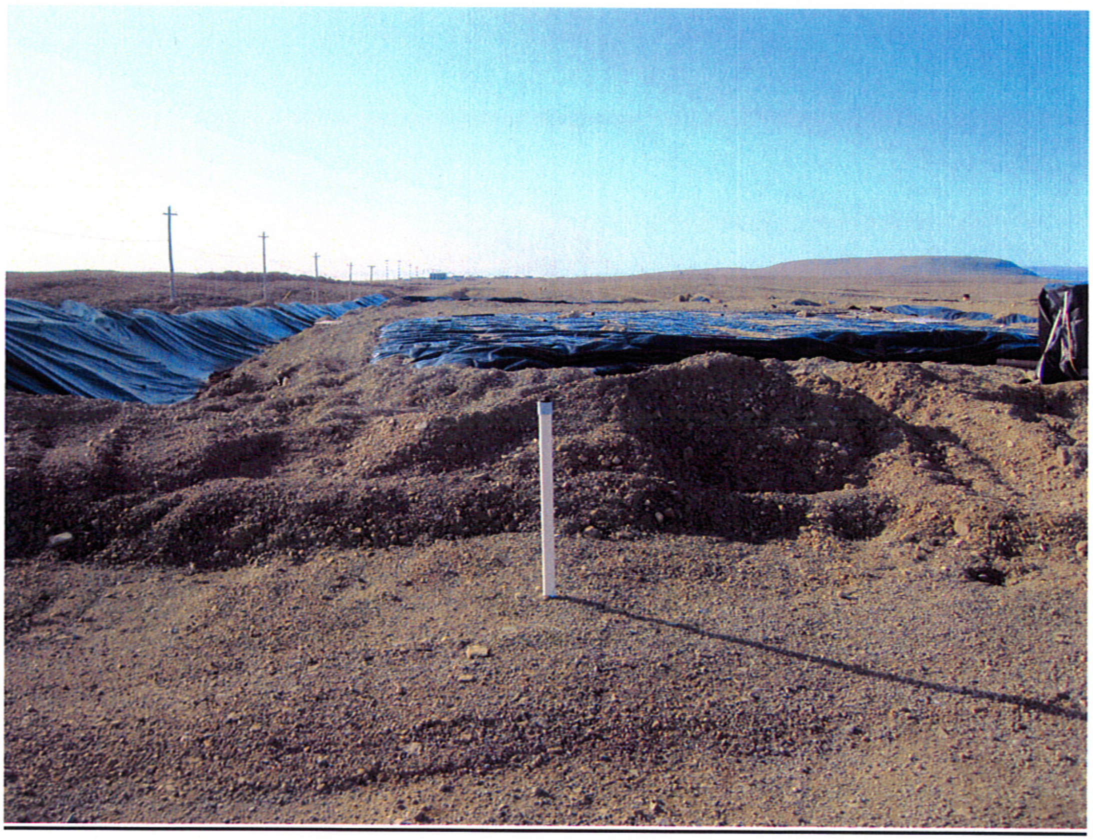
Resolute Bay, Nunavut Land Farm Operation and Maintenance Plan

Prepared by
Transport Canada

January 2012



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Introduction

Transport Canada (TC) is applying for a water license from the Nunavut Water Board to operate 2 Land Farms constructed in 2001 in order to treat petroleum hydrocarbon (PHC) contaminated soil at the Resolute Bay airport. The 2 Land Farms were constructed prior to NIRM and NWB requirements. The ongoing operation, maintenance and decommissioning of the facility will be considered in the O& plan. The plan will outline the types of material accepted at the facility, the procedures to be utilized in the treatment and storage of the PHC impacted soil, the criteria to be attained prior to soil being deemed remediated, and the ultimate deposition of any treated soil.

History

Prior to July 1, 1995 Resolute Bay Airport was owned by the Government of Canada and operated by the Quebec Region of the Department of Transport. From July 1, 1995 until April 1, 1999 the airport was owned by the Government of Northwest Territories and operated by the Arctic Airports Division of the Department of Transportation. Since April 1, 1999 the airport has been owned by the Government of Nunavut and operated by the Nunavut Airports Division of the Nunavut Department of Community Government, Housing and Transportation.

As a condition of the Arctic A Airport transfer agreement (July 1995) between GNWT and Transport Canada, the environmental issues, which existed prior to the airport transfer, are to be remediated as well as any items identified by the GN within six years of the transfer date. Works identified under this document address some of the issues identified in the transfer agreement as well as post transfer issues. For the purposes of this O&M Plan, PHC contaminated soil will be the only contaminated soil considered and the placement of this material in the Land Farm. Types of PHC contaminated soils encountered for disposal in the Land Farm are gasoline, diesel, and jet fuel (A,B) which are the main sources of fuel spills and leaks over the past 60 years at this location. The depth of contaminated soil in the Land Farm will not be greater then 1m and will be constructed based on the parameters outlined in the water licence application (also see attached engineered drawing).

Resolute Bay is located in the Northern Arctic Ecozone. Much of the Northern Arctic Ecozone consists of low rolling plains covered with soil and rock debris left by glaciers. In these areas, the landscape may be covered by nothing more than frost-patterned soils, frost-shattered limestone, and sandstone for hundreds of square kilometers, as in Resolute Bay.

Broad plateaus are common in the interior area. They often show deep V-shaped cuts along their shoulders where past or present streamflows have cut through their sedimentary layers.

Permafrost lies beneath the entire ecozone. Under a thin active layer, which freezes in winter and thaws each summer, permafrost may extend almost 1 km downwards.

Summers are short and cold, with mean daily temperatures above freezing only in July and August. Daily winter temperatures average less than -30°C. Snow cover usually lasts from September to June, but it can fall during any month. Annual ecozone precipitation is less than 250 mm except in southeast Baffin and Labrador where it can exceed 500 mm. While the northern islands have the least precipitation of the arctic ecozones, moisture is plentiful -- in lakes and rivers, in muskegs and permafrost, in the snow cover, in the permanent ice, and in the Arctic Ocean.

