SCIENCE INTEGRITY KNOWLEDGE

intrinsik

A RISK ASSESSMENT OF THE FORMER MULOCK FARM PROPERTY, NEWMARKET, ONTARIO

Revised Final for MOE Review

~~September, 2010~~May, 2011

Prepared For: **R.J. Burnside & Associates Limited; the Town of Newmarket, and Criterion Development Corporation**

6605 Hurontario Street., Suite 500, Mississauga, Ontario ▪ L5T 0A3
Tel: 905-364-7800 ▪ Fax: 905-364-7816 ▪ www.intrinsikscience.com

DISCLAIMER

Intrinsik Environmental Sciences Inc. (hereafter referred to as Intrinsik) provided this report for R.J. Burnside & Associates Limited (hereafter referred to as Burnside), Criterion Development Corporation (hereafter referred to as Criterion) and the Town of Newmarket. Intrinsik does not accept any responsibility for the use of this report for any purpose other than as specifically intended by Burnside, Criterion and the Town of Newmarket. Intrinsik does not have, and does not accept, any responsibility or duty of care whether based in negligence or otherwise, in relation to the use of this report in whole or in part by any third party. Any alternate use, including that by a third party, or any reliance on or decision made based on this report, are the sole responsibility of the alternative user or third party. Intrinsik does not accept responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Intrinsik makes no representation, warranty or condition with respect to this report or the information contained herein other than that it has exercised reasonable skill, care and diligence in accordance with accepted practice and usual standards of thoroughness and competence for the profession of toxicology and environmental assessment to assess and evaluate information acquired during the preparation of this report. Any information or facts provided by others, and referred to or utilized in the preparation of this report, is believed to be accurate without any independent verification or confirmation by Intrinsik. This report is based upon and limited by circumstances and conditions stated herein, and upon information available at the time of the preparation of the report.

Intrinsik has reserved all rights in this report, unless specifically agreed to otherwise in writing with Burnside, Criterion and the Town of Newmarket.

A RISK ASSESSMENT OF THE FORMER MULOCK PROPERTY, NEWMARKET, ONTARIO

Table of Contents

Page

A RISK ASSESSMENT OF THE FORMER MULOCK PROPERTY, NEWMARKET, ONTARIO

Table of Contents (cont'd)

Page

List of Tables

List of Figures

List of Appendices

**A RISK ASSESSMENT OF THE FORMER MULOCK PROPERTY,
NEWMARKET, ONTARIO**

PREFACE

The following risk assessment has been revised based on comments provided by the Ministry of the Environment. Detailed responses to these comments are provided in Appendix J. Although revisions to the report are too numerous to be listed within a revision table, revisions are clearly indicated throughout the report as underlined insertions and strikethrough deletions. Only those appendices that contain revisions were included within the revised report.

A RISK ASSESSMENT OF THE FORMER MULOCK PROPERTY, NEWMARKET, ONTARIO

EXECUTIVE SUMMARY

Intrinsik Environmental Sciences Inc. (Intrinsik) has been retained by R.J. Burnside & Associates Limited (Burnside) on behalf of the Town of Newmarket and Criterion Development Corporation (hereafter referred to as Criterion) to conduct a Risk Assessment (RA) of a portion of the former Mulock Farm Property, located in the vicinity of Mulock Drive, east of Bathurst Street, in Newmarket, Ontario. The property is also known as the forested areas around Summerhill Woods and the William Thomas Mulock Park (hereafter referred to as the Site). The bulk of the Site was used as an apple orchard until the late 1950s. Lead arsenate insecticides were used extensively in apple orchards in the mid 20th century and recent soil sampling has indicated that arsenic and lead are present in on-site soils, likely due to regular spraying of lead arsenate insecticides during the period of orchard operations.

On-site permanent water bodies exist (including the Armitage Creek) and therefore the Site is classified as “environmentally sensitive” under O. Reg. 153/04.

The Site consists of four distinct parcels, three of which form a horseshoe-shaped area around the un-forested property referred to as the Summerhill Woods Development (a residential subdivision). Another parcel, William Thomas Mulock Park, is situated north of Mulock Drive. The intended future land use of the Site, and therefore all parcels, is public parkland, and as such, no buildings or residential dwellings will be constructed on the property. Residential developments exist both to the east of the Site as well as within (but not part of) the Site property itself (*i.e.*, the Summerhill Woods Development)

A paved and compacted gravel walking trail exists on an eastern portion of the Site, along the east side of the Summerhill Woods residental subdivision and parallel to the Summerhill South residential subdivision beyond. Otherwise, the Site is rugged natural forest with no defined access. Moreover, the unforested areas on either immediate side of the walking trail are thickly vegetated with tall grasses and herbaceous plants. As such, there is limited opportunity or accessibility for visitors to the Site to spend significant amounts of time away from the walking trail, and therefore, limited opportunity for exposure to impacted soils.

The objectives of the current RA, conducted in accordance with Ontario Regulation 153/04, were as follows:

1. To evaluate human health and ecological risks associated with impacted soils and groundwater. More specifically, to evaluate the risks associated with exposure to COCs under a parkland land use for both the Forested Areas and the Trail Lands; and,
2. To derive property-specific standards for soil and groundwater protective of human health and ecological receptors present on- and off-site.

Human Health Risk Assessment (HHRA)

Direct exposure of human receptors to COCs in soil was assessed though inhalation, incidental ingestion and dermal contact with exposed soil/dust. Exposure to COCs *via* inhalation of vapours in ambient air was not evaluated since no COCs are volatile. No COCs in groundwater were retained for quantitative assessment in the HHRA.

Five exposure scenarios were considered to evaluate potential human health risks associated with exposure to COC in on-site soil:

- A long-term outdoor maintenance worker;
- A construction worker;
- An on-site resident;
- An off-site resident; and,
- A parkland visitor.

Results of the current RA indicated that unacceptable risks may occur to the maintenance worker and parkland visitor receptors as a result of direct exposure to arsenic in soil and dust (*i.e.*, inhalation of airborne particulates, incidental ingestion, and dermal contact). Soil remediation measures are required to limit direct exposure to chemicals in soil found at concentrations in excess of the health-based standards derived to be protective of the maintenance worker and parkland visitor receptors (due to current and future property use as parkland, on-site residents and construction workers are assumed not to be present on-site). Although the Site will remain in its current parkland state (*i.e.*, no future residential development), a Certificate of Property Use (CPU) can also be used as an administrative control to ensure on-site risks are minimized.

Ecological Risk Assessment

The current RA assessed risk to ecological receptors assuming that receptors have the potential to have direct contact with all on-site soils without any barriers or restrictions. Based on the current and anticipated parkland land use, the following Valued Ecosystem Components (VECs) were evaluated in the current RA:

- Urban vegetation (*e.g.* grasses, shrubs, trees);
- Soil invertebrates (as represented by the earthworm);
- Small mammals (as represented by the Meadow Vole and Short-tailed Shrew); and,
- Birds (as represented by the American Robin).

Risks were estimated for urban vegetation and soil invertebrates by comparing on-site soil concentrations to available benchmark concentrations. This comparison indicated that isolated areas of soil contained concentrations (or possible concentrations) of arsenic and lead that have the potential to cause unacceptable risk to plants and soil invertebrates. However, due to the limited number of samples and on-site areas with elevated levels of these compounds, it is anticipated that the plant and soil invertebrate communities will not be significantly impacted.

Risks were estimated for birds and mammals by predicting exposure resulting from the consumption of food items derived from the Site and through the ingestion of soil while feeding. When compared with toxicological reference values (TRVs), only lead has the potential to cause unacceptable risks populations of the American Robin. However, these are isolated occurrences since only 8 of 98 samples showed an exceedance for lead. Given that mobile receptors will forage across a larger area, it is not anticipated that unacceptable risks will occur to mammals utilizing the Site.

Risk Management

Based on the results of the HHRA and ERA, administrative risk management measures are ~~not~~ required to address potential exposure or risks to human or ecological receptors. Soil remediation measures such as targeted soil removal are recommended and will be implemented prior to filing of the RSC.

Conclusions / Recommendations

The main findings from the RA were as follows:

1) Because no volatile COCs were evaluated in the RA, there is no indication of unacceptable health risks to human receptors *via* inhalation of vapours migrating from impacted groundwater or soil;
2) No groundwater COCs were retained for quantitative evaluation in the HHRA; therefore, no receptor is anticipated to be subject to risks above allowable levels as a result of direct or indirect exposure to groundwater;
3) On-site construction workers may be subject to risks above allowable levels as a result of inhalation of airborne soil and dust impacted by arsenic (however, because no construction activities are anticipated on the parkland Site, this scenario was not included in the derivation of final property-specific standards);
4) Maintenance workers and parkland visitors on-site may be subject to risks above allowable levels as a result of direct contact with arsenic in soil;
5) There is no indication of unacceptable risks to off-site residential receptors as a result of inhalation of impacted airborne soil and dust migrating from the Site;
6) There is no indication of unacceptable risks to on- or off-site aquatic receptors (in either surface water or sediment) as a result of the migration of impacted groundwater and soil; and,
7) Although there is potential for localized risks to sensitive terrestrial plants and soil invertebrates as a result of exposure to arsenic, lead and DDE in on-site soil, it is anticipated that overall on-site populations of these receptors will not be subject to unacceptable risks. Similarly, although there is potential for localized risks to birds as a result of exposure to lead and DDE in on-site soil, on-site populations of these receptors are not anticipated to be subject to unacceptable risks.

1.0 SUMMARY OF RECOMMENDATIONS/FINDINGS

The risk assessment objectives, property-specific soil and groundwater standards, the assumptions used in deriving standards, and the recommended risk management measures are described in Sections 1.1 to 1.5.

1.1 Risk Assessment Objectives and Approach

Intrinsik Environmental Sciences Inc. (Intrinsik) has been retained by R.J. Burnside & Associates Limited (Burnside) on behalf of the Town of Newmarket and Criterion Development Corporation to conduct a Risk Assessment (RA) of a portion of the former Mulock Farm Property, located in the vicinity of Mulock Drive, east of Bathurst Street, in Newmarket, Ontario (Figure 1-1). The property is also known as the forested areas at Summerhill Woods (hereafter referred to as the Site). The Site contains permanent surface water bodies (*e.g.*, the Armitage Creek) and thus is classified as "environmentally sensitive" under O. Reg. 153/04.

Because of historical pesticide use on the former farm property (refer to Section 3.1 for details), an RA was requested in order to delineate the potential human health and ecological risks associated with residual chemicals. Other than the walking trail (the John F. Smith Trail, paved for approximately 100 metres at the northern entrance and covered with crushed gravel along the remaining portions) along the eastern portion of the Site, and the two metre clearance ("slashback") on either side, the Site is predominantly a mature, thickly forested area. The trees in these wooded areas add to the overall aesthetics of the residential developments in the immediate vicinity of the Site.

The Site consists of four distinct parcels, as outlined below and shown in Figure 1-2:

- Parcel 1: The area north of Mulock Drive, known as William Thomas Mulock Park. This is an environmentally protected area that is densely wooded, Town-owned and will remain parkland;
- Parcel 2: The eastern portion of the area south of Mulock Drive, known as the Trail Lands. This Town-owned parkland area primarily runs north-south and contains a paved and crushed gravel walking trail (plus slashback of approximately two metres to either side), as well as the Armitage Creek, running parallel to, and west of, the trail;
- Parcel 3: The Northern Forested Lands, just south of Mulock Drive, between Bathurst Street and Parcel 2. This parcel is owned by the developer (Criterion Development Corporation), but is to be conveyed to the Town of Newmarket; and,
- Parcel 4: The Southern Forested Lands, situated between Bathurst Street and Parcel 2, south of the Summerhill Woods Development. This parcel also owned by the developer, but is to be conveyed to the Town of Newmarket. A permanent creek runs west to east through this parcel.

The nature of the densely wooded portions of the Site (Parcels 1, 3 and 4) is such that frequent visits are unlikely. Moreover, the trail lands have only 2 metres of slashback on either side of the walking trail, which tends to grow in thickly with vegetation during the summer months. Therefore, it is anticipated that a parkland visitor to the Site would not have significant exposure to impacted on-site soils. This assumption is based on the following characteristics of the Site:

- The wooded areas are mature, thick forest with rugged terrain and thus are relatively inaccessible;
- Fences separate the residential developments adjacent to the Site boundaries, thereby further limiting access to the wooded areas and trail lands. Moreover, gates along these fences are prohibited by the Town of Newmarket;
- The slashbacks on either side of the trail are thickly vegetated, with little opportunity for exposure to potentially impacted soil; and,
- The Site does not contain a sports field, playground area or other amenities that might attract more frequent visits to the area. The wooded area is zoned as Environmental Protection – Oak Ridges Moraine (EP-ORM) by (Town of Newmarket) Bylaw 2007-35, and consequently, "the current zoning provision would not allow this woodlot area to be developed for residential purposes, or for active recreation purposes such as playing fields" (Town of Newmarket pers. comm., 2010).

Other than the John F. Smith Trail, there is no formal or encouraged access to these lands.

Photographs that depict the unique nature of the Site are presented in Figures 1-3(a-d). Figure 1-3a shows the walking trail in Parcel 2 in springtime conditions (March 2010), along with the thickly vegetated slashback on either side. Mid-summer vegetation alongside the trail (looking east from the trail towards the Summerhill South subdivision in August 2009) is shown in Figure 1-3b and affirms the assumption that exposure to on-site soils in limited in this parcel. The fence separating Parcel 2 from the residential properties to the east of the Site is visible in both photos. Figure 1-3c shows the relative inaccessibility of the Northern Forested Lands (Parcel 3), as seen looking south from Mulock Drive. Similarly rugged characteristics of William Thomas Mulock Park (Parcel 1) are shown in Figure 1-3d, looking west along Mulock Drive.

Aerial photographs that depict the rugged natural forest attributes of the wooded areas are presented in Figures 1-4 (William Thomas Mulock Park) and 1-5 (Parcels 2, 3 and 4). These photographs also clearly show the lack of open space (other than along the eastern trail) and the natural rugged parkland state of the Site.

The following report details the objectives, methodologies, results and conclusions of the RA conducted for the Site, including both a human health risk assessment (HHRA) (Section 4.0) and an ecological risk assessment (ERA) (Section 5.0).

Appendix A contains the toxicity reference values (TRVs) for the chemicals of concern (COCs) assessed in the HHRA. Appendix B contains soil, groundwater and sediment sampling data considered in the RA. The technical information, modeling methodology, a worked example, and summaries of parameters used in the HHRA modeling are provided in Appendix C. The Pre-Submission Form (PSF) is provided in Appendix D along with the MOE comments on the PSF and responses to the comments. The summary of the Environmental Site Assessment reports is presented in Appendix E, along with the complete site characterization diagrams, contaminant distribution diagrams and summary tables, as presented by Burnside (2010). Appendix F contains *curriculum vitae* of the project team members and Appendix G contains a list of supporting documents. The mandatory certifications of the QP_{RA} are provided in Appendix H. As part of the assessment, an *in vitro* bioaccessibility study was conducted using Site soils. Details of this study are provided in Appendix I. Appendix J includes the MOE comments on the initial Risk Assessment and responses to the comments.

The objectives of the current RA, conducted in accordance with O. Regulation 153/04, were as follows:

1. To evaluate human health and ecological risks associated with impacted soils. More specifically, to evaluate the risks associated with exposure to COCs under a generic parkland land use for the Site; and,
2. To derive property-specific standards for soil and groundwater protective of human health and ecological receptors present on- and off-site.

The following RA was conducted in accordance with Ontario Regulation 153/04 and the RA procedures endorsed by regulatory agencies including the Ontario Ministry of the Environment (MOEE, 1997; MOE, 2005; MOE, 2009), Environment Canada (Gaudet, 1994), Health Canada (2004), the Canadian Council of Ministers of the Environment (CCME, 1996), and the United States Environmental Protection Agency (US EPA, 1989). The RA approach taken to meet the objectives was for an RA within the requirements of a Wider Area of Abatement, as defined in Schedule C Part II of O. Reg. 153/04.

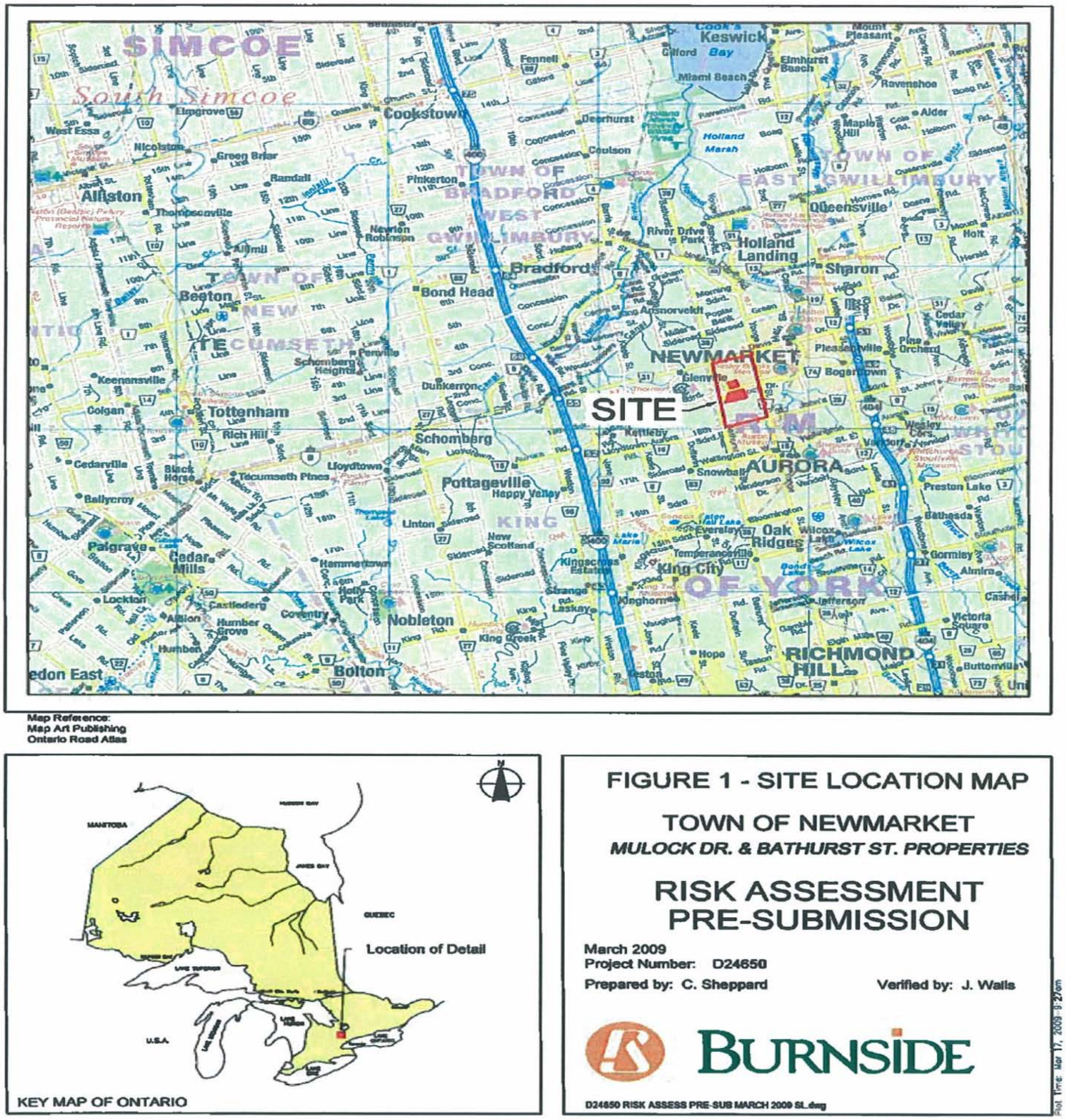


Figure 1-1 Site Location

FIGURE 1-2

TOWN OF NEWMARKET

PARKLANDS AT MULOCK DR. & BATHURST ST.

RISK ASSESSMENT

SITE PLAN

LEGEND

APPROXIMATE PROPERTY OUTLINES

APPROXIMATE BUFFER AREA AROUND RESIDENTIAL DEVELOPMENT (Topsoil was removed and replaced during development)

APPROXIMATE SUMMERHILL WOODS SUBDIVISION OUTLINE

N

Air Photo Source:
Background September 2009 air photo obtained from Google Earth Professional

0 20 40 60 80 100 120 140 160 180 200 220 240

Metres

Scale 1:3,000
April 2010
Project Number: D24650

Projection: UTM Zone 17
Datum: NAD83

Prepared by: C. Sheppard

Verified by: J. Walls

BURNSIDE

D24650 INTRINSIK RISK ASSESSMENT SP.dwg

Plot Time: Apr 09, 2010–1:50pm

Fig. 1-3a. Looking SSE along walking trail towards residential development.

Fig. 1-3b. Looking east from walking trail towards residential development during summer months.

Fig. 1-3c. Looking SSE along walking trail towards residential development.

Fig. 1-4d. William Thomas Mulock Park, looking west along Mulock Dr.

Figure 1-3(a-d) Ground-level Site Photographs

FIGURE 1

TOWN OF NEWMARKET

PARKLANDS AT MULOCK DR. & BATHURST ST.

VEGETATION CONDITIONS - SEPTEMBER 2009

WILLIAM THOMAS MULOCK PARK
(Town Owned)

LEGEND

- APPROXIMATE WILLIAM THOMAS MULOCK PARK OUTLINE
- AREAS REQUIRING RISK MANAGEMENT / REMEDIAL ACTION (Interpreted to have arsenic concentrations in soil in excess of 60 µg/g)
- MW-E MONITORING WELL LOCATION By Burnside October & November 2009

Air Photo Source:
Background September 2009 air photo obtained from Google Earth Professional

N

0 20 40 60 80 100 120 140 160
Metres

1:2,000
March 2010
Project Number: D24650

Projection: UTM Zone 17
Datum: NAD83

Prepared by: C. Sheppard

Verified by: J. Walls

BURNSIDE

D24650 VEGETATION CONDITIONS MULOCK PARK LANDS.dwg

Plot Time: Mar 17, 2010–3:42pm

FIGURE 2

TOWN OF NEWMARKET

PARKLANDS AT MULOCK DR. & BATHURST ST.

VEGETATION CONDITIONS - SEPTEMBER 2009

NORTHERN & SOUTHERN FORESTED LANDS & TRAIL LANDS

LEGEND

- APPROXIMATE PROPERTY OUTLINES
- APPROXIMATE BUFFER AREA AROUND RESIDENTIAL DEVELOPMENT (Topsoil was removed and replaced during development)
- APPROXIMATE SUMMERHILL WOODS SUBDIVISION OUTLINE
- AREAS REQUIRING RISK MANAGEMENT / REMEDIAL ACTION (Interpreted to have arsenic concentrations in soil in excess of 60 µg/g)
- MW-E MONITORING WELL LOCATION By Burnside October & November 2009

Air Photo Source:
Background September 2009 air photo obtained from Google Earth Professional

N

0 20 40 60 80 100 120 140 160

Metres

1:2,000
March 2010
Project Number: D24650

Projection: UTM Zone 17
Datum: NAD83

Prepared by: C. Sheppard

Verified by: J. Walls

BURNSIDE

D24650 VEGETATION CONDITIONS NORTH FORESTED AREA.dwg

Plot Time: Mar 17, 2010 - 3:38pm

1.2 Deviations from the Pre-Submission Form

There have been several deviations from the PSF which have impacted the overall approach of the RA. Deviation or correction requirements outlined in the MOE Comments to the Pre-Submission Form (PSF) and the responses thereof are not outlined in this section.

- Recent sampling by Burnside produced new maximum soil concentrations for DDD (0.024 µg/g) and DDE (0.44 µg/g). The maximum concentrations for all other analytes in soil did not change from those listed in the PSF. In groundwater, the maximum concentration of lead is now 1.21 µg/L, thus making lead a COC in groundwater;

- The approach and human health conceptual site model have been updated to include an off-site residential receptor scenario (toddler and composite). This receptor is exposed to COCs *via* the inhalation of airborne soil and dust migrating from the Site. Direct dermal contact and incidental ingestion of on-site soils were not considered for this off-site receptor;

- The Site is parkland and predominantly covered by thick vegetation (other than the paved and crushed gravel walking path in the Trail Lands parcel); thus, a construction worker was not assumed to spend significant amounts of time on-site. Moreover, the future land use is to remain rugged natural parkland; it was assumed that on-site residential receptors will not be present in perpetuity. Therefore, property-specific standards derived for the on-site residential receptor and construction worker scenarios were not included in the consideration of final human health property-specific standards; and,

- Risks associated with inhalation of airborned soil and dust were calculated using reference concentrations (RfC) and inhalation unit risks (IUR), rather than using a risk calculated from exposure based on body weight. RfC and IUR values employed in the RA are presented in Table 4-13.

1.3 Risk Assessment Standards

The final property-specific soil and groundwater standards are the more stringent of those derived for all human and ecological exposure scenarios evaluated in the current RA. Table 1-1 provides the final property-specific groundwater standards for residential/parkland/institutional land use. Property-specific soil standards were derived for residential/parkland/institutional land use (Table 1-2). It should be noted that, as indicated in Table 1-2, where soil removal is considered, remediation must be completed before the filing the of the Record of Site Condition (RSC).

Only those chemicals found in excess of the Table 1 Standards, as well as additional chemicals for which Table 1 Standards were not available, are included in Tables 1-1 and 1-2. The reporting format selected for these tables was as recommended in the MOE RA Procedures document (MOE, 2005). A detailed description of the derivation of the property-specific standards is provided in Section 6.1. The on-site residential receptor and the construction worker scenarios were not included in the derivation of final property-specific standards since the Site is fully forested parkland and will remain as such in the future (refer to Section 4.1.2 for details).

Table 1-1 Final Property-Specific Standards for Chemicals in Groundwater (µg/L)

COC	Maximum Groundwater Concentration	Table 1 Site Condition Standard	Property-Specific Standard	Basis of Property-Specific Standard	Risk Management Requirement
Barium	96	NV	1,000	2009 Table 8 Site Condition Standard	No
Lead	1.21	1	10	2009 Table 8 Site Condition Standard	No
Chloride	300,000	NV	790,000	2009 Table 8 Site Condition Standard	No
Sodium	37,000	NV	41,000	Maximum Concentration + 10% (protective of direct contact for on-site aquatic VECs)	No

NV Indicates that no value is available.

Table 1-2 Final Property-Specific Standards for Chemicals in Soil (µg/g)

COC	Maximum Soil Concentration	Table 1 Site Condition Standard	Property-Specific Standard	Basis of Property-Specific Standard	Risk Management Requirement
Arsenic	143	17	58	Lowest PSS protective of direct soil contact for parkland visitor	No (targeted soil remediation required prior to filling of RSC)
Boron	0.77	NV	1.5	2009 Table 2 Site Condition Standard	No
Lead	422	120	460	Maximum concentration + 10% (protective of plants, soil invertebrates and birds)	No
DDD	0.024	NV	0.026	Maximum concentration + 10% (protective of birds)	No
DDE	0.44	NV	0.48	Maximum concentration + 10% (protective of plants and soil invertebrates)	No

NV Indicates that no value is available.

1.4 Risk Assessment Assumptions

The Site is considered to be an *environmentally sensitive area* due to the presence of surface water bodies on-site (*i.e*., Armitage Creek and other tributary streams); therefore, MOE Table 1 Site Condition Standards were used for the selection of the COCs. Following this screening step, additional screening steps specific to each of the HHRA and ERA (and residential/parkland/institutional land use in a potable water scenario) were utilized to provide further refinement of the list of COCs to be carried forward through the full HHRA and ERA evaluations.

Although it is not anticipated that the Site will undergo significant disruption that could result in the re-distribution of chemicals found in sub-surface soils, it was assumed that both human and ecological receptors would have the potential to be exposed to all impacted soils regardless of current depth. As a result, the assessment of exposure and risks was completed using the maximum measured soil and groundwater concentrations.

1.5 Risk Management Requirements

The HHRA indicated that unacceptable risks may occur to receptors under both a parkland visitor and maintenance worker scenario as a result of direct contact with impacted soils. Because the locations of soil impact are isolated and within the parkland forest, final property-specific standards were derived with the requirement that targeted soil removal is completed before filing an RSC. This form of soil remediation is recommended to limit or eliminate the potential for exposure to soils that might cause unacceptable health risks in a mature forested area. In addition, some administrative risk management measures are required to address potential exposure or risks to human receptors.

The ERA indicated that although unacceptable risks may be present in isolated locations to terrestrial receptors exposed to COCs in soil, overall ecological health to receptor populations are not compromised. Therefore, risk management measures are not required for the protection of ecological receptors.

2.0 RISK ASSESSMENT TEAM MEMBERSHIP

The RA team areas of expertise and biographical details for team members are provided in Sections 2.1 and 2.2.

2.1 Required Areas of Expertise

The requirements for specific areas of expertise in the RA team (as per the *Records of Site Condition Regulation*, O. Reg. 153/04), and how they are accommodated in this RA, are outlined in Table 2-1 below.

Table 2-1 Risk Assessment Team Areas of Expertise - Concordance with RSC Regulation

Area of Expertise required by RSC Regulation, O. Reg. 153/04	***Risk Assessment Team Concordance***
Human health toxicity	The Intrinsik team assigned to this RA provides extensive experience and expertise in human health toxicity. In addition, Intrinsik has additional scientific staff, in four offices across Canada, who were consulted as required. Intrinsik's scientists have applied their specialized knowledge to hundreds of RAs since the mid-1980s. This work was led by Elliot Sigal and Mark Beasy. The biographical information for those involved in the preparation of this RA is provided below.
Ecotoxicity	The Intrinsik team assigned to this RA, including Ruth Hull and Mark Beasy, provides extensive experience and expertise in ecotoxicity. The biographical information for those involved in the preparation of this RA is provided below.
Hydrogeology	Hydrogeological information and monitoring data were provided by R.J. Burnside and MMM Group. This work was led by Jim Walls.
Soil science/chemistry	Expertise in soil science/chemistry was not specifically required for this RA, as the necessary information and interpretation was already provided by previous R.J. Burnside and MMM Group site investigation reports. However, review of all soil science/chemistry issues related to data used in the current assessment was provided by the QP_{ESA}, Jim Walls.
Environmental science	The Intrinsik team assigned to this RA provides extensive experience and expertise in environmental science, including Elliot Sigal and Mark Beasy. In addition, Intrinsik has additional scientific staff, in four offices across Canada, who were consulted as required. The biographical information for those involved in the preparation of this RA is provided below.
Environmental chemistry	Expertise in environmental chemistry was not specifically required for this RA, as the necessary information and interpretation was already provided in previous reports.
Analytical chemistry	Expertise in analytical chemistry was not specifically required for this RA, as the necessary information was provided by earlier R.J. Burnside and MMM Group reports and associated appendices.
Engineering	Engineering was not required.

2.2 Biographical Details for Risk Assessment Team

Elliot A. Sigal, B.Sc., (QP_{RA}, Executive Vice President, Senior Scientist - Human Health)
Toxicology and Risk Specialist

Mr. Sigal is Executive Vice President of Intrinsik. Mr. Sigal graduated with an Honours B.Sc. in Toxicology from the University of Toronto in 1988. He has had direct, senior level experience on contaminated sites human health risk assessments since the mid-1990s. He has overseen and contributed to hundreds of risk assessments since joining Intrinsik in 1989. Mr. Sigal is a full member of the Society of Toxicology and qualifies as a QP_{RA} under Ontario Regulation 153/04.

Mr. Sigal has extensive experience in all aspects of risk assessment and specific expertise in computer exposure modelling for human and ecological receptors. Mr. Sigal is responsible for leading risk assessment teams in determination of potential for exposure of and risk to receptors associated with complex contaminated sites, military base closures, underground storage tanks, incinerator emissions, landfill sites and industrial processes. Multi-pathway modelling initiatives led by Mr. Sigal have included determination of exposures of receptors from contaminated soil, air, water, and food, including agricultural and ecological food webs. Mr. Sigal has considerable expertise in conducting risk assessments in compliance with O. Reg. 153/04 and previously with Ontario's Guidelines for Use at Contaminated Sites in Ontario. In particular, Mr. Sigal has conducted peer reviews on many risk assessments in jurisdictions across Canada and the U.S. Since 1997, he has conducted numerous peer reviews of risk assessments on behalf of the Ontario Ministry of the Environment.

Mr. Sigal has been involved in the use of toxicological principles to facilitate the risk assessment process, such as development of a health-based method for the evaluation of total petroleum hydrocarbons (TPH), in provision of a benchmark comparison of remediation alternatives, in order to determine economically feasible and scientifically sound solutions to risk management problems. He also has conducted interpretive reviews of toxicology and mechanistic databases for a variety of chemicals including metals (*i.e.*, arsenic, nickel), chlorinated organics (*i.e.*, vinyl chloride, PCBs, dioxins and furans), volatile organic compounds (*i.e.*, benzene, toluene), combustion gases (NO_X, SO_X), and PAHs (*i.e.*, benzo[a]pyrene).

Mr. Sigal was the lead human health risk assessor for the SARA Group, a consortium of companies conducting a large-scale human health and ecological risk assessment in the Sudbury Basin of Ontario, as part of the multi-stakeholder Sudbury Soils Study. In this role, Mr. Sigal has been actively involved in activities such as bioaccessibility, toxicity of mixtures, chemical speciation, dose modelling, *etc*. Mr. Sigal is also integrally involved in development and implementation of deterministic (point estimate) and probabilistic (stochastic) exposure and hazard assessment modelling techniques. He also is project manager and senior reviewer for the Expert Advice contract with Health Canada. On-going and completed projects for Health Canada under this contract, include: critical analysis of the toxicological literature on 1,4-dioxane and perchlorate to develop inhalation and oral Reference Exposure Limits (RELs); critical review of recent inhalation toxicological literature on trichloroethylene (TCE) for development of REL (slope factor) for inhalation; review and update of the technical supporting document for the *Human Health Soil Quality Guideline for Dioxins and Furans*; and, development of a methodology to derive probabilistic Estimated Daily Intakes (EDIs) for use in developing *Canadian Soil Quality Guidelines for Contaminated Sites.* Mr. Sigal also conducted the senior review of the Intrinsik revision of the Health Canada 1994 blood lead document with recommendations for intervention levels.

Ruth N. Hull, M.Sc., (Senior Scientist and QP_{RA})
Ecological Toxicology and Risk Assessment Specialist

Ms. Hull has an MSc in ecotoxicology from Concordia University and a BSc in biology and chemistry from the University of Waterloo. Ms. Ruth Hull has over 17 years of experience in the fields of ecotoxicology and ecological risk assessment. She has managed and conducted complex risk assessments at sites across Canada, the U.S. and abroad. For example, Ms. Hull is currently involved as Intrinsik's technical manager for the wide-area ecological risk assessment of Teck Cominco's lead/zinc smelter in Trail, British Columbia, and she led the terrestrial wildlife ecological risk assessment related to smelter emissions for the City of Greater Sudbury and surrounding area in Ontario. She is managing two risk assessments for contaminated sites in Peru, and recently managed a human and ecological risk assessment associated with industrial airborne emissions in Egypt. Ms Hull regularly provides expert advice to the Ontario Ministry of the Environment (MOE) and other government agencies on ecotoxicology, ecological risk assessment of contaminated sites and other related environmental issues. For example, she completed a review of metal interactions in the aquatic environment on behalf of CCME, reviewed and recommended ecological exposure models for MOE, and provided ecotoxicological advice to MOE regarding a potential lawsuit.

