E. Beach POL Area

In 2003, a complete environmental assessment of the beach POL area could not be completed because drainage of the pond between the tanks was not carried out. Results from 2003 and 2004 are included here in order to give a complete picture of the TPH contaminated area. Map V-3 gives results from 2003 while Map V-4 shows the results obtained in 2004. Map V-5 indicates only TPH concentrations > 1000 ppm and the proposed area to be excavated which incorporates concentrations > 8000 ppm.

1. Description

Two large fuel tanks are present at the beach area. In previous years the contents of these tanks had been investigated. They had contained some water and fuel. The fuel had been removed into drums and the water treated to remove phenols prior to discharge. One of the tanks now has an indentation in its side, caused by the weather, which was not present five years ago. There is a lake between the tanks (Photograph V-9) which is largely fed by the big water lake below the barrel cache valley. The Beach PCB storage facility is adjacent to the area and various other materials are stored periodically in the vicinity. The area drains past the old beach landfill, which is now remediated, and then to the sea. This distance is approximately 300-320 meters.

2. *2003 Environmental Assessment Work*

Soil samples were collected from around the two large POL tanks at the beach area in 2003. Results are shown on Map V-3.

The presence of the lake between the two tanks prevented the assessment of the sediment beneath the lake. Discussions were held to come up with a plan to drain the small lake, but it was decided that time constraints precluded this activity in 2003. As a result, the volume and level of contamination was unknown in this area. However, samples collected from the edge were only contaminated in one or two places. In general the only severe contamination was in a limited area between the lake and the westernmost POL tank. The presence of hard packed gravel made depth sampling very difficult.

The hydrocarbon contamination was characterized by analyzing three soil samples, which contained elevated TPH levels, by the CCME-TPH method. Results are given in Table V-4. These show that the F2 fraction predominates. The fingerprints from the GC traces show the petroleum product is weathered diesel fuel. Analysis for BTEX

showed no benzene (<50 ppb) or the other compounds (<100 ppb). The GC traces for all were examined in order to determine the C_{17}/Pr ratios. These ratios generally showed that there was a large difference between diesel fuel (approximately 2.0) and those found in here (0.2-0.5). Figure V-4 shows the chromatograms obtained from two locations at this area. Both are similar but the sample from position 6 has a much higher TPH level while that from position 7 has a general shift to higher molecular weight – see comparison to diesel fuel chromatogram, Figure V-1, section C. The C_{17}/Pr ratio is similar from both samples. These results showed that the TPH is being naturally bioremediated.

3. 2004 Environmental Assessment Work

In 2004 the water from the lake below the barrel cache valley was diverted past the pond between the two POL tanks. Water was pumped from the pond to reduce its area as shown in Map V-4. The lake could not be pumped dry due to water infiltration. Twenty samples were collected from various locations mostly in the area previously below the pond. Some of these samples were taken from test pits at various depths (Photograph V-10). Result are given in Table V-4 and on Map V-4. The TPH was shown to be weathered diesel from the shape and position of the peaks on the chromatograms.

4. Proposed Remediation

As the area is greater than 55 m from the sea, the remediation criteria of 8000 ppm is appropriate. Only one sample gave a result exceeding this value. The average TPH concentration in the soil below the original pond was calculated to be 2,120 ppm. Since there is an active landfarm at the site, it is recommended that the soil in the vicinity of Tag 6732 where 11,000 ppm was found be excavated and added to the landfarm. The volume of soil is estimated as 10-20 m^3. Furthermore it is recommended that this area be used to study the potential of *in situ* remediation. Some locations in the area could be marked out and fertilizer added to them after first collecting baseline TPH levels. The levels of TPH would then be measured over the next few years and compared with those of adjacent unfertilized areas. Laboratory studies are planned to parallel this – see Section G.2. The main debate over the design of this field experiment concerns the heterogeneity of the soil with respect to TPH. Hydrocarbon contaminated areas are notorious for their lack of uniform levels of TPH. Therefore consideration is being given to excavating most of the area, screening the soil and replacing it. Screening was very successful in creating a relatively uniform TPH concentration in the main landfarm constructed as described in section F.3 below.