Transport Canada is obligated to remediate all hazardous substances that are the department's responsibility that do not comply with the applicable environmental laws.

The Resolute Bay airport is approximately 5 km northeast from the Inuit hamlet Resolute on Cornwallis Island in Nunavut, Canada. The airport was originally constructed in 1949 by the Royal Canadian Air Force. From 1964 to July 1, 1995, Resolute Bay Airport was owned by the Government of Canada and operated by Transport Canada.
In 2001/02 remedial works at the Fire Training Area (FTA) commenced. Work included removal and disposal of aircraft mock up consisting of several large steel tanks, removal and disposal of 20,000L above ground storage tank and associated piping, removal and disposal of the existing pump house and pump as well as a number of unlabeled 205L drums. Once this stage was completed, two Land Farms were constructed to contain approximately 5800m^3 of petroleum hydrocarbon contaminated soil. The soil was then removed and placed into the two Land Farms for subsequent treatment. On-going maintenance to the land farms is required to complete the remediation of the contaminated soil. This consists of turning the soil to increase aeration, reduce compaction and the addition of nutrients to further increase the rate of remediation. Once this is completed, soil and water samples are submitted for analysis to ascertain if the soils have reached the target levels. Once these levels have been achieved, the facility can be decommissioned and closed. This process of maintenance may take several years to complete due to the short summer season, amounts of rain and snow, the levels and type of contamination. Maintenance was completed in 2002/03 and 2003/04.

The process of decommissioning the facility includes soil and water testing to ensure the material has reached the required target levels. Once this is confirmed, the soil will be removed and stockpiled adjacent to the excavation, the liner will be removed and disposed of in the local landfill. The excavated area will be back filled with the remediated soil and graded to match the surrounding topography.

Operation and Maintenance Program

Sampling Program

The first objective is to conduct a comprehensive soil sampling program at the beginning of each field season to identify the levels of PHC contamination in the soil. Due to the long winter season at this location, TC anticipates initially sampling the LTU in the beginning of June depending on weather conditions. The soil criteria used for this site will be under the CCME Canada Wide Standards for Petroleum Hydrocarbon Contaminated Soils Tier 1, coarse grain soil, Industrial site. This criteria is used due to the location of the facility on airport land. Access to the site requires airport clearance. The location will not be used for commercial development due to the location adjacent to the runway.

1a) The sampling program will require eight (8) composite soil samples and a sample from each monitoring well from the Land Farm for submission to a laboratory for analysis. The sampling protocol for the Land Farm will require a random grid pattern covering the entire area. All sampling procedures will be in accordance with the standards contained in the CCME Guidance Manual on Sampling, Analysis and Data Management for Contaminated Sites Volume I &II. Quality assurance/quality control will be observed while conducting the sampling program and include at a minimum the following:

- Use of trip, field and equipment blanks;
- Use of duplicate and spiked samples;
- Proper sample containment, preservation, chain of custody; and
- Due regard for necessary health and safety precautions.

1b) All samples should be analyzed for the following parameters:

- BTEX;
- Total Extractable Hydrocarbons (TEH);
- CCME Canada Wide Standards for Petroleum Hydrocarbons in Soil for Fractions #1 to #4 for the Tier 1 criteria, coarse grain soil for Industrial Sites.
- Polycyclic Aromatic Hydrocarbons (PAH);
- Total Heavy Metals (Al, As, Cd, Co, Cu, Fe, Pb, Mo, Ni, Se, Ag, T1, Zn).

Summary of Tier 1 Levels (mg/kg) for surface soil CCME.*

Land Use	Soil Texture	F 1	F 2	F 3	F 4
Agriculture	Coarse grain soil Fine grain soil	30b 210 (170a)	150 150	300 1300	2800 5600
Residential/Parkland	Coarse grain soil Fine grain soil	30b 210(170a)	150 150	300 1300	2800 5600
Commercial	Coarse grain soil Fine grain soil	320(240a) 320(170a)	260 260(230a)	1700 2500	3300 6600
Industrial	Coarse grain soil Fine grain soil	320 (240a) 320 (170a)	260 260 (230a)	1700 2500	3300 6600

* Additional Tier 1 levels are presented in Technical Supplement.
a= Where applicable, for protection of potable groundwater.
b= assumes contamination near residence

2a) The use of a gas Photo Ionization Detector (PID) or similar equipment to monitor hydrocarbon vapours will be required to field screen the soil sample taken. The use of field screening the soil will provide an immediate representation of the conditions and levels of the PHC in the soil. This process does not replace laboratory results, however it does give a good sense of the conditions.

The results of the laboratory analysis are to be compared to the Nunavut Environmental Guidelines for Site Remediation (most current edition), CCME Canada Wide Standards Petroleum Hydrocarbon Guidelines (most current edition) and the CCME Interim Canadian Environmental Quality Criteria for Contaminated Sites (most current edition) remediation criteria for industrial zoned sites. The selected laboratory must provide quality assurance (QA) and quality control (QC) procedures. All samples are to be procured through approved methods and procedures and are to be submitted to a Certified Laboratory (CAEAL/ Standards Council of Canada) for formal analysis.

Maintenance Activities

In addition, Transport Canada will complete the following activities to address the Operation of Maintenance of the facility on an annual bases:

- TC inspects the Land Farm annually for operation and maintenance purposes;
- Address snow in the Land Farm. Typically due to the low levels of precipitation at this location this is not a concern;
- Address dust issues. Dust is typically not a issue due to the low traffic and remote location of the Land Farm;
- Restricted access to the site;

- All soil placed in the LTU is characterized by sampling and analyzed at an accredited lab;
- Provided operations and procedures for O&M., tilling/amendment practices
- TC requires a health and safety plan on site while contractors are working at the location.

1) The soil criteria used under the CCME Guidelines for Industrial Site is appropriate for this location. The soil is located in a restricted developed infield area of the Resolute Bay airport between the runway and Apron I. The soil is not intended to leave the site making the location logistically unreasonable to use this material as fill at a future date.