Prior to her years in environmental consulting, Ms. Hull was part of the ecological risk assessment team at Oak Ridge National Laboratory (ORNL) in Tennessee, and was responsible for ecological risk assessments at U.S. Department of Energy facilities in Tennessee, Ohio and Kentucky. While at ORNL, Ms. Hull was responsible primarily for assessment risks to benthic invertebrate communities from contaminated sediments, and developed the first comprehensive set of ecotoxicological benchmarks for screening chemicals of concern in sediments for protection of benthic communities (Hull and Suter, 1994). Prior to her work at ORNL, Ms. Hull provided human health and ecological risk assessment oversight for the State of Minnesota Superfund Program. She has been responsible for all technical aspects of risk assessment projects, including: project management; project scoping; review of environmental site assessments; data interpretation; bioaccumulation modelling, exposure analysis; review of toxicological studies and development of ecotoxicological benchmarks; effects assessment; characterization of ecological risks; and communication of results to regulators and the public. Currently, she also is assisting Teck Cominco Metals with development of components of the Wide Area Remediation Plan for Trail BC.

Ms Hull is an active member of the Society of Environmental Toxicology and Chemistry, has authored several papers on the topic of ecological risk assessment, co-edited a Special Technical Publication on environmental toxicology and risk assessment for the American Society for Testing and Materials, and recently had a paper published in the *Integrated Environmental Assessment and Management* journal related to an advanced weight-of-evidence methodology for ERA (Hull and Swanson, 2006).

Mark Beasy, M.Sc., (Environmental Risk Analyst)
Support to the Human Health and Ecological Risk Assessors

Mark received his M.Sc. in Chemistry from the University of Waterloo and his combined Honours B.Sc. in Chemistry and Mathematics from Dalhousie University in Halifax, Nova Scotia. His graduate research focused on the selective extraction of uranium and other heavy metals from mine wastewaters using functionalized ion exchange polymers, as well as the modeling of continuous extraction processes. Mark has a strong knowledge base in analytical and polymer chemistry, statistics and modeling. Since joining Intrinsik in 2007, Mark has worked on numerous human health and ecological risk assessments, involving exposure modeling, COC screening, and development of property-specific standards. Past and current work primarily includes risk assessments conducted under Ontario Regulations 153/04. Mark has also developed and contributed deposition and human exposure modeling for human health risk assessments related to incinerators, oil refineries and public transit rail corridors.

Prior to joining Intrinsik Environmental Sciences in August 2007, Mark was employed with the Ecology Action Centre, an environmental Non-Government Organization in Halifax. With the EAC, Mark administered the education and inspection programs for Halifax's Pesticide By-law Project. Mark has also worked in chemistry laboratories for Health Canada, Department of Fisheries and Oceans, and the Canadian Food Inspection Agency. Mark left Intrinsik in December 2010.

James R. Walls, B.Sc., P.Geo. (QP_{ESA})
R.J. Burnside & Associates Limited

James Walls is a Senior Project Manager and Geoscientist, with over 20 years of experience in providing geological and hydrogeological services. Mr. Walls is a Qualified Person, Environmental Site Assessment (QPESA) as per O.Reg. 153/04 and a QP as per National instrument 43-101. He provides technical environmental services to municipalities (large cities to small arctic Hamlets), private industry (development, industrial, and commercial), and government institutions (INAC, PWGSC, Environment Canada). In addition, Mr. Walls provides technical review and expert testimony for litigation and hearings.

Mr. Walls is experienced at conducting environmental site assessment and remediation projects at a variety of sites involving contaminated soil and groundwater. He has conducted hundreds of Phase I ESA's for public and private clients ranging from large industrial facilities and commercial developments to land parcels for development. He has conducted numerous Phase II ESA's and Phase III Environmental Issues Inventories, which involve the investigation and assessment of contaminated sites, including Canadian Environmental Assessment Act (CEAA) screening and National Classification for Contaminated Sites (NCCS) evaluations. He has also conducted a wide variety of projects involving the delineation of contamination, the analysis of remedial options, the development and oversight of remediation strategies and post-remedial assessments. His experience includes industrial sites contaminated with fuels, oils, chlorinated organics, PCBs, and DNAPL chemicals.

Mr. Walls has over 10 years of experience working with landfills, including environmental assessment, siting, design, rehabilitations, and closure. He has conducted Phase I ESA's of entire First Nation communities as part of the First Nation Land Management Agreement, and provided technical support to financial institutions and regulatory agencies. His projects have been conducted in urban and remote areas of northern Canada, South America and the Caribbean.

3.0 PROPERTY INFORMATION, SITE PLAN AND GEOLOGICAL INTERPRETATION

Information describing the property characteristics, historic uses, and sampling programs, as well as the selection of COCs, is provided in Sections 3.1 to 3.3. Figures describing the Site plan, cross-sections, hydrogeological interpretation, and sampling locations are provided in the PSF (Appendix D) and in the Environmental Site Assessment Summary (Appendix E).

The full description of the Site address is:

> Former Mulock Farm Property; Lot 90, Concession 1 between Bathurst and Yonge Streets in Newmarket, Ontario. William Thomas Mulock Parck is located north of Mulock Drive on Lot 91. The remainder of the Site is located south of Mulock Drive on Lot 90.

3.1 Property Information

Intrinsik Environmental Sciences Inc. (Intrinsik) has been retained by R.J. Burnside & Associates Limited (Burnside) on behalf of the Town of Newmarket and Criterion Development Corporation (Criterion) to conduct a Risk Assessment (RA) of a portion of the former Mulock Farm Property, located in the vicinity of Mulock Drive, east of Bathurst Street, in Newmarket, Ontario. The property is also known as the forested areas at Summerhill Woods (the Site).

The Site is primarily located southeast of the corner of Bathurst Street and Mulock Drive in Newmarket, Ontario, with an additional portion situated northeast of the same intersection. Figures 1 and 2 show the location and plan of the Site. The Site is considered to consist of four parcels, outlined as:

- Parcel 1: The area north of Mulock Drive, known as William Thomas Mulock Park. This is an environmentally protected area, is Town-owned and will remain in the rugged natural parkland state it is currently;
- Parcel 2: The eastern portion of the area south of Mulock Drive, known as the Trail Lands. This Town-owned parkland area primarily runs north-south and contains a walking trail (plus slashback of approximately two metres to either side of the paved and crushed gravel trail), as well as the Armitage Creek, running parallel to, and west of, the trail;
- Parcel 3: The Northern Forested Lands, just south of Mulock Drive, between Bathurst Street and Parcel 2. This parcel is owned by the developer (Criterion Development Corporation), but is to be conveyed to the Town of Newmarket; and,
- Parcel 4: The Southern Forested Lands, situated between Bathurst Street and Parcel 2, south of the Summerhill Woods Development. This parcel also owned by the developer, but is to be conveyed to the Town of Newmarket. A permanent creek runs west to east through this parcel.

Parcels 2, 3 and 4 form a horseshoe-shaped area around the un-forested property referred to as the Summerhill Woods Development (a residential subdivision). Residential and commercial properties are to the east of the Site, residential properties to the north and south of the Site, while open land and forested areas are to the west, across Bathurst Street. There are no buildings on-site. All four parcels are to remain as rugged natural parkland.

3.1.1 Site History

At least as far back as the mid-1920s, the majority of the Site was used as an apple orchard (primarily Parcels 2 and 3, as well as the southern portion of Parcel 1) (Burnside, 2008a). By the late 1950s, the orchard had ceased operations and the property resumed agricultural functions (Burnside, 2008a). Residential developments began appearing the northeast and east of the Site by the mid-1970s, roughly the period when the last remaining remnants of the apple orchards were removed (Burnside, 2008a).

Lead arsenate insecticides were used extensively in apple orchards in the mid 20th century and recent soil sampling has indicated that arsenic and lead are present in on-site soils, likely due regular spraying of lead arsenate insecticides during the period of orchard operations (MMM, 2008a). Starting in 2007, a new residential subdivision, The Summerhill Woods Development, was created within a previously cultivated area at the southeast limits of the former Mulock Farm. Soil sampling programs have taken place on the lands of the Summerhill Woods Development, as well as the areas forming the parcels of the Site, since 2007 (MMM, 2007; 2008a; 2008b; Burnside, 2008a; 2009; 2010).

3.1.2 Classification of Environmentally Sensitive Area

The Record of Site Condition Regulation (O. Reg. 153/04) defines a contaminated site as an environmentally sensitive area if it meets any of five conditions. The first condition is related to areas of natural significance. A site is considered sensitive if it includes or is adjacent to any one of the following:

- A provincial park designated by a regulation under the Provincial Parks Act;
- A conservation reserve established under the Public Lands Act;
- An area of natural and scientific interest (life science) identified by the Ministry of Natural Resources (MNR) as having provincial significance;
- A wetland identified by the MNR as having provincial significance;
- An area designated by a municipality in its official plan as environmentally significant, however expressed, including designations of areas and environmentally sensitive, as being of environmental concern and as being ecologically significant;
- An area designated as an escarpment natural area or an escarpment protection area by the Niagara Escarpment Plan under the Niagara Escarpment Planning and Development Act;
- A habitat of endangered or threatened species identified by the Ministry of Natural Resources; or,
- Property within an area designated as a natural core area or natural linkage area within the area to which the Oak Ridges Moraine Conservation Plan under the Oak Ridges Moraine Conservation Act, 2001 applies.

The Site does not contain, and is not adjacent to, any of these features. The Site is situated in a designated parkland area, surrounded by neighbouring parkland and residential properties. Moreover, the Site is within a settlement area of the Oak Ridges Moraine and not within an area designated as a natural core area or natural linking area. Therefore, the Site does not meet this requirement for classification as a sensitive site.

The second condition relates to soil pH. A site may be considered sensitive if the soil pH falls outside the range of pH 5 to 9 for surface soils, or pH 5 to 11 for subsurface soils (greater than 1.5m depth). The soil pH levels of eight on-site samples (ranging in depth from near surface to approximately 1.8 mbgs) were reported to be between 6.3 and 7.6 (Burnside, 2009). Therefore, the soil pH levels found in on-site soils were well within the prescribed MOE ranges for surface and subsurface soils.

The third condition for a site to be classified as sensitive relates to the thickness of the soil layer below the surface. The Record of Site Condition Regulation states that a site is considered to be a “shallow soil property”, and therefore, a sensitive site if one-third or more of the property area consists of soil equal to two metres or less in depth. Bedrock was encountered at depths ranging from 87 to 150 metres below ground surface (mbgs) (Burnside, 2010). Therefore, the Site does not meet this requirement for classification as a sensitive site.

The fourth condition relates to nearby water bodies. A site is considered sensitive if it includes, is adjacent to, or is within 30 metres of a water body. A permanent stream in Parcel 4 runs west to east towards the Armitage Creek, with an intermittent tributary flowing into it in the western portion of Parcel 4. In addition, the Armitage Creeks runs approximately west to east through Parcel 1 and approximately north to south through Parcel 2. In addition, an ephemeral (stormwater) watercourse runs through Parcel 3 towards the Armitage Creek. Therefore, the Site does meet this requirement for classification as a sensitive site.

The final condition for a site to be classified as sensitive relates to any other conditions or characteristics of the property which, in the opinion of a qualified person, make it appropriate to apply Table 1 Site Condition Standards to the site. No such condition or characteristic of the Site exists; therefore, the Site does not meet this requirement for classification as a sensitive site.

Therefore, because of the on-site surface water bodies, the Site does meet one of the requirements necessary to be classified as environmentally sensitive.

3.2 Site Plan and Hydrogeological Interpretation of RA Property

The Site and the surrounding areas are part of the Schomberg Clay Plain, bordering on the Oak Ridges Moraine, and contain deep deposits of clay and silt (Burnside, 2008a; 2010). The overburden deposit extends to depths of approximately 100 mbgs (Burnside 2010), and is predominantly a silty clay material of a laucustrine origin (MMM, 2008a). Depth to bedrock ranges from 87 to 150 mbgs; on-site soil is underlain by the Georgian Bay Formation, Blue Mountain Formation, Billings Formation, Collingwood Mb., and Eastwood Mb. (Burnside, 2010).

On-site groundwater depths measured in 2009 by Burnside ranged from 0 to 5 mbgs for the shallow groundwater unit (Burnside, 2010). Beneath this is a complex stratigraphical series, including the silty Halton Aquitard, occurring near the ground surface. Below this layer (approximately 30 mbgs) is the Oak Ridges Aquifer Complex which is the source of potable water in the area. Because this deeper aquifer is separated from the upper groundwater unit that discharges in the on-site surface water bodies by the Halton Aquitard, the two groundwater aquifers are not considered hydraulically connected. Groundwater flow in the water table is generally in an east to south-easterly direction towards the Armitage Creek, reflecting surface topography (Burnside, 2010).

Laboratory grain size analyses were conducted on soil samples collected on-site. Results indicated that more than 50% of particles (on dry weight basis) were smaller than 75 µm in diameter (MMM, 2008a) and, therefore, the Site was classified as medium/fine textured as per O. Reg. 153/04 (Burnside, 2010).

3.3 Contaminants of Concern (COCs)

The selection of COCs for the current assessment was based on the sampling programs for the current RA property (*i.e.*, not including samples taken from the Summerhill Woods Development area) conducted by MMM Group (2007; 2008a; 2008b) and Burnside (2008b; 2009; 2010), as described in Section 3.3.1.

3.3.1 Sampling Programs

Numerous environmental investigations have been conducted by MMM Group and Burnside, beginning in 2007, on both the current RA property as wells as the Summerhill Woods Development area (MMM, 2007).

Between August 2007 and April 2008, MMM Group conducted a Soil Management Plan. Seventy-five locations from the North and South Forested Areas, as well as the Trail Lands, were sampled for arsenic from the top 0.3m of topsoil (MMM, 2008a). Forty-six of these locations were also analyzed for lead. In addition, four of these samples were analyzed for a full inorganic parameter scan. Three locations (SWF-4, SWF-11 and SWF-31) had 3 to 4 samples taken from different depths in order to delineate vertical profiles of arsenic and lead contamination. Three groundwater samples were taken in December 2007 and analyzed for a full inorganic parameter scan. In addition, seven sediment samples were taken from the Armitage Creek and its on-site tributaries, in the areas of the North and South Forested Areas, as well as the Trail Lands. Four locations in the surface water bodies were sampled and analyzed for inorganic parameters.

In February and March 2008, MMM Group further delineated the extent of arsenic and lead in the Trail Lands area soil (*i.e.*, in the vicinity of the walking path and the Armitage Creek) (MMM, 2008b). Thirty-one locations (OS-1 to OS-31) in the Trail Lands area were sampled from the upper 0.15m of topsoil and analyzed for arsenic and lead. An addendum to this soil sampling plan consisted of an additional 13 locations sampled and analyzed for arsenic and lead (MMM, 2008c)

In August 2008, Burnside conducted a soil sampling program in the areas of the RA property, as well as within the residential areas to the east of the Site (Burnside, 2008b). A total of 20 samples (SS-33 to SS-52) from the Thomas Mulock Park (Parcel 1) were sampled from within the top 0.3m of topsoil and analyzed for arsenic. In December 2008, Burnside further delineated the extent of soil contamination in the RA study area (Burnside, 2009). Five soil sample locations (MSS-1 to MSS-5) were taken from topsoil at multiple depths varying from 0.05 to 0.3 mbgs in the Thomas Mulock Park and Trail Lands and analyzed for arsenic and lead. A nest of soil samples was taken in the vicinity of MSS-3 in order to characterize the lateral variability of arsenic distribution in topsoil. The surface sample for each of the five locations was also analyzed for a full inorganic parameter scan. Finally, a sample from each of the two parcels examined (MSS-1 and MSS-4) was analyzed for a full suite of herbicides and pesticides.

Between August and November 2009, Burnside completed additional site characterization and sampling in response to the MOE Comments to the PSF of the current RA (Burnside, 2010). A total of 42 soil locations (18 in William Thomas Mulock Park, 10 in the South Forested Area, 8 in the North Forested Area, and 6 in the Trail Lands) were sampled and analyzed for arsenic, lead and boron. Four of these samples (3 in William Thomas Mulock Park and one in the South Forested Area) were analyzed for herbicides and pesticides (including three of which were sampled at two different depths). Nine locations from the Armitage Creek and its tributaries were sampled and analyzed for arsenic, lead and boron in sediment, as well as pesticides and herbicides. Finally, 4 surface water samples (SW-1 to SW-4) were taken and sampled for arsenic, lead, boron, herbicides and pesticides.

During the field programs, duplicate sampling and QA/QC activities were followed as required for a Phase II Environmental Site Assessment, as per O.Reg. 153/04 and the MOE Guidance on Sampling and Analytical Methods for Use at Contaminated Sites in Ontario (MOE, 1996a). Duplicate samples were taken for QA/QC purposes for various parameters during the soil and groundwater sampling program. Duplicate data is included in the data tables and on the laboratory Certificates of Analysis included with the Phase II ESA and other technical reports. The QA/QC data was reviewed by the QP_{ESA} who confirmed that the data could be relied upon with confidence.

A complete media sampling plan is presented in Figure 3-1.

3.3.2 Screening and Selection of COCs for the Risk Assessment

Soil and groundwater were sampled and analyzed for chemicals that may have been used or released through historical activities on or near the Site. Analyzed chemicals included: metals and inorganics in groundwater; metals, inorganics and pesticides in soil.

For the current assessment, maximum soil and groundwater concentrations were compared to MOE Table 1 Full Depth Background Site Condition Standards.

<u>3.3.2.1 Selection of COCs in Groundwater</u>

MMM Group conducted groundwater sampling in December 2007 (MMM, 2008a), followed by additional groundwater sampling by Burnside in 2009 (Burnside, 2009). The maximum concentration (or the highest detection limit) of each chemical analyzed in groundwater was initially compared to the Table 1 Full-Depth Background Groundwater Standards under a residential/parkland/institutional property use. Table 3-1 presents the results of the COC groundwater screening.

FIGURE 3-1

TOWN OF NEWMARKET
PARKLANDS AT MULOCK DR. & BATHURST ST.
COMMENTS ON FINAL DRAFT OF RISK ASSESSMENT

MEDIA SAMPLING PLAN

N

LEGEND

- APPROXIMATE PROPERTY OUTLINES
- APPROXIMATE BUFFER AREA AROUND RESIDENTIAL DEVELOPMENT
- MAXIMUM EXTENT OF FORMER ORCHARDS
- SED-20 (Pb−261) — SEDIMENT SAMPLE LOCATION WITH ARSENIC & LEAD CONCENTRATION IN SEDIMENT (μg/g) By Burnside August 2009
- SS-5 (Pb−261) 1.8 — SOIL SAMPLE LOCATION WITH ARSENIC & LEAD CONCENTRATION IN SOIL (μg/g) By Burnside August 2009
- B-20 (Pb−261) 1.8 — SOIL SAMPLE LOCATION SUBMITTED FOR BIOAVAILABILITY ANALYSIS WITH ARSENIC & LEAD CONCENTRATION IN SOIL (μg/g) By Burnside August 2009
- SW-4 1.8 (Pb−261) — SURFACE WATER SAMPLE LOCATION WITH ARSENIC & LEAD CONCENTRATION IN WATER (μg/L) By Burnside August 2009
- MW-A 1.8 — MONITORING WELL LOCATION WITH ARSENIC, LEAD & BORON CONCENTRATIONS By Burnside October & November 2009

	DEPTH	As	Pb	B
IN SOIL (μg/g) -	0.8m	3	10.2	<0.1
IN GROUNDWATER - (μg/L)	MW−B	0.91	11.3	<0.05

- MSS-1 23.72 — MULTIPLE SOIL SAMPLE LOCATION & AVERAGE ARSENIC CONCENTRATION IN SOIL (μg/g) By Burnside December 22 & 23, 2008
- SS-1 1.8 — SOIL SAMPLE LOCATION & ARSENIC CONCENTRATION IN SOIL (μg/g) By Burnside August 5 & 6, 2008
- SOIL SAMPLE & ARSENIC CONCENTRATION (μg/g) By MMM Group Ltd., July - Sept. 2007
- SEDIMENT SAMPLE & ARSENIC CONCENTRATION (μg/g) By MMM Group Ltd., September 2007
- 2 — SOIL SAMPLE & ARSENIC CONCENTRATION (μg/g) By MMM Group Ltd., September 2007, March 2008
- 3 — TOPSOIL & SUBSOIL SAMPLE & ARSENIC CONCENTRATION (μg/g) By MMM Group Ltd, July 2008
- 6 / 3 — VERIFICATION SOIL SAMPLE & ARSENIC CONCENTRATION (μg/g) By MMM Group Ltd, November 2007 & June 2008
- 2 — SOIL SAMPLE, REG 153 METALS & ARSENIC CONCENTRATION (μg/g) By MMM Group Ltd, July 2008
- 1 — VERIFICATION TOPSOIL SAMPLE & ARSENIC CONCENTRATION (μg/g) By MMM Group Ltd, July 2008
- 3 — GROUNDWATER SAMPLE LOCATION & ARSENIC CONCENTRATION (μg/L) By MMM Group Ltd. Dec. 2007
- 3 — SURFACE WATER SAMPLE LOCATION & ARSENIC CONCENTRATION (μg/L) By MMM Group Ltd. January 2008
- 41.8 — ARSENIC CONCENTRATION IN SOIL ABOVE THE MOE TABLE 1 STANDARD (μg/g)
- 41.8 — ARSENIC CONCENTRATION IN SEDIMENT ABOVE THE MOE TABLE 1 STANDARD (μg/g)
- (Pb−44.8) — LEAD CONCENTRATION IN SOIL ABOVE THE MOE TABLE 1 STANDARD (μg/g)
- (Pb−44.8) — LEAD CONCENTRATION IN SEDIMENT ABOVE THE MOE TABLE 1 STANDARD (μg/g)
- 25 (Pb−78) — ARSENIC AND LEAD CONCENTRATION IN SURFACE WATER ABOVE THE MOE TABLE 1 STANDARD (μg/L)
- 1.5 — OC PESTICIDE CONCENTRATION IN SEDIMENT ABOVE MOE TABLE 1 STANDARD (μg/g)

TABLE 1 STANDARDS

	(μg/g) SOIL	(μg/g) SEDIMENT	(μg/L) GROUNDWATER
As	17	6	25
Pb	120	31	1
DDD	NV	0.008	0.025
DDE	NV	0.005	0.01
DDT	1.4	0.007	0.05
B	NV	NV	200

- AREAS REQURING REMDIAL ACTION INTERPRETED TO HAVE ARSENIC CONCENTRATIONS IN THE TOPSOIL (<0.3m depth) IN EXCESS OF 60(μg/g)

NOTES:

- SAMPLES COLLECTED FROM PRIVATELY OWNED RESIDENTIAL LAND ARE NOT SHOWN WITH THE EXCEPTION OF THE VERIFICATION SAMPLES FROM SUMMERHILL WOODS.
- SAMPLES COLLECTED FROM THE BUFFER LANDS AROUND SUMMERHILL WOODS PRIOR TO REMEDIATION ARE NOT SHOWN. ONLY THE POST REMEDIATION (CURRENT CONDITIONS) RESULTS ARE SHOWN.

Air Photo Source:
Background colour air photo circa 2007-2008 obtained from Google Earth Pro & from First Base Solutions Inc.

0 10 20 30 40 50 60 70 80 90 100
Metres

Scale 1:1,500
May 2011
Project Number: D24650000
Projection: UTM Zone 17
Datum: NAD83
Prepared by: C. Sheppard
Verified by: J. Walls

BURNSIDE

D24650 PARKLANDS FINAL DRAFT WITH INTRINSIK COMMENTS MAY 2011 SAMPLING PLAN.dwg

Plot Time: May 18, 2011−9: 45am

Table 3-1 Screening of Maximum Groundwater Concentrations Against MOE Table 1 Full Depth Background Site Condition Standards

COC	Location of Maximum Groundwater Concentration	MOE MDL (µg/L)	Maximum Groundwater Concentration (µg/L)	MOE Table 1 Site Condition Groundwater Standard (µg/L)
Metals				
Antimony	Multiple Locations	0.1	<0.5	6
Arsenic	SW MW-1S	0.5	4	25
Barium	SW MW-3	0.25	96	NV
Beryllium	Multiple Locations	0.25	<0.5	4
Boron	SW MW-1S	10	98	200
Cadmium	Multiple Locations	0.25	<0.1	0.5
Chromium (total)	Multiple Locations	2.5	<5.0	8.9
Chromium (VI)	Multiple Locations	10	<5.0	10
Cobalt	Multiple Locations	0.1	0.5	0.9
Copper	SW MW-3	2.5	2	2.5
Lead	**BHF-d**	**0.25**	**1.21**	**1**
Mercury	**Multiple Locations**	**0.02**	**<0.1**	**0.02**
Molybdenum	SW MW-1S	0.25	7	40
Nickel	Multiple Locations	1	<1.0	25
Selenium	Multiple Locations	5	<2.0	5
Silver	Multiple Locations	0.25	<0.1	0.25
Thallium	Multiple Locations	0.25	<0.05	0.5
Vanadium	SW MW-1S	0.25	2	6
Zinc	SW MW-3	1	8	20
Pesticides				
Aldrin	Multiple Locations	0.005	<0.01	0.005 (0.01)*
Lindane	Multiple Locations	0.08	<0.05	0.005 (0.01)
Chlordane (total)	Multiple Locations	0.03	<0.03	0.02 (0.06)
DDD	Multiple Locations	0.6	<0.05	0.025 (1.8)
DDE	Multiple Locations	2.0	<0.05	0.01 (10)
DDT	Multiple Locations	0.05	<0.04	0.05 (0.05)
Dieldrin	Multiple Locations	0.01	<0.01	0.01 (0.05)
Endrin	Multiple Locations	0.025	<0.02	0.025 (0.05)
Endosulfan	Multiple Locations	0.06	<0.05	0.06 (0.05)
Heptachlor	Multiple Locations	0.005	<0.01	0.005 (0.01)
Heptachlor Epoxide	Multiple Locations	0.03	<0.01	0.01 (0.01)
methoxychlor	Multiple Locations	0.03	<0.04	0.04 (0.05)
Inorganics				
Cyanide (free)	Multiple Locations	5	<2.0	5
Chloride	SW MW-3	2000	300,000	NV
Nitrite	Multiple Locations	250	<0.01	NV
Sodium	SW MW-1S	50	37,000	NV

BOLDED concentrations highlighted in grey scale were detected above MOE Table 1 Site Condition standards or the detection limit exceeded standards.

< Indicates that the concentration is lower than the value presented but cannot be more accurately quantified due to analytical uncertainty.

NV Indicates that a value is not provided by the MOE.

*(number) represents the MOE (2009) Table 1 SCS for the Pesticides

As shown in Table 3-1, maximum concentrations (or highest detection limits) of lead, ~~and~~ mercury, and several pesticides ~~were the only chemicals~~ in groundwater ~~whose maximum concentrations (or highest detection limits)~~ exceeded their 2004 Table 1 Site Condition Standards.

~~However, because m~~Mercury was not found in any groundwater sample above its analytical detection limit, and it is not associated with any historical property use, as a result, the QP_{ESA} has recommended that it not be retained as a COC for the RA. Furthermore, it is noted that the mercury deciton limit (<0.1 µg/L) is less than the new MOE (2009) Table 1 (0.1 µg/L), Table 2 (1 µg/L-medium/fine and 0.29 µg/L-coarse) and Table 8 (0.29 µg/L) Site Condition Standards (SCSs).

There were no measured exceedances of the Table 1 criteria for the the pesticides in soil, sediment, or groundwater. It is noted that the method detection limit (MDL) for several pesticides in groundwater of 0.05 ug/L exceeds the Table 1 Standard of 0.01 ug/L. AGAT Laboratories provided the following response:

> *"The reporting detection limits (RDL) are based on the method detection limits (MDL) which is a theoretical value determined from the variance of a number of low spikes. The MDL, in many cases, is lower than the RDL, however reporting at the MDL is not a reliable detection limit as false positives can occur. This is why an RDL is used as the detection limit, as the RDL is a set value that is slightly higher than the MDL (in most cases by a factor of 10), so it is easily detected by the instrument and is normally the lowest value at which we are confident that false positives will not occur. DLs can vary, depending on the instrument and method used, so it is possible that another lab/method could detect at the low level.*
>
> *In regards to the dl of 0.05 ug/1 for DDE, that is the lowest we are able to detect. Our DL would only vary if dilutions were required (which would cause the DL to increase)."*

Although the MDL for several parameters in groundwater exceed the Table 1 Standard based on the O.Reg. 153/04 criteria, with the exception of Lindane, all are less than the Table 1 Standards outlined in O.Reg. 511/09, which comes into force in July 2011. The detection limit for Lindane marginally exceeds the the 2004 and 2009 Table 1 Standards.

In the opinion of the QP_{ESA} the lack of any measured exceedances of any pesticides in soil, sediment, and groundwater on the site provides a significant level of confidence that these related compounds are not COC's on this site. No further investigation or assessment is required.

The MOE has not provided Table 1 Standards for four other chemicals analyzed in groundwater (barium, chloride, nitrite and sodium). Nitrite was not detected in any sample, and because it is not associated with historical property use, it also was not retained as a COC for the RA.

Therefore, the following four chemicals were retained as COCs in the RA:

- barium;
- lead;
- chloride; and,
- sodium.

3.3.2.2 Selection of COCs in Soils

Since fill materials are variable in thickness, no distinction was made between surface and subsurface soil for the purpose of selecting COCs. The values used in the chemical screening process are the maximum concentration, or highest detection limit, of each chemical measured in all surface and subsurface soil layers from on-site investigations conducted in 2007 to 2009 (MMM, 2007; 2008a; 2008b; Burnside, 2008b; 2009; 2010).

The maximum concentration for each chemical analyzed was screened against MOE Table 1 Full Depth Background Site Condition Standards for soil (Table 3-2). The sampling depth related to the maximum concentration found for each chemical analyzed is provided in Table 3-2. The maximum depth of contamination is 0.55 metres, the maximum depth of on-site topsoil.

Table 3-2 Screening of Maximum Soil Concentrations Against MOE Table 1 Full Depth Background Site Condition Standards

COC	*Location of Maximum Concentration*	*Sample Depth (m)*	*Maximum Soil Concentration (µg/g)*	*MOE Table 1 Site Condition Soil Standard (µg/g)*
Inorganics				
Antimony	**Multiple Locations**	**0 – 0.25**	**<1.6**	**1.0**
Arsenic	**SS2**	**0.05 – 0.15**	**143**	**17**
Barium	SS5	0.15 – 0.25	55.5	210
Beryllium	SS5	0.15 – 0.25	0.4	1.2
Boron	SS1	0.05 – 0.15	0.77	NV
Cadmium	Multiple Locations	0 – 0.25	<0.4	1.0
Chromium (total)	SS5	0.15 – 0.25	16.7	71
Chromium (VI)	Multiple Locations	0 – 0.25	<0.4	2.5
Cobalt	SS5	0.15 – 0.25	5.4	21
Copper	SS2	0 – 0.05	51.4	85
Lead	**SS2**	**0 – 0.05**	**422**	**120**
Mercury	SS5	0.15 – 0.25	0.071	0.23
Molybdenum	Multiple Locations	0 – 0.25	<0.5	2.5
Nickel	SS5	0.15 – 0.25	9.3	43
Selenium	Multiple Locations	0 – 0.25	<0.8	1.9
Silver	Multiple Locations	0 – 0.25	<0.4	0.42
Thallium	Multiple Locations	0 – 0.25	<0.4	2.5
Vanadium	SS5	0.15 – 0.25	28.6	91
Zinc	SS5	0.15 – 0.25	39.8	160
Inorganics				
Cyanide (free)	**Multiple Locations**	**0 – 0.25**	**<1.0**	**0.12**
OC Pesticides				
Aldrin	Multiple Locations	0.05 – 0.15	<0.005	0.05
Chlordane	Multiple Locations	0.05 – 0.15	<0.01	0.05
DDD	SS-15	0.0 – 0.2	0.024	NV
DDE	SS-15	0.0 – 0.2	0.44	NV
DDT	SS1	0.05 – 0.15	0.024	1.4
Dieldrin	Multiple Locations	0.05 – 0.15	<0.005	0.05
Endosulfan	Multiple Locations	0.05 – 0.15	<0.005	NV
Endrin	Multiple Locations	0.05 – 0.15	<0.005	0.05
Heptachlor	Multiple Locations	0.05 – 0.15	<0.005	0.05
Heptachlor Epoxide	Multiple Locations	0.05 – 0.15	<0.005	0.05
Hexachlorocyclohexane, gamma	Multiple Locations	0.05 – 0.15	<0.005	NV
Methoxychlor	Multiple Locations	0.05 – 0.15	<0.005	0.05
OP Pesticides				
Phorate	Multiple Locations	0.05 – 0.15	<0.1	NV
Dimethoate	Multiple Locations	0.05 – 0.15	<0.5	NV
Terbufos	Multiple Locations	0.05 – 0.15	<0.14	NV
Diazinon	Multiple Locations	0.05 – 0.15	<0.2	NV
Malathion	Multiple Locations	0.05 – 0.15	<1.0	NV

Table 3-2 Screening of Maximum Soil Concentrations Against MOE Table 1 Full Depth Background Site Condition Standards

COC	Location of Maximum Concentration	Sample Depth (m)	Maximum Soil Concentration (µg/g)	MOE Table 1 Site Condition Soil Standard (µg/g)
Chlorpyrifos	Multiple Locations	0.05 – 0.15	<0.2	NV
Parathion	Multiple Locations	0.05 – 0.15	<0.2	NV
Azinphos-methyl	Multiple Locations	0.05 – 0.15	<0.4	NV
Herbicides				
2,4-D	Multiple Locations	0.05 – 0.15	<0.05	NV
2,4,5-T	Multiple Locations	0.05 – 0.15	<0.05	NV
2,4,5-TP	Multiple Locations	0.05 – 0.15	<0.05	NV
Dicamba	Multiple Locations	0.05 – 0.15	<0.05	NV
Dichloroprop	Multiple Locations	0.05 – 0.15	<0.05	NV
Dinoseb	Multiple Locations	0.05 – 0.15	<0.05	NV
Picloram	Multiple Locations	0.05 – 0.15	<0.05	NV
Diclofop-methyl	Multiple Locations	0.05 – 0.15	<0.05	NV
Soil Chemistry				
Electrical Conductivity	SS5	0.15 – 0.25	0.29 (mS/cm)	0.57 (mS/cm)
Sodium Absorption Ratio (SAR)	SS4	0.10 – 0.15	0.919	2.4

BOLDED parameters highlighted in grey scale were detected above MOE Table 1 Site Condition standards or the detection limit exceeded standards.
< Indicates that the concentration is lower than the value presented but cannot be more accurately quantified due to analytical uncertainty.
NV Indicates that a value is not provided by the MOE.

As shown in Table 3-2, the maximum concentrations of arsenic and lead each exceeded their respective MOE Table 1 Soil Standard. In addition, the analytical detection limit for antimony and free cyanide exceeded their Table 1 Soil Standards. However, since antimony and cyanide are not related to historical property use on the Site and were not found at concentrations above their detection limits, these two chemicals were not retained for further evaluation.

There are currently no Table 1 Site Condition Standards available for twenty-one (21) chemicals analyzed, as seen in Table 3-2. With the exceptions of boron (0.77 µg/g), DDD (0.024 µg/g), and DDE (0.44 µg/g), all of these chemicals were found at concentrations below their respective detection limits. Since the remaining eighteen chemicals were not found in any detected concentrations and they are not associated with any historical property use, they were not retained for further evaluation in the RA for soil, as per the recommendations of the QP_{ESA}.

