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Hydrocarbon contamination, assessment and remediation practice

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Hydrocarbon Contamination, Assessment and Remediation Practice

by

Nizar Kazem, B. Sc. Civil Engineering,
Beirut Arab University, Lebanon 1994

A Project

Presented to Ryerson University

In partial fulfillment of the
requirements for the degree of

Master of Engineering
in the program of civil engineering

Toronto, Ontario, Canada,

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Hydrocarbon Contamination, Assessment and Remediation Practice
Master of Engineering 2008, Nizar Kazem,
Civil Engineering, Ryerson University

Abstract

Organic chemicals are used in all types of industries including but not limited to automotive and engine repair, dry cleaning, asphalt operations, dye manufacturing, agricultural activities, and food processing. The usage of organic chemicals is of increasing concern to regulators because of the contamination of soil and groundwater resulting from the mishandling and disposal of these chemicals. Typically, drums, underground and aboveground tanks are used to store these organic chemicals. The presence of large amount of chemicals, gasoline, and diesel fuel on-site is considering an indicator of the potential for soil and groundwater contamination.

Due to leaking UST or surface spills of organic chemicals and its constituent it becomes the common culprits of soil and groundwater contamination. The first step toward implementing a remediation is to provide for a have a better understanding of the physical properties of the organic chemicals themselves.

This study reviews the chemistry of hydrocarbon and the fundamental concepts and principles of geology and hydrogeology, since the media where the contamination is taking place, and followed by a discussion of the fate and transport of contaminants in the subsurface, from an industry and regulatory point of view. The types and design of remediation system was overlooked and applied in a real case of study of Phase I, II and II Environmental Site Assessment.

This study concluded with an overview of the application of the Remote Sensing in the environmental industry and its future potential involvement in the environmental site assessments, Phase I through Phase III audits.

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REFERENCES

1. INTRODUCTION

Organic chemicals are used in all types of industries including but not limited to automotive and engine repair, dry cleaning, asphalt operations, dye manufacturing, agricultural activities, and food processing. The usage of organic chemicals is of increasing concern to regulators because of the contamination of soil and groundwater resulting from the mishandling and disposal of these chemicals. Typically, drums, underground and aboveground tanks are used to store these organic chemicals. The presence of large amount of chemicals, gasoline, and diesel fuel on-site is considering an indicator of the potential for soil and groundwater contamination.

Due to leaking UST or surface spills of organic chemicals and its constituent it becomes the common culprits of soil and groundwater contamination. The first step towards implementing a remediation is to provide for a have a better understanding of the physical properties of the organic chemicals themselves.

This study reviews the chemistry of hydrocarbon and the fundamental concepts and principles of geology and hydrogeology, since the media where the contamination is taking place, and followed by a discussion of the fate and transport of contaminants in the subsurface, from an industry and regulatory point of view. The types and design of remediation system were overlooked and applied in a real case of study of Phase I, II and II Environmental Site Assessment.

This study concluded with an overview of the application of the Remote Sensing in the environmental industry and its future potential involvement in the environmental site assessments, Phase I through Phase III audits.

2. CHEMISTRY OF HYDROCARBON

The greater part of carbon-containing compounds are classified as organic compounds; virtually all contain hydrogen and possess at least one C-H bond in their chemical structure. Hydrocarbons constitute the most basic organic compound group, where they consist of elements of hydrogen and carbon.

Hydrocarbons are divided into two classes:

1. Aliphatic hydrocarbon, which is a straight-chain hydrocarbon without a benzene ring.
2. Aromatic hydrocarbon, which contains a benzene ring. A benzene ring contains six carbons joined in a ring structure with alternative single and double bonds. The formula for benzene is C_6H_6 .

2.2 Aliphatic Hydrocarbons

The aliphatic hydrocarbons are divided into three groups based on how their carbon atoms are joined:

- alkanes (joined by single bonds),

Alkanes are also known as paraffins, or saturated hydrocarbons. Alkanes are characterized by having only one carbon (C-C) bond and being rather uncreative chemically. There are three types of alkanes: straight-chain, branched-chain, and cycloalkanes.

- alkenes (joined by double bonds), and

Alkenes also called olefins or unsaturated hydrocarbons. They are characterized by carbon double bonds (C=C) and are named by locating the longest chain that contains the double bond. The general formula for alkene is C_2H_2 .

- alkynes (joined by triple bonds).

Alkynes or acetylenic hydrocarbons contained triple carbon bonds ($C\equiv C$). The general formula for alkynes is C_nH_{2n-2} . Acetylene, C_2H_2 , is an alkyne that is widely used as a welding gas.

2.3 Aromatic Hydrocarbons

Aromatic hydrocarbons, also called alkyl hydrocarbons, are characterized by carbon-carbon ring structures, and, as suggested by their name, a distinctive odor. Benzene, C_6H_6 , is the simplest compound of this group of hydrocarbons. Other molecules can be formed by joining functional groups to the basic benzene ring.

2.3.1 Alkylbenzenes

Alkylbenzenes form an extensive family of aromatic hydrocarbon. They are formed by replacing the hydrogen in benzene with alkyl groups or halogens, such as chlorine. Alkyl groups refer to alkenes minus one hydrogen atom.

2.3.2 Polycyclic Aromatic Hydrocarbons

Polycyclic Aromatic Hydrocarbons (PAH) is another group of aromatic hydrocarbons that are characterized by multiple fused rings. This is often referred to as “chicken wire” structures. They are also called polynuclear aromatic hydrocarbon (PNA).

2.4 Degradation of Hydrocarbons

Hydrocarbons degrade like many things that exist in this world. They may undergo microbial degradation or degradation by chemical reactions to form methane or carbon dioxide and water.

Hydrocarbons can be degraded under both aerobic and anaerobic conditions by microbes. Some bacteria that do this include *Micrococcus*, *Pseudomonas*, *Mycobacterium*, and *Nocardia*.

Hydrocarbons can also be degraded by chemical reactions. Some common chemical reactions involved in hydrocarbon degradation are substitution, dehydrogenation, oxidation, and reduction.

3. FUNDEMENTAL GEOLOGY AND HYDROGEOLOGY

3.1 Formation of the Soil

The character of natural soil deposits is influenced primarily by parent material and climate. The parent material is generally rock but may include partially indurated materials intermediate between soil and rock.

Soils are the results of weathering, mechanical disintegration, and chemical decomposition of the parent material. The products of weathering that remain in place are termed residual soils. In relatively flat regions, large and deep deposits of residual soils may accumulate; however, in most cases gravity and erosion by ice, wind, and water move these soils to form new deposits, termed transported soils.

There are two types of weathering, physical weathering and chemical weathering, where:

- Physical weathering causes disintegration of rocks into smaller-sized particles. Physical weathering agents include freezing and thawing, temperature changes, erosion, and the activity of plants and animals.
- Chemical weathering decomposes the minerals that make up rocks through reactions such as oxidation, reduction, carbonation, and other chemical processes.

3.2 Soil Texture

Soil texture is the appearance of a soil. Texturally, soils may be divided into coarse-grained or fine-grained soils. A convenient dividing line is the smallest grain that is visible to the naked eye. Soils with particles larger than this size (approximately 0.05 mm) are considered coarse-grained, while soils finer than this size are called fine grained.

Gravels and sands are examples of coarse-grained soils while silts and clays are examples of fine-grained soils. Alternatively soils can be classified according to their plasticity and

cohesion. For example, sands are nonplastic and noncohesive, whereas clays are both plastic and cohesive.

3.3 Grain Size and Grain Size Distribution

Soils can range from boulders several centimeters in diameter down to ultrafine-grained colloidal materials. Because the maximum possible range is on the order of 10^8 , grain size distributions are typically plotted against the logarithm of the average grain diameter.

The grain size is obtained by conducting a gradation test:

- For coarse grained soils, a sieve analysis is performed in which a sample of dry soil is shaken mechanically through a series of woven-wire square-mesh sieves with successively smaller openings.
- For fine-grained soils, the hydrometer analysis is used.

3.4 Classifications of Soils

Soil classification generally based on soil particle size. Four groups of soils, namely, gravels, sands, silts, and clays make up the basic types of soils.

The primary classification method of the system basically subdivides soil groups into two broad categories: coarse-grained soils (gravels and sands) and fine-grained soils (silts and clays). The secondary classification procedure is somewhat of a descriptive nature, based on factors such as the gradation and plasticity of the soil.

Classification system that has been developed by the United States Bureau of reclamation, is widely used all over the world. This system consists of two characters to indicate a soil type, as shown in Table 1. A soil of type SM, for instance, is a silty sand, which indicates that it is a sand, but containing considerable amounts of non-organic fine silty particles.

Character 1		Character 2	
G	gravel	W	well graded
S	sand	P	poorly graded
M	silt	M	silty
C	clay	C	clayey
O	organic	L	low plasticity
Pt	peat	H	high plasticity

Table 1- Soil Characters

3.5 Review of Hydrology

3.5.1 Classification of Subsurface Water

Water occurring in the ground surface is generally divided by the water table to two types: vadose zone water (water content in soil) and groundwater (water beneath the water table). The terms saturated zone and groundwater are arbitrary, since the soils directly above the water table (capillary fringe) may be fully saturated and, as such, are an integral part of the groundwater system.

The distinction between the vadose zone water and the groundwater lies in the difference in fluid pressure. Water above the water table exhibits a fluid pressure that is less than atmospheric pressure. Water beneath the water table has a pressure greater than atmospheric pressure and increases with depth (hydrostatic head of the water above). The water pressure at the water table is equal to atmospheric pressure. If wells are drilled into the saturated or water bearing zone, the static water level in each well marks the elevation of the groundwater table. Where the water-bearing zone is a confined aquifer, the height of the water column in the well represents the pressure in the aquifer.

3.5.2 Aquifers

3.5.2.1 Aquifer

An Aquifer is defined as a thick formation composed of several stratigraphic units of varying permeability and may be defined, as a "saturated permeable unit that can transmit significant quantities of water under ordinary hydraulic gradients."

In contaminant hydrogeology, this definition will need to be extended to a broader scope to encompass geological units that are not typically considered to be aquifers in the water supply sense. For example, a predominantly silty clay unit with little groundwater movement might be regarded an aquifer if it were located next to a surface water body that is utilized as a source of drinking water.

3.5.2.2 Aquitard

An aquitard is a relatively impermeable body that does not readily transmit water. It typically defines the upper or lower boundary of an aquifer. While an aquifer is defined as a thick formation composed of several stratigraphic units of varying permeability, the term aquitard sometimes refers to the low permeability strata within the aquifer.

The term aquifer and aquitard must be viewed as relative; a silt layer might be considered an aquifer in a silty clay unit, and an aquitard in a silty sand unit.

3.5.2.3 Unconfined Aquifer

An unconfined aquifer, also commonly known as a water table aquifer, is an aquifer with a water table as its upper boundary. In an unconfined aquifer, the water table separates the underlying saturated zone from the overlying unsaturated, or vadose, zone. As the unconfined aquifer is defined by the location of the water table, the fluctuation of the water table over time will change the zone of saturation. This change in the zone of saturation plays a significant part in contaminant hydrogeology.

Most groundwater contamination problems occur initially in unconfined aquifers because of the lack of an overlying low permeability confining layer. This leaves the unconfined

aquifer susceptible to direct contamination from liquid chemical spills, lagoons, landfill leachate, and other similar contaminant sources.

3.5.2.4 Confined Aquifer

A confined aquifer is an aquifer that is bound on its upper surface by an aquitard. The upper surface of a confined aquifer remains saturated and the zone of saturation does not fluctuate significantly over time in response to natural or induced changes in the flow system.