2) TC and the Resolute Bay Airport maintain records that are required to be submitted to the NIRB, this is comprise of:

- Description of the size and location of the LTU;
- Quantitative and qualitative data on the soil treated at the site;
- Monitoring data;
- Final destination of the treated soil and its intended use.

3) Mandatory requirements under the *Fisheries Act.* TC meets the requirements set forth.
4) CEPA Spill Prevention, no storage of PHC on site. Emergency line – 24-hour Spill (867) 920-8130.
5) No storage of PHC on site and no re-fueling on site. Spill containment is required for refuelling practices.
6) Spill response equipment is on site at all times and is mandatory for contractors to have a spill response plan.
7) CEPA – Hazardous Waste: all hazardous waste will be addressed if encountered. It is not anticipated hazardous waste will be encountered at this location.
8) No hazardous waste on site.
9) Wildlife – no contaminated soil is deposited in a way or area such that it is harmful to migratory birds or waters frequented by migratory birds.

- The facility has monitoring wells to identify if there is any contamination leaking from the facility. The wells are tested once per year at a minimum. If fuel is identified in a well the following steps will be implemented:
- Sample the well and identify the contamination from a certified lab
- Identify the location where the potential contamination is originating
- The likely location will be from the LTU, therefore, limit the search to the area nearest to the monitoring well
- Sample soil outside the facility to identify the direction of the source of contamination
- Inspect the liner for any rips and tears
- Remove the contaminate soil from the LTU up gradient from the well. The soil can be placed further back in the LTU or if required place in the adjacent LTU. Inspect the liner for any rips and tears. Continue until the source can be

identified. In the event of a tear in the liner, a proper weld/patch will be completed according to the manufacture specifications.

- If contaminated soil is identified outside the facility, remove and place into the LTU and backfill the excavation with clean fill material.
- Continue to sample monitoring wells 2-3 times per year to ensure the source of contamination has been eliminated

If the sump area is full of water and is required to be removed due to a wet season, the following steps are in place:

- Test the water to ensure the water may be discharged as per the requirements in the water license issued by NWB
- If the water does not meet the required discharge levels the water will need to be treated with in a oil water separator. The system will operate to treat the water prior to discharge. The water will be treated then sampled and sent to a certified lab to ensure it meets the discharge requirements under the water license. Only if it meets this requirement may it be discharged.

If a oil water separator is not sufficient to treat the water, the water will be pumped into 205L drums and sent to a certified facility to treat the contaminated water.

Once the laboratory and field screening results are obtained, TC can proceed with several options. The landfarm will require nutrient amendments and tilling if it does not meet the previous mentioned criteria. This process will immediately proceed the sampling program each June when the soil is able to be worked. The following procedures will be followed:

Nutrient Amendments and Tilling

Biodegradation requires micro-organisms are meeting nutritional requirements. The optimal range of carbon:nitrogen:phosphorus (C:N:P) is 100:10:1 to 100:1:0.5. Soil amendments in the form of commercially used solid fertilizers will be applied in sufficient amounts as recommended by the manufacturer to achieve this target ratio for the specified volume of soil in the LTU.

Once the nutrients have been added to the LTU the soil will be turned over with the use of a backhoe. This will expose the soil to oxygen and for micro-organisms as well as distributes nutrients and moisture in the soil, thereby aiding in biodegradation. Care must be taken by the backhoe operator not to tear the liner and report any cracks, blisters or punctures to the liner.

Leachate Management

The Land Farm is constructed with a 1% slope which allows any leachate to collect in the sump area. Visual monitoring of the sump ensures that water is collecting in the sump area indicates the liner is not damaged. Leachate may be recirculated over the Land Farm soil surface as a means of irrigation to maintain optimal biodegradation rates. Discharge of the leachate may be required if the sump collection area rises to within 1 foot of the top of the berm. This is not likely to happen due to the height of the engineered berms taking into consideration the amount of precipitation and evaporation rates at this location. If the leachate is required to be discharged it must first meet the discharge levels within CCME EQGs and the Water License requirements for Land Farm wastewater discharge criteria:

Parameter	Maximum Allowable Concentration (ug/l)
Oil & Grease	5000
Lead	1
Benzyene	370
Toluene	2
Ethylbenzene	90

The area designated for leachate disposal is located adjacent to the Land Farm in the open area east of the facility. This area is located greater than 1.4 km away from any water body and potable water source.

The Land Farm will continue to be monitored each field season to ensure the facility is operating as it has been designed. Additional soil sampling will be conducted in the fall of each year to determine the effectiveness of the previous amendments in the spring. A soil sampling program will be conducted in August or September as described earlier including monitoring wells. The following outlines when the samples and activities will be conducted:

Activity	Time of Year	Time of Year
Soil Sample	June	August - September
Monitoring Well Sample	June	August - September
Tilling/Fertilizer	June	If Required Aug - Sept

Monitoring Well Sampling

TC will undertake sampling the monitoring wells and the sump inside the LTU as described in the Water License No. 1BR-LTU0608. The frequency and time of year are outlined in the above table. The sump will be tested prior to any required discharge and tested prior to the decommissioning of the facility. The parameters for testing the monitoring wells are as follows:

Station	Location	Parameter	Frequency
LTU -1	Sump	PTH, BTEX, HM,PAH	Discharge
LTU – MW1	Upgradient - LTU	PTH, BTEX, HM,PAH	Twice/year
LTU – MW2	Downgradient - LTU	PTH, BTEX, HM,PAH	Twice/year
LTU – MW3	Downgradient - LTU	PTH, BTEX, HM,PAH	Twice/year

B) Remediation Targets and LTU Closure

As mentioned earlier, TC is required to meet the required PHC criteria under the Nunavut Environmental Guidelines for Site (most current edition), CCME Petroleum Hydrocarbon Guidelines (most current edition) and the CCME Interim Canadian Environmental Quality Criteria for Contaminated Sites (most current edition) remediation criteria for coarse grain soil, industrial zoned sites. Once the Land Farm has been sampled and shows PHC levels are below the required criteria, the facility will be decommissioned and restored back to its original state.