Therefore, the following five chemicals were retained as COCs in soil for the RA:

- Arsenic;
- Boron;
- DDD;
- DDE; and,
- Lead.

3.3.2.3 Selection of COCs in Sediment

Because permanent surface water bodies are present on-site (Armitage Creek and its tributaries), sediment samples were taken and analyzed for selected inorganic and pesticide parameters identified in the initial soil screening (MMM, 2008a; Burnside, 2010). The values used in the chemical screening process presented in Table 3-3 are the maximum concentration, or highest detection limit, of each chemical measured in sediment

Table 3-3 Screening of Maximum Sediment Concentrations Against MOE Table 1 Full Depth Background Site Condition Standards

COC	Location of Maximum Concentration	Sample Depth (m)	Maximum Sediment Concentration (µg/g)	MOE Table 1 Site Condition Sediment Standard (µg/g)
Inorganics				
Arsenic	**Sed-19**	**0.2**	**31.7**	**6**
Boron (HWS)	Sed-21	0.2	0.62	NV
Lead	**Sed-19**	**0.55**	**86.4**	**31**
Pesticides				
Aldrin	Multiple Locations	0.2 – 0.55	<0.005	0.002
Alpha-BHC	Multiple Locations	0.2 – 0.55	<0.005	NV
Gamma-BHC (Lindane)	Multiple Locations	0.2 – 0.55	<0.005	NV
Chlordane (total)	Multiple Locations	0.2 – 0.55	<0.010	0.007
DDD	**Sed-17**	**0.2**	**0.013**	**0.008**
DDE (total)	**Sed-17**	**0.2**	**0.11**	**0.005**
DDT (total)	Multiple Locations	0.2 – 0.55	<0.010	0.007
Dieldrin	Multiple Locations	0.2 – 0.55	<0.005	0.002
Endosulfan (total)	Multiple Locations	0.2 – 0.55	<0.005	NV
Endrin	Multiple Locations	0.2 – 0.55	<0.005	0.003
Heptachlor	Multiple Locations	0.2 – 0.55	<0.005	NV
Heptachlor Epoxide	Multiple Locations	0.2 – 0.55	<0.005	0.005
Methoxychlor	Multiple Locations	0.2 – 0.55	<0.005	NV

BOLDED parameters highlighted in grey scale were detected above MOE Table 1 Site Condition Standards or the detection limit exceeded standards.
< Indicates that the concentration is lower than the value presented but cannot be more accurately quantified due to analytical uncertainty.
NV Indicates that a value is not provided by the MOE.

As shown in Table 3-3, the maximum concentrations of arsenic, lead, DDD and DDE each exceeded their respective MOE Table 1 Sediment Site Condition Standard. In addition, the analytical detection limit for five pesticide chemicals (aldrin, chlordane, DDT, dieldrin, and endrin) exceeded their Table 1 Soil Standards. However, since these pesticides are not related to historical property use on the Site and were not found at concentrations above their detection limits, these ~~two~~ chemicals were not retained for further evaluation, as recommended by the QP_{ESA}.

There are currently no Table 1 Site Condition Standards available for six chemicals analyzed, as seen in Table 3-3. With the exceptions of boron (0.62 µg/g), all of these chemicals were found at concentrations below their respective detection limits. Since these remaining five chemicals were not found in any detected concentrations and they are not associated with any historical property use, they were not retained for further evaluation in the RA for sediment, as per the recommendations of the QP_{ESA}. Additionally, although no Table 1 Site Condition Standard was available for boron, this chemical was also not retained for further evaluation in sediment since it was determined that no quantitative assessment was necessary for boron in soil (refer to Section 5.1.1 for details).

Therefore, the following four COCs in sediment were retained for further evaluation in the RA:

- Arsenic

- Lead
- DDD
- DDE

3.3.2.4 Consideration of COCs in Surface Water

Because permanent surface water bodies are present on-site (Armitage Creek and its tributaries), surface water samples were taken and analyzed for selected inorganic and pesticide parameters identified by Burnside (2010). All results were below the Table 1 Standards, with the exception of sample SWNWSW located in the northwest corner of the northern forested lands. The QP_{ESA}, has indicted that this sample location represents surface water quality flowing onto the RA property from off-Site. The results indicate concentrations of arsenic (25 µg/L) and lead (78 µg/L) (this location is displayed on the site sampling plans presented in Figure 3.1 of the revised RA). The QP_{ESA} determined that the result was not a reflection of the surface water quantify on the RA property but a reflection of road related and off Site activities related sediment laden water from off-Site. The chemical signature of other suites of parameters tested when compared to the results of all other surface water sampling data supports this interpretation. The location has intermittent flow and did not have running water on other occasions when fieldwork was being conducted, so there was no opportunity to collect a duplicate sample. Additionally, the sample was taken from an intermittent water course upstream of Armitage Creek. The results of all surface water samples taken from on-Site and taken from the discharge leaving the Site were either below the Table 1 Standards or assumed to be not present on-site (refer to Appendix E of the revised RA for a complete summary of surface water sampling data obtained by Burnside). The anomalous sample does not indicate any significant impact to the surface water on the RA property or discharging from the RA property. The values used in the comparison with Provincial Water Quality Objectives (PWQOs; MOEE, 1994) are ~~the maximum concentration, or highest detection limit, of each chemical measured in surface water~~presented in Table 3-4 below.

Table 3-4 Comparison of Screening of Maximum Surface Water Concentrations Against PWQOs

COC	***Location of Maximum Concentration***	***Maximum Surface Water Concentration (µg/L)***	***PWQO (µg/L)***
Inorganics			
Arsenic	SW-2	3.36	5[a]
Boron	SW-4	20.9	200
Lead	SW-4	0.7	1[a]
Pesticides			
Aldrin	Multiple Locations	<0.01	NV
Dieldrin	Multiple Locations	<0.01	NV
Aldrin + Dieldrin	Multiple Locations	<0.02	0.001
Gamma-BHC (Lindane)	Multiple Locations	<0.05	0.01
Oxychlordane	Multiple Locations	<0.03	NV
Chlordane (total)	Multiple Locations	<0.03	0.06
DDD	Multiple Locations	<0.05	NV
DDE (total)	Multiple Locations	<0.05	NV
DDT (total)	Multiple Locations	<0.04	NV
DDD, DDE, DDT (total)	Multiple Locations	<0.14	0.003
Endrin	Multiple Locations	<0.02	0.002
Endosulfan (total)	Multiple Locations	<0.05	0.003
Heptachlor	Multiple Locations	<0.01	NV

Table 3-4 Comparison of Screening of Maximum Surface Water Concentrations Against PWQOs

COC	***Location of Maximum Concentration***	***Maximum Surface Water Concentration (µg/L)***	***PWQO (µg/L)***
Heptachlor Epoxide	Multiple Locations	<0.01	NV
Heptachlor + Heptachlor Epoxide	Multiple Locations	<0.02	0.001
Methoxychlor	Multiple Locations	<0.04	0.04
PCBs	Multiple Locations	<0.1	0.001

< Indicates that the concentration is lower than the value presented but cannot be more accurately quantified due to analytical uncertainty.
NV Indicates that a value is not provided by the MOE.
[a] Interim value provided by MOE (1994).

As shown in Table 3-4, the maximum surface water levels of all pesticide parameters (as represented by their analytical detection limits) were below their respective PWQO values, where available. Since all pesticides were non-detect (at the lowest reasonable detection limit provided by the laboratory) in every sample, it was assumed that no quantitative assessment was necessary for pesticides in surface water. Additionally, the maximum surface water concentrations of all three inorganic parameters (arsenic, boron and lead) were below their respective PWQO values. Therefore, no quantitative assessment was necessary for inorganics.

4.0 HUMAN HEALTH RISK ASSESSMENT (HHRA)

The current RA followed the standard RA process: Problem Formulation; Exposure Assessment; Hazard Assessment; and, Risk Characterization. The various tasks comprising these phases are detailed in Figure 4-1.

4.1 Problem Formulation

Problem formulation is an information-gathering and interpretation stage, designed to plan and focus the RA on critical areas of concern for the site being evaluated. The key tasks requiring evaluation within the problem formulation phase include the following: i) site characterization, which consists of a review of available site data to identify factors affecting the availability of chemicals to potential receptors (as described in Sections 3.1 and 3.2); ii) chemical characterization, which involves the identification of the COC based on site monitoring data (as described in Section 3.3); iii) receptor characterization to identify "receptors of concern", which include those with the greatest probability of exposure to chemicals from the site and those that have the greatest sensitivity to these chemicals (to be addressed in Section 4.1.2); and, iv) the identification of exposure pathways, which takes into account chemical-specific parameters, such as solubility and volatility, characteristics of the site, such as physical geography, as well as the physiology and behaviour of the receptors (to be addressed in Section 4.1.2).

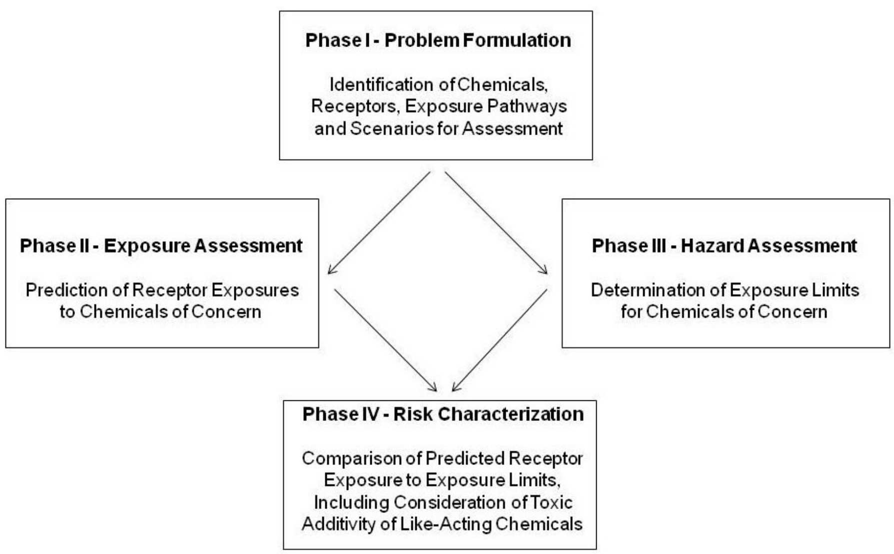


Figure 4-1 The Basic Steps of a Risk Assessment

<u>Exposure Assessment</u>

The assessment of the potential for adverse effects from chemicals is based on the dose-response concept that is fundamental to the responses of biological systems to chemicals (Filov *et al*., 1979; Amdur *et al*., 1991). Since it is not usually practical to measure concentrations of chemicals at the actual site where the adverse response occurs within tissues and cells, these concentrations are estimated based on either the dose of the chemical that actually enters a receptor or more commonly, by the concentrations in various environmental media that act as pathways for exposure. The degree of exposure of receptors to chemicals from the environment therefore depends on the interactions of a number of parameters, including:

- The concentrations of chemicals in various environmental media as determined by the magnitude of point sources as well as background or ambient concentrations;
- The characteristics of the COC which affect environmental fate and persistence (*e.g.*, physical-chemical properties);
- The impact of site-specific characteristics, such as local geology, geography and hydrogeology, on chemical behaviour;
- The physiological and behavioural characteristics of the receptors (*e.g.*, respiration rate, soils/dusts intake, time spent at various activities and in different environmental areas); and,
- The various physical, chemical and biological factors that determine the bioavailability (uptake) of chemicals through various exposure pathways.

Hazard Assessment

The toxic potency of a chemical is dependent upon the inherent toxicity of the chemical itself (*i.e.*, its ability to enact the mechanism of toxicity), as well as the ability of the chemical to reach the site of action (*i.e.*, bioavailability). Toxic potency may be modified by receptor-specific factors such as the ability to resist, repair or adapt to the toxic impact, and depending on the age, sex, species, *etc*., of the receptor. The dose-response principle is central to the RA methodology, and is characterized for a certain chemical *via* observations of the toxicological effects resulting from experimental exposures of organisms, either in the environment from various point and non-point sources, or in the laboratory under controlled conditions (Doull *et al.*, 1980; FDA, 1982). The development of an exposure limit must incorporate consideration of factors which affect the impact of a given chemical. These factors may be scenario-specific, such as variation in duration or levels of exposure, which may result in impact on different target organs; this requires that the exposure limit is derived from “realistic” exposures representative of those occurring under practical conditions. For many chemicals, the toxic endpoint is also dependent on the route of exposure, as exposure *via* different routes may impact tissues only at the site of entry. In such a case, different exposure limits would be recommended for the different routes of exposure. Similarly, the relative toxic potency of a chemical may vary from one receptor to another (*e.g.*, children are more sensitive than adults to lead toxicity). In these situations, separate exposure limits for different life stages would be used to ensure protection of sensitive stages of the population.

Risk Characterization

Risk characterization for chemicals with a threshold-type dose-response consists of a comparison between the toxicological criteria (*i.e.*, the rate of exposure that would not produce adverse effects) against the total estimated exposure. This comparison is expressed as an Exposure Ratio (ER) for oral and dermal exposures and a Concentration Ratio (CR) for inhalation exposures. These ratios are calculated dividing the predicted concentration or exposure by the appropriate toxicological criterion, as indicated in the following equations:

$$Exposure\,Ratio = \frac{Estimated\ Exposure\,(ug/kg/day)}{Exposure\,Limit\,(ug/kg/day)}$$

or

$$Concentration\ Ratio = \frac{Air\ \ Concentration\,(ug\,/\,m^3)}{Exposure\ Limit\,(ug\,/\,m^3)}$$

Risk characterization for chemicals with a non-threshold-type dose response (*i.e.*, carcinogens) consists of a calculation of the Incremental Lifetime Carcinogenic Risk (ILCR), which is defined as the predicted risk of an individual in a population of a given size developing cancer over a lifetime. The ILCR is expressed as a fraction representing the prediction that 1 person per n people would develop cancer, where the magnitude of n reflects the risks to that population; for example, if the ILCR is 0.1 (representing 1 person per 10), the predicted risks of any individual developing cancer would be higher than if the ILCR is 0.001 (1 per 1,000). The following equations provide the method whereby the ILCR is calculated:

$$ILCR\ =\ Estimated\ Exposure\ \ (ug\,/\,kg\,/\,day) \times Slope\ Factor\,(ug\,/\,kg\,/\,day)^{-1}$$

or

$$ILCR\ =\ Air\ Concentration\ \ (ug\,/\,m^3) \times Unit\ Risk\,(ug\,/\,m^3)^{-1}$$

ERs, CRs and ILCR levels are effective tools for expressing potential adverse health effects from exposures to COCs in that:

- They allow comparisons of potential adverse effects on health between chemicals and different exposure scenarios (*e.g.*, typical Ontario *versus* site-specific conditions);
- Potential adverse effects can be estimated from exposures to mixtures of chemicals that act on similar biological systems (*e.g.*, all chemicals that cause liver toxicity, or kidney toxicity, or respiratory tract cancers); and,
- They help simplify the presentation of the RA results so that the reader may have a clear understanding of the significance of these results, and an appreciation of their significance.

If the total exposure to a chemical is equal to or less than the toxicological criterion, then the ER would be 1.0 or less, and no adverse health effects would be expected. For human exposures to non-carcinogens, the toxicological criteria represent the level of total exposure derived from multi-source and multimedia exposures, which would not result in adverse health effects, regardless of the source or route of exposure. In cases where total exposure has been estimated from both background and site sources, it would be valid to compare the estimated exposure to the entire exposure limit, and an acceptable ER level would be 1.0. If the RA addresses risks associated with a single source and a limited number of environmental pathways, the selection of an ER of 1.0 as a benchmark to indicate that exposure does not exceed the toxicological criterion is not valid. In an attempt to address this problem, the MOE has apportioned 20% of the total exposure to any one environmental medium (O. Reg. 153/04). ER values for non-carcinogens that are less than 0.20 are considered to represent a situation in which media-related exposures account for less than 20% of the toxicological criterion, and no adverse effects are expected to be associated with the estimated level of exposure.

ILCR levels represent the predicted incremental risk of cancer over a lifetime to an individual member of a population of a given size and are expressed as a risk level. ILCRs are evaluated by comparison to a benchmark risk level that is considered to be acceptable. For example, negligible or de minimis cancer risk levels are generally considered to range from $1x10^{-4}$ to $1x10^{-6}$. The MOE considers $1x10^{-6}$ (1-in-1,000,000) an acceptable risk level.

In cases where the estimated exposures or risks are less than the acceptable level, it can be concluded that no observable adverse health effects would be expected to occur, considering the more sensitive members of the population or the majority of the exposure scenarios considered in the assessment.

If predicted ERs and CRs are greater than the acceptable level, this may trigger the need to re-evaluate the model parameters (*e.g.*, chemical concentration estimates, exposure parameters, and toxicological criteria) to minimize the uncertainty related to the initial predictions. ER and CR exceedances above 0.2 are not necessarily indicative of potential risks associated with a given medium, as they may reflect overestimation of risk due to the use of overly conservative estimates (*e.g.*, overestimating exposures through the use of maximum soil ingestion rates). This procedure is followed to ensure that the predicted potential impacts on human health were not under-estimated, but also recognizes the potential magnitude of the conservatism built into the risk estimate.

4.2 Problem Formulation

The problem formulation for the HHRA includes a human health conceptual site model (Section 4.1.1) and the RA objectives (Section 4.1.2). As discussed in Section 3.1, the site is considered to be an environmentally sensitive area as a result of the presence of permanent on-site water bodies (*e.g.,* Armitage Creek and the permanent stream in the southern portion of Site). Therefore, maximum concentrations of chemicals in groundwater and soil were initially compared to Table 1 Site Conditions Standards reflective of background concentrations, thereby establishing the list of COCs for the RA. This is required because the Table 2 and 3 Site Condition Standards may not be protective of aquatic receptors in a surface water body when impacted groundwater is in such close proximity (as defined per O. Reg. 153/04).

Although no residential properties are planned, the Site is in proximity of the capture zone of the York Region municipal wells. Therefore, Table 2 Generic Site Condition Standards in a Potable Groundwater Condition are appropriate for secondary COC screening. The deep aquifer used for potable water is found approximately 30 mbgs and is not considered hydrologically connected to the upper groundwater unit (typically found at 0 to 5 mbgs) to be impacted by any surface soil contamination (Burnside, 2010).

Vertical profiling studies with respect to arsenic and lead levels have indicated that impact from these analytes is present primarily within the upper 25cm of the topsoil, and not below the bottom layer of the topsoil (Burnside, 2009). This is primarily due to the low mobility of arsenic and lead in subsurface soil, as well as the low permeability of the silty-clay soils observed on-site (Burnside, 2009). Therefore, the QP_{ESA} has stated that arsenic and lead are not expected to be a groundwater concern (Burnside, 2010).

Chemicals of Concern in Groundwater

Based on the initial COC screening presented in Section 3.3.2, the following four chemicals were retained as COCs for groundwater and carried forward to the HHRA:

- Barium;
- Lead;
- Chloride; and,
- Sodium.

As discussed in Section 3.1, the Site is considered to be environmentally sensitive due to permanent water bodies existing on-site. As a result, the maximum concentrations of chemicals in groundwater were initially compared to Table 1 Site Condition Standards that are representative of typical Ontario background concentrations. This was done to be protective of ecological receptors utilizing the on-site surface water bodies as habitat since there may be limited attenuation of contaminants in on-site soil or groundwater prior to entering surface water through groundwater flow. However, because the use of Table 1 Standards for the selection of COCs is based on the protection of aquatic ecological receptors in the receiving surface water body, a secondary screening for the purpose of the HHRA was conducted using the Generic Site Condition Standards for Use within 30m of a Water Body in a Potable Ground Water Condition (MOE, 2009). The use of the 2009 Site Condition Standards for this secondary screening process reflects the most current science.

Table 4-1 provides the maximum groundwater concentrations, or highest detection limits, of the four COCs listed above and their respective 2009 Table 8 Site Conditions Standards.

Table 4-1 Comparison of Maximum Groundwater Concentrations with Table 8 Site Condition Standards Site (µg/L) (MOE, 2009)

COC	***Maximum Groundwater Concentration***	***Table 8 Site Condition Standard***
Barium	96	1,000
Lead	1.21	10
Chloride	300,000	790,000
Sodium	37,000	490,000

BOLDED concentrations in grey scale were detected above Table 2 Site Condition Standards.

< Indicates that the concentration is lower than the value presented but cannot be more accurately quantified due to analytical uncertainty.

As shown in Table 4-1, the maximum groundwater concentrations of all COCs are below their respective Table 8 Site Condition Standards. Therefore, these COCs were not retained for further evaluation in groundwater for the HHRA. The human health property-specific standard for all four COCs was set as their Table 8 Site Condition Standards.

Because none of the four COCs in groundwater were retained for further quantitative evaluation in the HHRA, groundwater-related exposure pathways were not evaluated in the HHRA.

Chemicals of Concern in Soil

Based on the initial COC screening presented in Section 3.3.2, the following five chemicals were retained as COCs for soil and carried forward to the HHRA:

- Arsenic;
- Boron;
- DDD;
- DDE; and,
- Lead.

As discussed in Section 3.1, the Site is considered to be environmentally sensitive due to permanent water bodies existing on-site. As a result, the maximum concentrations of chemicals in soil were initially compared to Table 1 Site Condition Standards (SCS) that are representative of typical Ontario background concentrations. This was done to be protective of ecological receptors utilizing the on-site surface water bodies as habitat since there may be limited attenuation of contaminants in on-site soil or groundwater prior to entering surface water through groundwater flow. However, because the use of Table 1 Standards for the selection of COCs is based on the protection of aquatic ecological receptors in the receiving surface water body, a secondary screening for the purpose of the HHRA was conducted using the 2009 Table 2 SCS for soil under a residential/parkland/institutional land use. Additionally, the Table 8 SCS for soil, reflective of a site within 30m of a surface water body, are relevant only to ecological receptors.

Table 4-2 provides the maximum soil concentrations, or highest detection limits, of the five COCs listed above and their respective 2009 Table 2 SCS. In addition, the 2009 Table S1 component value, protective of a child under a residential exposure scenario as a result of direct contact with impacted soil is also presented in Table 4-2. The S-GW1 component values, protective of the migration of soil to potable groundwater, was not considered since it was assumed (based on the recommendations of the QP_{ESA}) that groundwater is suitably characterized and that a sufficiently steady state exists on-site related to soil leaching (the use of lead arsenate pesticides ceased over five decades ago). Chemical concentrations were first compared with their respective Table 2 Site Condition Standard; those COCs that were in exceedance of this value were then compared with their respective S1 component value. Vapour inhalation-based component values (*e.g.*, S-IA) were not included this comparison since all COCs in soil are non-volatile.

Table 4-2 Comparison of Maximum Soil Concentrations with Table 2 Site Condition Standards for Residential/Parkland/Institutional Property Use and Medium to Fine Textured Soil (µg/g) (MOE, 2009)

COC	***Maximum Soil Concentration***	***Table 2 Site Condition Standard***	**S1 Human Health Component Value**
Arsenic	**143**	**18**	**0.95**
Boron (HWS)	0.77	1.5	NV
DDD	0.024	3.3	3.3
DDE	0.44	0.33	2.3
Lead	**422**	**120**	**200**

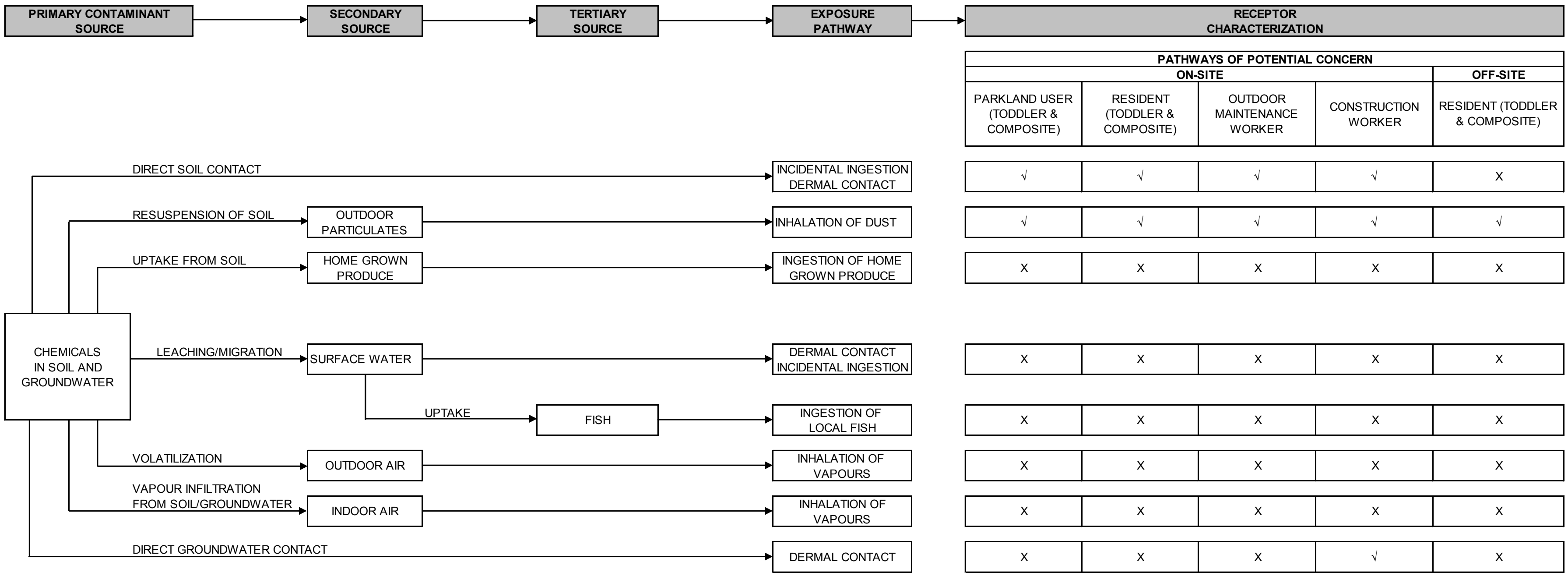
BOLDED concentrations in grey scale were detected above Table 2 Site Condition Standards.
NV Indicates that a value is not provided by the MOE.

As shown in Table 4-2, the maximum soil concentrations of arsenic and lead exceeded their respective 2009 Table 2 Soil Standards and S1 component values. Therefore, both elements were retained for further evaluation in soil for the HHRA. The maximum concentrations of boron and DDD were below their respective SCS and thus neither was retained for further evaluation in the HHRA. DDE was also not retained since its maximum concentration did not exceed its S1 component value.

Therefore, arsenic and lead were retained for further evaluation in soil for the HHRA.

4.2.1 Human Health Conceptual Site Model

The conceptual model brings together the information gathered during the problem formulation phase and provides an outline of the general exposure scenarios to be evaluated, by bringing together the chemicals, receptors, and exposure pathways into one overall conceptual framework (Figure 4-2). Details of receptors and exposure scenarios are provided below in Section 4.1.2 and in the Exposure Assessment discussion (Section 4.2).



√ Indicates exposure pathway is assessed
X Indicates exposure pathway is not assessed

Figure 4-2 Human Health Conceptual Model

It should be noted that the potential for adverse health effects resulting from exposure to chemicals in the environment is directly related to the ways in which individuals become exposed. If there is no possible exposure to a chemical, regardless of its toxic potency or environmental concentration, there is no potential for the development of adverse health effects. For example, because the only COCs in soil retained for quantitative evaluation in the HHRA (arsenic and lead) are considered non-volatile (*i.e.,* each has a Henry's Constant less than $1x10^{-5}$ atm•m^3/mol), inhalation of vapours migrating from soil to air (outdoor or indoor) was also not considered for the HHRA (US EPA, 2004). Similarly, because no groundwater COCs are considered volatile, no vapour inhalation-based pathways were considered for groundwater.

Since future property designation of the Site is to remain as rugged natural parkland, the exposure scenario related to a parkland user (recreational visitor) will be applied in the RA. Although the intention is to maintain the current parkland land-use in the future, the RA also conservatively assessed receptors associated with a residential land-use. The following exposure scenarios were considered for the quantitative evaluation of potential human health risks associated with exposure to COCs in on-site soil:

- A construction worker (adult);
- An outdoor maintenance worker (adult);
- An on-site resident (toddler and a lifetime composite);
- A parkland user (child and a lifetime composite); and,
- An off-site resident.

The exposure pathways considered for each receptor are as follows:

- Ingestion of soil/dust (outdoors);
- Inhalation of soil/dust (outdoors); and,
- Dermal contact with soil/dust (outdoors).

As mentioned above, because no COCs in groundwater were retained for quantitative evaluation in the HHRA, no pathways related to groundwater were considered further (the construction worker is typically the only receptor scenario considered for direct dermal contact with impacted groundwater). Furthermore, inhalation of vapours from soil to air was also not considered for the HHRA since arsenic and lead are non-volatile (US EPA, 2004).

4.2.2 Risk Assessment Objectives

The objectives of the HHRA were to qualitatively and quantitatively evaluate the on-site human health risks associated with exposure to impacted soil and to derive property-specific standards that are protective of human health under a parkland land use. The approach used was for an RA other than those identified in Schedule C Part II of O. Reg. 153/04. The qualitative evaluation of the HHRA is an additional, secondary chemical screening of COCs identified in Section 3 against appropriate generic standards and component values provided by MOE (2009). The quantitative assessment includes prediction of the exposures, risks and human health effects-based concentrations associated with those COCs retained following the qualitative evaluation, using the receptor scenarios outlined below.

Burnside and MMM have conducted several site investigations of the RA property spanning from 2007 to 2009. The data collected was used to characterize conditions for the current assessment. These investigations have provided environmental samples for soil, groundwater, sediment and surface water for a wide range of locations across the Site. The quality and quantity of data provided for environmental media were considered to be sufficient to meet the objectives of the current RA.

Human Receptor Selection

A human receptor is a hypothetical person (*e.g.*, infant, toddler, child, adolescent, adult) who resides, works or plays in the area being investigated and is, or could potentially be, exposed to the COCs. General physical and behavioural characteristics specific to the receptor type (*e.g.*, body weight, breathing rate, soil ingestion rate, *etc*.) are used to determine the amount of chemical exposure received by each receptor.

It is critical that the assessment be sufficiently comprehensive to ensure that overall risks have been adequately addressed. However, it is not feasible to consider all humans that may potentially be exposed to chemicals from the Site. As a result, it is important to select those human receptors that may be subject to the greatest potential risk from the property. These will be people with the greatest probability of exposure to the chemicals detected on-site and those that have the greatest sensitivity to these chemicals. Under a residential or parkland land use, it was assumed that toddlers would be subject to chronic exposure durations. Under a residential scenario (either on- or off-site), receptors of all age groups may be exposed to COCs. Therefore, to assess risks to residents, a toddler and a composite lifetime receptor (weighted according to the duration of each life stage) were selected for evaluation. A toddler and a composite lifetime receptor (weighted according to the duration of each life stage) were similarly selected for evaluation under a parkland visitor scenario,

Although the Site is intended to remain as rugged natural parkland in perpetuity, it was conservatively assumed that the property may involve some future redevelopment or large-scale improvement efforts. Therefore, construction workers may also be exposed to COCs for significant periods of time. Both the surface and subsurface soils would most likely be disturbed, allowing for direct exposure to impacted soil/dust. An adult construction worker working at the Site for 129 days per year for 7 years (MOEE, 1996b) was selected as the receptor for the construction scenario. Given that the assessment of carcinogenic compounds (*i.e*. arsenic) involves predicting the ILCR, it was considered most appropriate to assume that the construction worker could spend 7 years of his/her entire lifetime (*i.e.*, typically considered 80 years (Health Canada, 2006)) working on-site while being exposed to the COCs.

To be conservative, it was also assumed that an outdoor maintenance worker could potentially be exposed to COCs in the soil through various activities related to parkland upkeep at the Site. These activities may include brush clearing, litter cleanup, and mowing of exposed grass. For the current assessment, an adult maintenance worker was evaluated for exposure under the intended land-use scenario. The maintenance worker was assumed to spend 27 years at this occupation (MOEE, 1996b).

For the current assessment, the intended future property use for the Site is to remain as publicly accessible rugged natural parkland. Under the parkland land use designation a recreational parkland visitor scenario is typically assessed. Although a toddler (age 4 months to 5 years) is the most sensitive of the potentially receptor groups, a child (age 5 to 12 years) was selected to represent the most likely receptor type under a parkland visitor scenario for the current Site. Since any visitor in regular, long-term contact with the most impacted soils in the forested portions of the Site would likely be older than the age of a toddler, a child was assumed to a more appropriate receptor selection. The most sensitive individuals would be those associated with a high rate of exposure on a per body weight basis, and therefore a child was selected as a human receptor of concern. Given that the assessment of carcinogenic compounds involves predicting the ILCR, it was also assumed that a composite receptor could potentially visit the park for up to the first 30 years of an entire lifetime (*i.e.*, 80 years) while being exposed to the COCs. Thirty years is considered to be an upper estimate of a residential occupancy and was therefore considered to be a conservative exposure duration for a regular visitor to the Site.

4.2.3 Exposure Scenarios

Construction Worker

As part of the on-site residential scenario, a construction worker scenario, considering exposures of an adult construction worker involved in construction and utility maintenance, was evaluated. The worker was assumed to be exposed while working 8 hours/day, 129 days/year for 7 years (consistent with the MOEE construction worker assumptions). While at work, it was conservatively assumed that 100% of the worker's time was spent outdoors being exposed to COCs in impacted soils (*i.e.*, incidental ingestion of, inhalation of, and dermal contact with soil/dust). This scenario was not included for the parkland scenario since no construction activities would be anticipated in the forested or trail land areas. Furthermore, there are no utilities currently or anticipated in these areas.

Maintenance Worker

Under the outdoor maintenance worker scenario, it was assumed that an adult maintenance worker, responsible for upkeep of the trails and forest setbacks, as well as general maintenance of the forested lands, could potentially be directly exposed to contaminants in surface soils while conducting property maintenance at the Site (*i.e.*, incidental ingestion, inhalation, and dermal contact). The maintenance worker was assumed to be exposed while working 8 hours/day, 1 day every 2 weeks, for 39 weeks, during spring through the fall. Because the majority of the Site is thickly forested and relatively inaccessible, the maintenance worker was assumed to spend an average of 0.5 days/week on-site. The maintenance worker is expected to work for 27 years, spending 100% of the workday outdoors.

On-Site Residential Toddler and Composite Receptor

Under the on-site residential scenario, both receptors were assumed to be exposed to COCs in soil *via* incidental ingestion, inhalation, and dermal contact as a result of various indoor and outdoor activities on the Site. As previously noted, because no COCs are considered sufficiently volatile, exposure to COCs in indoor air migrating from impacted soil was not considered in the current RA. Both receptors were assumed to spend 24 hours/day (1.5 hours outdoors; 22.5 indoors), 7 days/week, 52 weeks/year at the Site. The exposure duration for the toddler was assumed to be the entire life stage (4.5 years), while the exposure duration for the composite was assumed to be 30 years (a conservative estimate of a residential exposure duration used by the MOE).

Off-Site Residential Toddler and Composite Receptor

Under the off-site residential scenario, both receptors were assumed to be exposed to COCs in soil *via* only inhalation of airborne soil and dust migrating from the Site to off-site residential locations. Both receptors were assumed to spend 24 hours/day (1.5 hours outdoors; 22.5 indoors), 7 days/week, 52 weeks/year at the Site. The exposure duration for the toddler was assumed to be the entire life stage (4.5 years), while the exposure duration for the composite was assumed to be 30 years (a conservative estimate of a residential exposure duration used by the MOE).