In a confined aquifer, two simultaneous processes accompany the withdrawal of groundwater. First, the pore space is reduced due to compaction of the bulk matrix because, as water pressure decreases, stresses on the solid grains increase causing the bulk volume to decrease. Second, the pore water expands due to the reduction in the pressure of the fluid.

3.5.2.5 Perched Aquifer

A special hydrogeological condition is created when a perched aquifer is encountered. A perched aquifer arises when a quantity of water collects on an impermeable stratum above a confined aquifer. Perched aquifers are usually limited in extent and quantity of water, which is recharged by either natural or human sources.

4. PERSPECTIVES ON HYDROCARBON CONTAMINATION

4.1 An Industry Perspective

The most driver of environmental clean up is regulatory requirements relating to the protection of natural resources and/or public health. Second, but related to regulatory pressures in the environmental concerns which affect real estate development, is the fact that to develop or redevelop a contaminated site, one needs to clean up the property for one or a combination of the following reasons:

- to make it safe (protect natural resources or public health)
- to satisfy a regulatory requirement
- to limit future liability.

All of these reasons to clean up a property apply to hydrocarbon contaminated soils. When discussing hydrocarbon contaminated soils, we're talking about a wide range of sites, such as:

- oil and gas fields,
- refineries and terminals,
- gas stations and pipelines.

HOW ARE THESE PROPERTIES RELATED TO THE REAL ESTATE DEVELOPMENT PROCESS?

First, oil fields in urban areas now represent the single largest source of open land for development. Land values also make it more attractive to spend more on extraction that co-exists with real estate uses, whether the use is commercial, industrial, or residential. Unlike old landfill properties which are restricted to commercial (if not golf course use), oil well properties can be remediated to allow just about any use if you try hard enough.

Second, there is increasing pressure to relocate oil refineries and terminals. Air quality regulations make it harder to do business as a refinery in some areas.

Third, gas station properties are constantly undergoing redevelopment. Consolidation in the industry has resulted in one or two stations per intersection instead of four. This allows for redevelopment of valuable properties at intersections.

HOW DID WE HANDLE THIS IN THE PAST?

In ancient times, five or so years ago, two basic approaches were used:

1. Cleanups were done randomly and to widely varying standards, if at all.
2. Properties lay fallow due to the inability to clean up or uncertainty of cleanup.

Neither of these approaches were very comforting from either the development or environmental perspective, but I think we have come a long way in the past five years. The outlook on developing hydrocarbon contaminated properties is much different now, and better.

WHY DID IT CHANGE?

Engineers think that the single most important force driving changes in the way hydrocarbon contaminated real estate is addressed is the attention given to underground storage tanks.

Underground storage tank regulations brought the impact of hydrocarbons on the environment into the limelight.

But the bottom line effect is that we have had to learn more about the fate and transport, toxicity, and cleanup of hydrocarbons. We are now capable of dealing with many problems that were beyond our capabilities five years ago. In addition, the ever-rising value of land has provided economic incentives to tackle previously unmanageable cleanup problems.

This may seem ironic when real estate values are now declining, but it is a relative thing. The old gas station property on the intersection is more valuable than the property at the edge of town. Real estate development in tough times tends to focus on redevelopment in established areas where infrastructure is in place and access to existing markets, jobs, etc., is more favorable. This promotes dealing with that corner gas station problem.

4.2 A Professional Perspective

Regulatory guidelines have been better defined, if not institutionalized. Documents such as Phase I Environmental Site Assessment, Canadian Standards Association CAN/CSA Z768-01., Phase II Environmental Site Assessment, Canadian Standards Association CAN/CSA Z769-00, established by the Canadian Standard Association and the other publication by the Ministry of the environment such as Guidance on Sampling and Analytical Methods for Use at Contaminated Sites in Ontario

Cleanup technologies have been invented, acquired a track record, and become off-the-shelf. "Catalog engineering" is a term I heard the other day from a consultant doing bioremediation. Call in the appropriate bioremediation specialists, such as the bacteria and nutrient specialist, or call the vacuum extractor, the organic vapor treater, etc. The availability of proven technology results in better estimation of cleanup costs necessary for the development process.

Real estate developers are smarter. On real estate deals, 90% of developers come to the lenders with Phase I Environmental Site Assessments in hand. They know the environmental issues need to be addressed.

Lenders are smarter. We can lend where we can quantify the risks. There are ways to do business (even if it's complicated) if you can know the risks and account for them.

WHAT SUPPOSE TO BE ACCCOMPLISHED?

We need better definition of "HOW clean is clean?" There is still confusion over the standards for cleanup vs characterization as a hazardous waste. And there is too much confusion between regulatory agencies.

From a "certainty" standpoint, there are distinct benefits to rigid soil and groundwater quality standards which allow developers to develop and lenders to lend.

However, conservatively set standards may not always make sense from a risk assessment standpoint. There is general recognition that such a level protects the environment and public health. The set levels should be fallback position; conservative enough not to be questioned in most circumstances by an agency or private party. However, where set standards may not be appropriate, regulatory agencies should allow for raising of set standards based on risk assessment. This would be beneficial where the cleanup project is large, and higher allowable concentrations would still protect while significantly decreasing costs.

5. ENVIRONMENTAL FATE AND TRANSPORTATION

The presence of organic chemicals in soil may or may not be problematic. This depends upon the source. If an industrial point source is responsible for the spill or bulk release, then remedial activity usually ensues. However, if the source is not an industrial release, then activity may not be required.

This section will briefly discuss the sources, other than industrial point sources, responsible for the presence of organic chemicals in soil systems.

5.1 Man-Made Sources of Organic Chemicals Found in Soil

Many organic chemicals that are found in soil are the result of human activities. These include agricultural amendments, atmospheric deposition, oil field brines, "inert" fill material, and septic systems. Common agricultural amendments, such as fertilizer, sewage sludge, and pesticides, are comprised of hundreds of organic and inorganic chemicals.

The detection of BTEX from soils where pesticides have been applied would not be considered exception since; pesticides are often diluted with petroleum distillates, BTEX. Where sewage sludge has been added to agricultural soils to increase the organic matter content of the soil resulted in the detection of a variety of organic chemicals in soil such as VOCs, SVOCs, polychlorinated biphenyls (PCBs), and pesticides.

Atmospheric deposition can result in the detection of small concentrations of a number of organic chemicals in soil. Atmospheric deposition can result in the discharge of VOCs, SVOCs, particulates, and chlorinated solvents onto the soil surface. Common sources of organic chemicals attributed to atmospheric deposition include automobiles, trucks, power plants, municipal incinerators, and paint operations.

Historically, "inert" fill material has been utilized to fill low-lying areas (e.g., wetlands, construction sites, and shore lines). Many industrial by-products have been used as fill material and include foundry sand waste, municipal incinerator ash, power plant ash, and manufacturing and processing aggregates. Because many household and commercial products contain organic solvents, the presence of BTEX and chlorinated organic chemicals from septic field soils is not unexpected.

5.2 Organic Chemicals in Soil Systems

In general, man-made sources of organic chemicals represent a minor contribution with respect to the total mass of organic chemicals in soil. However, chemicals deposited by man-made sources are frequently mistaken for chemicals discharged by onsite industrial or commercial operations.

The second source of organic chemicals in soil is biota. Soil biota can be placed into two categories: (a) vegetation, and (b) soil fauna and soil flora.' These two categories are responsible for the bulk of the organics present in soil. Topsoil can typically contain from 1% to 8% organic matter (i.e., 10,000 to 80,000 ppm). In the vadose zone, subsoil can contain from 0.1 % up to 1.0 % organic matter (i.e., 1,000 to 10,000 ppm).

The first category, vegetation, is comprised of the residues, dead parts, and exudates of green plants (i.e., grasses, trees, and shrubs), that enter soil. The residues and dead parts of vegetation can enter soil when foliage falls onto the soil surface and decays. The residues of agricultural plants typically are plowed into soils after harvest. Quantities of vegetation added to soils range from 200 to 18,000 kg/ha/yr, with an intermediate value of about 4,000 to 5,000 kg/ha/yr.

The second category, soil fauna and soil flora, is comprised of thousands of species of soil microorganisms and macroorganisms, some of which are present in tremendous numbers in soil. For example, the average agricultural soil contains 100,000,000 bacteria per gram of soil. The typical subsoil contains from 1,000 to 10,000,000 bacteria per gram

of soil. Typical populations for bacteria in groundwater range from 100 to 200,000 individual organisms per milliliter of groundwater. Soil fauna and flora exude various organic chemicals as a part of their metabolic functions. Also, when these soil organisms expire, cellular lysis occurs and causes the release of cell contents into the soil.

5.3 Contaminant Transportation

5.3.1 Contaminant Migration

Generally, contaminant when released into the ground surface, it migrates through the unsaturated zone toward the aquifer. Hence, contaminants move through soil, sediment, fractured rock, human-made conduits, or other pathways on their way to the saturated zone. Migration of LNAPL contaminants can be divided into three stages as follows:

- Seepage through the vadose zone
- Spreading over the water table
- Stabilization within the capillary zone

When the contaminant reaches the water table, it spreads over the water table and starts to accumulate on top of the water surface. Ideally, the downward movement of the contaminant will have minimal amount of lateral spreading. However, since the subsurface is usually of heterogeneous anisotropic materials, lateral spreading of contaminants should be expected.

5.3.2 Volatilization

Releases of contaminants into the subsurface, part of the contaminants will volatilize into the vapor phase and move by dispersion from areas of higher concentration to areas of lower concentration. Eventually, an equilibrium between the liquid phase and vapor phase of the contaminant will be established near the source of contamination. Air

movement within the subsurface will disturb the equilibrium and promote volatilization; however, the movement of air in the vadose zone is very slow under natural conditions.

5.3.3 Adsorption

Adsorption is an event phenomenon where molecules of the contaminants (solved in water) attach themselves to the surface of an individual soil particle. This surface attachment can be:

1. Physical adsorption is caused by Van der Waals force and is the easiest to separate.
2. Chemical adsorption is formed by chemical bonding and requires significant efforts to separate.
3. Exchange adsorption caused by the electrical attraction between adsorbate and the surface.

Adsorptive reactions of organic contaminants moving through soil are typically of the chemical type. Concentration equilibrium will eventually be reached between the contaminant molecule dissolved in the liquid phase and the contaminant molecule that is attached to the soil particles. When concentration conditions change, the soil may adsorb more organic molecules or release them. Since adsorption is a surface phenomenon, its activity is a direct function

5.3.4 Contaminant Pathways through the Vadose Zone

After contaminants are released from buried tanks, pipelines, building basements or any subsurface source can promote the migration of contaminants, since these locations are below the surface where direct observation is not possible, and typically, the releases are not realized for a long period of time. These releases place contaminant directly in the

subsurface vadose zone and will eventually migrate both vertically and laterally down to the groundwater.

5.3.5 Contaminant Movement within the Aquifer

Contaminant movement within the aquifer depends mainly on the properties of the contaminant, specifically the density of the contaminant. Three general migration pathways commonly identified:

1. Floaters are the immiscible contaminants that float on top of the water table because they are less dense than water,
2. mixers are the contaminants with uniform dissolution and movement in the aquifer, and
3. sinkers are contaminants that move vertically due to higher density makeup.

Besides density, other parameters such as chemical composition, molecular weight, solubility, viscosity, groundwater velocity, and aquifer geology will also influence contaminant movement.

Dissolved contaminants are transported by both advective and diffusive mechanisms. Advection is the principal mode of transport and results from the hydraulic gradients present in the saturated zone. In the absence of significant advective movements (due to hydraulic gradients that are very small), transport of dissolved contaminants still occurs by diffusion if concentration gradients are present.