The decommissioning will be done by removing the treated soil from the liner and removing the liner from the Land Farm. Using a gas Photo Ionization Detector (PID) or similar equipment to monitor hydrocarbon vapours, random samples of the material below the liner will be tested to ascertain if any contamination leached beneath the liner. In addition to the portable hydrocarbon vapour testing, 10 soil samples will be taken from under the liner area and sent to a certified laboratory for analysis of the same parameters as listed earlier. The liner itself will be taken to an approved landfill site for proper disposal. If contaminated soil is found below the Land Farm, this material will be removed and placed in an adjacent Land Farm TC is operating on site (please see attached drawing).

The treated soil will be used to backfill the LTU excavation and compacting, if necessary, to match the surrounding soil conditions. All monitoring wells will remain in place for future sampling until it is determined no contamination exists (approximately one year). Once this is completed the monitoring wells will be removed and sealed with bentonite using accepted standards under the Environmental Protection Agency (EPA).

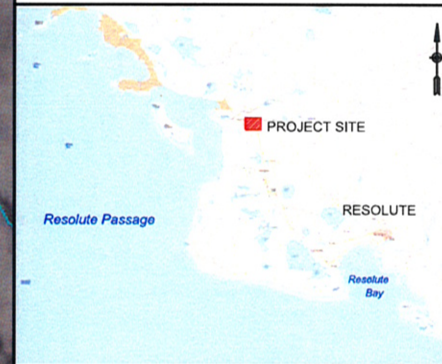
Finally, once the Land Farm area has been replaced with the treated soil, the soil and berms shall be leveled and compacted to match the surrounding conditions. More details are provided in the Stand Alone Abandonment/Restoration Plan completed with this application.

Appendix I

1 Contour Site Map
2 Engineered Drawing of LTU
3 Final Report of Activities (WERI/ENG-TECH) Resolute Bay FTA Remedial Works.

Transport Canada Programs Group | Transports Canada Groupe des programmes | Canada

PROFESSIONAL & TECHNICAL SERVICES
Prairie and Northern Region



KEY MAP (Not To Scale)
NTDB 1:50,000 Map Sheet 58F11, 58F12, 58F14, 58F15

SITE LOCATION (Not To Scale)
Project Site Geographic Location: 74 44' 33.22" N 95 0' 12.27" W
NTDB 1:50,000 Map Sheet 58F11, 58F12

