REVISED REPORT
TO
PUBLIC WORKS AND GOVERNMENT SERVICES CANADA

SITE-SPECIFIC RISK ASSESSMENT
HOPE ISLAND LIGHTSTATION
L.L. 857
GEORGIAN BAY, LAKE HURON, ONTARIO

Prepared by:

DECOMMISSIONING CONSULTING SERVICES LIMITED
121 Granton Drive, Unit 11
Richmond Hill, Ontario L4B 3N4
CANADA

Tel: (905) 882-5984
Fax: (905) 882-8962
E-Mail: engineers@dcsltd.ca
Web Page: www.dcsltd.ca

June 2005

48297-14

121 Granton Drive
Unit 11
Richmond Hill, Ontario
Canada L4B 3N4

DECOMMISSIONING CONSULTING SERVICES LIMITED

Tel: (905) 882-5984
Fax: (905) 882-8962
E-mail: engineers@dcsltd.ca
Web Site: http://www.dcsltd.ca

48297-14

15 June 2005

Public Works and Government Services Canada
Environmental Services Division
4900 Yonge Street, 11th Floor
Toronto, Ontario
M2N 6A6

Attention: Mr. Jimi Arey, P. Eng.

Re: **Revised Report**
Site-specific Risk Assessment for
Hope Island Lightstation
L.L. 857
Georgian Bay, Lake Huron, Ontario

Dear Mr. Arey:

Please find, herewith, our revised report on the site-specific risk assessment (SSRA) carried out for the Hope Island Lightstation, L.L. 857, Georgian Bay, Lake Huron, Ontario. The SSRA was completed incorporating the results of the Phase I Environmental Site Assessment prepared by Oliver, Mangione, McCalla and Associates in 1997, the Phase II Environmental Site Assessment completed by Decommissioning Consulting Services Limited (DCS) in 1999, and the results of the monitoring of remedial works by DCS at the lightstation in the summer of 2004, and incorporating comments offered by Health Canada following their review of an earlier version of the SSRA report issued in December 2004, and as per the discussions held at a meeting convened on 19 May 2005 at PWGSC's office.

We appreciate the opportunity to be of service to PWGSC on this assignment. We trust that the enclosed report is satisfactory. If you have any questions, please call.

Yours very truly,

DECOMMISSIONING CONSULTING SERVICES LIMITED

PROFESSIONAL ENGINEER
B. H. COOKE
PROVINCE OF ONTARIO
15 JUNE 2005

Barry Cooke, P.Eng.
Vice President

SENES CONSULTANTS LIMITED

Harriet Phillips, Ph.D.
Senior Specialist, Risk Assessment, Toxicology

Enc.

EXECUTIVE SUMMARY

A site-specific risk assessment (SSRA) was conducted on the Hope Island Lightstation property in Georgian Bay, Lake Huron. The focus of the SSRA was on lead and zinc soil contamination, which originated in part from the use of lead-based paint on lightstation buildings as well as from cinders and ash generated from the historic burning of coal and being spread over the lightstation. Other contaminants (such as other heavy metals, polycyclic aromatic hydrocarbons and petroleum hydrocarbons) were not included in the SSRA as it had been shown by laboratory analysis of soil samples collected during a Phase II ESA and site remediation work that these contaminants were not present in concentrations above the relevant CCME generic cleanup guidelines. Additionally, some lead-based paint remains on some lightstation building surfaces, plus asbestos containing materials (ACM) are present in several of the site buildings. The SSRA was carried out to investigate the potential impacts on human health and ecological receptors if the lightstation were to be redeveloped as a summer camp.

Conservative assumptions were made regarding the exposures of human and ecological receptors; for example, in the assessment it was assumed that exposure was occurring directly with contaminated soil. Meanwhile, most parts of the site that contain contaminated soils have been covered with topsoil and thus, the assumption of direct exposure results in an overestimation of risk, and the results of the SSRA should be interpreted in this context.

Exposure to lead and zinc contaminated soils was assessed with regards to their potential adverse effect on human health. Based on the assessment findings, the hazard quotients for both lead and zinc are below the appropriate action levels and therefore, negative human health effects are not expected to be experienced by the selected human receptors at the property under the conservative exposure assumptions for this assessment.

Population-level impacts on ecological health were also assessed. Although measured lead and zinc concentrations exceeded the CCME ecological guidelines, trees are well established and there is opportunistic vegetation growing in areas of the site. The ecological assessment determined that the lead and zinc concentrations on site do not pose a concern to small terrestrial mammals and birds that would potentially be at the site. Lead concentrations in the soil at the site do not pose a risk to Northern watersnakes that inhabit the island. However, the risk to watersnakes from zinc exposure could not be assessed due to lack of toxicological data,

nevertheless it is expected to be negligible based on consideration of the assessment for lead, as well as the fact that there is an abundant population of snakes on the island.

Site-specific soil criteria for use at the Hope Island Lightstation were developed for lead and zinc based on both human receptors, and the terrestrial animals and birds considered in the ecological risk assessment. As the site-specific criteria that were developed were higher than the maximum measured concentrations (for human health) or the average measured concentrations (for ecological receptors), there is no requirement to implement risk management measures.

In summary, there are no human health or ecological concerns related to the lead and zinc contamination at the Hope Island Lightstation site, and no risk management measures are recommended in this regard. However, in order to reduce the risks present from other hazards at the site, the following recommendations are made:

- Due to the inferred relationship between lead-based paint and lead and zinc soil contamination issues, the exterior of the existing buildings on the site that contain lead based paints should be managed (e.g. covered with a fresh coat of paint or by siding) so that further soil contamination will not occur; and

- If still present, loose friable ACM in the basement of the former lighthouse and pipe insulation in the Fog Alarm Building identified during the 1997 Phase I ESA, should be removed. However, no risk management measures are recommended for the non friable ACM identified by the Phase I ESA in several of the site buildings, nor for the friable ACM gaskets present in the furnaces of both dwellings.

This report has been prepared incorporating comments provided by Health Canada following a review of an earlier version of the SSRA report issued in December 2004, and as per discussions held on 19 May 2005 at a meeting attended by representatives of Indian and Northern Affairs Canada, PWGSC, SENES and DCS.

TABLE OF CONTENTS

PAGE

TABLE OF CONTENTS
(Continued)

PAGE

LIST OF TABLES

LIST OF APPENDICES .... AT REAR OF REPORT

LIST OF DRAWINGS — AT REAR OF REPORT

1.0 INTRODUCTION

Decommissioning Consulting Services Limited (DCS) has been retained by Public Works and Government Services Canada (PWGSC) to undertake a site-specific risk assessment (SSRA) related to soils containing elevated levels of the heavy metals lead and zinc at the automated lightstation on Hope Island in Georgian Bay. In addition to this report on the SSRA, the following environmental reports describe environmental assessments and remedial work carried out previously at the site:

- *Phase I Environmental Assessment, Hope Island Lightstation, L.L. 857, Georgian Bay, Lake Huron, Ontario,* by Oliver, Mangione, McCalla and Associates, March 1997;

- *Phase II Environmental Site Assessment and Risk Assessment, Hope Island Lightstation, L.L. 857, Georgian Bay, Lake Huron, Ontario,* by DCS, February 1999; and

- *Remedial Program, Hope Island Lightstation (L.L. 857), Georgian Bay, Lake Huron, Ontario,* by DCS, October 2004.

This SSRA report should be read in conjunction with the three reports listed above.

The 1997 Phase I environmental site assessment (ESA) identified several environmental issues attending the site: concentrations of heavy metal contaminants in near surface soils above the applicable CCME and MOE environmental evaluation criteria, the presence of paint on the surfaces of the lightstation buildings containing high concentrations of lead, the presence of soils containing petroleum hydrocarbon contamination near external aboveground storage tanks (ASTs) and in the crawl space of the Fog Alarm Building, the presence of both non friable and friable asbestos containing materials (ACM) in the buildings on site, and the presence of a large waste disposal dump in the forest approximately 80 m south of the developed area of the lightstation property. The 1999 Phase II ESA confirmed the presence of heavy metal contaminated soils in the vicinity of the former Lighthouse Building, confirmed the volume of waste in the dump described in the Phase I ESA as well as identifying a second, smaller dump in the vicinity of the first dump, but did not confirm the presence of petroleum hydrocarbon contamination in the vicinity of the external ASTs.

In the summer of 2004, PWGSC undertook a remedial program at the Hope Island Lightstation. All waste materials in the two dumps, plus a third small dump located near the first two dumps, were removed from Hope Island, along with any soils underlying the dumps that contained concentrations of heavy metals above the CCME and MOE cleanup criteria selected for the site (residential landuse, groundwater not used for human consumption). A passive venting system was installed in the crawl space of the Fog Alarm Building to enhance the natural biodegradation of petroleum hydrocarbon contamination in the basement's soils. The heavy metal contaminated soils in a burn area (fire pit) located between the dwellings was fully remediated, with the excavated soils being removed from Hope Island.

Soils contaminated with heavy metals in the vicinity of the former Lighthouse and Fog Alarm Building were partially remediated, but weather and budgetary constraints prevented the completion of the remedial works, although substantial areas around the former Lighthouse were fully remediated. Zones of heavy metal contaminated soil remain *in situ* south of the former Lighthouse, near the northeast corner of the Fog Alarm Building and north of Lightkeeper's dwelling. Contaminated soils excavated from the vicinity of the former Lighthouse that were not disposed off-site were relocated to the area south of the Fog Alarm Building. The estimated extent of contaminated soils remaining on Hope Island is shown on Drawing 48297-14-1.

At the outset of the remedial works it was believed that the heavy metal contamination in the soils was primarily due to lead rich paints flaking off of the lightstation buildings. However, as work progressed, it became apparent that much of the contamination was actually due to cinders and ash, the products of combustion of coal used during the early years of the lightstation, having been spread over a significant portion of the developed area of the lightstation.

At the end of the remedial works in September 2004, topsoil imported from Christian Island was spread over the remedial excavations in the vicinity of the former Lighthouse and Fog Alarm Building and overseeded with ryegrass. Measured topsoil thicknesses ranged from 50 to 150 mm.

The SSRA discussed in the following pages focuses on the heavy metal (lead and zinc) contamination in the surface and near surface soils present over portions of the developed area of the lightstation. Other contaminants (such as other heavy metals, polycyclic aromatic hydrocarbons and petroleum hydrocarbons) were not included in the SSRA as it had been shown by laboratory analysis of soil samples collected during a Phase II ESA and site remediation work that these contaminants were not present in concentrations above the relevant CCME generic cleanup guidelines. To a lesser extent, the SSRA considers, in a qualitative manner, the continuing presence of lead rich paint on various surfaces of the buildings, and the presence of ACM in some of the buildings.

2.0 METHODOLOGY

The use of site-specific risk assessment to establish whether a site can be safely used by the most sensitive receptors likely to occupy it involves the application of a staged, formal and reproducible process that incorporates procedures accepted by the regulatory authorities in the jurisdiction within which the study is being undertaken. The technical steps involved in undertaking the risk assessment for the Hope Island Lightstation involved:

- a human health risk assessment, focusing on heavy metals;
- an ecological risk assessment for terrestrial receptors, focusing on heavy metals;
- the development of site-specific soil criteria; and,
- if necessary, the identification and development of appropriate environmental risk management procedures for application at the site.

A site visit by a biologist was judged to be unnecessary because the vegetation in the vicinity of the lightstation prior to initiation of the recent remedial works was noted to be in a generally healthy state, and much of it had been removed by remedial activities undertaken in the summer of 2004.

3.0 SITE DESCRIPTION

Hope Island is located in Georgian Bay, Lake Huron, just north of Christian Island and approximately 25 km northwest of Penetanguishene, Ontario. The lightstation property (designation LL857) comprises approximately 40.5 ha (100 acres) of the northeastern end of the island. The developed portion of the property, which includes the original wooden lighthouse, newer navigation light, helicopter pad, Fog Alarm Building, Generator Building, Boathouse, wharf and two dwellings, is limited to the extreme northeast section. The remainder of the property is a mix of woodland and swamp, and is essentially undeveloped. The lightstation has not been staffed on a continuous basis since 1987. The general arrangement of the lightstation is shown on Drawing 48297-14-1.

The developed section of the property is relatively level, rising from a cobble and boulder beach. Soils are generally shallow with little organic matter, predominantly silty sand to sandy gravel, with unconsolidated till material below (numerous cobbles, pebbles). A 1960s test pit record indicated that, in the area of the houses, silty sand and clayey soils extended 1.25 to 2.0 m below surface. Limestone bedrock is anticipated to be present at shallow depth across the lightstation. Depth to groundwater has not been determined for the site, but is expected to approximate lake level in most areas. The potable water supply for the lightstation is derived from lake water drawn from Georgian Bay. A small, spring-fed pond near the boathouse flows into the lake. Prior to the remedial program in the summer of 2004, long grasses and occasional trees surrounded the buildings, with denser mixed forest cover beyond. Tree species that were identified in the vicinity of the lightstation included spruce, balsam, maple, cedar, mountain ash, aspen, poplar and apple.

As discussed in Section 1.0, extensive remedial works were undertaken on Hope Island in the summer of 2004. Three waste dumps on the island were fully remediated, and a significant quantity of heavy metal contaminated soil in the area of the lightstation buildings was excavated and disposed of off island, while other heavy metal contaminated soil was excavated and consolidated in an area south of the Fog Alarm Building. Zones of *in situ* heavy metal contaminated soil remain, however, south of the former Lighthouse, near the northeast corner of the Fog Alarm Building and north of the Lightkeeper's dwelling. At the end of the remedial program, topsoil imported from Christian Island was spread over the remedial excavations and overseeded with a rye grass mixture. In addition, a passive venting system was installed in the crawl space of the Fog Alarm Building.

It should be noted that an investigation of the presence of distribution of lead rich paint on the various building surfaces and the presence and distribution of ACM in the site buildings was not undertaken in preparation for this SSRA. As such, the information on these issues presented in the 1997 Phase I ESA was used. However, it was noted that the flaking paint on the exterior of the former Lighthouse had been scraped, thereby eliminating these surfaces as a future source of lead contamination. Also, friable asbestos material (air cell pipe insulation) was encountered buried in contaminated soils near the northeast corner of the Fog Alarm Building. Although several bags of this material were collected and disposed of, some additional air cell insulation remains buried near the northeast corner of the Fog Alarm Building.