6. INSITU REMEDIATION TECHNOLOGIES

a. Soil vapor extraction (SVE): SVE can be a cost-effective way to remove VOCs from unsaturated soils. Other names for SVE include “soil venting,” “soil vacuum extraction,” “vacuum extraction,” “subsurface venting,” “soil gas vapor extraction,” “in situ venting,” “enhanced volatilization,” and “vapor extraction.”

SVE can be summarized as an operation where airflow is induced in the subsurface by applying a pressure gradient through vertical or horizontal wells or horizontal trenches. SVE is often used in conjunction with other remediation technologies that treat the resulting contaminated air and water streams. SVE systems vary, but a typical SVE system consists of one or more extraction wells, an air/water separator, and a blower or vacuum pump. It may also include one or more air inlet or injection wells, an impermeable cap at the ground surface, and treatment systems for the air and/or water streams. SVE treatment rates are highly site-specific, varying greatly as a function of such factors as air permeability, contaminant concentrations, cleanup standards, and off gas treatment system characteristics.

b. Bioventing. BV is the process of advecting gases through subsurface soils to stimulate in situ biological activity and enhance bioremediation of contaminants. It generally involves supplying oxygen in situ to oxygen-deprived soil microbes by forcing air through unsaturated contaminated soil at low flow rates (Hoeppel, Hinchee, and Arthur 1990). Co-substrates such as methane and nutrients such as ammonia can also be introduced into the subsurface in the gaseous phase.

BV is similar to SVE, but its primary goal is different. They both usually involve volatilization and biodegradation, but whereas the goal of SVE is to volatilize and remove the air phase contaminants from the subsurface as quickly as possible, BV attempts to maximize the rate of biodegradation. BV utilizes low airflow rates to provide only enough oxygen to sustain optimal microbial activity (e.g., vapor-phase oxygen concentrations at or above 5 percent). Whereas SVE is limited to treating volatile

contaminants, BV can also be used to remediate contaminants of low volatility such as fuel oil and diesel constituents. The remediation time frame for such low-volatility and low-solubility contaminants may be long.

c. *Passive Venting.* Although in most cases mechanical blowers are used to induce the air movement for either SVE or bioventing, natural barometric pressure changes can be used to induce air flow to or from the subsurface. The key site condition is the presence of some near-surface (or at least above the zone to be treated) stratum or barrier that causes a delay of the response of the subsurface pressures to the changes in atmospheric pressure. This pressure "lag" results in a differential pressure that can be a driving gradient to induce air flow through the "short-circuit" presented by the SVE or BV well.

d. *Combined soil vapor extraction/bioventing.* The processes of volatilization and biodegradation are often hard to separate and thus SVE and BV can often be used together in a beneficial way. Whether to apply SVE, BV, or both at a site will depend on a number of factors, but the following general guidelines are suggested.

(1) At one extreme, SVE alone should be applied at sites where only volatile compounds which are difficult to biodegrade are present. BV alone should be applied at sites where only biodegradable compounds of low volatility are present or where low-to-moderate concentrations of volatile biodegradable compounds are present. A combined SVE/BV approach could be used at sites with:

- ❖ High concentrations of volatile biodegradable compounds (remove large amounts of contaminant mass and prevent air emissions with SVE, followed by polishing using BV).
- ❖ Volatile biodegradable compounds in sensitive areas where rapid response is critical.
- ❖ Both biodegradable and non-biodegradable volatile compounds.

e. *Multi-Phase Extraction.* Multi-Phase Extraction (MPE) entails simultaneous extraction of vapor phase, dissolved phase and separate phase contaminants from the vadose zone, capillary fringe, and saturated zone. It is a modification of SVE that allows

this technology to be extended to moderately permeable soils (intrinsic permeability 10^{-8} to 10^{-10} cm²). Because the resulting subsurface pressure is less than atmospheric, groundwater rises (upwells) and, if drawn into the well, is extracted and treated aboveground before discharge or re-injection.

(a) Bioslurping, is a form of TPE that aims to enhance the recovery of LNAPL, while also stimulating BV within the unsaturated zone . A bioslurper uses a suction tube positioned near the LNAPL-water interface to induce a pressure gradient causing water, LNAPL and gas to flow into the well.

(b) The three main strategies for applying MPE are: i) vacuum-enhanced recovery of NAPL, ii) vacuum dewatering to enable SVE and/or BV to remove and/or treat organic contaminants via the gas phase, and iii) vacuum-enhanced recovery of groundwater.

f. Dewatering to Enable SVE/BV. In low to moderately permeable formations that are in relatively close proximity to the capillary fringe, SVE and BV tend to have limited effectiveness. While air can flow through air-filled passages, it cannot flow through pores in such formations that tend to be saturated with water. The process of applying a vacuum to the soil to accomplish SVE also causes the water table to rise locally, or upwell, further limiting the zone through which air can flow. By removing both water and gas from the subsurface, these limitations, to some extent, can be overcome. Vacuum dewatering has had decades of use in the construction industry, where it is generally used to remove water from medium- to fine-textured soils that would otherwise flow into excavations made below the water table.

When performed in VOC-contaminated soil, vacuum dewatering permits the flow of air through some of the previously saturated soil, thereby allowing VOCs residing there to partition into the air stream. In addition, soluble VOCs present in the extracted groundwater are also removed. When carried out in soils contaminated with semi-volatile organic compounds

(SVOCs) that biodegrade under aerobic conditions, vacuum dewatering enhances the aeration of previously saturated soil, thus stimulating in-situ aerobic biodegradation. It can also result in an increase in the dissolved oxygen (DO) content of soil pore water, helping to further enhance aerobic biodegradation in soil that is not able to be desaturated. It is important to underscore that compared to most other regions above the water table, the zone where air permeability is quite low (the capillary fringe) will transmit very little airflow during SVE or BV operation.

Since in the case of LNAPL releases, this zone also tends to contain much residual LNAPL contamination (i.e., within the unsaturated portion of the smear zone), the problem of addressing the residual LNAPL is compounded unless the smear zone can be dewatered and exposed to airflow. MPE offers a means to overcome this problem.

7. DESIGN APPROACH

The plan of the investigation is to determine if soil and groundwater are impacted and to delineate the vertical and lateral boundaries of the contamination. On-site drilling usually involves boreholes and monitoring wells. Often, some of the monitoring wells will later be converted to remediation wells in the design stage.

Based on the assessment's findings and regulatory requirements, the engineer will evaluate several design alternatives to select the most appropriate technology. This should be a carefully thought-out process. A Remedial Action Plan (RAP) report or Corrective Action Plan report may be then be generated.

This report examines the site conditions detailed in the PAR and evaluates various remedial alternatives. Following the RAP, a pilot test is usually performed. Sometimes the RAP is performed after the pilot test is completed. Based on the results of the pilot test, the final remediation design will be performed. Sometimes a final remediation plan (FRP) will then be prepared.

The following summarizes a typical chronology of activities leading to final design of a remedial system.

(1) System Planning

Define basis of design

- Summarize previous findings and conclusions
- Establish design objectives
- Identify design parameters

Perform preliminary design

- Site information gathering
- Site survey
- Preliminary equipment list
- Sketch of system layout

- Estimate cost of system

(2) System Design

- Conceptual Design
- Review preliminary design
- Finalize design concept

Prepare appropriate process instrumentation and control diagrams

Final Design

- Perform detailed design evaluations as needed
- Prepare detailed plans and specifications to describe and locate
- proposed remedial system in the contract documents

(3) System Construction

Bidding Process

- Receive and evaluate bids and select bidder

Construction Management

- Provide resident inspection
- Provide construction administration services

(4) System Operation

- Prepare operation and - maintenance manual
- System start-up

8. BROWNFIELD CASE STUDY- ASSESSMENT AND DESIGN

The Environmental Site Assessment and Remediation can be divided into three steps:

Phase I Environmental Site Assessment (ESA), which is to identify, or "flag", indicators, which may signify that an environmental concern (i.e. contamination) may be present on the Site that would warrant further investigation.

Phase II Environmental Site Assessment (ESA), which is to confirm and or to further delineate the presence and extent of the contamination on a subject Site, and is accomplished primarily by collecting and analysing soil and ground water samples on a site.

Phase III Environmental Site Remediation and Restoration (ESRR) in which the site will be remediate and followed by confirmatory sampling and analyses of the residual soil and groundwater to conform that the concentration of the contaminants are within the applicable standards established in the Ministry Of Environment ('MOE') Guidelines.

The following is a case of study where a site was assessed to be contaminated due to leakage of an underground storage tank (UST)

8.1 PHASE I ENVIRONMENTAL SITE ASSESSMENT

8.1.1 Scope of Work

The scope of work for the Phase I ESA consisted of the following tasks:

- ❖ Reviewing current information of the Site, Evaluating historic land use, form available aerial photographs that may be showing general Site usage, adjacent land use, structures and improvements, poor drainage areas and/or access to the site. Search of available industrial or city directories and fire insurance plans (“FIPs”).
- ❖ Performing a “walk-through” site reconnaissance of the Site and its structures in order to determine present or previous land uses, which may have been a source of contaminants.
- ❖ Conducting interviews with knowledgeable persons about the Site and its current and/or former occupancy/land use;

8.1.2 REVIEW OF BACKGROUND INFORMATION

8.1.2.1 Site Description and Operations – Present

The subject site is located north side of Bath Road and consisted of two parcels with municipal address of 6700 Bath Road, Kingtown, Ontario.

At the time of our assessment, the site is occupied by one storey auto dealership building located to the eastern portion of the site; the building contained a garage service area at the northern portion. A paved parking lot situated to the west of the existing building.

The square shaped Site is generally flat and the general land use in the area is commercial and light industrial.

8.1.2.2 Surrounding Properties

The surrounding properties and their present land usage are as follows:

North of the Site: Gold Mil Road followed by commercial land use.

West of the Site: Commercial Buildings

South of the Site: Bath Road followed by commercial land use.

East of the Site: Commercial building i.e. Fried Chicken Restaurant

8.1.2.3 Site Waste Generation and Disposal

Wastewater discharged from the garage service area from an oil-water interceptor located to the north of the garage service area, other than domestic, at the subject site. Domestic waste water is/was discharged to the municipal sewer system.

There is high risk contamination associated with the garage floor runoff, in which it drains liquid to the sanitary sewer after passing it through oil-water separator system. However, it is recommended to properly maintain the system configuration and integrity so to confirm its discharged wastewater comply with the city bylaws.

Surface water at the site drains to the existing catch basins and according to the surface topography towards the municipal storm system.

Solid waste is collected by a special contactor, Waste Management. The bin is located on the northwest corner of the site and it appeared to be in good condition, no stains or spills evidently found on the ground.

The used oil is stored on Above Ground Tank “AST” prior to shipment off site by a licence contactor, Safety Kleen. The tank appeared to be rusty and oil stains was observed on the area of the AST.

Formerly, there was an Under Ground Tank “UST” which was used for fuel oil storing. The UST was identified at the northeast exterior side of the building.

8.1.2.4 Regional & Local Hydrogeology

The regional groundwater flow is south to Lake Ontario Basin, which indicates that any potential groundwater interference from adjacent properties will be predominantly from the north. The local groundwater flow direction is towards tributary creeks running at the southeast and southwest sides of the subject site.

The adjacent properties are mostly street and roadway, where the storm water is handled by catch basins.

8.1.2.5 Soil Maps

NAN reviewed the Quaternary Geology of Ontario Map (i.e., Ministry of Northern Development and Mines, Ontario), Map 2556, Southern Sheet which indicated that the prevailing subsoil conditions in the vicinity of the Site consist of Till, predominantly sandy silt commonly rich in clasts, often high in total matrix carbonate content.