Contour Interval: 10 m

Date	Revision	By

Scale 1: 10,000 — 0, 100, 200, 300, 400 m

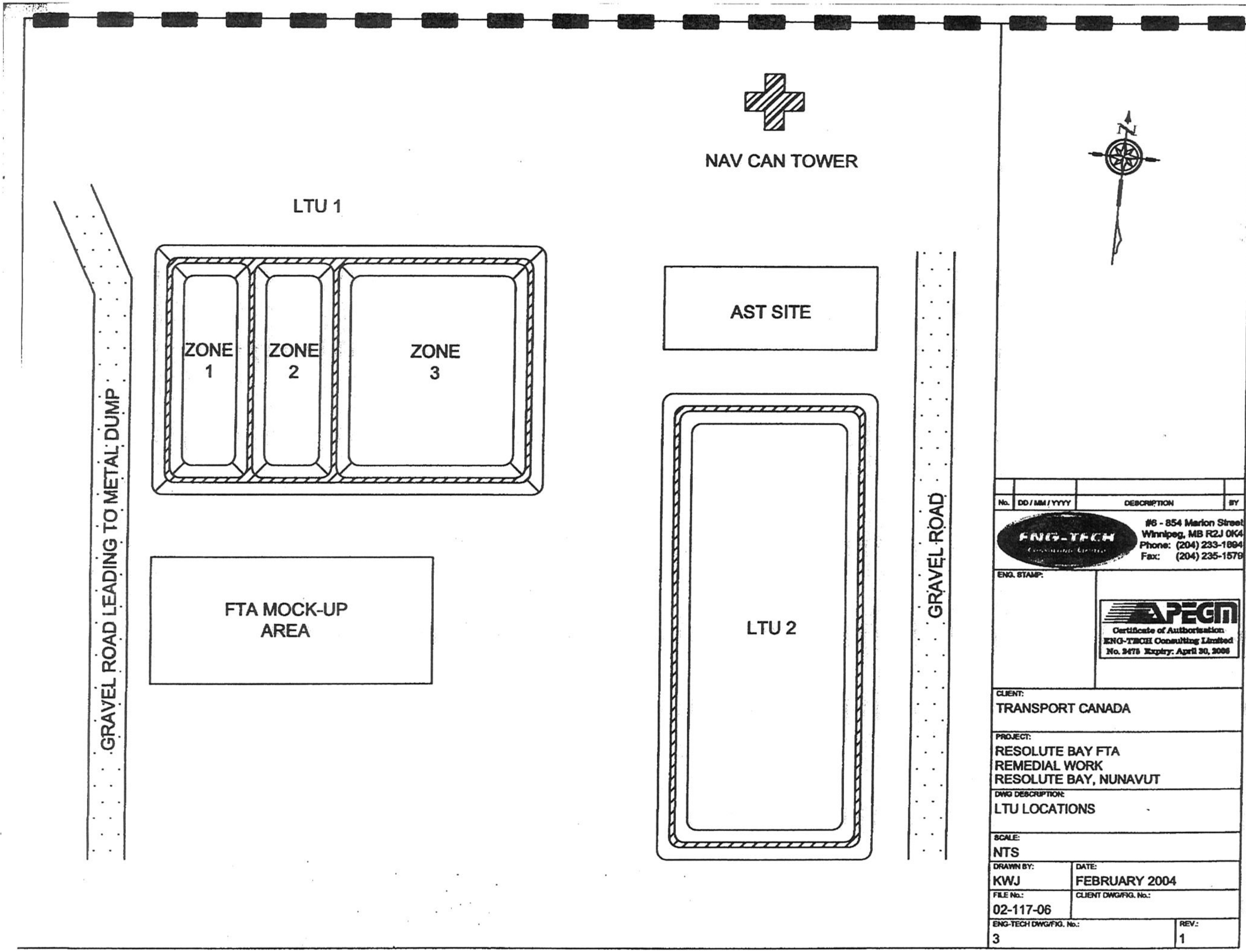
Site: RESOLUTE BAY AIRPORT, NU

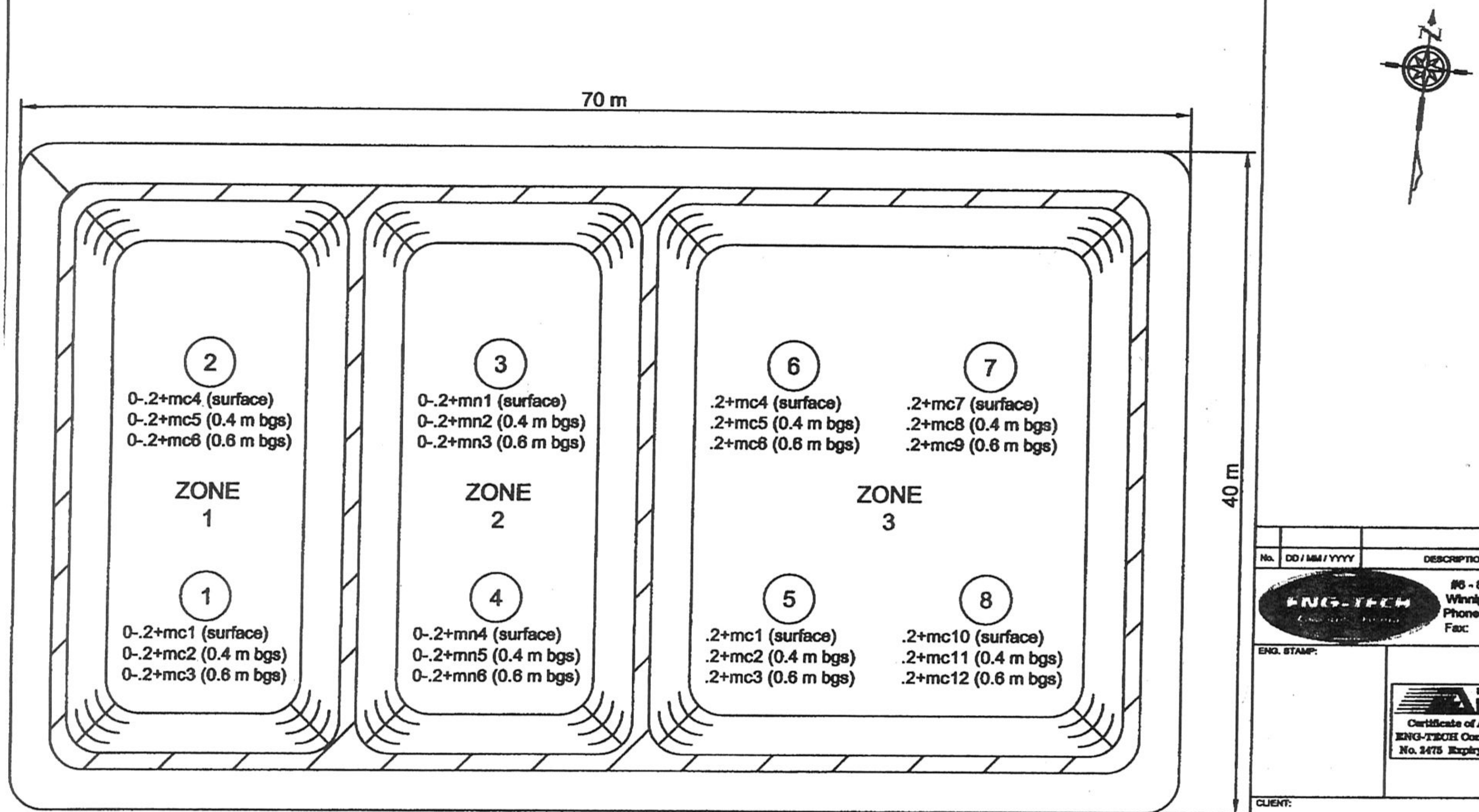
Title: LAND FARM SITE
SITE PLAN

Date: March 23, 2011

OFFICE OF REGIONAL MANAGER, PROFESSIONAL AND TECHNICAL SERVICES

Drawn By	Checked By	Project No.	Sheet
L.C.			1 of 1


NAV CAN TOWER
N
LTU 1
ZONE 1
ZONE 2
ZONE 3
AST SITE
LTU 2
FTA MOCK-UP AREA
GRAVEL ROAD
GRAVEL ROAD LEADING TO METAL DUMP
No.
DD / MM / YYYY
DESCRIPTION
BY
ENG-TECH
#6 - 854 Marion Street
Winnipeg, MB R2J 0K4
Phone: (204) 233-1694
Fax: (204) 235-1579
ENG. STAMP:
APEGM
Certificate of Authorization
ENG-TECH Consulting Limited
No. 2475 Expiry: April 30, 2006
CLIENT:
TRANSPORT CANADA
PROJECT:
RESOLUTE BAY FTA
REMEDIAL WORK
RESOLUTE BAY, NUNAVUT
DWG DESCRIPTION:
LTU LOCATIONS
SCALE:
NTS
DRAWN BY:
KWJ
DATE:
FEBRUARY 2004
FILE No.:
02-117-06
CLIENT DWG/FIG. No.:
ENG-TECH DWG/FIG. No.:
3
REV.:
1



NOTES:

(1) Sample Location

bgs = Below ground surface

0-.2+mc1 (surface) = Sample identification (depth of sample)

No.	DD / MM / YYYY	DESCRIPTION	BY

ENG-TECH
#6 - 854 Marion Street
Winnipeg, MB R2J 0K4
Phone: (204) 233-1694
Fax: (204) 235-1579

ENG. STAMP:

APEGM
Certificate of Authorization
ENG-TECH Consulting Limited
No. 2475 Expiry: April 30, 2006

