Environmental Risk Management Plan
Historic Waste Disposal Site
Lindsay Thurber
Comprehensive High School
Ptn. NE & SE 21-38-27 W4M

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Preface

The City of Red Deer is aware of several historic waste disposal sites containing municipal solid waste situated within fully developed urban areas. The Alberta Municipal Government Act, specifically Part 2, Section 13 of the Subdivision and Development Regulation AR 43/2002 specifies a minimum setback distance between the closed historic landfill to certain types of land developments. Restrictions of types of subdivision associated with this regulation include residential, food establishment, school or hospital. This regulation includes provisions for the Provincial Deputy Minister to consider a request to vary the minimum setback distance for a specific development application, provided the local municipal subdivision or development authority supports the proponent's specific development application.

The underlying objective of the project is to develop a level of understanding of the environmental risks arising from each historic waste disposal site leading to a site specific environmental risk management plan (ERMP). To structure the project into manageable components, the work was divided into the following three stages:

1. Phase I ESA — Compilation and review of information pertaining to a historic waste disposal site.
2. Phase II ESA — Subsurface investigation to verify and characterize information from the Phase I ESA.
3. ERMP — Develop a site-specific environmental risk management plan to serve as an aid for the municipal development review process.

This document reflects the third stage, specifically presenting the ERMP for the Lindsay Thurber Comprehensive High School Site. With the available information, the ERMP was developed on the basis of Health Canada guidelines for a preliminary quantitative risk assessment. The outcomes of the ERMP confirm the identified chemicals of concern and the relevant environmental risks are manageable to facilitate future developments which may lie within the regulated setback distance to the historic waste disposal site. This ERMP provides a first-order evaluation for potential future subdivision and development with a focus on methods to minimize the risk of human exposure to landfill gas and other hazards to the environment resulting from the historic waste disposal site.

Ultimately, the goal is to have an effective and timely review process for specific future subdivision and development applications while preserving an appropriate/equivalent level of protection for each stakeholder be it regulatory, developer, owner, public or the natural environment.

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1.0 INTRODUCTION

Assessment of environmental site data to identify potential hazards and exposures is, by its nature, a risk assessment process. The use of various risk assessment tools is a common practice to decision making in professional practice. The body of knowledge for risk assessment has produced a wide assortment of methods to conduct an environmental risk assessment. The many approaches to conducting a risk assessment ranging from very basic site-specific empirical information gathered from the field to complex numerical quantitative models. Typically, selection of the risk assessment protocol is determined by the type of data available and the attributes which are exposed to a potential risk. The risk management process can be a relatively straight-forward analysis to a complex evaluation involving multi-disciplinary team of professionals.

For example, a proposed residential development project within a prescribed river flood plain will have several environmental factors associated to vulnerabilities and potentials for an adverse effect to the proposed development from the river (flood, high groundwater, pollution impact from an upstream source, et cetera). Current practice involves multiple avenues of review ranging from regulatory requirements, design guidelines, codes of practice, industry standards and local considerations to address the potential identifiable vulnerabilities. These reviews and considerations are intended to assist the design professional to manage the identified vulnerabilities and the associated risks to ensure appropriate levels of mitigation and adaptation are incorporated into the development with the objective of having an appropriate level of protection for each stakeholder and the natural environment.

Risk assessment can be broadly categorized into three main types: qualitative, semi-quantitative and quantitative. Each type has unique limitations to subjectivity of data and each have a common outcome to serve as a decision making tool for management.

A commonly applied qualitative risk assessment tool can be simply illustrated in a matrix form below.

Level of Risk

Severity of Consequence				
	High	M	H	H
	Medium	L	M	H
	Low	L	M	H
		Low	**Medium**	**High**

Probability of Occurrence

A semi-quantitative approach to risk assessment requires some first-order estimates as inputs into a risk model. The semi-quantitative approach is more sophisticated relative to the subjective qualitative screening approach and is not as numerically demanding as a quantitative risk assessment involving more complex numerical models and environmental statistics.

The semi-quantitative approach is commonly applied to smaller project sites and is an appropriate approach for the LTCHS Site.

As noted, a semi-quantitative approach does not require analyzed probabilities or high level statistical and mathematical data sets, which may largely be subjective and difficult to verify, creating a new set of uncertainty. The semi-quantitative process includes a hierarchy of identified risks specific to the site, numerical risk estimation and an interpretation of qualitative considerations founded on professional experience and judgment. The hierarchy of identifiable risks is generally outlined into a matrix similar to the above, reflecting an order of project specific priorities. The matrix format is intended to illustrate in a logical fashion the likelihood of a possible vulnerability and its adverse impact. Risk rankings are usually divided into three groupings: low, medium and high with a prescribed level of action appropriate to respond to a potential level of adverse consequence such as:

- Low aggregate risk value. Management can decide what form of corrective action(s) to implement or accept the potential risk.

- Medium aggregate risk value indicates mitigative and/or adaptive actions would be deemed prudent to minimize the probability of an adverse effect. Immediate reaction is generally not required but action would be necessary within a site–specific time frame.

- High aggregate risk value. Mitigating and/or adaptive measures are to be exercised as soon as practical in order to reduce the identified hazard.

It should be noted, to a practical level as possible, a risk assessment should be exercised in an objective fact-based manner to avoid pre-determining a desired outcome, i.e. allow the facts to "speak." Accordingly, to effectively develop a risk management plan with a scientifically supported project decision making process, the risk assessment should be developed in a manner which is consistent and defensible while recognizing limitations to the data set and the inherent uncertainty to available site information and subsurface parameters. This knowledge can then be applied in a defensible and justified manner to make appropriate risk-based decisions.

In summary, within the practice of risk assessment, there are many other methods and approaches to completing a risk assessment. Each has differing attributes and limitations. The results of a risk assessment are either applied to better understand the levels of risk to potential identified hazards or the results become an indicator to support further investigation and research. Information on the types and the merits of differing risk assessments are widely available to the reader. For this project, an evaluation of risk is a systematic process involving the identification and comparison of specific assets and its associated vulnerabilities with consideration of the likelihood for an adverse effect to occur.

The development of a site-specific environmental risk management plan (ERMP) is a component of a structured risk management process utilized by The City of Red Deer. The results of the risk assessment are intended to support risk-based decisions by the Management at The City of Red Deer.

In order to develop a defensible risk management plan, the approach considered to be appropriate for this project is a preliminary quantitative risk assessment. Health Canada has developed guidance documents to enable a consistent and defensible evaluation of site-specific data. A simple semi-quantitative protocol rather than a detailed analytical protocol is appropriate for the level of data available. A semi-quantitative protocol is acceptable to most regulatory jurisdictions for a project of this scope and strikes a reasonable balance between a purely subjective qualitative protocol and the highly analytical intensive quantitative protocol. Health Canada refined and released the framework for environmental risk assessment in September 2010 and an update and revision in 2012. The Health Canada approach was selected over the CCME 1996 Framework for Ecological Risk Assessment. The CCME and the Health Canada risk assessment process are the two nationally accepted processes for risk assessment. Local provincial ministries have developed specific risk assessment protocols that are modeled from selected attributes of various risk protocols from various organizations. For instance, the Alberta Tier 1 and 2 Soil and Groundwater Remediation Guidelines are focused on the assessment and remediation of contaminated soil and groundwater. Generic numeric guidelines for target chemicals were derived by the application of the CCME 2006 Protocols for the Derivation of Environmental and Human Health Soil Quality Guidelines. The CCME Ecological Risk Assessment process is also focused on target chemicals at a site. These approaches are directed at the concentrations of target chemicals at a contaminated site.

The Health Canada approach focusses on the risk of exposure to a receptor and not the concentration of a target chemical. Hence, for this project, in order to develop and evaluate a risk model for potential receptors at various developments to the exposure of transient soil landfill vapours emanating from the LTCHS Site, the Health Canada model is considered more appropriate relative to the above noted alternative risk assessment models.

Health Canada outlines a preliminary quantitative risk assessment (PQRA) in order for various industries to apply a standard method and assumptions to ensure potential environmental exposures and their risks are not underestimated in the risk model. This approach is to address historic problems during peer review of past site risk assessments. The PQRA applies a conservative interpretation to the risk outcome, such that in the event of an identified potential risk outcome being negligible or acceptable; the actual site condition(s) will essentially present a negligible or acceptable level of risk. Conversely, should the outcome for a potential level of risk be deemed unacceptable, further investigation may be warranted to better refine the conservatism and reduce uncertainty or the actual site condition(s) present an unacceptable level of risk warranting a site-specific response to address and reduce the predicted risk for an adverse impact.

Key results from the Phase I and II ESA have been consolidated to construct a site-specific preliminary quantitative risk assessment. The output from the PQRA is incorporated into risk management strategies and the development of a site-specific risk management plan. Tiamat Environmental Consultants Ltd. (Tiamat) presents this Environmental Risk Management Plan (ERMP) for a historic waste disposal site designated as the Lindsay Thurber Comprehensive High School (LTCHS) site.

This report presents the scope of work, a summary of the findings of a PQRA and a proposed ERMP for the Lindsay Thurber Comprehensive High School Site. The information presented is intended to be a standalone document. Specific site information that is deemed supplementary and not critical to the ERMP has been excluded in this report. Should the reader wish to review this type of information, the reader should peruse the associated 2013 Phase I and II ESA reports for the LTCHS Site as prepared by Tiamat.

1.1 Scope of Work

A summary of the key tasks for this ERMP are outlined below:

Compile Data for PQRA

- Identify chemicals of concern in environmental media (soil, groundwater, soil gas);
- Assemble chemical and physical attributes of each identified chemical of concern;
- Collect toxicological information and identify data gap(s) for each identified chemical of concern;
- Identify receptors (human, biota and river) and the various routes of potential exposure;
- Evaluate the compiled data using a standard PQRA approach.

ERMP

- Develop a site-specific ERMP incorporating the findings of the PQRA with applications to the four limited/restricted land uses (school, hospital, food enterprise and residential), general commercial developments and the installation of infrastructure such as utilities.

1.2 Summary of Previous Work and Project Status

The original LTCHS facility predates the waste disposal activity. Municipal records suggest the historic waste disposal activity occurred over a period of about two years, between June 1965 and July 1967. The estimated age of the waste material, post closure, is about 46 years, more or less. The municipal records also indicate The City of Red Deer, with acknowledgement from the Provincial Health Region and the local School District, undertook the placement of sanitary waste onto this site. Since then, the LTCHS facility has been expanded several times to its current configuration. The interpreted area of the historic waste area lies within 30 m, more or less of the existing LTCHS facility. Other nearby developments includes various public institutions, residential houses and light commercial land uses.

Previous environmental investigations for the site and the high school facility have been conducted by various consultants since June 2004.

- Phase 2 Environmental Site Investigation, Landfill at Lindsay Thurber Comprehensive High School Property, SE 21-38-27 W4M, Red Deer, Alberta, June 2004. Prepared by Parkland Geotechnical Consulting Limited.

- Landfill Gas Control Proposal and Risk Management Plan for the Former Landfill in SE 21-38-27 W4M, Near Lindsay Thurber Comprehensive High School, Red Deer, Alberta, August 30, 2004. Prepared by Parkland Geotechnical Consulting Limited.

- Summary Report Former City Landfill Site Lindsay Thurber Comprehensive High School Property, Part of SE 21-38-27 W4M, Red Deer, Alberta, March 20, 2007. Prepared by Stantec Consulting Ltd. and Parkland Geotechnical Consulting Limited.

- Phase 2 Environmental Site Assessment, River Glen School Lands, Red Deer, Alberta, November, 2008. Prepared by Parkland Geotechnical Consulting Ltd.

- Lindsay Thurber Comprehensive High School, 2011 Gas Monitoring Program, October, 31, 2011. Prepared by Parkland Geotechnical Consulting Ltd.

- Lindsay Thurber Comprehensive High School, 2013 Gas Monitoring Program, June 3, 2013. Prepared by Parkland Geotechnical Consulting Ltd.

- Phase I Environmental Site Assessment, Historic Waste Disposal Sites, Lindsay Thurber Comprehensive High School, September 24, 2013, prepared by Tiamat.

- Phase II Environmental Site Assessment, Historic Waste Disposal Sites, Lindsay Thurber Comprehensive High School, March 6 2014, prepared by Tiamat.

The noted documents were provided by The City of Red Deer and the Red Deer Public School District No. 104. Key information from the referenced documents was consolidated and identified data gaps were addressed in the Phase I ESA report (Tiamat, 2013).

The scope of investigation for the 2013 Phase II ESA was designed to address the environmental concerns identified from the Phase I ESA.

The key results of the 2013 Phase II ESA are as follows:

- The estimated areal footprint of the historic waste is 105,800 m^2 (26.14 ac). The waste is situated on native pervious gravel and sand.

- Groundwater is approximately 2.8 m below the ground surface and lies within the waste material. The average horizontal hydraulic gradient leaving the site is 0.3% towards the Red Deer River. Applying an intrinsic horizontal permeability of 10^{-5} m/sec for the sand and gravel, the resulting estimate horizontal flow velocity is about 2.7 m/day, more or less.

- Dissolved volatile organic compounds (VOCs) and other petroleum hydrocarbon constituents were not detected at the down gradient groundwater monitoring wells.

- Laboratory results of groundwater samples from the down-gradient monitoring wells show several dissolved parameters (indicative of the presence of leachate) in the local groundwater leaving the site. This is further characterised by the field measured water quality indices showing high negative redox potential and near anoxic condition of dissolved oxygen in groundwater.

- Leachate in the down-gradient groundwater appears to be predominantly inorganic compounds and nutrients. VOCs and other dissolved hydrocarbons were not detected in the August 2013 testing event.

- Adjacent and nearby developments include two schools, public institution, residential homes and natural areas. There are presently no obvious activities on the adjacent lands that are interpreted as an environmental concern relative to the site.

- Light molecular-weight petroleum gases were not detected at the soil vapour wells.

- Volatile petroleum hydrocarbon constituents to carbon chain 12 were consistently detected in each of the five soil vapour wells. Additionally, semi-volatile, halogenated and oxygenated volatile hydrocarbons and ketones were identified in the soil vapour samples.

The findings of the 2013 Phase II ESA suggest mild to moderate strength leachate constituents are present in the groundwater leaving the site and flowing towards the Red Deer River.

The initial assessment of landfill gas (LFG) shows the soil gas to compose of numerous volatile chemicals. A summary of the identified chemicals of concern are tabulated in Table 2A.

1.2.1 Site Description and Environmental Setting

The historic waste material lies within three subdivided parcels of land. The legal descriptions are:

- Portion of Lot S Plan 4154S;
- Portion of Lot 1MR Plan 852 0510; and,
- Portion of Lot 4ER Plan 912 0819.

The above areas lie within the NE and SE quarters of 21-38-27 W4M.

The historic waste disposal area is bounded by the Lindsay Thurber School Legion Track on the south, the environmental reserve followed by an oxbow lake (the westerly Gaetz Lake) on the east and the Lindsay Thurber Comprehensive High School (LTCHS) on the west. The area bracketing the oxbow lake is designated as environmental reserve. Land bounding the west and north margins of the waste area are currently an open undeveloped field.

There are no buildings on the area of the historic waste site. An asphalt paved pedestrian trail/bike path meanders across the historic waste site. This public trail extends from the south side of the Lindsay Thurber School Legion Track, parallel to the westerly Gaetz Lake and branches to the Parkland School and the Kerry Wood Nature Centre.

Further west and northwest of this waste site are the River Glen and Parkland Schools and the Kerry Wood Nature Centre followed by the Red Deer River. A site plan showing the current surrounding land uses and the approximate footprint of the historic waste material is presented as Figure 1.

1.3 Regional Geology and Hydrogeology

Within the immediate area of the historic waste there is no noted direction of principal overland flow or surface run-off control measures. There are no obvious environmental concerns for surface water run-off or run-on throughout this area. This area is mapped outside of the 100-year flood fringe (Environment Canada and Alberta Environmental Protection, Edition 1, 1995).

Following the recent severe June 2013 flood event, it is recognized the flood fringe may be updated following a review by the provincial authority. The Red Deer River is about 200 m, more or less from the nearest point of the historic waste area.

Two (2) permanent surface water bodies, Gaetz Lakes (pair of oxbow lakes) and the Red Deer River are situated east and west of the historic waste site respectively. The site and immediate area lie within a zone of groundwater discharge with an upward component of flow to the lake and the river.

The river flows from a south to north easterly direction while ground topography indicates the oxbow lake approximately follows the elevation of the Red Deer River. Based on a local topographic map for this area, regional groundwater flow is expected to be north-northwest towards the Red Deer River. A previous study, by others, concluded the water level in the Gaetz Lakes (oxbow lakes) are likely hydraulically connected to the Red Deer River by the underlying river valley gravel. Thus, the inflow and outflow of groundwater at Gaetz Lakes is predominantly influenced by the level of the Red Deer River and other climatic and physical conditions (precipitation, evaporation, soil permeability). In the immediate area of the oxbow lakes, there may be some minor component of flow to the lakes. However, regionally, the lakes and the Red Deer River are interpreted to be hydraulically connected though in an attenuated manner. On this basis, there is a low potential for the oxbow lake to be exposed to leachate from the local groundwater system.

It should be noted that local topography, geology, land development and soil disturbances might influence the local movement and pattern of groundwater. Furthermore, groundwater may also fluctuate from seasonal and climatic conditions.

A summary of the published geological and hydrogeological information is presented in the September 2013 Phase I ESA report.

Underground municipal utilities identified to be in the immediate vicinity of the historic waste site consist of one storm sewer and two sanitary sewers aligned between the LTCHS facilities and the westerly perimeter of the historic waste. These three sewer pipes extend towards and then across the River Glen School yard. A dedicated storm sewer pipe serving the north portion of the LTCHS facility directs surface runoff through the historic waste site with an outfall at Gaetz Lake. The relative locations of the underground municipal utilities are shown on Figure 2.

Potential environmental concerns arising from the historic waste site are grouped into three broad categories:

- Ground stability issue where the historic waste lies;
- Continual generation of soil vapour from the decomposing waste materials; and
- Lateral transport of groundwater which passes through the waste material and ultimately discharging to the Red Deer River.

Several geochemical processes and physical settlement occurs as the buried historic waste materials decompose. There is visual evidence the cover for the historic waste has settled in an irregular manner. The grass and underlying loam lies in an uneven mat across areas underlain by the historic waste. Anecdotal reports from the City Parks Department to repair the surface of the running track on an annual basis due to ongoing settlement is indicative of the instability of the ground surface overlying the historic waste.