Photographs of current site conditions (fall 2004) of the area of the developed portion of the lightstation are included in Appendix C.

4.0 HUMAN HEALTH RISK ASSESSMENT

4.1 HAZARD IDENTIFICATION

The 1999 Phase II ESA (DCS 1999) confirmed the findings of the 1997 Phase I ESA that surface and near surface soils in the area of the lightstation buildings contained concentrations of heavy metals (principally lead and zinc) above the applicable provincial and federal environmental evaluation criteria. Although significant quantities of heavy metal contaminated soils were excavated on Hope Island in the summer of 2004, weather and budgetary constraints prevented complete remediation of all contaminated soils. Drawing 48297-14-1 shows the inferred extent of heavy metal contaminated soils remaining on Hope Island. This drawing also shows the known locations of ACM and lead rich paints in the buildings at the lightstation, as described in the 1997 Phase I ESA.

For the purposes of comparing contaminant levels with guideline values, the Hope Island Lightstation site was considered to be residential/parkland land use as the future development of the site indicated that a summer camp would be present at the site. It is understood that the camp will be located near the southern edge of the cleared area, in the general area of the former Fire Pit, which has been fully remediated. The soil is coarse textured and the groundwater is considered non-potable as it is not the source of potable water for the island.

Table 4.1 summarizes the verification soil sample locations where lead and zinc concentrations were measured in 2004 during the remedial works program, and compares these values to the CCME guidelines for soil criteria for a residential/parkland land-use situation. The locations of the verification soil samples are shown on Drawing 48297-14-1. It should be noted that the soil samples listed in Table 4.1 represent those soil samples collected from the final remedial excavation surfaces, which were covered with topsoil upon completion of the project. Other samples were collected but were from locations subsequently excavated as the remedial program progressed.

All of the verification soil samples were collected during the course of the summer 2004 remedial work program. However, four of the samples (160S to 163S), collected from just outside the limits of the remedial excavation north of the Lightkeeper's dwelling were analysed after authorization to proceed with the SSRA was received in October 2004. The laboratory certificates for these analyses are included in Appendix A. The laboratory certificates for all other analyses are provided in the October 2004 *Remedial Program* report.

TABLE 4.1
COMPARISON OF MEASURED LEAD AND ZINC LEVELS IN SOIL TO THE HUMAN HEALTH AND ECOLOGICAL COMPONENT OF THE CCME GUIDELINES – RESIDENTIAL/PARKLAND LAND-USE

SAMPLE LOCATION	MEASURED SOIL LEAD LEVEL (mg/kg)[a]	CCME CRITERIA FOR LEAD RESIDENTIAL/PARKLAND LAND-USE [B] (mg/kg)		MEASURED SOIL ZINC LEVEL (mg/kg)[a]	CCME CRITERIA FOR ZINC RESIDENTIAL/PARKLAND LAND-USE [B] (mg/kg)		DEPTH OF SAMPLE (mm)
		HUMAN HEALTH COMPONENT	ECOLOGICAL COMPONENT		HUMAN HEALTH COMPONENT	ECOLOGICAL COMPONENT	
2907-1W	28	140	300	20	ND	200	0-50
2907-13W	22	140	300	25	ND	200	0-50
0308-T1	102	140	300	62	ND	200	0-50
0308-T1 Repeat	93	140	300	54	ND	200	0-50
1008-37W	32	140	300	39	ND	200	0-50
1008-41B	108	140	300	45	ND	200	0-50
1008-41B Repeat	116	140	300	47	ND	200	0-50
3108-120	71	140	300	98	ND	200	0-50
3108-120 Repeat	76	140	300	103	ND	200	0-50
3108-123	65	140	300	60	ND	200	0-50
3108-125	9	140	300	13	ND	200	0-50
3108-127	39	140	300	43	ND	200	0-50
3108-127 Duplicate	47	140	300	56	ND	200	0-50
3108-130	41	140	300	35	ND	200	0-50
0809-137B	**1930**	140	300	738	ND	200	0-50
0809-137B Repeat	**2030**	140	300	738	ND	200	0-50
0809-138B	**221**	140	300	139	ND	200	0-50
0809-139W	**446**	140	300	193	ND	200	0-50
0809-140W	**532**	140	300	211	ND	200	0-50
0809-141B	**647**	140	300	152	ND	200	0-50
0809-141B Repeat	**716**	140	300	160	ND	200	0-50
0809-142B	**564**	140	300	223	ND	200	0-50
0809-143B	**158**	140	300	205	ND	200	0-50

TABLE 4.1
COMPARISON OF MEASURED LEAD AND ZINC LEVELS IN SOIL TO THE HUMAN HEALTH AND ECOLOGICAL COMPONENT OF THE CCME GUIDELINES – RESIDENTIAL/PARKLAND LAND-USE
(continued)

SAMPLE LOCATION	MEASURED SOIL LEAD LEVEL (mg/kg)[a]	CCME CRITERIA FOR LEAD RESIDENTIAL/PARKLAND LAND-USE [B] (mg/kg)		MEASURED SOIL ZINC LEVEL (mg/kg)[a]	CCME CRITERIA FOR ZINC RESIDENTIAL/PARKLAND LAND-USE [B] (mg/kg)		DEPTH OF SAMPLE (mm)
		HUMAN HEALTH COMPONENT	ECOLOGICAL COMPONENT		HUMAN HEALTH COMPONENT	ECOLOGICAL COMPONENT	
0809-144B	45	140	300	44	ND	200	0-50
0809-145B	84	140	300	86	ND	200	0-50
0809-145B Repeat	87	140	300	87	ND	200	0-50
0809-146W	87	140	300	113	ND	200	0-50
0809-147W	97	140	300	107	ND	200	0-50
0809-148W	25	140	300	31	ND	200	0-50
0809-149W	136	140	300	125	ND	200	0-50
0809-154/155B	**150**	140	300	89	ND	200	0-50
0809-156W	**2620**	140	300	1090	ND	200	0-50
0809-157W	**1400**	140	300	468	ND	200	0-50
0809-158W	**244**	140	300	167	ND	200	0-50
0809-159W	**148**	140	300	95	ND	200	0-50
0809-160S	**986**	140	300	617	ND	200	0-50
0809-160S Repeat	**924**	140	300	571	ND	200	0-50
0809-161S	**755**	140	300	599	ND	200	0-50
0809-162S	**170**	140	300	134	ND	200	0-50
0809-163S	59	140	300	109	ND	200	0-50
1309-170B	16	140	300	34	ND	200	0-50
1309-171B	46	140	300	29	ND	200	0-50
1309-172B	2.5	140	300	13	ND	200	0-50

TABLE 4.1
COMPARISON OF MEASURED LEAD AND ZINC LEVELS IN SOIL TO THE HUMAN HEALTH AND ECOLOGICAL COMPONENT OF THE CCME GUIDELINES – RESIDENTIAL/PARKLAND LAND-USE
(continued)

SAMPLE LOCATION	MEASURED SOIL LEAD LEVEL (mg/kg)[a]	CCME CRITERIA FOR LEAD RESIDENTIAL/PARKLAND LAND-USE [B] (mg/kg)		MEASURED SOIL ZINC LEVEL (mg/kg)[a]	CCME CRITERIA FOR ZINC RESIDENTIAL/PARKLAND LAND-USE [B] (mg/kg)		DEPTH OF SAMPLE (mm)
		HUMAN HEALTH COMPONENT	ECOLOGICAL COMPONENT		HUMAN HEALTH COMPONENT	ECOLOGICAL COMPONENT	
1309-173B	68	140	300	66	ND	200	0-50
1309-174B	2.5	140	300	17	ND	200	0-50
1309-175B	**144**	140	300	112	ND	200	0-50
2309-201R	**640**	140	300	325	ND	200	0-50
2309-201R Repeat	**582**	140	300	313	ND	200	0-50
2309-202R	**977**	140	300	466	ND	200	0-50
2309-203R	**612**	140	300	390	ND	200	0-50
2309-204R	**1260**	140	300	491	ND	200	0-50
2309-205R	**314**	140	300	220	ND	200	0-50
Maximum	**2620**	-	-	1090	-	-	0-50
95th Percentile	1639	-	-	671.5	-	-	-
Arithmetic mean (Average)	399.5	-	-	201.3	-	-	-

Note:

Bold means an exceedance of the human health component.
Underline means an exceedance of the ecological component.
ND is not determined.
a- From [DCS 2004]
b- From CCME [2002]. CCME Soil Guidelines.

From Table 4.1 it can be seen that the measured concentrations of lead and zinc exceed both the human health component and the ecological component of the CCME guidelines at several sample locations and must be evaluated with regards to the risk they may pose to human and ecological receptors at the site.

The potable water supply for the lightstation is derived from lake water from Georgian Bay. The lead is not present in a leachable form, as indicated by leachate tests carried out as part of the 1999 Phase II ESA, therefore there should not be any impacts on the groundwater at the site. In addition, groundwater was not encountered in any of the boreholes completed in the 1999 Phase II ESA, the deepest of which extended to 2.45 m depth, or during the 2004 remedial excavations. Therefore, the groundwater pathway was not considered in this assessment.

The maximum concentrations of lead and zinc measured at the Hope Island Lightstation site were used in this exposure assessment. Sample 0809-156W collected near the lightkeeper's dwelling was found to have the highest concentration of lead and zinc in the soil (2,620 mg/kg and 1,090 mg/kg, respectively).

4.2 HUMAN HEALTH RISK ASSESSMENT

Given that the measured concentrations of lead exceed the human health component of the CCME guidelines and that zinc does not have a human health component, further investigation is necessary to determine the potential impacts from exposure to these contaminants. The first step in this process is to examine potential exposure pathways. Exposure pathways comprise the routes by which these receptors at risk are exposed to lead and zinc and may include: dermal contact; inhalation of vapours and dusts; and ingestion of contaminated soil, water, produce, meat, etc.

Exposure Pathways

Based on the information provided in the Phase II ESA [DCS 1999], the exposure pathways for lead and zinc at the site comprise:

- soil ingestion:

  soil transferred to the mouth intentionally or unintentionally directly from the hand, or indirectly from airborne dust.

- dermal contact (soil):
  direct contact between the skin or mucous membranes and soil.

- dermal contact and ingestion of groundwater (groundwater):
  measured lead contaminants in the soil leaching into potable groundwater may provide an opportunity for ingestion of contaminated groundwater and dermal contact with contaminated groundwater. As discussed above, the leachate tests discount this pathway and thus this pathway is not discussed further.

In order to be conservative and protective, the human health risk assessment (HHRA) was performed assuming that exposure of human receptors considered that the topsoil and grass seed that had been spread over the remedial excavations was not present. This assumption represents an over-estimation because in reality, the contaminated soil is covered by a layer of topsoil that has been seeded, and human receptors are unlikely to be directly exposed to the contaminated soils.

The exposure from inhalation of respirable dust is insignificant compared to direct contact with soil as discussed by Health Canada (2003a). Therefore, this pathway was not included in this assessment. As well, no volatile contaminants have been identified as a potential concern. Thus, the exposure pathways considered in the assessment are the ingestion pathway and the dermal contact pathway. Ingestion of berries from shrubs growing in the study area was not considered as no vegetation bearing berries grows in the area where contaminated soil is present on the site.

Receptors

The nearest community is approximately 8 km south on Christian Island. The most frequent users of the site are likely to be the adult camp counsellors and children summer camp attendees from the nearby community at the First Nation's summer camp proposed as a possible future use of the site. The First Nation's group indicates that an adult camp counsellor would typically spend up to 5.5 months of the year (mid May through October) living and working on Hope Island, while child campers between the ages of 5-16 would typically spend up to two weeks a year attending the camp. Appendix D contains the e-mail communication providing the human receptor exposure parameters that were used in this SSRA. However, to be conservative, the risk assessment assumed that campers were present for up to eight weeks.

For this risk assessment, it is assumed that these receptors spend 24 hours a day 7 days a week residing directly on the contaminated Hope Island Lightstation site, while working at or attending the summer camp. Furthermore, the skin surface area exposed to contaminated soil was assumed to include the hands for camp counsellors and the hands, arms and legs of child campers. Although it is expected that the counsellors would not have as intimate contact with the site's soils as would the campers, the total of hands, arms and legs were used in the assessment for this receptor. These assumptions ensure that exposure is not underestimated.

Other users at the site, such as tourists and unauthorized trespassers visiting the site for recreational purposes, are not anticipated to use the site for periods as long as a camp counsellor or child camper, thus their exposures would be captured under the selected receptors.

Table 4.2 provides a summary of the exposure characteristics of the receptors selected for this assessment.

TABLE 4.2
SUMMARY OF RECEPTOR CHARACTERISTICS
Adult Camp Counsellor

PARAMETER	VARIABLE NAME	VALUE	REFERENCE
Body weight (kg)	BW_a	70.7	Health Canada, 2003a
Soil ingestion rate (g/d)	R_{ing}_a	0.02	Health Canada, 2003a
Soil adherence - (g/cm^2-event)	SL	$1x10^{-4}$	Health Canada, 2003a
Skin surface area - arms, legs and hands (cm^2)	SA	890	Health Canada, 2003a
Fraction of time at site [a]	Fsite_a	0.46	Assumed

Note:
a - Assumed camp counsellor would be at site for 24 h/d, for 5.5 months of the year.

Teen Camper 12-19 yrs old

PARAMETER	VARIABLE NAME	VALUE	REFERENCE
Body weight (kg)	BW_t	59.7	Health Canada, 2003a
Soil ingestion rate (g/d)	R_{ing}_t	0.02	Health Canada, 2003a
Soil adherence – body and hands (g/cm^2-event)	SL_H	$1.1x10^{-4}$	Health Canada, 2003a
Skin surface area – body and hands (cm^2)	SA_B	8000	Health Canada, 2003a
Fraction of time at site [a]	Fsite_t	0.15	Assumé

Note:
a - Assumed teen would visit the site for 24 h/d, for 56 days of the year.

Child Camper 5-11 yrs old

PARAMETER	VARIABLE NAME	VALUE	REFERENCE
Body weight (kg)	BW_c	32.9	Health Canada, 2003a
Soil ingestion rate (g/d)	R_{ing}_c	0.02	Health Canada, 2003a
Soil adherence – body and hands (g/cm^2-event)	SL_H	$1.1x10^{-4}$	Health Canada, 2003a
Skin surface area – body and hands (cm^2)	SA_B	5140	Health Canada, 2003a
Fraction of time at site [a]	Fsite_c	0.15	Assumed

Note:
a - Assumed child would visit the site for 24 h/d, for 56 days of the year.

