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Final Remediation Pre-Treatment Assessment Report

Project No. 1000417
Department of Transportation
Government of the Northwest Territories
James Creek Maintenance Camp
No. 8, Dempster Highway, NWT

28 March 2013

EXECUTIVE SUMMARY

Oxy Teknologies Inc. (OxyTek) was retained by the Government of the Northwest Territories (GNWT) Department of Transport (DOT) to undertake a Final Remediation Pre-Treatment Assessment at the DOT highway maintenance yard near James Creek, at kilometer 14 on Highway 8 (Dempster Highway) in the Northwest Territories [hereafter called, the Site]. The objective of the work was to provide enhanced delineation and quantification of environmental impacts to soil, surface water, and groundwater at the Site.

The mandate given by GNWT-DOT was:

- Delineating impacted soils and groundwater on-site using the laser-induced fluorescence (LIF) system;
- Conducting a hydrogeological/hydrological assessment ([including observation of the freshet, as per Department of Fisheries and Oceans (DFO) request];
- Completing a bedrock mapping and permafrost assessment;
- Conducting a treatability study on contaminated soil from the Site; and,
- Presenting the findings of these investigations in a structured report and provide the appropriate recommendations.

OxyTek utilized a team of experts to complete this assessment: Mr. Frank Colozza, M.Sc., P.Geo. (Partner and Senior Hydrogeologist with JFM Environmental Limited [JFMEL]); Dr. Norbert H. Maerz (Program Head, Geological Engineering – Missouri University of Science and Technology), an acknowledged leader in the field of rock mechanics; and the services of Matrix Environmental LLC, with the field involvement of Mr. Andrew Kirsch, to operate and interpret the LIF system.

In preparation of this Assessment, a site visit was conducted in late May 2012 to observe freshet. It was previously un-documented whether there was any interaction between the surface water (melt waters) and groundwater at the Site that could potentially cause environmental concerns to James Creek.

Through observing freshet, the 'event' did not appear visually to have interaction with the Site. However, based on the site observations, it was recommended that, during the August 2012 investigations, data loggers be installed in selected groundwater monitoring wells and a 'stilling well'. The stilling well was to be installed in James Creek to permit water elevation measurement to be taken from the creek without interference from turbulent water flow (during warm periods) or ice cover (during cold periods).

Conventional drilling techniques, using split-spoon sampling were used to collect soil samples and additional hard data to confirm the LIF findings. The LIF is a screening tool that uses a unique probe, in conjunction with a Geoprobe percussion drill, for in-ground definition of subsurface contaminant. The data were used to generate a three-dimensional digital model which displays the vertical and lateral extent of soil and groundwater contamination. The LIF system also mapped the bedrock and permafrost surfaces. The data were used to determine the potential for contamination migration and to determine if the contaminated soils and groundwater had an environmental impact on James Creek.

In conjunction with the LIF and bedrock investigations, 53 boreholes were advanced on-site. Representative soil samples were submitted for laboratory analyses of soil (pH), heavy metals, petroleum hydrocarbons (PHCs) (fractions F1 through F4 inclusive), and BTEX (benzene, toluene, ethylbenzene, and xylene). Groundwater samples, obtained from existing and newly installed monitoring wells, were submitted for analyses of groundwater (pH), electrical conductivity, anion / cation scan, heavy metals, PHCs (fractions F1 through F4, inclusive) and Volatile Organic Compounds (VOcs), which include BTEX.

The investigation determined that soil and fill within the operational area of the Site are contaminated with PHCs and BTEX. The contaminant-impacted soil area consists of two plumes: the primary plume, under the garage, having a volume of approximately 4,800 cubic metres (m3) (approximately 60 m X 27 m X 3 m thickness)), and a smaller northern plume having a volume of approximately 620 m^3 (approximately 25 m X 10 m X 2.3 m thickness). In addition, there are approximately 820 m^3 of soil in the land treatment units (LTUs) located at the Site. It is estimated that approximately 50 percent of these soils (in the lower half of the LTU) require treatment.

The soil under the garage pad is heavily contaminated with a range of PHCs that indicate the source of the contamination is not due exclusively to the diesel fuel spills that are known to have occurred at the Site. The presence of the garage has resulted in the permafrost below the pad forming a 'bowl-like' surface that holds wet unfrozen soil and groundwater that contains free-phase PHCs. It is estimated that approximately 50,000 litres of contaminated groundwater are present under the garage (approximately 140 m2 (approximately 15 m X 18 m)). The bowl structure is apparent in the screenshots from the LIF model provided in the body of the report. An additional 200,000 litres (approximate area of 390 square metres (approximately 18 m X 25 m X 1.5 m thickness)) of PHC-contaminated groundwater is present in a plume that extends in a northeasterly direction from the garage.

The assessment of the bedrock at the Site and the mapping of the bedrock and permafrost surfaces found that the permafrost was essentially impenetrable. The surface of the permafrost defines a potential pathway for groundwater perched above the permafrost. A thin layer of peat between the soil and the underlying bedrock was noted to have elevated volatile vapours, which were likely due to absorption from surface-derived water.

The bedrock was interpreted to have a north-westerly strike ('the direction of the line formed by the bedding plane of the stratum of sedimentary rock with a horizontal plane') at approximately N30°E and a dip ('the downward inclination of a stratum with reference to a horizontal plane') in the northeast direction (approximately 60°). The contamination does not extend down to the bedrock under the garage. The bedrock is comprised of two types of shale, both of which have low matrix permeability. One of the types of shale has within it a well-established network of discontinuities, which have low hydraulic conductivity and are not oriented in directions that match the hydraulic gradient or potential pathways to James Creek.

There is virtually no mobility of contaminant through the permafrost and bedrock, although there is a pathway in the thin layer of perched groundwater above the permafrost during the summer season. The contamination is NOT locked in place, but it remains as a continuing environmental liability. This pathway would move downgradient along the surface of the permafrost and through underground utilities. Data loggers have been installed in monitoring wells and a newly installed stilling well, adjacent James Creek. The analysis of the data logger output and water level readings will improve the assessment of liability and urgency when the direction of groundwater migration and the connection with the surface water is confirmed after the data loggers are retrieved in 2013. This will establish if there is or is not a connection between surface and groundwater as it was previously unknown.