Landfill gas is a by-product of a geochemical process associated with the decomposing waste materials. The soil vapours comprising of constituents from landfill gas can migrate in the subsurface. The geochemical process also yields soluble hydrocarbons to the groundwater system with some volatile components capable of degassing into the soil vapour regime.

Circa 2004/2005, the Red Deer Public School District and The City of Red Deer commissioned further investigation of the historic waste area and the installation of landfill gas control measures to protect the LTCHS facility from intrusion of landfill soil vapours. Other public institutional buildings lying within a 300 m radius of the historic waste include the River Glen and Parkland Schools and the Red Deer Memorial Centre, refer to Figure 1. To our knowledge, no other mitigative efforts have been undertaken at other nearby buildings.

For the urban developments situated in proximity to the historic waste, the environmental health concerns are broadly defined into two categories:

1. Landfill soil gas from the waste material, and
2. Leachate as groundwater passes through the waste material.

The ground stability overlying the waste area is deemed a structural maintenance issue and an avenue for water infiltration and percolation to the groundwater regime. As surface infiltration percolates through the historic waste materials and contacts the groundwater table, leachate is formed. This leachate is a potentially polluting liquid that can adversely affect the local groundwater system. A summary of the site-specific attributes for potential exposure to landfill soil vapours is presented as Table 1.

Concentration of landfill soil gas can be influenced by temporal effects such as temperature, precipitation, soil texture, soil moisture and the geochemical processes at the source area. Consequently, the most immediate concern to environmental health of urban developments is the potential exposure to landfill soil gas. There is also a potential for dissolved landfill soil gas constituents to degas from leachate leaving the waste area. This degassing is also capable of contributing to the landfill soil gas matrix.

1.4 Environmental Guidelines and Regulations

This historic waste site has been closed from landfilling for about 46 years and is considered to be a non-operating municipal landfill. It is understood there is no regulatory requirement to remediate or decommission/remove the waste material from its present location.

Within the Province of Alberta, The Municipal Government Act, Alberta Regulation 43/2002 with amendments up to and including AB Reg. 31/2012, Part 2 Subdivision and Development Conditions, Section 13 Distance from landfill waste sites prohibits subdivision and development of the following four types of developments:

- School,
- Hospital,
- Food establishment, or
- Residence,

within 300 m of the disposal area of a non-operating landfill. The regulation has a provision to permit the Deputy Minister of Alberta Environment Sustainable Resource and Development (ESRD) to consider a written consent to vary the regulated setback distance for the above stipulated types of development. ESRD has published a guideline for requesting consent to vary the setback distance for a development to a non-operating landfill. A copy of the most current version (May 2013) of this guideline is provided in Appendix A.

Presently, The Province of Alberta does not have reference criteria for volatile chemicals in air. For this ERMP, a systematic approach to assess the potential risk for an identified chemical of concern has been applied, refer to Section 3.2.2.

2.0 CONTAMINANT SITUATION

Chemicals of concern identified from the Phase II ESA have been applied for the development of a site-specific ERMP. Presumptions for the identified chemicals of concern are solely sourced from the historic waste disposal site and no other off-site source. The lands bounding the historic waste disposal site are considered to be potential receptors of contaminants migrating from the historic waste disposal site. The two principal pathways for exposure are landfill soil gas and groundwater containing leachate.

The available site-specific data set for the LTCHS Site reflects a summer (August 2013) testing event. To gain a “snap shot” of the seasonal range of soil vapour it is recommended a winter data set be obtained. The intent is to obtain subsurface data during frozen ground conditions where soil vapour constituents that would normally vent to atmosphere in the summer would be in a confined state and accumulate beneath the frozen ground. This scenario would reflect a “worst-case” for potential intrusion of soil vapour into a heated building.

2.1 Groundwater

The interpreted pattern of local groundwater appears to flow in a north-northwest direction relative to the historic waste disposal site. The water quality at the down gradient test locations indicate the level of impact by landfill leachate indicators to be relatively low with no detectable dissolved volatile compounds.

The natural gravel and sand in the river valley and underlying the waste material is pervious and the underground sewer pipes traversing the historic waste disposal site are interpreted to not influence the pattern of local groundwater. Thus, the migration of leachate would be governed by the natural pattern of flow.

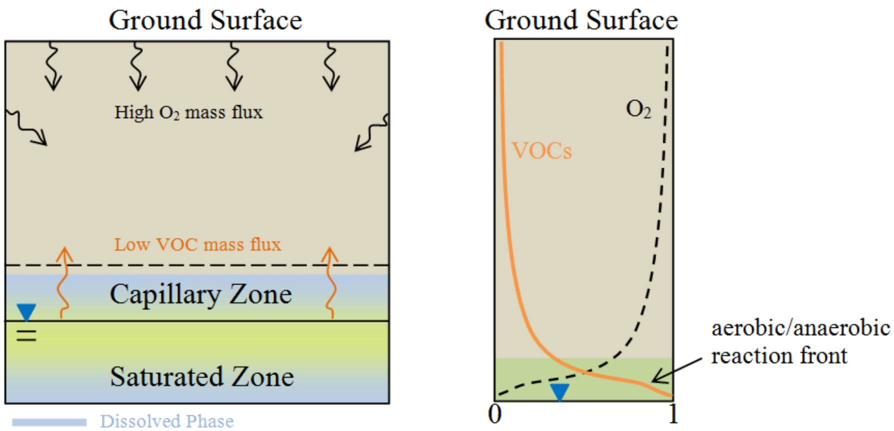
The groundwater velocity is estimated to be 2.7 m/day. Thus, excluding other influences, the groundwater with leachate leaving the site is predicted to reach the river in 75 to 80 days, more or less.

2.2 Soil Vapour

The concentration of landfill soil gas was not notably elevated at the test locations. However, a variety of VOCs including the presence of various siloxanes was noted and clearly suggests the presence of landfill soil gas.

Aside from soil landfill gas, other potential sources of indoor air vapour intrusion include radon gas, petroleum hydrocarbons and other refined petroleum solvents (chlorinated and non-chlorinated). The presence, fate and movement of these various chemical vapours vary substantially in an unsaturated zone. These boundary conditions can influence their respective persistence in the subsurface and the risk of intrusion into a building envelope. For this project, other potential sources and types of volatile soil vapours are not evaluated.

A general conceptualized illustration of volatile soil vapour in the unsaturated zone along with potential naturally occurring attenuating influences is depicted below.



To evaluate whether the potential attenuation of some soil vapour constituents is occurring at a specific development would require an on-site specific evaluation. This level of assessment for the soil landfill gas encountered at the LTCHS Site would require a rigorous seasonal testing program. Attenuation of a specified soil vapour constituent is the reduction of the concentration of the contaminant chemical in a subsurface plume as it migrates from the source area. Physical factors affecting the attenuation of an identified chemical contaminant that is present in a soil vapour plume include, in no order of priority and the following factors are not an exhaustive list:

- Vertical and horizontal separation of the receptor building relative to the source;
- Range of fluctuation, gradient and depth to groundwater;
- Preferential subsurface pathways for soil vapour migration and points of ingress (POIs) into a building; and
- Seasonal climatic effect of temperature to air and soil, wind, precipitation and barometric pressure.

Chemical attributes influencing the in-situ attenuation of soil vapour constituents include:

- Rate of bio-attenuation which is affect by biological (nature and type of microbial activity) processes;
- Availability of subsurface oxygen;
- Soil moisture content and fraction of organic carbon; and
- Vapour pressure and vapour density attributes of the chemical.

The collection of data to determine an attenuation factor for specified contaminant chemicals of concern and whether a chemical interaction exists is a complex and expensive series of tasks and (typically) the results would likely be of limited usefulness for this project.

Hence, natural attenuation factors can be inherently difficult to evaluate and conservatively for this project, attenuation of the soil landfill gas has been not been considered in the calculations for the PQRA.

2.3 Exposure Pathways

Soil Vapours
It is possible that subsurface soil vapour may be present underneath the building footprint. Soil vapour may migrate into the building by way of fractures and joints in the floor that serve as points-of-ingress (POIs). It is understood the building does not have a basement.

Subsurface soil vapour may migrate to near-by residences. The exposure pathway for vapour inhalation via vapour intrusion mechanisms is always considered to human health. Based on the laboratory results and field observations, there is a potential for soil vapours to migrate to residential properties west of the LTCHS facilities, across 43 Avenue. POEs for potential subsurface soil vapours are anticipated to be from pipe penetrations, cracks and joints in the basement floors and foundation walls. Field data and laboratory results for groundwater suggest the degree of saturation is very low. Thus, the potential for soil vapours containing landfill gas from the LTCHS Site is proportionately considered to be low or negligible.

Groundwater
The dissolved organic hydrocarbons measured in the groundwater presents an environmental concern for general water quality objectives. Presently, local groundwater is not utilized. However, the policy of ESRD is to protect all water resources and guidance for managing contaminated groundwater in Alberta on a risk-based approach is applied.

Present findings demonstrate a minor level of leachate parameters in the groundwater leaving the site. This condition and situation will likely continue and persist.

Soil Contamination
Given the depth to the zone of impact, direct contact by local residents with the impacted soil underlying the waste material is considered to be practically negligible. However, direct contact with impacted soil and groundwater may be possible by excavation contractors involved with maintenance and construction activities relating to buried utilities within the area of concern. Contractors should be informed and made aware of the potential hazards and implement an appropriate safe work (ECO, environmental construction operations) plan.

3.0 ENVIRONMENTAL RISK ASSESSMENT

The use of various risk assessment tools is a common practice to decision making in professional practice. For this discussion, an evaluation of risk is a systematic process involving the identification and evaluation of hazards, exposures and receptors with specific focus to its associated vulnerabilities with consideration of the likelihood for an adverse effect to occur. In general, a risk assessment is a tool to assist decision makers to manage the potential risk(s) for an adverse effect from an exposure to an identified hazard.

The reliability of the results from a risk assessment is contingent upon a certain amount of information. Consequently, a natural impediment for a risk assessment can arise from data gap(s) and uncertainties associated with available information. With professional judgement, a Factor of Safety or amplification factor is typically applied to compensate for the uncertainties and data gaps.

Consideration of the available data and resources for this project, a preliminary quantitative risk assessment (PQRA) is viewed as an acceptable approach to conducting a risk assessment to support a site-specific environmental risk management plan. The PQRA strikes a balance between a simple qualitative (highly subjective) risk screening process and a detailed quantitative environmental risk assessment. Generally, the degree of reliability, accuracy and defensible quantification of identified risks improves as the level of uncertainty diminishes from a subjective risk assessment to a quantitative model.

The PQRA may be viewed as a working model that can be further developed into a site-specific quantitative risk assessment. In essence, a PQRA can be directly developed into a site-specific quantitative risk assessment by incorporating more extensive physical data and more complex algorithms in the risk model.

The PQRA applied for this project utilizes prescribed methods to ensure exposures and the assessed risks are not underestimated. Hence, when a risk outcome is deemed negligible then the actual site risk would most likely be presented as negligible. Contrary, when a PQRA risk value shows a potential for an unacceptable level of risk, the actual site risk may be unacceptable or it may require further additional assessment to address the conservatism and uncertainty in the PQRA process such that the specific risk can be better understood and quantified.

At the LTCHS Site the various potential subdivision developments applicable to AB Reg. 43/2002 along with the other potential general commercial developments and activities associated with utility infrastructures, the potential receptor attributes input to the PQRA are outlined below:

Residential – is a primary activity of the property and includes detached houses and multi-family buildings (side-by-side, condominiums/apartments). Default exposure assumptions for adults and children are 32.9 kg child over 5 years old, 70.7 kg adult over 20 years old, inhalation rate 16.6 m^3/day for an adult and 14.5 m^3/day for a child, total annual exposure 24 hours a day, 365 days/year for a 80 year residence time.

Non-residential Institutional includes school and hospitals. 70.7 kg adult over 20 years old, inhalation rate 16.6 m^3/day for an adult and 14.5 m^3/day for a child, total annual exposure 8 hours a day, 5 days a week for 52 weeks/year for a 35 year period of employment for workers and 12 years for students.

Non-residential Commercial can include a diverse range of activities and land uses including low sensitive uses including warehousing, service station and more sensitive uses such as day care centre, medical clinic. Default exposure assumptions for workers are 70.7 kg adult, inhalation rate 16.6 m^3/day, total annual exposure 8 hours a day, 5 days a week for 52 weeks/year for a 35 year period of employment.

Other potential land developments which are not addressed by Section 13 of AB Reg. 43/2002 such as retail and light commercial activities and the installation and maintenance of underground utilities would also be subject to potential exposure. Thus, for other retail and light commercial activities the above attributes for non-residential activities and an additional group subject to potential exposure to remote soil landfill vapours is the:

Construction/Utility Worker at construction sites with exposure to soil vapours, not including exposure to any other site-specific chemicals. Default exposure assumptions for workers are 70.7 kg adult, inhalation rate 1.4 m^3/hr, total annual exposure 10 hours/day, 5 days a week for 48 weeks/year for a 35 year period of employment.

In general, the above exposure settings and the applied attributes are intended to yield a conservative outcome such that the real-case exposure situation would be expected to not be more than the model parameters for the given specified hazard. It is acknowledged the Health Canada protocol for residence time (80 years) and employment time (35 years) may not be reflective of the majority of situations. Regardless, this look-to-exempt approach, meaning that if a single HQ outcome is greater than 1 in a scenario then a mitigative requirement is identified. With receptors being "off-site" relative to the

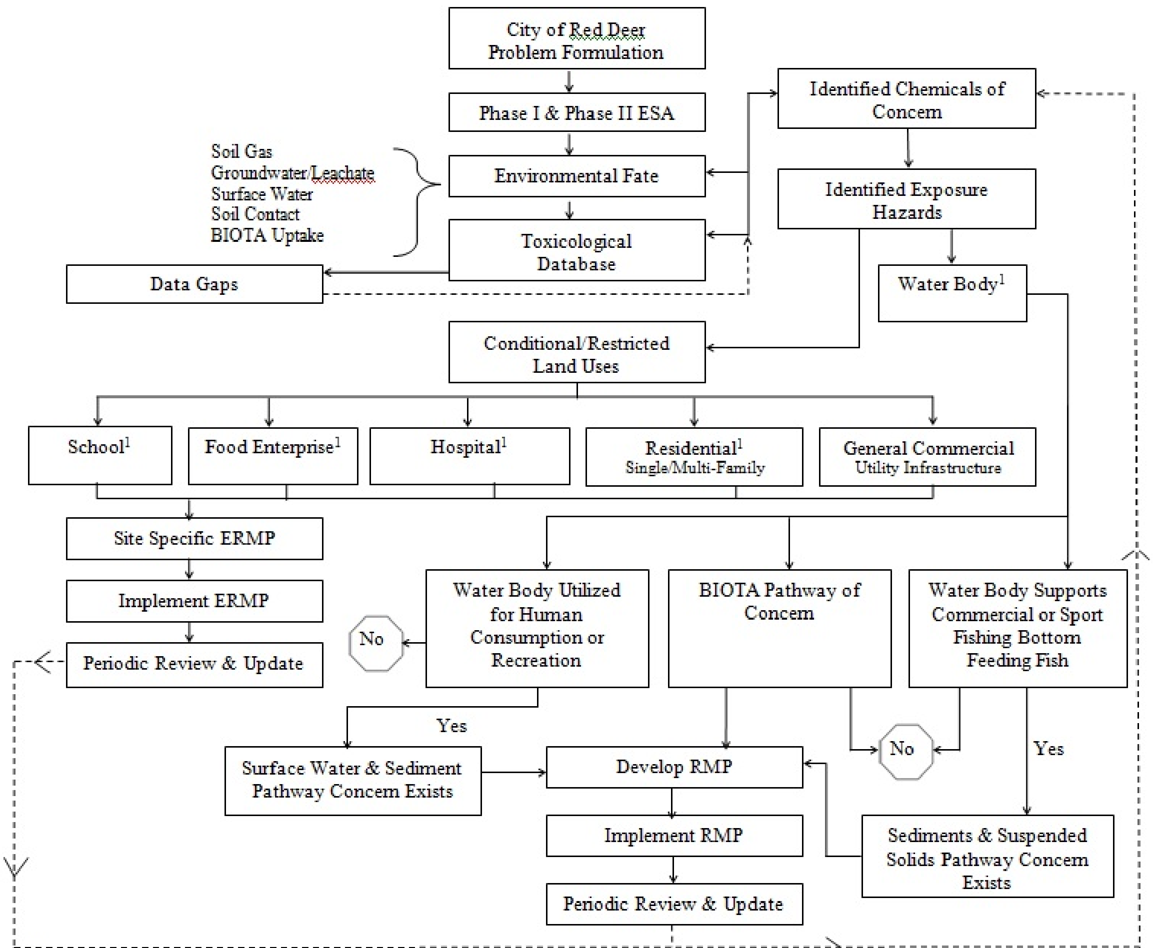
LTCHS Site, the inhalation route to a volatile chemical via vapour intrusion becomes the greatest potential concern for exposure. Subsurface VOCs may degas from leachate leaving the LTCHS Site and thereby contributing to the subsurface soil vapours.

Health effect(s) are contingent on a variety of factors including level, duration and frequency of exposure, toxicity of the chemical and individual sensitivity to the chemical. The principal concern for this PQRA is whether the identified chemicals of concern potentially pose an unacceptable level of risk for chronic health effects due to a long-term, low concentration exposure scenario.

It is recognized, the PQRA presented here is conducted with numerous assumptions and limitations. Consequently, this PQRA should not be viewed as a comprehensive analysis for any particular property lying within the prescribed distances from the LTCHS Site. As noted above, the PRQA is a standardized approach developed by Health Canada and for this project, the PQRA is intended to be utilized to support the regulatory review process for subdivision and development applications which fall into the regulatory framework of AB Reg. 43/2002 and other potential general commercial development and utility activities lying within the prescribed setback distance for the LTCHS Site.

The diagram below illustrates the process to formulate the risk assessment process to assist with the regulatory review process for a proposed future subdivision development within the regulatory setback distance of the LTCHS historic waste disposal site.