Parkland Visitor

The parkland area consists of two distinct types of areas, the forested or wooded areas and the paved and crushed gravel walking trail. While visiting these areas, receptors were assumed to be exposed to COCs *via* direct exposure to soil (*i.e.*, *via* inhalation, incidental ingestion and dermal contact). The Site does not contain a sports field, playground area or other amenities that might attract more frequent visits to the area. A visitor regularly (as often as daily) walking along the trail was not assumed to spend significant time straying from the walking path. A two metre clearance ("slashback") is present on either side of the trail, beyond which is thickly wooded areas not conducive to significant play areas or human movement. The Armitage Creek and its tributaries are present on-site, further limiting the potential for a visitor to spend significant time in direct contact with on-site soils. In addition, residential developments exist just to the east of the walking trail.

The North and South Forested Areas, as well as the William Thomas Mulock Park parcel, are rugged areas covered in thick vegetation and are therefore relatively inaccessible. Moreover, fences exist at the boundaries between the Site and the residential properties. Therefore, it was assumed that children would only occasionally spend time in these wooded areas with direct access to soil. This assumption included the following frequency on-site:

- five days per week during 5-week period of summer months, not including periods where child is away from home (vacation, at camp, *etc*.); and,
- one day per week spent on-site for an additional 34 weeks (does not include 13 weeks of year with assumed snow cover – December to March (MOE, 2009).

Therefore, it was assumed that a child parkland visitor would spend a total of 60 days per year in the forested areas (5 days/week x 5 weeks of peak summer + 1 day/week for additional 34 weeks). Although receptors may also visit the Site during the winter months, it was assumed that the snow cover and frozen ground would prevent any significant level of exposure to impacted soil.

Visitors were assumed to spend significantly more time (as often as daily) on the walking path (including walking, jogging, biking, *etc*., by all family members and pets). While on the path, visitors were assumed to not be exposed to impacted soils due to the limited potential exposure pathways related to the paved and crushed gravel walking trail and heavily vegetated slashback area. The areas of the slashback thus limit the potential for exposure to uncovered soils.

4.3 Exposure Assessment

The primary objective of the exposure assessment was to predict, using a series of conservative assumptions, the rate of exposure (expressed in µg/kg body weight/day) of human receptors to COCs, through the exposure scenarios and pathways identified in the problem formulation phase.

4.3.1 Receptor Characteristics

As previously discussed in Section 4.1.2, adults and toddlers were selected as the most appropriate receptors of concern. A series of standard human receptor characteristics and activity patterns (*e.g.*, body weight, surface areas, and time at work) were used in the exposure assessment. The Canada Wide Standards for Petroleum Hydrocarbons Supporting Technical Document (CCME, 2000), the Compendium of Canadian Human Exposure Factors for RA (Richardson, 1997), the Federal Contaminated Site Risk Assessment in Canada (Health Canada, 2006), and the Exposure Factors Handbook (US EPA, 2008; 2009) were the key sources of human exposure parameters used in the current assessment. Tables 4-3 to 4-5 provide a detailed list of human receptor characteristics.

Table 4-3 Receptor Characteristics for the Adult (20 years +)

Receptor Parameter	***Point Estimate***	***Description***	***Reference***
Body Weight (kg)	70.7	Arithmetic mean for male and female adults combined	Health Canada, 2006; Richardson, 1997
Surface Area of Hands (m^2)	0.089	Arithmetic mean for male and female adults combined	CCME, 2000; Health Canada, 2006; Richardson, 1997
Exposed Skin Surface Area (upper and lower arms) (m^2)	0.25	Arithmetic mean for male and female adults combined for upper and lower arms	CCME, 2000; Richardson, 1997
Soil Adherence Factor – Body (g/m^2/event)	0.1	Residents, visitors and maintenance workers	CCME, 2000; Health Canada, 2006; Kissel *et al*., 1996; 1998
	1.0	Construction workers	Health Canada, 2006
Soil Adherence Factor – Hands only (g/m^2/event)	1.0	Residents, visitors and maintenance workers	CCME, 2000; Health Canada, 2006; Kissel *et al*., 1996; 1998
	10	Construction workers	Health Canada, 2006
Amount of Soil/Dust Ingested (g/day)	0.05	Residents, visitors and maintenance workers	US EPA, 2009
	0.1	Construction workers	Health Canada, 2006

Table 4-4 Receptor Characteristics for the Child (5 – 12 years)

Receptor Parameter	***Point Estimate***	***Description***	***Reference***
Body Weight (kg)	32.9	Arithmetic mean for male and female toddlers combined	Richardson, 1997; CCME, 2000; Health Canada, 2006
Surface Area of Hands (m^2)	0.059	Arithmetic mean for male and female toddlers combined	Richardson, 1997; CCME, 2000; Health Canada, 2006
Exposed Skin Surface Area (other than hands) (m^2)	0.455	Arithmetic mean for male and female toddlers combined for upper and lower arms and legs	Richardson, 1997; Health Canada, 2006
Soil Adherence Factor – Body (g/m^2/event)	0.1	All skin surfaces others than hands	Kissel *et al*., 1996; 1998; CCME, 2000; Health Canada, 2006
Soil Adherence Factor – Hands only (g/m^2/event)	1.0	Hand skin surfaces only	Kissel *et al*., 1996; 1998; CCME, 2000; Health Canada, 2006
Amount of Soil/Dust Ingested (g/day)*	0.1	Incidental soil and dust ingested (residential)	US EPA, 2009
Amount of Soil Ingested (g/day)*	0.05	Incidental soil ingested (parkland)	US EPA, 2009

* Further details regarding soil/dust ingestion rates are provided below.

Table 4-5 **Receptor Characteristics for the Toddler (5 – 12 years)**			
Receptor Parameter	***Point Estimate***	***Description***	***Reference***
Body Weight (kg)	16.5	Arithmetic mean for male and female toddlers combined	CCME, 2000; Health Canada, 2006; Richardson, 1997
Surface Area of Hands (m^2)	0.043	Arithmetic mean for male and female toddlers combined	CCME, 2000; Health Canada, 2006; Richardson, 1997
Exposed Skin Surface Area (other than hands, soil related) (m^2)	0.258	Arithmetic mean for male and female toddlers combined for upper and lower arms and legs	Health Canada, 2006; Richardson, 1997
Soil Adherence Factor – Body (g/m^2/event)	0.1	All skin surfaces others than hands	CCME, 2000; Health Canada, 2006; Kissel *et al*., 1996; 1998
Soil Adherence Factor – Hands only (g/m^2/event)	1.0	Hand skin surfaces only	CCME, 2000; Health Canada, 2006; Kissel *et al*., 1996; 1998
Amount of Soil/Dust Ingested (g/day)*	0.2~~1~~	Incidental soil and dust ingested (residential)	~~US EPA~~MOE, 2009
Amount of Soil Ingested (g/day)*	0.1~~05~~	Incidental soil ingested (parkland)	US EPA, 2009; MOE, 2009

* Further details regarding soil/dust ingestion rates are provided below.

For the composite parkland visitor and residential receptors, the physical parameters are based on the recommended values for each life stage (*i.e.*, infant, toddler, child, teen, and adult). Since a residential receptor scenario typically assesses a 30-year residential occupancy (and thus the expected time span for a nearby resident or regular visitor to the Site), exposures for these two receptors were estimated for each of the individual life stages in order to estimate a 30-year composite receptor duration. The receptor characteristics for each life stage are presented in Table 4-6.

Table 4-6 **Individual Age Group Receptor Parameters for the Composite Receptors (30 Years Duration)**						
Parameter	***Units***	***Infant***	***Toddler***	***Child***	***Teen***	***Adult***
Age Group Duration	years	0.5	4.5	7	8	10
Fraction of 30-Year Residential Occupancy	unitless	0.02	0.15	0.23	0.27	0.33
Body Weight	kg	8.2	16.5	32.9	59.7	70.7
Soil/dust Ingestion Rate*	g/day	0.06	0.2~~1~~	0.1	0.1	0.05
Soil Ingestion Rate*	g/day	0.03	0.1~~05~~	0.05	0.05	0.05
Surface Area of Hands	m^2	0.032	0.043	0.059	0.08	0.089
Surface Area of Exposed Skin (Other than Hands)	m^2	0.146	0.258	0.455	0.720	0.822

* Further details regarding soil/dust ingestion rates are provided below.

Soil Ingestion Rate (SIR)

It is our understanding that current MOE guidance is to use the underlying exposure parameters used to develop the amended Soil, Ground Water and Sediment Standards provided in O.Reg. 511, when conducting Risk Assessments under O.Reg 153/04. MOE has indicated that current science supports the use of 200 mg/day when assessing the soil ingestion pathways for toddlers and 50 mg/day for all other receptor groups, with the exception of construction and maintenance workers. The Rationale Document (MOE, 2009) and the recently released Tier II Risk Assessment Model reference US EPA (2008) and US EPA (1997) as the basis for these numbers. Neither of these documents were clearly referenced in the Rationale document; however, they are presumably the Exposure Factors Handbook (US EPA, 1997) and the Child-Specific Exposure Factors Handbook (US EPA, 2008). It is noted that the Exposure Factors Handbook has been updated and should be referenced as US EPA (2009). The Tier II Risk Assessment Model references US EPA (2006), rather than US EPA (2008), as an earlier draft of the Child-Specific Exposure Factors Handbook.

US EPA (2008) recommends 'that when assessing risks for children who are not expected to exhibit soil pica or geophagy behavior, the recommended central tendency soil + dust ingestion estimate is 100 mg/day for children ages 1 to <6 years. If an estimate for soil only is needed, for exposure to soil such as manufactured topsoil or potted plant soil that could occur in either an indoor or outdoor setting, or when the risk assessment is not considering children's ingestion of indoor dust (in an indoor setting) as well, the recommendation is 50 mg/day.' A soil + dust ingestion rate for younger children (6 to <12 months) of 60 mg/day (30 mg/day soil only) is also recommended. US EPA (2009) provides similar recommendations for children. US EPA (2009) also recommends a soil ingestion rate of 50 mg/day for adults. It is noted that both reviews, the most current scientific reviews completed by US EPA, make no reference to the 200 mg/day value found in earlier versions of the Exposure Factors Handbook. US EPA (2008; 2009) clearly states that the recommended soil ingestion rates are central tendency estimates and no upper bound values are provided. US EPA (2008; 2009) also acknowledges that there is a low degree of confidence the recommended ingestion rates. An earlier version of the Exposure Factors Handbook (US EPA, 1997) indicated a medium level of confidence in central tendency estimates for children, a low level of confidence for adult estimates and insufficient data to recommend upper percentile estimates for both children and adults.

US EPA originally recommended a soil ingestion rate of 200 mg/day in its Risk Assessment Guidance for Superfund (US EPA, 1991) and reiterated that recommendation in its EFH (EPA, 1997) as a "conservative estimate of the mean." The recommendation was based primarily on tracer studies in children (ages 1 through 5) that were undertaken by Calabrese and his coworkers (Calabrese *et al.* 1989; Stanek and Calabrese, 1995a; 1995b). However, updated studies by these same authors (Stanek *et al*., 1999 and Stanek and Calabrese, 2000), conducted using improved methodologies and published since the original US EPA guidance was released, indicate that these previous estimates are overestimates and can be refined and improved. As described by Stanek and Calabrese (2000), this study implemented several improvements in study design and analytical procedures that occurred since the publication of their earlier papers and that led to an improved estimate of the 95th percentile soil ingestion estimate for this age group. The advantages of this recent study included: (1) a relatively large study group (n = 64 children); (2) improved particle size measurements that focused attention on soil of smaller particle size; (3) a longer study duration (365 days); (4) randomized selection of participants; (5) the use of a relevant age group (1 to 4 year old children); (6) use of a random sample of the population for that age group; and (7) better control for input/output error. The soil ingestion rates reported by Stanek and Calabrese (2000) for these children were:

- A 95th percentile rate of 106 mg/day (when evaluated over a 365-day period);
- An arithmetic mean ingestion rate of 31 mg/day; and,
- A median (50th percentile) ingestion rate of 17 mg/day.

This study also calculated the best linear unbiased predictors of the 95th percentile of soil ingestion over different time periods and reported the following results:

- Over a 7-day exposure period, the 95th percentile soil ingestion rate was 133 mg/day;
- Over a 30-day exposure period, the 95th percentile soil ingestion rate was 112 mg/day;
- Over a 90-day exposure period, the 95th percentile soil ingestion rate was 108 mg/day; and,
- Over a 365-day exposure period, the 95th percentile soil ingestion rate was 106 mg/day.

These data suggest that, as the length of time that the children are studied increases and as the precision of the analysis improves (*i.e.*, reduced uncertainty), the daily ingestion rates decline. This is reasonable due to the fact that daily fluctuations in soil ingestion rates will tend to average out over time. This narrowing of the distribution in the soil ingestion estimates when daily variability and uncertainty are reduced is not unexpected and is referred to as "regression to the mean" (Stanek and Calabrese, 2000). As noted by Stanek and Calabrese (2000), these longer-term estimates are more appropriate when assessing risks and hazards associated with chronic exposure, as is the case in the HHRA.

On the basis of this information, which is based on more recent studies, Dr. Calabrese has recommended that the soil ingestion rates to be used for young should be 100 mg/day for the upper bound and 20 mg/day (based on the median in this study) for the central tendency estimate.

At this time, we are not inclined to argue the Ministry's point, although we do find it flawed and with limited scientific basis, as most regulatory agencies including US EPA, California EPA, Health Canada, and RIVM have moved away for using an SIR of 200 mg/day. We take the comment to indicate that Ministry policy dictates that a SIR of 200 mg/day should be used for toddlers in most situations. The Ministry has indicated that in some circumstances it may be appropriate to consider an alternate value when limited exposure conditions exist. In the current situation, this option was considered due to the restricted parkland scenario (not a playing field or playground) under consideration, where the duration and nature of exposures are significantly limited. In their definition of current SIRs, regulatory agencies such as the US EPA apportion the SIR (rounded to 100 mg/day) to indoor (dust) and outdoor (soil) exposures (60 mg/day and 50 mg/day, respectively). For the current situation, it would be appropriate to adjust the MOE SIR of 200 mg/day, which is intended for soil and dust combined, by the EPA ratio of 50 mg soil/day:100 mg soil + dust/day, resulting in site specific SIR of 100 mg/day for the parkland scenario since this scenario is limited to only outdoor (soil) exposure.

The following table provides the SIR utilized for the Parkland Scenario in the RA.

Soil Ingestion Rates (SIR) Utilized for the Parkland Scenario

	September 2010 Risk Assessment	MOE (2009)	US EPA (2008) Soil (dust)	Revised Risk Assessment (April 2011)
Parkland				
• Infant	30 mg/day	30 mg/day	30 mg/day	30 mg/day
• toddler	100 mg/day	200 mg/day	50 (60) mg/day[a]	100 mg/day[c]
• child	50 mg/day	50 mg/day	50 (60) mg/day	50 mg/day
• adolescent	50 mg/day	50 mg/day	50 (60) mg/day	50 mg/day

	September 2010 Risk Assessment	MOE (2009)	US EPA (2008) Soil (dust)	Revised Risk Assessment (April 2011)
• adult	50 mg/day	50 mg/day	50 (-) mg/day[b]	50 mg/day

NOTE: The MOE and US EPA SIR values are not directly comparable, as the US EPA value is based on a central tendency estimate while the MOE value is based on a conservative estimate of the mean (as stated in the 2009 MOE Rationale Document)
[a]EPA(2008) indicates that total soil and dust ingestion rate is 110 mg/day; rounded to one significant figure it is 100 mg/day
[b]adult SIRs provided by EPA (2009) draft report.
[c]based on MOE (2009), SIR of 200 mg/day for soil and dust combined; adjusted by EPA ratio 50 mg soil/day:100 mg soil + dust/day

Rationale for considering soil only for SIR for parkland users:

- SIR is dependent on human behaviour and human activity throughout the day, therefore the selection of a site-specific SIR should be based on 1) site-specific conditions and 2) site-specific use as indicated below:
  - No buildings will be present on-site, the SIR has been modified to account for the fact that exposure to indoor dust will not be occurring. We acknowledge that no buildings on-property is a RMM and this will be identified as such in the HHRA and RMP. A residential scenario, utilizing a SIR of 200 mg/day for toddlers, was considered in the RA. This scenario indicated that residential land-use is not a viable option for the site;
  - Site-specific conditions would reduce airborne particulates associated with wind erosion (e.g. continued vegetation cover is assumed across the trail portion of the RA site, with the remainder of the site being heavily wooded and not conducive to significant particulate release. We acknowledge that this assumption is considered as RMM and this will be identified as such in the HHRA and RMP. As off-site residential exposure scenario was considered in the RA in which receptors were assumed to be exposed to COCs in soil via inhalation of airborne soil and dust migrating from the Site to off-site residential locations with no restrictions as described above;
  - The Site does not contain a sports field, playground area or other amenities that might attract more frequent visits to the area or more intensive exposure conditions;
  - The majority of the site consists of thickly wooded areas not conducive to significant play areas or human movement.

~~Since no indoor dust related pathways were considered in the parkland scenario and current guidance from the US EPA (2008; 2009) recommends the use of 50 mg/day as a soil ingestion rate for all receptor groups, this value has been utilized for the current assessment. For residential scenarios, the US EPA (2008; 2009) soil + dust ingestion rates of 60 mg/day for young children (6 to <12 months), 100 mg/day for toddlers and older children (1 to <21 years) and 50 mg/day for adults have been adopted.~~

4.3.2 Pathway Analysis

Humans may come into contact with chemicals in their environment in a variety of ways, depending on their daily activities and the ways in which they utilize local resources (*e.g.*, land, water bodies). The path that a chemical travels to reach an environmental medium (*i.e.*, air, soil, water, food, *etc*.) that a person may come into contact with is referred to as an exposure pathway. The means by which a chemical moves from the environmental medium into the body is called an exposure route. There are three major exposure routes through which chemicals can enter the body: inhalation, ingestion and dermal absorption through the skin. The exposure pathways and routes evaluated in the current assessment are summarized below in Table 4-7.

Table 4-7 Exposure Pathways and Assumptions for Each Exposure Scenario

Exposure Scenario	*Receptor*	*Pathways*	*Exposure Period*
Construction worker	Adult	- ingestion of outdoor soil - inhalation of outdoor soil and dust - dermal contact with outdoor soil	8 hr/d, 129 d/yr, 7 yrs
Outdoor maintenance worker	Adult	- ingestion of outdoor soil - inhalation of outdoor soil and dust - dermal contact with outdoor soil	8 hr/d, 0.5 d/wk, 39 wk/yr, 27 yrs
On-site Resident	Toddler and Composite	- ingestion of outdoor soil and indoor dust - inhalation of outdoor soil and dust - dermal contact with outdoor soil and indoor dust	1.5 hr/d outside, 365 d/yr, 30 yrs
Off-site Resident	Toddler and Composite	- inhalation of outdoor soil and dust	1.5 hr/d outside, 365 d/yr, 30 yrs
Parkland Visitor	Child and Composite	- ingestion of outdoor soil - inhalation of outdoor soil and dust - dermal contact with outdoor	60 d/yr, 30 yrs

4.3.3 Bioavailability / Bioaccessibility

The ingestion of soils is often considered to be the major route of potential exposure to metals in humans (Sheppard *et al*., 1995; Paustenbach, 2000). To effectively assess the dose of soil metals received by humans, the determination of bioavailability becomes an invaluable tool in risk assessment. Bioavailability is the fraction of a chemical which is ingested, inhaled, or applied on the skin surface that is absorbed and reaches the systemic circulation (Kelley *et al*. (2002). The approach for oral bioavailability assessment of contaminants can typically be divided into four fundamental processes: i) the oral intake of soil/dust including metals; ii) bioaccessibility; iii) intestinal absorption; and, iv) metabolism in the liver/intestines (Oomen *et al*., 2006; Sips *et al*., 2001). Out of these processes that construct the basis of bioavailability, bioaccessibility testing is a key component. The inclusion of bioaccessibility testing as part of the assessment process allows for a more realistic estimate of the systemic exposure to metals from soil and dust ingestion than using generic assumptions such as those employed to derive soil guideline values such as MOE Site Condition Standards (EAUK, 2005a).

Oral bioaccessibility can be defined as the fraction of a substance that is released from the soil or dust matrix during digestion, thus making it soluble and available for absorption through the gastrointestinal tract (Defra and Environment Agency, 2002). In effect, this fraction represents the upper limit of bioavailability. Oral bioaccessibility only takes into account the direct ingestion of soil and dust and does not incorporate other routes of exposure such as skin (dermal contact) and lungs (inhalation).

Given the importance of evaluating the potential toxicity of soil-bound COCs to on-site human receptors, *in vitro* bioaccessibility analyses were conducted. The analysis was conducted by Dr. Ken Riemer's laboratory at Royal Military College, in conjunction with the Analytical Services Unit at Queen's University.

The method utilized for bioaccessibility testing is consistent with the approach endorsed by the US EPA (EPA, 2008). This method advocates the use of a glycine buffer in a single (gastric) phase *in vitro* study. It should be noted that reported issues with glycine relate to its use with metals other than lead and arsenic (glycine has been found to complex with nickel under some study conditions). Furthermore, other *in vitro* test systems have employed a more complex fluid intended to simulate gastric fluid. For example, Medlin (1997) used a fluid that contained pepsin and a mixture of citric, malic, lactic, acetic, and hydrochloric acids. US EPA (2008) found that when the bioaccessibility of a series of test substances were compared using 0.4 M glycine buffer (pH 1.5) with and without the inclusion of these enzymes and metabolic acids, no significant difference was observed (p=0.196). This indicates that the simplified buffer employed in the procedure is appropriate, even though it lacks some constituents known to be present in gastric fluid.

In addition, it should be noted that EPA has validated this method with *in vivo* data and a better correlation between *in vitro* and *in vivo* studies has been observed with gastric phase results as compared to intestinal phase. From a physiological standpoint, any measure of available metal under the simulated conditions of the small intestine would be of great interest, as it relates to absolute bioavailability of metals, since residency times and absorption *via* the small intestines or intestinal phase (*i.e.*, stage 2) is considered significant relative to the stomach or gastric phase (*i.e.*, stage 1). DEPA (2003) suggests that bioaccessibility estimates (for use in HHRA) should represent reasonable worst-case conditions within the simulated human gastrointestinal environment. In other words, the method should provide the highest plausible bioaccessibility estimates which are likely to occur. According to Oomen *et al*. (2002), the use of a single-phase gastric model (*i.e.*, low pH in the absence of food) will tend to represent worst-case bioaccessibility conditions whereas a two-stage gastrointestinal model would be a more realistic average. This is consistent with the US EPA (2008) approach utilized herein.

Further details are provided in Appendix J.

The objective of these analyses was to estimate the bioaccessible fractions of arsenic and lead in soil samples (BA). These results were then used to derive a relative absorption factor (RAF) for each COC. An RAF based on a bioaccessibility evaluation is a simple quotient comparing the solubility of a COC in soil and the exposure medium used to develop the TRV (*i.e.*, spiked food) in simulated digestive fluids. The RAF makes no assumptions about digestive differences between humans and other mammalian species, and is calculated as follows:

$$RAF = \frac{Bioaccessibility\ of\ chemical\ in\ Soil\ (BA)}{Bioaccessibility\ of\ chemical\ in\ medium\ used\ to\ develop\ TRV}$$

A calculated average (95% UCLM) of individual sample BA values was estimated for each of arsenic and lead, and these are shown in Table 4-8. For arsenic, the RAF is calculated assuming a TRV BA of 95% based on data suggesting arsenic in drinking water, the medium of exposure in the TRV studies, is highly available. The BA value for lead was further refined using the regression equation of Drexler and Brattin (2007) and US EPA (2007), which relates *in vitro* bioaccessibility (IVB) to *in vivo* bioaccessibility (equivalent to the RAF).

Table 4-8 Summary of Recommended Relative Absorption Factors for Soil

COC	*95% UCLM BA*	*RAF*
Arsenic	0.68	0.68~~72~~
Lead	0.85	0.71[a]

[a] The RAF for lead in soil has been adjusted based on the Drexler and Brattin (2007) regression equation (RAF = 0.878 x IVB - 0.028).

4.3.4 Exposure Estimates

The previously discussed receptor parameters (*i.e.*, body weight, breathing rate, *etc*.), exposure assumptions and soil and groundwater concentrations were used to evaluate the potential exposure of a hypothetical receptor under each of the reasonable "worst-case" exposure scenarios. The exposure assessment was conducted using a "point estimate" or "deterministic" analysis. As implied, for each parameter or variable used to derive the potential exposure, a single point estimate value was used. This approach calls for the use of reasonable worst-case or most-likely assumptions and data points to ensure a conservative assessment.

The current exposure assessment involved the estimation of the amount of chemical received by individuals per unit time (*i.e.*, the quantity of chemical and the rate at which that quantity is received). The exposure assessment evaluated the data related to all COCs as well as the current human receptors and exposure pathways selected during the problem formulation phase of the assessment (Section 4.1). The rates of exposure to chemicals from the various environmental media *via* dermal contact and ingestion were expressed as the amount of chemical taken in per body weight per unit time (*i.e.*, µg chemical/kg body weight/day) while exposure to chemicals *via* inhalation were expressed as an air concentration (µg/m3).

Determining the reasonable maximum exposure (RME) of a hypothetical individual is of considerable importance when conducting an exposure assessment. Determining an appropriate exposure point concentration (EPC) (*i.e.*, the concentration of a chemical in any environmental medium to which a receptor could reasonably be expected to be exposed over an extended period of time) is important to the overall exposure assessment. The US EPA Risk Assessment Guidance for Superfund (US EPA, 1989) recommends that the RME should be evaluated using the upper 95% confidence interval on the arithmetic mean of the data set (*i.e.*, the 95% UCLM). This is considered to be the reasonable maximum exposure point concentration to which a receptor might be exposed over a significant amount of time. When enough data are present, the 95% UCLM incorporates the central tendency (*i.e.*, the arithmetic mean) and the variability associated with the data set. However, given that the preferred MOE approach for assessing risks involves the use of the maximum measured environmental concentrations, the maximum soil concentrations were conservatively selected as the EPCs for the HHRA (Table 4-9).

Table 4-9 Maximum Concentrations of COCs in On-Site Soil

COC	***Maximum Soil Concentration (µg/g)***
Arsenic	143
Lead	422

4.3.4.1 Exposure to COCs *via* Ingestion of Soil/Dust

Through typical outdoor activities which bring receptors into contact with soil and dust, human receptors may accidentally ingest soil or dust particles. It was assumed that the construction worker and the outdoor maintenance worker would spend 100% of their time on-site outdoors. The toddler/composite resident was assumed to spend 100% of their day at home, but only 1.5 hrs/day outdoors, exposed to airborne soil and dust. The child/composite parkland visitor was assumed to spend 100% of their time on-site outdoors. It was also conservatively assumed that 100% of the soil ingested daily was derived from the Site and contained COCs at the maximum concentrations. Table 4-7 provides the predicted oral exposure to COCs through the incidental ingestion of soil/dust. Oral ingestion exposures presented in Table 4-10 also consider the bioaccessibility of arsenic and lead and arsenic in soil, *i.e.,* the relative absorption factor described in Section 4.2.3 (and derived in Appendix J) is included in these exposure estimates.

Table 4-10 Exposure Estimates from Incidental Ingestion of Soil/Dust

COC	*Relative Absorption Factor*	*Predicted Oral Exposure (µg/kg/day)[a]*			
		Construction Worker	*Maintenance Worker*	*Toddler On-Site Resident*	*Child Parkland Visitor*
Arsenic	0.~~72~~68	~~5.12~~4.86E-02	3.~~9~~67E-03	~~6~~8.82~~1~~E-01	2.43~~56~~E-02
Lead	0.71	1.51E-01	1.1~~7~~4E-02	~~1.~~2.74~~83~~E+00	7.54E-02

[a] Predicted exposures for carcinogens are not amortized. Amortizations of 27/56~~80~~ for the maintenance worker, 7/56~~80~~ for the construction worker, and 30/80 for the both the resident and parkland visitor were applied during the risk characterization.

4.3.4.2 Exposure to COCs *via* Inhalation of Soil/Dust

Airborne dusts originating from on-site soils are available for uptake through inhalation. It was assumed that soil and dust would only be available for re-suspension for 39 weeks per year (*i.e.*, March to December), when the ground is not covered by snow or ice). However, because the Site is predominantly soil covered only by trees, grasses and other vegetation, no additional assumptions were made regarding the interruption of soil pathways in calculating airborne concentrations of re-suspended soil and dust. Therefore, it was conservatively assumed that 100% of the outdoor airborne dust inhaled while spending time on-site originated from on-site soils and contained COCs at the maximum concentration. Additionally, a higher airborne dust level was assumed for the construction worker scenario as a result of the heavy re-distribution of soils during construction, remediation and excavation activities.

Table 4-11 provides the predicted concentrations of arsenic and lead in outdoor airborne dust available for inhalation for the five scenarios. Predicted air concentrations presented in Table 4-11 are not time weighted based on time spent on-site. Adjustment factors of 0.12 (8/24 hours per day x 129/365 days per year) for the construction worker, 0.018 (8/24 hours per day x 20/365 days per year) for the maintenance worker, 0.047 (1.5/24 hours per day x 273/365 days per year) for the residential receptor, and 0.010 (1.5/24 hours per day x 60/365 days per year) for the parkland visitor were applied during the risk characterization.

Table 4-11 Predicted Concentrations of COCs in Re-Suspended Soil/Dust Available for Inhalation

COC	*Predicted Concentration (µg/m^3)**	
	Construction Worker	*Maintenance Worker, On-Site and Off-Site Resident Toddler, and Parkland Visitor*
Arsenic	3.58E-02	1.09E-04
Lead	1.06E-01	3.21E-04

* Predicted air concentrations are not time weighted based on time spent on-site. Adjustment factors of 0.12 (8/24 hours per day x 129/365 days per year) for the construction worker, 0.018 (8/24 hours per day x 20/365 days per year) for the maintenance worker, 0.047 (1.5/24 hours per day x 273/365 days per year) for the residential receptor, and 0.010 (1.5/24 hours per day x 60/365 days per year) for the parkland visitor were applied during the risk characterization. For the carcinogenic assessment of arsenic, additional amortizations of 7/~~80~~ 56 for the construction worker, 27/~~80~~ 56 for the maintenance worker, and 30/80 for both the composite resident and composite parkland visitors were also applied during the risk characterization.

4.3.4.3 Exposure to COCs *via* Dermal Contact with Soil/Dust

Dermal exposure of human receptors may occur through direct contact with chemically impacted soil and dust. All exposed skin, including hands and arms, was considered to be available for absorption of COCs in soil. Chemical-specific dermal absorption factors were taken from MOEE (1996b) and applied to determine an appropriate estimate of the fraction of chemical that is likely to be absorbed through the skin surface. It was conservatively assumed that dermal exposure was to soil containing COCs at the maximum concentration. Table 4-12 provides predicted dermal exposure to COCs through dermal contact with soil/dust.

Table 4-12 Exposure Estimates from Dermal Contact with Soil/Dust

COC	Predicted Dermal Exposure (µg/kg/day)[a]			
	Construction Worker	Maintenance Worker	Toddler On-Site Resident	Child Parkland Visitor
Arsenic	2.44E-02	3.79E-04	1.79E-02	2.24E-03
Lead	1.44E-02	2.24E-04	1.06E-02	1.32E-03

[a] Predicted exposures for carcinogens are not amortized. Amortizations of 27/~~80~~ 56 for the maintenance worker, 7/~~80~~ 56 for the construction worker, and 30/80 for the both the resident and parkland visitor were applied during the risk characterization.

4.3.5 Uncertainties in the Exposure Assessment

When assumptions need to be made during the RA process, either in filling data gaps or in selecting representative characteristics describing receptor behaviour, chemical environmental fate, *etc*., some degree of uncertainty can be ascribed to the assumption. In order to provide an RA which is overly protective, it is necessary to make assumptions which are conservative, that is, which tend to overestimate exposure, toxicity and risk, rather than underestimate these parameters. The following sections describe areas of uncertainty in the exposure assessment.

A number of conservative assumptions were employed in the exposure assessment which likely contributed to the overestimation of actual exposure. These include:

- Exposure estimates were calculated using the maximum measured soil and groundwater concentrations. Since humans are mobile receptors that would not spend 100% of their time within the immediate vicinity of the maximum concentration, this represents a higher concentration than what receptors would be anticipated to be exposed to over an extended period of time. In particular, it would not be anticipated that a parkland visitor would spend 100% of his/her time in any given area within the Wooded Areas of the Site; and,
- Construction worker receptors were assumed to spend 2 hours per day for 129 days per year on-site within an excavated trench exposed to COCs in soil and groundwater at the maximum concentration and were assumed to work for 7 years at the same location. It is anticipated that this is a significant overestimation of the actual amount of time that a construction worker would spend within an excavated trench on the RA Site. Since the current RA property is to remain as parkland in perpetuity, it is not likely that a construction worker would be on-site, in the same location, for that extended a period of time.

It is noted that individual conservative assumptions contribute to a potential overestimation of the actual risks. This overestimation is further magnified by the potential compounding effects of multiple conservative assumptions that were applied throughout the current exposure and risk characterization phases.

Several additional areas of uncertainty exist that may have varying degrees of influence on the exposure assessment. For example, dermal absorption factors (DAF) used to predict the absorbed dose of COCs as a result of direct dermal contact with impacted soil were those recommended by the MOE. The assessment of dermal exposure for the construction worker may be particularly sensitive to uncertainties associated with DAFs since a higher dermal adherence factor was assumed for this receptor.

In any RA, the findings are based on available data from the specific site and the scientific literature, in conjunction with a number of assumptions. Every effort is made to ensure these data and assumptions adequately represent conditions for the site. However, site-specific data can be limited which can result in uncertainty in the assessment. Where uncertainty exists, assumptions are made, and data are selected so as to err on the conservative side, where possible.

4.4 Toxicity Assessment

Toxicity is the potential for a chemical or agent to produce temporary or permanent damage to the structure or functioning of any part of the body. The toxicity of a chemical depends on the amount of chemical taken into the body (referred to as the "dose") and the duration of exposure (*i.e.*, the length of time the person is exposed to the chemical). For every chemical, there is a specific dose and duration of exposure necessary to produce a toxic effect in humans (this is referred to as the "dose-response relationship" of a chemical). In the toxicity assessment, information related to the dose-response relationships of each chemical is evaluated (usually from laboratory animal studies and studies of human exposure in the workplace) in order to determine the maximum dose of chemicals to which humans can be exposed that would be associated with a very low probability of experiencing adverse health effects. These toxicity estimates are called exposure limits and indicate an exposure that will not likely result in harmful effects.

4.4.1 Nature of Toxicity

Descriptions of the potential adverse health effects associated with exposure to COCs considered in the development of human exposure limits are provided in Appendix A along with an indication of the nature of the mode of action.

4.4.2 Dose Response Assessment

For each COC, a toxicological assessment was conducted, involving identification of mechanism of action and relevant toxic endpoints, and determination of receptor-specific toxicological criteria. In many cases, chemical-specific assessments have been completed by a regulatory agency (MOE, Health Canada, or the US EPA) involving a peer review process. Exposure criteria established by these agencies have been used in the current assessment.