The bowl-like formation in the permafrost under the garage is essentially a secondary containment for hydrocarbon spills and leaks from the garage area. The addition of water or liquid contaminants to the volume contained in the 'bowl' may cause it to overflow into the thin layer of perched groundwater above the permafrost. The presence of contaminated groundwater and free-phase PHCs under the garage provides a high potential for environmental liability and removal of that liquid material has the greatest urgency and highest priority for remediation at the Site.

Representative soil samples from the Site were used to conduct a treatability study. This study confirmed that chemical oxidation techniques can be used effectively to decrease the soil contamination from the current levels to well below the threshold for compliance with the Residential/Parkland (R/P) level.

The presence of wet soil, contaminated liquid groundwater, and free-phase PHCs under the garage had not been identified in earlier site assessments. While the mobility of contaminants has been determined to be more limited than had previously been thought, the presence of a perched mass of contaminant requires careful consideration for remedial action.

The separate reports of the expert consultants utilized for the investigation are available in their entirety within the Appendix.

This Final Remediation Pre-Treatment Assessment for the James Creek Highway Maintenance Yard, Km 14, Highway No. 8, Northwest Territories, has been prepared for the Department of Transportation, Government of the Northwest Territories, by Oxy Teknologies Inc.

This Executive Summary was written by

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1.0 INTRODUCTION

Oxy Teknologies Inc. (OxyTek) was contracted by the Government of the Northwest Territories (GNWT) Department of Transportation (DOT) to conduct a Final Remediation Pre-Treatment Assessment (the "Assessment") at the James Creek Maintenance Yard located at kilometer 14 on Highway 8 (Dempster Highway) in the Northwest Territories [the "Site"]. This assessment was completed as per our proposal (Final Remediation Pre-Treatment Assessment Proposal, James Creek Maintenance Yard, dated 11 May, 2012) and change order (Change Order to Reference No. SC 793979 Final Remediation Pre-Treatment Assessment, James Creek Maintenance Camp, Highway No. 8 (Dempster Highway, 26 June 2012).

1.1 Objectives

The objective of this Assessment was to provide enhanced delineation and quantification of environmental impacts to soil, surface water, and groundwater at the Site. The Assessment consisted of the following:

- Delineating impacted soils and groundwater on-site using the laser-induced fluorescence (LIF) system;
- Conducting a hydrogeological/hydrological assessment ([including observation of the freshet, as per Department of Fisheries and Oceans (DFO) request];
- Completing a bedrock mapping and permafrost assessment;
- Conducting a treatability study on contaminated soil from the Site; and,
- Presenting the findings of these investigations in a structured report and provide the appropriate conclusions and recommendations.

To achieve these objectives OxyTek utilized the expert services of:

- Mr. Frank Colozza, M.Sc., P.Geo. (Partner and Senior Hydrogeologist with JFM Environmental Limited (JFMEL)) conducted the hydrogeological/ hydrological assessment and assisted with the freshet investigations.
- Dr. Norbert H. Maerz, (Program Head, Geological Engineering – Missouri University of Science and Technology), an acknowledged leader in the field of rock mechanics, conducted the bedrock mapping and permafrost assessment
- Mr. Andrew Kirsch (Matrix Environmental, Inc.) operated and interpreted data collected using a Dakota Technologies UVOST® unit using laser-induced fluorescence (LIF)
- Mr. Dennis Owens, M.Sc. (OxyTek, Senior Microbiologist / Chemist) conducted a treatability study on samples collected as part of this Assessment to determine potential site remediation options.

1.2 Organization of this Report

OxyTek has relied upon the reports of the experts listed in Section 1.1 in the preparation of this report.

This report provides an overview of each aspect of the field investigations and the findings of the collective investigations. Based on these findings, conclusions are drawn based on the experts' opinions and recommendations are made.

The appendices of this report contain the experts' reports, and where possible we have included the relevant Appendix reference.

2.0 SITE DESCRIPTION

The Site is located approximately 60 km southwest of Fort McPherson, NT (Figure 1). The James Creek Highway Maintenance Yard occupies the Site and is situated at km 14 on Highway No. 8 (Dempster Highway). The latitude and longitude of the Site is 67°08'30 N and 135°59'53 W.

The Site is operated under Land Use Permit #G06H008 issued by the Gwich'in Land and Water Board (GLWB) and is used by DOT for maintaining and staging highway maintenance vehicles, such as snow ploughs and road graders. The facilities, including the maintenance camp, are operated and managed by Mackenzie Valley Construction Ltd. (MVC) of Inuvik, NT.

The operational area of the Site encompasses approximately 270 metres (m) by 60 m (approximately 1.62 hectare) (Figure 2). It is developed with a maintenance garage (approximate footprint of 340 square metres (m^2)) which is the only permanent aboveground structure on the Site, accommodation trailers, petroleum handling and storage facilities, equipment storage areas and heavy equipment parking areas. The boundaries of the Site are unmarked. Based on mapping, including the floodplain and the two land farm treatment areas, the entire Site encompasses approximately 4 hectare.

The Site is used as a maintenance depot, consequently vehicular fuel, primarily diesel, must be available. In addition, diesel fuel is required to operate the generators that provide power to the Site. An above ground fuel storage tank (AST), with a capacity of approximately 75,000 L is located outdoors near the east wall of the maintenance garage. The easternmost bay of the maintenance garage houses two diesel-powered generators that supply electrical energy to the Site. The outdoor AST supplies an indoor AST, with a capacity of approximately 1,150 L, which is located in the generator room and which feeds the diesel generators.

James Creek is the headwater area for the Vittrekwa River that, in turn, feeds the Peel River. Gwich'in people from throughout the Gwich'in Settlement Area (GSA) hunt and trap in the James Creek area. James Creek is an important freshwater drinking source for people from Fort McPherson and especially for people coming to the James Creek area to hunt.

2.1 Geology

The Site is located on the north side of the Dempster Highway (Highway No. 8) within the Richardson Mountains, a north-northeast trending valley.

Norris (1981) describes the bedrock geology as being of the Upper Devonian Imperial Formation, a thick marine siltstone and sandstone unit. Highlands surround the Site and they are covered with thin to thick colluvium with exposed bedrock boulders at the surface. In the valley, in the area of the Site, there is a thick deposit of glaciofluvial outwash consisting of sand and gravel with minor silt and peat which forms the gently sloping terrain (Duk-Rodkin and Hughes, 1992).