Process of Developing ERMP
Lindsay Thurber Comprehensive High School Site



[1] As defined in Part 2 Section 13 of AB Reg. 42/2002

3.1 Identified Environmental Health Concerns

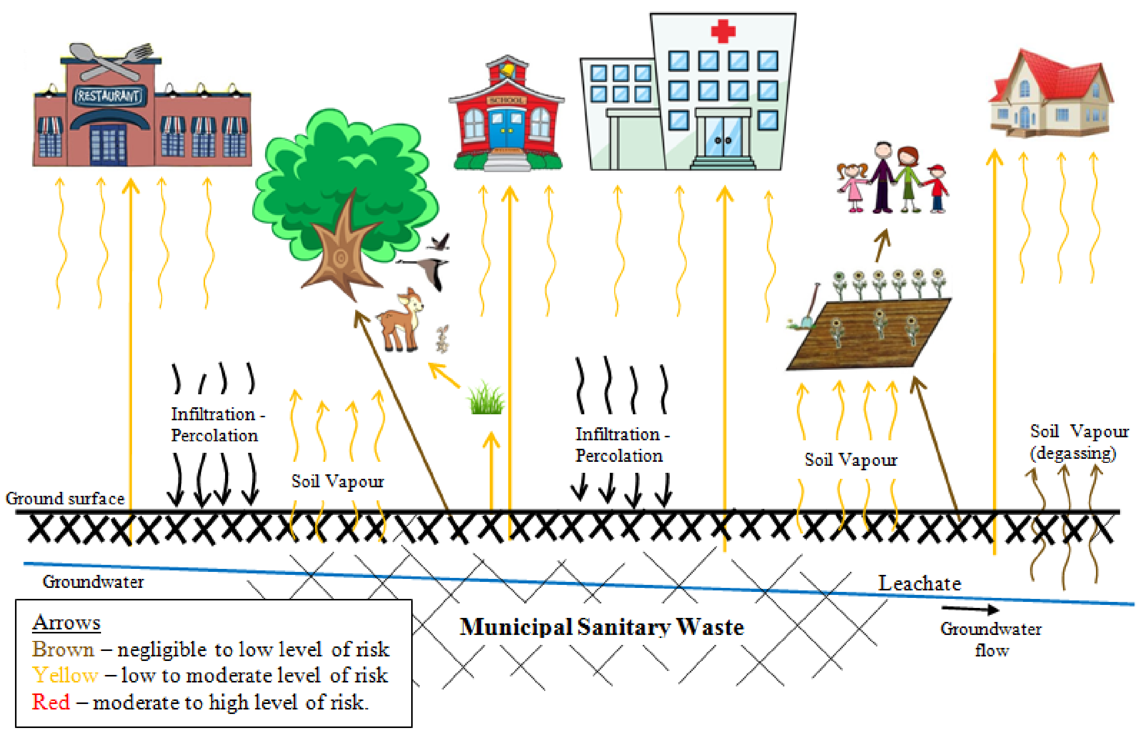
The environmental health risks presented by this historic waste site to the existing and future developments is primarily from landfill soil gas and to a lesser degree from volatile constituents that degas from leachate leaving the historic waste site into the unsaturated zone above the groundwater table.

The age of this non-operating landfill (about 46 years) suggests the production and quantity of landfill gas may have peaked and/or stabilized. As reported in the 2013 Phase II ESA. It is noted, the initial assessment for soil vapour occurred during the summer and higher subsurface concentrations may result during the winter, in frozen ground conditions. Generally, the potential risk of exposure to soil vapours increases during rising groundwater and frozen ground conditions. Opportunity to gather further seasonal data would assist to better understand the subsurface environmental conditions and whether potentials for transient variables persist at the LTCHS Site that could present further exposure hazard.

For the leachate leaving the site, the river is considered to be the most sensitive receptor. Initial results indicate the leachate is predominantly composed of a mixture of inorganic and nutrient compounds. The measured concentrations do not suggest an immediate risk to the water quality in the river. Hence, it is not anticipated the leachate will be a notable hazard to the river. Dissolved volatile compounds were not detected at the down gradient groundwater monitoring wells in August 2013. Hence, it is presumed VOCs degassing from groundwater will not be a factor to off-site subsurface soil gas.

In general, the risks associated with soil vapour and leachate to land that is off-site of the historic waste disposal area is the focus of protection by AB Reg. 43/2002. To demonstrate the complete soil vapour intrusion pathways for this project, a source, various migration routes and receptors are shown in the pictograph below.

Pictograph Depicting Potential Environmental Exposure Hazards for Soil Vapour Intrusion At Land Uses Near Historic Waste Disposal Sites



3.2 Boundary Conditions for PQRA

The logistical boundary for the PQRA is the prescribed 300 m regulatory setback distance shown on Figure 1. The existing residential homes and the schools lying within the regulatory setback are presumed to predate the historic waste disposal activity and AB Reg 43/2002.

Temporal factors (seasonal climate conditions, weather, and natural disasters) can influence the level and duration of exposure. Should data be insufficient to extrapolate the temporal variation; then when necessary, a reasonable conservative assumption(s) can be applied. Critically, it is important to identify the most sensitive temporal factor(s) and consider the potential maximum and minimum fluctuations and its impact to the outcome of the risk model. Accordingly, an extreme temporal event may warrant a special exposure consideration for the ERMP. This may be considered in a future iteration of the PQRA model with inclusion of appropriate climate change adaption factors.

3.2.1 Hazard Assessment

For this PQRA, the chemicals of concern identified from the Phase II ESA form the basis of the list of target chemicals. The chemicals of concern are summarised in Table 2A. It should be noted, this list should be viewed as an interim/provisional list. Additional chemicals may be added as new information from future testing becomes available.

A database for the identified chemicals of concern has been compiled, refer to Table 2B. Additionally, a brief abstract of each identified chemical of concern is provided in Appendix B. For consistency, physical, chemical and toxicological information was referenced from Canadian sources. It is recognized some Canadian sources do not update the chemical information as frequently as other countries. However, in many instances the values published in Canadian sources are commonly obtained from American agencies, World Health Organization and some European countries. To maintain an updated PQRA for the LTCHS Site, the toxicological information applied in this PQRA should be periodically reviewed and updated.

3.2.2 Exposure Assessment

The historic waste disposal site is viewed as the source of the identified chemicals. As noted in Section 1.4, the location of the waste materials remains fixed and no further mitigative actions are planned.

Consequently, the potential exposure pathways consist of the following in order of rising priority:

- Biotic uptake (plants, terrestrial animals, aquatic life).
- Dermal contact, soil ingestion and ponded water at the waste disposal site.
- Groundwater migration pathway.
- Unsaturated zone above the local groundwater table.
- Inhalation of landfill soil gas.

The calculated hazard quotient (HQ) is a risk estimate determined from the ratio of the estimated concentration in an environmental medium (air) and the toxicological reference value (TRV) or tolerable concentration for an identified chemical of concern.

3.2.3 Receptor Characterization

The historic waste disposal site is viewed as the source of the identified chemicals. As noted in Section 1.4, the location of the waste materials remains fixed and the city applies administrative controls to prevent development of either enclosed and/or occupied buildings within the area of the historic waste material. Consequently, the potential receptors consist of the following in order of rising priority:

- Gaetz Lake and the Red Deer River.
- Biotic factors (plants, terrestrial animals, aquatic life).
- Recreational users of the public pathways, park areas and the running track.
- People in occupied buildings including future buildings.

3.2.4 Risk Characterization

Toxicological parameters for the identified chemicals of concern and receptor characteristics were applied determine a Hazard Quotient (HQ). A calculated HQ less than 1 suggests the estimated potential exposure is below the TRV and the corresponding health risk to an exposed person would be negligible for this specific exposure pathway. When the HQ is greater than 1, the potential rate of exposure is predicted to exceed the established acceptable level of exposure thereby warranting a mitigative or adaptive protective requirement.

The inhalation of volatile chemical vapours by humans is quantitatively predicted by:

$$\text{Dose (mg/kg bw/day)} = \frac{C_A \times IR_A \times RAF_{Inh} \times D_1 \times D_2 \times D_3 \times D_4}{BW \times LE}$$

Where:
C_A = concentration of contaminant in air (mg/m^3)
IR_A = receptor air intake (inhalation) rate (m^3/day)
RAF_{Inh} = relative absorption factor for inhalation (unitless)
D_1 = hours per week exposed/24 hours
D_2 = days per week exposed/7 days
D_3 = weeks per year exposed/52 weeks
D_4 = total years exposed to site (to be employed for assessment of carcinogens only)
BW = body weight (kg)
LE = life expectancy (years) (to be employed for assessment of carcinogens only)

3.2.5 Potential Municipal Administrative Controls

Should soil gas and potential soil vapour intrusion controls are not feasible, other interim or permanent institutional measures can be considered by the City. These legal and administrative measures can include bylaw zoning conditions, restrictive covenants on land title and land use advisories.

4.0 CONCEPTUAL SITE MODEL (CSM)

A conceptual site model (CSM) has been developed to broadly identify the environmental concerns associated with this historic waste site. This CSM is a simplified representation of the identified chemicals of concern, the potential routes for contaminant migration and potential exposures. These various routes of migration and potential exposures are assessed to qualitatively develop the potential settings for risk (environmental liability). The reader should note, this CSM is preliminary in nature and is limited to initial information compiled from the results of the Tiamat 2013 Phase II ESA.

The CSM is applied to complete the PQRA. A complete environmental risk assessment and evaluation of environmental liability is beyond the context of this report. The information is solely to assist with the development of the site-specific ERMP.

To provide an overview of the contaminant situation, an initial CSM consists of bridging the identified chemicals of concern to the following two main pathways of exposure:

1. Pathways for contaminant migration; and

2. Pathways for exposure.

The migration pathway is illustrated by schematic cross sections. The cross sections are developed by integrating information from borehole logs, measured groundwater levels, measured groundwater indices and laboratory results. As shown on Figure 2, the selected cross sections transect the site in two directions, in the interpreted direction of local groundwater flow and traversing the flow direction. The interpreted cross sections are presented as Figure 3.

The primary contaminant transport pathways are described as follows:

- Lateral transport of dissolved volatile compounds in the groundwater passing through the waste material.
- Natural degradation process and the volatilization/degassing of dissolved hydrocarbon constituents from groundwater and from hydrocarbons sorbed onto soil particles which can develop into subsurface soil vapour.
- Plume of soil vapour, which, pending several physical and temporal factors, can migrate primarily through the porous media via natural advection and diffusion processes to building envelops and buried utilities. It is noted, lateral migration could also be influenced by the heterogeneity of the observed texture of subsurface soil (units of silt, sand, clay and gravel).
- The lateral extent of the soil vapours may extend off-site onto third party property. However, the magnitude of the soil vapours are not considered to be significant during summer months. Presently, there is no site data for a winter condition.

4.1 Contaminant Fate and Transport

Contaminant fate and transport refers to the way a substance travels through various environmental mediums. This section discusses the physical and chemical processes that affect the subsurface migration of dissolved chlorinated hydrocarbons identified in the on-site and off-site it areas.

<u>Convection</u>
Convection is the mechanism of transport by diffusion and advection. The generation and quantity of landfill soil gas is presumed to have peaked and/or stabilized at the LTCHS Site. Consequently, the most heavily impacted areas lie adjacent to the LTCHS facilities.

Landfill soil gas may migrate slowly from area of high concentration to regions of lower concentration. Preferential venting to atmosphere likely occurs during the summer. Exposure to volatile vapours exhibiting a specific gravity that is higher than air is generally low. For leachate, the transport process in advection is more rapid than diffusion as substances are usually transported via the bulk motion of groundwater to down gradient areas. In some instances, a dissolved plume can migrate at a rate exceeding the flow of groundwater.

Dispersion

The relative concentration of landfill soil gas in the soil and groundwater is considered low. Accordingly, a dispersion mechanism is not considered to be a dominant factor for the migration of dissolved landfill gas in the subsurface.

Natural Attenuation

Natural bio-chemical and geochemical occurring processes can be effective in reducing the toxicity of organic contaminants in the soil and groundwater. Several factors affecting the efficiency and effectiveness of natural attenuation processes are typically monitored as a method to assess natural biodegradation. Some factors for natural attenuation include:

- Mineral precipitation.
- Absorption – fluid permeates or dissolved by liquid or solid.
- Adsorption – formation of gas or liquid film on solid surface.
- Biological Uptake – transfer of substances from the natural environment to plants, animals and humans.
- Microbiological - biodegradation phenomena where the contaminant constituents are completely mineralized with end products of carbon dioxide and water.

It is noted natural attenuation processes are likely occurring at the site. An example of the dechlorination reduction of cis-1,2-Dichloroethylene can be summarized as: DCE → Vinyl Chloride (VC) → Ethane. To date, ethane and vinyl chloride have not been detected in the soil gas or in the groundwater. DCE was detected in soil samples at TH-04, TH-05 and TH-09.

4.1.1 Volatile Organic Compounds in Soil

DCE and trace amounts of BTEX compounds were noted in the soil underlying the waste material. The concentrations are not considered to be significant. In general the soil quality underlying the historic waste material appears to be relatively acceptable.

4.1.2 Volatile Organic Compounds in Groundwater

VOCs were not detected in the groundwater samples. It is uncertain whether this initial test result is indicative of the environmental quality of the local groundwater. Additional testing would be necessary to better understand the quality of the local groundwater leaving the site.

4.1.3 Combustible Headspace Vapours

On August 15, 2013 combustible headspace vapour readings at test locations lying outside of the historic waste area ranged from non-detect to 270 ppm. A test event during frozen ground conditions would reveal the potential seasonal range of variance for landfill soil gas outside of the waste area.

Headspace vapour readings at monitoring wells situated within the historic waste materials were notably higher with the highest combustible vapours to be greater than 100% LEL and volatile vapours to be 25 ppm.

4.1.4 Lateral Transport of Groundwater

Local groundwater beneath the site and the nearby areas are interpreted to be in an unconfined condition within a zone of discharge (upward flow gradient). The calculated horizontal velocity of the groundwater is about 2.7 m/day. The lateral migration of groundwater is one mechanism for the distribution of dissolved organic compounds and constituents of leachate, specifically ammonia, sulphates, chlorides and nitrates.

The principal direction of flow is estimated to be north-northwest. This suggests the groundwater with leachate leaves the site onto third party property.

4.1.5 Volatilization and Vapour Migration from Impacted Soil and Groundwater

The presence of various volatile organic compounds and methane are the primary components in landfill soil gas. Typically, under an equilibrium condition, the relative density of soil vapour would exhibit a vertical concentration gradient.

Thus, it is expected the soil vapour pattern would exhibit an increasing concentration with depth and proximity to the groundwater table.

The site information has been reviewed by Tiamat along with consideration of the relative age (46 years) of the waste material at this site. In August 2013, vapour measurements at the on-site borehole locations indicate detectable soil vapours are present but at low concentrations. Higher concentration may occur when the ground is frozen impeding ventilation to atmosphere.

Vapour measurements at the off-site borehole locations indicate combustible soil vapours are relatively low and are not a significant concern.

The mapping of the groundwater elevations and the dissolved compounds in the groundwater suggest the groundwater to flow to the north-northwest towards and across the park lands associated with the River Glen and Parkland Schools and the Kerry Wood Nature Centre. In addition, potentially, several residential houses located south of 59 Street and west of 43 Avenue are viewed to be along the interpreted flow path of the groundwater from the historic waste area to the river.

Physical factors influencing the distribution of soil vapours include moisture content and texture in the soil and chemical attributes of the contaminants of concern. Soil gas also has a tendency to migrate along pathways of least resistance, including permeable pathways and/or joints/fractures in soil sediments.

Attenuation factors include biodegradation process at the subsurface aerobic/anaerobic interface, refer to illustration in Section 2.2, and the availability of dissolved oxygen. Attenuation can also occur from the vertical and longitudinal separation between source(s) of dissolved VOCs and a building envelope and preferential flow paths. There is a significant knowledge base demonstrating aerobic based biodegradation of VOCs is the dominant mechanism to subsurface attenuation. Ideally, a site-specific test would be necessary to assess the seasonal variability of volatile soil vapour and its propensity to biodegrade within a specific soil texture, moisture regime and availability of oxygen. The cost and benefit to conduct such an evaluation is not viewed to be an effective application of project resource. Conservatively, no attenuating factors have been considered to reduce the potential concentration of the soil vapour constituents.

4.2 Summary of CSM

An initial interpretation of the subsurface stratigraphy, derived from borehole information, is presented as Figure 3. There is insufficient data to map landfill soil gas or the leachate beyond the boundaries of the LTCHS Site. A summary of the identified pathways and receptors at risk by the landfill soil gas and the leachate are as follows.

Groundwater Pathway

Groundwater lies at an average depth of 2.8 m below the ground surface with an interpreted upward hydraulic gradient. The groundwater table exhibits a gentle horizontal gradient of about 3 mm/m to the north-northwest. To our knowledge, groundwater is not utilized at locations down gradient of the waste material.

The soil cover over the waste material appears to be a thin veneer (less than 30 cm) of organic loam. Differential and irregular settlement of the underlying waste material and soil is clearly evident throughout the historic waste disposal area. The irregular surface topography hampers the ability of previous surface grading to divert surface water from the waste material. Furthermore, the texture of the observed soil cover is interpreted to be a poor material to prevent surface water from infiltrating and percolating into the waste material and generating leachate.

Vapour Pathway

There is no indication of soil vapour intrusion/nuisance into nearby buildings from the contaminants identified at the site. Concentrations of combustible vapours measured from on-site monitoring wells ranged from non-detect to greater than the lower explosive limit during field testing in August 2013. Concentrations of combustible vapours measured at off-site wells ranged from non-detect to 270 ppm in August 2013.

The pervious nature of the soil lying in the unsaturated zone will limit its effectiveness to minimize or inhibit the lateral migration of the soil gas.

Soil Contact Pathway

The historic waste area has been transformed into a natural park area for public use. The potential for visitors to contact the underlying waste is considered low. Pets may disturb the relatively soft and thin soil cover and the potential to expose the underlying waste exists.

Biotic Pathway

To our knowledge, there have been no notable adverse effects to the local flora and fauna located in the vicinity of the site. At this time, there is no obvious concern for food chain transfer or plant uptake leading to a potential adverse situation.

Environmental Receptors

Accordingly, the human exposure pathway is considered (qualitatively) to be low. Nevertheless, there will be a level of risk to soil contact and inhalation should future construction or re-development activities occur at depths below 4.6 m in the areas identified by this Phase III ESA.

For potential developments adjacent and in the vicinity (within 300 m) of the LTCHS Site, the risk of exposure to the identified chemicals of concern are limited to exposure vie soil vapour intrusion into an enclosed building. As noted in Section 4.1, migrating leachate leaving the LTCHS Site may also contribute to subsurface soil vapour by natural degasing. The primary route of exposure from the identified chemicals of concern emanating from the LTCHS Site is soil vapour intrusion.

