N
Selenium	2.9 <sup>a</sup>	14	2.3	N
Rubidium	NGA <sup>d</sup>	29	18	N
Lithium	NGA <sup>d</sup>	41	29	N
Silver	40 <sup>b</sup>	1.3	4.3	N
<b>Strontium</b>	<b>NGA</b> <sup>d,e</sup>	<b>470</b>	<b>27000</b>	<b>N</b>
Thallium	3.6 <sup>a</sup>	0.42	0.52	N
Tin	300 <sup>b</sup>	1.6	5.5	N
Uranium	33 <sup>c</sup>	3.9	11	N
<b>Vanadium</b>	<b>18</b> <sup>c</sup>	<b>40</b>	<b>57</b>	<b>Y</b>
<b>Zinc</b>	<b>340</b> <sup>c</sup>	<b>340</b>	<b>3600</b>	<b>Y</b>

**Notes**

Where applicable, guidelines were taken from Atlantic RBCA Ecological Tier II Pathway-Specific Standards for Soil - Commercial/Industrial Land Use. The original source is indicated below.

- a Guideline is from CCME Factsheets. SQGE (soil quality guideline ecological health); commercial land use; lower of direct contact pathways; coarse soils.
  - b Alberta Environment Protection (2019) - Surface soil remediation guideline for Commercial/Industrial land use for direct contact pathway; Ecological; coarse grained soils.
  - c MECP (2011) Table 3 Soil Components - Full Depth, Non-Potable Water - Institutional land use; Coarse soils; Lowest of Mammals & Birds and Plants & Soil Organisms
  - d NGA indicates no guideline is available.
  - e Strontium was identified as a COPC and carried forward due to being detected at elevated concentrations and not having a guideline.
- BOLDED** values indicate concentrations above applicable guideline and background.  
 < = concentration was less than reportable detection limit (RDL), value provided is the RDL.

Nova Scotia Lands Inc.

Human Health and Ecological Risk Assessment Problem Formulation (Final)

Lake Enon Former Mill Site, Enon, Nova Scotia

PID Nos. 15551369, 15340045, and 15340052

May 2023 - 22-3723



Table 6-7: Comparison of Lake Enon Former Mill Site Soil Chemistry Data for Initial COPCs to Receptor-Specific Ecological Health-Based Soil Quality Benchmarks.

Chemical	Number of Samples	# Detectable Samples	Max Concentration (mg/kg)	90th Percentile (mg/kg) <sup>d</sup>	Background Range (mg/kg) <sup>c</sup>	Ecological Health-Based Soil Quality Benchmarks by Receptor Group (mg/kg)		Number of Samples Exceeding Ecological Soil Quality Benchmarks and Background		Frequency of Exceedance Over Ecological Soil Quality Benchmarks and Background (%)	
						Terrestrial Vegetation / Soil Organisms <sup>a</sup>	Birds / Mammals <sup>b</sup>	Terrestrial Vegetation / Soil Organisms <sup>a</sup>	Birds / Mammals <sup>b</sup>	Terrestrial Vegetation / Soil Organisms <sup>a</sup>	Birds / Mammals <sup>b</sup>
Cadmium	58	57	21	5.7	<0.3 - 2.6	22	<b>1.9</b>	0	28	0%	48%
Cobalt	58	58	270	11	<1.0 - 10	300 <sup>e</sup>	180	0	1	0%	2%
Copper	58	58	120	53	<2.0 - 29	<b>91</b>	3,100	3	0	5%	0%
Lead	69	69	30,000	6,200	7 - 160	<b>600</b>	<b>32</b>	26	56	38%	81%
Strontium	58	58	27,000	14,400	4 - 470	NGA	NGA	NA	NA	NA	NA
Vanadium	58	58	57	36	7.8 - 40	130	<b>18</b>	0	2	0%	3%
Zinc	58	58	3,600	870	<5.0 - 340	<b>450</b>	<b>340</b>	28	40	48%	69%

**Notes**

**Bold** indicates maximum concentration exceeded the vegetation / soil organism guideline and background range; and / or the 90th percentile exceeds the bird / mammal guideline or background range.