8.1.2.6 Aerial Photographs

Aerial photographs of the site and its vicinity, taken since in the year 1970, were obtained from the Ministry of Natural Resources. The following observations were made from historical aerial photographs.

The interpretation of the maps is somewhat inaccurate, particularly due to the fact that the maps varied in scale and quality. Also it is necessary to remember that the photos show only a snapshot of the site for every five years, therefore anything that occurred on the site at the years in between is not accounted for here.

- 1971** No significant change of the site and surrounding properties were noticed except for road and highway widening.
- 1978** The existing buildings on site appeared to be constructed; the properties to the north of the Site and to the east of the Site were developed to be in commercial land use.
- 2005** The site generally unchanged, the parking lot appeared to be asphalted.

Aerial photo for the 2005 year is enclosed in Appendix "B".

8.1.2.7 Property Use Records

City directories were reviewed at the Toronto Reference Main Library back to the year 1970. The obtained information revealed that the properties with municipal addresses 5600 to 8600 Bath Road and 108 Gold Mil were listed with names which inferred commercial land use.

Prior to 1980 the site was listed as residential and surrounding properties most likely were in agricultural land use, which influenced that it was in agricultural land use and confirmed by reviewed aerial photos of the area.

8.1.3 DATABASE SEARCH AND REGULATORY REVIEW

8.1.3.1 Freedom of Information

The freedom of information and protection of privacy act FOI Act requires that the Ministry of Environment shall disclose any record to the public or persons affected if

there are reasonable and probable grounds to believe that it is in the public interest to do so and the record reveals a grave environmental, health or safety hazard to the public.

An inquiry was sent to the Ontario Ministry of Environment (MOE), Freedom of Information Office with regards to records of the subject site from the year 1985 and up. The response was received from MOE office and revealed no major incidents or environmental concern on the site.

8.1.3.2 Technical Standards and Safety Authority (TSSA)

TSSA's Fuels Safety Program administers the Technical Standards & Safety Act 2000, providing fuel-related safety services associated with the safe transportation, storage, handling and use of hydrocarbon fuels (such as gasoline, diesel, propane and natural gas). They work to protect the public, the environment and property from fuel-related hazards such as spills, fires and explosions.

A verbal request for information related to registered petroleum underground “USTs” and above ground storage tanks “ASTs” for the site and its adjacent properties was made to the TSSA office of administration and customers services. TSSA registers tanks since 1987. The Coordinator of TSSA stated that there were no records of any outstanding instructions, incident, reports, fuel oil spills, or contamination records respecting to the Site.

8.1.3.3 Registered Waste Generators

A search of the Ontario Ministry of Environment “MOE” database indicated that there were registered waste generators for the Site. The type of waste was chemical waste and liquid waste.

8.1.3.4 PCB Storage Site Inventory

A review of the Ontario Ministry of Environment “MOE” database revealed that there was no PCB Storage Site Inventory registered for the Site.

8.1.4 INTERVIEWS

During the Site Visit, Mr. Norm Asaad, President (the Site Owner), who accompanied us during the Site reconnaissance, was interviewed. Mr. Asaad stated that he is unaware of any environmental concerns on the Site.

The Site manager was interviewed as well, and he stated that during his presence and line of duty as a manager since 2004, he is unaware of any environmental spills or clean up that took place on the Site or surrounding properties.

All comments made by the interviewees are included in the following Part “Site Observations”.

8.1.5 SITE RECONNAISSANCE

Mr. Nizar Kazem, the assessor, conducted a site reconnaissance of the site. Observations and comments can be summarized as follows:

1. The site is occupied by one storey auto dealership building includes a garage service area and a paved parking lot situated to the west of the building.
2. Former under Ground Storage Tank (USTs) was removed from the outside northeast corner of the building, but still some visual condition shows certain chances of possible PHC contamination.

3. Present above Ground Storage Tank (ASTs) waste oil tank located at east side of the building found to be in rusty condition, oil stain was observed on the area.
4. There was a three stage oil-water interceptor within the garage area; the tank is serviced frequently by a licensed contactor.
5. The virgin oil tank located in the garage found to be in good condition.
6. Designated substances i.e. (asbestos, lead in pain, PCB in light Ballasts, etc...) may be present on the site due to the age of the building, however, it is not considering an environmental concern at this time.

8.1.6. RESULTS OF PHASE I ESA

1. The results of the Phase I ESA of the site indicated that there are potential contamination on the site associated with the:
 - Former underground storage tank USTs located near the northeast corner of the building.
 - Current presence of oil-water interceptor and present above-ground hoists in the garage service area.
 - Current land uses activities on the garage area associated with the oil change section, waste oil, petroleum products, and solvents.

Based on the above, it is our opinion that a Phase II Environmental Site Assessment (ESA), soil and ground water matrixes, is warranted at this time to investigate the above environmental concerns.

8.2 PHASE II ENVIRONMENTAL SITE ASSESSMENT

8.2.1 Scope of work of Phase II ESA

The scope of work for the Phase II ESA is to be designed based on the results of the Phase I ESA; therefore, Scope of work include the following components:

- ❖ Planning a site investigation, number and location of boreholes based on the Phase I ESA findings; Clearing underground services/utilities.
- ❖ Drilling four (4) sampled boreholes to a maximum depth of 6.0 meters below ground surface or to bedrock or to one meter below the estimated water table, whichever is encountered first;
- ❖ Installing groundwater monitoring wells to facilitate sampling for chemical analysis in boreholes where required; Field screening of all recovered soil samples for the presence of environmental impact (i.e. staining, odours),
- ❖ Collecting soil and groundwater samples in accordance with the MOE Guidance on Sampling and Analytical Methods for Use at Contaminated Site in Ontario, dated December 1996;
- ❖ Submitting selected soil and groundwater samples for laboratory analysis of parameters associated with the potential sources of contamination;
- ❖ Data Interpretation and evaluation by comparing the results of the laboratory analysis to the applicable Ontario Regulation Standard.

8.2.1.1 Objectives

The Phase II ESA was performed in light of recommendations made as a result of a Phase I ESA carried out by Mr. Nizar Kazem on August 2008.

The purpose of the Phase II ESA is to determine presence/absence of the following items:

- Petroleum hydrocarbon PHC (F1 to F4 fraction),
- Polycyclic Aromatic hydrocarbon (PAHs)
- Volatile Organic Compounds (VOCs) and
- Metals and Inorganics

The potential impacted soil and groundwater on the site originating from the previous

and current site activities related to the garage area, the former UST located to the northeast exterior side of the building, and to assess the soil and groundwater conditions within the whole site. The quality of the discharged water from the three-stage oil-water separator, which services the garage, is also to be analyzed.

8.2.1.2 Limitations and Exceptions of Assessments

The report has been prepared in accordance with generally accepted environmental methodologies referred to in National Standard of Canada; CAN/CSA Z769-00, and contains all of the limitations inherent in these methodologies. No other warranties, expressed or implied, are made as to the professional services provided under the terms of our contract and included in this report.

8.2.1.3 Limiting Conditions and Methodologies Used

No ESA can eliminate all uncertainty. Furthermore, any sample, either surface or subsurface, taken for chemical analysis may or may not be representative of a larger population. Professional judgment and interpretation are inherent in the process and uncertainty is inevitable. Additional assessment may be able to reduce the uncertainty.

Even when Phase II ESA work is executed with an appropriate site-specific standard of care, certain conditions present especially difficult detection problems. Such conditions may include, but are not limited to, complex geological settings, the fate and transport characteristics of certain hazardous substances and petroleum products, the distribution of existing contamination, physical limitations imposed by the location of utilities and other man-made objects, and the limitations of assessment technologies.

Phase II ESAs do not generally require an exhaustive assessment of environmental conditions on a property. There is a point at which the cost of information obtained and the time required to obtain it outweigh the usefulness of the information and, in fact, may be a material detriment to the orderly completion of transactions. If hazardous substance

or petroleum releases are confirmed on a parcel of property, the extent of further assessment is related to the degree of uncertainty that is acceptable to the user with respect to the real estate transaction.

Measurements and sampling data only represent the site conditions at the time of data collection. Therefore, the usability of data collected as part of this Phase II ESA may have a finite lifetime depending on the application and use being made of the data. An environmental professional should evaluate whether the generated data are appropriate for any subsequent use beyond the original purpose for which it was collected.

8.2.2 FIELD INVESTIGATION

8.2.2.1 Subsurface Investigation

The field work carried out on August 2008 consisted of drilling four (4) boreholes on the properties to address the soil and groundwater contamination and further delineate any plume migration on the surrounding targeted area. The rationale of the boreholes location is as follows:

Borehole 1 (BH1) was drilled adjacent to the rear of the service garage to address the possibility of soil and groundwater contamination from former presence of the UST and the oil-water separator.

Borehole 2 (BH2) was drilled adjacent to the front of the service garage to address the possibility of groundwater plume contamination from the previous activities on the garage area.

Borehole 3 (BH3) was drilled adjacent to the front of the service garage to address the possibility of groundwater plume contamination from the previous activities on the garage area.

Borehole 4 (BH4) was drilled adjacent to the front of the service garage to address the possibility of groundwater plume contamination from the previous activities on the garage area.

The boreholes were advanced using a truck mounted drilling rig and were bored to refusal on the surface of inferred limestone bedrock at a depth of 2.9 to 3.1 meters in boreholes below existing grade (elevation 96.1m and 96.3m respectively). Ground elevations were referenced to a fire hydrant on the north side of the site which was given a reference elevation of 100m.

The subsoil encountered at the borehole locations was subjected to visual and tactile examinations to determine soil type and classification. The soil type and subsurface stratigraphy at each borehole location was logged in the field for presentation purposes in this report. Subsoil samples were collected at 0.6 meter intervals in each borehole. Representative samples were then secured for further chemical analyses. To prevent cross-contamination between samplings, the sampling equipment was washed with warm water and detergent and then sterilised using distilled water, acetone, hexane, followed by a second application of acetone and a final rinse with distilled water.

All of the soil samples secured from the site were immediately placed in airtight, non-reactive, glass jars and stored at depressed temperatures until delivery to the analytical laboratory. Groundwater monitoring wells were installed in both boreholes with the lower 1.5 meters being made permeable.

Groundwater monitoring wells were installed in all boreholes. All monitoring wells were sealed with bentonite to prevent runoff from entering the wells. Groundwater samples were obtained from monitoring wells after adequate well purging had been performed and were immediately placed in the appropriate sampling containers. Each well was given its own monitoring pump to prevent cross contamination.

8.2.2.2 Subsoil Stratigraphy

A sandy gravel fill with some clay was encountered at BH1 and BH3 at a depth of 0.2 meters and continued to 1.1 meters. Granular A fill was encountered at BH2 and BH4 from 0.1 meters to a depth of 0.7 meters where a silty clay fill containing some organics was encountered. A layer of silty clay was then encountered in both boreholes. In BH1 and BH 3 the silty clay continued to a depth of 1.8 meters while in BH2 and BH 4 it was found between depths of 0.9 and 1.5 meters. A silty clay till with some sand was encountered next in both boreholes and continued to refusal at inferred bedrock at depths of 2.9 to 3.1 meters.

Visual and olfactory analyses of the subsoil materials encountered in the borehole excavations indicated that there was no obvious evidence of petroleum hydrocarbon or volatile organic chemicals in the subsurface materials.

Slow groundwater infiltration was observed within each of the boreholes just above the bedrock surface. Upon completion the maximum and minimum water level was measured in BH1 and was found to have a hydraulic head of 43 cm (free surface (FW) at 2.5 meters below the existing grade) while BH2 had a head of 69 cm (FW at 2.4 meters below the existing grade).