Underlying the fill material, the natural soils consisted of variations of one or more of the following: organic topsoil demarking original ground surface; a thin layer of peat; floodplain deposits of sand, gravel, silt and clay mixture; interlayered silty clay and silty sand lens; cobbles and coarse gravel, eroded and rounded; and; shale bedrock. The depth to bedrock was encountered at between 1.83 mbgs and 12.19 mbgs.

2.2 Topography and Drainage

The developed area of the Site is generally flat and slopes approximately 1 to 2 percent downwards to the east, towards James Creek. Its general topography has been modified to suit its use as a highway vehicle maintenance depot. Much of the operational area of the Site has been in-filled with tightly compacted sand and gravel to form a pad.

The northern perimeter of the pad area has a surface elevation difference of approximately 3 m compared to the creek's flood plain. The south(west) border of the property is defined by a sharp rock outcrop, forming a prominent wall-like feature. The rock outcrop consists primarily of weathered bituminous shale, with inter-bedded mudstone layers. This outcropping dips, below the overlying soil and underlying permafrost of the operational pad, in a northeast direction and the bedrock surface is interpreted as having an elevation difference of approximately 10 m across the Site (in a southwest-to-northeast direction).

3.0 REGULATORY CRITERIA

3.1 Applicable Criteria

The Site is leased by the DOT of the GNWT and is crown land. The regulatory criteria applicable to this Site are:

Canadian Council of the Ministers of the Environment (CCME) Canadian Soil Quality Guidelines (CSQG) for the Protection of Environmental and Human Health (1999, last updated 2007). The CCME CSQG for the Protection of Environmental and Human Health (1999, updated 2007) are risk-based and are typically used as a preliminary means of evaluating soil. For the James Creek Site, the analytical results are compared to both the parkland and industrial guidelines I standards. Based on the soil conditions, the analytical results are compared to coarse-grained soil criteria.

CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life [CWQG; 1999, last updated 2007]. These Guidelines are risk-based, and are typically used as a preliminary means of evaluating surface water. A potable freshwater ecosystem is located adjacent to the Site, therefore concentrations of benzene, toluene, ethylbenzene, metals and general chemistry parameters have been compared to the CWQGs for the Protection of Aquatic Life considering a freshwater environment.

CCME Canadian Sediment Quality Guidelines (1999, updated 2002). The Canadian Sediment Quality Guidelines for the Protection of Aquatic Life include guidelines known as the Interim Sediment Quality Guidelines (ISQG) and the Probable Effects Levels (PEL). For comparison purposes, the analytical results are compared to the most stringent criteria.

CCME Canada Wide Standards for Petroleum Hydrocarbons in Soil (CWS for PHCs in Soil; 2001, updated 2008. For this Site, the applicable Standards are coarse-grained surface soil in a Parkland land use. For comparison purposes, the analytical results are also compared to coarse-grained industrial land use guidelines / standards.

Health Canada Guidelines for Canadian Drinking Water Quality (1968, last updated December 2010). These guidelines are prepared by the Federal-Provincial-Territorial Committee on Drinking Water which is formed by representatives from each province and territory, and Health Canada.

Alberta Tier 1 Soil and Groundwater Remediation Guidelines (rev. December 2010). In cases where no CWQG or GCDWQ are available (xylenes and PHC fractions F1 and F2), the Alberta Environment Groundwater Remediation Guidelines are followed.

James Creek provides a potable groundwater source and therefore the Site and adjoining properties are considered residential land use. The analytical results for groundwater samples have been compared to the residential Tier 1 guidelines for coarse-grained soil.

Analytical test results were compared to the criteria shown in the following table. The "**x**" denotes the applicable regulatory criteria, and is appended, where applicable, by further references to the AENV Tier 1 Guidelines.

Sample Type	Parameter	Regulatory Criteria					
		CCME CSQGs	CCME CWS	CCME CWQG (FAL)	CCME CSQG (PELs)	GCDWQs	AENV Tier 1
Soil	Benzene, toluene, ethylbenzene and xylene	x					
	Petroleum hydrocarbons, F1 to F4		x				
	Metals	x					
Ground-water / Surface Water	Benzene, toluene, ethylbenzene			x		x[2]	
	Xylene					x[2]	x[3]
	Petroleum hydrocarbons, F1 to F4						x[3]
	Total and dissolved metals			x		x[2]	
	General Chemistry			x		x[2]	
Sediment	Benzene, toluene, ethylbenzene and xylene	x					
	Petroleum hydrocarbons, F1 to F4		x				
	Metals	x[4]			x		

CCME CSQGS – Canadian Council of the Ministers of the Environment Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health
CCME CWS – Canadian Council for the Ministers of the Environment Canada Wide Standards for Petroleum Hydrocarbons in Soil (2008), Tier 2 Pathway Specific Guidelines
CCME CWQG FAL – Canadian Council of the Ministers of the Environment Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life
CCME CSQG (PELs) – Canadian Council of Ministers of the Environment Canadian Sediment Quality Guidelines for the Protection of Aquatic Life
AENV Tier 1 Guidelines – Alberta Environmental Tier 1 Guidelines (2009)

1. Pathways specific (soil ingestion and eco soil contact (CCME CSQGs will be used for comparison of BTEX concentrations in soil
2. Health Canada GCDWQ will be where no CCME Human Health guidelines are available
3. AENV Tier 2 Guidelines will be used in the absence of CCME CWQGs and / or GCDWQs
4. CCME Soil Guidelines will be used for Human Health and Sediment Guidelines, used for Ecological Health

3.2 Sampling Quality Assurance I Quality Control Program

This section of the report describes the QA/QC procedures followed as part of this Assessment. Soil and groundwater samples obtained in the field were submitted to Maxxam Analytics Inc. (Maxxam). Maxxam is accredited by the Standards Council of Canada and their methodologies conform to Standard CAN-P-4E (ISO/IEG 17025:2005).

3.3 Sample Handling

All samples were collected following the appropriate sampling QA and QC procedures. Samples were placed in laboratory supplied containers and stored in dedicated coolers and kept cool with ice. Samples were uniquely labelled and control was maintained by the use of chain of custody forms.

3.4 Blind Field Duplicates

Field duplicates (or blind duplicates) were collected for soil, surface water and groundwater samples. All field duplicates were labelled with different sample names to prevent the laboratory from knowing the origins of the sample. As per standard work practices, 10% of samples taken were field duplicates.

