Nunatta Environmental Services Inc.

ᓄᓇᑦᑕ ᐊᕙᑎᓕᕆᔨᖕᒋᑦ ᑎᒥᖓᑦ

Additional information presented to the Nunavut Water Board regarding a water permit for a landfarming application

March 2005

Nunavut Water Board
APR 4 2005
Public Registry

INTERNAL	
PC	IP
MA	
FO	
LA	
BS	
ST	
TA1	
TA2	
RC	
ED	
CH	
BRD	
EXT.	

P.O. Box 267, Iqaluit (Nunavut) X0A 0H0. Telephone (867) 979-1488. Fax (867) 979-8800

Additional information presented to the
Nunavut Water Board
regarding a water permit for landfarming application

Note: the following issues will be addressed during 2005 and details will be transferred to the Nunavut Water Board upon completion of the specific tasks:

- Report on the installation of the 6 groundwater monitoring wells with Mercator coordinates (via GPS);
- Re-construction details of cell 2 (replacing 20 mil HDPE membrane with 30 mil HDPE membrane);
- Analytical results from groundwater monitoring and background noise concentration; and
- Geotechnical results (shear vane test) obtained from the cell's berms

Water use

The optimum soil water content for best biological activities is in the range of 20 to 35%. The natural water content of the soils at the landfarm falls within this range. Under dry conditions, Nunatta Environmental Services will introduce water with a water spraying system adapted for landfarming activities at the surface of the dry contaminated soil. Based on the 2004 landfarming season, it is estimated that this task will be performed on a bi-weekly basis from mid June to the end of August and once in September for a total of 7 applications. The surface area of the 3 cells is 5,500 m^2. The application of 0.25 centimetres of water on the entire surface will require 13 m^3 of water. Seven applications per summer will require a total of 91 m^3 of water.

The maximum yearly requirement for the landfarm operation is 91 m^3. A large proportion of this water may be filtered and recirculated rainwater collected along the cell's edges.

Landfarm Treatment Cell and Monitoring Well Design and Construction

Discussion on the design criteria of the groundwater monitoring wells

The groundwater monitoring wells installed in September 2004 were built rapidly to obtain water samples prior to freezing conditions. No groundwater could be sampled in October because the 6 wells were dry. During the 2005 summer season, Nunatta Environmental will proceed with the final and permanent groundwater monitoring well installation as represented in Figure 1. The NWB specifically requested that the tubing used for the construction of the wells shall not consist of Poly Vinyl Chloride. Nunatta Environmental will therefore use High Density Poly Ethylene (HDPE) tubing for the construction of the wells.

During the installation of the monitoring well, an engineer will ensure that the screened tubing (0.01 inch interval / width) covers the lower half of the tubing and that the lower section covers permafrost. A bentonite seal will be placed immediately above the screened tubing whereas waterproofing at the intersection of the well and ground surface will be ensured with a cement and bentonite mixture. This plug will be at least 45 centimeters thick and will prevent water surface water infiltration into the wells. The above ground tubing will be protected with a steel casing. The metal lid will be locked and boulders will be placed next to the steel casing as a protection against heavy equipment bumping into the casings.

The location of the groundwater monitoring wells will remain the same as suggested in the initial submittal (August 2004). Nunatta Environmental believes that the existing groundwater monitoring wells will serve their purpose until September 2005. The monitoring well reconstruction will occur in September 2005 to allow a maximum thawing of the active layer to ensure that the wells are anchored below permafrost level. We expect that permafrost level at the end of September will range from 2 to 3 meters from ground surface. The depth of the monitoring wells will be governed by the following factors:

- Presence of bedrock: the monitoring wells will be anchored in bedrock if encountered before permafrost soil. If bedrock is encountered within 1.25 meters, an adjacent location will be selected.

- Soil permafrost depth: if bedrock is not encountered, the length of the monitoring wells will be extended 30 cm below permafrost level.

An engineering report will be prepared following the installation of the groundwater wells. The report will cover installation procedures and as-built drawings. An example of the construction detail of the groundwater monitoring well is shown in Annex 4. Note that the PVC casing will be replaced with HDPE.