Toxicity Assessment

Toxicity is defined as the ability of a substance to cause damage to living tissue, impairment of the central nervous system, severe illness or, in extreme cases, death, when ingested, inhaled or absorbed by the skin. Both lead and zinc are known to be associated with non-cancer adverse health effects at certain doses.

For lead, the toxicity information was obtained from Health Canada [2003b]. The toxicity reference value provided in this document was 3.6×10^{-3} mg/kg-d. This value is similar to the WHO value of 0.0035 mg/kg-d (WHO 1987) which is based on biochemical and neurological effects in infants and young children. This value was derived for the oral exposure route, but was also used to assess risk from the dermal route due to an absence of toxicity data. This is standard practice in risk assessment.

For zinc, Health Canada recommends the use of a tolerable intake level of 40 mg/d for adults (Health Canada 2005) which when normalized to a 70.7 kg body weight provides a toxicity reference value of 0.57 mg/kg-d. The tolerable intake is based on a reduction in erythrocyte copper-zinc superoxide dimutase activity (IOM 2000). This value was derived for the oral exposure route, but was also used to assess risk from the dermal route due to an absence of toxicity data. This is standard practice in risk assessment.

Estimated Exposure

As discussed above, the soil ingestion/dermal contact pathway is the only pathway of exposure for both the adult camp counselors and child campers using this site. The equations and assumptions used to calculate the intake of lead and zinc are shown below.

Incidental Ingestion of Soil

The dose due to ingestion of soil (mg/kg-d) was calculated using equation (4-1) for non-carcinogens. This approach was based on the equation given in Health Canada [2003a]. All variables used are described in Table 4.2.

$$D_o = \frac{C_s \times R_{ing} \times AF_{gut} \times Fsite}{BW} \qquad (4\text{-}1)$$

where:

D_o	=	ingestion (oral) dose (mg/kg-d)
C_s	=	concentration of contaminant in soil (mg/kg)
R_{ing}	=	ingestion rate (kg/d)
AF_{gut}	=	gut absorption factor (unitless); assumed to be 1
Fsite	=	fraction of time at site (unitless)
BW	=	body weight (kg)

The oral doses of lead and zinc for the camp counsellor, and for the child and teen camper are summarized in Table 4.3. Calculations are provided in Appendix B.

TABLE 4.3
SUMMARY OF ORAL DOSES OF LEAD AND ZINC FOR HUMAN RECEPTORS

HUMAN RECEPTOR	ORAL DOSE – LEAD (mg/kg-d)	ORAL DOSE – ZINC (mg/kg-d)
Adult Camp Counsellor	3.4×10^{-4}	1.4×10^{-4}
Teen Camper	1.4×10^{-4}	5.6×10^{-5}
Child Camper	2.5×10^{-4}	1.0×10^{-4}

Dermal Exposure

The approach used for estimating the dermal exposure to contaminants in soil was based on the equations given in Health Canada [2003a]. Non-carcinogenic contaminant exposure via dermal contact with soil can be calculated as shown below in equation (4-2). All variables and calculations used are described in Table 4.2.

$$D_d = \frac{C_s \times SA_E \times SL_H \times AF_{skin} \times Fsite \times EF}{BW} \qquad (4\text{-}2)$$

where:

D_d	=	absorbed dose per event (mg/kg-d)
C_s	=	concentration of contaminant in soil (μg/g or mg/kg)
SA_E	=	exposed skin surface area (cm^2)
SL_H	=	soil adherence value (kg/(cm^2-event))
AF_{skin}	=	dermal absorption factor (unitless)
Fsite	=	fraction of time at site (unitless)
EF	=	exposure frequency (events/d); assumed to be 1

The soil adherence value (SL_H) represents the amount of soil retained on the skin. Skin surface area parameters are derived from standard values for adults, teens and children. All parameter values were derived from Health Canada [2003a]. Dermal absorption factors were taken from Health Canada [2003a], which were estimated after MOEE [1996b], and were 0.006 for lead and 0.02 for zinc.

The dermal doses of lead and zinc for the camp counsellor, and for the child and teen camper are summarized in Table 4.4. Calculations are provided in Appendix B.

TABLE 4.4
SUMMARY OF DERMAL DOSES OF LEAD AND ZINC FOR HUMAN RECEPTORS

HUMAN RECEPTOR	DERMAL DOSE – LEAD (mg/kg-d)	DERMAL DOSE – ZINC (mg/kg-d)
Adult Camp Counsellor	9.3×10^{-5}	1.6×10^{-4}
Teen Camper	3.6×10^{-5}	4.9×10^{-5}
Child Camper	4.2×10^{-5}	5.8×10^{-5}

Risk Characterization

Risk characterization involves integration of the information from the exposure assessment and the toxicity assessment.

For non-carcinogens such as lead and zinc, the Hazard Quotient (HQ) is defined as shown in equation (4-3):

$$HQ = \frac{D_o}{TRV_o} + \frac{D_d}{TRV_d} \qquad (4\text{-}3)$$

where:

- D_o = Dose due to oral (ingestion) exposure (mg/kg-d).
- TRV_o = Toxicity reference value for oral exposure (mg/kg-d).
- D_d = Dose due to dermal exposure (mg/kg-d).
- TRV_d = Toxicity reference value for dermal exposure (mg/kg-d) {the oral toxicity reference value was used for the dermal pathways – see page 4-5}.

Calculations are provided in Appendix B.

As seen in Table 4.5, for the adult camp counsellor (the most exposed individual), the Hazard Quotient (HQ) from exposure to lead was calculated to be 0.012. This is primarily due to oral exposure. For the teen and child campers, exposure to lead also occurred primarily via oral exposure. The HQ from exposure to zinc was small (<0.01) for all receptors.

TABLE 4.5
SUMMARY OF CALCULATED HAZARD QUOTIENTS

HUMAN RECEPTOR	CALCULATED HAZARD QUOTIENT – LEAD	CALCULATED HAZARD QUOTIENT - ZINC
Camp counsellor	0.12	<0.01
Teen camper	0.05	<0.01
Child camper	0.08	<0.01

Different magnitudes of hazard quotients have been used to screen for potential adverse health effects. Where all pathways are considered, a hazard quotient less than one (1) represents an insignificant impact to the receptor as the predicted exposure dose not exceed the applicable benchmark. The CCME allocates 20% of the toxicity reference value for each exposure pathway. For this assessment, a hazard quotient value of 0.2 was adopted as a cautious and conservative action level. These calculated Hazard Quotient values indicate that the selected receptors (the camp counsellor and camper) can use the Hope Island Lightstation site in its existing state without any significant risk of adverse health effects from lead or zinc, presuming that the exposure assumptions made adequately approximate receptor behaviour. The specific adverse health effect under consideration in the HHRA included risk of neurological damage in children for lead [Health Canada., 2003b], while the toxicological endpoint for the zinc toxicity reference value was changes in enzyme activity [IOM 2000].

To put these results into perspective, the HHRA was conducted assuming that the contaminated soils are accessible, however, a layer of clean topsoil and grass seed has been spread over most of the remedial excavations at the site. Hence, hazard quotients presented here are based on conservative assumptions and in reality, are most likely significantly less.

4.3 ADDITIONAL HUMAN HAZARDS AT THE HOPE ISLAND LIGHTSTATION

Additional human hazards other than heavy metal soil contamination exist at the Hope Island Lightstation site. These include: lead-based paint remaining on both interior and exterior surfaces of several lightstation buildings in various stages of aging, and several buildings containing asbestos in the form of chrysotile asbestos. This section describes the ways that concerns surrounding these additional hazards can be addressed.

Lead and zinc soil contamination at Hope Island has been linked to the use of lead-based paints at the lightstation facility. The 1997 Phase I ESA indicated that lead based paints were present on the exterior surfaces of the former Lighthouse, Generator Building, the Boathouse and both dwellings, as shown on Drawing 48297-14-1. The area around the Lighthouse had the highest measured lead levels in near surface soils and the exterior of the former Lighthouse has been stripped of flaking paint, but the surfaces of other buildings on the site have not been addressed. Given the relationship between soil contamination and the use of lead-based paints, it is recommended that the surfaces of the buildings on the site be managed so that further flaking will not occur. This can be accomplished through encapsulation with vinyl or aluminum siding on exterior surfaces or by new coats of paint for both internal and exterior surfaces.

The 1997 Phase I ESA identified non friable ACM as being present in the Fog Alarm Building (interior wall board), Generator Building (walls and ceiling panels) and both dwellings (vinyl floor tiles). Friable ACM was identified in the 1997 Phase I ESA as loose gaskets lying on the floor of the basement of the former Lighthouse, in gaskets installed on the furnaces in both dwellings and a segment of pipe insulation in the crawl space of the Fog Alarm Building. Additionally, buried friable air cell pipe insulation was encountered in the summer of 2004 while excavating contaminated soils near the northeast corner of the Fog Alarm Building, and some of this material remains buried at this location. The locations of ACM identified in the 1997 Phase I ESA and during the 2004 remedial works program are shown on Drawing 48297-14-1.

With respect to the friable ACM in the basement of the former Lighthouse and the crawl space of the Fog Alarm Building, due to its limited quantity, it is recommended that it be removed and disposed of off site in a licensed landfill. Otherwise, an asbestos management program should be developed and implemented. The gaskets installed in the furnaces in the dwellings do not pose a significant hazard to human health and may be left in place. Similarly, the friable ACM buried near the northeast corner of the Fog Alarm Building poses no risk to human health as long as it remains buried, and no corrective action is therefore recommended. As well, the non friable wall and ceiling panels and vinyl floor tiles identified in some of the site buildings do not pose a significant risk to human health if left undisturbed, and no risk management measures are considered to be necessary. However, future operators of the summer camp should be made aware of the presence of the non friable ACM, and be advised to leave it undisturbed.

5.0 ECOLOGICAL RISK ASSESSMENT

The Canadian Council of Ministers of the Environment [CCME] provides a framework for conducting ecological risk assessment [CCME, 1996].

5.1 SITE DESCRIPTION

Field observations made during completion of the Phase II ESA and remedial works found that potential terrestrial receptors at the site include birds, animals and plants. Of special note was the abundant population of Northern watersnake (*Nerodia sipedon*) present at the Hope Island Lightstation site. The Phase II ESA identified various tree species in the vicinity of the lightstation, including spruce, balsam, maple, cedar, mountain ash, aspen, poplar and apple [DCS, 1999]. The apple trees (2) were located by the old lighthouse and were probably imported by a former lightkeeper.

A site visit by a biologist was judged to be unnecessary because the vegetation in the vicinity of the lightstation prior to initiation of the recent remedial works was noted to be in a generally healthy state, and much of the shrubs and bushes had been removed by remedial activities. Prior to remedial activities, the Phase II ESA identified two areas of vegetative distress containing heavy metal concentrations in exceedence of both MOE [2004] and CCME [2002] cleanup criteria. The first area was located around the fire pit between the Lightkeeper's and Assistant Lightkeeper's dwellings, and this area was subsequently remediated, but was not covered with topsoil as were other remediated areas. The second area was located east of the Fog Alarm Building. Remedial activities occurring in this area consisted of excavating contaminated soils and covering the remediated area with topsoil and reseeding.

Photographs taken in September 2004 of various parts of the lightstation site following remediation are included in Appendix C.

5.2 HAZARD IDENTIFICATION

Heavy metal soil contamination was present throughout the Hope Island Lightstation site prior to remedial activities. Remedial activities completed in September 2004 included soil excavation, followed in most areas by spreading of topsoil and subsequent reseeding with grass seed. Immediately following remedial activities, most of the remediated areas were covered with topsoil and did not contain vegetation. However, vegetative growth is expected in the near future, and thus the site will be suitable to support vegetation.

In order to be conservative and protective, the ecological risk assessment was performed under the same considerations as the HHRA. That is, exposure of ecological receptors was considered assuming that no topsoil and grass seed had been spread over any part of the site.

Average values were used to approximate lead and zinc concentrations in soil as opposed to using the maximum value. This was because an ecological risk assessment assesses the impact on populations and not on individuals. Additionally, ecological receptors do not stay in one place and are expected to move across the site. Average soil concentrations were 400 mg/kg for lead, and 201 mg/kg for zinc. Furthermore, most ecological receptors were conservatively assumed to spend all of their time exposed to contaminated soil on the site.

5.3 RECEPTOR SELECTION

An important step in the risk assessment of ecological receptors is the determination of which ecological receptors should be selected. Ecological receptors are generally chosen to capture various levels of exposure via the different types of diets that they consume. They are also selected if they are considered important: (1) in the functioning of the ecosystem; (2) in the production of food for subsistence; or (3) due to their cultural or medicinal significance. In this assessment, exposure results from soil pathways; thus, ecological receptors have been selected to capture this exposure pathway.

Terrestrial plants and soil-dwelling organisms comprise the most potentially exposed populations, since these receptors reside in the soil and are therefore continually exposed to contaminated soil. Since these receptors are not mobile or have limited mobility, they would be exposed to the contamination in place over a lifetime. The earthworm was used as a representative soil-dwelling organism, while a grass was used as a representative terrestrial plant.

Potential ecological receptors at the site also include birds and animals. Terrestrial mammal receptors chosen as indicator species for this assessment include a deer mouse and an Eastern Cottontail rabbit. While these receptors may not be the particular receptors observed at the site, these receptors are selected since they have a mixed diet of vegetation and earthworms (potentially most impacted media) and would spend the majority of their time on site.

The avian receptor chosen as an indicator species for this assessment is the American robin. The American robin has a diet consisting of 20% earthworms and 80% other invertebrates which were assumed to be not contaminated and were not considered in the robin's exposure. The fraction of time spent on the contaminated site by the robin was estimated by calculating the ratio of contaminated site area (0.64 ha) by the foraging home range of 0.8 ha. This produced an estimate of 0.8, which was modified to 0.4 because the robin migrates and thus it was assumed that the robin would spend only half the year at the Hope Island site. This value was further modified to 0.2 to account for the fact that:

1) few trees are available in the contaminated areas that would be suitable habitat for the robin, and

2) the contaminated area only makes up a small fraction of Hope Island.