<sup>a</sup> CCME SoQG<sub>E</sub> soil contact guidelines unless otherwise noted; commercial land use; coarse-grained soil.

<sup>b</sup> MECP (2011) Table 3 Soil Components - Full Depth, Non-Potable Water - Institutional land use; Coarse soils; Lower of Mammals & Birds Soil Components.

<sup>c</sup> Range of 12 background soil samples; Dillon 2022.

<sup>d</sup> For 90th percentile calculations, non-detectable concentrations were assumed to equal the detection limit and the higher of a sample and its corresponding field duplicate were used in the calculation. Values rounded to 2 significant figures.

<sup>e</sup> Alberta Environment and Parks (2019) - Ecological direct soil contact; Commercial land use

The following parameters were detected in soil in at least one sample, but were below their applicable ecological-health based guideline, and were therefore excluded from further assessment. The only exception to this is modified TPH which is discussed below.

#### PHC F2 (>C10-C16)

- Frequency of detection: 1/13 samples
- Guideline (ARBCA, 2022): 260 mg/kg
- Maximum observed concentration: 17 mg/kg

#### PHC F3 (>C16-C34)

- Frequency of detection: 1/13 samples
- Guideline (ARBCA, 2022): 1,700 mg/kg
- Maximum observed concentration: 950 mg/kg

#### PHC F4 (>C34-C50)

- Frequency of detection: 1/13 samples
- Guideline (ARBCA, 2022): 3,300 mg/kg
- Maximum observed concentration: 510 mg/kg

#### Fluoranthene

- Frequency of detection: 1/23 samples
- Guideline (ARBCA, 2022): 180 mg/kg
- Maximum observed concentration: 0.06 mg/kg

#### Phenanthrene

- Frequency of detection: 2/23 samples
- Guideline (ARBCA, 2022): 12 mg/kg
- Maximum observed concentration: 0.031 mg/kg

#### Modified TPH

- Frequency of detection: 5/13 samples
- Guideline (ARBCA): 1,700 mg/kg<sup>a</sup>
- Maximum observed concentration: 2,600 mg/kg

<sup>a</sup>Guideline of 1,700 mg/kg is for the F3 fraction (>C16-C34), which corresponds most closely to the TPH resemblance reported by the laboratory in the current field program (likely lube oil fraction).

Although the maximum reported concentration of modified TPH of 2,600 mg/kg exceeds the ARBCA guideline of 1,700 mg/kg (for PHC F3 for coarse soils) by approximately 1.5-fold. The exceedance was only observed in one of the 13 samples collected, with the other samples being low in comparison (i.e., 21 to 44 mg/kg). In addition, PHCs are readily metabolized by vertebrates and do not accumulate in tissues. In addition, PHC are not readily absorbed into and accumulated into plants (CCME, 2008). Given these considerations, and the low frequency and degree of exceedance, modified TPH was not carried forward.

No ecological-health based soil quality benchmarks were available for the following parameters, but they were detected in at least one sample:

- 1-Methylnaphthalene (detected in 3 of 23 samples; max. concentration 0.05 mg/kg); and
- 2-Methylnaphthalene (detected in 4 of 23 samples; max. concentration 0.05 mg/kg).

Given that the majority of PAHs were not detected, and detectable concentrations of 1- and 2-methylnaphthalene were reported in only three and four samples, respectively, it is unlikely that these parameters would be of concern. Additionally, the US EPA EcoSSL for Low Molecular Weight PAHs (LMWPAHs) of 29 mg/kg for soil invertebrates and 100 mg/kg for mammals are at least two orders of magnitude higher than the highest observed concentrations of these parameters (0.020 and 0.04 mg/kg for 1- and 2-methylnaphthalene, respectively). Given that most PAHs were not detected, there is a negligible likelihood that the sum of LMWPAHs would exceed the guideline. Therefore, 1- and 2-methylnaphthalene were not carried forward for further assessment.

No guidelines were available for aluminum, bismuth, iron, manganese, rubidium, lithium, and strontium. For all but strontium, values reported at the site were within the range of or similar to background concentrations and therefore were not carried forward for further evaluation. Strontium was carried forward as it was elevated across the site relative to background concentrations and is expected to be related to previous site activities.