Analytical program, groundwater monitoring well

The monitoring wells will be reconstructed during the summer of 2005. The analytical program described in the original permit application will change to best reflect the new situation. The following Table proposes a monitoring well sampling frequency / component for a 6 year period (2005 to 2011).

Groundwater well number	**Chemicals analyzed and sampling year**
GW1, GW3, GW5 (downgradient)	TPH, BTEX and HM: every year for 6 years starting in 2005. PAH will be analyzed every second year starting in 2005.
GW2, GW4, GW6 (upgradient)	TPH, BTEX, HM and PAH: every second year for 6 years starting in 2005.

Where TPH is Total Petroleum Hydrocarbons; BTEX is Benzene, Toluene, Ethylbenzene and Xylenes; PAH is Poly Aromatic Hydrocarbons; HM is Heavy Metals. In 2011, the groundwater monitoring program (component and frequency) will be proposed based on historical values.

The coordinates of the 6 monitoring wells will be surveyed during the 2005 field season. Results will be transferred to the NWB. The coordinates will be obtained from a hand held GPS instrument with a 3 meter tolerance.

Containment berm: characteristics of the construction material

The perimeter berms were built using granular material obtained from the site layout and from Iqaluit's quarry (North 40). The previous owner built cells 1 and 2 whereas cell 3 was built by Nunatta. Construction documentation is described in this section. To ensure that the berms are structurally sound, Nunatta Environmental will proceed as soon as practically possible with a soil shear strength measurements using a shear vane apparatus. Based on the analytical results, a geotechnical opinion on the bearing capacity of the berm soils will be emitted.

From an environmental standpoint, protection of groundwater is assured by geomembranes waterproofing the cells. Cells 1 and 3 were built with 30 mil thick HPDE geomembrane, whereas cell 2 was built using a 20 mil HDPE geomembrane. During summer 2005, Nunatta Environmental will relocate fuel impacted soils form cell 2 into cell 3 to replace the 20 mil geomembrane with a 30 mil HDPE geomembrane.

The geomembranes used for the 3 cells were assembled at the manufacturer's plant (Texel, Quebec and Layfield Plastics, Alberta) to the exact specified dimensions. Texel and Layfield plastics fusion welded 5 meter wide geomembrane strips to the required cell widths and lengths, folded, packaged and shipped the geomembranes to Nunatta Environmental.

Quality assurance and quality control documents are supplied by the geomembrane manufacturers. The QA/QC documents will be transferred to the NWB upon completion of the construction of cell 2. Annex 2 shows electronic photographs of the construction of the landfarm.

Landfarm Treatment Cell Operation and Maintenance

Efficiency of the treatment process

Based on its experience acquired from the construction and operation of a landfarm in Pelly Bay (Kugaaruk) and from its landfarm in Iqaluit, Nunatta Environmental has the confidence that bioremediation under Arctic conditions is an appropriate method to reduce petroleum hydrocarbon concentrations from impacted soils. Reduction of petroleum hydrocarbon concentration through landfarming is well documented in the literature and several communities under Arctic conditions are using this approach to manage fuel impacted soils. While the microbiological efficiency is reduced by cold temperatures experience 9 months per year, the warm season is sufficient for the bioremediation process to occur. Nunatta Environmental has reviewed scientific literature on this matter to optimize field conditions for bioremediation to occur. The governing factors to optimize bioremediation treatment efficiency is summarized below:

- The contaminants present in the soils must only be of petroleum hydrocarbon nature. Carbon chain lengths ranging from C_{10} to C_{50} can be biologically degraded with time. Contaminated soils containing heavy metals, mercury, persistent PAH, PCB and other complex / recalcitrant contaminants will not be accepted at Nunatta Environmental's landfarm under any consideration. Incoming soils are tested prior to entering the landfarm unless they originate from a freshly fuel spilled area that is well documented.

- The contaminated soils entering the landfarm shall not have concentrations exceeding 11,000 Parts Per Million (ppm). A chemical analysis including C_{10}-C_{50}, heavy metals (6) and mercury will be required for every 500 m^3 of contaminated soil entering the landfarm. For smaller quantities, i.e. less than 500 m^3 originating from the same location, one complete analytical analysis set will be done. PAH and PCB testing may be required if the contaminated soil is suspected of containing other contaminants than heating fuel, Diesel or gasoline.