5.0 PROPOSED SITE-SPECIFIC ENVIRONMENTAL RISK MANAGEMENT PLAN

Soil vapour intrusion into enclosed buildings is well documented. Preferential pathways of least resistance and various POIs present in building foundations are concerns for potential exposure and resulting impact to human health.

Exposure to soil vapours typically arises from three scenarios:

1. Soil vapours may originate from volatile and semi-volatile organic compounds released into the subsurface.

2. Soil vapours may be sourced from specific inorganic compounds such as radon, hydrogen sulphide and elemental mercury.

3. Soil vapours degas in the subsurface from a dissolved state in groundwater.

In Canada, federal and provincial regulatory agencies have published vapour intrusion guidance information with an objective to educate and protect the envornment and human health. Presently, there are no statutory requirements or regulators for soil vapour intrusion. Regulators address soil vapour intrusion on a case-by-case basis.

Given the elapsed time (about 46 years, more or less) for the landfill soil gas, the natural geochemical processes may have reached its limit steady-state and degradation processes have likely stabilized with equilibrium conditions established.

For the fully developed urban setting with consideration of the potential hazards, level of potential exposure and potential receptors, a proposed site-specific environmental risk management plan (ERMP) is presented. The proposed ERMP is a tool to assist with the review of future subdivision and development applications on lands lying within the regulated setback distance from the historic waste disposal site. The ERMP has considered the identified hazards from the historic waste disposal site for each of the four types of regulated land uses (school, food establishment, hospital and residential), general commercial developments and infrastructure utilities lying within the setback distance.

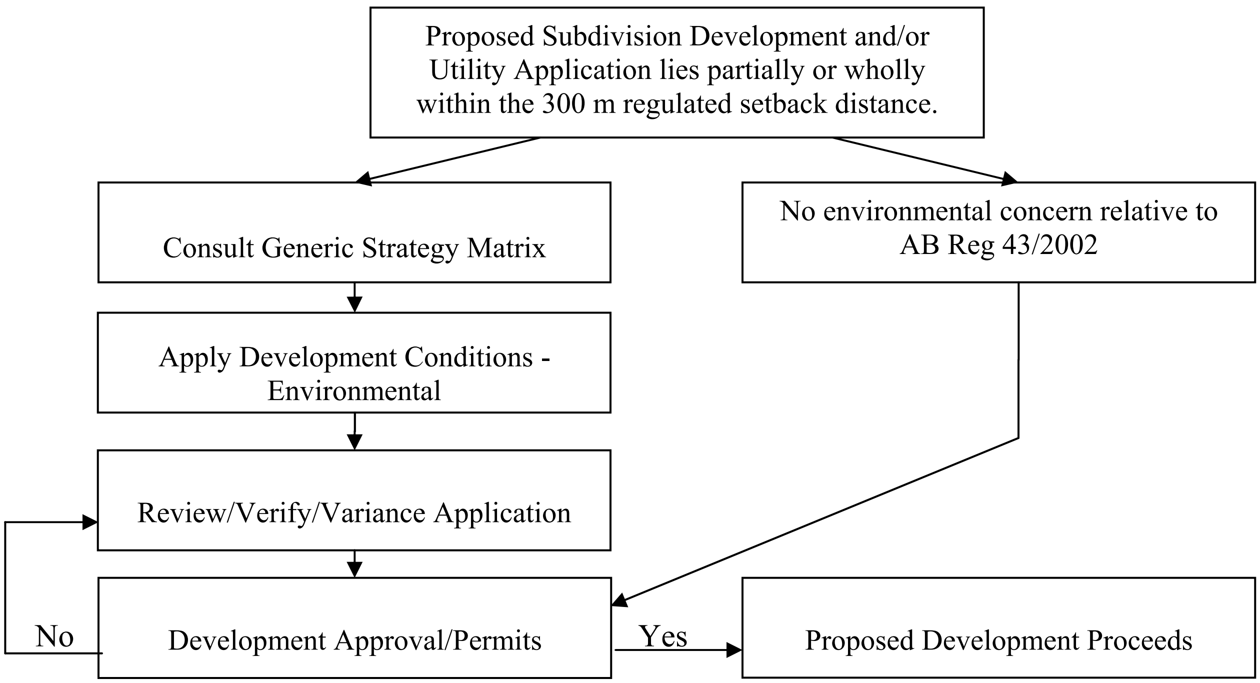
The proposed ERMP is intended to serve as a tool during the review process for a proposed subdivision and development that is located within the regulatory setback distance. Subject to a proponent's application to addressing requirements for design and land use planning, (presently), the general steps for the development review process by The City Inspections & Licensing are application preparation, submission, screening/review, permitting, verification/inspection and approval for occupancy.

The proposed ERMP is consolidated into a spreadsheet format intended to assist the subdivision/development application review process in a timely and effective manner. Where applicable, the risk management actions are presented in an objective-based format. This approach is to provide flexibility to the proponent for an application with minimal prescriptive restrictions to what and how environmental protective measures can be employed to provide the identified level of protection. Ultimately, responsibility for the specific mitigative measure(s) to effectively address the identified risk lies with the design professional. It is anticipated site inspection during installation would become part of the verification process during construction.

An overview of the proposed process for the screening and review of subdivision development near non-operating landfill applications is presented in the flow chart below.

Flow Chart for Development Application
Decision Review Process Near Non-Operating Landfill

School/Hospital/Food Establishment/Residential (as defined in AB Reg. 43/2002)
Other General Commercial Developments and Utility Infrastructure Activities



The primary risk for the potential ingress of landfill soil gas is a result of the initial screening of identified chemicals of concern having a Hazard Quotient greater than 1.0.

Residential type developments have been identified to be the most sensitive receptors. As such, to address uncertainties, a 10x amplification factor of safety for residential developments has been applied in the PQRA with no applied reduction(s) for attenuation factors. The amplification factor is subject to review and amendment when (and if) additional data such as additional contaminant information become available. As additional site-specific information is evaluated into the PQRA, the uncertainties may also be reviewed and the level of conservatism may be adjusted or reduced.

The exposure ratings for the other types of land uses with enclosed buildings will generally be not more than the values for residential. Notwithstanding, other types of building developments such as school, public institutions and commercial complexes typically include higher performance HVAC systems with greater rates of air exchanges and lower periods of human occupancy. Unique exceptions to these generalities would need to be addressed on a specific case basis. The other noteworthy activity subject to worker exposure to potential landfill soil gas is the underground utility worker and the subsurface utility infrastructure including public and private underground utilities.

The results of the risk characterization model as calculated values of HQ for the identified chemicals of concern are summarised in Tables 3A to 3D. The uncertainties and the conservatism applied for this initial PQRA have been incorporated into the baseline ERMP. Generally, a HQ value greater than 1 indicates a level of risk requiring a level of mitigative and/or adaptive action. This broad-based approach is designed to improve the clarity and timeliness for the development application review process. It must be recognized and acknowledged, the proposed ERMP for the LTCHS Site is an approach based on test results obtained from the LTCHS Site. Extrapolations for potential environmental risks associated with leachate and landfill soil gas migrating from the historic waste disposal site have been factored into the proposed ERMP. In the event the city utilizes the proposed ERMP in whole or part, it is recommended, the City view the ERMP as a dynamic guide subject to periodic update, refer to Section 5.6.

It is acknowledged, an applicant may accept the protocols applied in this ERMP or chose to develop their own site-specific plan. In this event, it is recommended the applicant apply a similar assessment and testing methodology to ensure the results can be standardized and compared to the information presented herein. At the discretion of The City of Red Deer and in consultation with the Provincial Ministry, a blanket application for variance may be pursued to reduce the technical and administrative burden for future site-specific variance applications.

The following subsections outline the suggested minimum strategy for the four stipulated types of subdivision developments identified in Part 2 Section 13, AB Reg. 43/2002 along with general commercial developments and activities associated with utility infrastructure. The strategies have been separated into three zones extending radially from the boundary of the non-operating LTCHS historic waste disposal site; refer to Figure 1 for the approximate radial limits.

Each level of preventative/protective action is intended to prevent the ingress of landfill soil gas constituents into a building or enclosed worker space. The two general approaches to achieve this objective are:

1. Seal individual points of ingress (POIs); or

2. Create a barrier to isolate/separate the building from the soil gas.

Historically, either approach has been proven effective. There is a diverse range of engineered controls that can successfully satisfy a particular situation. The specifics for each are dependent on the considerations of the design professional working with specific building configuration, chemicals of concern, subsurface conditions beneath the proposed building and other parameters and boundary conditions.

It is noted, many design standards have unclear prescriptive directions when the design professional is reviewing potential adverse impacts which may result from a known source of environmental pollution. The decisions to manage these potential impacts will include considerations (factor of safety) to address inherent uncertainties arising from subsurface conditions. Consequently, in recognition of this and to provide flexibility to a design professional for a development application, it is recommended in the event an applicant wishes to seek an alternative risk management solution, the existing site information requirements outlined by Alberta ESRD (copy provided in Appendix A) should be consulted.

Generic strategies for the land developments prescribed in Section 13 AB Reg. 43/2002 is divided into three lateral zones as measured from the boundary of the LTCHS Site. Additionally, general commercial developments and utility work have also been evaluated. The various strategies are summarised in the table below and further details are discussed Sections 5.1 to 5.3. The recommended protocols for an ERMP for subsurface utilities is discussed in Section 5.4.

Proposed ERMP Strategies for Subdivision Developments and Utility Infrastructure Activities within 300 m of the LTCHS Site

Distance from Boundary of Landfill	Residential	School/ Hospital	Food Establishment	Other Retail/Commercial and Utility
0 - 100 m	Passive/Active	NR	NR	NR
100 - 200 m	NR	NR	NR	NR
200 - 300 m	NR	NR	NR	NR

Notes:

1) Above applicable to buildings with or without basement.
2) NR - No requirement for potential soil vapour intrusion.

HQ’s are calculated for each land use type: residential, food enterprise, commercial developments and public institutions and are shown in Tables 3A to 3F. Calculated HQ’s are based solely on receptor variables provided from Health Canada’s PQRA.

As shown in Table 3A, residential land use appears to be the scenario exhibiting the most sensitivity for a receptor to soil vapours. Calculated HQ values for residential land use are higher than other land uses due to increased exposure times; see Section 3.0. For example, the adjusted safety factor for benzene in residential land use is 56.1, compared to the other land uses at 5.8. This represents almost one order of magnitude amplification. Notwithstanding, calculated HQ values over 1.0 signifies a level of concern to hazard exposure.

Tables 3B to 3E show the calculated HQ values for other land development uses including food enterprise (Table 3B), public institutions including schools and hospitals (Table 3C), general retail/commercial type developments (Table 3D) and Table 3E reflects workers in the construction and maintenance for utility infrastructure. Excepting two chemicals (ethylbenzene and toluene), the identified chemicals of concern that have an adjusted safety factor over 1.0 are similar for the other reviewed land uses.

Various generic measures to mitigate potential soil vapour intrusion for an enclosed building are outlined in the following subsections.

5.1 Strategy for Subdivision Developments Within 100 m

The approach to this strategy consists of either a passive and/or active mitigation strategy. The strategy is a progressively increasing level of protection as the relative level of hazard increases. Examples of engineered mitigative actions as directed by the maximum HQ, refer to Table 3, are outlined as follows:

<u>Passive Measures</u>

1. Passive Measures for HQ values > 1 and < 5 – Level A
   Subgrade preparation with placement of a compacted clay liner with a minimum compacted thickness of 1 m and confirmed maximum hydraulic conductivity of 10^{-6} cm/sec.

2. Passive Measures for HQ values > 5 and < 50 – Level B
   Synthetic liner deployed to underlie the entire footprint of the building structure. The type of material, thickness and installation details are dependent on the design professional.

3. Passive Measures for HQ values > 50 and < 100 – Level C
   Passive sub-slab depressurization (SSD) system with a minimum depressurization of 4 to 10 Pa. In some instances (such as a pervious subgrade), the actual depressurization necessary may be require an active SSD or alternative active ventilation system.

Active Measures

Field verify the presence of the identified chemicals of concern and other potential chemicals in the soil gas state at the development site. If confirmed, determine the most appropriate manner to prevent soil vapour intrusion.

1. Active Measures for HQ values > 100 and < 200 – Level D
   Active SSD must be configured to compensate for depressurization of the building and have adequate negative pressure gradients across the entire footprint of the foundation.

2. Active Measures for HQ values > 200 – Level E
   Installation of a geomembrane and active soil vapour extraction with system fault notification/alarm.

3. Active Measure Alternative to approach to prevent vapour intrusion – Level F
   Establish a balanced building ventilation scheme to maintain an interior positive pressure gradient with adjustments for seasonal and temporal effects (extreme low and high temperatures and wind effects).

It should be noted, pending the type and configuration of a structure, the above generic alternative can be modified and/or combined by the design professional.

5.2 Strategy for Subdivision Developments Between 100 m to 300 m

As discussed in Sections 4 and 5, conservatively, the age of the historic waste and the relative concentrations of soil vapour measured during the August 2013 testing event are not deemed to be of sufficient concentration to adversely impact properties beyond 100 m of the boundary of the LTCHS Site. Currently, numeric models to predict transient subsurface soil vapour concentrations from a point source are complex and parameterizing a potential scenario for this project with the available data will include significant uncertainties and the output results would not be considered reliable.

On the basis of the available information, there is presently no identified risk of soil vapour intrusion by soil landfill gas into an enclosed building where the property boundary of the subdivision development lies 100 m or more from the boundary of the LTCHS Site. As noted in Section 5.0, the level of risk for developments beyond 100 m is viewed as negligible and not warranting special environmental mitigative or adaptive considerations.

It is acknowledged that other subsurface sources of contaminants originating from other source(s) which coincidently lie within the generic landfill setback distance and/or in proximity to a proposed subdivision and development application may present unique risks and such situations will likely require a separate and independent environmental evaluation and consideration.

5.3 Strategy for Subdivision Developments Beyond 300 m

There are no considerations necessary for subdivision developments beyond 300 m from a non-operating landfill in AB Reg. 43/2002.

5.4 Strategy Other Commercial Developments and Subsurface Utilities

For development activities which are not addressed in Section 13 AB. Reg. 43/2002, the same strategy to mitigate potential exposure to soil vapour intrusion in enclosed buildings should be applied. HQ values have been calculated with the available results and summarised in Tables 3D and 3E.

For installation of underground utility, the design professional should review the site conditions with consideration of potential soil landfill gas in areas lying within 100 m of the boundary of the LTCHS Site. Appropriate PPE for workers should be included in their respective Safe Work Plan.

In the event, a future utility line is proposed to cross the LTCHS Site and traverse the historic waste, the utility owner should review the proposed work with The City of Red Deer Waste Management to ensure the viability of the proposed utility line within a solid waste environment.

Maintenance activities for underground utilities including confined space entry should include a hazard assessment for the potential presence of soil landfill gas in underground vaults, manways, buried chambers and enclosed work spaces.

5.5 Proposed Regulatory Monitoring and Quality Assurance

A follow-up monitoring event may be required to track and verify the effectiveness of the mitigative measure(s) for an approved and completed development. The manner and specifics of verification testing should be proposed by the design professional.

The Design professional shall show all installation details on as-built drawings along with Assurance Declarations – Schedules A, B, C Alberta Building Code for the generic alternatives above.

5.6 Proposed Risk Communication Plan

Present risk management actions consist of the current environmental site investigations and regulatory review process of Part 2 Section 13 AB Reg. 43/2002. The information compiled by the Tiamat 2013 Phase I and II ESAs better identifies the environmental risks associated with the historic waste disposal site. This site specific information has been applied to support this site specific ERMP.

At the discretion of the City, Management in the City Licensing and Inspections and other property owners should also be notified of the proposed risk management actions to address the identified contaminants of concern. In summary, a communication mechanism should be considered for each affected community stakeholder with the objective to ensure questions and issues arising from future property and infrastructure developments within the communities are responded in an appropriate manner.

5.7 Future Review and Update to ERMP

The identified chemicals of concern reflect the initial environmental site assessment conducted in 2013. The list of identified chemicals of concern may be expanded pending results of future testing events. Furthermore, research and development of health risk information for chemical exposures whether the exposure route is direct contact, ingestion or inhalation is an ongoing progressive effort by many organizations.

Notwithstanding the above, technological advancements in building science and risk management tools continues to evolve. Accordingly, it is recommended the information presented in this PQRA be reviewed and updated as new site information becomes available. Pending the scope of an updated PQRA, a review of the ERMP should also be conducted. For instance, in the event the PQRA has been updated with higher concentrations of carcinogenic types VOCs, a review of the ERMP should then be undertaken to ensure the equivalent level of protection is preserved. Alternatively, should updates to the PQRA show no significant changes or a reduction to the level of risk characterization, then the ERMP may be left as-is or amended accordingly.

Regardless of the rate of update to the PQRA, a review and amendment of the ERMP should be undertaken at intervals of not more than 5-years. This proposed 5-year interval is aligned to how standards in the construction and land development industry are generally updated. Topically, regulatory agencies target efforts to publish an updated code edition at approximately 5-year intervals. This is “loosely aligned” with construction and building innovations and related environmental technologies. The objective of this proposed review and amendment strategy is to ensure the level of acceptable risk of human exposure to constituents of landfill soil gas is at an equivalent or lower level set forth in this PQRA.

6.0 STATEMENT OF LIMITATIONS

The conditions prevalent and noted at this time must be recognized as having a limited life. Should activities be introduced or practices change, either of which may be deemed to comply with generally accepted environmental practices, the site conditions would be altered sufficiently for this report to be invalid. This report has been prepared and is intended solely for the use of The City of Red Deer and their approved designates for the specific application described in Section 1.0 of this report.

Tiamat is not the sole source of information, records or documents contained in this report. Tiamat has not verified the information, records or documents of others contained in this report and is not liable for opinions based on inaccurate or misleading information. No representation, warranty, covenant or guarantee is made or given, nor is any responsibility assumed, with respect to the completeness, accuracy or reliability of the information, records or documents contained in this report. This report reflects work in progress and as such, the data and interpretations presented herein are not absolute. However, the general environmental concerns addressed are considered representative of the conditions at the site for which the data reflects. This report does not contain all available data for this project as relevant data is presented in other documents. Tiamat reserves the right to re-evaluate the conclusions in this report should new information become available.

