

Table V-14: Soil and Air Temperatures at the Main Landfarm From 17 July to 6 September 2005

	Soil Temperature (° C)					Air Temperature (° C)
Depth	10 cm	20 cm	30 cm	40 cm	10-40 cm	-
Average	8.6	7.8	7.3	6.9	7.7	8.6
Range	13.9-1.9	12.0-2.2	10.3-2.8	9.5-3.8	-	19.7-0.4

Table V-13 gives the analytical results for the 3 sampling dates. The results from the first sampling data are all lower than the latter two sampling dates. The reason for this is unclear as the % moisture in these samples were no different than the other two sets (8.5 % versus 7.4 % and 7.6 %). The mean TPH concentration found from the three samplings was 2450 ± 1150 ppm as compared to the value of 3320 ± 970 ppm found after initial construction. The C_{17}/Pr ratios show little change also indicating that TPH losses due to bioremediation were very low. The TPH concentration found in the untilled area was 4000 ± 1020 ppm. Results for samples taken at 0-30 cm and 30-60 cm depths showed no significant differences. Overall much less TPH was lost than was found in the experiment plots over a similar time period. This is likely due to a number of circumstances. The temperature data show that this site is colder than the barrel cache valley site. Soil temperatures were lower with an average of 7.7 °C as opposed to 9.3 °C. The area is subject to more fog than the lower site which would lead to a decreased evaporation rate. The landfill was thicker than the experimental plots due to space limitations resulting in less aeration and colder temperatures at the base of the landfarm, 6.9 °C versus 8.5 °C.

Total and extractable phosphorus and nitrogen were determined on four representative soil samples from 2004 and eight from 2005. Results are given in Table V-15. These show that extractable ammonia was present until mid-summer but absent by September 2005. This may mean that more urea should be added. However it could also mean that the added nitrogen is now present as organic nitrogen and is still available to the hydrocarbon degraders. Tests are to be carried out before the start of the 2006 season to determine if added nutrients increase the rate of biodegradation on a sample from the landfarm relative to one to which no further nutrients are added; these tests will be conducted at room temperatures in order to accelerate the bioremediation.

Table V-15: Soil Nitrogen and Phosphorus Levels (ppm) at the Main Landfarm

Sample	Date	Unit	TKN	Ext. Ammonia	Ext. Nitrate	Ext. Nitrite	Total P	Ext P
RI04-687	2-Sep-04	ppm	370	6.5	<4	<2	140	7
RI04-690	2-Sep-04	ppm	421	29	<4	<2	250	4
RI04-714	2-Sep-04	ppm	296	10.7	<4	<2	220	4
RI05-351	31-Jul-05	ppm	338	7	<1	<1	110	-
RI05-352	31-Jul-05	ppm	359	7	<1	<1	77	-
RI05-353	31-Jul-05	ppm	340	<5	<1	<1	140	-
RI05-354	31-Jul-05	ppm	265	25	<1	<1	86	-
RI05-1201	4-Sep-05	ppm	295	<0.25	<4	<2	270	4
RI05-1209	4-Sep-05	ppm	243	<0.25	<4	<2	210	4
RI05-1219	4-Sep-05	ppm	220	<0.25	<4	<2	190	4
RI05-1222	4-Sep-05	ppm	181	<0.25	<4	<2	180	3
RI05-1229	4-Sep-05	ppm	224	<0.25	<4	<2	220	2

Results from the analysis of soils for hydrocarbon degraders are given in Table V-16. These show some increase for 2005 over those obtained for 2004.

Table V-16 Results of Analyses for Hydrocarbon Degraders at the Main Landfarm

Sample	Date	Unit	Hydrocarbon Degraders
RI04-648	2-Sep-04	cfu/g	9.6×10^4
RI04-649	2-Sep-04	cfu/g	4.8×10^4
RI04-650	2-Sep-04	cfu/g	6.2×10^4
RI04-687	2-Sep-04	cfu/g	4.1×10^5
RI04-690	2-Sep-04	cfu/g	2.8×10^5
RI04-714	2-Sep-04	cfu/g	2.7×10^5
RI05-1201	4-Sep-05	cfu/g	5.3×10^5
RI05-1219	4-Sep-05	cfu/g	4.3×10^5
RI05-1229	4-Sep-05	cfu/g	2.6×10^5

Two soil samples were analysed by the CCME-TPH method from samples collected in 2004. Results are given in Table V-17. These show that the major fraction is F2 with a lesser amount of F3. This is consistent with the diesel fuel GC pattern.