A reptilian receptor was also selected for the ecological risk assessment (ERA) due to the abundance of Northern watersnakes on the Hope Island Lightstation site. The indicator species chosen was the Northern watersnake. Northern watersnakes were assumed to spend all of their time in the contaminated area even though a substantial portion of their lifetime would be spent in the water. The Northern watersnake diet composition consists of a mixture of aquatic prey and birds and small mammals. Since soil contamination issues are the main issue at the site, the portion of the snake's diet comprising small mammals and birds was considered in the assessment. Furthermore, since small mammals are likely more exposed than birds, only consumption of small mammals was considered in the watersnake assessment. Soil ingestion was also considered for the snake. Table 5.1 summarizes the receptor characteristics used in this assessment.

There is uncertainty associated with the use of the exposure assessment for the watersnake, as exposure to reptiles and amphibians is not typically included in ecological risk assessment. Uncertainty associated with the watersnake exposure assessment includes:

- The watersnake diet was listed as comprising mostly aquatic organisms, and these were assumed to be not contaminated. The remaining fraction of the watersnake diet comprised birds and small mammals, and it was assumed for the exposure assessment that this fraction was made up entirely of small mammals. The impact of this assumption on the exposure estimates is not known.

- It is known that the diets of some reptiles and amphibians vary greatly, and that season, temperature, activity level and moisture level can affect feeding rates [Birge *et al.*, 2000]. Thus, it is not known whether the exposure factors provided for the Northern watersnake may a) differ for the population found on Hope Island, and b) change significantly according to local conditions.

- It was also assumed that the snakes ingested contaminated soil, which may tend to overestimate exposure as the snakes spend a considerable portion of their time in the water.

TABLE 5.1
ECOLOGICAL RECEPTOR CHARACTERISTICS

PARAMETER DESCRIPTION	UNITS	DEER MOUSE	EASTERN COTTONTAIL RABBIT	AMERICAN ROBIN	NORTHERN WATERSNAKE
Scientific name	--	*Peromyscus maniculatus*	*Sylvilagus floridanus*	*Turdus migratorius*	*Nerodia sipedon*
Body weight	kg	0.021[a]	1.2[a]	0.077[a]	0.207[a]
Food ingestion rate	g (fresh weight)/d	4.2[a]	360[d]	69[f]	12.63[a]
Fraction that is terrestrial vegetation	--	0.6[a]	1[a]	--	--
Fraction that is earthworms	--	0.4[a]	--	0.2[a]	--
Fraction that is small mammals	--	--	--	--	0.12[h]
Soil ingestion rate	g (dry weight)/d	0.11[b]	6.3[e]	0.19[g]	0.15[i]
Fraction of time at site	--	1[c]	1[c]	0.20[c]	1[c]

Note:

a- U.S. EPA [1993]

b- From Beyer *et al.*[1994]. Calculated using an assumed soil ingestion as a fraction of dry weight diet of 0.04 (mammal average) and applied this to a dry weight food ingestion rate of 2.9 g dw/d (calculated using an allometric equation for all mammals from U.S. EPA [1993]).

c- Assumed that deer mouse, cottontail rabbit and snake would spend the majority of the time at the site whereas the robin may spend 20% of its time at the site while in the general vicinity of the site.

d- Calculated using allometric equation (3-7) or all mammals from U.S. EPA [1993] with a factor of 3.6 to convert from dry weight to wet weight.

e- From Beyer *et al.*[1994]. Calculated using an assumed soil ingestion as a fraction of dry weight diet of 0.063 (for jackrabbit) and applied this to a dry weight food ingestion rate of 99.9 g dw/d (calculated using an allometric equation for all mammals from U.S. EPA [1993]).

f- Calculated using the allometric equation (3-3) for all birds from U.S. EPA [1993] with a factor of 3 to convert from dry to wet weight.

g- From Beyer *et al.*[1994]. Calculated using an assumed soil ingestion as a fraction of dry weight diet of 0.104 (a value for American woodcock) and applied to a dry weight food ingestion rate of 2.3 g dw/d (calculated using an allometric equation for non-passerines from U.S. EPA [1993]).

h- From Sample *et al.*[1998b]. The snake diet also included aquatic prey including fish, crustaceans and amphibians, but these were not included since they are not contaminated.

i- From Beyer *et al.*[1994]. Fraction of food ingestion rate that is soil for the snake was based on the available value for the Eastern painted turtle (6%). Soil ingestion rate in dry weight calculated by applying a dietary moisture content of 80% to the snake's food ingestion rate and multiplying by the fraction of food ingestion rate that is soil.

5.4 TOXICITY ASSESSMENT

Toxicity reference values were obtained from a number of different ecological databases such as the CCME and the U.S. Department of Energy. A discussion of these toxicity reference values is provided below.

Terrestrial Plants and Soil-Dwelling Organisms

For plant species, the potential for effects is determined from a straight comparison of the concentration of the contaminants in the soil to a toxic level of the contaminant that has been reported for plants. In the absence of generic ecological guidelines, available ecological toxicity values can be used.

The CCME ecological soil contact value is based on potential ecological effects on selected receptors such as plants and microbes. This value is generally based on the evaluation of field and laboratory toxicity data and the use of a 25% effect level as an estimate of the minimal effect level. This level is then used with an appropriate safety factor depending on the land use. The safety factor can range between 1 and 5.

Lead is generally taken up passively by roots and its translocation to shoots is generally limited [Efroymson *et al.*, 1997a]. The phytotoxicity of lead is relatively low in comparison to other trace elements. Dixon [1988] examined the effect of lead ($PbCl_2$) on red oak seedlings grown in sandy loam. He found that lead at a concentration of 50 mg/kg reduced tree weight by 26% whereas 20 mg/kg had no effect. Experiments with Sitka-spruce seedlings [Burton *et al.*, 1984] determined that a concentration of 100 mg/kg lead ($PbCl_2$) caused a 25% reduction in root and shoot weight. Another study using $PbCl_2$ [Carlson and Rolfe, 1979] found that a concentration of 5,000 mg/kg resulted in a 46% reduction in clipping weight of ryegrass and a 31% reduction in fescue. The effects of lead on soil-dwelling organisms are summarized in Efroymson *et al.*[1997b]. Benchmarks for lead include 50 mg/kg for plants, 500 mg/kg for earthworms and 900 mg/kg for soil microorganisms [Efroymson *et al.*1997a; 1997b]. The CCME has an ecological benchmark of 300 mg/kg, which falls within the range of these benchmarks and is appropriate to use at this site.

At low concentrations, zinc is an essential nutrient for plant growth, while at high concentrations, phytotoxic effects such as chlorosis and depressed plant growth can occur [Chapman, 1966]. Zinc is actively taken up by roots, and it becomes fairly evenly distributed between roots and shoots [Efroymson *et al.*, 1997a]. Aery and Sakar [1991] examined the effect of zinc ($ZnSO_4$) on soybean plants grown in an average garden soil. They found that zinc at a concentration of 25 mg/kg reduced seed yield per plant by 28%, while having no effect on nodule weight and number, or seed weight. Concentrations at 10 mg/kg were shown to have no effect. Further experiments with soybeans [White *et al.*, 1979] determined that zinc ($ZnSO_4$) at 131 mg/kg in a sandy loam soil at pH 5.5 reduced leaf weight by 30%, while no reductions were seen at 115 mg/kg. At an increased pH of 6.5, 393 mg/kg zinc resulted in a 33% reduction of leaf weight. Experiments with spinach and coriander [Lata and Veer, 1990] established that zinc at a concentration of 87 mg/kg led to a reduction of plant weight of 45% and 22% for spinach and coriander, respectively, after 60 days in soil spiked with zinc.

Studies on earthworms [*Eisenia foetida*; Sheppard *et al.* 1993] identified an LC_{50} of 80 mg of Zn per kg of dry soil, and highlighted zinc became more bioavailable to earthworms at lower soil pH [*Lumbricus rubellus*; Ma, 1982]. Further earthworm studies report zinc benchmarks that vary according to soil characteristics [Efroymson *et al.*, 1997b] and are generally in line with the 200 mg/kg earthworm benchmark value. The effects of zinc on other soil-dwelling organisms are summarized in Efroymson *et al.* [1997b].

Toxicity reference values for zinc include 50 mg/kg for plants, 200 mg/kg for earthworms and 100 mg/kg for soil microorganisms. The CCME ecological benchmark of 200 mg/kg falls at the upper end of the range of these benchmarks.

Table 5.2 summarizes the toxicity benchmarks for soil-dwelling organisms and terrestrial plants in soil for lead and zinc. The CCME ecological values were selected for comparison for plants, soil invertebrates and soil microorganisms.

TABLE 5.2
TOXICOLOGICAL BENCHMARKS FOR LEAD AND ZINC FOR SOIL-DWELLING ORGANISMS AND TERRESTRIAL PLANTS IN SOIL

Contaminant	Terrestrial Plants	Soil Invertebrates (Earthworms)	Soil Microorganisms	CCME Ecological Benchmark	Units
Lead	50[a]	500[b]	900[b]	300[c]	mg/kg
Zinc	50[a]	200[b]	100[b]	200[c]	mg/kg

Note:
a – EC_{10} from Efroymson *et al.*[1997a] for terrestrial vegetation.
b – EC_{10} from Efroymson *et al.* [1997b] for earthworms.
c – From CCME [2002]. CCME Soil Quality Guidelines.

For the mammalian and avian species, toxicity reference values were obtained from the U.S. Department of Energy (DOE) database [Sample *et al.*, 1996] and from the Environment Canada Reptile and Amphibian Toxicology Literature (RATL) database [Pauli *et al.*, 2000] for reptiles. The no observable adverse effects level (NOAEL) was used in this assessment. Toxicity reference values are presented in Table 5.3.

TABLE 5.3
TOXICITY REFERENCE VALUES FOR MAMMALIAN, AVIAN AND REPTILIAN SPECIES

CONTAMINANT	CONTAMINANT FORM	TEST SPECIES	ENDPOINT SPECIES	NOAEL (mg/kg-d)
Lead	Lead acetate	rat	Deer Mouse	16.20
	Lead acetate	rat	Eastern Cottontail	5.88
	Lead acetate	Japanese quail	American Robin	1.13
	Not specified	toad	Northern Watersnake	5.79[a]
Zinc	Zinc oxide	rat	Deer Mouse	323.28
	Zinc oxide	rat	Eastern Cottontail	117.60
	Zinc sulfate	white leghorn hen	American Robin	14.50
	-	-	Northern Watersnake	-[b]

Note:
Data obtained from Sample *et al.*[1996], with the exception of the lead toxicity reference value for the Northern watersnake.

a - For the watersnake's lead toxicity reference value, a NOAEL of 57.9 mg/kg-d was calculated from a study on *Xenopus laevis* toads [Ireland, 1977]. An uncertainty factor of 10 was applied to this value to account for interspecies differences, and a final value of 5.79 mg/kg-d was derived for the watersnake.

b – No appropriate toxicity studies on zinc were identified for reptiles or amphibians, and therefore a zinc toxicity reference value was not derived.

There is some uncertainty associated with the use of all the ecological toxicity reference values. However, there is particular uncertainty associated with the watersnake value, as reptiles and amphibians are not typically assessed in ecological risk assessment. Uncertainty associated with the watersnake toxicity reference value includes:

- the toxicity study related to the feeding of contaminated earthworms to toads, and watersnakes do not typically eat earthworms;
- the toxicity endpoints studied included developmental effects and not the more ecologically-relevant reproductive effects;
- it is unknown what kind of an impact the extrapolation from amphibian (toad) data to reptiles (watersnakes) would have as toxicity may differ between these animal groups.

5.5 EXPOSURE ASSESSMENT

In order to determine the concentrations of lead and zinc in vegetation, earthworms and small mammals, transfer factors are needed to calculate the concentrations based on the soil lead and zinc concentrations. This is a common methodology used in assessments when measured data are unavailable. The transfer factors used in this assessment are summarized in Table 5.4 below.

TABLE 5.4
SUMMARY OF TRANSFER FACTORS USED IN THE ASSESSMENT

CONTAMINANT	TRANSFER FACTOR DESCRIPTION	SYMBOL	VALUE	REFERENCE
Lead	Soil to terrestrial vegetation	TF_{tv}	0.004	NCRP 1996
	Soil to earthworm	TF_{ewm}	0.266	Sample *et al.* 1998a
	Soil to small mammal	TF_{sm}	1.3	Sample *et al.* 1998b
Zinc	Soil to terrestrial vegetation	TF_{tv}	0.4	NCRP, 1996
	Soil to earthworm	TF_{ewm}	3.2	Sample *et al.* 1998a
	Soil to small mammal	TF_{sm}	0.162	Sample *et al.* 1998b

The calculations of estimated lead and zinc intakes to mammalian, avian and reptilian receptors are provided in Appendix B. In essence, the total intake of the contaminant for the selected receptors is equal to the sum of contaminant intake from the ingestion of soil, terrestrial vegetation, soil invertebrates (e.g. earthworms) and small mammals. For the deer mouse, the intake of contaminant is by ingestion of all of the pathways mentioned above. For the Eastern cottontail rabbit, the intake of contaminant is through ingestion of soil and terrestrial vegetation. For the American robin, the intake of contaminant is via ingestion of soil and earthworms. Lastly, for the Northern watersnake, the intake of contaminant is through the ingestion of soil and small mammals. The equations ((5-1) to (5-4)) used to calculate each of the intake routes are as follows:

Soil Ingestion

$$I_{soil} = C_s \, S_{ir} \, loc/1000 \quad (5\text{-}1)$$

Terrestrial Vegetation Ingestion

$$I_{tv} = C_{tv} \, F_{ir} \, Fr_{veg} \, loc/1000 \quad (5\text{-}2)$$

Earthworm Ingestion

$$I_{ewm} = C_{ewm} \, F_{ir} \, Fr_{ewm} \, loc/1000 \quad (5\text{-}3)$$

Small Mammal Ingestion

$$I_{sm} = C_{sm} \, F_{ir} \, Fr_{sm} \, loc/1000 \quad (5\text{-}4)$$

Where:

I_{soil}	=	Intake of contaminant via soil, vegetation, or soil invertebrates (mg/d)
C_s	=	average contaminant concentration (400 mg/kg for lead, 201 mg/kg for zinc)
C_{tv}	=	contaminant concentration in terrestrial vegetation (mg/kg, equals C_s x soil to terrestrial vegetation transfer factor (TF_{tv}) from Table 5.4)
C_{ewm}	=	contaminant concentration in earthworms (mg/kg, equals C_s x soil to earthworm transfer factor (TF_{ewm}) from Table 5.4)
C_{sm}	=	contaminant concentration in small mammals (mg/kg, equals C_s x soil to small mammal transfer factor (TF_{sm}) from Table 5.4)
S_{ir}	=	soil ingestion rate (g/d, see Table 5.1)
F_{ir}	=	food ingestion rate (g/d, see Table 5.1)
Fr_{veg}	=	fraction of diet that is terrestrial vegetation
Fr_{si}	=	fraction of diet that is soil invertebrates
Fr_{sm}	=	fraction of diet that is small mammals
loc	=	fraction of time at site (see Table 5.1)
1000	=	unit conversion (g/kg)

Finally, in order to compare the total contaminant intake to the toxicity reference value (which has the unit of mg/kg-d), the total intake was divided by the body weight of the ecological receptor (BW).