Two basic and quite different methods are commonly recognized by regulatory agencies for the estimation of toxicological criteria for humans and are applied depending on the mode of toxic action of the compound (FDA, 1982; US EPA, 1989). These are the threshold approach (or the no-observed-adverse-effect levels [NOAELs] - extrapolation factor approach) and the non-threshold (or the mathematical model unit risk estimation) approach.

For chemicals with threshold type dose-response relationships (*i.e.*, for which NOAELs can be determined), it is assumed for practical purposes, that there is a threshold of exposure below which the risk of adverse effects is essentially zero, and no adverse effects will occur. This threshold is commonly referred to as a reference dose (RfD), or allowable daily intake (ADI). Conservative estimates of this threshold are based on an experimentally-determined NOAEL, with the application of low-dose extrapolation factors. These factors are also called "safety factors" or "uncertainty factors" (FDA, 1982; US EPA, 1989; Health Canada, 1993), and their magnitude is dependent on the level of confidence in the use of available data as a basis for extrapolation to the exposure scenario of the RA. This confidence is dependent on differences in species and duration of exposure, safety of sensitive species and individuals, and the quality of available data (*i.e.*, the weight of evidence of the supporting data).

Where available, route-specific exposure limits (*e.g.*, inhalation RfCs and oral RfDs) are used to characterize the hazard of chemicals.

The mathematical model unit risk estimation approach assumes that there would be no risk of the occurrence of adverse effects if the rate of exposure or dose was zero. This approach, generally applied to genotoxic carcinogens, yields an estimate of a cancer slope factor (SF) or inhalation unit risk (IUR) cancer potency estimate. The SF or IUR may be used directly in risk characterization to yield predicted risks of cancer incidence in a population. The MOE has indicated that Incremental Lifetime Carcinogenic Risk (ILCR) levels that are less than one-in-one million are considered acceptable (MOEE, 1997), that is, risks which are associated with an increased risk of cancer in one person out of one million people.

The selection of the appropriate method to establish an exposure limit depends on several factors including the characteristics of the relationship between exposure level and adverse response (*i.e.*, the shape of the dose-response curve) and available scientific data on the mechanism(s) through which the chemical produces its adverse response (*i.e.*, does the chemical cause damage to genetic material in cells).

Individuals with compromised health or within sensitive life stages (*e.g.*, pregnancy, newborn infants, children and elderly) were considered in the assessment by ensuring that the selected exposure limits were sufficiently stringent to protect such individuals under most exposure conditions. Where exposure limits from Canadian regulatory agencies such as Health Canada and the MOE were not available, data from US EPA Integrated Risk Information System (IRIS) and the Cal EPA were used. Table 4-13 contains the exposure limits selected for the COCs assessed in the HHRA. In the case of arsenic, where more than one toxicological endpoint has been reported (*i.e.*, carcinogenic *versus* non-carcinogenic), both endpoints have been selected.

Table 4-13 Summary of Exposure Limits for Human Receptors

Chemical	Route	Exposure limit		Endpoint	Study	Reference
		Type	Value[a]			
Inorganic Compounds						
Arsenic	Inhalation	RfC	0.015	Decreased intellectual function, adverse effects on neurobehavioural development (children)	Tsai *et al*., 2003; Wasserman *et al*., 2004	Cal EPA, 2008
		IUR	0.0043	Lung cancer (occupational exposure)	Enterline and Marsh, 1982; Higgins *et al*., 1982; Brown and Chu, 1983a,b,c; Lee-Feldstein, 1983	US EPA IRIS, 1998
	Oral	RfD	0.3	Hyperpigmentation, keratosis and possible vascular complications (humans)	Tseng *et al*., 1968; Tseng, 1977	US EPA IRIS, 1993
		SF	0.0015	Skin cancer prevalence rates (humans)	Tseng *et al*., 1968; Tseng, 1977	US EPA IRIS, 1998
Lead	Inhalation	RfC[b]	6.5	Behavioural effects and learning disabilities in children	Ziegler *et al*., 1978; Ryu *et al*., 1983	MOE, 1994
	Oral	RfD	1.85			

[a] Units: RfC µg/m^3; RfD: µg/kg/day; inhalation unit risk (IUR): (µg/m^3)$^{-1}$;oral slope factor (SF): (µg/kg/day)$^{-1}$.

[b] Inhalation RfC (6.5 µg/m^3) is calculated by multiplying the IOC_{pop} by the adult body weight (70 kg) and dividing by the adult breathing rate (20 m^3/day).

4.4.3 Uncertainties in the Toxicity Assessment

Conservative assumptions were employed in the toxicity assessment which likely contribute to the overestimation of actual health risks. These include:

- For arsenic, a genotoxic carcinogen, it was assumed that no repair of genetic lesions occurs, and that no threshold exists for chemicals that produce self-replicating lesions. However, the existence of enzymes that routinely repair damage to DNA are well documented in the scientific literature, and the potential adverse effects arising from damage to DNA would only be observed if the ability of these repair enzymes to "fix" the damage was exceeded;
- Large safety factors (*i.e.*, 100-fold or greater) were used in the estimation of the RfD for threshold-type chemicals. These safety factors were applied to exposure levels from studies where no adverse effects are observed (*i.e.*, to the NOAEL). Thus, exceeding the toxicological criterion does not mean that adverse effects would occur. Rather, it means that the safety factor beyond the no-effect exposure is somewhat reduced;
- Humans were assumed to be the most sensitive species with respect to the toxic effects of the COC. However, for obvious reasons, toxicity assays are not generally conducted on humans, so toxicological data (incorporating safety factors) from the most sensitive laboratory species were used in the estimation of toxicological criteria for humans; and,
- The most sensitive toxicological endpoint was selected for each chemical from the available scientific literature to represent the exposure limit.

4.5 Risk Characterization

The following subsections describe the results of the risk characterization phase. ILCRs and ERs were approximated for carcinogenic and non-carcinogenic COCs, respectively. Predicted risks and property-specific standards are provided.

4.5.1 Interpretation of Health Risks

The risks attributable to COCs for each exposure route for human receptors on the RA property will be quantitatively assessed in Section 4.54.2.

4.5.2 Quantitative Interpretation of Health Risks

A quantitative comparison of the estimated exposures and the selected exposure limits for receptors under each of the scenarios assessed are provided in Sections 4.54.2.1 to 4.45.2.4. Final property-specific human health standards for COCs in soil and groundwater for parkland land use are provided in Section 4.45.2.5. An acute exposure scenario is considered in Section 4.5.2.6.

4.5.2.1 Human Health Risk Estimates for the Construction Worker Exposure Scenario

The construction worker scenario consisted of an analysis of the human health risks to workers exposed to COCs in soil/dust *via* inhalation, incidental ingestion, and dermal contact. ERs/CRs and ILCRs for exposure to arsenic and lead in soil are presented in Table 4-14 along with maximum effects-based concentrations (EBC) protective of this exposure scenario.

Table 4-14 Predicted Risks and Property-Specific Soil Standards Protective of the Construction Worker Exposed to COCs in Soil

Non-Carcinogens	***Soil/Dust Inhalation CR***	***Soil/Dust Oral ER***	***Soil/Dust Dermal ER***	***Total Oral/Dermal ER***	***Effects-Based Concentration[a] (µg/g)***
Arsenic	**2.81E-01**	1.7162E-01	8.15E-02	**2.5244E-01**	12010 (100)
Lead	1.91E-03	8.15E-02	7.80E-03	8.93E-02	9430
Carcinogen	***Soil/Dust Inhalation ILCR***	***Soil/Dust Oral ILCR***	***Soil/Dust Dermal ILCR***	***Total Oral/Dermal ILCR***	***Effects-Based Concentration[a,b] (µg/g)***
Arsenic	**1.582.26E-06**	**6.729.11E-06**	**3.214.58E-06**	**1.379.93E-065**	30 (890)

Bolded values highlighted in grey scale are in excess of the acceptable ILCR of 1.0×10^{-6} or CR/ER of 0.2.

[a] EBC presented is for oral/dermal exposure routes. Values in brackets represent inhalation-based pathways for arsenic. For lead, all exposure pathways were combined since the toxic effects to humans are considered the same, regardless of the route of entry.

[b] Arsenic EBC based on carcinogenic endpoints takes into account background concentrations (17 µg/g).

Total non-carcinogenic risks for arsenic exceeded the acceptable ratio of 0.2 as a result of the inhalation of this COC in airborne soil/dust, as well as *via* oral/dermal exposure pathways. In addition, carcinogenic risks for arsenic exceeded the acceptable cancer risk level of 1-in-1,000,000 (1.0×10^{-6}) for a construction worker working for 7 years in a parkland setting while exposed to this COC *via* soil-based pathways. This indicates that portions of the Site contain concentrations of these compounds that may result in unacceptable health risks should construction/remediation workers be exposed to these soils for prolonged periods of time. Although this scenario predicts unacceptable risks based on the assumptions described in the HHRA, it is important to note that the construction worker scenario was conservatively assessed within the HHRA despite the fact a construction worker is not likely to spend significant amount of time on-site since the future property designation of the Site is to remain as parkland (*i.e.*, no construction worker would actually be exposed to these maximum concentrations of COCs in soil under the scenario conditions described). Any construction/remediation activities undertaken on-site must include the use of personal protective equipment (PPE) to prevent inhalation, incidental ingestion, and direct dermal contact to soils with concentrations of these COC in excess of the health–based property-specific standards.

4.5.2.2 Human Health Risk Estimates for the Maintenance Worker Exposure Scenario

The outdoor maintenance worker scenario consisted of an analysis of the human health risks to workers exposed to COCs in soil/dust *via* inhalation, incidental ingestion, and dermal contact. ERs/CRs and ILCRs for exposure to arsenic and lead in soil are presented in Table 4-15 along with maximum effects-based concentrations (EBC) protective of this exposure scenario.

Table 4-15 Predicted Risks and Property-Specific Soil Standards Protective of the Maintenance Worker Exposed to COCs in Soil

Non-Carcinogens	***Soil/Dust Inhalation CR***	***Soil/Dust Oral ER***	***Soil/Dust Dermal ER***	***Total Oral/Dermal ER***	***Effects-Based Concentration[a] (µg/g)***
Arsenic	1.29E-04	1.232E-02	1.236E-03	1.345E-02	2,0100 (220,000)
Lead	8.79E-06	6.3216E-03	1.218E-04	6.4428E-03	13,000

Table 4-15	**Predicted Risks and Property-Specific Soil Standards Protective of the Maintenance Worker Exposed to COCs in Soil**				
Carcinogen	***Soil/Dust Inhalation ILCR***	***Soil/Dust Oral ILCR***	***Soil/Dust Dermal ILCR***	***Total Oral/Dermal ILCR***	***Effects-Based Concentration[a,b] (µg/g)***
Arsenic	24.801E-09	**2.0166E-06**	1.922.67E-07	**2.920E-06**	8066 (5136,000)

Bolded values highlighted in grey scale are in excess of the acceptable ILCR of $1.0x10^{-6}$ or CR/ER of 0.2.

[a] EBC presented is for oral/dermal exposure routes. Values in brackets represent inhalation-based pathways for arsenic. For lead, all exposure pathways were combined since the toxic effects to humans are considered the same, regardless of the route of entry.

[b] Arsenic EBC based on carcinogenic endpoints takes into account background concentrations (17 µg/g).

Total non-carcinogenic risks for arsenic and lead were below the acceptable ratio of 0.2 as a result of inhalation, oral and dermal exposures to these COCs. However, carcinogenic risks for arsenic exceeded the acceptable cancer risk level of 1-in-1,000,000 ($1.0x10^{-6}$) for a maintenance worker working for 27 years in a parkland setting while exposed to this COC *via* incidental oral ingestion of soil/dust. This indicates that portions of the Site contain concentrations of arsenic that may result in unacceptable health risks should workers be exposed to these soils for prolonged periods of time. Soil remediation measures (targeted soil removal) are recommended to reduce exposure to impacted soils during maintenance activities.

4.5.2.3 Human Health Risk Estimates for the On-Site Residential Exposure Scenario

The on-site residential receptor consisted of an analysis of the human health risks to toddlers and composite receptors exposed to COCs *via* inhalation, incidental ingestion, and dermal contact. ERs/CRs and ILCRs for exposure to arsenic and lead in soil are presented in Table 4-16 along with maximum effects-based concentrations (EBC) protective of this exposure scenario.

Table 4-16	**Predicted Risks and Property-Specific Soil Standards Protective of the On-Site Residential Toddler and 30-Year Composite Exposed to COCs in Soil**				
Non-Carcinogens	***Soil/Dust Inhalation CR***	***Soil/Dust Oral ER***	***Soil/Dust Dermal ER***	***Total Oral/Dermal ER***	***Effects-Based Concentration[a] (µg/g)***
Arsenic	3.39E-04	**2.9407E+00**	5.964.46E-02	**2.9813E+00**	10 (84,000)
Lead	2.31E-06	**1.489.98E-001**	5.714.27E-03	**1.489.94E-001**	9060
Carcinogen	***Soil/Dust Inhalation ILCR***	***Soil/Dust Oral ILCR***	***Soil/Dust Dermal ILCR***	***Total Oral/Dermal ILCR***	***Effects-Based Concentration[a,b] (µg/g)***
Arsenic	8.19-09	**1.3640E-04**	**7.115.32E-06**	**1.427E-04**	20 (17,000)

Bolded values highlighted in grey scale are in excess of the acceptable ILCR of $1.0x10^{-6}$ or CR/ER of 0.2.

[a] EBC presented is for oral/dermal exposure routes. Values in brackets represent inhalation-based pathways for arsenic. For lead, all exposure pathways were combined since the toxic effects to humans are considered the same, regardless of the route of entry.

[b] Arsenic EBC based on carcinogenic endpoints takes into account background concentrations (17 µg/g).

Total non-carcinogenic risks for both arsenic and lead exceeded the acceptable ratio of 0.2 as a result of incidental oral ingestion of these COCs in airborne soil/dust. In addition, carcinogenic risks for arsenic exceeded the acceptable cancer risk level of 1-in-1,000,000 ($1.0x10^{-6}$) for a resident living on-site for 30 years exposed to this COC *via* oral ingestion, inhalation of airborne soil/dust, and dermal contact with soil/dust. This indicates that portions of the Site contain concentrations of these compounds that may result in unacceptable health risks should residents be exposed to these soils for prolonged periods of time. Although this scenario predicts unacceptable risks based on the assumptions described in the HHRA, it is important to note that the residential scenario was conservatively assessed within the HHRA despite the fact that the future property designation of the Site is to remain as parkland (*i.e.*, no residents would actually be exposed to these maximum concentrations of COCs in soil under the scenario conditions described). Because the property-use restriction for the Site includes no residential dwellings on-site, final property-specific standards for this scenario were not derived.

4.5.2.4 Human Health Risk Estimates for the Off-Site Residential Exposure Scenario

The off-site residential receptor consisted of an analysis of the human health risks to toddlers and composite receptors exposed to COCs *via* inhalation of airbone soil and dust migrating from the Site to off-site residential locations. ERs/CRs and ILCRs for exposure to arsenic and lead in soil are presented in Table 4-17 along with maximum effects-based concentrations (EBC) protective of this exposure scenario.

Table 4-17 Predicted Risks and Property-Specific Soil Standards Protective of the Off-Site Residential Toddler and 30-Year Composite Exposed to COCs in Soil

Non-Carcinogens	***Soil/Dust Inhalation CR***	***Total CR***	***Effects-Based Concentration (µg/g)***
Arsenic	4.53E-04	4.53E-04	63,000
Lead	3.08E-06	3.08E-06	27,000,000
Carcinogen	***Soil/Dust Inhalation ILCR***	***Total ILCR***	***Effects-Based Concentration (µg/g)***
Arsenic	1.10E-08	1.10E-08	13,000[a]

Bolded values highlighted in grey scale are in excess of the acceptable ILCR of $1.0x10^{-6}$ or CR/ER of 0.2.

[a] Arsenic EBC based on carcinogenic endpoints takes into account background concentrations (17 µg/g).

Total non-carcinogenic risks for arsenic and lead were below the acceptable ratio of 0.2 as a result of oral and dermal exposures to these COCs. Moreover, carcinogenic risks for arsenic were below the acceptable cancer risk of 1-in-1,000,000 ($1.0x10^{-6}$) for a resident living off-site for 30 years exposed to this COC *via* inhalation of airborne soil/dust migrating from the Site to off-site residential locations. Since no unacceptable risks were predicted for either COC in soil, risk management measures are not required to prevent or reduce exposure to impact soil.

4.5.2.5 Human Health Risk Estimates for the Parkland Visitor Exposure Scenario

The parkland visitor scenario consisted of an analysis of the human health risks to children and composite receptors exposed to COCs *via* inhalation, incidental ingestion, and dermal contact while spending time on-site. ERs/CRs and ILCRs for exposure to arsenic and lead in soil are presented in Table 4-18 along with maximum effects-based concentrations (EBC) protective of this exposure scenario.

Table 4-18 Predicted Risks and Property-Specific Soil Standards Protective of the Child and 30-Year Composite Parkland Visitor Exposed to COCs in Soil

Non-Carcinogens	***Soil/Dust Inhalation CR***	***Soil/Dust Oral ER***	***Soil/Dust Dermal ER***	***Total Oral/Dermal ER***	***Effects-Based Concentration[a] (µg/g)***
Arsenic	7.44E-05	8.1053E-02	7.47E-03	9.28.84E-02	3210 (380,000)
Lead	5.07E-07	4.07E-02	7.15E-04	4.15E-02	2,000
Carcinogen	***Soil/Dust Inhalation ILCR***	***Soil/Dust Oral ILCR***	***Soil/Dust Dermal ILCR***	***Total Oral/Dermal ILCR***	***Effects-Based Concentration[a,b] (µg/g)***
Arsenic	5.86E-09	**3.1936E-06**	2.94E-07	**2.943.66E-06**	60 58 (24,000)

Bolded values highlighted in grey scale are in excess of the acceptable ILCR of $1.0x10^{-6}$ or CR/ER of 0.2.

[a] EBC presented is for oral/dermal exposure routes. Values in brackets represent inhalation-based pathways for arsenic. For lead, all exposure pathways were combined since the toxic effects to humans are considered the same, regardless of the route of entry.

[b] Arsenic EBC based on carcinogenic endpoints takes into account background concentrations (17 µg/g)..

Total non-carcinogenic risks for arsenic and lead were below the acceptable ratio of 0.2 as a result of inhalation, oral and dermal exposures to these COCs. However, carcinogenic risks for arsenic exceeded the acceptable cancer risk level of 1-in-1,000,000 ($1.0x10^{-6}$) for a 30-year composite parkland visitor in a parkland setting while exposed to this COC *via* incidental oral ingestion of soil and dust. This indicates that portions of the Site contain concentrations of arsenic that may result in unacceptable health risks should visitors be exposed to these soils for prolonged periods of time. Soil remediation measures (targeted soil removal) are recommended to reduce exposure to impacted soils during activities common to a child visiting the Site.

4.5.2.6 Acute Exposure Scenario

At the Ministry's request, an acute exposure scenario will be considered as well, utilizing the 1000 mg/day soil-pica ingesting rate provided by EPA. For this evaluation, an acute TRV of 1.5 ug/kg/day was identified for Arsenic, based on the Ministry's Screening Level Health Risk Assessment of the Historical Mining Tour of Cobalt, Ontario conducted in 2005 (http://www.cobaltmininglegacy.ca/studies/SLHRA_Full_Report.pdf). Ministry review comment 14) b) indicates that it is possible to assess acute toxicity of lead for toddlers. As of this time, Intrinsik has been unable to identify an appropriate acute oral TRV for lead. For the purpose of this evaluation an acute TRV for lead of 10 ug/kg/day has been developed based on the following assumption:

- World Health Organization indicates that a blood lead level of 10 ug/dL generally corresponds to a dose of 3.6 ug/kg/day
- The available scientific literature, as summarized by ATSDR (2008) indicates that evidence of acute effects resulting from lead exposure occur at blood lead levels between 30 and 40 ug/dL for children
- Based on this information, an acute TRV for lead of 10 ug/kg/day was assumed

Based on the acute TRVs selected for arsenic and lead, and the soil-pica ingestion rate provided by EPA, no acute effects would be expected at the levels proposed as PSS for Parkland Visitor Scenario.

~~4.5.2.6~~4.5.2.7 Final Property-Specific Human Health Standards for a Parkland Land Use Scenario

Chemicals of Concern in Groundwater

Final property-specific standards for groundwater were derived for those chemicals either found in excess of the Site Condition Standards, or for those for which the MOE has not provided Site Condition Standards (Table 4-19).

Chemicals of Concern in Soil

Property-specific standards for soil were derived for those chemicals that were found in excess of the Table 1 Site Condition Standards, or for those for which the MOE has not provided Site Condition Standards. The property-specific standards are the lowest of the values derived to be protective of a construction worker, an outdoor maintenance worker, a residential toddler (or composite receptor), and a child parkland visitor (or composite). Summaries of the effects-based concentrations for each exposure scenario and for each COC quantitatively assessed in the HHRA are provided in Tables 4-20.

As discussed in Section 4.5.2.3, the on-site residential scenario was not included in the consideration of final PSSs since a property use restriction requires no residential dwellings on-site. In addition, the construction worker was also not included in the consideration of final PSSs since no construction activities are anticipated on-site and since the future land use is to remain as parkland. Because the areas of unacceptable risks to arsenic as a result of soil concentrations in excess of human health-based property-specific standards are limited, risk management measurements in the form of soil capping are not recommended. Instead, soil remediation in the form of targeted soil removal is recommended to limit or eliminate the potential for exposure to soils that might cause unacceptable health risks in a mature forested area. Table 4-21 shows the final human health PSSs with the recommendation of incorporating soil remediation, to be completed before filing an RSC.

Table 4-19	**Human Health-Based Property-Specific Standards for Chemicals in Groundwater (µg/L)**				
COC	***Maximum Groundwater Concentration***	***2004 Table 1 Site Condition Standard***	***Human Health-Based Property-Specific Standard***	***Basis of Human Health-Based PSS***	***Risk Management Required***
Barium	96	NV	1,000	2009 Table 8 Site Condition Standard	No
Lead	1.21	1	10	2009 Table 8 Site Condition Standard	No
Chloride	300,000	NV	790,000	2009 Table 8 Site Condition Standard	No
Sodium	37,000	NV	490,000	2009 Table 8 Site Condition Standard	No

NV Indicates that no value is available.
< Indicates that the concentration is lower than the value presented but cannot be more accurately quantified due to analytical uncertainty

Table 4-20	**Summary of Effects-Based Soil Standards Protective of Individual Exposure Scenarios (Lower of Inhalation and Oral/Dermal) (µg/g)**						
COC	***Maximum Soil Concentration***	***Construction Worker***	***Maintenance Worker***	***On-Site Local Resident***	***Off-Site Local Resident***	***Forested Area Parkland Visitor***	***Lowest Effects-Based PSS***
Arsenic[a]	143	NA	**~~80~~66**	NA	13,000	**~~60~~58**	~~60~~58
Lead	422	NA	13,000	NA	27,000,000	2,000	2,000

Bolded effects-based PSSs in grey-scale indicate target soil level concentrations derived from maximum concentrations that show unacceptable risks.
NA Indicates that a health-based PSS for each of the construction worker and the on-site local resident is not relevant to the derivation of the final PSS since an administrative restriction limiting their presence on-site precludes the calculated risks.
[a] Arsenic human health PSS are based on carcinogenic endpoints take into account background concentrations (17 µg/g).
[b] Concentration represents the maximum on-site concentration + 10% to account for variability in sampling and analysis.

Table 4-21	**Human Health-Based Property-Specific Standards for Chemicals in Soil (µg/g)**			
COC	***Maximum Soil Concentration***	***2004 Table 1 Site Condition Standard***	***Human Health-Based Property-Specific Standard***	***Basis of Human Health-Based PSS***
Arsenic	143	17	~~60~~58	Direct Contact For Parkland Visitor
Boron (HWS)	0.77	NV	1.5[a]	2009 Table 2 Site Condition Standard
Lead	422	120	2,000	Direct Contact For Parkland Visitor
DDD	0.024	NV	3.3	2009 Table 2 Site Condition Standard
DDE	0.44	NV	2.3	2009 Table 2 S1 Component Value (protective of direct soil contact for resident and parkland visitor)

NV Indicates that no value is available.
[a] The human health-based property-specific standards for boron (HWS) is MOE (2009) Table 2 Site Condition Standard. Although this standard is based on ecological protection, it is by definition also protective of human health. Therefore, it is considered an appropriate selection as the human health PSS.

4.5.3 Qualitative Interpretation of Health Risks

A qualitative interpretation of risks was completed in the current HHRA in the form of a secondary chemical screening step using appropriate generic standards and component values recommended by MOE (2009). Property-specific standards for those COCs not retained for quantitative evaluation were based on 2009 generic standards and component values and are provided in Tables 4-19 and 4-21.

4.5.4 Special Considerations for Environmentally Sensitive Area

The Site currently being assessed is classified as an environmentally sensitive area as a result of the presence of permanent on-site water bodies (*e.g.*, Armitage Creek and the permanent stream in the southern portion of the Site). Since this sensitive site trigger does not impact the assessment of exposure and risks to human receptors or the leaching of contaminants from soil to adequately characterized groundwater, no special considerations were required to justify the property-specific health standards proposed in the current HHRA.

4.5.5 Interpretation of Off-Site Health Risks

The property-specific human health standards presented in Section 4.4.2.6 are not likely to result in a concentration greater than the applicable full depth Site Condition Standard at the nearest human receptor location located off the RA property. It is not anticipated that unacceptable risks will occur to off-site locations as a result of the migration of impacted water to off-site areas located down gradient of the Site.

4.5.6 Uncertainties in the Risk Characterization

The following discussion describes areas of uncertainty in the risk characterization and the degree of conservatism in the assumptions made to address those uncertainties. Given the general tendency for the assumptions described in the exposure and toxicity assessments to overestimate both exposure and toxicity, it is considered likely that the overall risk characterization may have overestimated actual risks by a considerable degree, but is unlikely to have underestimated potential health risks.

- Use of the maximum soil and groundwater concentrations to predict exposure to human receptors likely resulted in a significant overestimation of exposure, including for the maintenance worker and parkland visitor who are not anticipated to spend prolonged periods of time in any one given area. While still conservative, use of the maximum soil concentrations for the off-site residential receptors may be less so since the potential exists that a residential property could be situated downwind from an area of elevated concentrations. However, given that these impacted areas are relatively small and not adjacent to existing developments, the overall predicted exposure is still considered to be highly conservative;
- The exposure frequency assumptions selected for the parkland visitor (5 days per week during a 5-week period during the summer, as well as one day per week for an additional 34 weeks of the year without snow cover) are considered to be highly conservative. The forested areas of the Site are thickly wooded and relatively inaccessible; therefore, it is unlikely that a child would spend a significant amount of time in the areas of impacted soil;

- The on-site occupational durations for the maintenance worker (27 years) and the construction worker (7 years) are considered to be highly conservative. In particular, the construction worker was assumed to be involved in excavation/trench activities in an area with the maximum concentration of each COC in soil and groundwater for 129 days per year for 7 years. It is considered to be highly unlikely that any one person would be required to spend this amount of time in any one given area, particularly on a parkland site; and,
- The characterization of risks to non-carcinogenic COCs assumed that the acceptable ER was 0.2 per environmental medium (*i.e.*, soil and groundwater). This assumption reserves 60% of the RfD to other sources of exposure (*e.g.*, food items, consumer products, *etc*.). For many chemicals, sources of exposure other than contaminated environmental media may be negligible; therefore, reserving only 20% of the RfD for each soil and groundwater may be highly conservative.

Overall, individual conservative assumptions made in the exposure and toxicity assessments contribute to a potential overestimation of the actual risks. This overestimation is further magnified by the potential compounding effects of multiple conservative assumptions that were applied throughout the current exposure and risk characterization phases.

5.0 ECOLOGICAL RISK ASSESSMENT (ERA)

As required by the *Records of Site Condition Regulation* (O. Reg. 153/04), an ERA was conducted as part of the current RA. The purpose was to evaluate the potential impacts of chemicals in groundwater and soil to ecological receptors.

5.1 Problem Formulation

The Problem Formulation for the ERA includes a review of COCs in groundwater and soil, an ecological conceptual site model, the ERA objectives, and a discussion of uncertainties. The Site is considered to be an *environmentally sensitive area* as a result of the presence of permanent on-site water bodies (*e.g.,* Armitage Creek and the permanent stream in the southern portion of Site).

5.1.1 Chemicals of Concern for the ERA

The chemicals to be retained as COCs in groundwater and soil are discussed below. Since no chemicals were identified as a potential concern in surface water (refer to Section 3.3.2.4), no further consideration of exposure to current on-site surface water was considered in the ERA.

<u>Chemicals of Concern in Groundwater</u>

Based on the initial COC screening presented in Section 3.3.2, the following four chemicals were retained as COCs for groundwater and carried forward to the ERA:

- Barium;
- Lead;
- Chloride; and,
- Sodium.

As discussed previously, the Site is considered to be environmentally sensitive as a result of the presence of on-site permanent water bodies. Therefore, maximum concentrations of chemicals in groundwater were compared to Table 1 Site Condition Standards reflective of background concentrations. Site Condition Standards for many chemicals are based on component values derived to be protective of human receptors; therefore, a secondary screening based on component values derived to be protective of ecological receptors was performed using the values provided by the MOE. Although the existing Table 1 Site Condition Standards (MOE, 2004) were used in the COC selection process (Section 3.3.2.1), in order to reflect the most current science, component values provided in the MOE Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario (MOE, 2009) were used for the secondary screening. Because of the presence of on-site surface water, the GW3 component values from the Table 8 Generic Site Condition Standards for a Site within 30m of a water body in a potable groundwater condition for medium/fine textured soils use were utilized in this secondary screening process (MOE, 2009). These ecologically-based values were established based on Aquatic Protection Values (APV) obtained from the US EPA Ambient Water Quality Criteria (AWQC), lowest effects-based toxicity values for freshwater organisms from published journals (as provided in available databases such as the US EPA ECOTOX database), or the lowest ecologically based criteria presented by the Massachusetts Department of Environmental Protection (MADEP). The Table 8 GW3 component values reflect a Site in proximity to a surface water body and thus no attenuation is assumed within the migration of groundwater to surface water. However, a ten-fold dilution factor is applied to the APV by the MOE to account for surface water dilution.

Maximum groundwater concentrations of the four chemicals listed above were compared to the 2009 Table 8 GW3 values for medium-fine textured soils for non-potable groundwater, and for all categories (agricultural, parkland, industrial/commercial) (Table 5-1).

Table 5-1 Comparison of Maximum COC Groundwater Concentrations to the Ecological Component Values (µg/L)

COC	*Maximum Groundwater Concentration*	*2004 Table 1 Site Condition Standard*	*2009 Table 8 GW3*
Barium	96	NV	23,000
Lead	1.21	1	20
Chloride	300,000	NV	1,800,000
Sodium	**37,000**	**NV**	**NV**

Bolded concentrations in grey scale were detected above the GW3 or the MOE does not provide requisite values.
NV Indicates that no value is available.

The maximum concentration of barium, lead and chloride in groundwater did not exceed their respective GW3 values and therefore these COCs were not retained for further evaluation in the ERA. The MOE does not provide a GW3 value for sodium, and therefore this COC was retained for further evaluation in groundwater for the ERA.

Chemicals of Concern in Soil

Based on the initial chemical screening process completed in Section 3.3.2, the following five chemicals were retained as COCs for the ERA:

- Arsenic;
- Boron;
- DDD;
- DDE; and,
- Lead.

Although the Site is considered to be environmentally sensitive, its proximity to surface water does not influence the assessment of exposure or risks to terrestrial receptors as a result of direct exposure to impacted soil. As a result, the maximum concentrations of arsenic, boron, DDD, DDE and lead were compared to the ecotoxicity component values of the Table 2 Site Condition Standards for residential/parkland/institutional land use with medium to fine textured soils. These values are designed to be protective of plants and soil invertebrates directly exposed to impacted soils.

In addition, the S-/GW3 component value of the Table 2 Site Condition Standard represents the soil concentration that is protective of the leaching of contaminants in soil to groundwater and the subsequent movement to surface water. Therefore, this value is protective of any aquatic receptors that may inhabit surface water bodies impacted by on-site soil contamination in cases where surface water is in greater than 30 metres from the Site. However, for the current assessment this assumption is invalid since permanent water courses, such as the Armitage Creek and its tributaries, are present on-site. To account for the proximity of surface water bodies, the Table 8 Site Condition Standards (MOE, 2009) were used since they are inherently protective of the leaching of contaminants in soil to groundwater and the subsequent movement to surface water (S-/GW3 values are not available for Table 8 Site Condition Standards).

Therefore, the maximum on-site soil concentrations were compared to ecological component values designed to be protective of aquatic and terrestrial ecological receptors, as well as to their respective Table 8 Site Condition Standards (Table 5-2).

Table 5-2 Comparison of Maximum COC Soil Concentrations to the Ecological Component Values for Medium to Fine Textured Soils and Parkland Land Use (µg/g)

COC	Maximum Soil Concentration	2004 Table 1 Site Condition Standard	2009 Table 2 Ecotoxicity Component Values		2009 Table 8 Site Condition Standard
			Plants and Soil Organisms	Mammals and Birds	
Arsenic	**143**	**17**	**25**	**51**	**18**
Boron (HWS)	0.77	NV	1.5	6[a]	1.5
DDD	**0.024**	**NV**	**8.5**	**NV**	**0.5**
DDE	**0.44**	**NV**	**0.33**	**NV**	**0.5**
Lead	**422**	**120**	**310**	**32**	**120**

Bolded concentrations in grey scale either were detected above the ecologocial component values or the MOE does not provide requisite values.
NV Indicates that no value is available.
[a] Ecotoxicity component value for mammals and birds (120 µg/g) is based on total concentration rather than the hot water soluble (HWS) form. Value presented is converted to HWS form assuming that the HWS fraction represents 5% of the total concentration, as recommended by MOEE (1996b) and Gupta (1979).

Since the maximum soil concentration of boron did not exceed its ecotoxicity criteria or its Table 8 Site Condition Standard, boron was not retained for further evaluation in the ERA.

Based on the above comparison, the maximum concentration of arsenic and lead exceeded their respective ecotoxicity component values while ecotoxicity values for DDD and DDE are not provided by the MOE. Therefore, the following four COCs will be retained for further evaluation in soil for the ERA:

- Arsenic;
- DDD;
- DDE; and,
- Lead.