3.5 Trip and Field Blanks

Distilled water samples were placed in laboratory supplied containers and were used as trip blanks. They were present on-site for the duration of the project and following completion of the investigations, and were submitted for laboratory analyses of the COC.

Trip blanks were used to determine if the samples were cross contaminated or if samples were compromised during transport for the field to the lab. One trip sample was submitted for PHCs, dissolved metals and general water chemistry parameters.

4.0 FIELD INVESTIGATIONS

4.1 Delineating Impacted Soils and Groundwater using the LIF System

The LIF investigations were completed by Mr. Andrew Kirsch of Matrix Environmental, Inc. A copy of the LIF report is included as Appendix 2c.

A laser-induced fluorescence (LIF) system is a state-of-the-art screening tool for determining the extent and distribution of subsurface light non-aqueous phase liquids (LNAPL) contamination. A unique probe, utilizing a sapphire window, for radiation emitted from a XeCl laser was used in conjunction with a Geoprobe drill.

Thirty-seven (37) boreholes were advanced as part of the LIF survey. The boreholes were advanced near the known diesel fuel spill location and then in a planned grid pattern to define the extent of the contaminant plume. Each borehole was pushed to the maximum depth that the Geoprobe drill could handle. Most boreholes made it into the permafrost zone.

Several of the LIF boreholes were placed near to soil sampling locations, especially to assess the fluorescence signal obtained in the transition through the upper surface of the permafrost. That correlation makes it possible to state that the permafrost acts as a barrier for migration of LNAPL.

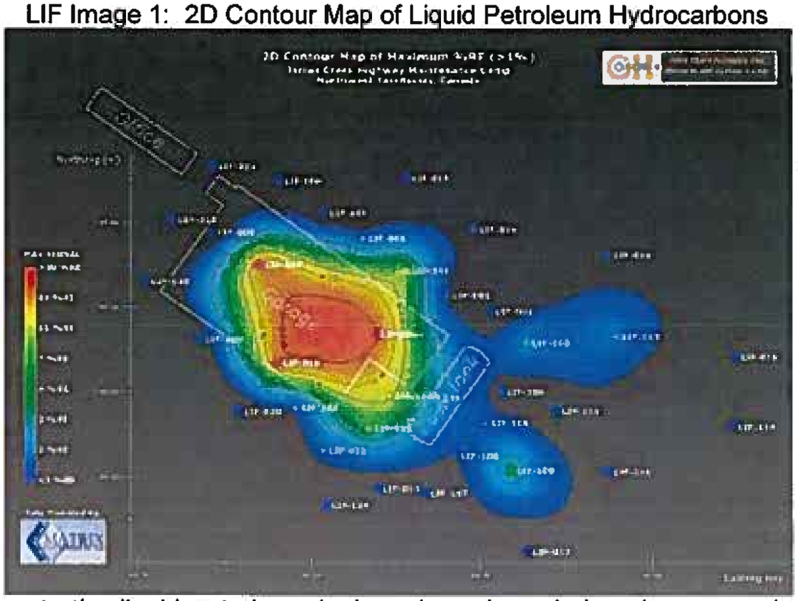
The probe collected data that was used to build a visual image of the real-time vertical and horizontal contamination at the Site. These data were also used to further guide the hydrogeological / hydrological and bedrock investigations.

The LIF system generated the following images of the subsurface contamination. In addition to providing a "visual location" of the impairment these images are also used for:

- estimating the volume of contaminated soil and groundwater
- assessing migration routes to surface water
- diagnosing contamination source issues
- developing detailed excavation and remediation plans

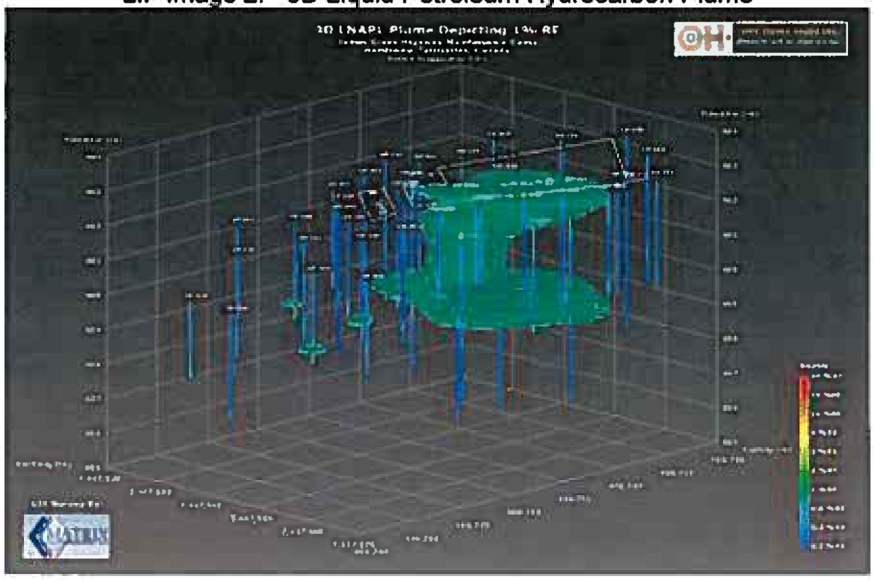
LIF Images 1 through 5 provide the LIF models for the area of the garage building where diesel fuel spill known to have occurred:

LIF Image 1: 2D Contour Map of Liquid Petroleum Hydrocarbons



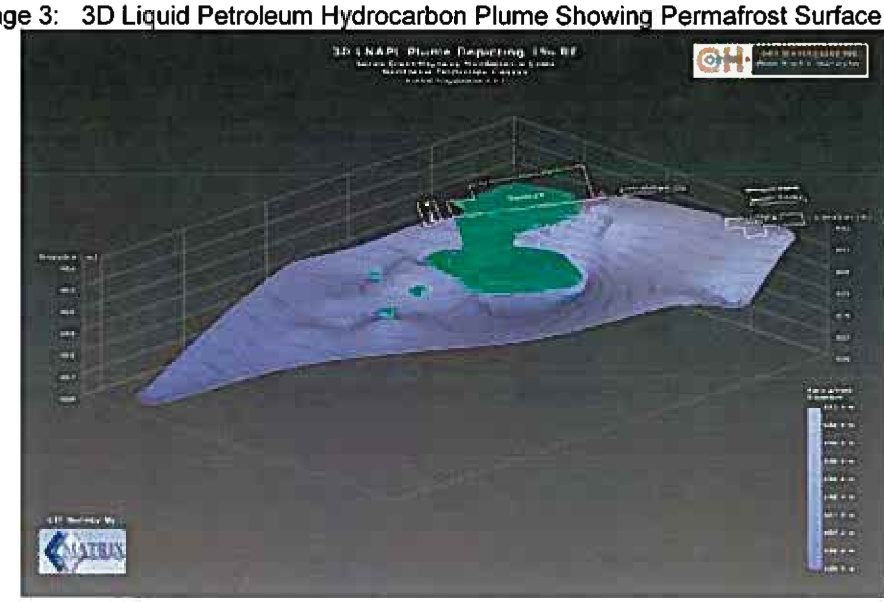
This model represents the liquid petroleum hydrocarbon plume below the garage building (outlined in white) where the spill occurred in 2008. The higher concentrations of hydrocarbons are shown in red while the areas shown in blue represent the lower hydrocarbon concentrations.