The final calculation of total intake is as follows:

Deer Mouse: Total intake (mg/kg-d) = $(I_{soil} + I_{tv} + I_{ewm})/BW$ (5-5)

Eastern Cottontail: Total intake (mg/kg-d) = $(I_{soil} + I_{tv})/BW$ (5-6)

American Robin: Total intake (mg/kg-d) = $(I_{soil} + I_{ewm})/BW$ (5-7)

Northern Watersnake: Total intake (mg/kg-d) = $(I_{soil} + I_{sm})/BW$ (5-8)

As indicated earlier, site specific average lead and zinc concentrations of 400 mg/kg and 201 mg/kg (as per Table 4.1), respectively, were used in this assessment. Table 5.5 provides a summary of the lead and zinc intakes of the different receptors.

TABLE 5.5
SUMMARY OF ESTIMATED INTAKES TO ECOLOGICAL RECEPTORS

ECOLOGICAL RECEPTOR	ESTIMATED LEAD INTAKE (mg/kg-d)	ESTIMATED ZINC INTAKE (mg/kg-d)
Deer Mouse	3.64	19.0
Eastern Cottontail	2.58	25.2
American Robin	0.81	3.79
Northern Watersnake	4.20	0.39

5.6 RISK CHARACTERIZATION

For the risk characterization, a comparison was made between the exposure estimates for the receptors and toxicity reference values available for lead and zinc to determine a screening index value. A Screening Index is defined as a ratio of the estimated intake to the toxicity reference value. A Screening Index value below 1 indicates that there are no potential impacts on the given receptor. The Screening Index values for the various receptors are provided in Table 5.6.

TABLE 5.6
SUMMARY OF SCREENING INDEX CALCULATIONS

RECEPTOR	CONTAMINANT	ESTIMATED INTAKE (TABLE 5.5) (mg/kg-d)	NOAEL (TABLE 5.3) (mg/kg-d)	SCREENING INDEX VALUE
Deer Mouse	Lead	3.64	16.2	0.22
	Zinc	19.0	323	0.06
Eastern Cottontail	Lead	2.58	5.88	0.44
	Zinc	25.2	118	0.21
American Robin	Lead	0.81	1.13	0.71
	Zinc	3.79	14.5	0.26
Northern Watersnake	Lead	4.20	5.79	0.73
	Zinc	0.39	-[a]	-

Note:

a – No appropriate toxicity studies on zinc were identified for reptiles or amphibians, and therefore a zinc toxicity reference value was not derived.

As seen in the above table, all the Screening Index values are below 1, indicating that there are no anticipated potential adverse health effects on terrestrial ecological populations from exposure to the lead and zinc containing soils at the Hope Island Lightstation site.

For earthworms and terrestrial vegetation, the soil lead concentration is compared directly to the CCME benchmarks discussed above. Table 5.7 shows this comparison.

TABLE 5.7
COMPARISON OF TOXICITY BENCHMARKS TO AVERAGE MEASURED LEAD AND ZINC CONCENTRATIONS

CONTAMINANT	AVERAGE SOIL CONTAMINANT CONCENTRATION (mg/kg)[a]	DEPTH OF SAMPLE (mm)	TOXICITY BENCHMARKS (mg/kg)	EXCEEDS BENCHMARK?
Lead	400	0-50	300 (CCME)[b]	Yes
			50 (Terrestrial Plants)	Yes
			500 (Earthworm)[c]	No
			900 (Soil Microorganisms)[c]	No
Zinc	201	0-50	200 (CCME)[b]	Yes
			50 (Terrestrial Plants)	Yes
			200 (Earthworm)[c]	Yes
			100 (Soil Microorganisms)[c]	Yes

Note:

a - From DCS [2004] - Average of 51 samples across the lightstation site -surface soil samples at depth of 0-50 mm.

b - From CCME [2002]. CCME Soil Guidelines.

c - From Efroymson *et al.*[1997b] for effects on soil and litter invertebrates and heterotrophic process.

From the above table it can be seen that the average measured lead and zinc concentrations in soil both exceed the CCME soil toxicity benchmarks. As mentioned previously, most remedial areas have been covered with a soil thickness of 50 to 150 mm. Given the size of the contaminated areas in comparison to the overall Hope Island site, it is unlikely that earthworm populations on Hope Island will experience any adverse effects. In addition, it is unknown if earthworms are even present at the site.

Both average lead and zinc concentrations exceed the terrestrial vegetation benchmark, indicating that terrestrial plants may be potentially at risk, from both lead and zinc exposures. However, given that opportunistic vegetation is presently growing at the site, it is unlikely that terrestrial vegetation that is expected to grow at the site will experience any adverse effects.

6.0 DEVELOPMENT OF SITE-SPECIFIC SOIL CRITERIA

The final component of the SSRA involved the development of site-specific soil criteria for use at the Hope Island Lightstation site. To develop the site-specific criteria, a ratio of the contaminant soil concentration at the site and the hazard quotient or screening index calculated for the particular receptor under consideration at the site is quantified. This ratio is then applied to the action level for the hazard quotient or screening index. In the case of human receptors, an action level of 0.2 is selected as the action level, while for ecological receptors, an action level of 1 is selected as the action level. These action levels are commonly adopted by regulatory agencies and are considered conservative and protective of human health at the individual level, and of ecological health at the population level. The calculations used in the development of the site specific soil criteria are included in Appendix B.

For the human receptors, the adult was selected because it is the most exposed individual. Site-specific soil criteria of 4,361 mg/kg and 456,686 mg/kg were calculated for lead and zinc, respectively. As no measured concentrations of lead or zinc exceed these values, there is no need for risk management measures from a human health perspective.

Site-specific soil criteria were developed for each of the ecological receptors. Site-specific criteria for lead included 1,776 mg/kg, 912 mg/kg, 560 mg/kg and 551 mg/kg for the deer mouse, Eastern cottontail rabbit, American robin and Northern watersnake, respectively. Site-specific criteria for zinc included 3,432 mg/kg, 939 mg/kg and 769 mg/kg for the deer mouse, Eastern cottontail rabbit and American robin, respectively. A site-specific criterion for zinc for the Northern watersnake could not be determined due to lack of toxicological data. As the average measured concentrations of lead and zinc do not exceed the ecological site-specific criteria, there is no need for risk management measures from an ecological perspective.

The site-specific criteria developed for use at the Hope Island Lightstation are presented in Table 6.1.

TABLE 6.1
SITE-SPECIFIC SOIL CRITERIA DEVELOPED FOR USE AT THE HOPE ISLAND LIGHTSTATION (mg/kg)

RECEPTOR	SITE-SPECIFIC CRITERIA FOR LEAD	SITE-SPECIFIC CRITERIA FOR ZINC
Human adult	4,361	456,686
Deer mouse	1,776	3,432
Eastern cottontail	912	939
American robin	560	769
Northern watersnake	551	-

7.0 CONCLUSIONS

A site-specific risk assessment (SSRA) was conducted on the Hope Island Lightstation property in Georgian Bay, Lake Huron. The focus of the SSRA was on lead and zinc soil contamination, which originated in part from the use of lead-based paint on lightstation buildings as well as from cinders and ash generated from the historic burning of coal and being spread over the grounds of the lightstation. Additionally, some lead-based paint remains on some lightstation building surfaces, plus asbestos containing materials (ACM) are present in several of the site buildings.

Exposure to lead and zinc contaminated soils was assessed with regards to their potential adverse effect on human health. The hazard quotients for both lead and zinc are below the appropriate action levels and therefore, negative health effects are not expected to be experienced by the selected human receptors at the property under the conservative exposure assumptions for this assessment.

Population-level impacts on ecological health were also assessed. Although measured lead and zinc concentrations exceeded the CCME ecological guidelines, trees are well established and opportunistic vegetation is growing on the site. The ecological assessment determined that the lead and zinc concentrations on site do not pose a concern to small terrestrial mammals and birds that would potentially be at the site. Lead concentrations in the soil at the site do not pose a risk to Northern watersnakes that inhabit the island. However, the risk to watersnakes from zinc exposure could not be assessed due to lack of toxicological data, nevertheless it is expected to be negligible based on consideration of the assessment for lead, as well as the fact that there is an abundant population of snakes on the island.

Site-specific soil criteria for use at the Hope Island Lightstation were developed for lead and zinc based on both human receptors, and the terrestrial animals and birds considered in the ecological risk assessment. As the site-specific criteria that were developed were higher than the maximum measured concentrations (for human health) or the average measured concentrations (for ecological receptors), there is no requirement for risk management measures.

In summary, there are no human health or ecological concerns related to the lead and zinc contamination in soils at the Hope Island Lightstation site, and no risk management measures are recommended in this regard. However, in order to reduce the risks present from other hazards at the site, the following recommendations are made:

- Due to the inferred relationship between lead-based paint and lead and zinc soil contamination issues, the exterior of the existing buildings on the site that contain lead based paints should be managed (e.g. covered with a fresh coat of paint or by siding) so that further soil contamination will not occur; and

- If still present, loose friable ACM in the basement of the former lighthouse and pipe insulation in the crawl space of the Fog Alarm Building identified during the 1997 Phase I ESA, should be removed. However, no risk management measures are recommended for the non friable ACM identified by the Phase I ESA in several of the site buildings, nor for the friable ACM gaskets present in the furnaces of both dwellings.

8.0 REFERENCES

Aery, N.C. and S. Sakar. 1991. *Studies on the effect of heavy metal stress on growth parameters of soybean*. J. Environ. Biol. 12(1): 15-24.

Beyer, W. N., E. Connor and S. Gerould. 1994. *Survey of Soil Ingestion by Wildlife*. Journal of Wildlife Management 58:375-382.

Birge, W. J., A. G. Westerman and J. A. Spromberg. 2000. *Ecotoxicology of Amphibians and Reptiles*. In D.W. Sparling, G. Linder, and C. A. Bishop (eds), Society of Environmental Toxicology and Chemistry (SETAC) Press, Pensacola, FL.

Burton, K.W., E. Morgan, and A. Roig. 1984. *The Influence of Heavy Metals upon the Growth of Sitka-Spruce in South Wales Forests. II Greenhouse Experiments*. Plant Soil 78:271-282.

Canadian Council of Ministers of the Environment (CCME). 2002. *Canadian Environmental Quality Guidelines.*

Canadian Council of Ministers of the Environment (CCME). 1996. *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines.* March.

Carlson, R.W. and G.L. Rolfe. 1979. *Growth of Rye Grass and Fescue as Affected by Lead-Cadmium-Fertilizer Interaction*. J. Environ. Qual. 8(3):348-352.

Chapman, H.D. 1966. Zinc. In: *Diagnostic Criteria for Plants and Soils*. H.D. Chapman (ed). Univ. of California, Div. Agric. Sci. pp. 484-499.

Decommissioning Consulting Services Limited (DCS). 2004. *Remedial Program, Hope Island Lightstation (L.L.857), Georgian Bay, Lake Huron, Ontario*. October.

Decommissioning Consulting Services Limited (DCS). 1999. *Phase II Environmental Site Assessment and Risk Assessment: Hope Island Lightstation, LL857, Georgian Bay, Lake Huron, Ontario.* Prepared for: Public Works and Government Services Canada (PWGSC). February.

Dixon, R.K. 1988. *Response of Ectomycorrhizal Quercus rubra to Soil Cadmium, Nickel and Lead.* Soil Biol. Chem. 20(4):555-559.

Efroymson, R.A., M.E. Will, G.W. Suter II, and A.G. Wooten. 1997a. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision*. Prepared for the U.S. Department of Energy, Office of Environmental Management. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-85/R3.

Efroymson, R.A., M.E. Will, and G.W. Suter II. 1997b. *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision*. Prepared for the U.S. Department of Energy, Office of Environmental Management. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-126/R2

Health Canada. 2002. *Canadian Guidelines on Drinking Water Quality, Supporting Documentation.* Ottawa, ON.

Health Canada. 2003a *Federal Contaminated Site Risk Assessment in Canada. Part I: Guidance on Human Health Screening Level Risk Assessment (SLRA).* Version 1.1. October 3rd.

Health Canada. 2003b. *Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs).* Version 1.0, October 3rd.

Health Canada. 2005. *Health Canada Comments on Site Specific Risk Assessment, Hope Island Lighstation, LL857, Georgian Bay, Lake Huron, Ontario*, prepared by DCS, December 2004, 17 May.

Institute of Medicine (IOM). 2000. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium and Zinc.* National Academy Press, http://www.nap.edu/books/0309072794/html/442.html.

Ireland, M.P. 1977. *Lead Retention in Toads Xenopus Laevis Fed Increasing Levels of Lead-Contaminated Earthworms*. Environ. Pollut. 12: 85-92.

Lata, K. and B. Veer. 1990. *Phytotoxicity of Zn amended soil to Spinacia and Coriandrum*. Acta Bot. Indica. 18: 194-198.

Ma, W.C. 1982. *The influence of soil properties and warm-related factors on the concentration of heavy metals in earthworms*. Pedobiologia. 24: 109-119.

Oliver, Mangione, McCalla and Associates. 1997. *Phase 1 Environmental Assessment: Hope Island Light Station, Georgian Bay, Ontario – L.L. 857*. Prepared for the Canadian Coast Guard, Central and Arctic Region.