Please refer to the attached Borehole Logs in Appendix A for full details of the subsoil and groundwater conditions encountered at the sampling locations.

8.2.2.3 Oil-Water Separator

A full review of the in-situ three stage oil-water separator was performed. The separator currently services six (6) mechanic bays in the garage as well as an automobile preparation station. Mr. technician stated that collection equipment is used to receive and store antifreeze and oils from the vehicles being serviced.

The oil/water separator is of a three (3) stage (tank) gravity design. Each tank is approximately 1.0 meter square by 1.5 meters deep. Total fluid depth in the three tanks was measured at 1.02 meters. The oil layer thickness was not found to be excessive. Staff at Site stated that annual tank pumping was performed.

An effluent wastewater sample should be extracted at the system outflow location to determine the quality of the discharged water and its conformity with the City Sewer Bylaw requirements.

8.2.2.4 Applicable Guideline

The MOE document Decommissioning Guidelines for Use at Contaminated Sites in Ontario (February 1997) was used to establish criteria for determining if the property is environmentally sensitive.

The subject property is not classified as a "Potentially Sensitive Site" according to the MOE outline. The site is presently zoned as General Commercial and the present and proposed land use for the property is not subject to change or re-zoning at this time.

Potable water is supplied to all area sited by means of municipal services; there are no potable water wells on the site. Based on these criteria and using the Generic Approach to establish clean up guidelines, Table 3 of the MOE document Soil, Ground Water and Sediment Standards for Use under Part XV.1 of the Environmental Protection Act (2004) will be used as the guideline criteria for determining maximum acceptable contamination concentrations.

MOE Guideline - Table 3 is enclosed in Appendix D.

8.2.3 LABORATORY ANALYTICAL WORK

8.2.3.1 Laboratory Testing

8.2.3.1.a Soil

Representative soil samples collected during the investigation were submitted to ATEST Laboratories Ltd. for chemical testing for Petroleum Hydrocarbon Fractions (PHC) F1 to F4 plus Benzene, Toluene, Ethylbenzene, Xylene (BTEX), Regulation 153 Metals and Inorganics and VOC's.

8.2.3.1.b Water

Groundwater samples collected from ALL boreholes BH1, BH2, BH3 and BH4 were submitted to ATEST Laboratories Ltd. for chemical analyses testing for Petroleum Hydrocarbon Fractions (PHC) F1 to F4 plus Benzene, Toluene, Ethylbenzene, Xylene (BTEX), Regulation 153 Metals and Inorganics and VOC's.

8.2.3.2 Laboratory Analytical Results

8.2.3.2.a Soil

Liquid phase petroleum hydrocarbons (LPH) were observed during drilling of the boreholes.

The soil analytical results along with the applicable or relevant and appropriate guidelines are summarized in the Certificate of Analysis in Appendix D.

The soil samples from BH1-SS2 had measurable concentrations of Benzene and Toluene 880 ug/g and 2300 ug/g versus criteria of 5.3ug/g and 34ug/g respectively. These concentrations are well above the MOE Table 3 standards.

8.2.3.2.b Groundwater

Liquid phase petroleum hydrocarbons (LPH) were observed at the groundwater table in the monitoring wells.

The groundwater analytical results along with the applicable or relevant and appropriate requirements are summarized in the Certificate of Analysis in Appendix D.

The groundwater samples from all boreholes had measurable concentrations of but these concentrations are below the MOE Table 3 standards.

8.2.3.4 PHASE I AND II FINDINGS & CONCLUSIONS

Our Phase I ESA revealed evidences of potential environmental contamination associated with the previous and or current land uses of the Site.

Therefore, a Phase II ESA investigation was initiated. The investigation consisted of advancing four (4) sampled boreholes which revealed visual and olfactory evidence of contamination.

Furthermore, soil samples recovered during our investigation, and submitted for laboratory chemical analysis were compared to the Ministry of the Environment document "Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act (March 9, 2004), Table No. 3, Full Depth Generic Site Condition Standards in a Non-Potable Ground Water Condition",

The analytical results for soil samples in BH 2, 3 and 4 had measured concentrations that are below the Table 3 criteria with the exception of BH1-SS2 had measurable concentrations of Benzene and Toluene 880 ug/g and 2300 ug/g versus criteria of 5.3

ug/g and 34 ug/g respectively. These concentrations are well above the MOE Table 3 standards.

The analytical results for groundwater all samples met the MOE Table 3 standards.

It is apparent based upon the information developed to date, that the soil contamination will be present within the former tank cluster to a depth above groundwater level. Soil contamination has apparently migrated away and beyond the limit of well installed in BH1. However, no contamination was identified in the area of installed wells in BH2, BH3 and BH4 to date.

Based on the physical condition of this site and the information gathered, it our professional opinion that remediation of the onsite soil to a limits established in the MOE criteria cited in Table 3.

8.3 PHASE III ENVIRONMENTAL REMEDIATION

Based on the previous recommendations, the Site is identified as a candidate for remediation and restoration. The Site presents the greatest potential exposure risks, and also a high potential for successful and cost-effective remediation and restoration. The remediation and restoration plans proposed for the Site are summarized in the following paragraph. It is anticipated that these plans will be refined through the subsequent completion of a Remediation Plan for the site.

The proposed remediation approach is multi-media in nature, and will address the remediation and/or protection of the soil media. However, contaminants of concern identified at the Site include petroleum hydrocarbon and volatile organic compounds.

The initial step, often the most critical one, of a typical soil remediation project is to determine the extent of the contamination and design the remediation steps. Suggested type of remediation is:

8.3.1 Soil Vapor Extraction (SVE)

- ❖ SVE removes volatile and some semi-volatile contaminants from the vados zone through the application of vacuum, using a system of well vents placed in the unsaturated zone.
- ❖ SVE systems can be combined with groundwater pumping wells to remediate soil previously beneath the water table.
- ❖ The gas removed from the soil may be then discharged directly to the environment or more likely to an off-gas treatment process.

8.3.1.1 How is SVE carried out?

- ❖ Vapor extraction wells and injection wells are installed at appropriate locations at the contaminated site.
- ❖ Vacuum pumps or blowers induce a pneumatic pressure gradient in the subsurface, resulting in an flow field about an extraction well.
- ❖ Ambient air enters the subsurface either passively, through leaky boundaries, or, actively by injection, if necessary.
- ❖ Gas-phase contaminants are removed via advective air flow entering extraction.

The soil properties that impact on SVE design are:

- ❖ Relative air permeability of porous media:
- ❖ Heterogeneities
- ❖ Porosity and Void Ratio
- ❖ Stratigraphy
- ❖ Moisture Content Temperature of the porous media
- ❖ Organic carbon content (partitioning of contaminants is dependent on foc)
- ❖ Chemical permeability of porous media:
- ❖ Volatility

- ❖ Relative polarity
- ❖ Affinity to soil organic matter

i) Desirable features:

- ❖ It is a simple, possibly low-cost, and safe method. It has been tested as a pilot scale and can treat significant soil depths in the unsaturated zone.
- ❖ SVE has been used to remove chemical spills before they reach groundwater.

ii) Limitations:

- ❖ Its applicability is limited to cases involve VOCs,
- ❖ Permeability of the contaminated soil will greatly affect clean up time
- ❖ Mass transfer resistances and liquid-phase resistances will affect the removal rate of the compound in the NAPL from low permeability lens.

8.3.2 Design Considerations

8.3.2.1 Amount of Contaminant soil in the Vadose zone

a. Volume of contaminated soil

Determine the area of contaminated plume at each sampling depth, A_i .

Determine the thickness interval for each area calculated above, h_i

Determine the Volume of contaminated soil, V_s

$$V_s = \sum A_i \times h_i$$

b. Mass of contaminated soil: $M_s = \rho_b \times V_s$,

Where, M_s is the mass of concentration

ρ_b is the soil bulk density = 1.8 ton/m^3

V_s is the volume of the contaminated soil

Volume of Impacted Soil: $V_s = (12\text{m} \times 8\text{m}) \times 2.9\text{m} = 278.4 \text{ m}^3$

Mass of contaminated soil = $278.4\text{m}^3 \times 1.8 \text{ ton/m}^3 = 502,000 \text{ Kg}$

c. Mass of contaminants in soil:

Mass of TPH (F1) in soil = $502,000 \text{ Kg} \times 320 \text{ g/Kg}$
= $1.60640000 \times 10^8 \text{ mg}$
= $1.606 \times 10^6 \text{ g}$

Mass of Benzene in soil = $502,000 \text{ Kg} \times 88 \text{ mg/Kg}$
= $4.4176000 \times 10^7 \text{ mg}$
= $4.4176 \times 10^4 \text{ g}$

Mass acceptable as per Criteria $502,000 \text{ Kg} \times 5.3 \text{ mg/Kg} = 2.66 \times 10^3 \text{ g}$

Mass of Toluene in soil = $502,000 \text{ Kg} \times 230 \text{ mg/Kg}$
= $1.15460000 \times 10^8 \text{ mg}$
= $1.1546 \times 10^6 \text{ g}$

d. Molecular fraction of a compound = mass of each compound / mass of TPH

Mass fraction of Benzene = $4.4176 \times 10^4 \text{ g} / 1.606 \times 10^6 \text{ g}$
= 2.75

Mass fraction of Toluene = $1.1546 \times 10^6 \text{ g} / 1.606 \times 10^6 \text{ g} = 0.71$

Mole of TPH = $1.606 \times 10^6 \text{ g} / 100 = 16060 \text{ g-mole}$

Mole of Benzene = $1.606 \times 10^6 \text{ g} / 78 = 20589 \text{ g-mole}$

Mole of Toluene = $1.606 \times 10^6 \text{ g} / 92 = 17456 \text{ g-mole}$

Table 2- Some Physical Properties of BTEX:

Compound	Molar Mass g/mole	Solubility (mg/L)	Vapor Pressure (mmHg)	Henry's Const. atm/M
Benzene (C ₆ H ₆)	78	1780	95 @ 25oc	5.55
Toluene (C ₆ H ₅)	92	515	22 @ 25°c	92.1
Ethylbenzene (C ₆ H ₅)	106	152	7 @ 20°c	6.44
Xylenes (C ₆ H ₄)	106	198	10 @ 20°c	5.1

From U.S.EPA, CERCLA Site Discharges to POTWs Treatability Manual EPA 540/2-90-007, office of Wyter Washington, DC, 1990.

8.3.2.2 Expected vapor concentration

Volatile organic compound in a vadose zone may be present in four phases:

- 1) in the soil due to dissolution
- 2) on the soil grain surface due to adsorption
- 3) in the porer void due to the volatilization
- 4) as the free product

If the free-product is present, the vapor concentration in the pore void can be estimated from Raoult's law as:

$$P_A = P_{\text{vap}} \times X_A$$

Where, P_A = partial pressure of compound A in the vapor phase
 P_{vap} = vapor pressure of compound A as a pure liquid
 X_A = mole fraction of compound A in the liquid phase

In the absence of the free-product phase, the vapor concentration,

Convert Henry's constant to a dimensionless value: $H^* = H / RT$

Where, H^* = Henry's constant in dimensionless form
 H = Henry's constant i
 $R = 0.00825 \text{ atm/ (K) (M)}$, m solution molarity in (g mole/L)
 T = System temperature in Kelvin

$$H^* = (5.55) / \{(0.082)(273 + 25)\} = 0.23 \text{ (dimensionless)}$$

Soil vapor concentration for Benzene in equilibrium with this contaminant concentration in soil:

$$M_t/V = [(\Phi_w/H) + (\rho_b K_p / H) + \Phi_a] G \dots\dots\dots^1$$

$$M_t/V = [(0.35 \times 45\%) / 0.23 + ((1.8 \times 2.6) / 0.23) + (0.35)(1 - 45\%)] G = 880 \text{ mg/L}$$

$$\text{Therefore, } G = 44.1 \text{ mg/L} = 44,100 \text{ mg/m}^3$$

Convert the vapor concentration into a volume concentration:

$$1 \text{ ppmV benzene} = 78 / 24.5 = 3.2 \text{ mg/m}^3 @ 25^\circ\text{C}$$

$$44,100 \text{ mg/m}^3 = 44,100 / 3.2 = 13,781 \text{ ppmV}$$

¹ Eq. II.3.23, practical design calculations for groundwater and soil remediation, lewis publishers.