LIF Image 2: 3D Liquid Petroleum Hydrocarbon Plume



This model shows the three dimensional location and shape of the liquid petroleum hydrocarbon plume below the garage building (outline of building shown in white) showing the horizontal and vertical extent of the impairment. The blue vertical lines are the placements of borings surrounding the garage building.

LIF Image 3: 3D Liquid Petroleum Hydrocarbon Plume Showing Permafrost Surface Contours



This model shows the three dimensional image of the liquid petroleum hydrocarbon plume below the garage building (outline of building shown in white) as compared to the permafrost surface contours.

LIF Image 4: 3D Hydrocarbon Plume Showing Permafrost and Bedrock

This model shows the three dimensional image of the liquid petroleum hydrocarbon plume below the garage building (outline of building shown in white) and all site features, the permafrost contours and the depth of the bedrock. NOTE: Model is zoomed out at a 3-1 vertical exaggeration

LIF Image 5: 3D Liquid Petroleum Hydrocarbon Plume Showing Bedrock Surface

This model shows the three dimensional image of the liquid petroleum hydrocarbon plume below the garage building (outline of building shown in white) and the depth of the bedrock. NOTE: Model is zoomed out at a 5-1 vertical exaggeration

The LIF model shows clearly a 'bowl'-like formation in the permafrost surface under the garage. The LIF system also identified other types of hydrocarbon impairment below the garage floor - contaminants other than the diesel contamination that prompted the current Assessment.

While the static screenshots from the LIF model are a significant benefit to visualizing the subsurface contamination, the LIF system also generated an interactive 'four'-dimensional modeling tool that greatly enhances the visualization benefit and is particularly valuable for planning efficient remediation tactics. Instructions on how to use this modeling system are provided in Appendix 2a in association with the Matrix Environmental report.

4.2 HYDROGEOLOGICAL / HYDROLOGICAL ASSESSMENT

The hydrogeological / hydrological assessment was conducted in two stages. The first phase consisted of viewing and documenting the freshet event because no historical data existed relating to the effects of freshet on the Site. This first stage occurred from May 22 to May 25, 2012 (Section 4.2.1).

The second stage of the hydrogeological / hydrological assessment (Section 4.2.2) was conducted in conjunction with the LIF investigations (Section 4.1) and the bedrock investigations (Section 4.3) between July 29 and August 9, 2012.

4.2.1 Freshet

The freshet event was attended by Dr. Daniel Cassidy, M.A.Sc. Ph.D., P.Eng., Associate Professor, Western Michigan University, Dept. of Geosciences and Ross Anderson, B.Sc., B.A.Sc., P.Eng. of OxyTek. A copy of the Freshet report is included as Appendix 3. The OxyTek team traveled to the Site on May 22, 2012, accompanied by a representative from both DFO and DOT.

The flow in James Creek was determined to have crested on May 24, 2012. General observations from the freshet were that although the flow in the creek increased significantly it was not accompanied by a significant rise in the creek level. Rather, ice dams in the many rivulet channels and at the culverts crossing Highway 8 were melting rapidly at the same time as the creek flow volume was increasing, which led to the creek's braided channels altering course. The net effect was that the creek did not rise to the point that it impacted any location of known soil impairment at the Site.

The objective of the freshet site visit was to determine whether there was any interaction between the surface water and groundwater at the Site that could potentially cause environmental concerns to James Creek. Based on the site observations, it was recommended that, during the August 2012 investigations, water level and temperature transducers (also referred to as 'data loggers') could be synchronized and installed in selected groundwater monitoring wells and a 'stilling well'. It was recommended that a stilling well be installed in James Creek to permit water elevation measurements to be taken from the creek without interference from turbulent water flow (during warm periods) or ice cover (during cold periods).

As a consequence of the ground still being frozen in late May the groundwater flow into the monitoring wells was not sufficient to properly establish water levels and determine the hydraulic gradient.

Through observing freshet, the 'event' did not appear visually to have interaction with the Site.

4.2.2 Hydrogeological / Hydrological Field Investigations – August 2012

The hydrogeological / hydrogeological assessment was conducted by JFM Environmental Limited. A copy of their report is included as Appendix 2.

In conjunction with the borehole and LIF investigations, 53 boreholes were advanced on-site (Figure 3) and representative soil samples were obtained for analyses of soil (pH), Heavy Metals, PHCs (fractions F1 through F4, inclusive), and BTEX. Groundwater samples, obtained from existing and newly installed monitoring wells, were submitted for analyses of groundwater (pH), electrical conductivity, anion / cation scan, heavy metals; PHCs (fractions F1 through F4, inclusive) and Volatile Organic Compounds (VOcs), which include BTEX. The analytical results were compared to the regulatory criteria listed in Section 3.0 of this report.

4.2.2.1 Surface Water and Creek Sediment

Flow measurements were made at each of the three culverts that enable James Creek to cross the Dempster Highway. The estimated total discharge (i.e., creek volumetric flow rate) was 524 litres per second [approximately 2,000 m^3/hr], with a flow velocity of 116 cm/s [approximately 4.2 km/hr]. The creek flow is sufficiently vigorous to scour the creek bed and expose rocks and boulders. Nevertheless, there are eddies and backwaters in which sediments have accumulated. None of the creek sediment samples, both upstream and downstream of the Site, were contaminated with PHCs or VOCs (including BTEX compounds).