Table V-17: Results of Analyses of Samples for CCME-TPH from the Main Landfarm (ppm)

Samples	F2 (C6-C10)	F3 (C10-C16)	F4 (C16-C34)	F4G (C34-C50)
RI04-690D	2400	830	<80	na
RI04-708	2700	1000	<80	na

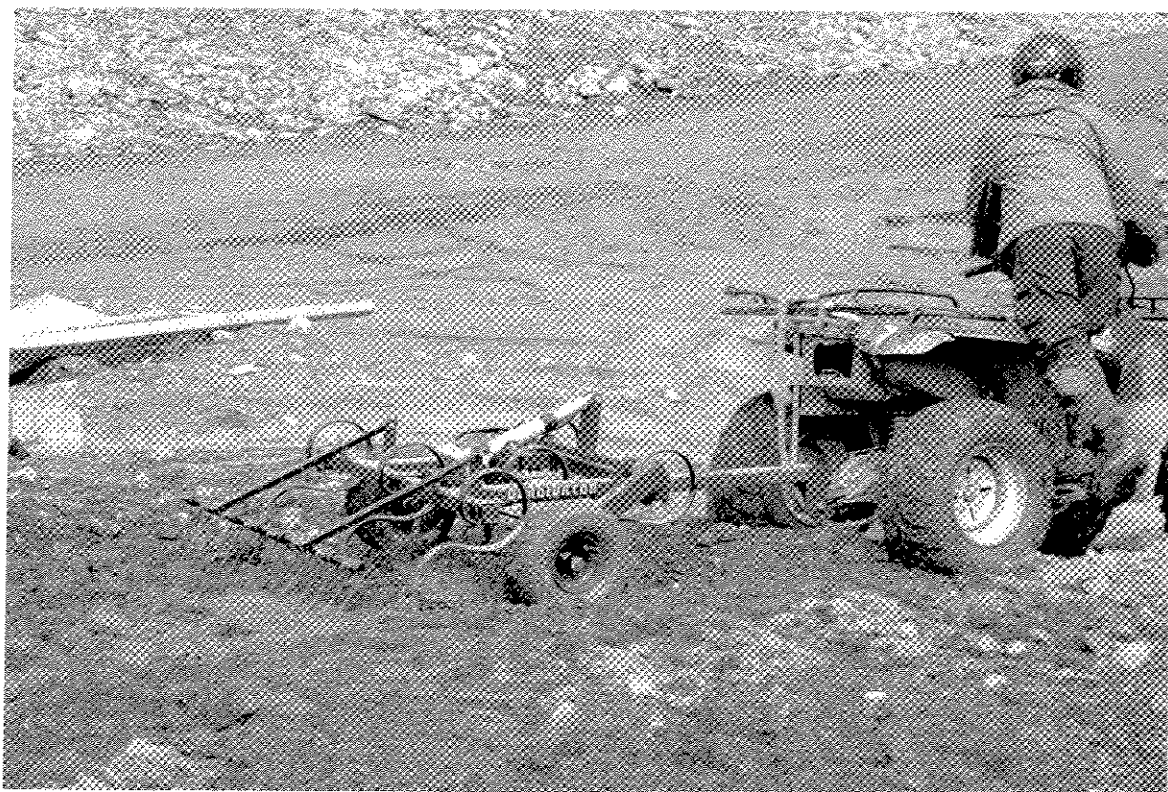
Total Organic Carbon was determined to be 0.54 % in sample RI04-698 which was collected in 2004. This was done in order to confirm the low organic content expected in this Arctic soil.

In 2006 it is planned that the landfarm will be aerated by heavy equipment several times in the planned four week visit by Qikiqtaaluk Corporation. ASU will continue to monitor the landfarm and add nutrients if this is deemed to be necessary. In addition some additional contaminated soil from the areas previously occupied by the beach POL tanks will be added. Currently there is a small quadrant of the main landfarm that is not being aerated. This will continue to remain undisturbed and monitored separately. While the ASU are on site in 2006, another small quadrant will be marked off and this will be rototilled daily. This quadrant will also be monitored separately. Results from these two sub-plots should give important results with respect to the effectiveness of aeration in lowering the TPH levels at a temperature lower than the experimental landfarm.