This report has been prepared in accordance with generally accepted environmental engineering practice and no other warranty is made, either express or implied. The opinions, conclusions and recommendations presented herein reflect the best judgment of Tiamat Environmental Consultant Ltd. (Tiamat), ©2014 Tiamat, all rights reserved. As such, Tiamat reserves the right to re-evaluate our conclusions in this report should new information become available.

Any use by a third party of this report or any reliance by a third party upon the information, records or documents in this report is undertaken solely at the risk and responsibility of such third party. Tiamat shall not in any way be responsible for any damages suffered by a third party due to decisions or actions taken by a third party on the basis of this report.

This report was issued electronically in an encrypted PDF format. Notwithstanding, the file encryption, Tiamat cannot guarantee the contents of this report have not been altered. Should an authenticated copy be required, the reader should contact The City of Red Deer and our office.

7.0 CLOSURE

We trust the information presented herein satisfies your present requirements. Should you have any questions, we invite the reader to contact our office at (403) 640-9009.

Respectfully submitted,
Tiamat Environmental Consultants Ltd.

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/kjs

The Association of Professional Engineers and Geoscientists of Alberta
Permit To Practice No.: P 7109

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2. Phase 2 – Environmental Site Investigation - Assessment of Former Landfill in SE 21-38-27-W4M near Lindsay Thurber Comprehensive High School, Red Deer, Alberta by Parkland Geotechnical Consulting Ltd., June 2004.

3. Landfill Gas Control Proposal and Risk Management Plan for the Former Landfill in SE 21-38-27-W4M near Lindsay Thurber Comprehensive High School, Red Deer, Alberta by Parkland Geotechnical Consulting Ltd. August 2004.

4. Summary Report Former City Landfill Site Lindsay Thurber Comprehensive High School Part of SE 21-38-27-W4M, Red Deer, Alberta by Stantec Inc. and Parkland Geotechnical Consulting Ltd., March, 2007

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6. Lindsay Thurber Comprehensive High School, 2011 Gas Monitoring Program by Parkland Geotechnical Consulting Ltd., October 31, 2011.

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8. Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0 by Contaminated Sites Division, Health Canada, September 2010.

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10. Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals ($DQRA_{CHEM}$) by Contaminated Sites Division, Health Canada, September 2010.

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15. Interstate Technology & Regulatory Council (ITRC) Vapour Intrusion Pathway: A Practical Guideline, Washington, DC, 2007.

16. Assessing the Significance of Subsurface Contaminant Vapour Migration to Enclosed Spaces: Site-Specific Alternatives to Generic Estimates, Journal of Soil Contamination, Volume 8, No. 3 Pg. 389 -421, Johnson, R.L, Johnson, P.C., M.W. Kemblowski,1999.

TABLES

Table 1
General Site Attributes for Exposure to Soil Vapour Inhalation

Site Information and Environmental Setting	
Site Description:	The site is currently retained as a natural area. A walking/biking trail meanders across the site. Other than the potential pathways, there are currently no buildings within the boundaries of the site.
Legal Description:	Plan 912 0819, 4154 RS Within Ptn N & SE 21-38-27 W4M
Surrounding Land Use:	Urban Setting (City of Red Deer). Undeveloped fields and environmental reserves to the north, west and east. The Westerly Gaetz Lake is further to the east. Lindsay Thurber School Legion Track and High School (LTCHS) bounds the south and west sides of the site. The residential Community of Waskasoo is located to the south and west. The community of Woodlea is south across 55 Street. The Red Deer River is located to the west and north.
Groundwater Usage:	No usage on the site presently nor likely in the future.
Surface Water:	No noted direction of principal overland flow or surface run-off control measures. There are no obvious environmental concerns for surface run-off or run-on throughout this area.
Underground Structures:	Municipal utilities include one underground storm sewer and two sanitary storm sewers traversing the site.
Special Environmental Conditions:	The historic waste is bracketed by Gaetz (oxbow) Lakes and the Red Deer River. Landfill has been closed for about 46 years.

Receptor	Potential Exposure Routes	Soil Gas		
		Oxygenated	Ketone	Chlorinated
On-Site:				
Recreational Visitors	Inhalation of vapours from soil	×	×	✓
	Inhalation of vapours from groundwater	×	×	✓
	Ingestion of groundwater	✓	✓	✓
Off-Site:				
LTCHS and Running Track	Inhalation of vapours from soil	×	×	✓
	Inhalation of vapours from groundwater	✓	✓	✓
	Ingestion of groundwater	✓	✓	✓
River Glen School	Inhalation of vapours from soil	×	×	✓
	Inhalation of vapours from groundwater	✓	✓	✓
	Ingestion of groundwater	✓	✓	✓
Residential Houses (with basement)	Inhalation of vapours from soil	×	×	×
	Inhalation of vapours from groundwater	×	×	✓
	Ingestion of groundwater	✓	✓	✓
Gaetz Lake	Impact of vapours from soil	×	×	×
	Impact from leachate into groundwater	×	×	×
	Ingestion of groundwater	✓	✓	✓
Underground Utilities:				
Storm Sewer	Impact of vapours from groundwater	×	×	×
	Impact of vapours from soil	×	×	×
Sanitary Sewers	Impact of vapours from groundwater	×	×	×
	Impact of vapours from soil			

× - Potential Exposure Hazard
✓ - "Negligible" Potential Exposure Hazard

Table 2A
Identified Chemicals of Concern - Physical Attributes

Chemical	Media			Physical Attributes											
	Soil	Groundwater	Soil Vapour	Molecular Weight	Vapour Pressure	Specific Gravity		Solubility in Water	Henry's Law Constant	Octanol/water coefficent	Organic carbon/ water coefficient	Soil/Sediment-water coefficient	Half-life		Odour Threshold
	mg/kg	mg/L	ppbv	g/mol	mmHg	Water	Air	mg/L	Pa m3/mol	log K_{ow}	log K_{oc}	k_d	air	soil	ppm
Methane	- -	- -	ND	16.04	47,000 *	0.422	0.55	Insoluble	66874.5	1.09	90	- -	7-10 years	- -	- -
Dichlorodifluoromethane	ND	- -	0.84 - 225	120.9	4,332	1.50	4.20	Insoluble	34754.475	2.16	356	- -	105 -169 yrs	- -	- -
Chloromethane	ND	ND	0.59 - 1.34	50.5	3,800	0.92	1.80	5,000	893.6865	0.91	14	- -	1 year	- -	10
Chloroethane	ND	ND	0.39	64.5	1,000	0.92	2.22	6,000	1124.7075	1.43	24	- -	39 days	- -	4.2
Trichlorofluoromethane	ND	ND	0.21 - 0.64	137.4	690	1.49	4.70	Insoluble	9828.525	2.53	97	- -	52-207 years	- -	- -
Ethanol	- -	- -	18.1 - 44.9	46.1	44	0.80	1.60	Miscible	0.506625	-0.31	1	- -	5 days	- -	0.35
Trichlorotrifluoroethane	- -	- -	0.24	187.38	360	1.56	6.50	21	27357.75	2.35	225	- -	20 years	- -	135
2-Propanone	- -	- -	22.7 - 37.8	58.1	180	0.80	2.00	Miscible	161.1	-0.24	0.73	- -	22-23 days	1-7 days	20
Methyl Ethyl Ketone	- -	- -	3.4 - 4.3	72.1	71	0.80	2.41	Soluble	5.7653925	0.63	0.56	- -	14 days	- -	5.4
cis-1,2-Dichloroethylene	0.080 - 0.696	ND	0.26 - 1.51	97	180-265	1.28	3.34	4,000	415.4325	1.86	250	- -	6.1 days	0.14 - 9.9 yrs	0.085
Methylene Chloride	ND	ND	0.84 - 0.90	84.9	350	1.30	2.90	20,000	9098.985	1.25	24	- -	119 days	- -	250
Chloroform	ND	ND	0.31 - 1.26	119.4	160	1.48	4.12	5,000*	371.86275	1.97	34-196	- -	150 days	0.3 - 1.4 days	85
trans-1,3-Dichloropropene	ND	ND	1.82	111	28	1.21	3.80	2,000	359.70375	1.82	20-42	- -	2 days	3-4 weeks	1
Trichloroethylene	0.01	ND	8.05	131.4	58	1.46	4.50	1,280*	998.05125	2.61	101	0.093	7 & 114 days	- -	28
Tetrachloroethylene	0.027	ND	0.25 - 0.83	165.8	14	1.62	5.80	206*	1793.4525	3.40	200-237	- -	96 days	1.2-5.4 hrs	1
Benzene	0.0152	ND	0.62 - 1.43	78.1	75	0.88	2.70	700	562.35	2.13	85	- -	13 days	- -	1.5
Toluene	ND	ND	1.31 - 2.66	92.1	21	0.87	3.10	700 @ 23.3°C	672.798	2.73	37-178	- -	3 days	3 hrs - 71 days	2.9
Ethylbenzene	0.144	ND	0.21 - 0.86	106.17	7	0.87	3.70	152	798.441	3.15	2.21-3.04	- -	55 hrs	- -	2.3
Total Xylene	0.39	ND	1.05 - 5.44	106.2	0.896 @ 21°C	0.86	3.70	130	- -	- -	- -	- -	8-14 hours	- -	1
O-Xylene	- -	- -	0.34 - 1.45	106.2	7	0.88	3.70	200	524.8635	3.12	24-251	- -	1.2 days	- -	0.05
M-Xylene	- -	- -	0.71 - 4.10	106.2	9	0.86	3.70	Slight	727.5135	3.20	166-182	- -	16.3 hrs	- -	0.05
P-Xylene	- -	- -		106.2	9	0.86	3.70	200	699.1425	3.15	246-540	- -	27 hrs	- -	0.05
Styrene	ND	ND	0.25	104.2	5	0.91	3.60	300	0.27661725	2.95	960	- -	3.5-9 hours	4 months	0.008
1,2,4 Trimethylbenzene	0.118	ND	0.60 - 0.70	120.2	1 @ 13.33°C	0.88	4.10	60	524.8635	3.78	3.5	- -	6 hours	- -	0.4
Hexane	- -	- -	0.72 - 13.4	86.2	124	0.66	3.00	20	185424.75	3.90	150	- -	3 days	- -	130
Heptane	- -	- -	0.56 - 0.88	100.2	40 @ 22.2°C	0.68	4.60	3	202650	4.66	8,200	- -	54 hrs	- -	220
Cyclohexane	- -	- -	0.27 - 1.19	84.2	78	0.78	2.90	Insoluble	15198.75	3.44	160	- -	45 hrs	- -	0.41
Tetrahydrofuran		- -	2.93 - 4.78	72.1	132	0.89	2.50	Miscible	7.1434	0.46	18	- -	21-24 hrs	- -	30
1,4-Dioxane	- -	- -	2.6	88.1	29	1.03	3.00	Miscible	0.48636	-0.27	29	0.17	35 hrs	>182 days	24
2,2,4-Trimethylpentane	- -	- -	0.29 - 0.32	114.22	40.6 @ 21°C	0.69	3.93	Insoluble	307000	4.08	4.35	- -	4.5 days	- -	- -
Carbon Disulfide	- -	- -	3.55 - 15.2	76.1	297	1.26	2.63	3,000	30470.1475	1.94	270	- -	5.5 days	- -	0.016

Notes:
1) Above identified chemicals of concern are dervied from the results of a Phase II ESA, 2013. Additional chemicals may be added pending future investigation and testing events.
2) Solubility in water, Vapour pressure, Specific Gravity are at 20 °C unless otherwise stated
3) Henry's Law Constant and any value with * Temperature at 25°C
4) - -/N/E - Not tested, no value established or not evaluated.

Table 2B
Identified Chemicals of Concern - Guidelines and Toxicological Values

Chemical Chemical	Hazard Classification	Soil Vapour LTCHS site	Guidelines and Toxicology						
			Bioconcentration factor	8-hour Occupational Exposure Limit		Acceptable Daily Intake	Tolerable Daily Intake	TRV	
								TC	UR
		ppbv		ppm	mg/m^3	mg/kg/day	ppm bw/day	mg/m^3	$(mg/m^3)^{-1}$
Methane	Asphyxiant	ND	1	1,000	706	- -	- -	- -	- -
Dichlorodifluoromethane	Non-Carcinogen	0.84 - 225	25	1,000	4,950	- -	- -	- -	- -
Chloromethane	Carcinogen	0.59 - 1.34	3	50	105	- -	0.003	0.1	0.4
Chloroethane	N/E	0.39	2.5	100	264	- -	- -	- -	- -
Trichlorofluoromethane	Non-Carcinogen	0.21 - 0.64	49	1,000 [5]	5,600 [5]	- -	- -	- -	- -
Ethanol	Carcinogen	18.1 - 44.9	3	1,000	1,880	- -	- -	- -	- -
Trichlorotrifluoroethane	Non-Carcinogen	0.24	50	- -	- -	- -	- -	- -	- -
2-Propanone	N/E	22.7 - 37.8	3.2	250 [5]	590 [5]	- -	- -	- -	- -
Methyl Ethyl Ketone	Non-Carcinogen	3.4 - 4.3	1.2-27.5	200	590	- -	0.6	- -	5
cis-1,2-Dichloroethylene	N/E	0.26 - 1.51	5	200	793	- -	0.002	- -	0.15
Methylene Chloride	Carcinogen	0.84 - 0.90	2	50	174	- -	0.05	3	0.000023
Chloroform	Carcinogen	0.31 - 1.26	2.9-10.35	10	49	- -	0.01	0.04475	0.023
trans-1,3-Dichloropropene	Carcinogen	1.82	5	1	4.5	0.0003	- -	- -	- -
Trichloroethylene	Carcinogen	8.05	4-39	50	269	- -	0.00146	0.04	0.00061
Tetrachloroethylene	Carcinogen	0.25 - 0.83	26-115	25	170	- -	0.014	0.36	0.25
Benzene	Carcinogen	0.62 - 1.43	1.1-20	0.5	1.6	- -	0.004	- -	0.0033
Toluene	Non-Carcinogen	1.31 - 2.66	13 & 90	50	188	- -	0.22	3.8	5
Ethylbenzene	Non-Carcinogen	0.21 - 0.86	0.67 - 15	100	434	1.6	0.1	0.1	1
Total Xylene	Non-Carcinogen	1.05 - 5.44	1-24	100	434	- -	1.5	0.18	0.7
O-Xylene	Non-Carcinogen	0.34 - 1.45	6.2-21	100	434	- -	1.5	- -	- -
M-Xylene	Non-Carcinogen	0.71 - 4.10	6-23.4	100	434	- -	1.5	- -	- -
P-Xylene	Non-Carcinogen		15	100	434	- -		- -	- -
Styrene	Non-Carcinogen	0.25	13.5	20	85	0.133	0.12	0.092	0.26
1,2,4-Trimethylbenzene	Non-Carcinogen	0.60 - 0.70	439	25	123	- -	0.0016	0.007	- -
Hexane	Non-Carcinogen	0.72 - 13.4	200	500	1,760	- -	0.7	- -	- -
Heptane	N/E	0.56 - 0.88	2,000	400	1,640	- -	- -	- -	-
Cyclohexane	N/E	0.27 - 1.19	89	300	1,010	- -	- -	- -	- -
Tetrahydrofuran	Possible Carcinogen	2.93 - 4.78	3	50	147	- -	0.9	- -	- -
1,4-Dioxane	Possible Carcinogen	2.6	0.2-0.7	20	72	- -	0.03	- -	3.6
2,2,4-Trimethylpentane	N/E	0.29 - 0.32	2.57	- -	- -	- -	- -	- -	- -
Carbon Disulfide	Non-Carcinogen	3.55 - 15.2	<6.1 & <60	1	3.1	- -	0.1	0.1	- -

Notes:
1) Above identified chemicals of concern are dervied from the results of a Phase II ESA, 2013 at the LTCHS site. Additional chemicals may be added pending future investigation and testing events.
2) 8 Hour occupational Exposure Limit is referenced from Alberta Occupational Health & Safety Code 2009 unless no value available in which Time Weighted Average is referenced from NIOSH standards.
3) TC - Tolerable Concentration
4) UR - Unit Risk
5) - -/N/E - Not tested, no value established or not evaluated.

Table 2 Notes

1. Above identified chemicals of concern are derived from the results of a Phase II ESA, 2013. Additional chemicals may be added pending future investigation and testing events.
2. Solubility in water, Vapour pressure, Specific Gravity are at 20 °C unless otherwise stated.
3. Henry's Law Constant and any value with * Temperature at 25°C.
4. 8 Hour occupational Exposure Limit is referenced from Alberta Occupational Health & Safety Code 2009 unless no value available in which Time Weighted Average is referenced from NIOSH standards.
5. TC – Tolerable Concentration.
6. UR – Unit Risk.
7. ND – Not Detected, value is below limit of detection.
8. - -/NE – Not tested, no value established or not evaluated.
9. Alberta Environment Sustainable Resource & Development.
10. Environment Canada, Health Canada
11. Ontario Ministry of the Environment, Standards Development Branch
12. United States of America Department of Labor, Occupational Safety & Health Administration
13. Alberta Tier 1 Soil and Groundwater Remediation Guidelines December 2010
14. National Institute for Occupational Safety and Health (NIOSH) Education and Information Division
15. Federal Contaminated Site Risk Assessment in Canada
16. US National Library of Medicine, National Institutes of Health, Department of Health & Human Services, Hazardous Substance Database
17. The Merck Index, 12th Edition, 1996
18. EPA United States Environmental Protection Agency, Technology Transfer Network – Air Toxics Web Site
19. EPA United States Environmental Protection Agency, Chemical Summary Fact Sheets
20. NOAA National Oceanic and Atmospheric Administration - Cameo Chemicals Web Site
21. World Health Organization - International Agency For Research on Cancer
22. UNEP - United Nations Environment Programme

Table 3A Residential Land Use
Calculated Hazard Quotients for Identified Chemicals of Concern

Chemical	Estimate Dosage	Carcinogenic	Hazard Quotient	
	ppm bw/day	Carcinogen	Calculated	Adjusted
Chloromethane	0.1700	Carcinogen	**56.7**	**567.0**
Benzene	0.0224	Carcinogen	**5.6**	**56.1**
Methylene Chloride	0.0632	Carcinogen	**1.26**	**12.6**
Chloroform	0.0191	Carcinogen	**1.91**	**19.1**
trans-1,3-Dichloropropene	0.0190	Carcinogen	- -	- -
Trichloroethylene	0.0575	Carcinogen	**39.3**	**393.5**
Tetrachloroethylene	0.0863	Carcinogen	**6.2**	**61.6**
Ethanol	0.0199	Carcinogen	- -	**- -**
Ethylbenzene	0.0311	Possible Carcinogen	0.3115	**3.1**
Tetrahydrofuran	0.0033	Possible Carcinogen	0.0037	0.0368
1,4-Dioxane	0.0022	Possible Carcinogen	0.0733	0.7332
Trichlorotrifluoroethane	0.0004	Non-Carcinogen	- -	- -
Methyl Ethyl Ketone	0.0030	Non-Carcinogen	0.0050	0.0496
Dichlorodifluoromethane	0.2612	Non-Carcinogen	- -	- -
Trichlorofluoromethane	0.4666	Non-Carcinogen	- -	- -
Toluene	0.0279	Non-Carcinogen	0.1263	**1.3**
Total Xylene	0.0528	Non-Carcinogen	0.0352	0.3519
M-Xylene	0.0593	Non-Carcinogen	0.0396	0.3956
P-Xylene	0.0572	Non-Carcinogen	0.0381	0.3813
O-Xylene	0.0413	Non-Carcinogen	0.0275	0.2752
Carbon Disulfide	0.0111	Non-Carcinogen	0.1111	**1.1**
Styrene	0.0003	Non-Carcinogen	0.0022	0.0219
1,2,4 Trimethylbenzene	0.0257	Non-Carcinogen	**16.1**	**160.5**
Hexane	0.0111	Non-Carcinogen	0.0158	0.1585
cis-1,2-Dichloroethylene	0.0211	N/E	**10.5**	**105.5**
2-Propanone	0.0211	N/E	- -	- -
Chloroethane	0.1068	N/E	- -	- -
Heptane	0.0008	N/E	- -	- -
Cyclohexane	0.0010	N/E	- -	- -
2,2,4-Trimethylpentane	0.0004	N/E	- -	- -
Methane	- -	Asphyxiant	- -	- -

Notes:
1) Hazard Quotients are calculated on the basis of site-specific values. Generic Health Canada exposure and receptor factors are applied.
2) Landfill soil gas is the gaseous constituents present in the pores between soil particles. Once the soil gas enters into a structure, the soil gas is referred to as soil vapour.
3) Vapour inhalation for a coarse-grained soil in a basement.
3) - - No reference information for derivation.
4) Adjusted HQ - Calculated HQ with a Factor of Safety (10) applied to developments with human occupancy.
5) Bold represents HQ's greater than 1 signifying a level of concern to hazard exposure.
6) HQ's are calculated based solely on Health Canada Variables obtained in the PQRA.