CLIENT:
TRANSPORT CANADA

PROJECT:
RESOLUTE BAY FTA
REMEDIAL WORK
RESOLUTE BAY, NUNAVUT

DWG DESCRIPTION:
LTU 1 SAMPLING LOCATIONS

SCALE:
NTS

DRAWN BY:	DATE:
KWJ	FEBRUARY 2004
FILE No.: 02-117-06	CLIENT DWG/FIG. No.:
ENG-TECH DWG/FIG. No.: 4	REV.: 1

TRANSPORT CANADA

FINAL REPORT
Resolute Bay FTA Remedial Work
Resolute Bay, Nunavut, Canada

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1.0 INTRODUCTION

1.1 Terms of Reference

Winnipeg Environmental Remediations Inc. (WERI) and ENG-TECH Consulting Limited (ENG-TECH) were retained by Transport Canada (TC) to conduct a soil sampling program that utilizes bioremediation as a means to degrade petroleum hydrocarbons from contaminated soils, placed in two (2) land treatment units (LTUs). A separate undertaking included installing ground heating system into one of the LTUs in order to enhance petroleum hydrocarbons degredation by providing an optimum temperature for microbial growth. This report details the activities conducted to date.

1.2 Background

In August of 2002, WERI conducted demolition and remedial activities at the former Fire Training Area (FTA) in an attempt to bring the Resolute Bay Airport in compliance with current Canadian environmental legislation. The work included 1) excavation of petroleum hydrocarbon contaminated soil from a fire training mock-up area; 2) excavation of contaminated soil from a former above ground storage tank (AST) site; and 3) the construction of two (2) LTUs. The LTUs were excavated to permafrost 1-1.5 m below grade, and lined with 20 mil Oil-Resistant Reinforced Polyethylene (OR RPE) liner supplied by TC. LTU 1 had outside dimensions of 70 m x 40 m and was divided into 3 zones separated by berms. Zone 1 and Zone 2 contained heavier hydrocarbons while Zone 3 contained lighter hydrocarbons. LTU 2 was not subdivided and contained lighter hydrocarbons.

Approximately 5500 m^3 of petroleum impacted soil was excavated from the fire training mock-up area encompassing an area approximately 95 m x 65 m, with an average depth of 0.9 m below grade. Approximately 300 m^3 of contaminated soil was excavated from the AST site, approximately 20 m x 20 m in area with an average depth of 0.75 m below grade. Field screening for organic vapours using a photo ionization detector (PID), in conjunction with confirmatory soil sampling, was conducted at both excavation locations to ascertain that all contaminated soil was excavated.

Bioremediation was employed in the LTUs in an effort to reduce the hydrocarbon concentrations. Bioremediation or biodegradation is a process of degradation by biological means, where organisms (most often bacteria, but also fungi and plants) oxidize organic compounds (substrate), during respiration processes, both aerobic (oxygen present) and anaerobic (oxygen absent), to produce carbon dioxide, water and biomass. Other bacteria are known to break down organic material via reductive processes (opposed to oxidative processes). Any form of organic substance may be susceptible to biodegradation, which includes hydrocarbons. A detailed review of remediation and remediation technologies is included in Appendix A.

1.3 Objectives

The following project consisted of two principle objectives. The first objective was to conduct confirmatory soil sampling programs in order to assess changes to petroleum hydrocarbon concentrations, from petroleum contaminated soils (PCS) using an LTU system.
The second objective was to install a ground heating system in one of the LTUs to determine its effectiveness towards enhancing bioremediation. The efficacy of this system could be beneficial for northern communities that want to eliminate hydrocarbon contaminated soils, cost effectively.

1.4 Scope of Work

The scope of work for the project consisted of:

- An initial soil sampling and testing program, for petroleum hydrocarbon and micro-organism concentrations, followed by the applying nutrients and surfactants to Zone 1 in LTU 1, nutrients alone to LTU 2, and no nutrients to zone 2 and 3. After applying nutrients, the surfaces were to be blended and graded using a D4 blade.

- Conducted a second soil sampling and testing program of the remediating soils in the LTUs the following year. Samples were taken from the same locations and depths as previously sampled during the first year. Nutrients were added to Zone 1 and 2 of LTU 1, to LTU 2, and no nutrients to zone 3. After applying nutrients, the surfaces were to be blended and graded using a D4 blade.

- Conducted a third soil sampling and testing program of the remediating soils in the LTUs after 2 years. Samples were taken from the same locations and depths as the previous two years.

- A soil heating system was installed in a section of LTU 2, in order to increase the remediation time available for soil treatment. The heating system was designed to include heaters with intake and exhaust chambers to cycle warm air through the impacted soil.

- Thermocouples were installed to assess the soil temperature at different locations and depths within the soil heated system (LTU 2).

1.5 Methodology

Soil sampling was conducted using guidelines and criteria outlined in publications from the American Society for Testing and Materials (ASTM), and the Canadian Council of Ministers of the Environment (CCME).

2.0 SITE CONDITIONS

2.1 Site Location and Description

Resolute Bay (74.7N, 94.83W) is located on the south shore of Cornwallis Island in the Arctic, as shown in Figure 1. The site of investigation is located approximately 6 km north of the community of Resolute Bay, just north of the airport, as shown in Figure 2.

The Former FTA

The former FTA, shown in Figure 3, was located approximately 2 km north of the Air Terminal Building at Resolute Bay Airport and south of the Nav Canada control tower. It consisted of a fire training mock-up area, four (4) ASTs, a fuel pump house and underground piping. Two gravel roads bounded the former FTA to the west and east; one leading to the metal dump and the other to the Nav Canada control tower, respectively.

LTU 1 and LTU 2

LTU 1 and LTU 2 are located within the boundaries of the former FTA. LTU 1 is located north of the fire training mock-up area and LTU 2 is located south of the AST site, as shown in Figure 3.

2.2 Site Geology and Groundwater

The Resolute Bay area is dominated by glacial features. Surficial material in the area consists of coarse, angular weathered grey shale. The Resolute Bay area is subject to continuous permafrost.