Photograph V-7: Digging a Pit in Order to Collect a Soil Sample From the Grid Set Out on the Main Landfarm



Photograph V-8: Attempting to Use an ATV and Harrow to Till the Main Landfarm





Photograph V-9: Aerating the Main Landfarm With the IT24 Loader



Photograph V-10: Aerating the Main Landfarm



4. *In Situ Landfarm*

An ideal way to remediate fuel contaminated soil in the Arctic would be to add fertilizer on top of the affected area. The fertiliser might then percolate into the contaminated zone and promote bioremediation. Such an in situ scheme would be extremely cost effective and would result in no physical disturbance of the tundra. Such an in situ bioremediation might be successful in that most TPH contamination is in the surface active layer. On the negative side, the soil temperatures are low, particularly at the base of the active layer where contamination might be greatest, oxygen may be limited and the added nutrients may not reach the contaminated zone.

In order to investigate the performance of bioremediation in an in situ study in the Arctic one needs to add nutrients to a fuel contaminated area and observe changes in TPH concentration. At the same time TPH levels in an associated control plot in which no nutrients are added needs to be followed. The main problem with this concept is that TPH levels in soil from a spill are extremely heterogeneous. Therefore, in order to carry out the study at Resolution Island it was necessary to excavate some TPH contaminated soil and homogenize it and then place it back in the ground. It was further decided that in this study that the soil should be compacted into plots formed by excavation of pits in the ground in order to simulate undisturbed soil. One trial plot would be left for at least one year before nutrients were added so that the soil would be more settled and oxygen levels stabilized.

The construction of the in situ landfarm plots was initiated on 27 July 2005. A 12 m by 12 m area between the two POL tanks was excavated to bedrock and large boulders were removed from the soil. There had been several days of constant precipitation, and as a result the water table at the beach POL tank area was less than 50 cm below the ground surface. The soil was therefore saturated with water. As a result of this it was decided to move the location of the in situ landfarm to the barrel cache valley. The soil was therefore screened and placed in conical steel containers (Photograph V-11).

At the barrel cache valley four holes were excavated in the ground. These measured 5 m by 5 m and with a depth of 0.6 m. They were spaced out so that there would be no transference of fertilizer between the plots. The soil was then transferred from the conical containers on 13 August 2005 to three of the holes where it was spread out and compressed with an excavator bucket (Photograph V-12). As a result the final plots were level with the ground and were in a similar state to unexcavated soil. For the

fourth plot, fertilizer was thoroughly mixed with the soil before it was placed in the hole. The amount of fertilizer added was 124 g of urea and 21 g of DAP per plot. The same amount of fertilizer was sprinkled on top of one of the other plots. Thus the four plots were as follows:

- Control Plot 1 (CP1) – no fertilizer added
- Control Plot 2 (CP2: FAS2) – no fertilizer added – fertilizer will be added to this plot in 2006
- Fertiliser added to the surface (FAS)
- Fertiliser mixed with the soil (FAM)

The four plots were then sampled twice on 14 and 18 August 2005. For the 14 August sampling, 5 samples were collected from each plot. These were from the center and towards each corner from 0-60 cm. For the 18 August sampling one was from the center, one from near one corner and one from the opposite corner with three samples from depths 0-30 cm, 30-60 cm and 0-60 cm. Results are presented in Table V-19. The average concentrations from the two samplings was 918 ± 250 ppm and 926 ± 340 ppm. Examination of the data showed no significant difference of TPH with depth or between plots. The C_{17}/Pr ratios in the TPH from the plots was found to be 0.48 ± 0.04 , again with no difference between plots as would be expected at the start of the experiment. Initial nitrogen and phosphorus data are presented in Table V-18

Table V-18: Soil Nitrogen and Phosphorus Levels (ppm) at the In Situ Landfarm

Sample	Date	Plot	TKN	Ext. Ammonia	Ext. Nitrate	Ext. Nitrite	Total P	Ext P
RI05-1140	14-Aug-05	CP1	244	<0.25	<4	<2	270	3
RI05-1143	14-Aug-05	CP1	239	<0.25	<4	<2	310	3

In 2006 the plots will be sampled for TPH and nutrients. Soil and air temperatures will be recorded when ASU personnel are on site and fertiliser will be added to plot CP2. Methodology for sampling will be developed so as not to unduly disturb the plots. The sampling locations will be marked so that these small areas are not sampled again in future years.