Table 3B Food Enterprise Land Use
Calculated Hazard Quotients for Identified Chemicals of Concern

Chemical	Estimate Dosage ppm bw/day	Carcinogenic Carcinogen	Hazard Quotient Calculated	Hazard Quotient Adjusted
Chloromethane	0.0177	Carcinogen	**5.9**	**59.0**
Benzene	0.0023	Carcinogen	0.5841	**5.8**
Methylene Chloride	0.0066	Carcinogen	0.1316	**1.3**
Chloroform	0.0020	Carcinogen	0.1986	**2.0**
trans-1,3-Dichloropropene	0.0020	Carcinogen	- -	- -
Trichloroethylene	0.0060	Carcinogen	**4.1**	**41.0**
Tetrachloroethylene	0.0090	Carcinogen	0.6422	**6.4**
Ethanol	0.0021	Carcinogen	- -	**- -**
Ethylbenzene	0.0032	Possible Carcinogen	0.0324	0.3244
Tetrahydrofuran	0.0003	Possible Carcinogen	0.0004	0.0040
1,4-Dioxane	0.0002	Possible Carcinogen	0.0076	0.0764
Trichlorotrifluoroethane	0.0001	Non-Carcinogen	- -	- -
Methyl Ethyl Ketone	0.0007	Non-Carcinogen	0.0012	0.0118
Dichlorodifluoromethane	0.0622	Non-Carcinogen	- -	- -
Trichlorofluoromethane	0.1111	Non-Carcinogen	- -	- -
Toluene	0.0066	Non-Carcinogen	0.0301	0.3010
Total Xylene	0.0126	Non-Carcinogen	0.0084	0.0838
M-Xylene	0.0141	Non-Carcinogen	0.0094	0.0940
P-Xylene	0.0136	Non-Carcinogen	0.0091	0.0908
O-Xylene	0.0098	Non-Carcinogen	0.0066	0.0655
Carbon Disulfide	0.0025	Non-Carcinogen	0.0264	0.2645
Styrene	0.0001	Non-Carcinogen	0.0005	0.0052
1,2,4 Trimethylbenzene	0.0061	Non-Carcinogen	**3.8**	**38.2**
Hexane	0.0026	Non-Carcinogen	0.0038	0.0377
cis-1,2-Dichloroethylene	0.0050	N/E	**2.5**	**25.1**
2-Propanone	0.0050	N/E	- -	- -
Chloroethane	0.0254	N/E	- -	- -
Heptane	0.0002	N/E	- -	- -
Cyclohexane	0.0002	N/E	- -	- -
2,2,4-Trimethylpentane	0.0001	N/E	- -	- -
Methane	- -	Asphyxiant	- -	- -

Notes:
1) Hazard Quotients are calculated on the basis of site-specific values. Generic Health Canada exposure and receptor factors are applied.
2) Landfill soil gas is the gaseous constituents present in the pores between soil particles. Once the soil gas enters into a structure, the soil gas is referred to as soil vapour.
3) Vapour inhalation for a coarse-grained soil in a basement.
3) - - No reference information for derivation.
4) Adjusted HQ - Calculated HQ with a Factor of Safety (10) applied to developments with human occupancy.
5) Bold represents HQ's greater than 1 signifying a level of concern to hazard exposure.
6) HQ's are calculated based solely on Health Canada Variables obtained in the PQRA.

Table 3C Public Institution - School & Hospital Developments Land Use
Calculated Hazard Quotients for Identified Chemicals of Concern

Chemical	Estimate Dosage ppm bw/day	Carcinogenic Carcinogen	Hazard Quotient Calculated	Hazard Quotient Adjusted
Chloromethane	0.0177	Carcinogen	**5.9**	**59.0**
Benzene	0.0023	Carcinogen	0.5841	**5.8**
Methylene Chloride	0.0066	Carcinogen	0.1316	**1.3**
Chloroform	0.0020	Carcinogen	0.1986	**2.0**
trans-1,3-Dichloropropene	0.0020	Carcinogen	- -	- -
Trichloroethylene	0.0060	Carcinogen	**4.1**	**41.0**
Tetrachloroethylene	0.0090	Carcinogen	0.6422	**6.4**
Ethanol	0.0021	Carcinogen	- -	**- -**
Ethylbenzene	0.0032	Possible Carcinogen	0.0324	0.3244
Tetrahydrofuran	0.0003	Possible Carcinogen	0.0004	0.0040
1,4-Dioxane	0.0008	Possible Carcinogen	0.0076	0.0764
Trichlorotrifluoroethane	0.4666	Non-Carcinogen	- -	- -
Methyl Ethyl Ketone	0.0030	Non-Carcinogen	0.0012	0.0118
Dichlorodifluoromethane	0.2612	Non-Carcinogen	- -	- -
Trichlorofluoromethane	0.4666	Non-Carcinogen	- -	- -
Toluene	0.0278	Non-Carcinogen	0.0301	0.3010
Total Xylene	0.0528	Non-Carcinogen	0.0084	0.0838
M-Xylene	0.0593	Non-Carcinogen	0.0094	0.0940
P-Xylene	0.0572	Non-Carcinogen	0.0091	0.0908
O-Xylene	0.0413	Non-Carcinogen	0.0066	0.0655
Carbon Disulfide	0.0025	Non-Carcinogen	0.0264	0.2645
Styrene	0.0003	Non-Carcinogen	0.0005	0.0052
1,2,4 Trimethylbenzene	0.0257	Non-Carcinogen	**3.8**	**38.2**
Hexane	0.0111	Non-Carcinogen	0.0038	0.0377
cis-1,2-Dichloroethylene	0.0050	N/E	**2.5**	**25.1**
2-Propanone	0.0211	N/E	- -	- -
Chloroethane	0.1068	N/E	- -	- -
Heptane	0.0008	N/E	- -	- -
Cyclohexane	0.0010	N/E	- -	- -
2,2,4-Trimethylpentane	0.0004	N/E	- -	- -
Methane	- -	Asphyxiant	- -	- -

Notes:
1) Hazard Quotients are calculated on the basis of site-specific values. Generic Health Canada exposure and receptor factors are applied.
2) Landfill soil gas is the gaseous constituents present in the pores between soil particles. Once the soil gas enters into a structure, the soil gas is referred to as soil vapour.
3) Vapour inhalation for a coarse-grained soil in a basement.
3) - - No reference information for derivation.
4) Adjusted HQ - Calculated HQ with a Factor of Safety (10) applied to developments with human occupancy.
5) Bold represents HQ's greater than 1 signifying a level of concern to hazard exposure.
6) HQ's are calculated based solely on Health Canada Variables obtained in the PQRA.

Table 3D General Retail/Commercial Developments Excluding Food Establishments Land Use Calculated Hazard Quotients for Identified Chemicals of Concern

Chemical	Estimate Dosage	Carcinogenic	Hazard Quotient	
	ppm bw/day	Carcinogen	Calculated	Adjusted
Chloromethane	0.0177	Carcinogen	**5.9**	**59.0**
Benzene	0.0023	Carcinogen	0.5841	**5.8**
Methylene Chloride	0.0066	Carcinogen	0.1316	**1.3**
Chloroform	0.0020	Carcinogen	0.1986	**2.0**
trans-1,3-Dichloropropene	0.0020	Carcinogen	- -	- -
Trichloroethylene	0.0060	Carcinogen	**4.1**	**41.0**
Tetrachloroethylene	0.0090	Carcinogen	0.6422	**6.4**
Ethanol	0.0021	Carcinogen	- -	**- -**
Ethylbenzene	0.0032	Possible Carcinogen	0.0324	0.3244
Tetrahydrofuran	0.0003	Possible Carcinogen	0.0004	0.0040
1,4-Dioxane	0.0008	Possible Carcinogen	0.0076	0.0764
Trichlorotrifluoroethane	0.4666	Non-Carcinogen	- -	- -
Methyl Ethyl Ketone	0.0030	Non-Carcinogen	0.0012	0.0118
Dichlorodifluoromethane	0.2612	Non-Carcinogen	- -	- -
Trichlorofluoromethane	0.4666	Non-Carcinogen	- -	- -
Toluene	0.0278	Non-Carcinogen	0.0301	0.3010
Total Xylene	0.0528	Non-Carcinogen	0.0084	0.0838
M-Xylene	0.0593	Non-Carcinogen	0.0094	0.0940
P-Xylene	0.0572	Non-Carcinogen	0.0091	0.0908
O-Xylene	0.0413	Non-Carcinogen	0.0066	0.0655
Carbon Disulfide	0.0025	Non-Carcinogen	0.0264	0.2645
Styrene	0.0003	Non-Carcinogen	0.0005	0.0052
1,2,4 Trimethylbenzene	0.0257	Non-Carcinogen	**3.8**	**38.2**
Hexane	0.0111	Non-Carcinogen	0.0038	0.0377
cis-1,2-Dichloroethylene	0.0050	N/E	**2.5**	**25.1**
2-Propanone	0.0211	N/E	- -	- -
Chloroethane	0.1068	N/E	- -	- -
Heptane	0.0008	N/E	- -	- -
Cyclohexane	0.0010	N/E	- -	- -
2,2,4-Trimethylpentane	0.0004	N/E	- -	- -
Methane	- -	Asphyxiant	- -	- -

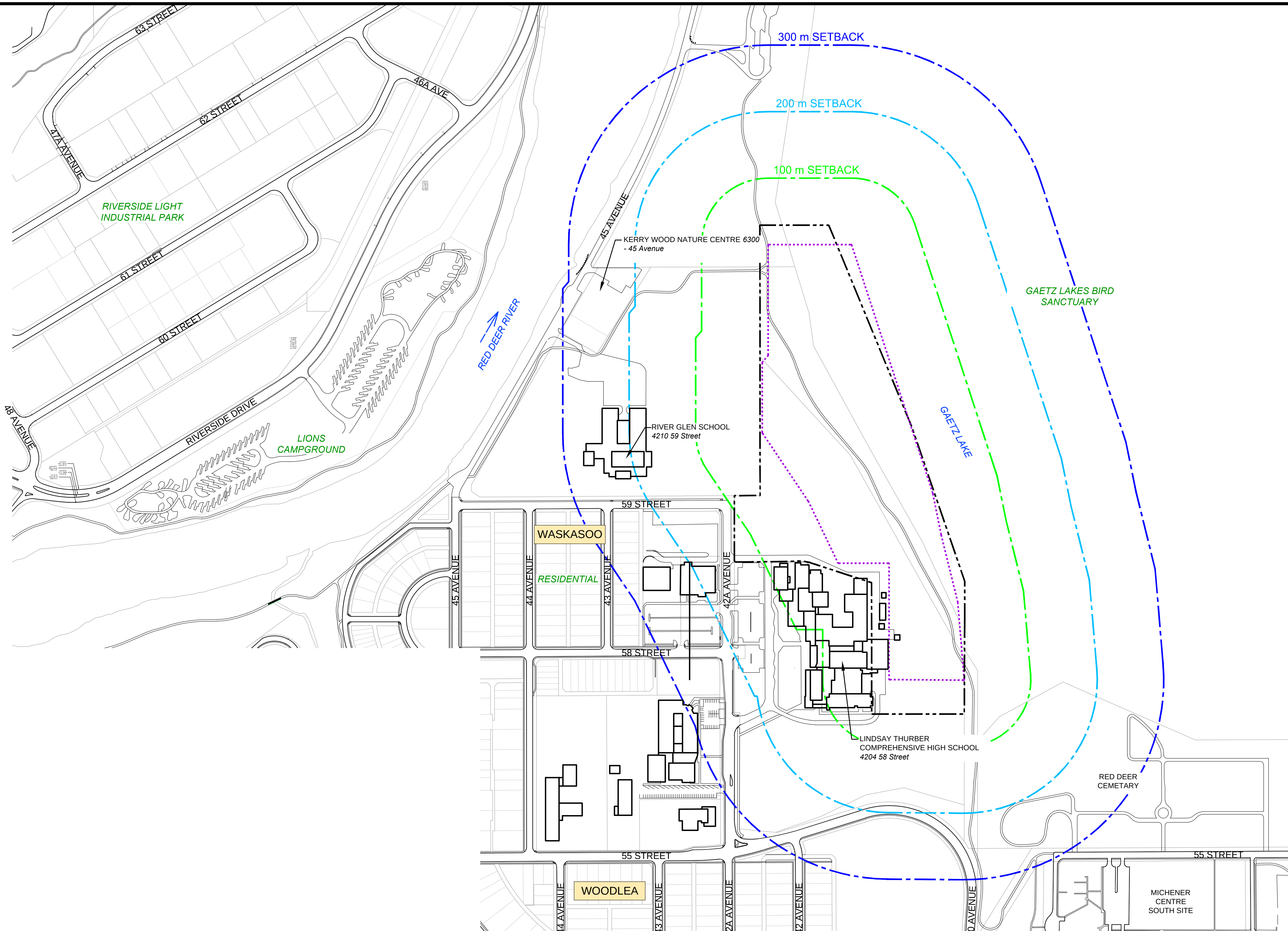
Notes:
1) Hazard Quotients are calculated on the basis of site-specific values. Generic Health Canada exposure and receptor factors are applied.
2) Landfill soil gas is the gaseous constituents present in the pores between soil particles. Once the soil gas enters into a structure, the soil gas is referred to as soil vapour.
3) Vapour inhalation for a coarse-grained soil in a basement.
3) - - No reference information for derivation.
4) Adjusted HQ - Calculated HQ with a Factor of Safety (10) applied to developments with human occupancy.
5) Bold represents HQ's greater than 1 signifying a level of concern to hazard exposure.
6) HQ's are calculated based solely on Health Canada Variables obtained in the PQRA.

Table 3E Utility Infrastructure Activities Land Use
Calculated Hazard Quotients for Identified Chemicals of Concern

Chemical	Estimate Dosage	Carcinogenic	Hazard Quotient	
	ppm bw/day	Carcinogen	Calculated	Adjusted
Chloromethane	0.0172	Carcinogen	**5.7**	**57.5**
Benzene	0.0023	Carcinogen	0.5684	**5.7**
Methylene Chloride	0.0064	Carcinogen	0.1280	**1.3**
Chloroform	0.0019	Carcinogen	0.1933	**1.9**
trans-1,3-Dichloropropene	0.0019	Carcinogen	- -	- -
Trichloroethylene	0.0058	Carcinogen	**4.0**	**40.0**
Tetrachloroethylene	0.0087	Carcinogen	0.6249	**6.2**
Ethanol	0.0020	Carcinogen	- -	**- -**
Ethylbenzene	0.0032	Possible Carcinogen	0.0316	0.3160
Tetrahydrofuran	0.0003	Possible Carcinogen	0.0004	0.0040
1,4-Dioxane	0.0002	Possible Carcinogen	0.0074	0.0743
Trichlorotrifluoroethane	0.0001	Non-Carcinogen	- -	- -
Methyl Ethyl Ketone	0.0007	Non-Carcinogen	0.0011	0.0115
Dichlorodifluoromethane	0.0605	Non-Carcinogen	- -	- -
Trichlorofluoromethane	0.1282	Non-Carcinogen	- -	- -
Toluene	0.0065	Non-Carcinogen	0.0293	0.2943
Total Xylene	0.0122	Non-Carcinogen	0.0082	0.0820
M-Xylene	0.0137	Non-Carcinogen	0.0092	0.0920
P-Xylene	0.0133	Non-Carcinogen	0.0088	0.0880
O-Xylene	0.0096	Non-Carcinogen	0.0064	0.0640
Carbon Disulfide	0.0026	Non-Carcinogen	0.0257	0.2574
Styrene	0.0001	Non-Carcinogen	0.0005	0.0051
1,2,4 Trimethylbenzene	0.0059	Non-Carcinogen	**3.7**	**37.2**
Hexane	0.0026	Non-Carcinogen	0.0037	0.0370
cis-1,2-Dichloroethylene	0.0049	N/E	**2.4**	**24.4**
2-Propanone	0.0049	N/E	- -	- -
Chloroethane	0.0248	N/E	- -	- -
Heptane	0.0002	N/E	- -	- -
Cyclohexane	0.0002	N/E	- -	- -
2,2,4-Trimethylpentane	0.0001	N/E	- -	- -
Methane	- -	Asphyxiant	- -	- -

Notes:
1) Hazard Quotients are calculated on the basis of site-specific values. Generic Health Canada exposure and receptor factors are applied.
2) Landfill soil gas is the gaseous constituents present in the pores between soil particles. Once the soil gas enters into a structure, the soil gas is referred to as soil vapour.
3) Vapour inhalation for a coarse-grained soil in a basement.
3) - - No reference information for derivation.
4) Adjusted HQ - Calculated HQ with a Factor of Safety (10) applied to address for uncertainty potential to unknown exposures.
5) Bold represents HQ's greater than 1 signifying a level of concern to hazard exposure.
6) HQ's are calculated based solely on Health Canada Variables obtained in the PQRA.
7) Hazard Quotients are based on new construction, maintenance and decommissioning activities.