Ontario Ministry of Environment and Energy (MOE). 2004. *Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act*. March 9th.

Pauli, B.D., J.A. Perrault and S.L. Money. 2000. *RATL: A Database of Reptile and Amphibian Toxicology Literature*. Prepared for Environment Canada, National Wildlife Research Centre, Canadian Wildlife Service, Hull, Quebec. Technical Report Series No. 357.

Sample, B.E., J.J. Beauchamp, R.A. Efroymson, G.W. Suter II, T.L. Ashwood. 1998a. *Development and Validation of Bioaccumulation Models for Earthworms*. Prepared for the United States Department of Energy, Office of Environmental Management. By Oak Ridge National Laboratory.

Sample, B.E., J.J. Beauchamp, R.A. Efroymson, G.W. Suter II.. 1998b. *Development and Validation of Bioaccumulation Models for Small Mammals*. Prepared for the United States Department of Energy, Office of Environmental Management. By Oak Ridge National Laboratory. ES/ER/TM-219.

Sample, B.E., D.M. Opresko and G.W. Suter II. 1996 . *Toxicological Benchmarks for Wildlife: 1996 Revision*. Prepared for the United States Department of Energy, Office of Environmental Management. By Oak Ridge National Laboratory. ES/ER/TM-86/R3.

Sheppard, S.C., W.G. Evenden, S.A. Abboud, and M. Stephenson. 1993. *A plant life-cycle bioassay for contaminated soil, with comparison to other bioassays: Mercury and zinc*. Arch. Environ. Contam. Toxicol. 25: 27-35.

United States Environmental Protection Agency (U.S. EPA). 1993. *Wildlife Exposure Factors Handbook*. EPA/600/R-93/187. December.

United States Environmental Protection Agency (U.S. EPA). 1992. *Dermal Exposure Assessment: Principles and Applications.* Interim Report. EPA/600/8-91/011B. January.

United States National Council on Radiation Protection and Measurements (NCRP). 1996. *Screening Models for Release of Radionuclides to Atmosphere, Surface Water and Ground.* NCRP Report No. 123.

White, M.C., R.L. Chaney, and A.M. Decker. 1979. *Differential cultivar tolerance in soybean to phytotoxic levels of soil Zn. II. Range of Zn additions and the uptake and translocation of Zn, Mn, Fe and P.* Agronomy J. 71: 126-131.

World Health Organization (WHO). 1987. *Report of the 30th Meeting of the Joint FAO/WHO Expert Committee on Food Additives.* 2-11 June 1986, Rome,, cited by Health Canada 2002.

APPENDIX A

LABORATORY CERTIFICATES

PSC
ANALYTICAL SERVICES

21-Oct-2004

DECOMMISSIONING CONSULTING SERVICES
121 Granton Drive, Unit #11
Richmond Hill, ON
L4B 3N4

Page: 1
Copy: 1 of 2

Attn: Grant Yule
Received: 14-Oct-2004 13:18
Project: 48297-9
PO #:

Job: 2460691
Status: Final

Soil Samples

Sample Id	Ag ICAP ppm	Al ICAP ppm	Ba ICAP ppm	Be ICAP ppm	Ca ICAP ppm	Cd ICAP ppm	Co ICAP ppm	Cr ICAP ppm
1605	<1	4110	172	<0.2	36700	1.8	3	10
1615	<1	4500	207	0.2	33100	1.3	4	13
1625	<1	5700	52	0.2	17200	0.7	4	10
1635	<1	4480	36	<0.2	7790	<0.5	2	8
Blank	<1	<20	<5	<0.2	<50	<0.5	<2	<1
QC Standard (found)	2	16200	161	0.6	6510	0.5	27	50
QC Standard (expected)	2	16400	162	0.6	6350	0.6	26	49
Repeat 1605	<1	4040	160	<0.2	35400	1.7	3	10

Sample Id	Cu ICAP ppm	Fe ICAP ppm	K ICAP ppm	Mg ICAP ppm	Mn ICAP ppm	Mo ICAP ppm	Na ICAP ppm	Ni ICAP ppm
1605	37	7330	1060	4700	466	<3	146	17
1615	34	8200	1210	3670	487	<3	145	17
1625	22	9100	1020	3420	320	<3	215	14
1635	10	6470	589	1790	106	<3	191	7
Blank	<1	<50	<100	<20	<1	<3	<50	<2
QC Standard (found)	32	33000	2620	8360	1190	<3	308	44
QC Standard (expected)	32	32300	2670	8180	1160	<3	328	43
Repeat 1605	34	7100	1040	4850	456	<3	161	16

PSC

ANALYTICAL SERVICES

21-Oct-2004

DECOMMISSIONING CONSULTING SERVICES
121 Granton Drive, Unit #11
Richmond Hill, ON
L4B 3N4

Attn: Grant Yule
Received: 14-Oct-2004 13:18
Project: 48297-9
PO #:

Job: 2460691 Status: Final

Soil Samples

Sample Id	P ICAP ppm	Pb ICAP ppm	Sr ICAP ppm	Ti ICAP ppm	V ICAP ppm	Zn ICAP ppm
1605	1750	986	44.0	188	11	617
1615	1550	755	41.9	226	12	599
1625	1130	170	23.6	298	16	134
1635	849	59	13.7	269	13	109
Blank	<20	<5	<0.3	<5	<1	<5
QC Standard (found)	919	28	27.2	1170	50	130
QC Standard (expected)	892	25	27.7	1080	49	124
Repeat 1605	1600	924	42.0	184	11	571

ANALYTICAL SERVICES

21-Oct-2004

DECOMMISSIONING CONSULTING SERVICES
121 Granton Drive, Unit #11
Richmond Hill, ON
L4B 3N4

Attn: Grant Yule
Project: 48297-9 PO #:
Received: 14-Oct-2004 13:18

Job: 2460691 Status: Final

All work recorded herein has been done in accordance with normal professional standards using accepted testing methodologies and QA/QC procedures. PSC Analytical is limited in liability to the actual cost of the pertinent analyses done unless otherwise agreed upon by contractual arrangement. Your samples will be retained by PSC Analytical for a period of 30 days following reporting or as per specific contractual arrangements.

Job approved by:

Signed:
....
Malgorzata Dancziger
Project Manager

APPENDIX B

CALCULATIONS

Parameter	Units	Symbol	Value	Reference or Equation
HUMAN HEALTH RISK ASSESSMENT				
Adult (20yr +)				
Body weight	kg	BW_a	70.7	Health Canada, 2003
Soil ingestion rate	kg/d	R_{ing}_a	2.00E-05	Health Canada, 2003
Gut absorption factor - lead	-	AF_{gut-pb}	1	assumed
Gut absorption factor - zinc	-	AF_{gut-zn}	1	assumed
Fraction of time at site	-	Fsite_a	0.46	5.5 months of the year = 167.3/365
Skin surface area - arms, legs and hands	cm^2	SA	9110	Health Canada, 2003
Soil adherence value	kg/(cm^2-event)	SL_H	1.00E-07	assumed
Exposure frequency - number of events per day	events/day	EF	1	equals 1 exposure event for each day
Dermal absorption factor - lead	-	$AF_{skin-pb}$	0.006	Health Canada, 2003
Dermal absorption factor - zinc	-	$AF_{skin-zn}$	0.020	Health Canada, 2003
LEAD				
Soil Concentration	mg/kg	C_s	2620	Maximum measured soil concentrations
Ingestion Exposure				
Ingestion dose	mg/kg-d	D_o	3.40E-04	$=C_s*R_{ing}\_a*AF_{gut-pb}*Fsite\_a/BW\_a$ (see equation (4-1))
Toxicity Reference Value - oral	mg/kg-d	TRV_o	0.0036	Health Canada, 2003b
Hazard Quotient - oral	-	HQ_o	0.094	$=D_o/RfD_o$ (see equation (4-4))
Dermal Exposure				
Dermal exposure	mg/kg-d	D_d	9.3E-05	$=Cs*SA*SL*AF_{skin-pb}*Fsite\_a*EF/BW\_a$ (see equation (4-2))
Toxicity Reference Value - dermal	mg/kg-d	TRV_d	0.0036	assumed same as oral
Hazard Quotient - dermal	-	HQ_d	0.026	$=D_d/RfD_d$ (see equation (4-4))
Total Hazard Quotient	-	HQ	0.120	$=HQ_o+HQ_d$ (see equation (4-4))
ZINC				
Soil Concentration	mg/kg	C_s	1090	Maximum measured soil concentrations
Ingestion Exposure				
Ingestion dose	mg/kg-d	D_o	1.41E-04	$=C_s*R_{ing}\_a*AF_{gut-zn}*Fsite\_a/BW\_a$ (see equation (4-1))
Toxicity Reference Value - oral	mg/kg-d	TRV_o	0.57	Health Canada, 2005
Hazard Quotient - oral	-	HQ_o	0.0002	$=D_o/RfD_o$ (see equation (4-4))

Parameter	Units	Symbol	Value	Reference or Equation
Dermal Exposure				
Dermal exposure	mg/kg-d	D_d	1.3E-04	=Cs*SA*SL*$AF_{skin\text{-}Zn}$*Fsite_a*EF/BW_a (see equation (4-2))
Toxicity Reference Value - dermal	mg/kg-d	TRV_d	0.57	assumed same as oral
Hazard Quotient - dermal	-	HQ_d	0.00023	=D_d/RfD_d (see equation (4-4))
Total Hazard Quotient	-	HQ	0.00048	=HQ_o+HQ_d (see equation (4-4))
Teen (12-19yrs)				
Body weight	kg	BW_t	59.7	Health Canada, 2003
Soil ingestion rate	kg/d	R_{ing}_t	2.00E-05	Health Canada, 2003
Gut absorption factor - lead	-	$AF_{gut\text{-}pb}$	1	assumed
Gut absorption factor - zinc	-	$AF_{gut\text{-}zn}$	1	assumed
Fraction of time at site	-	Fsite_t	0.15	8 weeks of the year = 8/52
Skin surface area - hands, legs, arms	cm^2	SA	8000	Health Canada, 2003
Soil adherence value	kg/(cm^2-event)	SL_H	1.10E-07	assumed
Exposure frequency - number of events per day	events/day	EF	1	equals 1 exposure event for each day
Dermal absorption factor - lead	-	$AF_{skin\text{-}pb}$	0.006	Health Canada, 2003
Dermal absorption factor - zinc	-	$AF_{skin\text{-}zn}$	0.020	Health Canada, 2003
LEAD				
Soil Concentration	mg/kg	C_s	2620	Maximum measured soil concentrations
Ingestion Exposure				
Ingestion dose	mg/kg-d	D_o	1.35E-04	=C_s*R_{ing}_t*$AF_{gut\text{-}pb}$*Fsite_t/BW_t (see equation (4-1))
Toxicity Reference Value - oral	mg/kg-d	TRV_o	0.0036	Health Canada, 2003b
Hazard Quotient - oral	-	HQ_o	0.0375	=D_o/RfD_o (see equation (4-4))
Dermal Exposure				
Dermal exposure	mg/kg-d	D_d	3.6E-05	=Cs*SA*SL_H*$AF_{skin\text{-}pb}$*Fsite_a*EF/BW_a (see equation (4-2))
Toxicity Reference Value - dermal	mg/kg-d	TRV_d	0.0036	assumed same as oral
Hazard Quotient - dermal	-	HQ_d	0.0099	=D_d/RfD_d (see equation (4-4))
Total Hazard Quotient	-	HQ	0.047	=HQ_o+HQ_d (see equation (4-4))
ZINC				
Soil Concentration	mg/kg	C_s	1090	Maximum measured soil concentrations
Ingestion Exposure				
Ingestion dose	mg/kg-d	D_o	5.62E-05	=C_s*R_{ing}_t*$AF_{gut\text{-}zn}$*Fsite_t/BW_t (see equation (4-1))

Parameter	Units	Symbol	Value	Reference or Equation
Toxicity Reference Value - oral	mg/kg-d	TRV_o	0.57	Health Canada, 2005
Hazard Quotient - oral	-	HQ_o	0.00010	$=D_o/RfD_o$ (see equation (4-4))
Dermal Exposure				
Dermal exposure	mg/kg-d	D_d	4.9E-05	$=Cs*SA*SL_H*AF_{skin-pb}*Fsite\_a*EF/BW\_a$ (see equation (4-2))
Toxicity Reference Value - dermal	mg/kg-d	TRV_d	0.57	assumed same as oral
Hazard Quotient - dermal	-	HQ_d	0.000087	$=D_d/RfD_d$ (see equation (4-4))
Total Hazard Quotient	-	HQ	0.00019	$=HQ_o+HQ_d$ (see equation (4-4))
Child (5-11yrs)				
Body weight	kg	BW_c	32.9	Health Canada, 2003
Soil ingestion rate	kg/d	R_{ing}_c	2.00E-05	Health Canada, 2003
Gut absorption factor - lead	-	AF_{gut-pb}	1	assumed
Gut absorption factor - zinc	-	AF_{gut-zn}	1	assumed
Fraction of time at site	-	Fsite_c	0.15	8 weeks of the year = 8/52
Skin surface area - hands, legs, arms	cm^2	SA	5140	Health Canada, 2003
Soil adherence value	$kg/(cm^2\text{-event})$	SL_H	1.10E-07	assumed
Exposure frequency - number of events per day	events/day	EF	1	equals 1 exposure event for each day
Dermal absorption factor - lead	-	$AF_{skin-pb}$	0.006	Health Canada, 2003
Dermal absorption factor - zinc	-	$AF_{skin-zn}$	0.02	Health Canada, 2003
LEAD				
Soil Concentration	mg/kg	C_s	2620	Maximum measured soil concentrations
Ingestion Exposure				
Ingestion dose	mg/kg-d	D_o	2.45E-04	$=C_s*R_{ing}\_c*AF_{gut-pb}*Fsite\_c/BW\_c$ (see equation (4-1))
Toxicity Reference Value - oral	mg/kg-d	TRV_o	0.0036	Health Canada, 2003b
Hazard Quotient - oral	-	HQ_o	0.068	$=D_o/RfD_o$ (see equation (4-4))
Dermal Exposure				
Dermal exposure	mg/kg-d	D_d	4.2E-05	$=Cs*SA*SL_H*AF_{skin-pb}*Fsite\_a*EF/BW\_a$ (see equation (4-2))
Toxicity Reference Value - dermal	mg/kg-d	TRV_d	0.0036	assumed same as oral
Hazard Quotient - dermal	-	HQ_d	0.012	$=D_d/RfD_d$ (see equation (4-4))
Total Hazard Quotient	-	HQ	0.08	$=HQ_o+HQ_d$ (see equation (4-4))