5.1.2 Ecological Conceptual Site Model

The Site is current zoned for parkland use and the future property designation is to remain as such in perpetuity. The Site is surrounded by other forested and residential areas, as well as limited commercial properties. The Site is considered to consist of four parcels, outlined in Section 3.1 as:

- Parcel 1: The area north of Mulock Drive, known as William Thomas Mulock Park. This is an environmentally protected area, is Town-owned and will remain in the current parkland state;

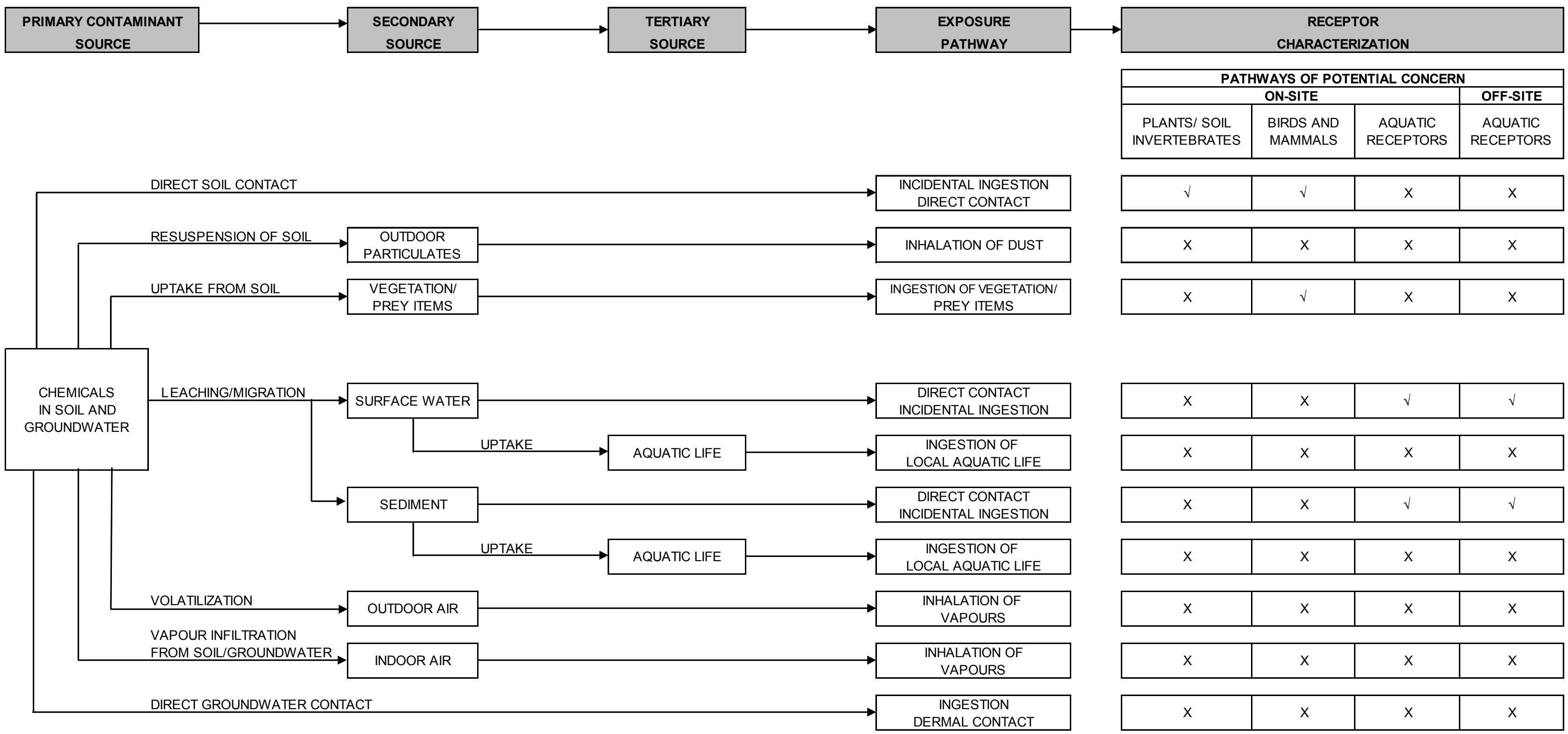
- Parcel 2: The eastern portion of the area south of Mulock Drive, known as the Trail Lands. This Town-owned parkland area primarily runs north-south and contains a walking trail (plus clearance setback of a few metres to either side of the paved and crushed gravel path), as well as the Armitage Creek, running parallel to, and west of, the trail;
- Parcel 3: The Northern Forested Lands, just south of Mulock Drive, between Bathurst Street and Parcel 2. This parcel is owned by the developer (Criterion Development Corporation), but is to be conveyed to the Town of Newmarket; and,
- Parcel 4: The Southern Forested Lands, situated between Bathurst Street and Parcel 2, south of the Summerhill Woods Development. This parcel also is owned by the developer, but is to be conveyed to the Town of Newmarket. A permanent creek runs west to east through this parcel.

The four parcels that make up the Site are predominantly forested, with two permanent streams (including the Armitage Creek) flowing generally from the northwest towards the southeast. Therefore, because of the existence of on-site surface water bodies, the Site is classified as environmentally sensitive. A detailed description of the Site was provided in Section 3.1.

In groundwater, chloride and sodium were retained for quantitative evaluation in the ERA based on their potential to adversely affect aquatic receptors in on- and off-site surface water bodies. In soil, arsenic, lead, DDD and DDE were retained for further assessment in the ERA based on their potential to adversely affect terrestrial receptors such as plants, soil invertebrates, small mammals and birds.

The conceptual model provides an outline of the general exposure scenarios to be evaluated by bringing together the COCs, receptors and exposure pathways into one overall conceptual framework (Figure 5-1). Additional detail on exposure pathways and receptors is provided in Sections 5.2 and 5.3.

The current assessment assessed risks to ecological receptors assuming that receptors have the potential to have direct contact with all on-site soils without any barriers or restrictions.



√ Indicates pathway was assessed in the ERA
X Indicates pathway was not assessed in the ERA

Figure 5-1 Ecological Conceptual Site Model

5.1.3 Risk Assessment Objectives

The objectives of the current ERA are to qualitatively and quantitatively evaluate ecological risks associated with exposure to impacted soils and groundwater and to derive property-specific standards that are protective of ecological receptors. The qualitative evaluation of the ERA is an additional, secondary chemical screening of COCs identified in Section 3 against appropriate generic standards and component values provided by MOE (2009). The quantitative assessment includes prediction of the exposures, risks and ecological effects-based concentrations associated with those COCs retained following the qualitative evaluation, using the receptor characterizations outlined below.

Although a limited amount of targeted soil removal may be required as part of an overall remediation plan, the current assessment assumed that ecological receptors would be exposed to levels of COCs in soil currently found on-site.

The quality and quantity of data provided for environmental media were considered to be sufficient to meet the objectives of the ERA. Soil samples were analyzed for organic pesticides and inorganic chemicals related to historical land use at surface and subsurface depths across the Site. Groundwater samples were analyzed for a range of inorganic chemicals consistent with historical property use and are considered to sufficiently characterize on-site groundwater quality for assessment of risks to on- and off-site aquatic receptors. In addition, sediment samples from on-site water bodies were analyzed for organic pesticides and inorganic chemicals related to historical property use in order to further characterize existing and potential impacts on on- and off-site aquatic receptors.

5.1.4 Discussion of Uncertainty in the Problem Formulation

The selection of COCs involved a comparison of the maximum measured concentration (or highest detection limit) of each chemical in soil and groundwater to the relevant Site Condition Standard. It is assumed that the soil and groundwater samples collected as part of the site characterization programs provide an accurate representation of on-site conditions. Although the data provided are considered to be adequate to meet the objectives of the ERA, concentrations in excess of those reported may exist in areas of the Site. However, given the distribution of sampling locations throughout the Site, any areas of contamination not identified in the available data are likely to be isolated and not anticipated to significantly influence the outcome of the ERA.

Given that on-site sampling was biased towards the areas requiring delineation of contamination, it is anticipated that the use of groundwater and soil data for the exposure assessment and risk characterization will result in an overestimation of risks for the Site as a whole.

5.2 Receptor Characterization

For the purpose of this assessment, the valued ecosystem components (VECs) are receptors that are representative of groups of species that are common components of natural ecosystems in southern and eastern Ontario. VECs are selected to be representative of a variety of organisms with varying feeding and behavioural characteristics. They are selected generally based on natural features studies conducted on the area of study or on areas that have a similar land use and ecological state. VECs have been identified for both the terrestrial and aquatic environments.

5.2.1 VECs in the Aquatic Environment

The Armitage Creek is a permanent water course running approximately west to east through Parcel 1 and approximately north to south through Parcel 2. In addition, a permanent creek runs west to east in Parcel 3 towards the Armitage Creek and an ephemeral (stormwater) watercourse runs through Parcel 4 towards the Armitage Creek as well. Therefore, within this assessment, potential risks to various species of fish, invertebrates, amphibians and aquatic plants (based on availability of toxicity information) were evaluated to ensure that populations of these groups are able to successfully survive, grow, and reproduce in these on-site watercourses, and in areas that may be influenced by the migration of COCs from on-site groundwater. Because no rare, threatened or endangered terrestrial species, or species of special concern, are known or expected to occur on the property, no VECs were evaluated at the individual level of protection.

5.2.2 VECs in the Terrestrial Environment

Because the four parcels comprising the overall Site include significant areas of wooded parkland, it is assumed that the Site offers significant ecological habitat throughout. Because it is not possible to evaluate all ecological species at a site, representative VECs are selected based on several criteria (Suter, 1989; CCME, 1997), including:

- Threatened or endangered species;
- Sensitivity to the chemicals at the site;
- Biological and ecological relevance;
- Ability to measure or predict effects; and,
- Social relevance (species of recreational, industrial or social importance).

The Site is expected to be frequented by some common bird species that would consume earthworms and other invertebrates, as well as seeds or fruit. The American Robin was selected to represent birds that would consume a diet composed of a significant amount of soil invertebrates. Since uptake of chemicals through the consumption of invertebrates is typically higher than that from consumption of vegetation, estimated risks to the American Robin would exceed those for herbivorous bird species.

A few common mammals are also expected to frequent the Site, such as the striped skunk, coyote, hare, and raccoon, as well as small rodents. Voles and shrews are likely to receive relatively large chemical doses because they consume a large amount of food relative to their body weight; they also will commonly ingest soil during feeding. Therefore, the Meadow Vole and Short-tailed Shrew were selected to represent small mammals that would have a diet composed of 100% vegetation and 100% soil invertebrates, respectively. In connection with the selection of VECs, assessment endpoints are identified for the ERA. Assessment endpoints are the explicit expressions of the actual environmental value that is to be protected (Suter, 1989). The assessment endpoints and VECs selected for evaluation in this ERA include the survival, growth, and reproduction of:

- Vegetation (*e.g.*, grasses, shrubs, trees);
- Soil invertebrates (*e.g.*, beetles, collembolans, earthworm);
- Birds (as represented by the American Robin); and,
- Small mammals (as represented by the Meadow Vole and Short-tailed Shrew).

Because no rare, threatened or endangered terrestrial species, or species of special concern, are known or expected to occur on the property, no VECs were evaluated at the individual level of protection.

Terrestrial vegetation was not assessed to address exposure to COCs in on-site groundwater. Groundwater in the overburden unit was found at depths ranging from 0 to 5 mbgs, as reported by Burnside (2010). However, greater than 75% of the Site has groundwater at depths of greater than 30cm (Burnside, 2010). Studies have shown that 80% of the roots of most trees lie within the top 30cm of soil (Himelick, 1986), while 94% of Kentucky bluegrass roots are found within this area (Stewart *et al*., 2004). Under nursery conditions, it was demonstrated that the natural root distribution of seven species of trees (Norway, Red and Sugar Maple, Green Ash, Redbud, Ginkgo, Pin Oak) were most developed at 13-38cm (Watson and Himelick, 1982). Therefore, risks to plants as a result of root uptake of groundwater were not assessed in the ERA.

5.2.3 Avian and Mammalian Characteristics

Parameters, including body weight, food and soil consumption rates, home range and dietary composition, are required in order to determine wildlife exposure to COCs. Measured values for food consumption were used over allometric equations, if available. Table 5-3 summarizes parameters for the avian and mammalian receptors.

Table 5-3 Avian and Mammalian Wildlife Receptor Parameters[a]

Parameter	*American Robin*	*Meadow Vole*	*Short-tailed Shrew*
Body weight (kg)	0.077	0.044	0.015
Dietary breakdown	Assumed 100% soil invertebrates (earthworms)	Assumed 100% terrestrial vegetation	Assumed 100% soil invertebrates (earthworms)
Food consumption rate (kg wet wt/day)	0.093	0.005	0.009
Food consumption rate (kg dry wt/day)	0.015	0.0015	0.0013
Soil ingestion (% of diet)	10	2.4	3.0
Soil ingestion (kg dry wt/day)	0.0096	0.00012	0.00027
Home range (ha)	0.42	0.04	0.39

[a] Exposure parameters were obtained from Sample and Suter (1994).

Since the area of the Site is larger than the home ranges for each of the three selected terrestrial receptors, it was assumed that 100% of their diet originated from on-site resources. The moisture content of dietary items was assumed to be 84% for earthworms and 70% for terrestrial vegetation (Sample and Suter, 1994).

5.3 Exposure Assessment

The exposure assessment includes an analysis of the pathways through which VECs may be exposed to COCs and an estimate of the levels to which they are exposed.

5.3.1 Pathway Analysis

Ecological receptors may be exposed to chemicals *via* any of several potential exposure pathways, such as ingestion, inhalation and dermal contact. The exposure pathways that were included in the ERA are described below for aquatic VECs, terrestrial plants, soil invertebrates, birds, and mammals.

Aquatic VECs

Since on-site groundwater has the potential to migrate downgradient and enter the surface water of the on-site watercourses, aquatic receptors were assumed to be exposed to COCs in surface water and sediment *via* direct contact.

The ERA assumed that aquatic plants are exposed primarily to COCs in water *via* diffusion of chemicals through the cell membrane. Therefore, exposure and risk to aquatic plants are predicted by comparing COC concentrations in water to concentrations that have been determined to be acceptable for aquatic plants (*i.e.*, benchmark concentrations).

To assess exposure and risk to aquatic invertebrates, COC concentrations in groundwater were compared to concentrations that have been determined to be acceptable for invertebrate communities (*i.e.,* benchmark concentrations). Based on the availability of chemical-specific toxicity data, organisms that will be used to represent the invertebrate community may vary from chemical to chemical but the benchmarks are intended to be protective of a community of invertebrates native to this type of environment.

Fish and amphibians may be exposed to COCs by consumption of food/prey items and water, or through diffusion across the gill membrane (for low molecular weight, and/or highly soluble chemicals). Dermal exposure occurs when chemicals are absorbed through the skin from water. Exposure to fish and amphibians was assumed to be most significant *via* direct exposure to COCs dissolved within the water column.

Therefore, exposure and risks are predicted by comparing concentrations of COCs in groundwater to concentrations that have been determined to be acceptable for fish, invertebrates, amphibians and aquatic plants.

In addition, to assess exposure and risk to benthic invertebrates, COC concentrations in sediment were compared to concentrations that have been determined to be acceptable for benthic invertebrate communities (*i.e.,* benchmark concentrations). Based on the availability of chemical-specific toxicity data, organisms that will be used to represent the benthic invertebrate community may vary from chemical to chemical but the benchmarks are intended to be protective of a community of invertebrates native to this type of environment.

Terrestrial Plants

The ERA assumed terrestrial plants would be exposed primarily to COCs in soil *via* root uptake. Therefore, exposure and risk to terrestrial plants are predicted by comparing COC concentrations in soil to concentrations that have been determined to be acceptable for growing plants. Root uptake of COCs in groundwater was excluded as an exposure pathway for terrestrial plants as the depths to groundwater exceed 30cm over more than 75% of the Site (Burnside, 2010). The root structure of most plant species does not typically extend beyond 30 cm (see Section 5.2.2); therefore, this exposure pathway was excluded from consideration.

Soil Invertebrates

The feeding and burrowing habits of soil invertebrates determine the exposure of these organisms to chemicals in soil. Some invertebrates, such as many earthworm species, are exposed to chemicals in soil because they ingest large amounts of soil during feeding. Other invertebrates that may be exposed to chemicals in the soil include mites, woodlice, snails and slugs, nematodes, insects, spiders, centipedes, carabid beetles, and many others. For the current ERA, soil invertebrates are assumed to be exposed only to chemicals in soil. To assess exposure and risk to soil invertebrates, COC concentrations in soil are compared to concentrations that have been determined to be acceptable for soil invertebrates.

Terrestrial Wildlife

Wildlife may be exposed to chemicals in the environment *via* three distinct pathways: ingestion, inhalation, and dermal contact. Chemicals may be ingested by consumption of impacted food and water, and by incidental ingestion of soil. Dermal exposure occurs when chemicals are absorbed through the skin as a result of direct contact with impacted soil. Dermal exposure is generally assumed to be negligible for birds and mammals. This is because feathers on birds and fur on mammals reduce dermal exposure by limiting the contact of skin with chemicals in soil (Sample *et al*., 1997). Exposure may occur *via* inhalation if chemicals are volatile, or if they are components of fine particulate matter which may be re-suspended in ambient air. However, there is a paucity of available data describing the inhalation toxicity of chemicals to birds, and use of mammalian data for birds is not possible due to the differences in avian and mammalian physiology. Inhalation toxicity data for mammalian wildlife are also limited for endpoints of interest in ERA (*e.g*., reproduction). Food and soil ingestion tend to be the most significant routes of exposure, contributing the greatest to overall risk. This agrees with US EPA (1999) and Environment Canada (1994) who also acknowledge that ingestion is the major pathway of concern for wildlife. Wildlife species may also receive exposure as a result of the consumption of surface water from on-site water bodies. However, the magnitude of chemical exposure *via* water ingestion rarely approaches that from soil or food ingestion, even where concentrations in surface water are relatively high. Therefore, only exposure *via* ingestion of food and soil was considered in this ERA.

5.3.2 Exposure Estimates

Groundwater

The assessment of potential exposure to aquatic receptors in on-site water courses considers the measured maximum groundwater concentrations of sodium (the only COC retained for quantitative evaluation in the ERA) as detailed below in Table 5-4.

Table 5-4 Maximum Concentrations of COCs in On-Site Groundwater Used to Assess Risks to Aquatic Receptors

COC	***Maximum Groundwater Concentration (µg/L)***
Sodium	37,000

Soil

The MOE has indicated that the use of a one sided 95% upper confidence limit on the mean (UCLM) is not appropriate for the assessment of plants or soil invertebrates as a result of their essential immobility (MOE, 2005). The MOE acknowledges that an RA is not required to be protective of individual plants or soil organisms and that the assessment should consider the spatial distribution of exceedances of selected benchmarks. Therefore, the maximum soil concentration for each COC was used to predict risks to plants and soil invertebrates. Although birds and mammals are mobile receptors that will forage from a specific home range, risks to these receptors were also based on the maximum concentrations of COCs in soil (Table 5-5).

Table 5-5 Maximum Concentrations of COCs in On-Site Soil Used to Assess Risks to Terrestrial Receptors

COC	***Maximum Soil Concentration (µg/g)***
Arsenic	143
Lead	422
DDD	0.024
DDE	0.44

Exposure Modelling for Terrestrial Wildlife

Exposure *via* ingestion may occur by consumption of chemicals in food and soil, as represented by the following equation:

$$E_{ingestion} = E_{food} + E_{soil}$$

where:

$E_{ingestion}$ = total ingestion exposure (mg/kg/day)
E_{food} = exposure from food consumption (mg/kg/day)
E_{soil} = exposure from soil consumption (mg/kg/day)

Exposure from food ingestion is estimated by the following equation:

$$E_{food} = (C_{food} * IR_{food})/BW$$

where:

E_{food} = exposure from food consumption (mg/kg/day)
C_{food} = concentration of chemical in food (mg/kg)
IR_{food} = ingestion rate (kg/d)
BW = body weight (kg)

Similarly, exposure from soil ingestion is estimated by the following equation:

$$E_{soil} = (C_{soil} * IR_{soil})/BW$$

where:

E_{soil} = exposure from soil consumption (mg/kg/day)
C_{soil} = concentration of chemical in soil (mg/kg)
IR_{soil} = soil ingestion rate (kg/d)
BW = body weight (kg)

These exposure estimates are compared to Toxicity Reference Values (TRVs) to provide an estimate of risk.

In the current ERA, the chemical concentrations in food (*e.g.*, plants, soil invertebrates) were modelled. Two methods are commonly used to model uptake: uptake factors; and regression equations. The use of an uptake factor (UF) is the simplest method of estimating a concentration in food based on a soil concentration:

$C_{food} = C_{soil} * UF$

However, the use of uptake factors assumes that the chemical concentration in an organism (*i.e.*, food item) is linearly related to the concentration in soil. This is seldom the case, as uptake factors are lower at higher chemical concentrations in the environment. Therefore, regression equations have been developed for estimating concentrations in earthworms and plants.

When available, a regression equation (Sample *et al*., 1998; BJC, 1998; US EPA, 2007) was selected for use over an uptake factor. Empirical data also were used preferentially over an uptake factor estimated based on Kow. The regression equation or uptake factor used for each chemical is presented in Table 5-6.

Table 5-6 Regression Equation or Uptake Factor to Determine Chemical Concentrations in Worms and Plants

COC	***Soil-to-Worm***	***Soil-to-Plant***
Arsenic[a]	Y = -1.42 + 0.71x	Y = -1.99 + 0.56x
Lead[a]	Y = -0.22 + 0.81x	Y = -1.33 + 0.56x
DDD	Y = 1.16 + 0.698x[b]	0.0124[c]
DDE	Y = 2.48 + 0.880x[b]	0.00645[c]

[a] x= ln(dry weight concentration in soil); y= ln (dry weight concentration in organism). Selected regression equations were taken from Sample *et al*. (1998) for earthworms, and BJC (1998) for plants.
[b] x= ln(dry weight concentration in soil); y= ln (dry weight concentration in earthworm). Regression equation taken from US EPA Eco-SSLs (US EPA, 2007).
[c] Uptake factor was taken from RAIS (2009).

Using the regression equations and uptake factors presented in Table 5-6, and the maximum on-site soil concentrations presented in Table 5-5, concentrations of COCs in earthworms and plants were calculated (Table 5-7).

Table 5-7 Predicted Concentrations of COCs in Wildlife Food Items (µg/g dry weight)

COC	***Predicted Concentration in Earthworms***	***Predicted Concentration in Plants***
Arsenic	8.0	2.2
Lead	106	7.9
DDD	0.24	3.0E-04
DDE	5.8	2.9E-03

5.3.3 Discussion of Uncertainty in the Exposure Assessment

To be consistent with the MOE preferred approach for the completion of ERAs, the exposure assessment was conducted using the maximum concentrations of COCs in soil and groundwater for predicting exposure rather than using a measure of central tendency of the sampling data. As a result, it is anticipated that exposures to ecological populations and communities are overestimated. Recognizing that it is the goal of the ERA to be protective of the plant and soil invertebrate communities, use of the maximum soil concentrations to represent exposure point concentrations will overestimate exposure to the communities and as a whole and is a more accurate approach to be protective of individual organisms. Assuming that every individual organism within the plant and soil invertebrate communities is exposed to the maximum concentrations (regardless of sample depth) is anticipated to significantly overpredict exposure, and subsequently, risks to these VECs.

In addition, use of the maximum soil concentrations to predict concentrations in plants and soil invertebrates as a food source to the Meadow Vole, Short-tailed Shrew and American Robin is anticipated to overpredict exposure *via* this pathway. This approach assumes that a mobile receptor such as the Meadow Vole, Short-tailed Shrew or American Robin would only consume plants or earthworms growing in soil with the maximum COC concentrations. Incidental ingestion of soil for the Meadow Vole, Short-tailed Shrew and American Robin also assumes that only soil with the maximum COC concentrations is consumed. In reality, mobile receptors would likely forage over a larger area and be exposed to a wide range of COC concentrations in soil and food items.

Use of regression equations or uptake factors to predict concentrations of COCs in food items inherently assumes that the form of the chemical in on-site soil and the soil characteristics are similar to those associated with the studies used to derive these factors. If conditions at the Site differ significantly from those used to derive these factors, there will be uncertainty in the applicability of these factors for predicting exposure.

The soil and diet consumption rates used in the exposure assessment were taken from reputable sources but may have been based on animals in captivity. These values may not be completely representative of parameters for individuals in the wild. This may result in the over- or under-estimation of exposure. In addition, dietary compositions were simplified to assume 100% of a single food type. Wildlife consume a variety of dietary items, including various invertebrate and plant materials, and therefore exposure may be over- or under-estimated.

5.4 Hazard Assessment

Benchmarks and toxicity reference values (TRVs) are concentrations or doses that are considered to provide protection to VECs. Benchmarks for the protection of aquatic VECs are provided in Section 5.4.1 and those for the protection of terrestrial plants and soil invertebrates are provided in Section 5.4.2. TRVs for the protection of avian and mammalian terrestrial wildlife are described in Section 5.4.3.

5.4.1 Benchmark Concentrations for Aquatic VECs

The selected benchmark concentrations used to predict risks to aquatic VECs as a result of the movement of groundwater to surface water was taken from Suter and Tsao (1996). Benchmark concentrations from Suter and Tsao (1996) represent the lowest chronic value for fish, daphnids, non-daphnid invertebrates, and aquatic plants. Standard chronic tests typically include all or most of the life-cycle of the test organism and consider effects on growth, deformities, reproductive success, and lethality (Suter and Tsao, 1996). These values are considered to be protective of population productivity during chronic exposure to chemicals in surface water for sensitive aquatic receptors.

A summary of the benchmark concentrations protective of aquatic receptors is presented in Table 5-8. The benchmarks given by Suter and Tsao (1996) is and Aquatic Protection Value (APV), protective of aquatic biota exposed to COCs migrating from impacted groundwater to surface water. A 10-fold dilution factor was applied to the literature benchmark to account for mixing in surface water; this approach is consistent with current MOE guidance (refer to Section 7.8 and page 354 of the MOE Rationale document (2009)).

Table 5-8 Groundwater Benchmark Concentrations for Aquatic Receptors	
COC	**Benchmark Concentration (µg/L)**
Sodium	6,800,000[a]

[a] Suter and Tsao (1996), with 10-fold dilution factor.

5.4.2 Benchmark Concentrations for Terrestrial Plants and Soil Invertebrates

Concentrations selected as benchmarks to predict risks to terrestrial plants and soil invertebrates were taken from US EPA Region 5 (2003), Efroymson *et al*. (1997a,b), and MOE (2009). Each of these sources provides soil concentrations that are designed to be protective of target VECs during prolonged exposure. The selected benchmarks are screening concentrations that are intended to prevent the occurrence of unacceptable risks rather than represent concentrations at which risks will occur. As a result, exceedance of these values does not necessarily indicate that adverse effects will occur.

A summary of the benchmark concentrations for plants and soil invertebrates is provided in Table 5-9.

Table 5-9 Soil Benchmarks for Terrestrial Plants and Soil Invertebrates (µg/g)		
COC	**Benchmark for Plants**	**Benchmark for Soil Invertebrates**
Arsenic	22[a]	60[b]
Lead	250[a]	
DDD	8.5[a]	
DDE	0.33[a]	

[a] Benchmark is protective of plants and soil invertebrates in a parkland land use (MOE, 2009).
[b] Benchmark is a screening benchmark concentration for the toxicity to soil invertebrates (Efroymson *et al*.,1997a).
[c] Benchmark is a US EPA Region 5 (2003) ecological screening level (ESL).

5.4.3 TRVs for Terrestrial Wildlife

TRVs for terrestrial wildlife are summarized in Table 5-10. TRVs are the Lowest-Observed-Adverse-Effect Level (LOAEL) for each species unless otherwise indicated. All wildlife TRVs were taken from either Sample *et al.* (1996) (body-weight dose scaling was not applied to the test species TRV), the 2009 MOE Rationale document (MOE, 2009), or Edens and Garlich (1983). Of note, the avian TRV for lead is 9.9 mg/kg/d. This TRV is not the TRV used by the Ministry to develop the updated Site Condition Standards (MOE, 2009). However, the data taken from the same critical study were used as the basis of the TRV, in order to be consistent with the Ministry's preferred study. The TRV is the EC20 of the data from Edens and Garlich (1983), as estimated from the dose-response curve developed by US EPA (2001).

Table 5-10 Toxicity Reference Values for Wildlife (mg/kg/d)		
COC	**Small Mammals**	**Birds**
Arsenic	1.26[a]	12.84[b]
Lead[c]	80[a]	9.9[d]
DDD[e]	0.7[a]	1[a]

Table 5-10 Toxicity Reference Values for Wildlife (mg/kg/d)		
COC	***Small Mammals***	***Birds***
DDE[e]	0.7[a]	1[a]

[a] TRV from MOE (2009).
[b] TRV from Sample *et al*. (1996).
[c] TRV is for lead acetate.
[d] TRV is EC20 of the data provided by Edens and Garlich (1983), using dose-response curve developed by US EPA..
[e] TRVs are for DDT and metabolites.

5.4.4 Benchmark Concentrations for Benthic Invertebrates

Sediment benchmarks for benthic invertebrates for arsenic, lead, DDD and DDE are summarized in Table 5-11. The sediment quality guidelines provided by the MOE (2008) include multiple levels of effect, including:

- Lowest Effect Level (LEL): the level of contamination that can be tolerated by the majority organisms in sediment; and,
- Severe Effect Level (SEL): the level of contamination that is expected to be detrimental to the majority of organisms in sediment.

Table 5-11 Benchmarks for Sediment		
COC	***LEL (µg/g)***	***SEL (µg/g)***
Arsenic	6	33
Lead	31	250
DDD	0.008	0.3[a]
DDE	0.005	1[a]

[a] SEL provided in units of µg/g organic carbon by MOE (2009) and converted to value presented by multiplying by the fraction of organic carbon in on-site sediment (assumed 5% for Site).

5.4.5 Discussion of Uncertainty in the Hazard Assessment

Due to limitations in toxicity databases, wildlife TRVs selected in the hazard assessment may have been derived from toxicity data for laboratory species. This assumes that a similar toxic effect would occur in the target species as observed in the test species. Differences in the effects between the species create uncertainty in the applicability of the TRV to wildlife. The chemical form of the COC used to derive the TRV may differ from the form found in on-site soils or in food items. Every attempt was made to select TRVs for the form anticipated to be most representative of on-site contamination.

Soil benchmarks are meant to be conservative values designed to rule out risks, rather than predict risks. That is, concentrations below these levels can safely be assumed to not result in unacceptable impacts. However, concentrations which exceed these levels do not necessarily imply adverse effects will occur. Although individual benchmark concentrations for lead were not derived for plants and soil invertebrates by the MOE (2009), the selected values are assumed to be protective of both types of receptors. However, even though these benchmarks are protective of both receptor types, there may be differences in sensitivities, and use of these values to predict risks may over predict risks to the less sensitive of the two groups.

For the assessment of risks to plants, soil invertebrates and wildlife, the bioavailability of COCs in soil and diet was assumed to be equivalent to the bioavailability in the studies used to derive the benchmark concentrations and TRVs. If the bioavailability of COCs in on-site soil and diet items is greater or less than those used to develop the benchmarks and TRVs, the predicted risks may be under- or over-estimated, respectively.

5.5 Risk Characterization

There are several ways that ecological risks may be characterized. For the current ERA, the method used was the calculation of an "exposure ratio" (ER), which is a unitless value defined as:

Exposure Ratio = Level of Exposure / TRV (or Benchmark)

Exposure ratios are calculated for each VEC/chemical combination. If the ER is less than or equal to 1, no unacceptable risks to VECs would be expected. If the ER exceeds 1, the implication is that adverse ecological risks may occur, and either more assessment is required, or remedial measures or risk management must be considered.

When an ER greater than 1 was calculated for terrestrial receptors and soil-based pathways, the number of samples containing a concentration exceeding the benchmark (or leading to an ER>1) was noted. The benchmark concentrations and TRVs selected for use in the ERA are conservative and are designed to prevent the occurrence of adverse effects to sensitive plants, invertebrates and individual animals as a result of prolonged exposure to impacted soils. However, the MOE states that an RA is not required to be protective of individual plants, soil organisms or animals, and that the assessment should consider the spatial distribution of exceedances of selected benchmarks or TRVs. Therefore, if a chemical is found in less than 20% of the samples at concentrations above the effects-based concentration, for any given terrestrial receptor, the impact on that receptor population or community is considered to be within a range that is widely considered to be acceptable as well as within the range of natural variation and limit of detection.

The 20% level was selected because the most commonly-cited acceptable ecological benchmark is "less than 20% reduction in the abundance or production of an exposed endpoint population" (Suter *et al*., 1995). Suter *et al.* (1995) continue with two additional acceptable risk benchmarks: (1) loss of less than 20% of the species in an endpoint community in an area, and (2) loss of less than 20% of the area of an endpoint community in a specific area. Loss of more than 20% of a community may be considered acceptable if the community has negligible ecological value (*e.g*., a baseball field) or if the loss is brief because the community is adapting to physical disturbance (Suter *et al*., 1995). Suter *et al*. (1995) developed the 20% effect rule by reviewing the regulatory precedents in the United States (*e.g*., development of National Ambient Water Quality Criteria, the Office of Pesticide Programs pesticide testing with birds), while also recognizing the power of toxicity tests (*i.e*., tests used to regulate effluents cannot reliably detect less than a 20% reduction in the test endpoints), as well as understanding that 20% is approximately the limit of detection of many field measurement techniques (*e.g*., benthic invertebrate community metrics). In addition, a 20% change in the abundance of particular invertebrate species is often well within the range of natural variability. This 20% level was the first to be defined, and has since been used in ERAs and other programs in the US and Canada (*e.g*., the Canadian Environmental Effects Monitoring (EEM) programs).

Risks are estimated for aquatic VECs in Section 5.5.2, for terrestrial plants and soil invertebrates in Section 5.5.3, and for birds and mammals in Section 5.5.4. Property-specific standards (PSS) protective of all VECs are provided in Section 5.5.5.

5.5.1 Interpretation of Ecological Risks

The risks attributable to each COC for each VEC are quantitatively assessed in Sections 5.5.2 to 5.5.4. The effects-based concentrations presented therein reflect the soil concentrations required to produce an ER=1.

5.5.2 Quantitative Interpretation of Ecological Risks to Aquatic VECs

Risks to aquatic VECs within on-site watercourses were assessed as a result of COCs in groundwater and sediment.

5.5.2.1 Risks to Aquatic VECs as a Result of COCs in Groundwater

Risks were estimated to aquatic VECs in on-site water courses by comparing concentrations of sodium in groundwater to an adjusted benchmark that is protective of aquatic life during prolonged exposure (Table 5-12).

Table 5-12 Exposure Ratios for Aquatic Receptors Based on Maximum Groundwater Concentrations

COC	Maximum Groundwater Concentration (µg/L)	Benchmark Concentration (µg/L)	Exposure Ratio
Sodium	37,000	6,800,000	0.0054

As shown in Table 5-12, the maximum groundwater concentrations of sodium does not exceed its selected benchmark concentrations. Therefore, it is not expected that any unacceptable risks will occur to the aquatic VECs as a result of exposure to on-site groundwater after it enters on-site water bodies.

5.5.2.2 Risks to Benthic Invertebrates as a Result of Soil COCs in Sediment

Risks were estimated to sediment-based VECs in on-site surface water bodies by comparing concentrations of arsenic and lead in sediment to sediment quality guidelines protective of benthic invertebrates (Table 5-13).

Table 5-13 Comparison of Sediment Concentrations Against Ontario Sediment Quality Guidelines (MOE, 2008)

COC	Range of Sediment Concentrations (µg/g)	Number of Sediment Sampling Locations	Lowest Effect Level (LEL) (µg/g)	Severe Effect Level (SEL) (µg/g)
Arsenic	2 - 31.7	14	6	33
Lead	4 - 86.4	13	31	250
DDD	<0.005 - 0.013	7	0.008	0.3
DDE	<0.005 - 0.039	7	0.005	1

< Indicates that the concentration is lower than the value presented but cannot be more accurately quantified due to analytical uncertainty.