FIGURES

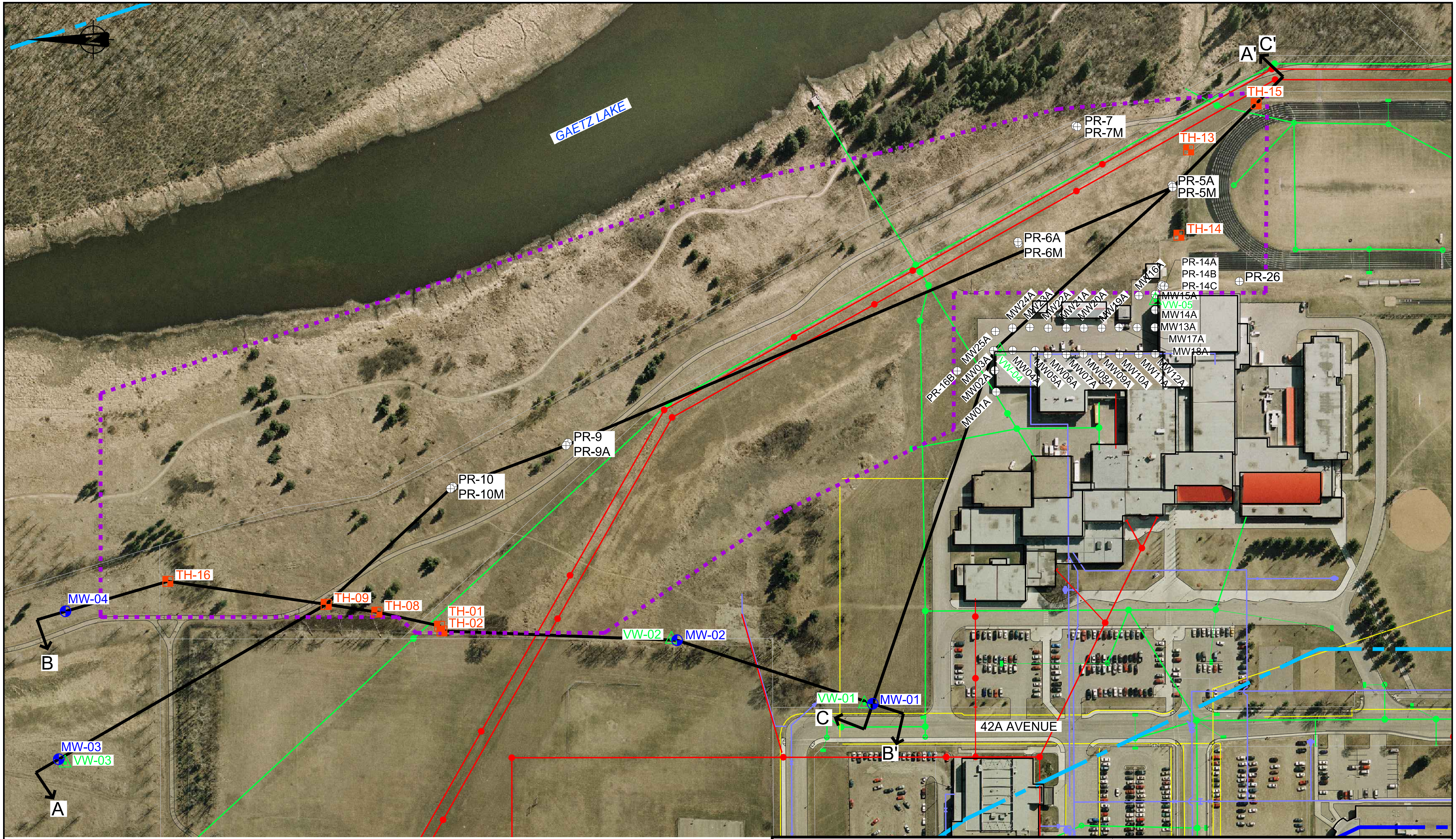


0 100 200 300m

Scale 1:6000

LEGEND
- SITE BOUNDARY
- HISTORIC WASTE DISPOSAL
- LOT BOUNDARY
- NAME COMMUNITY NAME
- 100 m SETBACK
- 200 m SETBACK
- 300 m SETBACK

CLIENT: THE CITY OF RED DEER	Tiamat Environmental Consultants Ltd.			
PROJECT: ENVIRONMENTAL RISK MANAGEMENT PLAN HISTORIC WASTE DISPOSAL SITE LINDSAY THURBER COMPREHENSIVE HIGH SCHOOL SITE	SCALE: 1 : 4000	DATE: JAN. 27/13	PROJECT NO.: 12-435	FIGURE NO.: FIGURE 1
TITLE: SITE SHOWING SURROUNDING LAND USE	DRAWN BY: LCH	CHECKED BY: LTM	CAD FILE NO.: ERMP v1.02.dwg	



SOURCE
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0 20 50 100m
Scale 1:2000

PHASE II TEST LOCATIONS

- MW-## GROUNDWATER MONITORING WELL INSTALLED BY TIAMAT (4)
- TH-## TESTHOLE (7)
- VW-## SOIL VAPOUR MONITORING WELL (5)
- MW-## GROUNDWATER MONITORING WELL INSTALLED BY OTHERS (40)
- ** APPROXIMATE LOCATION - NOT SURVEYED

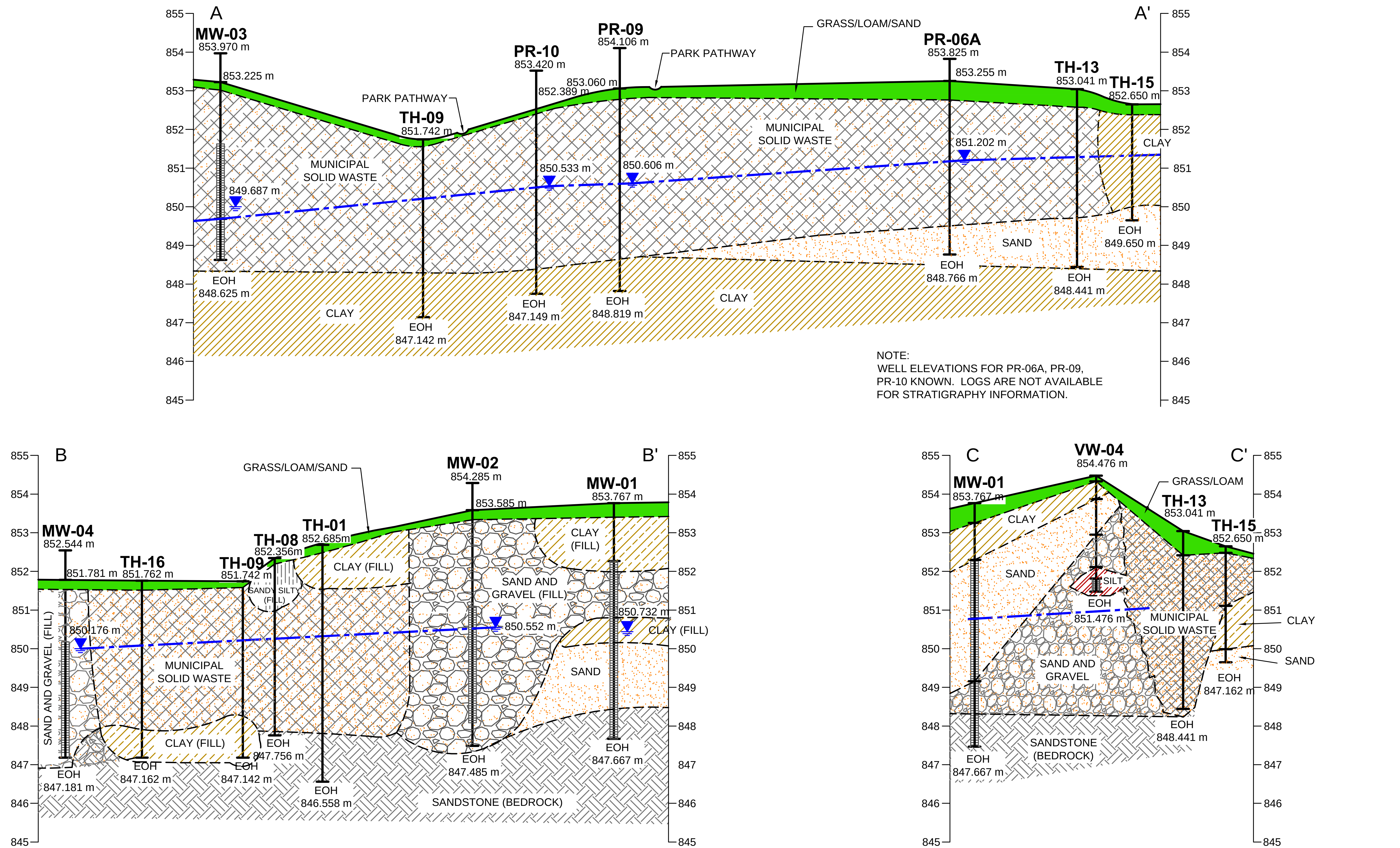
LEGEND

- HISTORIC WASTE DISPOSAL
- LOT BOUNDARY
- CROSS SECTION LOCATION
- ELECTRICAL
- SANITARY
- STORM
- WATER

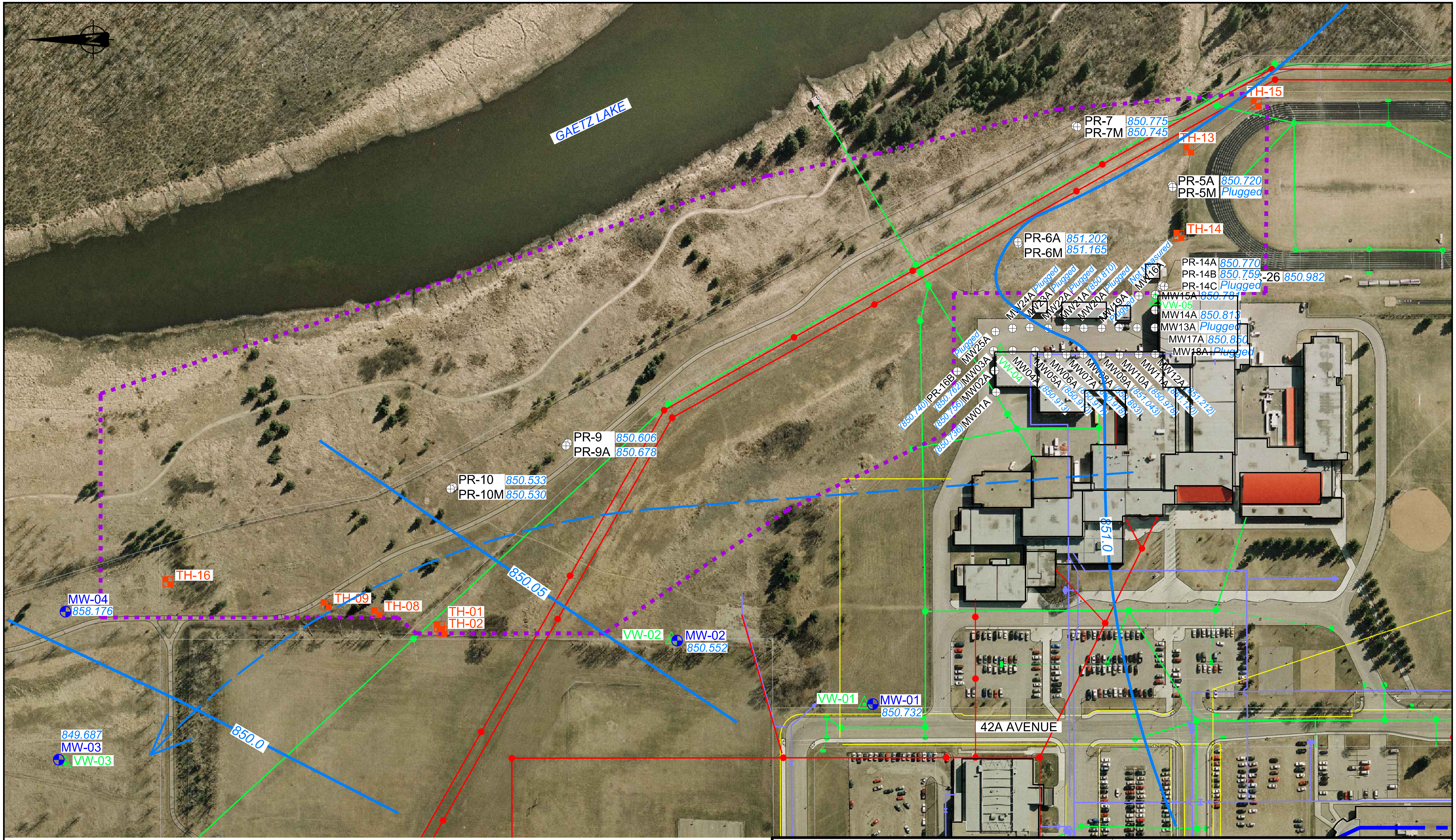
CLIENT:	THE CITY OF RED DEER
PROJECT:	ENVIRONMENTAL RISK MANAGEMENT PLAN HISTORIC WASTE DISPOSAL SITE LINDSAY THURBER COMPREHENSIVE HIGH SCHOOL SITE
TITLE:	SITE SHOWING INTERPRETED EXTENT OF WASTE

Tiamat Environmental Consultants Ltd.

SCALE:	DATE:	PROJECT NO.:	FIGURE NO.:
1 : 2000	JAN. 6/13	12-435	FIGURE 2
DRAWN BY: LCH	CHECKED BY: LTM	CAD FILE NO.: ERMP v1.01.dwg	



CLIENT: THE CITY OF RED DEER		Tiamat Environmental Consultants Ltd.		
PROJECT: PHASE II ESA HISTORIC WASTE DISPOSAL SITES LTCHS PTN NE & SE 21-38-27 W4M				
TITLE: CROSS SECTIONS A - A', B - B' AND C - C'	SCALE: 1 : 2000	DATE: MAR. 14/14	PROJECT NO.: 12-435	FIGURE NO.: FIGURE 3
	DRAWN BY: LCH	CHECKED BY: LTM	CAD FILE NO.: Section v1.03.dwg	



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0 20 50 100m
Scale 1:2000

PHASE II TEST LOCATIONS
- MW-## GROUNDWATER MONITORING WELL INSTALLED BY TIAMAT (4)
- TH-## TESTHOLE (8)
- VW-## SOIL VAPOUR MONITORING WELL (5)
- MW-## GROUNDWATER MONITORING WELL INSTALLED BY OTHERS (40)

GROUNDWATER LEGEND
- 850.000 GROUNDWATER ELEVATION (m)
- INTERPRETED GROUNDWATER CONTOUR (m)
- INTERPRETED GROUNDWATER FLOW DIRECTION

LEGEND
- SITE BOUNDARY
- HISTORIC WASTE DISPOSAL
- LOT BOUNDARY
- ELECTRICAL
- SANITARY
- STORM
- WATER

CLIENT: THE CITY OF RED DEER
PROJECT: ENVIRONMENTAL RISK MANAGEMENT PLAN
HISTORIC WASTE DISPOSAL SITE
LINDSAY THURBER COMPREHENSIVE HIGH SCHOOL SITE
TITLE: INTERPRETED GROUNDWATER ELEVATIONS - AUGUST 2013

Tiamat Environmental Consultants Ltd.

SCALE:	DATE:	PROJECT NO.:	FIGURE NO.:
1 : 2000	JAN. 6/13	12-435	FIGURE 4
DRAWN BY:	CHECKED BY:	CAD FILE NO.:	
LCH	LTM	ERMP v1.01.dwg	

APPENDIX A

ALBERTA ENVIRONMENT ESRD
REQUESTING CONSENT TO VARY THE SETBACK DISTANCE FOR A DEVELOPMENT TO A NON OPERATING LANDFILL

Requesting Consent To Vary The Setback Distance For A Development To A Non Operating Landfill

INFORMATION REQUIREMENT

May 2013

Introduction

Section 13 of the *Subdivision and Development Regulation* defines the setback distance required from a subdivision development for a residence, school, hospital, or food establishment to a non-operating landfill. The Regulation allows the subdivision or development authority to vary regulated setback distance upon receiving written consent from Alberta Environment and Sustainable Resource Development.

Setback distance from a residence school, hospital, or food establishment to a non-operating landfill is 300m.

Considerations for consent

Alberta Environment and Sustainable Resource Development (ESRD) will consider a consent to lessen the setback distance from developments near non-operating landfills, based on the following criteria:

1. All Information Requirements set out in this document must be submitted to ESRD by the subdivision or development authority;
2. The subdivision or development authority commits to developing a mechanism whereby future property owners are made aware of any consents issued;
3. Consent will not be considered when all three of the following conditions exist:
    a. Gas levels above background are present within the waste disposal area of the landfill;
    b. The land area where development is to occur has no natural physical barrier to gas movement i.e. a valley between the development and the landfill; and
    c. The development has underground infrastructure or basements
4. Where groundwater has been contaminated, consent will only be considered where:
    a. potable water to the proposed development is being supplied from a municipal system; and
    b. vegetation, or other receptors or property will not be affected by the contaminated groundwater

Only the subdivision or development authority may submit a request for variance

Consent after development

Consent to lessen the setback distance will not be considered after a development permit or subdivision approval has been issued by the local authority**.**

Information Requirements:

Consent must be provided before proceeding with any development not adhering to landfill setback requirements.