Parameter	Units	Symbol	Value	Reference or Equation
ZINC				
Soil Concentration	mg/kg	C_s	1090	Maximum measured soil concentrations
Ingestion Exposure				
Ingestion dose	mg/kg-d	D_o	1.02E-04	$=C_s*R_{ing}\_c*AF_{gut\text{-}zn}*Fsite\_c/BW\_c$ (see equation (4-1))
Toxicity Reference Value - oral	mg/kg-d	TRV_o	0.57	Health Canada, 2005
Hazard Quotient - oral	-	HQ_o	0.00018	$=D_o/RfD_o$ (see equation (4-4))
Dermal Exposure				
Dermal exposure	mg/kg-d	D_d	5.8E-05	$=Cs*SA_E*SL_H*AF_{skin\text{-}pb}*Fsite\_a*EF/BW\_a$ (see equation (4-2))
Toxicity Reference Value - dermal	mg/kg-d	TRV_d	0.57	assumed same as oral
Hazard Quotient - dermal	-	HQ_d	0.000102	$=D_d/RfD_d$ (see equation (4-4))
Total Hazard Quotient	-	HQ	0.00028	$=HQ_o+HQ_d$ (see equation (4-4))
ECOLOGICAL RISK ASSESSMENT				
LEAD				
Average Soil Lead Concentration	mg/kg DW	C_s	399.5	=average of lead concentrations presented in Table 4.1
Deer Mouse				
Body weight	kg	BW	0.02	U.S. EPA, 1993
Food ingestion rate	g FW/d	F_{ir}	4.2	calculated using U.S. EPA, 1993. "fw" indicates fresh weight.
Fraction of diet that is terrestrial vegetation	-	Fr_{veg}	0.6	U.S. EPA, 1993
Fraction of diet that is earthworms	-	Fr_{ewm}	0.4	U.S. EPA, 1993
Soil ingestion rate	g DW/d	S_{ir}	0.11	calculated from Beyer *et al*., 1994. "dw" indicates dry weight.
Fraction of time at site	-	loc	1	assumed
Soil-to-terrestrial vegetation transfer factor	kg/kg (FW)	TF_v	0.004	NCRP, 1996
Lead concentration in terrestrial vegetation	mg/kg (FW)	C_{tv}	1.60	$=C_s*TF_v$
Soil-to-earthworm transfer factor	kg/kg (DW)	TF_{ewm}	0.27	Sample *et al*., 1998a
Lead concentration in earthworms	mg/kg (FW)	C_{ewm}	17.0	$=C_s*TF_{ewm}*WC_{ewm}$
Intake of lead from soil	mg/d	I_{soil}	0.04	$=C_s*S_{ir}/1000*loc$ (see equation 5-1)
Intake of lead from terrestrial vegetation	mg/d	I_{tv}	0.004	$= C_{tv}*F_{ir}/1000*Fr_{veg}*loc$ (see equation 5-2)
Intake of lead from earthworms	mg/d	I_{ewm}	0.03	$=C_{ewm}*F_{ir}/1000*Fr_{ewm}*loc$ (see equation 5-3)
Total intake - lead	mg/d	I_total	0.08	$=I_{soil}+I_{tv}+I_{ewm}$

Parameter	Units	Symbol	Value	Reference or Equation
Total intake by body weight	mg/kg-d	Intake	**3.64**	=I_total/BW (see equation 5-5)
Toxicity reference value	mg/kg-d	tox	16.20	Sample *et al*., 1996, scaled for body weight
SI	-	SI	0.22	=Intake/tox
Eastern Cottontail				
Body weight	kg	BW	1.2	U.S. EPA, 1993
Food ingestion rate	g FW/d	F_{ir}	360	Calculated using U.S. EPA, 1993
Fraction of diet that is terrestrial vegetation	-	Fr_{veg}	1	U.S. EPA, 1993
Soil ingestion rate	g DW/d	S_{ir}	6.3	Calculated from Beyer *et al*., 1994
Fraction of time at site	-	loc	1.00	Assumed
Soil-to-terrestrial vegetation transfer factor	kg/kg (FW)	TF_v	0.004	NCRP, 1996
Lead concentration in terrestrial vegetation	mg/kg (FW)	C_{tv}	1.60	$=C_s*TF_v$
Intake of lead from soil	mg/d	I_{soil}	2.52	$=C_s*S_{ir}/1000*loc$ (see equation 5-1)
Intake of lead from terrestrial vegetation	mg/d	I_{tv}	0.58	$= C_{tv}*F_{ir}/1000*Fr_{veg}*loc$ (see equation 5-2)
Total intake - lead	mg/d	I_total	3.09	$=I_{soil}+I_{tv}$
Total intake by body weight	mg/kg-d	Intake	**2.58**	=I_total/BW (see equation 5-6)
Toxicity reference value	mg/kg-d	tox	5.88	Sample *et al*., 1996
SI	-	Si	0.44	=Intake/tox
American Robin				
Body weight	kg	BW	0.077	U.S. EPA, 1993
Food ingestion rate	g FW/d	F_{ir}	69	Calculated using U.S. EPA, 1993
Fraction of food that is earthworms	-	Fr_{ewm}	0.20	U.S. EPA, 1993
Soil ingestion rate	g DW/d	S_{ir}	0.19	Calculated from Beyer *et al*., 1994
Fraction of time at site	-	loc	0.20	Assumed (see section 4.3.3 for description)
Soil-to-earthworm transfer factor	kg/kg (DW)	TF_{ewm}	0.27	Sample *et al*., 1998a
Lead concentration in earthworms	mg/kg (FW)	C_{ewm}	17.00	$=C_s*TF_{ewm}*WC_{ewm}$
Intake of lead from soil	mg/d	I_{soil}	0.02	$=C_s*S_{ir}/1000*loc$ (see equation 5-1)
Intake of lead from earthworms	mg/d	I_{ewm}	0.05	$=C_{ewm}*F_{ir}/1000*Fr_{ewm}*loc$ (see equation 5-3)
Total intake - lead	mg/d	I_total	0.06	$=I_{soil}+I_{ewm}$

Parameter	Units	Symbol	Value	Reference or Equation
Total intake by body weight	mg/kg-d	Intake	**0.807**	=I_total/BW (see equation 5-7)
Toxicity reference value	mg/kg-d	tox	1.13	Sample *et al*., 1996
SI	-	SI	0.71	= Intake/tox
Northern Water Snake				
Body weight	kg	BW	0.207	U.S. EPA, 1993
Food ingestion rate	g FW/d	F_{ir}	12.63	Calculated using U.S. EPA, 1993
Fraction of diet that is small mammal	-	Fr_{sm}	0.12	U.S. EPA, 1993
Fraction of diet that is soil	-	Fr_s	0.06	Calculated from Beyer *et al*., 1994 for Eastern Painted Turtle
Moisture content - water snake food	-	MC_{food}	0.8	Assumed
Soil ingestion rate	g DW/d	S_{ir}	0.15	$=F_{ir}*MC_{food}*Fr_s$
Fraction of time at site	-	loc	1	assumed
Soil-to-small mammal transfer factor	kg/kg (DW)	TF_{sm}	1.34	Sample *et al*. 1998b; General small mammal
Lead concentration in small mammals	mg/kg (DW)	C_{sm}	533.4	$=C_s*TF_{sm}$
Intake of lead from soil	mg/d	I_{soil}	0.06	$=C_s*(S_{ir}/1000)*loc$ (see equation 5-1)
Intake of lead from small mammals	mg/d	I_{sm}	0.81	$=C_{sm}*(F_{ir}/1000)*Fr_{sm}*loc$ (see equation 5-4)
Total intake - lead	mg/d	I_total	0.87	$=I_{soil}+I_{sm}$
Total intake by body weight	mg/kg-d	Intake	**4.20**	=I_total/BW (see equation 5-8)
Toxicity reference value	mg/kg-d	tox	5.79	Calculated from Ireland, 1977 for the *Xenopus laevis* toad
SI	-	SI	0.73	=Intake/tox
ZINC				
Average Soil Zinc Concentration	mg/kg (DW)	C_s	201.3	=average of zinc concentrations presented in Table 4.1
Deer Mouse				
Body weight	kg	BW	0.021	U.S. EPA, 1993
Food ingestion rate	g FW/d	F_{ir}	4.2	calculated using U.S. EPA, 1993. "fw" indicates fresh weight.
Fraction of diet that is terrestrial vegetation	-	Fr_{veg}	0.6	U.S. EPA, 1993
Fraction of diet that is earthworms	-	Fr_{ewm}	0.4	U.S. EPA, 1993
Soil ingestion rate	g DW/d	S_{ir}	0.11	calculated from Beyer *et al*., 1994. "dw" indicates dry weight.
Fraction of time at site	-	loc	1	assumed
Soil-to-terrestrial vegetation transfer factor	kg/kg (FW)	TF_v	0.4	NCRP, 1996

Parameter	Units	Symbol	Value	Reference or Equation
Zinc concentration in terrestrial vegetation	mg/kg (FW)	C_{tv}	80.52	$=C_s*TF_v$
Soil-to-earthworm transfer factor	kg/kg (DW)	TF_{ewm}	3.20	Sample *et al*., 1998a
Zinc concentration in earthworms	mg/kg (FW)	C_{ewm}	103.1	$=C_s*TF_{ewm}*WC_{ewm}$
Intake of zinc from soil	mg/d	I_{soil}	0.02	$=C_s*S_{ir}/1000*loc$ (see equation 5-1)
Intake of zinc from terrestrial vegetation	mg/d	I_{tv}	0.20	$= C_{tv}*F_{ir}/1000*Fr_{veg}*loc$ (see equation 5-2)
Intake of zinc from earthworms	mg/d	I_{ewm}	0.17	$=C_{ewm}*F_{ir}/1000*Fr_{ewm}*loc$ (see equation 5-3)
Total intake - zinc	mg/d	I_total	0.40	$=I_{soil}+I_{tv}+I_{ewm}$
Total intake by body weight	mg/kg-d	Intake	**19.0**	=I_total/BW (see equation 5-5)
Toxicity reference value	mg/kg-d	tox	323.3	Sample *et al*., 1996, scaled for body weight
SI	-	SI	0.06	=Intake/tox
Eastern Cottontail				
Body weight	kg	BW	1.2	U.S. EPA, 1993
Food ingestion rate	g FW/d	F_{ir}	360	Calculated using U.S. EPA, 1993
Fraction of diet that is terrestrial vegetation	-	Fr_{veg}	1	U.S. EPA, 1993
Soil ingestion rate	g DW/d	S_{ir}	6.3	Calculated from Beyer *et al*., 1994
Fraction of time at site	-	loc	1.00	Assumed
Soil-to-terrestrial vegetation transfer factor	kg/kg (FW)	TF_v	0.400	NCRP, 1996
Zinc concentration in terrestrial vegetation	mg/kg (FW)	C_{tv}	80.52	$=C_s*TF_v$
Intake of zinc from soil	mg/d	I_{soil}	1.3	$=C_s*S_{ir}/1000*loc$ (see equation 5-1)
Intake of zinc from terrestrial vegetation	mg/d	I_{tv}	29.0	$= C_{tv}*F_{ir}/1000*Fr_{veg}*loc$ (see equation 5-2)
Total intake - zinc	mg/d	I_total	30.3	$=I_{soil}+I_{tv}$
Total intake by body weight	mg/kg-d	Intake	**25.21**	=I_total/BW (see equation 5-6)
Toxicity reference value	mg/kg-d	tox	117.6	Sample *et al*., 1996
SI	-	Si	0.21	=Intake/tox
American Robin				
Body weight	kg	BW	0.077	U.S. EPA, 1993
Food ingestion rate	g FW/d	F_{ir}	69	Calculated using U.S. EPA, 1993
Fraction of food that is earthworms	-	Fr_{ewm}	0.20	U.S. EPA, 1993
Soil ingestion rate	g DW/d	S_{ir}	0.19	Calculated from Beyer *et al*., 1994

Parameter	Units	Symbol	Value	Reference or Equation
Fraction of time at site	-	loc	0.20	Assumed (see section 4.3.3 for description)
Soil-to-earthworm transfer factor	kg/kg (DW)	TF_{ewm}	3.20	Sample *et al*., 1998a
Zinc concentration in earthworms	mg/kg (FW)	C_{ewm}	103.1	$=C_s*TF_{ewm}*WC_{ewm}$
Intake of zinc from soil	mg/d	I_{soil}	0.008	$=C_s*S_{ir}/1000*loc$ (see equation 5-1)
Intake of zinc from earthworms	mg/d	I_{ewm}	0.28	$=C_{ewm}*F_{ir}/1000*Fr_{ewm}*loc$ (see equation 5-3)
Total intake - zinc	mg/d	I_total	0.29	$=I_{soil}+I_{ewm}$
Total intake by body weight	mg/kg-d	Intake	**3.79**	=I_total/BW (see equation 5-7)
Toxicity reference value	mg/kg-d	tox	14.50	Sample *et al*., 1996
SI	-	SI	0.26	= Intake/tox
Northern Water Snake				
Body weight	kg	BW	0.207	U.S. EPA, 1993
Food ingestion rate	g FW/d	F_{ir}	12.63	Calculated using U.S. EPA, 1993
Fraction of diet that is small mammal	-	Fr_{sm}	0.12	U.S. EPA, 1993
Fraction of diet that is soil	-	Fr_s	0.06	Calculated from Beyer *et al*., 1994 for Eastern Painted Turtle
Moisture content - water snake food	-	MC_{food}	0.8	Assumed
Soil ingestion rate	g DW/d	S_{ir}	0.15	$=F_{ir}*MC_{food}*Fr_s$
Fraction of time at site	-	loc	1	assumed
Soil-to-small mammal transfer factor	kg/kg (DW)	TF_{sm}	0.162	Sample *et al*. 1998b; General small mammal
Zinc concentration in small mammals	mg/kg (DW)	C_{sm}	32.5	$=C_s*TF_{sm}$
Intake of zinc from soil	mg/d	I_{soil}	0.031	$=C_s*(S_{ir}/1000)*loc$ (see equation 5-1)
Intake of zinc from small mammals	mg/d	I_{sm}	0.049	$=C_{sm}*(F_{ir}/1000)*Fr_{sm}*loc$ (see equation 5-4)
Total intake - zinc	mg/d	I_total	0.080	$=I_{soil}+I_{sm}$
Total intake by body weight	mg/kg-d	Intake	**0.385**	=I_total/BW (see equation 5-8)
Toxicity reference value	mg/kg-d	tox	N/A	No appropriate toxicity data was located.
SI	-	SI	-	=Intake/tox
SITE-SPECIFIC SOIL CRITERIA				
Adult (20yr +)				
LEAD				
Soil Concentration	mg/kg	C_s	2620	Maximum measured soil concentrations
Total Hazard Quotient - Adult	-	HQ	0.120	See above for calculation