- The contaminated soil present at the landfarm was analyzed for nitrogen, phosphorus and potassium content to determine if the nutrient content was optimal for fast biodegradation of substrate by soil microorganisms. Laboratory analyses indicate that the addition of fertilizer is required to optimize soil microorganism degradation performance. All purpose 20-20-20 fertilizer will be mechanically added to the contaminated soil.

- The number and type of soil microorganisms present in the contaminated soil presently stored at the landfarm was evaluated to determine if the microorganisms could efficiently do the remediation work without the addition of indigenous cultures. The microbiological laboratory indicated that the population exceeded 2,400,000 microbial count per gram of dry soil and that the families present (*staphylococcus spp. and bacillus subtis*) were appropriate to undertake efficiently the biodegradation of the fuel-impacted soil.

- Proper soil aeration is essential to optimize bioremediation efficiency. This is done to ensure that aerobic conditions prevail below soil surface (oxygen incorporation). Nunatta Environmental uses a soil tillage tool pulled by heavy equipment. The soil moving tools have a reaching depth of 60 cm below ground level. Soil aeration starts as soon as surface soils have thawed until the freezing season sets in. The frequency of soil aeration depends on factors such as soil wetness, temperature and wind. Generally, complete contaminated soil tilling is required once or twice weekly for 10 to 12 weeks per season. An electronic photograph of the soil tillage tool is represented in Annex 1.

- During the construction of the landfarm, a 30 cm layer of screened non-contaminated soil was placed below the 30 mil HPDE geomembrane (refer to Annex 1 for surface smoothness). A second layer of clean and screened soil was placed above the 30 mil liner to prevent membrane puncture (soil screened for rocks smaller than 3/8"). Considering that the soil tilling tool has an operating depth of 60 cm, the operating cells will have a contaminated soil thickness ranging from 70 to 80 cm.

- Optimizing water content is essential for suitable biodegradation conditions. 20 to 35% water content is necessary. Based on Nunatta Environmental's experience, these conditions were always met in 2004. In the event that soil tillage combined to unusually dry summer conditions, soil wetting would be required as described in the "water use" section.

To evaluate the biological treatment efficiency and progress with time, 3 blended soil samples obtained from the active cells will be obtained at the end of each field season (end of September). The samples will be analyzed for the following parameters:

- TPH
- C_{10}-C_{15}
- C_{16}-C_{35}
- C_{36}-C_{50}
- Total microorganism count and type
- Nitrogen, phosphorus and potassium content

These analytical results will be compared to the average TPH concentration results from incoming soils for the on-going year and for the previous years. The ratio of TPH results (TPH concentration after treatment over TPH concentration prior to treatment) will give the efficiency of the process with time. The analytical results will also determine the nutrient requirements for the following year: a correlation can be made between the efficiency of the microbiological process and the amount of fertilizer used.

It is expected that the microbiological process to reduce TPH concentration in the landfarming operation will have a maximum efficiency of 90%. If soils entering the landfarm have a TPH concentration of 11,000 ppm or less, a 90% reduction will yield final TPH concentrations of 1,100 ppm. This value is below the CCME's commercialTPH guidelines. The literature reviewed for optimizing field conditions for Nunatta Environmental's landfarm is summarized in Annex 1.

Contaminated soil acceptance criteria

Typical industrial soils in Iqaluit have a potential of being impacted with various contaminants as listed below:

1. Petroleum hydrocarbons (heating and diesel fuel, gasoline, avgas and lubricants)
2. BTEX (Benzene, Toluene, Ethylbenzenes and Xylenes)
3. Heavy metals (lead, cobalt, nickel, zinc, copper and cadmium)
4. Poly Aromatic Hydrocarbons (pyrene, benzo-a-pyrene, etc)
5. Poly Chlorinated Byphenyls
6. Mercury

Bioremediation is only efficient towards the reduction of contaminants listed in items 1 and 2: petroleum hydrocarbons and BTEX. The bioremediation process on soils impacted with large concentrations of contaminants present in items 4 and 5 (PAH and PCB) is theoretically possible to some extent but low temperatures experienced in the Arctic considerably slow down the process. Soils contaminated with large heavy metals and mercury concentrations cannot be treated by conventional landfarming. Consequently, Nunatta Environmental Services will not accept soils containing contaminants described in items 3, 4, 5 and 6 above. However, heavy metals are naturally present in soils. Soils having heavy metal concentrations up to their respective noise levels will be accepted at the landfarm.