Groundwater is not used as a drinking water source as glacial water is readily available and used as the local potable water supply.

3.0 PROJECT DETAILS

3.1 August 2002 Work Program

In August 2002 the initial sampling program for attaining petroleum hydrocarbon concentrations was undertaken, along with the application of nutrients and/or surfactant to selected zones. Thirty-six (36) soil samples were collected and tested for hydrocarbon concentration as follows:

- Zone 1 and Zone 2 in LTU 1 – A total of twelve (12) samples, six (6) from each zone at two (2) sampling point locations. Three (3) samples were collected at each location; One (1) at the surface, one (1) 0.4 m below the surface, and one (1) 0.8 m below the surface, as shown in Figure 4.

- Zone 3 in LTU 1 and LTU 2 – A total of twenty-four (27) samples, twelve (12) from Zone 3 and twelve (15) from LTU 2, at specified sampling point locations. Three (3) samples were collected at each location; One (1) at the surface, one (1) 0.4 m below the surface, and one (1) 0.8 m below the surface, as shown in Figure 5. In addition, three (3) samples were collected from LTU 2, as shown in Figure 5.

Each of the above noted soil samples were also tested for the presence of aerobic and anaerobic heterotrophic bacteria.

Upon completion of the soil sampling program, nutrients and a surfactant were applied to selected zones as follows:

- 145 kg (320 lbs) of 38-0-0 Nitrogen-Phosphorus-Potassium (N-P-K), and 40 kg (88 lbs) of "Cyclone White" surfactant were added to zone 1 in LTU 1.
- 2273 kg (5000 lbs) of 38-0-0 (N-P-K) was added to LTU 2.

Surfactants are substances that can be used to separate contaminants from the soil structure, allowing for greater microbial-induced hydrocarbon degradation. The zones were tilled and graded using a D4 blade after the application of the nutrients and surfactant to a maximum depth of 0.3 m below the surface.

3.2 September 2003 Work Program

On September 5th 2003, the second round of soil testing was conducted to assess soil remediation progress. Hydrocarbon odours were present at all sample locations. Soil samples were collected at the same locations and depths as previously done during the first year (August 2002), with a few exceptions. Sample location 10 from LTU 2, as well as all sample locations from LTU 1, were sampled at a depth of 0.6 m instead of 0.8 m as previously done in August 2002. LTU 2 was frozen at a depth of 0.5 m below grade, with only minor frost above. Three (3) additional confirmatory samples from locations not previously sampled in August 2002 were collected and submitted for testing. These can be seen in Figure 5. A total of thirty-nine (39) soil samples were collected and tested for petroleum hydrocarbons.

A total of six (6) samples were tested for the presence of aerobic and anaerobic heterotrophic bacteria for comparative analysis with samples collected in August 2002. In Addition, hydrocarbon reducing bacteria plate counts were determined from six (6) samples.

Upon completion of soil sampling, nutrients were applied to selected zones as follows:

- 91 kg (200 lbs) of 38-0-0 (N-P-K) was added to Zone 2 in LTU 1.
- 634 kg (1400 lbs) of 38-0-0 (N-P-K) was added to LTU 2.

Zone 2 in LTU 1 and LTU 2 was tilled and graded using a D4 blade after the application of the nutrients to a maximum depth of 0.3 m below the surface.

The ground heating system was installed at the north end of LTU 2 upon completion of tilling activities. The air exchange components of the system comprised of three (3) heat inflow lines and four (4) return air lines as illustrated in Figure 6. The inflow lines were 75 mm (3") diameter pipes with slit cuts. The return lines were 150 mm (6") diameter pipe and 24.4 m (80 ft.) long, with the exception of the most westerly return line, which was only 19.8 m (65 ft.) long, with the southern 12.2 m (40 ft.) of pipe being 75 mm in diameter. All inflow lines and return lines were connected using tees to solid 200 mm (8") PVC manifolds. All pipe lines were installed at 0.4 m below grade. The air exchange housing was 2.4 x 1.2 x 1.2 m (L x W x H) and consisted of two (2) heaters and two (2) exhaust fans as shown in Figure 7.

Thermocouples were installed at various locations along the inflow and return lines at 0.4 m below grade, at the intake chamber, at the exhaust/heater chamber, and at grade within the heated area. Figure 8 illustrates the locations of the thermocouples. The approximate depth of the thermo lines were installed at 0.4 m below grade.

Following installation of the ground heat monitoring system, the pipes were covered with soil, and overlain with insulation. The area was covered with an Enviro Liner® supplied by Layfield Geosynthetics weighted down with rocks and steel pipes. The perimeters were secured by burying them in trenches backfilled with soil. Final electrical connections were completed at the exhaust house and the site was cleaned of excess supplies. Photographs of the installation process are shown in Appendix B.

3.3 August 2004 Work Program

Temperature readings of the thermocouples were taken on August 11th, 2004 prior to the heaters and blowers being turned on. The temperatures were taken again on August 12th, 2004 after the blowers and heaters had been running for 12 consecutive hours. Temperature data are shown in Table 4. The heaters were shut down for the winter in early October.

Nutrients and a surfactant were applied to selected zones as follows:

- 100 kg (220 lbs) of "Cyclone White" surfactant was added to Zone 1 in LTU 1.
- 400 kg (880 lbs) of 38-0-0 (N-P-K) was added to Zones 1 and 2 in LTU 1.
- 600 kg (1323 lbs) of 38-0-0 (N-P-K) was added to the non-covered Zone in LTU 2.

The zones were tilled and graded using a D4 blade after the application of the nutrients and surfactant to a maximum depth of 0.3 m below the surface.

3.4 August 2005 Work Program

On August 28th, 2005 a third round of soil testing was conducted to assess soil remediation progress. Soil samples were collected at the same locations and depths as previously sampled during first two rounds of testing in August 2002, and September 2003. A total of thirty-nine (39) soil samples were collected and tested for petroleum hydrocarbons. The locations of all soil samples collected from LTU 1 and LTU 2 are illustrated in Figures 4 and 5, respectively.