The following information is required to be provided to ESRD by the subdivision or development authority before ESRD will consider consenting to a variance request for a development near a non-operating landfill:

1. A covering letter from the subdivision or development authority requesting a variance.
2. A letter of consent from the landfill owner consenting to the encroachment.
3. A letter from the proponent (developer) stating the reasons the site must encroach the landfill setback and the alternatives if the variance is not granted.
4. Details of the type of development within the setback (including proposed design, water supply, wastewater and stormwater systems, topography, location of proposed residences, schools, etc.).

Requesting Consent To Vary The Setback Distance For A Development To A Non Operating Landfill

INFORMATION REQUIREMENT

May 2013

Consent is not provided for developments that have already occurred.

The Standards for Landfills in Alberta can be found at: http://environment.alberta.ca/02956.html

For more information on setback variances please contact your Alberta Environment regional office. http://environment.alberta.ca/contact.html

Information Requirements cont.:

5. Department of Health Permit Number or Alberta Environment and Sustainable Resource Development approval or registration number of the landfill being encroached upon.
6. An engineering report*, completed by a professional registered with APEGA, that includes, as a minimum, the following information:
   a) landfill cell delineation including approximate waste depth (use of test pits, historical aerial photography, etc.),
   b) duration of operation (actual, or estimated if actual not available),
   c) amount, types of waste, and degree of waste stabilization in the landfill,
   d) landfill topography for site drainage,
   e) landfill final cover details such as thickness and composition,
   f) a visual inspection report that details, at a minimum, vegetative stress and degree of cover, landfill settlement, exposed refuse, leachate breakout, and any other visually notable landfill issues,
   g) regional and site specific geology and hydrogeology,\
   h) a map showing all water wells and residences within a 1 kilometre radius of the site and other topographical features, such as water bodies, within 5 kilometres of the site,
   i) the applicable sections of the area structure plan documenting the zoning and expected use of the landfill and surrounding area,
   j) groundwater monitoring results,
   k) landfill gas monitoring results,
   l) an opinion on whether encroachment is feasible (under what mitigative measures, to what distance, etc.), and
   m) if mitigative measures are proposed, the design details, monitoring, and maintenance program for the mitigative measures.
7. Documentation from the Alberta Health Services that they have provided or refused the variance to construct a private water well within the 450-metre setback as per the Public Health Regulations, if applicable. (Water wells also have a setback requirement under Public Health jurisdiction. Any development with a water well will require both waivers before it can proceed.)
8. Documentation on how the development authority will deal with potential complaints from any residents within the setback.
9. Documentation on how the development authority will convey information on the setback variance to existing and successive property owners.
10. A letter from Alberta Health Services confirming that they have no concerns with the proposed development.

**The subdivision or development authority must utilize applicable sections of the current Standards and Guidelines for Landfills in Alberta to develop the information required in (6).*

APPENDIX B

GLOSSARY

Glossary

Physical and Toxicological Terms

8-Hour Occupational Exposure Limit is the maximum concentration of a substance that a worker can be exposed to during a standard 8-hour work day.

Bioconcentration Factor (BCF) provides a measure of the extent of chemical partition at equilibrium between a biological medium (e.g. fish tissue, plant tissue) and an external medium (e.g. water). The higher the BCF, the greater the accumulation in living tissue.

Carcinogenicity is the ability of a substance to produce or result in cancer.

Estimate Dosage is the predicted intake of a substance via inhalation. Calculation is derived from Health Canada's PQRA equation for inhalation of volatile substances.

Half-life is the amount of time it takes for the concentration of a given substance to fall to half its original concentration.

Hazard Quotient (HQ) is the ratio of the calculated estimated dosage of a substance to its tolerable concentration or TRV. If the HQ is greater than 1, the potential rate of exposure could exceed the acceptable levels of exposure. If the HQ is less than 1, the exposure potential is considered negligible.

Henry's Law Constant (H) provides a measure of the extent of chemical partitioning between air and water at equilibrium. The higher the Henry's Law constant, the more likely a chemical is to volatize than to remain in water.

Molecular Weight is the sum of the weight of all the atoms in a molecule.

Octanol-Water Partition Coefficient (K_{ow}) provides a measure of the extent of chemical partitioning between water and octanol at equilibrium. The greater the K_{ow} the more likely a chemical is to partition to octanol than to remain in water. Octanol is used as a surrogate for lipids (fats) and K_{ow} can be used to predict bioconcentration in aquatic organisms.

Odour Threshold is the lowest concentration of a substance that can be identified by human olfactory sense.

Organic Carbon-Water Partition Coefficient (K_{oc}) provides a measure of the extent of chemical partitioning between organic carbon and water at equilibrium. A higher K_{oc}, the more likely a chemical is to bind to soil or sediment than to remain in water.

Soil/Sediment-Water Partition Coefficient (K_d) provides a soil or sediment-specific measure of the extent of the chemical partitioning between soil or sediment and water, unadjusted for dependence upon organic carbon. To adjust for the fraction of organic carbon present in soil or sediment (foc), use $K_d = K_{oc}$ H f_{oc}. The higher the K_d the more likely a chemical is to bind to soil or sediment than to remain in water.

Solubility is an upper limit of a chemical's dissolved concentration in a solvent at a specified temperature. Aqueous concentrations in excess of solubility may indicate sorption onto sediments, the presence of a non-aqueous phase liquid.

Specific Gravity is the ratio of the density of a substance to the density of a reference substance (in this case, water or air) at the same temperature. A substance with a specific gravity greater than 1.0 has a higher mass per unit volume than the reference substance and will therefore preferentially "sink" beneath the reference substance.

Toxicological Reference Value (TRV)/Acceptable Daily Intake (ADI)/Tolerable Daily Intake (TDI) is the maximum concentration of a substance that can be ingested daily over a lifetime without risk. It is expressed based in body weight.

Vapour Pressure is the pressure exerted by a chemical vapour in equilibrium with its solid or liquid form at any given temperature. It is used to calculate the rate of volatilization of pure substance from a surface, or to estimate a Henry's Law constant for chemicals with low water solubility. The higher the vapour pressure, the more likely a chemical is to exist in a gaseous state.

Abstract for Identified Chemicals of Concern

Benzene
Chemical Formula: C_6H_6
Human Carcinogenicity: Known Carcinogen

Benzene is a well-known petroleum hydrocarbon and is a known carcinogenic, based on numerous toxicity studies. The odour threshold is 1.5 ppm. The current Alberta Tier 1 Guidelines for benzene in soil and groundwater are 0.078 mg/kg and 0.005 mg/L. The 1-hour Alberta Ambient Air Quality Objective for benzene is 0.009 ppm. The Alberta 8-hour occupational exposure limit is 0.5 ppm. Benzene is on Health Canada's Cosmetic Ingredient Hot List and Canada's National Pollutant Release Inventory.

Carbon Disulfide
Chemical Formula: CS_2
Human Carcinogenicity: Non-Carcinogenic

Carbon disulfide has an odour threshold of 0.016 ppm. Currently, there are no guidelines or standards in Alberta for carbon disulfide in soil and water; the 1-hour average Alberta Ambient Air Quality Objective is 0.010 ppm. The Alberta 8-hour occupational exposure Limit is 1 ppm. Carbon disulfide is not classified as toxic under the Canadian Environmental Protection Act (1999). Carbon disulfide is included in Health Canada’s Cosmetic Ingredient Hotlist.

Chloroethane
Chemical Formula: C_2H_5Cl
Human Carcinogenicity: Not Classified

Chloroethane has an odour threshold of 4.2 ppm. There are no published standards or guidelines In Alberta for chloroethane in soil or groundwater. British Columbia and the State of New Jersey have implemented an interim water guideline of 0.005 mg/L.
The Alberta 8-hour occupational exposure limit is 100 pm. Chloroethane is on Canada's National Pollutant Release Inventory.

Chloroform
Chemical Formula: $CHCl_3$
Human Carcinogenicity: Possible Carcinogen

Chloroform is a chlorinated hydrocarbon. The established odour threshold is 85 ppm. The current Alberta Tier 1 Guidelines for chloroform in soil and groundwater are 0.0010 mg/kg and 0.0018 mg/L, respectively. The Alberta 8-hour occupational exposure limit is 10 ppm. Chloroform is on Health Canada's Cosmetic Ingredient Hot List and Canada's National Pollutant Release Inventory.

Chloromethane
Chemical Formula: CH_3Cl
Human Carcinogenicity: Not Classified

Chloromethane has an odour threshold of 10 ppm. There are no published standards or guidelines in Alberta for chloromethane in soil and groundwater. The State of New Hampshire has implemented a drinking water guideline of 0.03 mg/L. The Alberta 8-hour occupational exposure limit is 50 ppm. Chloromethane is on Canada's National pollutant Release Inventory.

Cyclohexane
Chemical Formula: C_6H_{12}
Human Carcinogenicity: Not Classified

Limited information exists regarding cyclohexane. The established odour threshold is 0.41 ppm. There are no published standards or guidelines in Alberta for cyclohexane in soil or groundwater. The Alberta 8-hour occupational exposure limit is 300 ppm.

Dichlorodifluoromethane
Chemical Formula: CCL_2F_2
Human Carcinogenicity: Non-Carcinogenic

Dichlorodifluoromethane (Freon 12) is part of a group of synthetic chemicals called Chlorofluorocarbons (CFC’s). An odour threshold for Freon 12 has not been established. Currently, there are no published guidelines or standards in Alberta for Freon 12 in soil or groundwater. The Alberta 8-hour occupational exposure limit is currently 1,000 ppm.

cis-1,2-Dichloroethylene
Chemical Formula: $C_2H_2Cl_2$
Human Carcinogenicity: Not Classified

cis-1,2-Dichloroethylene is a chlorinated hydrocarbon with an odour threshold of 0.085 ppm. There are no published standards or guidelines in Alberta for cis-1,2-dichloroethylene in soil or groundwater. The Alberta 8-hour occupational exposure limit is 200 ppm.

trans-1,3-Dichloropropene
Chemical Formula: $C_3H_4Cl_2$
Human Carcinogenicity: Possible Carcinogen

trans-1,3-Dichloropropene is a chlorinated hydrocarbon. The established odour threshold is 1 ppm. There are currently no published standards or guidelines for trans-1,3-dichloropropene in soil and groundwater. The Alberta 8-hour occupational exposure limit is 1 ppm.

1,4-Dioxane
Chemical Formula: $C_4H_8O_2$
Human Carcinogenicity: Possible Carcinogen

1,4-Dioxane vapour has an odour threshold of 24 ppm. Currently, there are no published standards or guidelines in Alberta for 1,4-dioxane in soil or groundwater. Ontario's Ministry of the Environment has a Provincial Water Quality Guideline of 58 mg/L. The Alberta 8-hour occupational exposure limit is 20 ppm. 1,4-dioxane is included in Health Canada's Cosmetic Ingredient Hot List and Canada's National Pollutant Release Inventory. The US EPA is developing a cancer risk assessment for 1,4-dioxane (as of April 2012).

Ethanol
Chemical Formula: C_2H_6O
Human Carcinogenicity: Known Carcinogen

Ethanol has an odour threshold of 0.35 ppm. There are no published standards or guidelines in Alberta for ethanol in soil or groundwater. The Alberta 8-hour occupational exposure limit is 1,000 ppm.

Ethylbenzene
Chemical Formula: $C_6H_5CH_2CH_3$
Carcinogenicity: Possible Carcinogen

Ethylbenzene is a petroleum hydrocarbon and has an odour threshold of 2.3 ppm. The current Alberta Tier 1 Guidelines for Ethylbenzene in soil and groundwater are 0.21 mg/kg and 0.0024 mg/L, respectively. The 1-hour Alberta Ambient Air Quality Objective for Ethylbenzene is 0.460 ppm. The Alberta 8-hour occupational exposure limit is 100 ppm.

Heptane
Chemical Formula: C_7H_{16}
Human Carcinogenicity: Not Classified

Heptane vapour has an odour threshold of 220 ppm. There are no published standards or guidelines in Alberta for heptane in soil and groundwater. The State of New Jersey has adopted a groundwater standard of 0.1 mg/L. The Alberta 8-hour occupational exposure limit is 400 ppm.

Hexane
Chemical Formula: C_6H_{14}
Human Carcinogenicity: Non-Carcinogenic

Hexane vapour has an odour threshold of 130 ppm. There are no published standards or guidelines in Alberta for hexane in soil and groundwater. The Canadian Council for the Ministers of the Environment (CCME) recommends soil guidelines ranging between 0.49 to 21 mg/kg, depending on land use. The 1-hour average Alberta Ambient Air Quality Objective is 5.958 ppm. The Alberta 8-hour occupational exposure limit is 500 ppm.

Methane
Chemical Formula: CH_3
Human Carcinogenicity: Non-Carcinogenic

Methane is a common component of landfill gas. Methane vapour is colourless, odourless and classified as a non-toxic asphyxiant. No odour threshold has been established. There are no published standards or guidelines in Alberta for in methane soil and groundwater. The current Alberta 8-hour occupational exposure limit is 1,000 ppm. It is highly combustible with a lower explosive limit of 50,000 ppm in air (5% by volume).

Methylene Chloride
Chemical Formula: CH_2Cl_2
Human Carcinogenicity: Possible Carcinogen

Methylene Chloride is a chlorinated hydrocarbon and had an odour threshold of 250 ppm. The current Alberta Tier 1 Guidelines for methylene chloride in soil and groundwater are 0.095 mg/kg and 0.05 mg/L, respectively. The Alberta 8-hour occupational exposure limit is 50 ppm. Methylene Chloride is on Health Canada's Cosmetic Ingredient Hot List and Canada's National Pollutant Release Inventory.

Methyl Ethyl Ketone
Chemical Formula: C_4H_8O
Human Carcinogenicity: Not Classified

Methyl Ethyl Ketone has an odour threshold established at 5.4 ppm. There are no published standards or guidelines in Alberta for methyl ethyl ketone in soil or groundwater. The Alberta 8-hour occupational exposure limit is 200 ppm.

2-Propanone
Chemical Formula: C_3H_6O
Human Carcinogenicity: Not Classified

2-Propanone has an odour threshold of 20 ppm. There are no published standards or guidelines in Alberta for methyl ethyl ketone in soil or groundwater. The 1-hour Alberta Ambient Air Quality Objective is 2.4 ppm. The 8-hour occupational exposure limit is 250 ppm. Acetone is on Canada's National Pollutant Release Inventory.

Styrene
Chemical Formula: $C_6H_5CH{=}CH_2$
Human Carcinogenicity: Possible Carcinogen

Styrene has an odour threshold of 0.008 ppm. The current Alberta Tier 1 Guidelines for styrene in soil and groundwater is 0.80 mg/kg and 0.072 mg/L, respectively. The 1-hour Alberta Ambient Air Quality Objective is 0.052 ppm. The Alberta 8-hour occupational exposure limit is 200 ppm.

Tetrachloroethylene
Chemical Formula: $Cl_2C{=}CCl_2$
Human Carcinogenicity: Known Carcinogen

Tetrachloroethylene (PCE) is a chlorinated hydrocarbon and a known carcinogen. The established odour threshold is 1 ppm. The current Alberta Tier 1 Guidelines for PCE in soil and groundwater are 0.77 mg/kg and 0.03 mg/L, respectively. The Alberta 8-hour occupational exposure limit is 25 ppm. PCE is on Canada's National Pollutant Release Inventory.

Tetrahydrofuran
Chemical Formula: C_4H_8O
Human Carcinogenicity: Possible Carcinogen

Tetrahydrofuran vapour has an odour threshold of 30 ppm. There are no published standards or guidelines in Alberta for tetrahydrofuran in soil and groundwater. The Alberta 8-hour occupational exposure limit is 50 ppm.

Toluene
Chemical Formula: $C_5H_5CH_3$
Human Carcinogenicity: Not Classified

Toluene is a petroleum hydrocarbon with an odour threshold of 2.9 ppm. The current Alberta Tier 1 Guidelines for Toluene in soil and groundwater are 0.29 mg/kg and 0.024 mg/L, respectively. The 1-hour Alberta Ambient Air Quality Objective for Toluene is 0.499 ppm. The Alberta 8-hour occupational exposure limit is 50 ppm.

Trichloroethylene (TCE)
Chemical Formula: $ClCH=CCl_2$
Human Carcinogenicity: Known Carcinogen

Trichloroethylene (TCE) is a chlorinated hydrocarbon and a known carcinogen. The established odour threshold is 28 ppm. The current Alberta Tier 1 Guidelines for TCE in soil and groundwater are 0.012 mg/kg and 0.005 mg/L, respectively. The Alberta 8-hour occupational exposure limit is 50 ppm.

Trichlorofluoromethane
Chemical Formula: CCl_3F
Human Carcinogenicity: Non-Carcinogenic

Trichlorofluoromethane (Freon 11) is a CFC with an odour threshold of 5 ppm. Currently, there are no published guidelines or standards in Alberta for Freon 11 in soil or groundwater. The NIOSH 8-hour occupational exposure limit is currently 1,000 ppm.

Trichlorotrifluoroethane
Chemical Formula: $C_2Cl_3F_3$
Human Carcinogenicity: Non-Carcinogenic

Trichlorotrifluoroethane (Freon 113) is a CFC with an odour threshold of 5 ppm. Currently, there are no published guidelines or standards in Alberta for Freon 113 in soil or groundwater. No occupational exposure guideline has been established.

1,2,4-Trimethylbenzene
Chemical Formula: C_9H_{12}
Human Carcinogenicity: Non-Carcinogenic

1,2,4-Trimethylbenzene has an odour threshold of 0.4 ppm. There are no published standards or guidelines for hexane in soil and groundwater. The United States Environmental Protection Agency (EPA) has adopted a drinking water guideline of 0.07 mg/L. The Alberta 8-hour occupational exposure limit is 25 ppm.

2,2,4-Trimethylpentane
Chemical Formula: C_8H_{18}
Human Carcinogenicity: Not Classified

Limited information exists regarding 2,2,4-trimethylpentane. No odour threshold for 2,2,4-trimethylpentane has been established. Currently, there are no published guidelines or standards in Alberta for 2,2,4-trimethylpentane in soil, water or air.

Xylenes
Chemical Formula: C_8H_{10}
Human Carcinogenicity: Not Classified

Mixed (or total) xylenes are composed of isomers o-xylene, m-xylene and p-xylene. Each isomer has an odour threshold of 0.5 ppm. The current Alberta Tier 1 Guidelines for Xylenes in soil and groundwater are 12 mg/kg and 0.3 mg/L, respectively. The 1-hour Alberta Ambient Air Quality Objective for Xylenes are 0.529 ppm. The Alberta 8-hour occupational exposure limit is 100 ppm.