Parameter	Units	Symbol	Value	Reference or Equation
Site-specific soil criteria ratio - Adult	-	SSr_a_{pb}	21806	$=C_s*HQ$
Site-specific soil criteria - Adult	mg/kg	SSC_a_{pb}	**4361**	$=SSr\_a_{pb}*0.2$
ZINC				
Soil Concentration	mg/kg	C_s	1090	Maximum measured soil concentrations
Total Hazard Quotient - Adult	-	HQ	0.00048	See above for calculation
Site-specific soil criteria ratio - Adult	-	SSr_a_{zn}	2283431	$=C_s*HQ$
Site-specific soil criteria - Adult	mg/kg	SSC_a_{zn}	**456686**	$=SSr\_a_{zn}*0.2$
Deer Mouse				
LEAD				
Average Soil Lead Concentration	mg/kg DW	C_s	399.5	=average of lead concentrations presented in Table 4.1
Total Deer Mouse Screening Index	-	SI	0.225	See above for calculation
Site-specific soil criteria ratio - Deer mouse	-	SSr_dm_{pb}	1776	$=C_s*SI$
Site-specific soil criteria - Deer mouse	mg/kg	SSC_dm_{pb}	**1776**	$=SSr\_dm_{pb}*1$
ZINC				
Average Soil Zinc Concentration	mg/kg (DW)	C_s	201.3	=average of zinc concentrations presented in Table 4.1
Total Deer Mouse Screening Index	-	SI	0.059	See above for calculation
Site-specific soil criteria ratio - Deer mouse	-	SSr_dm_{zn}	3432	$=C_s*SI$
Site-specific soil criteria - Deer mouse	mg/kg	SSC_dm_{zn}	**3432**	$=SSr\_dm_{zn}*1$
Eastern Cottontail				
LEAD				
Average Soil Lead Concentration	mg/kg DW	C_s	399.5	=average of lead concentrations presented in Table 4.1
Total Eastern Cottontail Screening Index	-	SI	0.438	See above for calculation
Site-specific soil criteria ratio - Eastern Cottontai	-	SSr_ec_{pb}	912	$=C_s*SI$
Site-specific soil criteria - Eastern Cottontail	mg/kg	SSC_ec_{pb}	**912**	$=SSr\_ec_{pb}*1$
ZINC				
Average Soil Zinc Concentration	mg/kg (DW)	C_s	201.3	=average of zinc concentrations presented in Table 4.1
Total Eastern Cottontail Screening Index	-	SI	0.214	See above for calculation
Site-specific soil criteria ratio - Eastern Cottontai	-	SSr_ec_{zn}	939	$=C_s*SI$
Site-specific soil criteria - Eastern Cottontail	mg/kg	SSC_ec_{zn}	**939**	$=SSr\_ec_{zn}*1$

Parameter	Units	Symbol	Value	Reference or Equation
American Robin				
LEAD				
Average Soil Lead Concentration	mg/kg DW	C_s	399.5	=average of lead concentrations presented in Table 4.1
Total American Robin Screening Index	-	SI	0.714	See above for calculation
Site-specific soil criteria ratio - American Robin	-	SSr_ar_{pb}	560	$=C_s*SI$
Site-specific soil criteria - American Robin	mg/kg	SSC_ar_{pb}	**560**	$=SSr\_ar_{pb}*1$
ZINC				
Average Soil Zinc Concentration	mg/kg (DW)	C_s	201.3	=average of zinc concentrations presented in Table 4.1
Total American Robin Screening Index	-	SI	0.262	See above for calculation
Site-specific soil criteria ratio - American Robin	-	SSr_ar_{zn}	769	$=C_s*SI$
Site-specific soil criteria - American Robin	mg/kg	SSC_ar_{zn}	**769**	$=SSr\_ar_{zn}*1$
Northern Watersnake				
LEAD				
Average Soil Lead Concentration	mg/kg DW	C_s	399.5	=average of lead concentrations presented in Table 4.1
Total Northern Watersnake Screening Index	-	SI	0.725	See above for calculation
Site-specific soil criteria ratio - Northern Watersr	-	SSr_nw_{pb}	551	$=C_s*SI$
Site-specific soil criteria - Northern Watersnake	mg/kg	SSC_nw_{pb}	**551**	$=SSr\_nw_{pb}*1$
ZINC				
Average Soil Zinc Concentration	mg/kg (DW)	C_s	201.3	=average of zinc concentrations presented in Table 4.1
Total Northern Watersnake Screening Index	-	SI	-	See above for calculation
Site-specific soil criteria ratio - Northern Watersr	-	SSr_nw_{zn}	-	$=C_s*SI$
Site-specific soil criteria - Northern Watersnake	mg/kg	SSC_nw_{zn}	-	$=SSr\_nw_{zn}*1$

APPENDIX C

SITE PHOTOGRAPHS

Photograph No. 1: Completed remedial excavation east of lightkeepers dwelling.

Photograph No. 2: Air cell insulation embedded in contaminated soil at northeast corner of Fog Alarm Building.

Photograph No. 3: Looking west to Fog Alarm Building after topsoil spread over remedial excavation.

Photograph No. 4: Looking northwest to Lighthouse after topsoil spread over remedial excavation.

Photograph No. 5: Looking northwest toward mound of contaminated soil located west of Lighthouse after topsoil placed.

Photograph No. 6: Looking west toward Generator Building after topsoil spread over remedial excavation.

APPENDIX D

E-MAIL PROVIDING HUMAN RECEPTOR EXPOSURE PARAMETERS

Barry Cooke

From: "Jimi Arey" <Jimi.Arey@pwgsc.gc.ca>
To: "Barry Cooke (E-mail)" <bcooke@dcsltd.ca>
Cc: "George Fenn (E-mail)" <IMCEAX400-c=CA+3Ba=GOVMT+2ECANADA+3Bp=GC+2BDFO+2EMPO+3Bo=XCA+3Bs=Fenn+3Bg=George+3Bi=P+3B@pwg "Shannon Doyle (E-mail)" <DOYLES@inac-ainc.gc.ca>
Sent: Wednesday, September 01, 2004 1:58 PM
Subject: FW: Hope Island Site Remediation

Barry,

Please take the info below into consideration when and if we ever go into conducting a site specific risk assessment.

As it stands now, we will remove as much of the contamianted soils as the project budgets will allow.

Thanks. Jimi Arey

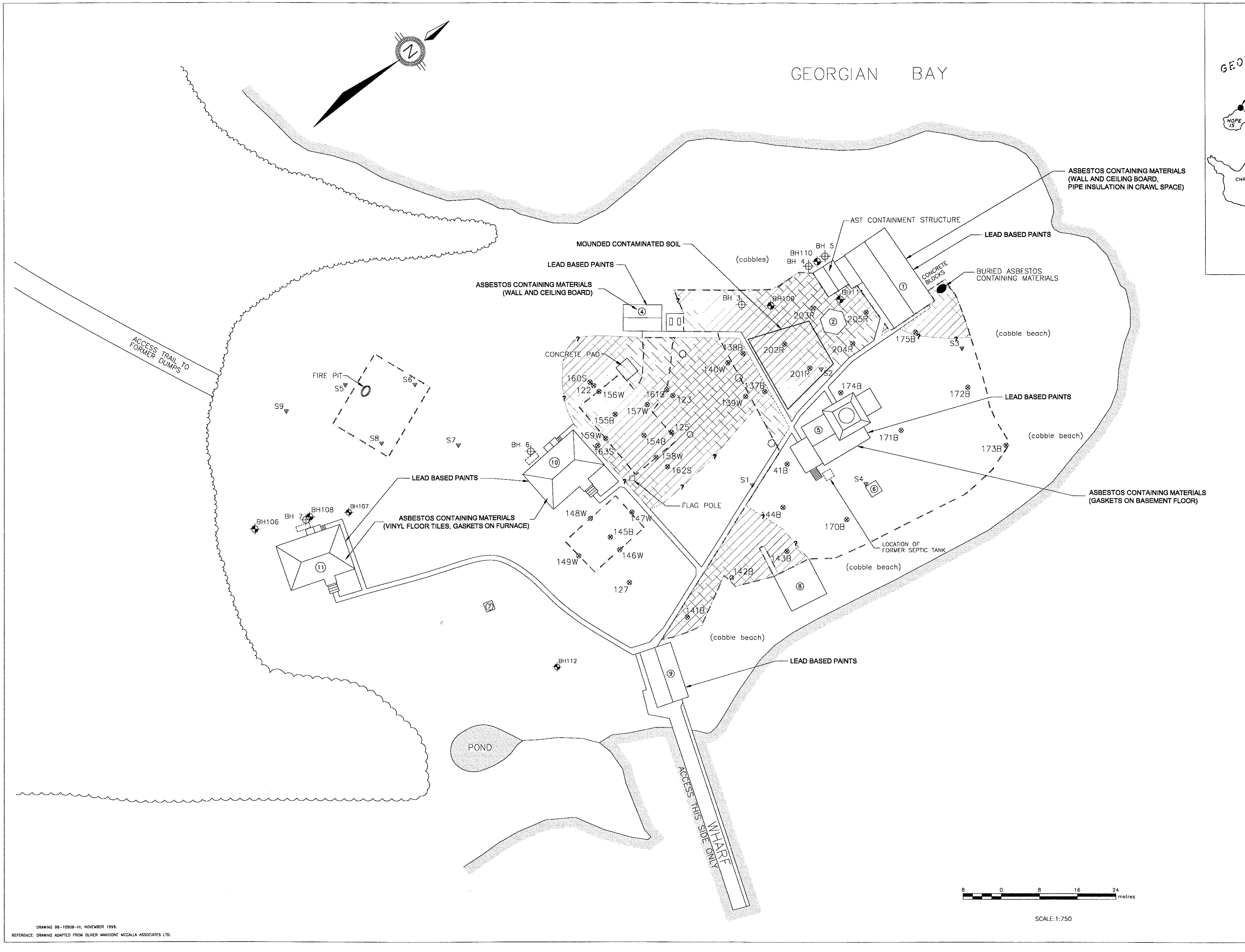
-----Original Message-----
From: Keith Maracle [mailto:kmaracle@ogemawahj.on.ca]
Sent: Tuesday, August 31, 2004 2:57 PM
To: Jimi Arey
Cc: 'jcopegog@chimnissing.ca'
Subject: Hope Island Site Remediation

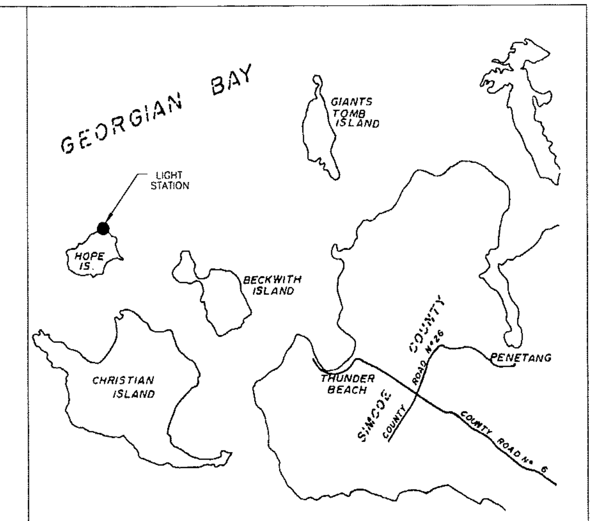
Jimi,

As discussed at the Hope Island site meeting earlier today, please be informed the First Nation's intended future use of the site will be for a children's summer camp. The targeted ages will range from five (5) years of age to sixteen (16) years of age. The camp could potentially run from May through to mid October every year. The intended duration of any given group of campers stay at the site is up to two weeks. The general philosophy of the camp would be to use the natural environment as the learning area.

It is likely that other general tourism type activities would also take place in addition to the children's camp. Hope this provides the information you need to complete the risk assessment. If you have any further questions, please call.

Thanks,
Keith Maracle
Ogemawahj Tribal Council





KEY PLAN

LEGEND

1. FOG ALARM BUILDING
2. CONCRETE PAD FOR FORMER RADIO BEACON TOWER
3. FORMER TANK FARM (DEMOLISHED)
4. GENERATOR BUILDING
5. OLD LIGHTHOUSE AND DWELLING
6. LIGHT TOWER
7. OUTHOUSE (WASH ROOM)
8. CONCRETE HELIPAD
9. BOATHOUSE
10. LIGHTKEEPERS' DWELLING
11. ASSISTANT KEEPERS' DWELLING

- BH101 BOREHOLE LOCATION, NUMBER (DCS, 1998)
- BH102 BOREHOLE AND MONITORING WELL LOCATION, NUMBER (DCS, 1998)
- BH 3 BOREHOLE LOCATION, NUMBER (BY OTHERS)
- ▽ SOIL SAMPLE LOCATION (DST, 2003)
- – – EXTENT OF REMEDIAL EXCAVATION (JULY–SEPT 2004)
- ⊗ SOIL SAMPLE COLLECTED DURING 2004 REMEDIATION CAMPAIGN
- INFERRED LIMITS OF CONTAMINATED SOIL

PUBLIC WORKS AND GOVERNMENT SERVICES CANADA

DCS
DECOMMISSIONING CONSULTING SERVICES LIMITED

SITE SPECIFIC RISK ASSESSMENT
HOPE ISLAND LIGHT STATION L.L. 857

LOCATION PLAN

Drawn by:	Checked:	Approved:
I.S.K.	B.H.C.	B.H.C.
Date:	Scale:	Dwg. No.:
DECEMBER 2004	1:750	48297-14-1