As shown in Table 5-13, the maximum on-site sediment concentrations of all COCs are greater than their respective LEL values. However, for each COC, a limited number of locations showed sediment concentrations exceeding twice the LEL (2xLEL) (3 for arsenic, 2 for lead, 0 for DDD, and 2 for DDE). Moreover, for some of these locations with concentrations exceeding 2xLEL, additional sampling at approximately the same location showed concentrations less than 2xLEL, showing variability in sampling and analysis. In addition, the on-site sediment concentrations for all COCs are below their respective SEL. Therefore, it was assumed that there are no unacceptable risks to benthic VECs from exposure to COCs in sediment at the Site.

All sediment data were obtained on-site from the Armitage Creek and its tributaries. No upstream data was provided. Details of sediment sampling locations and their respective COC concentrations are presented in Appendix C.

5.5.3 Quantitative Interpretation of Ecological Risks to Plants and Soil Invertebrates

Risks were estimated for terrestrial plants and soil invertebrates by comparing on-site soil concentrations to available benchmark concentrations as described in Section 5.4.2. The comparisons were made to the maximum soil concentrations. In addition, the number of sampling locations with concentrations in excess of the benchmark was determined to provide an indication of the spatial extent of soil contamination (Table 5-14).

As noted in Section 5.5, when the maximum concentration resulted in an ER>1, the number of samples containing concentrations exceeding the effects benchmark was recorded. For invertebrates exposed to arsenic, and both plants and invertebrates exposed to lead and DDE, although the ERs exceeded ER=1, the extent of exceedances was less than 20%, which was not considered significant. Although 38% of the sample locations have an arsenic soil exposure greater than the plant benchmark, there is no evidence on-site that plant communities are impacted (an urban forest community exists throughout the Site). This is clearly evidenced in the photographs presented in Figures 5-2a to 5-2b. Each of these photos (taken during peak growing season of August 2009) present areas of the Site with elevated levels of arsenic, including portions of the Site requiring targeted soil removal (as recommended in the current HHRA). In each case, no vegetation stress is evident. On-site areas identified as requiring remediation activities are identified in Section 7.0. Therefore, it was assumed that there are no unacceptable risks to plants from exposure to arsenic in soil at the Site.

The property-specific standard for those COCs with an ER>1 was set as the maximum concentration + 10%, to account for variability in sampling and analysis. Additionally, the PSS for DDD was conservatively set similarly since the benchmark is significantly larger than the maximum on-site soil concentration.

Fig. 5-2a. Southwest corner of Thomas Mulock Park (Parcel 1); treed area in background has elevated levels of arsenic (requiring remedial action) and lead.

Fig. 5-2b. Northwest corner of Northern Forested Lands (Parcel 3); elevated levels of arsenic and lead identified in topsoil in treed areas in background (but not in foreground).

Fig. 5-2c. Looking southwest along trail towards Northern Forested Lands (Parcel 3); elevated levels of arsenic and lead in highly vegetated areas (area requiring remediation shown in black circle).

Fig. 5-2d. Looking south along trail (Parcel 2); elevated levels of arsenic and lead identified on either side (no remediation required); no vegetative stress evident.

Figure 5-2(a-d) Ground-level Site Photographs Depicting Mature Vegetation Growth in Areas of Elevated Arsenic Levels

In summary, this assessment indicates that sensitive plants and soil invertebrates living within specific areas of contamination may be subject to adverse effects from lead and arsenic. Assuming that the sampling data represents an approximate spatial distribution of contamination in on-site soils, most of the Site contains soils that will allow communities of plants and soil invertebrates to successfully survive, grow and reproduce. As a result, risk management measures are not considered to be necessary to prevent or reduce exposure to these isolated areas of impacted soil. Therefore, the property-specific standards for arsenic and lead were set as the maximum concentration +10% to account for variability in sampling and analysis.

5.5.4 Quantitative Interpretation of Ecological Risks for Terrestrial Wildlife

Risks were estimated for avian and mammalian wildlife by estimating doses to each VEC and comparing them to acceptable TRVs, as described in Section 5.4.3. Exposure levels were estimated using the maximum soil concentrations to determine concentrations in food items (*i.e.*, earthworms and vegetation) and in soil ingested during feeding. A sample calculation for arsenic exposure is provided for each VEC. For each COC, an effects-based concentration (EBC) was derived to be protective of VEC. Where the estimated EBC significantly exceeded the maximum on-site concentration, the recommended property-specific standard was set as the maximum +10%, to account for variability in sampling and analysis.

Meadow Vole

No unacceptable risks (*i.e.,* ERs greater than 1) were predicted for the Meadow Vole exposed to the maximum concentration of any of the COCs in soil. This scenario assumed that the vole would obtain 100% of its diet from plants growing within soils containing each COC at the maximum concentration. Therefore, these COCs are not found in on-site soils at levels anticipated to cause unacceptable risk to individuals or populations of the vole using the Site as habitat under current conditions (Table 5-15). Effects-based concentrations (EBC) for the vole were back-calculated to be protective of an ER of 1.0. For those COCs where the EBC was significantly larger than the maximum on-site concentration (lead, DDD and DDE), the property-specific standard was set as the maximum concentration +10%, to account for variability in sampling and analysis.

The total estimated intake of arsenic for the Meadow Vole was calculated as follows:

$$EXP_{vole} = \frac{(C_{soil} \times ING_{soil-\%} \times FCR_{vole-dw}) + (C_{plant} \times FCR_{vole-dw})}{BW_{vole}}$$

where:

EXP_{vole}	=	Exposure (estimated daily intake) of arsenic for Meadow Vole (mg/kg-day dw)
C_{soil}	=	Concentration in soil (143 mg/kg)
$ING_{soil-\%}$	=	Soil Ingestion for Meadow Vole (2.4 % of diet)
$FCR_{vole-dw}$	=	Food Consumption Rate for Meadow Vole (0.0015 kg/day dw)
C_{plant}	=	Concentration in plant (2.2 mg/kg)
BW_{vole}	=	Body weight of Meadow Vole (0.044 kg)

Therefore, the predicted total intake of arsenic for the Meadow Vole is 0.19 mg/kg-day.

Short-tailed Shrew

No unacceptable risks (*i.e.,* ERs greater than 1) were predicted for the Short-tailed Shrew exposed to the maximum concentration of any of the COCs in soil. This scenario assumed that the vole would obtain 100% of its diet from soil invertebrates living within soils containing each COC at the maximum concentration. Therefore, these COCs are not found in on-site soils at levels anticipated to cause unacceptable risk to individuals or populations of the shrew using the Site as habitat under current conditions (Table 5-16). Effects-based concentrations (EBC) for the shrew were back-calculated to be protective of an ER of 1.0.

The total estimated intake of arsenic for the Short-tailed Shrew was calculated as follows:

$$EXP_{shrew} = \frac{(C_{soil} \times ING_{soil-\%} \times FCR_{shrew-dw}) + (C_{worm} \times FCR_{shrew-dw})}{BW_{shrew}}$$

where:

EXP_{shrew}	=	Exposure (estimated daily intake) of arsenic for Meadow Vole (mg/kg-day dw)
C_{soil}	=	Concentration in soil (143 mg/kg)
$ING_{soil-\%}$	=	Soil Ingestion for Short-tailed Shrew (3.0 % of diet)
$FCR_{shrew-dw}$	=	Food Consumption Rate for Short-tailed Shrew (0.0013 kg/day dw)
C_{worm}	=	Concentration in soil invertebrates (8.0 mg/kg)
BW_{shrew}	=	Body weight of Short-tailed Shrew (0.015 kg)

Therefore, the predicted total intake of arsenic for the Short-tailed Shrew is 1.1 mg/kg-day.

American Robin

No unacceptable risks (*i.e.,* ERs greater than 1) were predicted for the American Robin exposed to the maximum concentration of arsenic and DDD. Effects-based concentrations (EBC) for the robin were back-calculated to be protective of an ER of 1.0. However, the ERs for lead and DDE were calculated to be greater than ER=1. Of the 98 samples analyzed for lead, 15 (15% of total samples) were found at concentrations exceeding the calculated EBC of 120 µg/g. Similarly, of the 21 samples analyzed for DDE, only one was found at a concentration exceeding the calculated EBC of 0.38 µg/g. Because fewer than 20% of the samples were found to have lead and/or DDE concentrations in excess of the calculated EBC, lead and DDE are not anticipated to cause unacceptable risk to populations of robins using the Site as habitat under current conditions (Table 5-17). This scenario assumed that the robin would obtain 100% of its diet from soil invertebrates living within soils containing each COC at the maximum concentration.

The total estimated intake of arsenic for the American Robin was calculated as follows:

$$EXP_{robin} = \frac{(C_{soil} \times ING_{soil-\%} \times FCR_{robin-dw}) + (C_{worm} \times FCR_{robin-dw})}{BW_{robin}}$$

where:

EXP_{robin}	=	Exposure (estimated daily intake) of arsenic for American Robin (mg/kg-day dw)
C_{soil}	=	Concentration in soil (143 mg/kg)
$ING_{soil-\%}$	=	Soil Ingestion for American Robin (10 % of diet)
$FCR_{robin-dw}$	=	Food Consumption Rate for American Robin (0.015 kg/day dw)
C_{worm}	=	Concentration in soil invertebrates (8.0 mg/kg)
BW_{robin}	=	Body weight of American Robin (0.077 kg)

Therefore, the predicted total intake of arsenic for the American Robin is 4.3 mg/kg-day.

Table 5-14 Exposure Ratios for Plants and Soil Invertebrates at the Maximum Soil Concentration (µg/g)

COC	*Maximum Soil Concentration*	*Benchmark*		*Exposure Ratio*[a]		*% of All Samples in Excess of Lower Benchmark*		*Property Specific Standard*
		Plants	*Inverts*	*Plants*	*Inverts*			
Arsenic	143	22	60	**6.5**	**2.4**	38% (54 of 142)	4.2% (6 of 142)	160[b]
Lead	422	250		**1.7**		2.0% (2 of 98)		460[b]
DDD	0.024	8.5		0.0028		0%		0.026[cb]
DDE	0.44	0.33		**1.3**		4.8 (1 of 21)%		0.48[b]

Bolded values in grey scale exceed an ER of 1.0

[a] ER (Exposure Ratio) = Exposure / Benchmark.

[b] Value represents the maximum measured concentration (+ 10% to account for variability in sampling and analysis).

[c] Since the MOE does not support the derivation of property-specific standards that are significantly higher than the current maximum on-site concentrations, a value equal to the maximum +10% to account for variability in sampling and analysis was selected for each of these COCs.

Table 5-15 Exposure Ratios for the Meadow Vole

COC	*Total Estimated Intake (mg/kg/day)*	*Exposure Limit (mg/kg/day)*	*ER*[a]	*Effects-Based Concentration*[b] *(EBC) (µg/g)*	*% of All Samples in Excess of EBC*	*Property-Specific Standard (µg/g)*
Arsenic	0.19	1.3	0.15	1,200	0%	160[c]930
Lead	0.61	80.0	0.0077	9.1E+04	0%	460[cd]
DDD	3.0E-05	0.7	4.3E-05	560	0%	0.026[de]
DDE	4.6E-04	0.7	6.5E-04	670	0%	0.48[de]

[a] ER (Exposure Ratio) = Exposure / TRV.

[b] Percent of samples in excess of effects-based concentration calculated only for those COC where the ER is greater than 1.

[c] Value represents the maximum measured concentration (+ 10% to account for variability in sampling and analysis).Since the MOE does not support the derivation of property-specific standards that are significantly higher than the current maximum on-site concentrations, a value equal to the maximum +10% to account for variability in sampling and analysis was selected for each of these COCs.

[d] Value represents the maximum measured concentration (+ 10% to account for variability in sampling and analysis).

Table 5-16 Exposure Ratios for the Short-Tailed Shrew

COC	Total Estimated Intake (mg/kg/day)	Exposure Limit (mg/kg/day)	ER[a]	Effects-Based Concentration[b] (EBC) (µg/g)	% of All Samples in Excess of EBC	Property-Specific Standard (µg/g)
Arsenic	1.1	1.3	0.88	170	0%	170
Lead	10.6	80	0.13	4,800	0%	~~4,800~~460[c]
DDD	0.021	0.7	0.030	3.5	0%	0.026[c]
DDE	0.52	0.7	0.74	0.62	0%	0.62

[a] ER (Exposure Ratio) = Exposure / TRV.
[b] Percent of samples in excess of effects-based concentration calculated only for those COC where the ER is greater than 1.
[c] Since the MOE does not support the derivation of property-specific standards that are significantly higher than the current maximum on-site concentrations, a value equal to the maximum +10% to account for variability in sampling and analysis was selected for each of these COCs.

Table 5-17 Exposure Ratios for the American Robin

COC	Total Estimated Intake (mg/kg/day)	Exposure Limit (mg/kg/day)	ER[a]	Effects-Based Concentration[b] (EBC) (µg/g)	% of All Samples in Excess of EBC	Property-Specific Standard (µg/g)
Arsenic	4.3	13	0.34	470	0%	470
Lead	29	9.9	**2.9**	120	15% (15 of 98)	460[c]
DDD	0.05	1	0.046	1.9	0%	0.026[d~~e~~]
DDE	1.1	1	**1.1**	0.38	4.8% (1 of 21)	0.48[c]

Bolded values in grey scale exceed an ER of 1.0.
[a] ER (Exposure Ratio) = Exposure / TRV.
[b] Percent of samples in excess of effects-based concentration calculated only for those COC where the ER is greater than 1.
[c] Since the MOE does not support the derivation of property-specific standards that are significantly higher than the current maximum on-site concentrations, a value equal to the maximum +10% to account for variability in sampling and analysis was selected for each of these COCs.
[d] Value represents the maximum measured concentration (+ 10% to account for variability in sampling and analysis).
~~[e] Value represents the maximum measured concentration (+ 10% to account for variability in sampling and analysis).~~

5.5.5 Property-Specific Standards Protective of Ecological Receptors

Property-specific groundwater standards were developed to be protective of aquatic receptors living within on-site surface water bodies (Armitage Creek and its tributaries) which may be impacted by migrating groundwater. Property-specific soil standards were developed to be protective of plant and soil invertebrate communities, and avian and mammalian populations present on the Site.

Property-Specific Groundwater Standards

Property-specific standards are presented in Table 5-18 for chemicals in groundwater that were identified as COCs in Section 3. For lead (in excess of the Site Condition Standard but below the GW3 component value), a quantitative evaluation was not completed and the 2009 Table 8 GW3 value was set as the PSS. No Table 1 Site Condition Standard was available for either barium or chloride, but since their maximum concentrations were below their respective GW3 values, the GW3 was also selected for the barium and chloride PSS. Since ecological effects-based concentration for sodium (6,800,000 µg/L) is significantly larger than the maximum on-site groundwater concentration, the PSS was set as the maximum measured concentration +10%, to account for variability in sampling and analysis.

Table 5-18 Property-Specific Groundwater Standards Protective of Ecological Receptors (µg/L)

COC	*Maximum Groundwater Concentration (µg/L)*	*Table 1 Site Condition Standard (µg/L)*	*Property-Specific Standard (µg/L)*	*Basis of Aquatic PSS*	*Risk Management Requirement[a]*
Barium	96	NV	23,000	Table 8 GW3 Component Value	No
Lead	1.21	1	20	Table 8 GW3 Component Value	No
Chloride	300,000	NV	1,800,000	Table 8 GW3 Component Value	No
Sodium	37,000	NV	41,000	Maximum Concentration + 10%	No

NV Indicates that no value is available.

Property-Specific Soil Standards

Property-specific standards have been developed for all chemicals in soil that exceeded the Table 1 Site Condition Standards or for which no Site Condition Standards are available. For boron (in excess of the Site Condition Standard but below its ecological component values), a quantitative evaluation was not completed and the PSS was set at the ecotoxicity component value. The final PSS for the COCs retained for quantitative evaluation in the ERA was set as the lowest of the PSSs protective of individual receptor groups (*i.e.*, plants, invertebrates, birds, and mammals). All property-specific standards are presented in Table 5-19.

Table 5-19 Property-Specific Soil Standards Protective of Ecological Receptors (µg/g)

COC	***Maximum Soil Concentration***	***Table 1 Site Condition Standard***	***Table 2 Ecotoxicity Component Value***	***Property-Specific Standards Protective of Individual Receptor Groups***				***Final Eco Effects-Based Concentration***	***Basis of Final Eco Effects-Based Concentration***	***Risk Management Requirement***
				Plants and Soil Inverts	***Meadow Vole***	***Short-tailed Shrew***	***Birds***			
Arsenic	143	17	25	160	~~1,200~~160	170	470	160	Maximum concentration + 10%	No
Boron	0.77	NV	1.5	-	-	-	-	1.5	2009 Table 2 Ecotoxicity Component Value	No
Lead	422	120	NV	460	460	~~4,800~~460	460	460	Maximum concentration + 10%	No
DDD	0.024	NV	NV	0.026	0.026	0.026	0.026	0.026	Maximum concentration + 10%	No
DDE	0.44	NV	NV	0.48	0.48	~~1.9~~0.62	0.48	0.48	Maximum concentration + 10%	No

NV Indicates that no value is available.
\- Indicates that this pathway was not quantitatively assessed.

5.5.6 Qualitative Interpretation of Ecological Risks

A qualitative interpretation of risks was completed in the current ERA in the form of a secondary chemical screening step using appropriate generic standards and component values recommended by MOE (2009). Property-specific standards for those COCs not retained for quantitative evaluation were based on 2009 generic standards and component values and are provided in Tables 5-18 and 5-19.

5.5.7 Interpretation of Off-Site Ecological Risks

The property-specific ecological standards proposed in Tables 5-19 and 5-20 are not anticipated to result in the occurrence of unacceptable risks to ecological receptors at the nearest receptor location located off the RA property. Based on the characterization of risks to aquatic receptors in on-site bodies of surface water, unacceptable risks are not expected to occur to aquatic receptors at any off-site locations if contaminants were found on-site at the proposed standards. The property-specific ecological standards for groundwater are based on the assumption that aquatic receptors would be directly exposed to these concentrations for a chronic duration and that a conservative 10-fold dilution would occur within the surface water.

The property-specific ecological soil standards are designed to be protective of plants, soil invertebrates, and mammals through direct contact and ingestion of food items. No unacceptable risks are anticipated to occur to on or off-site terrestrial receptors as a result of exposure to COCs in soil.

5.5.8 Discussion of Uncertainty in the Risk Characterization

In any RA, the findings are based on available data from the specific site, and the scientific literature, in conjunction with a number of assumptions. Every effort is made to ensure these assumptions and data adequately represent conditions at the site. However, data and scientific understanding of key environmental processes and factors can often be limited, resulting in uncertainty in the assessment. Varying degrees of uncertainty are introduced at all stages of the RA process. In order to clearly interpret the results of any RA, the major sources of uncertainty must be acknowledged and documented. Where uncertainty exists, assumptions are made, and data are selected so as to err on the conservative side. This ensures that potential impacts are much more likely to be overestimated rather than underestimated. This precautionary approach is in accordance with the ultimate goal of RA - protection of the environment. Some key sources of uncertainty associated with the current ERA that are likely to result in the over-prediction of risks include:

- Screening benchmarks and TRVs from the literature and regulatory agencies for soil invertebrates, plants, aquatic receptors and wildlife are meant to be conservative and rule out risks, rather than predict risks. That is, concentrations or doses below these levels can safely be assumed to not result in unacceptable impacts. However, concentrations which exceed these levels do not necessarily imply adverse effects will occur. Use of these values for the purpose of predicting risks is likely to result in the derivation of conservative ER and PSS values;
- It was assumed that 100% of the diet of the robins and the shrews was composed of earthworms living in on-site soils. It is more realistic to assume that their diets would be composed of other food items, such as fruits, seeds, and arthropods, that would not contain levels of COCs as high as those predicted to be found in earthworms;

- It was assumed that the Meadow Vole, Short-tailed Shrew and American Robin would only consume food items living and growing within on-site soils that contain COCs at the maximum measured concentration. It is more realistic to assume that a population of wildlife would forage throughout a larger area that contained soils with average COC concentrations significantly lower than the maximum concentrations;
- It was assumed that all COCs in soil were 100% bioavailable for wildlife receptors.
- Risks predicted using the ER approach are for individual organisms, whereas the assessment endpoint for the ERA is focused on the protection of populations of wildlife and communities of plants and invertebrates; and,
- The assessment of risks to terrestrial receptors considered the maximum concentrations of COCs in soil as well as the spatial distribution of soils with COC concentrations above effects-based concentrations across the Site. Given that the ERA is not intended to be protective of individual organisms, but rather receptors on a population or community level, the consideration of the spatial extent of contamination provides a more realistic indication of potential ecological risk. This was accomplished by comparing the effects-based concentrations protective of ecological receptors to each individual sample concentration and calculating the percentage of samples that exceeded these values. This approach assumed that the soil sampling programs have accurately delineated the extent of COC contamination throughout the property and that the available samples are spatially representative of this contamination. It is recognized that the percentage of samples in excess of an effects-based concentration is not equivalent to the percentage of the Site area above this concentration; however, given that there were a significant number of soil samples collected from across the Site, it is anticipated that this approach does provide a fair representation of the spatial extent of contamination. Given that on-site sampling was biased towards the areas requiring delineation of contamination, it is anticipated that this approach will have resulted in an overestimation of risks for the Site as a whole.

Overall, uncertainties were addressed through the selection of conservative exposure point concentrations, wildlife characteristics, and toxicity values that would result in the overestimation of exposure and risks. These uncertainties likely resulted in a significant overestimation of risks to populations of birds and mammals, and communities of plants, soil invertebrates, and aquatic receptors.

6.0 CONCLUSIONS / RECOMMENDATIONS

The main findings from the RA were as follows:

1) Because no volatile COCs were evaluated in the RA, there is no indication of unacceptable health risks to human receptors *via* inhalation of vapours migrating from impacted groundwater or soil;

2) No groundwater COCs were retained for quantitative evaluation in the HHRA; therefore, no receptor is anticipated to be subject to risks above allowable levels as a result of direct or indirect exposure to groundwater;

3) On-site construction workers may be subject to risks above allowable levels as a result of inhalation of airborne soil and dust impacted by arsenic (however, because no construction activities are anticipated on the parkland Site, this scenario was not included in the derivation of final property-specific standards);

4) Maintenance workers and parkland visitors on-site may be subject to risks above allowable levels as a result of direct contact with arsenic in soil;

5) There is no indication of unacceptable risks to off-site residential receptors as a result of inhalation of impacted airborne soil and dust migrating from the Site;

6) There is no indication of unacceptable risks to on- or off-site aquatic receptors (in either surface water or sediment) as a result of the migration of impacted groundwater and soil; and,

7) Although there is potential for localized risks to sensitive terrestrial plants and soil invertebrates as a result of exposure to arsenic, lead and DDE in on-site soil, it is anticipated that overall on-site populations of these receptors will not be subject to unacceptable risks. Similarly, although there is potential for localized risks to birds as a result of exposure to lead and DDE in on-site soil, on-site populations of these receptors are not anticipated to be subject to unacceptable risks.

6.1 Recommended Property-Specific Standards

The final property-specific soil and groundwater standards are designed to be protective of human health and ecological receptors. Since the Site is deemed environmentally sensitive, standards were derived for those chemicals in excess of Table 1 Standards (or for which no Standards are available). However, it was demonstrated in the RA that Table 2 Site Condition Standards are appropriate as a secondary chemical screening step under a residential/parkland/institutional land use.

Table 6-1 provides the final property-specific groundwater standards protective of a parkland land use. Tables 6-2 provides the final property-specific soil standards, with the recommendation of targeted soil removal (to be completed before filing an RSC) to limit potential exposure to soils impacted by arsenic.

Table 6-1 Final Property-Specific Standards for Chemicals in Groundwater (µg/L)

COC	***Maximum Groundwater Concentration***	***Table 1 Site Condition Standard***	***Property-Specific Standard***	***Basis of Property-Specific Standard***	***Risk Management Requirement***
Barium	96	NV	1,000	2009 Table 8 Site Condition Standard	No
Lead	1.21	1	10	2009 Table 8 Site Condition Standard	No
Chloride	300,000	NV	790,000	2009 Table 8 Site Condition Standard	No
Sodium	37,000	NV	41,000	Maximum Concentration + 10% (protective of direct contact for on-site aquatic VECs)	No

NV Indicates that no value is available.

Table 6-2 Final Property-Specific Standards for Chemicals in Soil (µg/g)

COC	***Maximum Soil Concentration***	***Table 1 Site Condition Standard***	***Property-Specific Standard***	***Basis of Property-Specific Standard***	***Risk Management Requirement***
Arsenic	143	17	~~60~~58	Lowest PSS protective of direct soil contact for parkland visitor	~~No~~ Yes (targeted soil remediation required prior to filing of RSC; administrative RMM required to mitigate future risks)
Boron	0.77	NV	1.5	2009 Table 2 Site Condition Standard	No
Lead	422	120	460	Maximum concentration + 10% (protective of plants, soil invertebrates and birds)	No
DDD	0.024	NV	0.026	Maximum concentration + 10% (protective of birds)	No
DDE	0.44	NV	0.48	Maximum concentration + 10% (protective of plants and soil invertebrates)	No

NV Indicates that no value is available.

6.2 Consideration of Risks from Property-Specific Standards

To ensure that the property-specific standards (PSSs) derived in the current RA are protective of both human health and the environment, the MOE requires that risks be assessed using the PSSs as exposure point concentrations. Therefore, the PSSs provided in Tables 6-1 and 6-2 were first used in an additional qualitative assessment that ensures suitable protection.

6.2.1 Groundwater

Because MOE (2009) Table 8 Site Condition Standards (and their accompanying component values) for groundwater were used in the qualitative assessments in the HHRA and ERA, these Standards were used in a comparison with the groundwater PSSs, as shown in Table 6-3.

Table 6-3 Qualitative Assessment of Risks in Groundwater Using Comparison with MOE (2009) Site Condition Standards (µg/L)

COC	*Property-Specific Standard*	*MOE (2009) Table 8 SCS*
Barium	1,000	1,000
Lead	10	10
Chloride	790,000	790,000
Sodium	41,000	490,000

As shown in Table 6-3, the property-specific standard for each COC in groundwater is below (or equal to) its respective Table 8 Standard (MOE, 2009), where available. Therefore, it was assumed that there are no potential unacceptable risks associated with the PSSs derived for groundwater COCs. Moreover, although the MOE has not provided a GW3 component value for sodium, it was demonstrated in the current ERA that no unacceptable risks to aquatic organisms are present due to migration of impacted groundwater to on-site or off-site surface water bodies.

6.2.2 Soil

As discussed in Sections 4.1 and 5.1.1, the Table 8 Site Condition Standards (MOE, 2009) and their related component values were considered appropriate for a qualitative assessment of potential risks for COCs in soil in both the HHRA and ERA. Therefore, these Standards were used in a comparison with the final soil PSSs, as shown in Table 6-4.

Table 6-4 Qualitative Assessment of Risks in Soil Using Comparison with MOE (2009) Site Condition Standards for Residential/Parkland/Institutional Property Use and Medium to Fine Textured Soil (µg/g)

COC	*Property-Specific Standard*	*MOE (2009) Table 8 SCS*
Arsenic	~~60~~58	18
Boron (HWS)	1.5	1.5
DDD	0.026	0.05
DDE	0.48	0.05
Lead	460	120

As shown in Table 6-4, the property-specific standards for boron (HWS) and DDD in soil are equal to or below their respective Table 8 Standard (MOE, 2009). However, the PSSs for arsenic, lead and DDE are greater than their respective Table 8 SCSs. Therefore, these three COCs were retained for further evaluation of risks based on their PSSs.

Risks to Human Health from Property-Specific Soil Standards

As discussed in Section 4.2 of the HHRA, the maximum soil concentrations of each COC was compared to the Table 2 S1 human health component value protective of a child under a residential exposure scenario as a result of direct contact with impacted soil for a residential/parkland/institutional property use and medium to fine texture soil. The same approach was taken with the PSSs, as shown in Table 6-5 (as discussed in Section 4.2, the S-GW1 component value was not considered in this qualititative evaluation since it was assumed that the groundwater is sufficiently characterized and that the leaching of COCs in soil is already accounted for in groundwater analysis).

Table 6-5 Comparison of Final Property-Specific Soil Standards with Table 2 S1 Component Value for Residential/Parkland/Institutional Property Use and Medium to Fine Textured Soil (µg/g) (MOE, 2009)

COC	***Property-Specific Standard***	**S1 Human Health Component Value**
Arsenic	~~60~~58	0.95
DDE	0.48	2.3
Lead	460	200

As shown in Table 6-5, the final PSS for DDE is below its respective S1 component value. Therefore, DDE was not considered for quantitative evaluation (*i.e.*, the PSS is protective of human health for DDE). Because the PSSs for arsenic and lead are below their respective S1 component values, each was retained for quantitative assessment in the current evaluation.

Using the same methods described in Section 4.3 to 4.5, the following total risks were identified for arsenic and lead using the PSSs as exposure point concentrations (Figure 6-6). Note that the construction worker and on-site resident exposure scenarios are not included in this evaluation since they were not considered to be realistic receptors on the forested and trail areas of the Site designated to remain as parkland in perpetuity (refer to Sections 4.2.3 and 4.5.2 for details). Additionally, the final PSS derived for arsenic is based on carcinogenic endpoints to human receptors, and it takes into account background concentrations (17 µg/g). Therefore, the carcinogenic arsenic calculation results provided in Table 6-6 are estimated using the non-adjusted standard of 43 µg/g. This was done since the ILCR represents an incremental cancer risk above background.

Table 6-6 Total ER/CR and ILCR Values for Arsenic and Lead Based on Property-Specific Soil Standards

COC	***Property-Specific Standard (µg/g)***	***Maintenance Worker[a]***	***Off-Site Local Resident[a]***	***Forested Area Parkland Visitor[a]***
Non-Carcinogens				
Arsenic	~~60~~58	0.0057~~61~~	1.4~~9~~x10^{-4}	0.03~~9~~6
Lead	460	0.0070	3.4x10^{-6}	0.045
Carcinogen				
Arsenic	~~60~~58[b]	~~6.6~~8.4x10^{-7}	2~~3~~.3x10^{-9}	1.0~~1~~x10^{-6}

[a] The value provided for non-carcinogens is the total ER/CR, and the value for carcinogens is the total ILCR.

[b] Because the arsenic PSS is based on carcinogenic endpoints and takes into account background concentrations (17 µg/g), the concentration used in the calculations for Table 6-6 is 4~~3~~1 µg/g (*i.e.*, ~~60~~ 58 µg/g minus 17 µg/g).

As shown in Table 4-6, all the ER/CR values are below the acceptable ratio of 0.2 as a result of oral and dermal exposures to arsenic and lead. Additionally, the carcinogenic risks for arsenic were also below the acceptable cancer risk of 1-in-1,000,000 ($1x10^{-6}$), with the exception of the parkland visitor for which the ILCR = $1.1x10^{-6}$. This exceedance is an artifact of rounding during the calculation process. Moreover, due to the significant sources of error and conservatism built into the evaluation process, an ILCR of $1.1x10^{-6}$ was not considered significant. Therefore, it was assumed that not unacceptable risks to human health are anticipated based on the final property-specific standards.

Risks to Ecological Health from Property-Specific Soil Standards

As discussed in Section 5.1.1 of the ERA, the maximum soil concentrations of each COC was compared to the MOE (2009) Table 2 ecotoxicity component values protective plants and soil invertebrates under a residential land use and medium to fine texture soil, as well as to the MOE (2009) Table 8 Site Condition Standards, reflective of a site within 30 metres of a surface water body. Because a comparison with MOE (2009) Table 8 Site Condition Standards was already made in Table 6-4, only the eocotoxicity component value comparisons with the PSSs are presented in Table 6-7.

Table 6-7 Comparison of Property-Specific Soil Standards to MOE (2009) Ecotoxicity Component Values for Medium to Fine Textured Soils and Parkland Land Use (µg/g)

COC	*Property-Specific Standard*	*2004 Table 1 Site Condition Standard*	*2009 Table 2 Ecotoxicity Component Values*	
			Plants and Soil Organisms	*Mammals and Birds*
Arsenic	6058	17	25	51
DDE	0.48	NV	0.33	NV
Lead	460	120	310	32

NV Indicates that no value is available.

As shown in Table 6-7, the property-specific soil standard for each of arsenic, lead and DDE exceeds both of its respective ecotoxicity component values. Therefore, each COC requires a quantitative evaluation. As done in the ERA, Table 6-8 presents the exposure ratios for these three COCs and the VECs assessed, using the PSSs derived.

Table 6-3 Ecological Exposure Ratios for Each COC Retained for Quantitative Evaluation Based on Property-Specific Soil Standards

COC	*Property-Specific Standard (µg/g)*	*ER Plants*	*ER Soil Invertebrates*	*ER Meadow Vole*	*ER Short-tailed Shrew*	*ER American Robin*
Arsenic	6058	**2.7**	1.0	0.076	0.44	0.16
DDE	0.48	0.81	0.81	0.00071	0.80	**1.2**
Lead	460	**1.8**	**1.8**	0.0082	0.14	**3.1**

Bolded values in grey scale exceed an ER of 1.0.

As shown in Table 6-8, the ER value predicted for arsenic and on-site plants exceeded the acceptable value of ER=1. Additionally, the ER value for DDE and the robin, as well as the ERs for lead with plants, soil invertebrates and the robin. However, as discussed in Sections 5.5.3 and 5.5.4, no unacceptable risks populations of each of these VECs are anticipated. This is because in each case where the ER>1, the PSS is greater than the effect-based concentration used to evaluate spatial impacts (as presented in Section 5.5.3 and 5.5.4). Therefore, it is assumed that no unacceptable risks to ecological receptors are anticipated to be present based on the property-specific soil standards derived in the revised RA.

7.0 RISK MANAGEMENT PLAN

7.1 Overview

The Risk Management Plan (RMP) for the site consists of two primary components:

1. Remediation by targeted removal of small areas of impacted soil and reestablishment of any disturbed vegetation

2. Filing a Record of Site Condition (RSC) with Risk Management Measures (RMM) that will likely include a Certificate of Property Use (CPU) registered on title.

The first component of the RMM will be conducted by an appropriately qualified remediation contractor with environmental consultant oversight. The work will be conducted in accordance with a Site Specific Health and Safety Plan (SSHSP), prepared by the remediation contractor specifically for the work and based on the environmental data set. This work does not fall under the landuse and exposure limitations used in the RA, as the SSHSP will provide the appropriate protection as per the Occupational Health and Safety Act (OHSA) for the qualified professionals conducting the remediation. Only when this is completed can the preparations for filing a RSC begin.

The second component involves developing the RMM with input from stakeholders, as outlined in the public consultation process. Stakeholders providing input to the RMM would include:

- MOE
- Town of Newmarket
- Region of York (Health Services)
- Advancement landowners
- Park visitors
- General public.

A commitment has been made to these parties to involve them and obtain their input into the draft RMM. This process will begin following the acceptance of the RA,

The current RA has evaluated human health ~~risks both with the recommendation that remediation measures are taken to reduce human health risks~~ *via* inhalation of airborne soils, as well as incidental ingestion and direct dermal contact with impacted on-site soils. Soil remediation measures ~~includ~~including~~e~~ a limited amount of targeted removal of impacted soil, to be completed prior to filing a~~n~~ RSC, is necessary to mitigate incidental ingestion and direct dermal contact risks for parkland visitors. The ~~R~~results of the current RA indicate that the extent of soil removal would be small enough to ensure that the woodlots remain undisturbed. A ~~(~~areas requiring soil remediation/removal are presented in Figure 7.1~~)~~. In addition, ~~a~~ property use constraints and other administrative measures ~~that precludes the development of residential properties may be~~ are required to prevent or reduce exposure to COCs in soil *via* ingestion and direct dermal contact for other potential receptors. These administrative risk management measures (RMM) would include:

- Restriction on residential development on all four parcels
- Restriction on changes in current park configuration onof all four parcels
- Fencing and controlled access to parcels 1, 3 and 4
- A prohibition on construction work on the RA lands; including a prohibition on the use of the subject lands for installation of subsurface utilities

Use of RMM of this nature , which at the MOE Directors discretion, may then require issuance of a cCertificate of pProperty uUse (CPU) restriction (Section 51 of O. Reg. 153/04) for the property.