In practice, the landfarm will only accept fuel impacted soils (diesel and heating fuel) and gasoline impacted fuel. Scientific studies reported in Annex 1 claim that landfarms operating under northern conditions can treat soils having total petroleum concentration as high as 11,000 parts per million. Nunatta Environmental will therefore set the upper acceptance concentration limit at 11,000 ppm. The acceptance criteria are summarized in Table 1.

Table 1: Landfarm's acceptable criteria for contaminated soil

Parameter / contaminant	**Maximum acceptable level (or range)**	**Note**
pH	6-8	Soils may require stabilization
C_{10}-C_{15}	Not to exceed 11,000 ppm	
C_{16}-C_{35}	Not to exceed 8,000 ppm	
C_{36}-C_{50}	Not to exceed 4,000 ppm	
TPH	**Σ** not to exceed 11,000 ppm	
BTEX	Total not to exceed 5,000 ppm	
Moisture	10-40%	
Recalcitrant organics	Not accepted at the landfarm	

Heavy metals, mercury	Accepted to natural noise level	Background concentration to be issued by 8/05

Soil impacted with antifreeze, batteries and any other hazardous waste will not be accepted at the landfarm.

Contaminated soils already present in the landfarm

There is presently approximately 3,500 cubic meters of fuel impacted soil at the landfarm. Table 2 summarizes the characteristics of the contaminated soil accepted at the landfarm:

Table 2: Characteristics of soils present at the landfarm

Origin	Volume	Characteristics
Iqaluit hospital (2003)	3,000 m^3	Granular soil contaminated with petroleum hydrocarbons; Chemical analysis confirms the absence of PAH, PCBs and heavy metals. Analytical results reported in Annex 3.
Private origin (2004)	300 m^3	Granular soil contaminated with heating fuel
Private origin (2004)	200 m^3	Granular soil recuperated from a heating fuel spill. No analytical results yet.
Total	**3,500 m^3**	**No presence of persistent organic components, heavy metals or mercury.**

Contaminated soil: temporary storage

Accepting large quantities of contaminated soil (> 500 m^3) at the landfarm requires conditioning and may required temporary storage. In such cases, the contaminated soils are temporarily stored in cell 2 or 3. If the temporary storage is required for 1 or 2 months prior to conditioning, the stockpile is left as is. If the temporary storage is required over the winter (when the soils are accepted at the end of the season) the stockpile is shaped to prevent water accumulation. A waterproof tarp is placed on the contaminated soil and is solidly anchored into the adjacent ground and also serves as a dust control measure.

Surface water management

The 3 treatment cells consist of perimeter berms having 1 meter in height and a 2.5 meter width at the base. A 30 mil HDPE geomembrane waterproofs the cell's floor and berms. Contaminated soil is contained within the bermed area. Snowmelt and rainwater being in contact with contaminated soil will end up along the cell's perimeter. The water is intercepted by the berm and can therefore not leave the site.

The surface water management is addressed in 5 different manners:

1. Surface water is absorbed by the contaminated soil;

2. Excess surface water accumulating along the cell's perimeter is treated with a mobile activated carbon treatment unit as described in the original permit application;

3. The treated water is then pumped in a 5,000 liter tank and store for future use (to increase soil water content when less than 20%).

4. When required, accumulated water can be pumped onto the contaminated soil to optimize (or increase) soil water content;

5. Accumulated water evaporates under sun and wind action; and

6. Accumulated water freezes and is addressed once melted.

Accumulated water along the cell's perimeter will not be allowed to stand free more than 1 week unless frozen.

<u>Leachate containment and/or treatment</u>

The leachate containment and treatment facility is described in the original permit application and consists of pumping surface waters into a holding tank placed on the contaminated soil (5000 litres) and an activated carbon water treatment facility.