Only those chemicals with maximum site soil concentrations exceeding the applicable soil quality benchmark (or having no benchmark available) were considered as COPCs and evaluated further. Based on the comparisons presented in **Table 6-6** and **Appendix F; Table F-1**, the following chemicals were carried forward for further evaluation (on the basis of maximum site soil concentrations exceeding applicable ecological soil quality benchmarks and/or not having a guideline available; number of samples that exceed provided in parentheses):

#### Initial COPCs

- Cadmium (34 of 58);
- Cobalt (1 of 58);
- Copper (3 of 58);
- Lead (69 of 69);
- Strontium (NGA);
- Vanadium (39 of 58); and
- Zinc (40 of 58).

As previously mentioned, the ecological health-based benchmarks selected in the initial soil screening were the lowest available benchmark for any receptor. Chemicals with maximum concentrations in soil that exceeded these ecological benchmarks were identified as initial COPCs (**Table 6-6**). These COPCs were then carried forward for a receptor-specific secondary screening (i.e., separate screening conducted for soil invertebrates and vegetation, and mammals and avian ROC) (**Table 6-7**). The soil quality guidelines specific to vegetation and soil invertebrates for direct soil contact exposure pathways were compared to the maximum site soil chemical concentrations as these receptors are immobile. The soil quality guidelines specific to mammalian and avian receptors for soil and food ingestion exposure pathways, were compared to the 90<sup>th</sup> percentile site soil chemical concentrations. This is in keeping with

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



FCSAP (2012a) guidance, which indicates that a 90<sup>th</sup> percentile soil concentration can be used for screening mobile receptors if the sample size is > 10 and a site is adequately characterized. This site had > 10 samples and the site has been adequately characterized; as such, the 90<sup>th</sup> percentile soil concentrations were used in the secondary screening. Soil concentrations were also compared to the background soil concentration range (**Table 6-7**).

**Table 6-7** compares maximum site soil chemical concentrations (for the initial COPCs) to vegetation and soil invertebrate-specific ecological health-based soil guidelines, and compares 90<sup>th</sup> percentile soil chemical concentrations across the entire site for the initial COPCs (n = 58 for all metals except 69 for lead) to mammal and avian-specific ecological health-based soil guidelines. The maximum and 90<sup>th</sup> percentile concentrations were also compared to background soil concentrations where available. Chemicals that exceeded both the applicable guideline and available background concentrations were assessed further. **Table 6-7** also provides the frequency of soil guideline exceedance.

Lead, cadmium, selenium and vanadium had at least one local background sample that exceeded the ecological health-based soil quality guideline (**Table 6-7**). Metals were generally higher in this sample than the other background samples. There is no indication from past studies that any of the background samples were collected in areas potentially impacted by historical site activities. As such, the higher metals in these samples may be partially related to differences in the bedrock geology.

For the initial COPCs identified in **Table 6-7**, a significance level of 5% was used for both frequency of detection and frequency of exceedance. While there is no consistent regulatory guidance on a significance level or cut-off value to use when considering the frequency of detection, and/or exceedance over benchmarks in a COPC identification process, a value of 5% has some regulatory precedent within the U.S. Superfund program and as per the U.S. Navy HHRA Guidance document (US Navy, 2008). The U.S. EPA Superfund Program has used a 5% cut-off value for detection frequency to eliminate chemicals from further consideration since the early 1990s, and the U.S. Navy (2008) HHRA guidance also supports the use of a 5% cut-off value when considering detection and benchmark exceedance frequency. Thus, the initial COPCs in **Table 6-7** carried forward for the receptor specific benchmark comparison that displayed a frequency of detection, and/or a frequency of exceedance over the applicable soil benchmark of less than 5%, were excluded from further consideration in the HHRA. If the frequency of detection was equal to or greater than 5% for the carried forward substances, they were then evaluated on the basis of their frequency of exceedance over the applicable soil quality benchmark. In addition, the degree of benchmark exceedance was also considered. If the frequency of exceedance over the soil benchmark was equal to or greater than 5%, then the substance was carried forward into the next step of the COPC identification process. Also, a 5% significance level is consistent with the default alpha value used in most statistical calculations with environmental data sets. This approach in COPC identification procedures have been applied for at least twenty years in the numerous ERAs and HHRA's conducted by Dillon, and the approach has been accepted by the applicable federal and provincial regulatory authorities.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