The pH of the creek sediment is considered to be 'acidic', with pH values of approximately 5.6.The samples were obtained both upstream and downstream of the Site. For comparison, the pH of the soil samples at the Site ranged from 3.95 to 6.95. The pH of the creek water samples was approximately 6.3, which was similar to the pH of groundwater at the Site (5.9<pH<6.8). The only parameter to exceed the applicable guideline criteria was the result for 'Total Nickel' at 81 ppm versus the CCME guideline of 50 ppm. According to the Geological Survey of Canada (2005), these results are normal for the region and the relatively high nickel results can be attributed to the effect of 'acid' leaching of nickel from the rocks contacting the surface water.

The flow rates of the magnitude measured for James Creek in August 2012 have the ability to 'flush' contaminants downstream if they migrate to the surface water by means of the groundwater. The flushing capacity of James Creek is much greater during the spring freshet. Regardless of the capacity of the creek to flush contaminants, no evidence was found in surface water samples of the presence of any chemicals of concern. Hydrocarbon contamination from the maintenance garage has not impacted James Creek.

A Stilling Well was installed in the creek bank at the creek's closest point to the operational area of the Site. Data loggers measuring and storing water level and temperature data at 30-minute intervals, were installed in the stilling well and seven (7) groundwater-monitoring wells. Each data logger was placed inside a latex bladder, filled with polypropylene glycol, to protect the data logger's sensitive pressure diaphragm from damage due to freezing. When the data loggers are recovered (in August of 2013) the data recorded will be downloaded to provide the necessary information to interpret the dynamic and direction of the connection between the surface water from the creek and the groundwater.

STN	Serial Number of Data Loggers	Static Water Level at Deployment (mbgs)	Water Temperature at Deployment (°C)
MW10-20	0112012304	2.27	4.4
MW10-24	0112012322	2.38	4.6
MW10-26	0112012330	2.26	3.7
MW10-28	0112012317	2.89	3.1
MW141	0112012327	2.92	8.5
MW142	0112012326	2.92	7.4
MW143	0112011592	2.88	6.5
Stilling Well (SW3)	0112011577	2.18	7.5
Barometric Recorder	0012012021	N/A	N/A
Barometric recorder deployed above the groundwater level in MW10-26.			
All of the data loggers and barometric recorder were programmed to commence at 4:00 PM on August 8, 2012. Measurements are recorded every 30 minutes. The data loggers must be removed before November 1, 2014 at which time the units will stop recording (the acquired data will be stored until it is downloaded).			

4.2.2.2 Groundwater

As a consequence of the far northern latitude and the elevation associated with the Site's location in the Richardson Mountains, the soil at the Site is frozen for much of the year. In the warmer months, groundwater forms as the frozen soil melts; the groundwater melt is 'perched' (i.e. "trapped") above the frost line (the top surface of the permafrost). Three new groundwater monitoring wells were established inside the maintenance garage in order to characterize the groundwater, soil, permafrost, and bedrock condition and potential impairment.

Water level measurements are typically taken over a period of months to determine a 'stabilized' groundwater surface. Data loggers were installed [see section 4.2.2.1] in 7 groundwater monitoring wells, to gather data over the course of a year and will be recovered in 2013. The data will be analyzed and compared to similar data from the stilling well at creek side to provide important information about the connection between the groundwater and surface water.

Field measurements show the groundwater to be located at a depth ranging between approximately 1.7 mbgs (MW5) and approximately 3.6 mbgs (MW10-34). The bailers in some of the monitoring wells were still bound in ice at the start of the investigation in late July. Groundwater measurements could be taken at all serviceable monitoring wells by the end of the investigatory trip on August 8th. Liquid groundwater is confined to a thin zone above the permafrost, which – with the exceptions noted in section 4.3 – is also located above the bedrock surface. The exception that is most relevant to this investigation is the area located under the garage floor slab, where the permafrost has melted and forms a bowl containing wet soil, free groundwater, and LNAPL.

Groundwater samples were analyzed for pH, PHCs (fractions F1 – F4), BTEX, VOCs, Heavy Metals, and General Chemistry [see the JFMEL hydrogeological assessment in Appendix 2 for the detailed results]. Several of the groundwater samples had pH values slightly lower than the applicable guidelines (5.84 – 6.45 compared to the guideline range of 6.5 – 8.5) but this appears to be typical of soil and water in the region and is not believed to be caused due to anthropogenic activity. Similar to the surface water and sediment analyses, every groundwater sample showed concentrations of certain elements greater than the applicable guidelines. These elevated concentrations appear to be ubiquitous in the region and a consequence of natural processes associated with the slightly acidic nature of the water in the region.

The groundwater flow (Figure 4) was interpreted to be in an east-southeast direction. The groundwater levels at the Site were measured to be at a slightly higher elevation than the creek water at the time of the investigation, so there remains the potential that it will contribute to the stream flow. The hydraulic conductivity of the soil and fill is low and groundwater remains bound in the permafrost and bedrock for most of the year (as was evident in early August). There was no evidence of hydrocarbon 'sheen' in the snow melt or at the creek's edge during the time of freshet.

The analysis of groundwater samples defines two areas ('plumes') of PHC-contaminated groundwater (Figure 5 and Figure 6). One area is below the garage slab and the other area is located on the (south) east side of the garage and extends from the area under the diesel storage AST in the general direction of the groundwater gradient.

The groundwater under the garage was the most heavily contaminated on-site, with BTEX and Chlorobenzene. Samples taken from the monitoring wells inside the garage yielded phase-separated (i.e., free-product) PHC and BTEX. Globules of thick, black, oily product were also observed. The contamination-saturated soil was estimated to cover an area of approximately 140 m^2; with a saturated thickness of approximately 1 m. Assuming a soil porosity factor of 0.35, the volume of contaminated groundwater under the garage is estimated to be approximately 50 m^3 (50,000 L).

The other plume was delineated to cover an area of approximately 390 m^2. The saturated thickness was determined to average approximately 1.5 m, for an estimate of the volume of contamination-saturated soil at approximately 585 m^3, or approximately 200,000 L of contaminated groundwater.

4.2.2.3 Soil and Fill

Soil and fill samples collected using both the split-spoon on the rotary auger and disposable plastic tube samplers with the Geoprobe drill rig were placed in clean re-sealable bags for taking headspace measurements of volatile vapour with a photo ionization detector (PID). In addition, selected samples were sent for laboratory chemical analysis.