<u>Site grade</u>

The first two cells were built 5 years ago. The third cell was built in 2003 and was completed in 2004. The landfarm layout sits on relatively flat land but is slightly sloped (1%) so that running surface water accumulates along the eastern and southern edges of the cells.

<u>Dust control</u>

The only activity susceptible of creating dust is soil aeration. Knowing that optimal landfarming operations require that the soil water content ranges between 20 and 35%, dust problems are automatically eliminated. Aeration operations are done 10 to 12 times per summer and are usually preceded by water sprinkling operations when conditions are dry. Dust control is implicitly addressed during water sprinkling operations required to optimize soil water content.

<u>Rock reject management</u>

Once fuel impacted soils enter the landfarm, they are dumped on one of the 3 cells, depending of space and treatment advancement. To mechanically aerate the contaminated soil, rocks larger than 3 inches in diameter must be removed. The freshly stockpiled contaminated soil is passed through a mechanical screener that separates 3 inch plus rocks from the soil and fine gravel. The material passing through the 3-inch sieve is placed on the treatment cell in a 45 to 60 cm thick layer. The rocks greater than 3 inches in diameter (the rejects) are stockpiled and pressure washed to remove adhering fines on the rocks and boulders. The washing operation occurs in one of the 3 treatment cells. The wash runs off to the berm edges. The excess water is managed according to the “surface water management” section. Once a year, a 5 kg rock sample (3 to 5 inch diameter) is sent to a laboratory where it is finely crushed. A TPH analysis will determine if hydrocarbons are still present. If the analysis shows that the rock power is free of contamination, it can be disposed of. Otherwise, additional pressure washing is required. It is anticipated that the landfarm will have to manage up to 500 m^3 yearly. If clean, the rock rejects can be disposed of (a 100 ppm TPH concentration is the maximum allowed concentration for disposal):

- The rock rejects can be used as foundation material to raise the eastern section of the property where the landfarm is located. A 3,000 m^3 volume is required (the equivalent of 6 production years)
- The rock rejects can be sent to the municipal landfill
- The rock rejects can be hauled to a crushing operator to produce gravel

<u>Treated soil disposal plan</u>

Nunatta Environmental anticipates that the contaminated soil treatment will require 3 to 4 seasons to lower TPH concentrations to CCME’s residential or commercial levels. Once treated, the remediated soil will leave the landfarm to accept new contaminated soil. The remediated soils will be disposed of as follows:

- Sent to the municipal landfill for daily cover use
- Foundation material for road construction, if acceptable by the applicable legislation
- Some reluctant contaminants may not have undergone the expected remediation process. These soils will be containerized and shipped to an approved southern disposal facility

ANNEX 1 Literature review

Borresen, M., G., Breedveld, and A. Rike, 2003. Assessment of the biodegradation potential of hydrocarbons in contaminated soil from a permafrost site. *Cold Regions Science and Technology*, volume 37, 137-149

Braddock, J., J. Walworth and K. McCarthy, 1999. Biodegradation of Aliphatic vs. Aromatic Hydrocarbons in Fertilized Arctic Soils. *Bioremediation Journal.* Volume 3, issue 2, 105-116.

Filler, D., Lindstrom, J., Braddock, J., Johnson, R. and R. Nickalaski, 2001. Integral biopile components for successful bioremediation in the Arctic. *Cold Regions Science and Technology*, volume 32, 143-156

Frankenberger, W., 1997. The need for a laboratory feasibility study in bioremediation of petroleum hydrocarbons. In: Calabrese, E.J., Kostecki, P.T. (Eds.) Hydrocarbon contaminated soils and groundwater. Lewis Publishers, Boca Raton, Fl, pp237-293.

McCullough, R. and R. Burkill, 2000. The establishment of a simple, low cost, bio-remediation pilot project in Cambridge Bay, Nunavut. Contaminants in freezing ground. Collected proceedings of the 2nd international Conference, 1-6. Cambridge, UK.

Mohn W. and G. Stewart, 2000. Limiting factors for hydrocarbon biodegradation at low temperature in Arctic soils. *Soil Biology and Biochemistry*. Volume 32, issues 8-9, 1161-1172

Rike, A., Borresen, M. and A. Instanes, 2001. Response of cold-adapted microbial populations in a permafrost profile to hydrocarbon contaminants. *Polar Record*, volume 37 (202), 239-248.