8.3.2.3 Radius of Influence and Pressure Profile

Selecting the number and locations of vapor extraction wells is one of the major tasks in design of in situ SVE systems. The decisions are typically based on radius of influence R_I , which can be defined as the distance from the extraction well where the pressure drawdown is very small.

For the steady-state radial flow subject to the boundary conditions ($P = P_w$ @ $r = R_w$ and $P = P_{atm}$ @ $r = R_I$), the pressure distribution in the subsurface can be derived:

$$P_r^2 - P_w^2 = (P_{RI}^2 - P_w^2) \frac{\ln(r / R_w)}{\ln(R_I / R_w)} \dots\dots\dots^2$$

P_r = Pressure at a radial distance r from the vapor extraction well

P_w = Pressure at the vapor extraction well

P_R = Pressure at a radius of influence = atmospheric pressure

r = radial distance from the vapor extraction well

R_I = radius of influence where pressure equal to atmospheric pressure

R_w = Well radius of the vapor extraction well

So, determining the radius of influence of a soil venting well, with the following information:

Pressure at the extraction well = 0.9 atm

Pressure at monitoring well 30 feet away from the venting well = 0.98 atm

Diameter of the venting well = 4 inches

Then,

$$\ln [30 / (2/12)]$$

² Equation V.1.2 practical design calculations for groundwater and soil remediation, lewis publishers.

$$(0.98)^2 - (0.9)^2 = (1.0^2 - 0.9^2) \frac{\text{---}}{\ln [R_I / (2/12)]}$$

Therefore,

$$R_I = 118 \text{ ft} = 36 \text{ m}$$

8.3.2.4 Vapor Flow Rates

a. The radial Darcian velocity, u_r , in homogeneous soil systems can be expressed as:

$$u_r = \left(\frac{K}{2\mu} \right) \frac{\left[\frac{P_w}{r \ln (R_w / R_I)} \right] \left[1 - \frac{P_{RI}}{P_w} \right]}{\{ 1 + [1 - (P_{RI} / P_w) 2] \times \ln (r / R_w) / \ln (R_w / R_I) \}^{0.5}} \dots\dots\dots 3$$

Where u_r is the vapor flow velocity at a radial distance “r” away from the well.

Permeability of the formation = 1 darcy

Well screen length = 10 feet

Viscosity of air = 0.018 centipoise

Temperature of the formation = 20° c

We need to perform a few unit conversions:

$$1 \text{ atm} = 1.013 \times 10^5 \text{ N} / \text{m}^2$$

$$1 \text{ Darcy} = 10^{-8} \text{ cm}^2 = 10^{-12} \text{ m}^2$$

$$1 \text{ poise} = 100 \text{ centipoise} = 0.1 \text{ N} / \text{s} / \text{m}^2$$

³ Equation V.1.3 practical design calculations for groundwater and soil remediation, Lewis Publishers.

So, viscosity of air = 0.018 centipoise = 1.8×10^{-4} poise = 1.8×10^{-5} N / s / m²

$$u_r = [10^{-12} / 2(1.8 \times 10^{-5})] \frac{[\{0.9 \times 1.013 \times 10^5\} / (20 \times 0.3048 \ln (2/12) / 118)][1 - (1/0.9)^2]}{\{1 + (1 - (1/0.9)^2) [\ln 10 / (2/12) / \ln (2/12) / 206]\}^{0.5}}$$

$$u_r = (2.78 \times 10^{-8})(-2.28 \times 10^3)(-0.2346) / 0.9^{0.5}$$

$$u_r = 1.567 \times 10^{-5} \text{ m / s} = 1.35 \text{ m / d}$$

b. The velocity at the wellbore, u_w , can be found by replacing r with R_w in the above equation as

$$u_w = \left(\frac{K}{2\pi} \right) \left[\frac{P_w}{\ln (R_w / R_I)} \right] \left[1 - \left(\frac{P_{RI}}{P_w} \right)^2 \right]$$

$$u_w = [10^{-12} / 2(1.8 \times 10^{-5})] \times [(0.9 \times 1.013 \times 10^5) / \{(2/12) \times 0.3048 \times \ln((2/12) / 206)\}] \times [1 - (1/0.9)^2]$$

$$u_w = (2.78 \times 10^{-8})(-2.52 \times 10^5)(-0.2346)$$

$$u_w = 1.64 \times 10^{-3} \text{ m / s} = 0.1 \text{ m / min} = 141 \text{ m / d}$$

c. The volumetric vapor flow rate entering the extraction well, Q_w can be found as

$$Q_w = 2 \pi R_w u_w H$$

$$Q_w / H = 2 \times 3.14 \times [(2 / 12)(0.3048) \text{ m}] (0.1 \text{ min}) = 0.032 \text{ m}^3 / \text{min} / \text{m}$$

Where, H is the perforation interval of the extraction well

$$\text{The vapor flow rate in the well} = (0.032 \text{ m}^3 / \text{min} / \text{m} \times 10 \text{ ft} \times 0.3048 \text{ m / ft})$$

$$= 0.0975 \text{ m}^3/\text{min} \quad = 3.45 \text{ ft} / \text{min}$$

To convert the vapor flow Q_{atm} (where $P = P_{\text{atm}} = 1 \text{ atm}$), the following relationship can be used

$$Q_{\text{atm}} = \left(\frac{P_{\text{well}}}{P_{\text{atm}}} \right) Q_{\text{well}}$$

$$= (0.9 / 1) 0.0975$$

$$= 0.0877 \text{ m}^3/\text{min}$$

$$= 3 \text{ ft} / \text{min}$$

8.3.2.5 Contaminant Removal Rate

The contaminant removal rate (R_{removal}) can be calculated by multiplying the extracted vapor flow rate (Q) with the vapor concentration (G):

$$R_{\text{removal}} = \eta \times Q \times G$$

η : efficiency factor assumed to be 1.0

$$R_{\text{removal}} = 1.0 \times 0.0877 \text{ m}^3/\text{min} \times 44.1 \text{ g}/\text{m}^3$$

$$= 3.87 \text{ g} / \text{min}$$

$$= 5.600 \text{ kg} / \text{d}$$

8.3.2.6 Number of Vapor Extraction Wells

The flow rate from one venting well has been determined as $0.19 \text{ m}^3/\text{min}$. At this flow rate, the clean up will take 209 days.

The radius of influence of one venting well has been determined from Section 12.2 as 118 ft. the number of wells needed to cover the plume can be calculated as follows:

$$N_{\text{wells}} = \frac{1.2(A_{\text{contamination}})}{\pi R_I^2} = \frac{1.2(850)}{3.14(118)^2} = 0.23$$

Therefore, one well should be enough to cover the entire plume, unless the plume has a very long strip shape. As if the clean up time is not an issue with the client, one venting well would be required. Otherwise two can be installed to reduce the clean up time.

9. REMOTE SENSING APPLICATION IN THE ENVVIRONMENT

Digital Airborne Imaging Spectrometers (DAIS) are remote sensors that can provide high resolution hyperspectral imaging data of the terrain below. The data gathered is efficient in Phase I audits for large or multiple sites, and effective at providing drill location information for Phase II and III audits.

Hyperspectral imaging using remote sensors can provide data to detect and identify contaminated areas on a site, as well as provide the same data to adjoining sites. The latter can be important in assessing the source of a contaminate that may be found on site. In addition to establishing an anomaly (contamination) map to assist environmental engineers in well location and distribution, remote sensing can be used for periodic monitoring to determine if wells need to be moved or eliminated, if corrective action is effective and if migratory contamination is involved monitoring, and exploration for minerals and petrochemical resource prospecting.

9.1 Methodology

The following serves to illustrate the method that would be used to gather remote sensing data on a site. The site for assessment is a one square mile area located in an established industrial park. The terrain and vegetation is variable, and a stream traverses the property. The remote sensing equipment used is a DAIS 3715 scanner that contains 37 detectors to include two highly sensitive thermal detectors. The instrument is mounted in a highly modified twin engine aircraft. The plane will over-fly the site at about 90 knots and 1000 ft above ground level to achieve the optimum spatial and spectral data for analysis.

The pilot and/or staff divide not only the site to be investigated but also adjoining sites into a series of overlapping flight lines while taking into consideration sun angle, maximum reflectance, wind direction and other variables. As the plane is flying, the remote sensor's scanner sweeps the ground below storing terrain and geography information on a data tape that is later corrected for aircraft movement and atmosphere.

The data in the tape is in the form of a digital array, square meter by square meter, of the terrain (sites) below.

9.2 Data Collection and Analysis

Digital Airborne Imaging Spectrometers operate by gathering light that is reflected or energy emitted from the earth's surface. The sun provides energy in the form of a continuum of discrete wavelengths over the entire electromagnetic (light) spectrum. Animate and inanimate objects, solids, liquids and gases all absorb certain wavelengths from the sun and reflect or emit others depending on their molecular structures or structural arrays. Since no two entities are the same, the wavelengths they reflect or emit are not the same to include their ability to retain heat. It is the differences or spectral signatures (fingerprints) of dissimilar physical characteristics at sites that hyperspectral imaging scanners can collect for analysis and assessment.

The data that is collected from a site or sites is stored on a data tape and pre-processed by computer to account for aircraft movement and atmospheric conditions. Global positioning information is also included for geography location. The data is then ready for additional processing using imagery analysis software that is commercially available.

10. CONCLUSION

The presence of large amount of chemicals, gasoline, and diesel fuel on-site is considering an indicator of the potential for soil and groundwater contamination. The first step towards implementing a remediation is to provide for a have a better understanding of the physical properties of the organic chemicals themselves as well as physical properties and characteristic of the |Site and its type of soil.

Accordingly, a case study involves a Phase I ESA revealed evidences of potential environmental contamination associated with the land uses of the site. Therefore, a Phase II ESA investigation was initiated. The investigation consisted of advancing sampled boreholes and submitting samples for chemical analyses. The analytical results for soil samples revealed exceedances to the MOE applicable criteria.

Based on the physical condition of this site and the information gathered, it was our recommendation to remediate and restore the site to the meet MOE criteria. SVE was discussed then after with the operation description and desired features and limitations. Based on the known concentration and site characterization, elements of the system were designed. It appeared that the work can be done within an acceptable time frame to the client.

On the other hand, environmental application for remote sensing has not been widely used for environmental site assessments by engineering consultants. Yet, the majority of remote sensing services, which mostly involve satellite imagery, are provided to academic and governmental institutions. The availability of airborne hyperspectral imaging services to the private sector is a recent development. When a Phase II-III site assessment is requested based on a Phase I assessment, remote sensing technology can be of great economic advantage to consultant companies, and financial institutions.