Soil pH ranged from 3.95 to 6.95 pH units. The pH of all but three soil samples were below the applicable guidelines, which is consistent with pH measurements in all media at the Site and appears to be typical of the region.

The detailed results of all laboratory analyses are located within the JFMEL hydrogeological assessment report located in the Appendix. Although nearly every soil sample contained certain metal concentrations higher than the applicable guidelines, there is no human activity with which to associate the presence of trace elements to any anthropogenic source. It is our assessment that the analyses of soil, sediment, surface water, and groundwater indicate the relatively high trace metal presence and the relatively low pH to be normal background levels for the region.

The Site was constructed for use as a highway maintenance depot, using fill, consisting of dense-packed sand and gravel, overlying natural soil layers of silt, silty clay, and fluvial sediments. A thin layer of peat was observed within the soil samples taken at the Site. This layer of peat was noted to have elevated odour of volatile vapours, due to absorption from surface-derived water (i.e., snow melt or rainwater percolating through the unfrozen soil). The soil and fill were observed to be generally coarse-textured but very densely packed. Contaminants are expected to seep through the soil at rates dependent on the density of the packing. The conclusion from previous environment investigations done at the Site was that surface-derived water would tend to migrate by overland flow rather than percolate into the soil. This tendency was observed during this investigation; rainwater cut well-defined channels across the operational pad and access road. The location of the drainage paths was similar after each rain shower.

The LIF was used to build a digital interactive model of the contamination envelope at the Site (Section 4.1) that corroborated the observations from the core samples. The thickness of the contaminated soil under the garage averaged approximately 3.0 m (although the thickness varied across the cross-section of the 'bowl') and the thickness of the smaller contaminated soil plume averaged to approximately 2.3 m. The soil plume underlying the garage had an area of 1,592 m^2, giving an estimated volume of contaminated soil under the garage of approximately 4,800 m^3 (approximately 60 m X 27 m X 3 m thickness) (Figure 7 and Figure 8).

The smaller northerly plume had a footprint estimated to be approximately 270 m^2 and is estimated to have a volume of approximately 620 m^3 (approximately 25 m X 10 m X 2.3 m thickness).

4.3 Bedrock Mapping and Permafrost Assessment

The bedrock mapping and permafrost assessment was undertaken by Dr. Norbert Maerz, an expert in the field of rock mechanics. Dr. Maerz' full report is included as Appendix 2b.

The objective of this phase of the project was to identify, delineate and quantify bedrock conditions at the Site as related to on-site impairment. Further, the investigations were to determine whether PHCs had infiltrated the permafrost or impacted the bedrock. The bedrock was mapped and characterized to determine whether the bedrock structure provided a path for contaminant migration to James Creek.

4.3.1 Permafrost

The depth to the frost line (i.e., the permafrost surface) was established as the depth at which the *in situ* soil temperature was measured as being 0°C or less. Permafrost occurs at an average depth of 2.7 m below ground surface (mbgs) and across most of the Site the permafrost occurs at an elevation above the bedrock. The cliff face south of the maintenance garage is exposed and weathered bedrock. It plunges below the ground surface and the permafrost layer close to the base of the cliff (Figure 11).

The permafrost layer under the garage is thinner than elsewhere on the Site. Beneath the garage floor pad, the frost line is at a lower depth (beyond 4 mbgs). The permafrost surface may reach the bedrock surface in a limited area under the garage pad. The effect has resulted in the creation of a 'bowl'-like structure in the permafrost surface under the garage. This bowl was found to contain wet unfrozen soil, a liquid groundwater pool, and free-phase PHC contaminants. It was also found to contain hydrocarbon contaminants that are not derived from diesel fuel, which is evidence that the ground impairment is not exclusively due to the known diesel fuel spills. The light non-aqueous phase liquids (LNAPL) found under the garage make this the area of greatest concern on the Site, both in terms of urgency and potential future liability.

Towards the perimeter of the garage pad the permafrost surface rises to the depth typical of the rest of the Site. The permafrost was found to be essentially impenetrable. Only a miniscule amount of contaminant was found within any permafrost samples. This contamination is interpreted to be present due to freeze-thaw cycles over the years, during which the upper permafrost surface is more of a thin zone than a distinct bright line. The permafrost appears to be an effective barrier to groundwater and contaminant migration.

4.3.2 Bedrock

The south west border of the property is defined by a near vertical rock cut, forming a prominent wall-like feature. The bedrock outcrop consists of weathered soft shale inter-bedded with hard siliceous shale. This outcropping continues underground at a shallower dip below the overlying soil permafrost of the operational pad, in a northeast direction and the bedrock surface is interpreted as having an elevation difference of approximately 10 m across the Site (in a southwest-to-northeast direction) (Figure 12).

The bedding was interpreted to have a south-westerly strike ('the direction of the line formed by intersection of the bedding plane of the stratum of sedimentary rock with a horizontal plane') at approximately 215° and a dip ('the downward inclination of a stratum with reference to a horizontal plane') in the northwest direction of approximately 60°. The contamination does not extend down to the bedrock under the garage.

The bedrock is comprised of two types of shale, both of which have low matrix permeability. One of the types of shale has within it a well-established network of discontinuities, which have low hydraulic conductivity and are not oriented in directions that match the hydraulic gradient or potential pathways to James Creek. There is a small potential for down gradient flow through these tortuous flow paths, but the hydraulic conductivity is sufficiently low that the potential for groundwater and contaminant migration through the bedrock is very small.

5.0 TREATABILITY STUDY

The treatability study was completed by Mr. Dennis Owens Senior Microbiologist / Chemist of OxyTek. Appendix 4 contains the full Treatability Study.

The purpose of the treatability study was to:

- Determine if the hydrocarbon impacted soils on-site were suitable for treatment using chemical oxidation;
- Study the on-site soil and groundwater conditions and based on the findings, formulate a site specific chemical oxidant using Modified Fenton's Chemistry; and,
- Determine if there would be organic tailing effects on the overburden soils collected from the Site.

The treatability study was carried out with composite samples of contaminated soils collected from fifteen locations collected during the field investigations. A site specific formulated stabilized hydrogen peroxide (Modified Fenton's Chemistry) was applied to soils contaminated with diesel fuel and gasoline from the Site.

The results of the treatability study confirmed:

- F2 (C10-C16) diesel contaminated soil contained as average concentrations of 400 ppm which exceeds the residential/parkland levels of 150 ppm. The chemical oxidation treatment decreased the F2 fraction by an average of 93%, from 400 ppm to 28 ppm.