Because arsenic is found in soil at concentrations that exceed human health effects-based concentrations in limited locations, those areas requiring soil remediation/removal are presented in Figure 7.1.

7.17.2 Risk Management Plan and Risk Management Measures

Soil remediation measures include a limited amount of targeted removal of impacted soil prior to filing an RSC (see Figure 7-1). All remediation activities will be conducted prior to the issuance of the RSC and CPU (including RMM and administrative restrictions). These activities will be carried out by a contaminated sites specialist contractor with environmental consultant oversight.

The RA includes a number of assumptions that constitute administrative RMM to ensure no unacceptable risks to on and off site receptors. These restrictions include:

- Land use designations limiting the future use and development of the lands (*i.e.*, no residential development)
- Designation of the parklands and their configurations
- Controlling access to the sites by a variety of methods potentially including:
    - Selected areas of fencing
    - Maintenance of restrictive vegetation
    - Other access controls and physical detractions to human use as needed
- Limitations on construction activities and workers, except for skilled remediation specialist's contractors and consultants conducting remediation of the COC's. The contractors and consultantsfconsultants will have the skills to address contaminant issues through the use of a Site Specific Health and Safety pPlan (SSHSP) of their specific tasks. This work does not need to be addressed as a RMM and included with the CPU since it will be conducted prior to filing of the RSC.

The RMM will be included in a CPU.

Targeted remediation prior to the submission of RSC is not included in the CPU. The CPU will however include RMM intended to limit the exposure of site workers and the public, to the degree specified in the RA.

These RMM will include:

- Access limits for site workers conducting forest maintenance for limited periods of time
- Maintenance of natural dense vegetation and enhancement of vegetation, to deter casual visitors and limit exposure (Note, that vegetation of remediated areas will be conducted by the remediation contractor and environmental consultant, as part of the remedial activities prior to the RSC and CPU).
- No utilities will be installed on the site and therefore no construction work scenarios
- No construction work will be conducted with the exception of minor maintenance of the forest and lands, to ensure the forest cover stays intact and erosion is minimized
- Limit on development to parkland use only (no residential use)
- Limit parkland use to vegetated woodlands with sufficient density of vegetation to deter access
- Restrict the development of more active park uses such as sports fields
- Maintain current zoning as Oak Ridges Moraine Environmental Protection
- Prohibition on gates from yards backing onto the lands
- Requirements to maintain fencing (without gates) between residential lots and the lands
- Encouraging vegetation and increasing vegetation density across site to deter casual access to the lands
- Limiting the slash back along trails to 2 m
- Establishing fencing, dense vegetation, at strategic locations to deter access to the site.

Communication of the RA, RMM including risk to park visitors, off site residents, and general public is part of the Public Communications Plan in Section 8.0.

The RA assumes limited access to the lands and limited exposure risk, due to the limited activities carried out in the lands and the limited duration of time spent on the land, as well as the maintained condition of the lands (densely vegetated).

The administrative controls/restrictions and physical conditions of the site (maintained in perpetuity) are part of the RMM described above. The remediation work is part of the RMP but the details of the work and restoration of the vegetation are not described in detail as a RMM, as the work will be conducted by contaminated sites specialists prior to filing the RSC and preparing the CPU. The remediation work does not require the protection of the RA and RMM. The risk management measure in the form of a certificate of property use (CPU) restriction (Section 51 of O. Reg. 153/04)
~~to prohibit the construction or use of on-site residential developments may be required to prevent or reduce exposure to COCs in soil *via* ingestion and direct dermal contact.~~

7.1.1 7.2.1 Risk Management Performance Objectives

The Risk Management performance o~~O~~bjective is to limit exposure as defined in the RA using the RMM included in the CPU in perpetuity. Refer to the RA for exposure limits and required restrictions to limit exposure. Refer to the RMM as the objective to be maintained for the site for all times.
~~Not applicable.~~

7.1.2 7.2.2 Risk Management Measures

The Risk Management ~~Plan~~ Measures (RMM) includes:

- Requirement that all activities for remediation prior to the issuance of the RSC and CPU (including RMM) be done by a contaminated sites ~~specialists~~specialist's contractor with environmental consultant oversight (as described above)~~.~~

- RMM that will be included in the CPU.

~~Not applicable.~~

7.1.3 7.2.3 Duration of Risk Management Measures

~~In perpetuity as outlined in the RMM in the CPU.~~
~~Not applicable.~~The Risk Management Measures will be established to remain in place in perpetuity.

7.1.4 7.2.4 Requirements for Monitoring and Maintenance

~~Monitoring and maintenance of the vegetation, access controls are~~ to be outlined in the RMM to be included in the CPU. No analytical monitoring is required as part of the RMM just inspections, vegetation maintenance, and administrative controls~~An on-going monitoring and maintenance program was not deemed necessary for the RA property.~~

The details of the RMM will be developed in consultation with the stakeholders, to meet the expense restriction outlined in the RA. These details can only be finalized after the consultation process. Once the RMM details are finalized they will be included in the CPU.

FIGURE A

TOWN OF NEWMARKET

PARKLANDS AT MULOCK DR. & BATHURST ST.

PHASE 2 - E.S.A. - JANUARY 2010

AREAS REQUIRING RISK MANAGEMENT / REMEDIAL ACTION

N

LEGEND

- APPROXIMATE PROPERTY OUTLINES
- APPROXIMATE BUFFER AREA AROUND RESIDENTIAL DEVELOPMENT
- MAXIMUM EXTENT OF FORMER ORCHARDS
- SED-20 1.8 (Pb–261) — SEDIMENT SAMPLE LOCATION WITH ARSENIC & LEAD CONCENTRATION IN SEDIMENT (µg/g) By Burnside August 2009
- SS-5 1.8 (Pb–261) — SOIL SAMPLE LOCATION WITH ARSENIC & LEAD CONCENTRATION IN SOIL (µg/g) By Burnside August 2009
- B-20 1.8 (Pb–261) — SOIL SAMPLE LOCATION SUBMITTED FOR BIOAVAILABILITY ANALYSIS WITH ARSENIC & LEAD CONCENTRATION IN SOIL (µg/g) By Burnside August 2009
- SW-4 1.8 (Pb–261) — SURFACE WATER SAMPLE LOCATION WITH ARSENIC & LEAD CONCENTRATION IN WATER (µg/L) By Burnside August 2009
- MW-A — MONITORING WELL LOCATION WITH ARSENIC, LEAD & BORON CONCENTRATIONS By Burnside October & November 2009

	DEPTH	As	Pb	B
IN SOIL (µg/g) -	0.8m	3	10.2	<0.1
IN GROUNDWATER - (µg/L)	MW–B	0.91	11.3	<0.05

- MSS-1 23.72 — MULTIPLE SOIL SAMPLE LOCATION & AVERAGE ARSENIC CONCENTRATION IN SOIL (µg/g) By Burnside December 22 & 23, 2008
- SS-1 1.8 — SOIL SAMPLE LOCATION & ARSENIC CONCENTRATION IN SOIL (µg/g) By Burnside August 5 & 6, 2008
- 2 — SOIL SAMPLE & ARSENIC CONCENTRATION (µg/g) By MMM Group Ltd., July - Sept. 2007
- 3 — SEDIMENT SAMPLE & ARSENIC CONCENTRATION (µg/g) By MMM Group Ltd., September 2007
- 6 — SOIL SAMPLE & ARSENIC CONCENTRATION (µg/g) By MMM Group Ltd., September 2007, March 2008
- 3 — TOPSOIL & SUBSOIL SAMPLE & ARSENIC CONCENTRATION (µg/g) By MMM Group Ltd, July 2008
- 2 — VERIFICATION SOIL SAMPLE & ARSENIC CONCENTRATION (µg/g) By MMM Group Ltd, November 2007 & June 2008
- 1 — SOIL SAMPLE, REG 153 METALS & ARSENIC CONCENTRATION (µg/g) By MMM Group Ltd, July 2008
- 3 — VERIFICATION TOPSOIL SAMPLE & ARSENIC CONCENTRATION (µg/g) By MMM Group Ltd, July 2008
- 3 — GROUNDWATER SAMPLE LOCATION & ARSENIC CONCENTRATION (µg/L) By MMM Group Ltd. Dec. 2007
- 3 — SURFACE WATER SAMPLE LOCATION & ARSENIC CONCENTRATION (µg/L) By MMM Group Ltd. January 2008
- 41.8 — ARSENIC CONCENTRATION IN SOIL ABOVE THE MOE TABLE 1 STANDARD (µg/g)
- 41.8 — ARSENIC CONCENTRATION IN SEDIMENT ABOVE THE MOE TABLE 1 STANDARD (µg/g)
- (Pb–44.8) — LEAD CONCENTRATION IN SOIL ABOVE THE MOE TABLE 1 STANDARD (µg/g)
- (Pb–44.8) — LEAD CONCENTRATION IN SEDIMENT ABOVE THE MOE TABLE 1 STANDARD (µg/g)
- 1.5 — OC PESTICIDE CONCENTRATION IN SEDIMENT ABOVE MOE TABLE 1 STANDARD (µg/g)

TABLE 1 STANDARDS	(µg/g)		(µg/L)
	SOIL	SEDIMENT	GROUNDWATER
As	17	6	25
Pb	120	31	1
DDD	NV	0.008	0.025
DDE	NV	0.005	0.01
DDT	1.4	0.007	0.05
B	NV	NV	200

- AREAS REQURING RISK MANAGEMENT / REMDIAL ACTION INTERPRETED TO HAVE ARSENIC CONCENTRATIONS IN THE TOPSOIL (<0.3m depth) IN EXCESS OF 60(µg/g)

NOTES:

- SAMPLES COLLECTED FROM PRIVATELY OWNED RESIDENTIAL LAND ARE NOT SHOWN WITH THE EXCEPTION OF THE VERIFICATION SAMPLES FROM SUMMERHILL WOODS.
- SAMPLES COLLECTED FROM THE BUFFER LANDS AROUND SUMMERHILL WOODS PRIOR TO REMEDIATION ARE NOT SHOWN. ONLY THE POST REMEDIATION (CURRENT CONDITIONS) RESULTS ARE SHOWN.

Air Photo Source:
Background colour air photo circa 2007-2008 obtained from Google Earth Pro & from First Base Solutions Inc.

0 10 20 30 40 50 60 70 80 90 100
Metres

Scale 1:1,500
January 2010
Project Number: D24650

Projection: UTM Zone 17
Datum: NAD83

Prepared by: C. Sheppard
Verified by: J. Walls

BURNSIDE

D24650 PARKLANDS PH-2 ESA JAN 2010 REMEDIAL ACTION AREAS.dwg

Plot Time: Feb 12, 2010–2:17pm

8.0 PUBLIC COMMUNICATIONS PLAN

Through the development approval process, The Town of Newmarket was informed by Criterion, a local developer, that arsenic was detected in the soil in the vicinity of Mulock and Bathurst. The Town became aware of the situation in September 2007, at which time on-going investigations were conducted to delineate the extent of impacts. Once the option of risk assessment was confirmed to be preferred, the Town put in place a public communications strategy as outlined below.

8.1 Objectives

- To inform residents of the situation and to share our understanding of the information provided to us;
- To provide assurances regarding public health and safety where appropriate;
- To inform residents on how The Town of Newmarket is coordinating all applicable agencies to proactively manage the matter and protect public health and safety;
- To inform residents that the Town of Newmarket is commencing a process called an environmental risk assessment on the woodlot and trail lands, in conjunction with the Ministry of the Environment, Medical Officer of Health and a team of environmental specialist to determine any action necessary;
- To provide you with further opportunity to learn more and provide input;
- To reinforce with residents that Town of Newmarket officials are committed to ensuring we have a safe and healthy environment; and,
- To ensure situation is managed well and kept in context.

8.2 Strategy

Inform area residents and general public using a cross-section of tools, including direct mail, Public Information Centre (PICs; equivalent to public meetings), Web postings, Q&As, media relations.

8.3 Tactics and Critical Path

1. December 3, 2008. Deliver a letter to residents and future residents explaining the situation and action steps and invite them to a Public Information Centre (PIC) for further information. Include a comprehensive Q&A, web sites and phone numbers for further information.
2. Customer Service Associates to track calls through a heat board. Commenced Week of October 20, 2009 to continue throughout.
3. Friday December 5, 2008. Meet with local media, issue media release/backgrounder.
4. December 5, 2008. Post information and links on Town's Website. http://www.newmarket.ca/en/townhall/summerhillwoodsdevelopmentarea.asp

5. Tuesday January 13, at 7 p.m. 2009. Hold PIC, with a presentation by experts that includes a clear plan of action, and:
   - Invite media to PIC;
   - Have environmental and health experts (MOE, Medical Officer of Health, Burnside, Intrinsik), Developer and Mayor available to answer questions; and,
   - Have take-away Q&A info.

6. Monitor public interest and follow-up as information becomes available or as is necessary to meet objectives.

7. April 20, 2009 – Submission of the Pre-Submission Form to the Ministry of the Environment and York Region Community and Health Services (YRCHS)

8. May 19, 2009 – Comments regarding the Pre-Submission Form received from YRCHS; June 1, 2009 – Ministry of the Environment response to Pre-Submission Form

9. July 15, 2009 – Recommendations made for additional site characterization studies to address Ministry of the Environment and York Region Community and Health Services comments

10. August 2009 – Bioaccessibility study started.

11. September and October 2009 – Field program for additional site characterization undertaken. Bioaccessibility study completed.

12. November 2009. Completion of the site characterization program.

13. December 2009. Follow-up letter to area residents from Mayor and area Councillor.

14. Early 2010. Completion and submission of the Risk Assessment to Ministry of the Environment and York Region Community and Health Services.

15. Ministry of the Environment review period – 16 to 22 weeks (approximately March to May 2010).

16. Submission of the final Risk Assessment to the Ministry of the Environment – approximately 3 weeks after receipt of Ministry of the Environment comments – April to June 2010.

17. Community update letter – January 2011.

18. Resubmission of the final Risk Assessment to the Ministry of the Environment — May 2011.

16.19. Final Ministry of the Environment review and acceptance – early summer 20102011.

17.20. PIC to present final results to the public, including communication of the RA results and RMM including risks to park visitors, off site residents, and general public.

9.0 DOCUMENT SIGN-OFF

This report has been performed in accordance with the requirements of O.Reg. 153/04. The RA has been performed in accordance with accepted practice and usual standards of thoroughness and competence for the profession of toxicology and environmental RA. The information, opinions and recommendations provided within the aforementioned report have been developed using reasonable and responsible practices, and the report was completed to the best of our knowledge and ability.

INTRINSIK ENVIRONMENTAL SCIENCES INC.

Elliot Sigal, B.Sc., QP_{RA}
Executive Vice-President and Senior Scientist

10.0 REFERENCES

References are subdivided into general references (Section 10.1) and references related to the human exposure limits presented in Table 4-13 (Section 10.2).

10.1 General References

Amdur, M.O., Doull, J., and Klassen, C.D. (Eds.). 1991. Casarett and Doull's Toxicology: The Basic Science of Poisons. 4th Edition. Pergamon Press Ltd., New York, NY.

Burnside. 2008a. Town of Newmarket, Phase I Environmental Site Assessment, Former Mulock Farm Property, Newmarket Ontario. Prepared by R.J. Burnside & Associates Limited. July, 2008.

Burnside. 2008b. Town of Newmarket, Draft Memorandum to Town of Newmarket, re: Soil Sampling Program – August 2008, Summerhill Woods Subdivision and Surrounding Lands, Newmarket Ontario. Prepared by R.J. Burnside & Associates Limited. August, 2008.

Burnside. 2009. Soil Sampling Programs, Town Owned Lands in the Vicinity of Mulock Drive and Bathurst Street, Newmarket Ontario. Prepared by R.J. Burnside & Associates Limited. March, 2009.

Burnside. 2010. Phase II Environmental Site Assessment, Parklands at Mulock Drive and Bathurst Street, Town of Newmarket. Prepared by R.J. Burnside & Associates Limited. January, 2010.

BJC (Bechtel Jacobs Company). 1998. Empirical models for the uptake of inorganic chemicals from soil by plants. BJC/OR-133. Oak Ridge National Laboratory. Oak Ridge, TN.

CCME. 1996. A Framework for Ecological Risk Assessment: General Guidance. Canadian Council of Ministers of the Environment, National Contaminated Sites Remediation Program, Ottawa, ON.

CCME. 1997. A Framework for Ecological Risk Assessment: Technical Appendices. March 1997. The Canadian Council of Ministers of the Environment. The National Contaminated Sites Remediation Program. Winnipeg, MB.

CCME. 2000. Canada-Wide Standards for Petroleum Hydrocarbons (PHCs) in Soil: Scientific Rationale. Supporting Technical Document. Canadian Council of Ministers of the Environment. December 2000.

Defra and Environment Agency. 2002. Contamination in soil: Collation of toxicological data and intake values for humans. R&D Publication CLR 9. Cited In: EAUK, 2005b.

DEPA, 2003. Danish Environmental Protection Agency. Environmental Project No. 840 2003 Technology Programme for Soil and Ground water Contamination. Human Bioaccessibility of Heavy Metals and PAH from Soil. http://www.mst.dk/homepage/

Doull, J., Klassen, C.D., and Amdur, M.O. 1980. Casarett and Doull's Toxicology: The Basic Science of Poisons. Second Edition. MacMillan Publishing Company, New York, NY.

Drexler, J.W. and W. J. Brattin. 2007. An *In Vitro* Procedure for Estimation of Lead Relative Bioavailability: With Validation. Human and Ecological Risk Assessment, 13: 383–401.

EAUK. 2005a. Bioaccessibility Testing. Questions and Answers. Environment Agency U.K January 2005. Available at: http://www.environmentagency.gov.uk/commondata/acrobat/bioaccessibility_faq_1284070.pdf [Feb 8, 2007]

EAUK. 2005b. Environment Agency's Science Update on the use of Bioaccessibility Testing in Risk Assessment of Land Contamination. February, 2005. Environment Agency U.K. Available at: http://www.environmentagency.gov.uk/commondata/acrobat/science_update_1284046.pdf [Feb 8, 2007]

Edens, F.W., and Garlich, J.D. 1983. Lead-induced egg production decrease in Leghorn and Japanese quail hens. Poult Sci 62:1757-1763.

Efroymson, R.A., M.E. Will, and G.W. Suter II. 1997a. Toxicological benchmarks for screening potential contaminants of concern for effects on soil and litter invertebrates and microbial processes: 1997 revision. ES/ER/TM-126/R2. Oak Ridge National Laboratory, Oak Ridge, TN.

Efroymson, R.A., M.E. Will, G.W. Suter II and A.C. Wooten. 1997b. Toxicological benchmarks for screening contaminants of potential concern for effects on terrestrial plants: 1997 revision. ES/ER/TM-85/R3. Oak Ridge National Laboratory, Oak Ridge, TN.

Environment Canada. 1994. A Framework for Ecological Risk Assessment at Contaminated Sites in Canada: Review and Recommendations. Scientific Series No. 199. Environment Canada, Ecosystem Conservation Directorate, Evaluation and Interpretation Branch, Ottawa, ON. ISBN 0-662-22156-7.

FDA. 1982. Toxicological Principles for the Safety Assessment of Direct Food Additives and Color Additives Used in Food. (US) Food and Drug Administration, Bureau of Foods, Washington, DC.

Filov, V., Golubev, A., Liublina, E., and Tolokontsev, N. 1979. Quantitative Toxicology: Selected Topics. John Wiley and Sons, New York, NY.

Gaudet, C.L. 1994. A Framework for Ecological Risk Assessment at Contaminated Sites in Canada: Review and Recommendations. Environment Canada, Ecosystem Conservation Directorate, Evaluation and Interpretation Branch, The National Contaminated Sites Remediation Program, Ottawa, ON, (Scientific Series) No. 199.

Gupta, U.C. 1979. Boron nutrition of Crops. In: Advances in Agronomy. Vol. 31. Brady, N.C. (ed). Academic Press Inc. New York. pp 273-307. Cited In: MOEE, 1996b.

Health Canada. 1993. Health Risk Determination. The Challenge of Health Protection. ISBN 0-662-20842-0.

Health Canada. 2004. Federal Contaminated Site Risk Assessment in Canada. Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA). Contaminated Sites Program.

Health Canada. 2006. Federal Contaminated Site Risk Assessment in Canada. Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA). Contaminated Sites Program.

Himelick, EB. 1986. Root development of trees growing in an urban environment. Illinois Natural History Survey Rep. No. 262. December 1986.

Hull, R.N., and Suter, G.W.II. 1994. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-associated Biota: 1994 Revision. ES/ER/TM-95/R1. Oak Ridge National Laboratory, Oak Ridge, TN.

Hull, R.N., and Swanson, S.M. 2006. Sequential Analysis of Lines of Evidence – An Advanced Weight-of-Evidence Approach for Ecological Risk Assessment. Integrated Environmental Assessment and Management. Vol 2(4): 302-311.

Kelley, M.E., Brauning, S.E., Schoof, R.A., Ruby, M.V. 2002. Assessing Oral Bioavailability of Metals in Soil. Batelle Press. Columbus, Ohio.

Kissel, J.C., K.Y. Richter, and R.A. Fenske. 1996. Field Measurement of Dermal Soil Loading Attributable to Various Activities: Implications for Exposure Assessment. Risk Analysis. 16(1): 115-125. Cited In: Health Canada, 2006.

Kissel, J.C., J.H. Shirai, K.Y. Richter, and R.A. Fenske. 1998. Investigation of Dermal Contact with Soil in Controlled Trials. J. Soil Contam. 7(6): 737-752. Cited In: Health Canada, 2006.

Medlin, E.A. 1997. An *In Vitro* method for estimating the relative bioavailability of lead in humans. Masters thesis. Department of Geological Sciences, University of Colorado, Boulder.

MMM. 2007. Soil Management Plan, Summerhilll Woods Development, Newmarket, Ontario. Prepared by MMM Group Limited. September, 2007.

MMM. 2008a. Review of Soil Management Options, Forested Areas at Summerhill Woods, Newmarket, Ontario. Prepared by MMM Group Limited. March, 2008.

MMM. 2008b. Delineation of Arsenic Impacts in Topsoil, Municipal Lands Adjacent to Summerhill Woods, Newmarket, Ontario. Prepared by MMM Group Limited. ~~April,~~May, 2008.

MMM. 2008c. Addendum No. 1 to Delineation of Arsenic Impacts in Topsoil, Municipal Lands Adjacent to Summerhill Woods, Newmarket, Ontario. Prepared by MMM Group Limited. May, 2008.

MOEE. 1994. Provincial Water Quality Objectives of the Ministry of Environment and Energy. Ontario. July 1994.

MOEE. 1996a. Guidance on Sampling and Analytical Methods for Use at Contaminated Sites in Ontario. Ontario Ministry of Environment and Energy Standards Development Branch. ISBN-0-7778-4056-1.

MOEE. 1996b. Rationale for the Development and Application of Generic Soil, Groundwater and Sediment Criteria for Use at Contaminated Sites in Ontario. Ontario Ministry of the Environment and Energy. ISBN 0-7778-4504-5.

MOEE. 1997. Guideline for use at contaminated site in Ontario. Ontario Ministry of the Environment. Standards Development Branch. Revised February 1997. ISBN 0-7778-6114-3.

MOE. 2004. Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act. Standards Development Branch. Ontario Ministry of the Environment. March 9, 2004.

MOE. 2005. Procedures for the Use of Risk Assessment under Part XV.1 of the Environmental Protetion Act. Ontario Ministry of the Environment. Standards Development Branch. October 2005.

MOE. 2008. Guidelines for Identifying, Assessing and Managing Contaminated Sediments in Ontario. Ontario Ministry of the Environment. May 2008. PIBS 6658e.

MOE. 2009. Rationale for the Development of Generic Soil and Groundwater Standards for Use at Contaminated Sites in Ontario. Standards Development Branch. Ontario Ministry of the Environment. December, 2009.

Oomen, A.G., Brandon, E.F.A., Swartjes, F.A. and Sips, A.J.A.M. 2006. How can information on oral bioavailability improve human health risk assessment for lead-contaminated soils? Implementation and scientific basis. RIVM report 711701042/2006

Oomen, A.G., Hack, A., Minekus, M., Zeijdner E., Cornelis C., Schoeters G., Verstraete W., Van de Wiele T., Wragg J., Rompelberg C., Sips A., Wijnen, J. 2002. Comparison of Five *In Vitro* Digestion Models To Study the Bioaccessibility of Soil Contaminants. Environ. Sci. Technol. 36(15): 3326-3334.

Paustenbach, D.J. 2000.The practice of exposure assessment: a state-of-the-art review. J. Toxicol. Environ. Health, Part B 3: 179-291. Cited In: Sips *et al*., 2001

RAIS. 2009. The Risk Assessment Information System. Soil to dry plant uptake factor. Available Online: http://rais.ornl.gov/tools/eco_search.php

Richardson, M.G. 1997. Compendium of Canadian Human Exposure Factors for Risk Assessment.1155-2720 Queensview Dr., Ottawa, Ontario.Ottawa, ON. O'Connor Associates Environmental Inc. Revised July 5, 1996.

Sample, B.E., and Suter, G.W. 1994. Estimating Exposure of Terrestrial Wildlife to Contaminants. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-125.

Sample, B.E., Opresko, D.M., and Suter, G.W. 1996. Toxicological Benchmarks for Wildlife: 1996 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-86/R3.

Sample, B.E., Aplin, M.S., Efroymson, R.A., Suter II, G.W., and Welsh, C.J.E. 1997. Methods and tools for estimation of the exposure of terrestrial wildlife to contaminants. ORNL/TM-13391. Oak Ridge National Laboratory, Oak Ridge, TN.

Sample, B.E., Beauchamp, J.J., Efroymson, R.A., Suter II, G.W. and Ashwood, T.L. 1998. Development and validation of bioaccumulation models for earthworms. ES/ER/TM-220. Oak Ridge National Laboratory, Oak Ridge, TN.

Sheppard, S.C., Evenden, W.G. and Schwartx, W.J. 1995. Heavy metals in the environment. Ingested soil: bioavailability of sorbed lead, cadmium, cesium, iodine, and mercury. J. Environ. Qual. 24: 498-505. Cited In: Sips *et al*., 2001

Sips, A.J.A.M., Bruil, M.A., Dobbe, C.J.B., Van de Kamp, E., Oomen, A.G., Pereboom, D.P.K.H., Rompelberg, C.J.M. and Zeilmaker, M.J. 2001. Bioaccessibility of contaminants from ingested soil in humans. Mehod development and research on the bioaccessibility of lead and benzo[a] pyrene. RIVM report 711701012/2001.

Stewart JR, Kjelgren R, Johnson PG, and Kuhns MR. 2004. Soil-water-use characteristics of precision-irrigated Buffalograss and Kentucky Bluegrass. Plant Management Network.

Suter, G.W. II. 1989. Ecological endpoints. In: Ecological Assessment of Hazardous Waste Sites: A field and laboratory reference document. Warren-Hicks, W, Parkhurst, B.R. and Baker, S.S. (eds.). Section 2.0. US Environmental Protection Agency, EPA/600/3-89/013, Washington, D.C.

Suter, G.W., II, B.E. Sample, D.S. Jones, T.L. Ashwood, and J.M. Loar. 1995. Approach and strategy for performing ecological risk assessments for the US Department of Energy's Oak Ridge Reservation: 1995 revision. Oak Ridge National Laboratory, Oak Ridge TN. ES/ER/TM-33/R2.

Suter, G.W., and C.L. Tsao. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. Risk Assessment Program, Health Sciences Research Division. Oak Ridge Tennessee, ES/ER/TM-96/R2.

TNRCC. 2001. Texas Natural Resource Conservation Commission, Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas. Toxicology and Risk Assessment Section, Texas Natural Resource Conservation Commission, Austin, TX. RG-263 (revised).

Town of Newmarket, pers. comm. 2010. Personal Communication between Richard Nethery and Esther Armchuk-Ball, both of the Town of Newmarket, regarding legal land-use options for the Former Mulock Property. March 11, 2010.

US EPA. 1989. Risk Assessment Guidance for Superfund. US Environmental Protection Agency, Washington, DC. EPA

US EPA. 1993. Wildlife Exposure Factors Handbook. Volume I of II. Office of Research and Development, Washington, D.C. EPA/600/R-93/187a.

US EPA. 1997. Exposure Factors Handbook Vol I, General Exposure Factors. (US) Environmental Protection Agency. EPA/600/p-95/002Fa.

US EPA. 1999. Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities. Volume One and Appendices. Peer Review Draft. EPA530-D-99-001A. August 1999. Office of Solid Waste and Emergency Response (5305W).

US EPA (United States Environmental Protection Agency). 2001. Final Ecological Risk Assessment – Coeur d'Alene Basin Remedial Investigation/Feasibility Study. U.S. Environmental Protection Agency, Region 10. Prepared by: CH2M Hill and URS Corp. May, 2001.

US EPA. 2004. User's Guide for Evaluating Subsurface Vapour Intrusions into Buildings. United States Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C., February, 2004.

US EPA. 2006. Child-Specific Exposure Factors Handbook (External Review Draft). EPA/600/R/06/096A. US Environmental Protection Agency. September 2006.

US EPA. 2007. Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). *Exposure Factors and Bioaccumulation Models for Derivation of Wildlife Eco-SSLs.* Attachment 4-1. OSWER Directive 9285.7-55. Issued November 2003. Revised April 2007. Available online: http://www.epa.gov/ecotox/ecossl/pdf/ecossl_attachment_4-1.pdf

US EPA. 2008. Child-Specific Exposure Factors Handbook. EPA/600/R-06/096F. September 2008. Available online: www.epa.gov/ncea.

US EPA. 2008. Standard Operating Procedure for an *In Vitro* Bioaccessibility Assay for Lead in Soil. U.S. Environmental Protection Agency. EPA 9200.1-86

US EPA. 2009. Exposure Factors Handbook – 2009 Update. External Review Draft. Office of Research and Development. National Center for Environmental Assessment. US Environmental Protection Agency. Washington, DC 20460. July 2009. EPA/600/R-09/052A.

US EPA Region 5. 2003. Ecological Screening Levels. United States Environmental Protection Agency. Available online: http://www.epa.gov/reg5rcra/ca/ESL.pdf

Watson, G.W. and Himelick, E.B. 1982. Root distribution of nursery trees and its relationship to transplanting success. Journal of Arboriculture 8(9):225-229.

10.2 Human Exposure Limit References

Brown, C.C., and Chu, K.C. 1983a. Approaches to epidemiologic analysis of prospective and retrospective studies: Example of lung cancer and exposure to arsenic. In: Risk Assessment Proc. SIMS Conf. on Environ. Epidemiol. June 28-July 2, 1982, Alta, VT. SIAM Publications. Cited In: US EPA IRIS, 1998a.

Brown, C.C., and Chu, K.C. 1983b. Implications of the multistage theory of carcinogenesis applied to occupational arsenic exposure. J. Natl. Cancer Inst. 70(3): 455-463. Cited In: US EPA IRIS,1998a.

Brown, C.C., and Chu, K.C. 1983c. A new method for the analysis of cohort studies: Implications of the multistage theory of carcinogenesis applied to occupational arsenic exposure. Environ. Health Perspect. 50:293-308. Cited In: US EPA IRIS,1998a.

Cal EPA. 2008. Technical Support Document for the Derivation of Noncancer Reference Exposure Levels, Appendix D. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Branch. Available at: http://www.oehha.ca.gov/air/hot_spots/2008/AppendixD1_final.pdf. [December 3, 2009].

Enterline, P.E., and Marsh, G.M. 1982. Cancer among workers exposed to arsenic and other substances in a copper smelter. Am. J. Epidemiol. 116(6): 895-911. Cited In: US EPA IRIS, 1998. Cited In: US EPA IRIS, 1998a.

Higgins, I., Welch, K., and Burchfield, C. 1982. Mortality of Anaconda smelter workers in relation to arsenic and other exposures. University of Michigan, Dept. Epidemiology, Ann Arbor, MI. Cited In: US EPA IRIS, 1998a.

Lee-Feldstein, A. 1983. Arsenic and respiratory cancer in man: Follow-up of an occupational study. In: Arsenic: Industrial, Biomedical, and Environmental Perspectives, W. Lederer and R. Fensterheim, Ed. Van Nostrand Reinhold, New York. Cited In: US EPA IRIS, 1998a.

MOE. 1994. Soil, Drinking Water, and Air Quality Criteria for Lead: Recommendations to the Minister of the Environment and Energy. Ontario. Ministry of the Environment and Energy (MOE), Advisory Committee on Environmental Standards (ACES), Toronto, ON. ACES Report No. 94-02.

Ryu, J.E., Ziegler, E., Nelson, S. and Formon, S.1983. Dietary intake of lead and blood lead concentration in early infancy. Am. J. Dis. Child., 137:886. Cited In: MOE, 1994.

Tsai, S.Y., Chou, H.Y., The, H.W., Chen, C.M., Chen, C.J. 2003. The effects of chronic arsenic exposure from drinking water on the neurobehavioral development in adolescence. Neurotoxicology 24(4-5):747-753. Cited In: Cal EPA, 2008.

Tseng, W.P., Chu, H.M., How, S.W., Fong, J.M., Lin, C.S., and Yeh, S. 1968. Prevalence of skin cancer in an endemic area of chronic arsenicism in Taiwan. J. Natl. Cancer Inst. 40: 453-463. Cited In: US EPA IRIS, 1998a; US EPA IRIS, 1993a.

Tseng, W.P. 1977. Effects and dose-response relationships of skin cancer and blackfoot disease with arsenic. Environ. Health Perspect. 19:109-119. Cited In: US EPA IRIS, 1998a; US EPA IRIS, 1993a.

US EPA IRIS. 1993. Arsenic, inorganic (CASRN 7440-38-2). Chronic Health Hazard Assessments for Noncarcinogenic Effects. Integrated Risk Information System. US Environmental Protection Agency. Available at: www.epa.gov/iris [January 11, 2010].

US EPA IRIS. 1998. Carcingenicity Assessment: Arsenic, inorganic (CASRN 7440-38-2). US Environmental Protection Agency Integrated Risk Information System. Office of Research and Development, National Center for Environmental Assessment, Washington, DC. Available at: www.epa.gov/iris [January 11, 2010].

Wasserman, G.A., Liu, X., Parvez, F., Ahsan, H., Factor-Litvak, P., van Geen, A., Slavkovich, V., LoIacono, N.J., Cheng, Z., Hussain, J., Momotaj, H., Graziano, J.H. 2004. Water arsenic exposure and children's intellectual function in Araihazar, Bangladesh. Environ Health Perspect 112(13):1329-1333. Cited In: Cal EPA, 2008.

Ziegler, E.E., Edwards, B.B., Jensen, R.L., Mahaffey, K.R. and Fomon, S.J. 1978. Absorption and retention of lead by infants. Pediatr. Res., 12: 29. Cited In: MOE, 1994.