APPENDIX A

FIGURE 1- KEY MAP

FIGURE 2- SITE MAP

Dwn. By: NAN	Nominal North: 	<div data-bbox="831 1493 1383 1588" data-label="Image"> </div> <div data-bbox="831 1618 1383 1723" data-label="Text"> <p>Graduation Project 2008 Environmental Site Investigation and Remediation 6700 Bath Road, Kingstons, Ontario</p> </div>
Ref.: Google		
Date: August 2008		Key Map

(Nominal)

BUILDING BOUNDARY

SITE BOUNDARY

GROUNDWATER LEVEL

PUMPING WELL

INJECTION/EXTRACTION WELL

MONITORING WELL

GRADUATION PROJECT 2008
GEO-ENVIRONMENTAL ENGINEERING

SITE PLAN

Scale	Project No.
N. T. S.	E2008
Date	FIGURE NO.
AUGUST 2008	1

GRADUATION PROJECT 2008			
GEO-ENVIRONMENTAL ENGINEERING			
CROSS SECTION A-A			
Scale	Project No.		
N. T. S.	E2008		
Date	FIGURE NO.		
AUGUST 2008	2		

APPENDIX B

AIREAL PHOTO

Dwn. By:	NAN	Nominal North:
Ref.:	MNR		Graduation Project 2008 Environmental Site Investigation and Remediation 6700 Bath Road, Kingtown, Ontario
Date:	August 2008		Aerial Photo

OLE No. BH12

OLE No. BH12

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OLE No. BH12

APPENDIX C

RECORD OF BOREHOLES (BH1 TO BH4)

NIA

Logged by:

Compiled by:

Reviewed by:

Revision No.:

S
Pac

RECORD OF BOREHOLE No. BH2

Project Number: 001-1520	Drilling Location: BH 2	Logged by: NK
Project Client: DR. MOSTAFA WARITH	Drilling Method: 150 mm Solid Stem Augers	Compiled by: AM
Project Name: SOIL REMEDIATION PROJECT	Drilling Machine: Truck Mounted Drill	Reviewed by: NM
Project Location: 8700 BATH ROAD	Date Started: Sep 12, 07 Date Completed: Sep 12, 07	Revision No.: 9/17/07

LITHOLOGY PROFILE		SOIL SAMPLING				FIELD TESTING		LAB TESTING		INSTRUMENTATION INSTALLATION	COMMENTS	
Lithology Plot	DESCRIPTION	Sample Type	Sample Number	Recovery (%)	SPT 'N' Value or RQD	DEPTH (m)	ELEVATION (m)	Penetration Testing ○ SPT ● DCPT MTO Vane* Nilcon Vane* ▲ Intact ◇ Intact ▲ Remould ◆ Remould * Undrained Shear Strength (kPa) 20 40 60 80	★ Rinse pH Values 2 4 6 8 10 12 Soil Vapour Reading parts per million (ppm) ▲ 100 200 300 400 ▲ Lower Explosive Limit (LEL) W _p W _L Plastic Liquid 20 40 60 80			
		Local Ground Surface Elevation: 99.0 m Topsoil silty sand with roots and organics dark brown soft Fill sand with gravel some silty clay brown compact to loose	SS	1	75	20	99	○				
		SS	2	70	4	1	98	○				
Silty SAND brown firm to stiff		SS	3	67	8	2		○				
Till; silty sand some clay light brown stiff		SS	4	96			97					
End of borehole Auger refusal on inferred bedrock at 3.8m												

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 CIVIL ENGINEERING

NIZAR KAZEM
 NAEM MAMOON
 ABDULKARIM MOSTAF

Groundwater depth on completion of drilling: 3.52 m.
 Groundwater depth observed on sept 12 11:00 am at a depth of: 3.52 m.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying 'Notes to Record of Boreholes'.

Scale: 1 : 26

Page: 1 of 1

NE

Logged by:

Compiled by:

Reviewed by:

Revision No.:

COMMENT

Page

RECORD OF BOREHOLE No. BH4

Project Number: 001-1520	Drilling Location: BH4	Logged by: NK
Project Client: DR. MOSTAFA WARITH	Drilling Method: 150 mm Solid Stem Augers	Compiled by: AM
Project Name: SOIL REMEDIATION PROJECT	Drilling Machine: Truck Mounted Drill	Reviewed by: NM
Project Location: 6700 BATH ROAD	Date Started: Sep 12, 07 Date Completed: Sep 12, 07	Revision No.: 9/17/07

Lithology Plot	LITHOLOGY PROFILE	SOIL SAMPLING				DEPTH (m)	ELEVATION (m)	FIELD TESTING	LAB TESTING	INSTRUMENTATION INSTALLATION	COMMENTS
	DESCRIPTION	Sample Type	Sample Number	Recovery (%)	SPT 'N' Value or RQD			Penetration Testing ○ SPT ● DCPT MTO Vane* Nilcon Vane* ▲ Intact ◇ Intact ▲ Remould ◇ Remould * Undrained Shear Strength (kPa) 20 40 60 80	★ Rinse pH Values 2 4 6 8 10 12 Soil Vapour Reading parts per million (ppm) 100 200 300 400 Lower Explosive Limit (LEL) W _p W W _L Plastic Liquid 20 40 60 80		
	Local Ground Surface Elevation: 99.0 m										
	Topsoil silty sand with roots and organics dark brown soft Fill sand with gravel some silty clay brown compact to loose	SS	1	75	20		99				
	98.9 0.2										
	Silty SAND brown firm to stiff	SS	2	70	4	1	98				
	97.9 1.1										
	Till; silty sands some clay light brown stiff	SS	3	67	8	2	97				
	97.2 1.8										
	End of borehole Auger refusal on inferred bedrock at 3.97 m						3.97				

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 CIVIL ENGINEERING

NIZAR KAZEM
 NAEEM MAMOUN
 ABDULKARIM MOSTAF

☒ Groundwater depth on completion of drilling: 3.75 m.
☒ Groundwater depth observed on sept 12 11:00 am at a depth of: 3.75 m.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying 'Notes to Record of Boreholes'.

Scale: 1 : 26

Page: 1 of 1

APPENDIX D

LABORATORY CERTIFICATE OF ANALYSIS

Report: K7-3700

Report Number: 2721306

Date: 2008-07-06

Date Submitted: 2008-08-01

Client: NAN Engineering

Attention: Mr. Nizar Kazem

Project: CV8001

Chain of Custody Number: 52886

P.O. Number:

Matrix:

Soil

PARAMETER		LAB ID:		1238	1239	1239	1240	GUIDELINE	
		UNITS	MRL	Sample Date:	BH1-SS2	BH2-SS3	BH3-SS2	BH4-SS2	O.Reg.153 - Table 3 - Soil - Res/Park
Metals									
Cyanide (free)	ug/g	0.005		5.000	7.000	5.000	7.000	100	ug/g
Electrical Conductivity	mS/cm	0.01		0.26	0.45	0.26	0.45	0.70	mS/cm
Moisture	%	0.1		17.7	16.8	17.7	16.8		
pH				7.3	7.800	7.3	7.800		pH Units
Sodium Absorption Ratio (SAR)				1.85	2.50	1.85	2.50		No Units
Antimony	ug/g	1		1	12	1	12	N/A	
Arsenic	ug/g	1.0		10.0	12	10.0	12	13	ug/g
Barium	ug/g	1		153	153	153	153	20	ug/g
Beryllium	ug/g	1		<1	<1	<1	<1	750	ug/g
Boron	ug/g	0.5		0.80	0.90	0.80	0.90	1.2	ug/g
Cadmium	ug/g	0.5		4	<0.5	4	<0.5	1.5	ug/g
Chromium	ug/g	1		540	650	540	650	12	ug/g
Cobalt	ug/g	1		8	16	8	16	750	ug/g
Copper	ug/g	1		220	198	220	198	40	ug/g
Cr(VI)	ug/g	1		4	6	4	6	225	ug/g
Lead	ug/g	1		180	100	180	100	8.0	ug/g
Mercury	ug/g	0.1		<0.1	<0.1	<0.1	<0.1	200	ug/g
Molybdenum	ug/g	1		<1	<1	<1	<1	10	ug/g
Nickel	ug/g	1		20	26	20	26	40	ug/g
Selenium	ug/g	1		3	5	3	5	150	ug/g
Silver	ug/g	0.42		2	1	2	1	10	ug/g
Thallium	ug/g	1		<1	<1	<1	<1	20	ug/g
Vanadium	ug/g	1		75	80	75	80	4.1	ug/g
Zinc	ug/g	1		550	480	550	480	200	ug/g
								600	ug/g

MRL = Method Reporting Limit INC = Incomplete AO = Aesthetic Objective OG = Operational Guideline MAC = Maximum Allowable Concentration IMAC = Interim Maximum Allowable Concentration

Comment: This is an amendment and supercedes all previous copies of this report. Guidelines have been added as per client request.

APPROVAL: _____

Report: K7-3700
 Report Number: 2721306
 Date: 2008-07-06
 Date Submitted: 2008-08-01
 Project: CV8001

Client: NMN Engineering
 Attention: Mr. Nizar Kazem

Chain of Custody Number: 58267

P.O. Number:
 Matrix:

Groundwater

LAB ID: 12311							GUIDELINE		
Sample Date: 2008-07-06							O.Reg.153 - Table 3 - Non-Potable Ground		
Sample ID: BH1									
BH2									
BH3									
BH4									
UNITS							LIMIT		
MRL							TYPE		
PARAMETER							UNITS		
VOLATILE ORGANIC COMPOUNDS - VOCs									
1,1,1,2-tetrachloroethane	ug/L	0.5	<0.5	<0.5	<0.5	<0.5	STD	200	ug/L
1,1,1-trichloroethane	ug/L	0.4	<0.4	<0.4	<0.4	<0.4	STD	200	ug/L
1,1,2,2-tetrachloroethane	ug/L	0.5	<0.5	<0.5	<0.5	<0.5	STD	22	ug/L
1,1,2-trichloroethane	ug/L	0.4	<0.4	<0.4	<0.4	<0.4	STD	16000	ug/L
1,1-dichloroethane	ug/L	0.4	<0.4	<0.4	<0.4	<0.4	STD	9000	ug/L
1,2-dibromoethane	ug/L	1.0	<1.0	<1.0	<1.0	<1.0			
1,2-dichloropropane	ug/L	0.5	<0.5	<0.5	<0.5	<0.5	STD	9.3	ug/L
1,3,5-trimethylbenzene	ug/L	0.3	<0.3	<0.3	<0.3	<0.3			
1,3-dichlorobenzene	ug/L	0.4	<0.4	<0.4	<0.4	<0.4	STD	7600	ug/L
Bromomethane	ug/L	0.5	<0.5	<0.5	<0.5	<0.5	STD	3.7	ug/L
c-1,2-Dichloroethylene	ug/L	0.4	<0.4	<0.4	<0.4	<0.4	STD	70	ug/L
c-1,3-Dichloropropylene	ug/L	0.2	<0.2	<0.2	<0.2	<0.2			
Chloroethane	ug/L	1.0	<1.0	<1.0	<1.0	<1.0			
Chloromethane	ug/L	1.0	<1.0	<1.0	<1.0	<1.0			
t-1,2-Dichloroethylene	ug/L	0.4	<0.4	<0.4	<0.4	<0.4	STD	100	ug/L
t-1,3-Dichloropropylene	ug/L	0.2	<0.2	<0.2	<0.2	<0.2	STD	3.8	ug/g
Trichlorofluoromethane	ug/L	0.5	<0.5	<0.5	<0.5	<0.5			
1,1-dichloroethylene	ug/L	0.5	<0.5	<0.5	<0.5	<0.5	STD	70	ug/L
1,2-dichlorobenzene	ug/L	0.4	<0.4	<0.4	<0.4	<0.4	STD	7600	ug/L
1,2-dichloroethane	ug/L	0.5	<0.5	<0.5	<0.5	<0.5	STD	17	ug/L
1,4-dichlorobenzene	ug/L	0.4	<0.4	<0.4	<0.4	<0.4	STD	7600	ug/L
Benzene	ug/L	0.5	7568	1850	<0.5	<0.5	STD	1900	ug/L
Carbon Tetrachloride	ug/L	0.5	<0.5	<0.5	<0.5	<0.5	STD	17	ug/L
Dichloromethane	ug/L	4.0	<4.0	<4.0	<4.0	<4.0	STD	50000	ug/L
Ethylbenzene	ug/L	0.5	27000	2500	<0.5	<0.5	STD	28000	ug/L
Monochlorobenzene	ug/L	0.2	<0.2	<0.2	<0.2	<0.2	STD	500	ug/L
Styrene	ug/L	0.5	<0.5	<0.5	<0.5	<0.5	STD	940	ug/L
Tetrachloroethylene	ug/L	0.3	<0.3	<0.3	<0.3	<0.3	STD	5.0	ug/L
Toluene	ug/L	0.5	9570	4975	<0.5	<0.5	STD	5900	ug/L

MRL = Method Reporting Limit INC = Incomplete AO = Aesthetic Objective OG = Operational Guideline MAC = Maximum Allowable Concentration IMAC = Interim Maximum Allowable Concentration

Comment: This is an amendment and supercedes all previous copies of this report. Kingston report number has been corrected. 572118: BTEX and F1 not available due to the fact no VOC vials were submitted.