- The F3 fraction (oils and lubricants) was already below residential / parkland levels, but oxidative chemistry treatment decreased the F3 fraction by an average of 50%, from concentrations of 140 ppm to 70 ppm. .

- Elevated concentrations of the BTEX and F1 fractions exist on-site (JFMEL report, Section 7.1). The soil samples collected for the treatability study were shipped to the OxyTek laboratory however during shipment, the elevated BTEX and F1 concentrations dissipated. Research conducted as part of the treatability study confirmed that reduction of the BTEX and F1 fractions will occur by chemical oxidation. (The priority of this study was to determine the organic influence on the F2 fractions rather than studying the BTEX and F1 fractions).

- There was no or very limited organic tailing effect at this Site.

- The site conditions are amenable to chemical oxidation. The native soils on-site are acidic, are coarse grained and have naturally occurring high levels of metals (zinc, iron, etc.) at levels which will promote the chemical oxidation process.

Chemical oxidation is a viable remediation method at the James Creek Site because the site conditions favour the use of Modified Fenton's Chemistry.

6.0 DISCUSSIONS AND CONCLUSIONS

6.1 Impact on James Creek

Observations made during the freshet (May 2012) concluded that the high water level in the creek associated with the spring snow melt is not sufficient to impact any area of known contamination at the Site. In the second phase of investigation (August 2012), state-of-the-art data loggers were installed in a new stilling well and in seven monitoring wells. The information that is to be retrieved from these data loggers combined with water level readings during the next phase of remedial activity at the Site (later in 2013) will be critical to a measurement-based interpretation of whether the potential for groundwater migration down the hydraulic gradient actually concludes with a connection to the surface water in the creek.

Samples of surface water and sediment taken from the creek showed no indication that PHC contamination had impacted the water way. Although the creek water and sediment had pH values slightly lower than standard guidelines, we conclude that the low ('acid') pH is a natural phenomenon for this region and is not due to anthropogenic activity. Trace metal content in sediment and soil at the Site can be interpreted as due to natural leaching processes associated with 'acidic' surface water contact with mineral-bearing soil in the James Creek catchment. Although certain metal elements, particularly nickel, are at levels higher than the standard guidelines, this is a natural phenomenon and no remedial action is required.

6.2 Contamination Migration Pathways

Surface–derived water tends to drain by overland routes, but some portion seeps into the soil to a depth defined by the permafrost surface.

The hydraulic conductivity of the soil is low in the operational area of the Site. Migration of groundwater through the soil will be more rapid if contaminants reach the less densely packed and coarse-textured sand and gravel associated with the flood plain and the creek bank area.

The permafrost and bedrock at the Site are essentially impenetrable. In addition, the bedrock was interpreted to have a fracture pattern that is not oriented in a direction that promotes easy interaction and groundwater migration in the direction of the creek. The bedrock has low hydraulic conductivity. It was also determined to be below the permafrost, with the exception of where it juts above the ground surface to form the cliff face and, possibly, where the frost is at a lower elevation under the garage. In addition, beyond the low hydraulic conductivity of the bedrock, the sub-surface bedrock is permanently frozen at the Site and groundwater is immobile within the bedrock.

6.3 Delineation of PHC Contaminants in Soil

Soils within the operational area of the Site are contaminated with PHCs (F1 to F3 fractions). Two separate plumes of PHC impairment exist which require remediation:

- Below the garage building extending south: The soil plume underlying the garage had an area of 1,592 m^2, giving an estimated volume of contaminated soil under the garage of approximately 4,800 m^3 (approximately 60 m X 27 m X 3 m thickness)).
- Northern plume area: The northern plume has a footprint estimated to be approximately 270 m^2 and is estimated to have a volume of approximately 620 m^3 (approximately 25 m X 10 m X 2.3 m thickness)).

Some soil samples that were taken beneath the frost line were reported to be contaminated with either PHCs or BTEX (JFMEL Report – Section 7.1). Although no historical data exists for this site, the fact that contamination exists below the frost line indicates that the frost line historically occurred at a lower elevation. This would have provided an opportunity for the contaminant to penetrate deeper, later to be frozen in place when the frost line did not extend to the same depth.

6.4 Land Treatment Farms

Two land treatment units were previously constructed at the Site and both units are lined and bermed. LTU#1 contains soil that was excavated over ten years ago. LTU#2 contains soil that was excavated in early 2009 as a consequence of the diesel fuel spill that occurred in December 2008.

The temperature and relatively short warm summer season at the latitude of the Site are not conducive to the efficient bioremedial processes typical of southern locations and climates. Test pits were dug in both LTUs during this assessment to obtain soil samples and analytical results show contamination exceeding applicable guidelines at the base of the LTU. An additional 820 m^3 of impacted soil are present in the LTUs.

6.5 Hydrocarbon Impacted Groundwater

Based on the findings of the OxyTek Final Remediation Pre-Treatment Assessment, the groundwater plume below the footprint of the garage was estimated to have an area of approximately 140 m^2 (situated beneath the garage building (approximately 15 m X 18 m)). Its average saturated thickness is approximately 1 m, suggesting that approximately 140 m^3 (or 50,000 L) of contaminated groundwater is located beneath the garage (based on assumed porosity of 0.35).

Comparatively, the contaminated groundwater plume located southeast of the garage has an approximate area of 390 square metres (approximately 18 m X 25 m). Its average saturated thickness is approximately 1.5 m, suggesting that approximately 200 cubic metres (or 200,000 L) of contaminated groundwater that extends in a northeasterly direction from the garage.

7.0 CLOSING

This report has been prepared for the exclusive use of the Department of Transportation (DOT) of the Government of the Northwest Territories (GNWT), in evaluating the environmental condition of the soil, surface water and groundwater regimes at the Site at the time of OxyTek's site assessment. OxyTek is not responsible for the use of this report by any other third party, or reliance on or any decision to be made based on it without the prior written consent of OxyTek. OxyTek is not responsible for any damages, by any third party as a result of decisions or actions based on this report.

This report presents an overview of issues of environmental concerns and issues that were applicable at the time the fieldwork was undertaken and reflect OxyTek's best judgment. This report has been prepared by OxyTek using information understood to be factual and correct and OxyTek shall not be responsible for conditions arising from information or facts that were concealed or not fully disclosed to OxyTek during the period of time for which the work was conducted.

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