For vegetation and soil invertebrate ROC, the maximum concentrations exceeded the applicable guidelines for copper (3 of 58 samples, 5%), lead (26 of 69 samples; 38%), and zinc (28 of 58 samples, 48%) (**Table 6-7**). Maximum concentrations for copper, lead, and zinc exceeded their applicable guidelines at 1.3-fold, 50-fold, and 8-fold, respectively. The frequency of detection of copper, lead, and zinc were all 100%. Strontium is considered a COPC despite having no guidelines as it is expected as a result of previous site activities. Based on these considerations, copper, lead, strontium, and zinc were carried forward for further assessment for terrestrial vegetation and soil invertebrates.

For mammalian and avian ROC, the maximum concentrations exceeded the applicable guidelines for cadmium (28 of 58 samples, 48%), lead (56 of 69 samples; 81%), vanadium (2 of 58 samples; 3%), and zinc (40 of 58 samples, 69%) (**Table 6-7**). Maximum concentrations for cadmium, lead, vanadium, and zinc exceeded their applicable guidelines at 11-fold, 938-fold, 3-fold, and 11-fold, respectively. The frequency of detection of lead, vanadium and zinc were all 100% and cadmium was 98%. Strontium is considered a COPC despite having no guidelines as it is expected as a result of previous site activities. Based on these considerations, cadmium, lead, strontium, and zinc were carried forward for further assessment for mammalian and avian ROC.

#### 6.8.6 Final COPCs for the ERA Problem Formulation

Based on the COPC identification steps and considerations described above, a number of COPCs were carried forward for soil as listed below:

##### **COPCs for Terrestrial Vegetation and Soil Invertebrates:**

- Copper;
- Lead;
- Strontium; and
- Zinc.

##### **COPCs for Small Mammals and Birds:**

- Cadmium;
- Lead;
- Strontium; and
- Zinc.

## 6.9 Conceptual Site Model for Ecological Receptors

The ERA conceptual site model (CSM) for site soils is presented on **Figure 6-1**. The CSM for ecological receptors provides a simplified representation of potential exposure pathways and routes that link the identified COCs in site environmental media to the ecological receptors of interest. Based on the COPC screening, COPCs were carried forward for terrestrial vegetation and soil invertebrates as well as small mammals and birds. This CSM is based on site soil exposures only. A CSM for exposures from other site media can be included when an ERA is conducted.