APPROVAL:

Report: K7-3700
Report Number: 2721306
Date: 2008-07-06
Date Submitted: 2008-08-01

Client: NMN Engineering

Attention: Mr. Nizar Kazem

Project: CV8001

P.O. Number:

Chain of Custody Number: 58267

Groundwater

LAB ID: 12311						12312		12313		12314		GUIDELINE	
Sample Date:						2008-07-06		2008-07-06		2008-07-06		O.Reg. 153 - Table 3 - Non-Potable Ground	
Sample ID:						BH2		BH3		BH4			
BH1						BH2		BH3		BH4			
										</			

Report: K7-3700
Report Number: 2721306
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Client: NAN Engineering

Attention: Mr. Nizar Kazem

Project: CV8001

P.O. Number:

Chain of Custody Number: 524481

Groundwater

Chain of Custody Number: 324481										
LAB ID: 12311 Sample Date: 2008-07-06 Sample ID: BH1				12312 1900-01-00 BH2	12313 1900-01-00 BH3	12314 1900-01-00 BH4	GUIDELINE O.Reg.153 - Table 3 - Non-Potable Ground			
PARAMETER		UNITS	MRL					TYPE	LIMIT	UNITS
Metals										
Cyanide (free)	mg/L	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	STD	0.052	mg/L
N-NO2 (Nitrite)	mg/L	0.10	<0.10	<0.10	<0.10	<0.10	<0.10	STD	2.0	mg/L
N-NO3 (Nitrate)	mg/L	0.10	2.66	2.66	2.66	2.66	2.66	STD	N/V	mg/L
Antimony	mg/L	0.001	8	12	2	4	4	STD	16	mg/L
Arsenic	mg/L	0.001	0.001	0.001	0.001	0.001	0.001	STD	0.48	mg/L
Barium	mg/L	0.01	5	3	2	6	6	STD	23	mg/L
Beryllium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	STD	0.053	mg/L
Boron	mg/L	0.01	5.00	3.00	6.00	4.00	4.00	STD	50	mg/L
Cadmium	mg/L	0.0001	0.0004	0.0004	0.0004	0.0004	0.0004	STD	0.011	mg/L
Chromium	mg/L	0.005	1.800	1.200	0.008	0.008	0.008	STD	2	mg/L
Cobalt	mg/L	0.0002	0.0143	0.0143	0.0143	0.0143	0.0143	STD	0.1	mg/L
Copper	mg/L	0.001	0.016	0.016	0.016	0.016	0.016	STD	0.023	mg/L
Cr(VI)	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	STD	0.11	mg/L
Lead	mg/L	0.001	0.007	0.007	0.007	0.007	0.007	STD	0.032	mg/L
Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	STD	0.00012	mg/L
Molybdenum	mg/L	0.005	1.000	3.200	<0.005	<0.005	<0.005	STD	7.3	mg/L
Nickel	mg/L	0.005	0.020	0.020	0.020	0.020	0.020	STD	1.6	mg/L
Selenium	mg/L	0.001	0.001	0.001	0.001	0.001	0.001	STD	0.05	mg/L
Silver	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	STD	0.00012	mg/L
Thallium	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	STD	0.4	mg/L
Vanadium	mg/L	0.001	0.019	0.019	0.019	0.019	0.019	STD	0.2	mg/L
Zinc	mg/L	0.01	0.09	0.05	0.05	0.04	0.04	STD	1.1	mg/L

MRL = Method Reporting Limit INC = Incomplete AO = Aesthetic Objective OG = Operational Guideline MAC = Maximum Allowable Concentration IMAC = Interim Maximum Allowable Concentration
Comment: This is an amendment and supercedes all previous copies of this report. Kingston report number has been corrected.

Report: K7-3700
Report Number: 2721306
Date: 2008-07-06
Date Submitted: 2008-08-01

Client: NAN Engineering

Attention: Mr. Nizar Kazem

Project: CV8001

P.O. Number:

Chain of Custody Number: 51815

Soil

Matrix:

LAB ID: 1234										1235										1236										1237										1238										GUIDELINE																			
Sample Date: 2007-09-12										2007-09-12										2007-09-12										2007-09-12										2007-09-12										O.Reg.153 - Table 3 - Soil - Res/Park																			
Sample ID: BH1-SS2										BH1 SS5										BH2-SS2										BH3 SS2										BH4 SS2																													
PARAMETER										UNITS		MRL																																TYPE		LIMIT		UNITS																					
PERCENT MOISTURE										%		0.1		17.7										23.5										18										16										18															
Moisture										ug/g		0.002		<0.002										<0.002										<0.002										<0.002										<0.002										STD		0.019		ug/g	
VOLATILE ORGANIC COMPOUNDS - VOCs										ug/g		0.005		10										<0.005										<0.005										<0.005										<0.005										STD		26		ug/g	
1,1,1,2-tetrachloroethane										ug/g		0.004		<0.004										<0.004										<0.004										<0.004										<0.004										STD		0.037		ug/g	
1,1,1-trichloroethane										ug/g		0.002		1.1										<0.002										<0.002										<0.002										<0.002										STD		2.3		ug/g	
1,1,2-trichloroethane										ug/g		0.002		6.0										<0.002										<0.002										<0.002										<0.002										STD		22		ug/g	
1,1-dichloroethane										ug/g		0.002		<0.002										<0.002										<0.002										<0.002										<0.002										STD		0.019		ug/g	
1,2-dibromoethane										ug/g		0.002		<0.002										<0.002										<0.002										<0.002										<0.002										STD		30		ug/g	
1,2-dichloropropane										ug/g		0.002		<0.002										<0.002										<0.002										<0.002										<0.002										STD		2.3		ug/g	
1,3,5-trimethylbenzene										ug/g		0.002		<0.002										<0.002										<0.002										<0.002										<0.002										STD		0.0066		ug/g	
1,3-dichlorobenzene										ug/g		0.002		13.0										<0.002										<0.002										<0.002										<0.002										STD		4.1		ug/g	
c-1,2-Dichloroethylene										ug/g		0.003		1.3										<0.003										<0.003										<0.003										<0.003										STD		0.0024		ug/g	
Chloromethane										ug/g		0.003		<0.003										<0.003										<0.003										<0.003										<0.003										STD		30		ug/g	
t-1,2-Dichloroethylene										ug/g		0.003		<0.003										<0.003										<0.003										<0.003										<0.003										STD		0.0066		ug/g	
t-1,3-Dichloropropylene										ug/g		0.003		<0.003										<0.003										<0.003										<0.003										<0.003										STD		0.0024		ug/g	
Trichlorofluoromethane										ug/g		0.012		<0.012										<0.012										<0.012										<0.012										<0.012										STD		30		ug/g	
1,1-dichloroethylene										ug/g		0.002		<0.002										<0.002										<0.002										<0.002										<0.002										STD		0.0024		ug/g	
1,2-dichlorobenzene										ug/g		0.002		<0.002										<0.002										<0.002										<0.002										<0.002										STD		30		ug/g	
1,2-dichloroethane										ug/g		0.002		<0.002										<0.002										<0.002										<0.002										<0.002										STD		0.022		ug/g	
1,4-dichlorobenzene										ug/g		0.002		5.0										<0.002										<0.002										<0.002										<0.002										STD		30		ug/g	
Benzene										ug/g		88		<0.002										<0.002										<0.002										<0.002										<0.002										STD		5.3		ug/g	
Carbon Tetrachloride										ug/g		0.002		<0.002										<0.002										<0.002										<0.002										<0.002										STD		0.10		ug/g	
Dichloromethane										ug/g		0.003		<0.003										<0.003										<0.003										<0.003										<0.003										STD		120		ug/g	
Ethylbenzene										ug/g		0.002		270										<0.002										<0.002										<0.002										<0.002										STD		290		ug/g	
Monochlorobenzene										ug/g		0.002		<0.002										<0.002										<0.002										<0.002										<0.002										STD		8.0		ug/g	
Styrene										ug/g		0.002		<0.002										<0.002										<0.002										<0.002										<0.002										STD		1.2		ug/g	
Tetrachloroethylene										ug/g		0.002		<0.002										<0.002										<0.002										<0.002										<0.002										STD		0.45		ug/g	
Toluene										ug/g		230		<0.002										<0.002										<0.002										<0.002										<0.002										STD		34		ug/g	

Report: K7-3700
 Report Number: 2721306
 Date: 2008-07-06
 Date Submitted: 2008-08-01
 Project: CV8001

Client: NAN Engineering
 Attention: Mr. Nizar Kazem

P.O. Number:
 Matrix:

Chain of Custody Number: 51815

Chain of Custody Number: 31013																
LAB ID: 1234						1235		1236		1237		1238				
Sample Date: 2007-09-12						2007-09-12		2007-09-12		2007-09-12		2007-09-12				
						Sample ID: BH1-SS2		BH1 SS5		BH2-SS2		BH3 SS2		BH4 SS2		
PARAMETER						UNITS	MRL									
Trichloroethylene						ug/g	0.004									
Vinyl Chloride						ug/g	0.003									
Bromodichloromethane						ug/g	0.002									
Bromoform						ug/g	0.002									
Chloroform						ug/g	0.002									
Dibromochloromethane						ug/g	0.003									
m/p-xylene						ug/g	0.002									
o-xylene						ug/g	0.002									
VOC SURROGATES																
Toluene-d8						%										
4-bromofluorobenzene						%										
1,2-dichloroethane-d4						%										
CCME Total Petroleum Hydrocarbons																
F1 (C6-C10)						ug/g	20	320	12	<20	<20	<20	<20	STD	30	ug/g
F1-BTEX (C6-C10)						ug/g	20	110	<20	<20	<20	<20	<20	STD	150	ug/g
F2 (C10-C16)						ug/g	20	78	<20	<20	<20	<20	<20	STD	400	ug/g
F3 (C16-C34)						ug/g	20	55	<20	<20	<20	<20	<20	STD	2800	ug/g
F4 (C34-C50)						ug/g	20	<20	<20	<20	<20	<20	<20	STD		
O.Reg.153 - Table 3 - Soil - Res/Park																

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