Rike, A., K. Haugen, M. Børresen, B. Engene and P. Kolstad, 2003. In situ biodegradation of petroleum hydrocarbons in frozen arctic soils. *Cold Regions Science and Technology*, volume 37, 97-120

Roy, R. and C. Greer, 2000. Hexadecane mineralization and denitrification in two Diesel-fuel contaminated soils. FEMS Microbiology, *Ecology*, volume 32, 17-23

Sandvik, S., Lode, A. and T. Pederson. 1986. Bioremediation of oily sludge in Norwegian soils. *Appl. Microbial. Biotechnol*. Volume 23, 297-301.

Song, H., X. Wang and R. Bartha. 1990. Bioremediation potential of terrestrial fuel spills, *Appl. Environ. Microbiol.* Volume 56, 652-656.

Walworth, J., Woolard, C. and K. Harris, 2003. Nutrient amendments for contaminated peri-glacial soils: use of code bone meal as a controlled release nutrient source. *Cold regions science and technology,* volume 37, 81-88.

Walworth, J., Braddock, J. and C. Woolard, 2001. Nutrient and temperature interactions in bioremediation of cryic soils. *Cold Regions Science and Technology*, volume 32, 85-91

Whyte, L., Goalen, B., Hawari, J., Labbé, D., Greer, C. and M. Nahir, 2001. Bioremediation treatability assessment of hydrocarbon-contaminated soils from Eureka, Nunavut. *Cold Regions Science and Technology*, volume 32, 121-132.

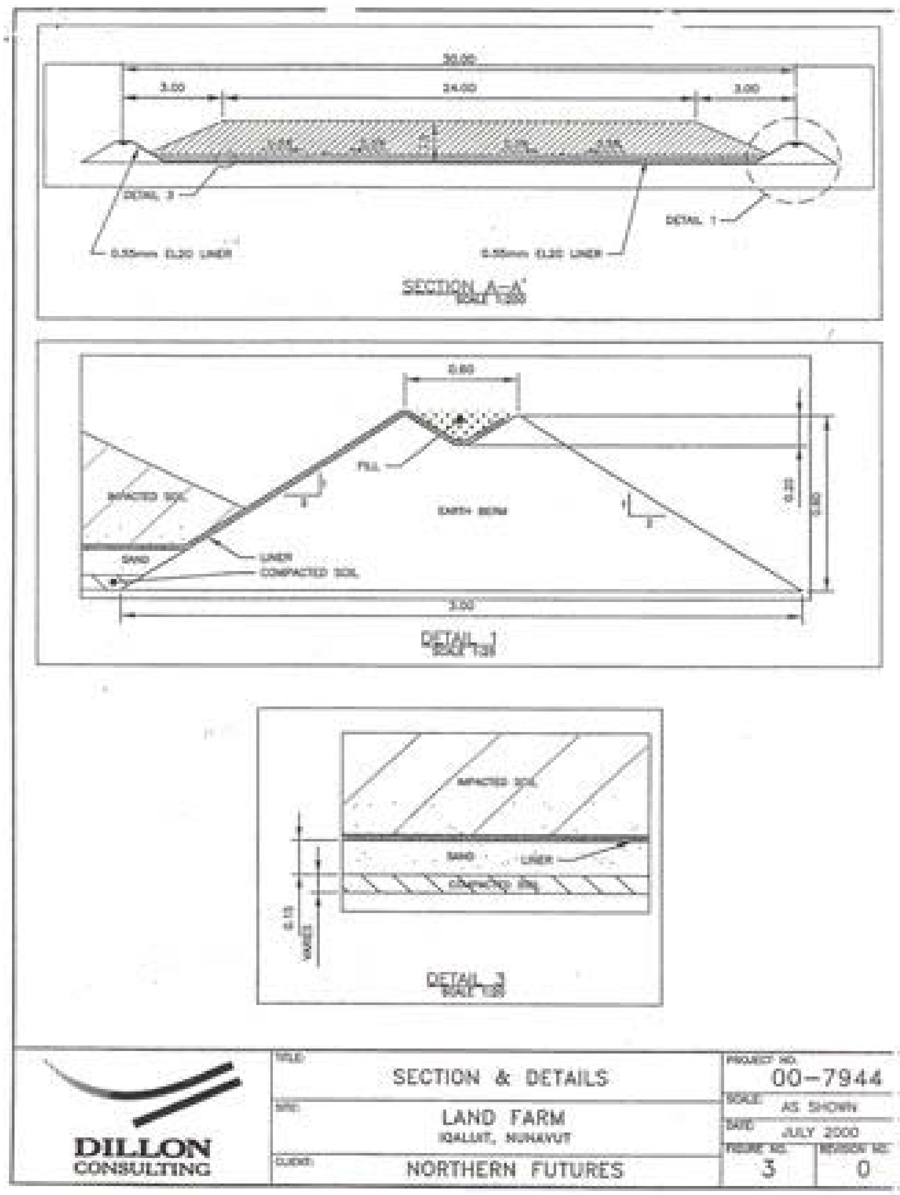
ANNEX 2: Electronic photographs of the landfarm during construction