**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



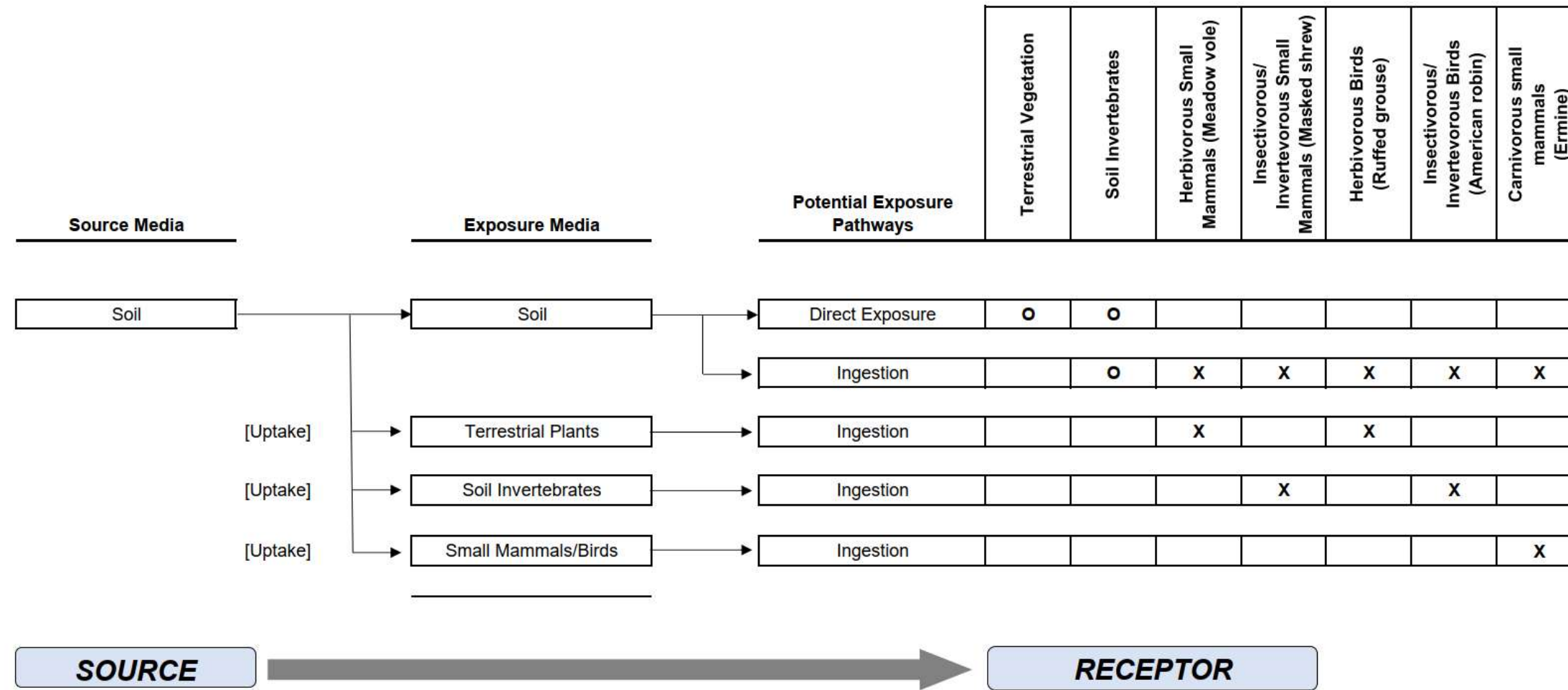


Figure 6-1: Conceptual Site Model for Soils for Ecological Receptors at the Lake Enon Former Mill Site, Enon, Nova Scotia

## 7.0

# Summary of HHERA Problem Formulation Outcomes, Data Gaps and Next Steps

A summary of the overall outcomes of the Human Health and Ecological Health Risk Assessment Problem Formulation for the study boundary is provided below in **Table 7-1**. Identified data gaps are also provided in **Table 7-1**, with recommendation on next steps to address them.

**Table 7-1: Summary of Problem Formulation Outcomes for Lake Enon HHERA Problem Formulation of Soil**

Receptors	Exposure Pathways	Soil COC	Data Gaps and Recommended Next Steps
<b>Human Health Risk Assessment Problem Formulation</b>			
Site visitor (all ages)	- Ingestion of outdoor soils/dusts - Inhalation of outdoor soils/dusts	Lead Strontium	As COCs have been identified for both human and ecological receptors, a human and ecological health risk assessment should be completed. Other media (sediment, surface water and groundwater) should be assessed and incorporated into the HHERA where relevant.
Site excavation / remediation worker (teen adult)	- Dermal contact with outdoor soils/ dusts - Ingestion of groundwater as drinking water	Lead Strontium	
<b>Ecological Risk Assessment Problem Formulation</b>			
Terrestrial vegetation	- Direct contact with soils - Root uptake	Copper Lead Strontium Zinc	Soils to the north west of the site (between the study boundary and the nearby Lake) have not been fully characterized. Surface soil samples should be collected within this area.  Surface water and sediment samples should be collected in the adjacent unnamed lake to identify whether tailings may have spread into these areas and to identify any COPCs.
Soil invertebrates	- Direct contact with soils - Soil ingestion		
Herbivorous small mammals (surrogate: meadow vole)	- Soil ingestion - Vegetation ingestion	Cadmium Lead Strontium Zinc	The degree to which contamination on the site may be contributing to contaminant concentrations in adjacent aquatic areas is unknown. Therefore, a hydrological and sediment transport study should be conducted to determine if contaminated sediments and fines are being transported off-site to the
Insectivorous/ Invertevorous small mammals (surrogate: masked shrew)	- Soil ingestion - Ingestion of soil invertebrates		
Herbivorous birds (surrogate ruffed grouse)	- Soil ingestion - Vegetation ingestion		
Insectivorous/ Invertevorous birds (surrogate: American robin)	- Soil ingestion - Ingestion of invertebrates		

Nova Scotia Lands Inc.