Temperature readings to assess the heating system were taken at 10:00 am on August 28th, 2005. Temperature data are shown in Table 4.

3.5 Analytical Analysis

A total of one-hundred-fourteen (114) soil samples from the three (3) sampling work programs were submitted to Enviro•Test Laboratories in Winnipeg, Manitoba for petroleum hydrocarbon analyses. Each sample was tested for benzene, ethyl-benzene, toluene, xylene (BTEX) and petroleum fractions F1 (C6-C10), F2 (C10-C16), F3 (C16-C34), and F4 (C34-C50). An outline of the results for samples from LTU1 and LTU2 are shown in Tables 1 and 2 respectively. Microbial plate counts were conducted on all samples collected during the August 2002 work program, as well as on six (6) samples collected during the September 2003 work program. Table 3 outlines the aerobic, anaerobic heterotrophic, and hydrocarbon reducing bacteria plate count results. A copy of the analytical test results from Enviro•Test is included in Appendix C. Weekly temperature readings were taken by site staff between August 2004 and August 2005. However, the data obtained collected was misplaced by site staff and therefore does not appear in this report, with the exception of the three days of readings shown in Table 4. The purpose of retrieving the weekly temperature data was to demonstrate that the heated soil remained above freezing longer than the unheated soil, thus increasing the time for bioremediation.

3.6 Remediation Criteria

The laboratory results of the BTEX analyses of the submitted soil samples were compared to the 1998 Government of the Northwest Territories (GNWT) Guideline for Contaminated Site Remediation of industrial sites and the 2003 CCME Canadian Environmental Quality Guidelines for soil at industrial sites. The laboratory results of CCME F1-F4 were compared to the 2001 Canada-Wide Standards for Petroleum Hydrocarbons in Soil Tier 1 levels for coarse-grained surface soils at industrial sites. Included in Appendix D is a sieve analysis illustrating that the soil in the LTUs is coarse-grained.

4.0 DISCUSSION and CONCLUSION

The purpose of this study was to determine if bioremediation is a feasible alternative to reducing (destroying) hazardous contaminants (in the form of petroleum hydrocarbon), for North Canadian communities, in an event that soils become contaminated, and that the treated soils meet the safety standard criteria.

The data obtained indicates that bioremediation process worked in reducing hydrocarbon concentrations from the contaminated soils. Since the primary organisms used in the bioremediation process were bacteria, it was important to establish their presence. The bacteria plate counts confirm viable populations of aerobic and anaerobic heterotrophic bacteria in the soil. Some lower counts of anaerobic bacteria were found in Zone 3 soils and soils exposed to heat, however, this did not have an over all influence on its ability to degrade the hydrocarbon concentrations from the soils, from both LTUs. In general, it there was a trend towards reducing the hydrocarbon concentrations, as time progressed. Of all hydrocarbons analyzed, the larger portions reduced were Benzene, Toluene, Ethyl Benzene, and F4 (34-C50) and to a lesser extent xylene, F1 (C6-C10), F2 (C10-C16), and F3 (C16-C34). Some treatments that show an increase in hydrocarbon concentration may be ignored; what appears as a increase in concentration is likely caused by a high hydrocarbon concentration plume migrating from one area of the zone to another, thereby confounding the results.

To enhance the rate of degradation, microorganisms will require the optimum conditions that provide optimum growth rates. These conditions include substrate (hydrocarbon), ecological niche (space), nutrients and temperature. The first two are found in abundance. The third condition is that organisms have adequate nutrients. LTU 1 tested for the effect nutrients and, in addition, a surfactant had on the effectiveness of hydrocarbon degradation. It is inconclusive whether the addition of the nutrients or surfactant improved the degradation of the contaminants. It is recommended to further investigate with different nutrient concentrations.

The remediation criteria for Benzene, Toulene, Ethyl Benzene, Xylene and F1 (C6-C10) were obtained from the 1998 GNWT Guileline, the remaining hydrocarbon fractions were obtained from 2001 CCME CWS for PHCs in Soil, respectively. Each contaminant was met for all hydrocarbon species tested, except for the hydrocarbon fraction F2 (C10-C16). Although an observable reduction in concentration for this fraction occurred, the total reduction was insufficient to meet the standard criterion. This implies that the bioremediation process is working, however, it requires more time to fully remediate the site to the specified standards, and longer still to reduce the F2 (C10-C16) fraction to a safe level. Since hydrocarbon concentrations will not increase at a site unless it is further contaminated, with sufficient time an adequate reduction may be achieved.

The greatest challenge facing bioremediation in the north is the cold temperatures occurring during winter months. A brief analysis of the historic temperature data for the area revealed that the mean monthly maximum temperatures that are above freezing occur during June, July and August. The short summer season gives only a short period of time where bacteria may grow in temperatures above freezing. As such, the effect of heat on microbial growth and in turn their effects on hydrocarbon degradation were investigated in LTU 2 treatment area. Employing a heating system would help prevent the ground from freezing, and thus prolonging the biodegradation process. A heating system during the months in which the mean temperature is just below freezing (ie. above -10°C) can effectively double the time the biodegradation process has to operate. As mentioned above, heat had an effect on bacterial growth; more specifically it impeded the growth of anaerobic heterotrohic bacteria. Despite the reduction in anaerobic heterotroph populations, there still was a reduction in concentration for some of the hydrocarbon species. This is an indication that aerobic bacteria are the dominant organisms conducting the degradation. As a result, a proper system of soil aeration is required to maintain an adequate air supply to microorganisms in the soil. Some hydrocarbons appear to be unaffected by the bacteria, whereas others hydrocarbon species were degraded up to 600 % more than the unheated treatments. As such faster rates of bioremediation could be obtained by having the system run for several more years, extend the heating temperature time over the entire winter period, and monitor the temperature more regularly.

5.0 CLOSURE

This report outlines the remedial work currently completed at Resolute Bay from August 2002 to September 2005. If you have any questions regarding the work presented herein, please contact the undersigned.

Sincerely,

ENG-TECH Consulting Limited	Winnipeg Environment Remediation Inc.
Clark Hryhoruk.	for CA.
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