Photograph 1: Cell 3 during construction (2003)

Photograph 2: Cell 3 surface smoothness and geomembrane deployment

Photograph 3: 30 mil HDPE geomembrane over contour berms

Photograph 4: Agricultural tilling tool used to aerate the soil during treatment



Photograph 5: Construction details, cell 1, 2000

ANNEX 3: Analytical results

Note: LF1, LF2 and LF3 refers to analytical results from cell, cell 2 and cell 3. It is assumed that mixing of the soil was complete and represented general landfarm conditions at the end of 2004. The TPH concentrations (C_{16}-C_{35}) reached 13,000 ppm (confidential Client).

ANNEX 4: Groundwater monitoring wells

Note that PVC will be replaced by HDPE

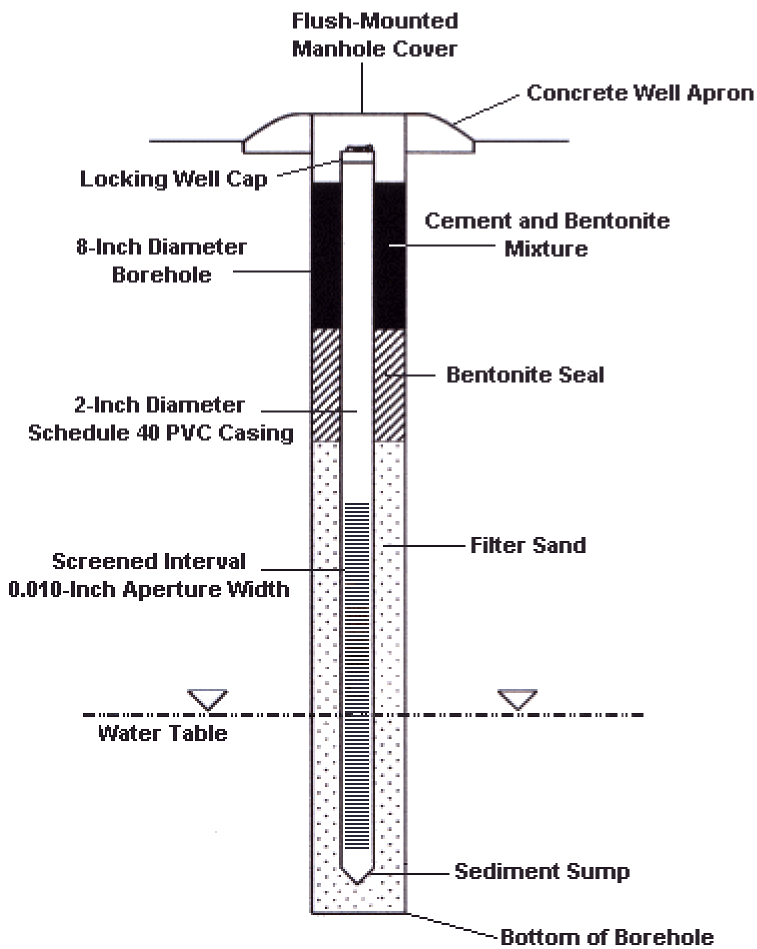


FIGURE 1: Landfarm layout at the North 40 park, Iqaluit, Nunavut