Human Health and Ecological Risk Assessment Problem Formulation (Final)

Lake Enon Former Mill Site, Enon, Nova Scotia

PID Nos. 15551369, 15340045, and 15340052

May 2023 - 22-3723



Receptors	Exposure Pathways	Soil COC	Data Gaps and Recommended Next Steps
Carnivorous small mammals (surrogate: ermine)	<ul style="list-style-type: none"> <li>- Soil ingestion</li> <li>- Ingestion of prey</li> </ul>		adjacent lake. Also confirm existing overall site drainage characteristics including the brook and culvert.
Amphibians	<ul style="list-style-type: none"> <li>- Soil / sediment ingestion</li> <li>- Direct contact with soil, sediments and surface water</li> <li>- Ingestion of aquatic and terrestrial foods</li> </ul>		<ul style="list-style-type: none"> <li>-Complete an aquatic habitat assessment for Lake Enon that includes benthos, fish and amphibians. Depending on the habitat assessment results, a benthic community study may be required in Lake Enon along with paired sediment samples.</li> </ul>
Freshwater aquatic life	<ul style="list-style-type: none"> <li>- Direct contact with sediment / surface water</li> </ul>	COCs to be determined using surface water, groundwater and sediment data	<p>Contamination in site soil is not fully delineated so receptors were conservatively selected assuming contamination extended into areas of suitable habitat for receptors. Receptors and surrogate receptors should be refined following site delineation.</p> <p>Some of the site was reported to be very damp and have wetland vegetation (e.g., cattails). In addition, a brook was noted within the study boundary. A survey of these areas within the study boundary should be conducted to identify the presence of suitable habitat for amphibians and / or aquatic life receptors.</p> <ul style="list-style-type: none"> <li>- There is uncertainty associated with the potential presence and use of the site by SAR. Although potential presence of the common nighthawk was qualitatively discussed, a formal SAR assessment should be undertaken within a full ERA to reduce uncertainty associated with this aspect of the Problem Formulation.</li> </ul>

**Note:**  
COC = contaminant of concern



## Limitations and Closure

This report was prepared exclusively for the purposes, project and site location outlined in the report. The report is based on information provided to, or obtained by Dillon as indicated in the report, and applies solely to site conditions existing at the time of the site investigation. Although a reasonable investigation was conducted by Dillon, Dillon's investigation was by no means exhaustive and cannot be construed as a certification of the absence of any contaminants from the site. Rather, Dillon's report represents a reasonable review of available information within an agreed work scope, schedule, and budget. It is, therefore, possible that currently unrecognized contamination or potentially hazardous materials may exist at the site, and that the levels of contamination or hazardous materials may vary across the site. Further review and updating of the report may be required as local and site conditions, and the regulatory and planning frameworks, change over time.

This report was prepared by Dillon for the sole benefit of Build Nova Scotia. The material in the report reflects Dillon's best judgment in light of the information available to Dillon at the time of preparation. Any use which a third party (e.g., a party other than Build Nova Scotia) makes of this report, or any reliance on or decisions made based on it, are the responsibilities of such third parties. Dillon accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Respectfully submitted,

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## 9.0

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**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*

*Lake Enon Former Mill Site, Enon, Nova Scotia*

*PID Nos. 15551369, 15340045, and 15340052*

May 2023 - 22-3723



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**Nova Scotia Lands Inc.**

*Human Health and Ecological Risk Assessment Problem Formulation (Final)*  
*Lake Enon Former Mill Site, Enon, Nova Scotia*  
*PID Nos. 15551369, 15340045, and 15340052*

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