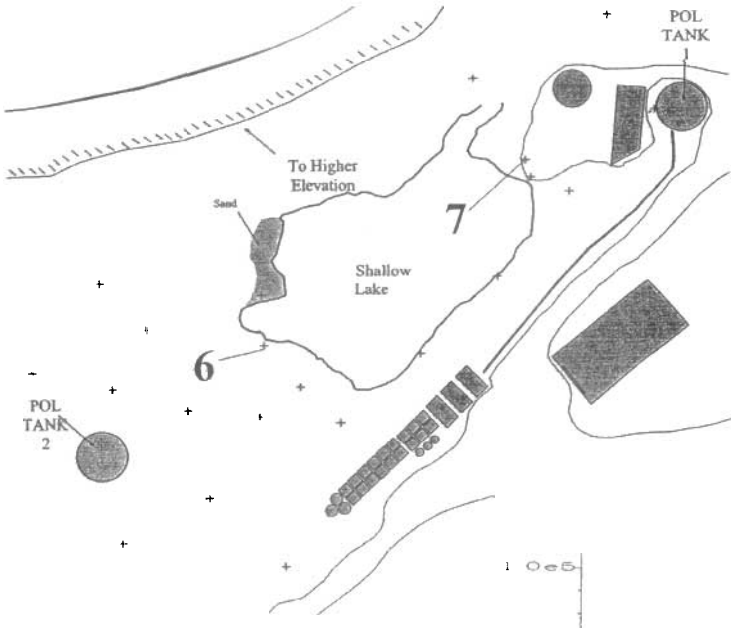
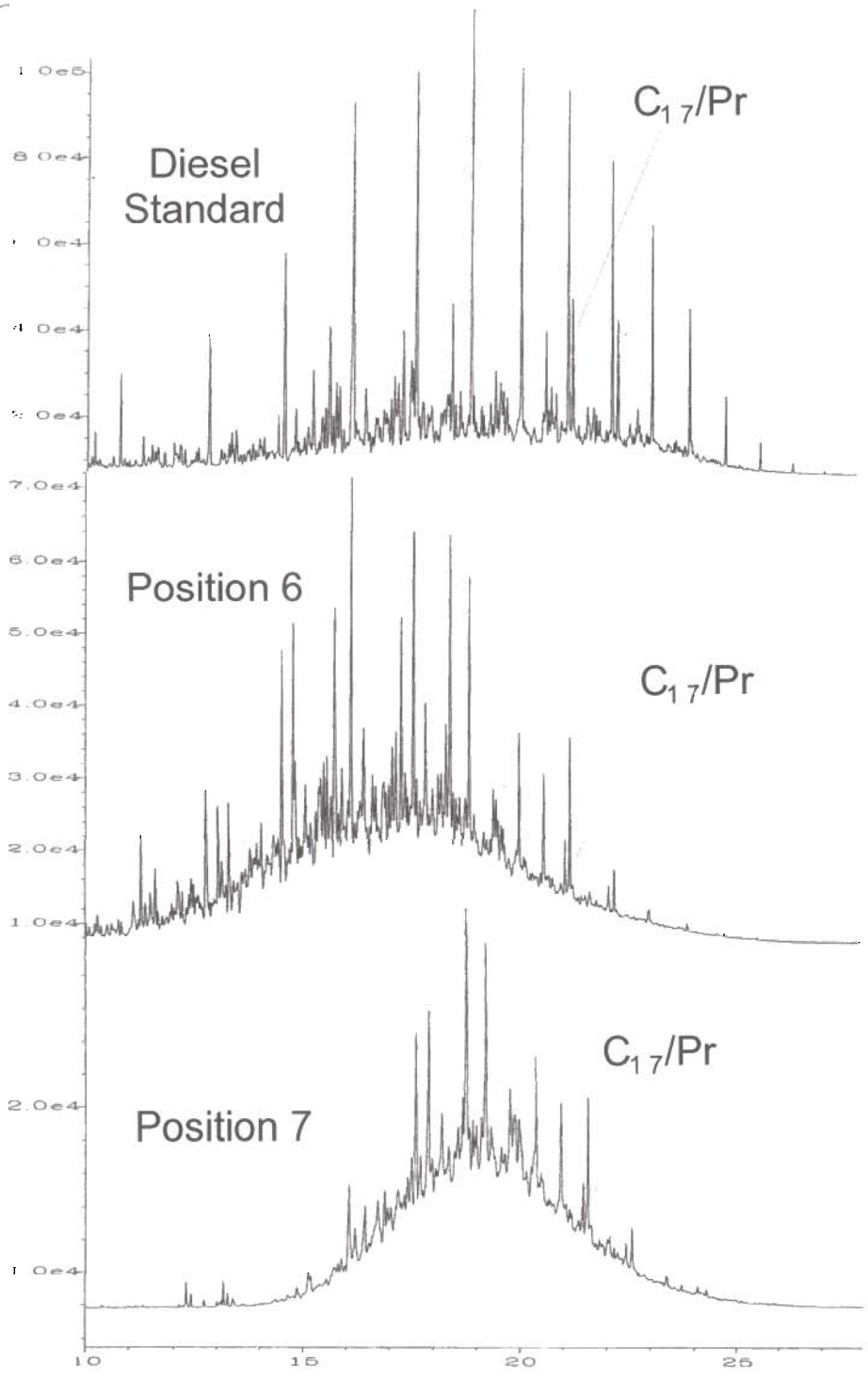
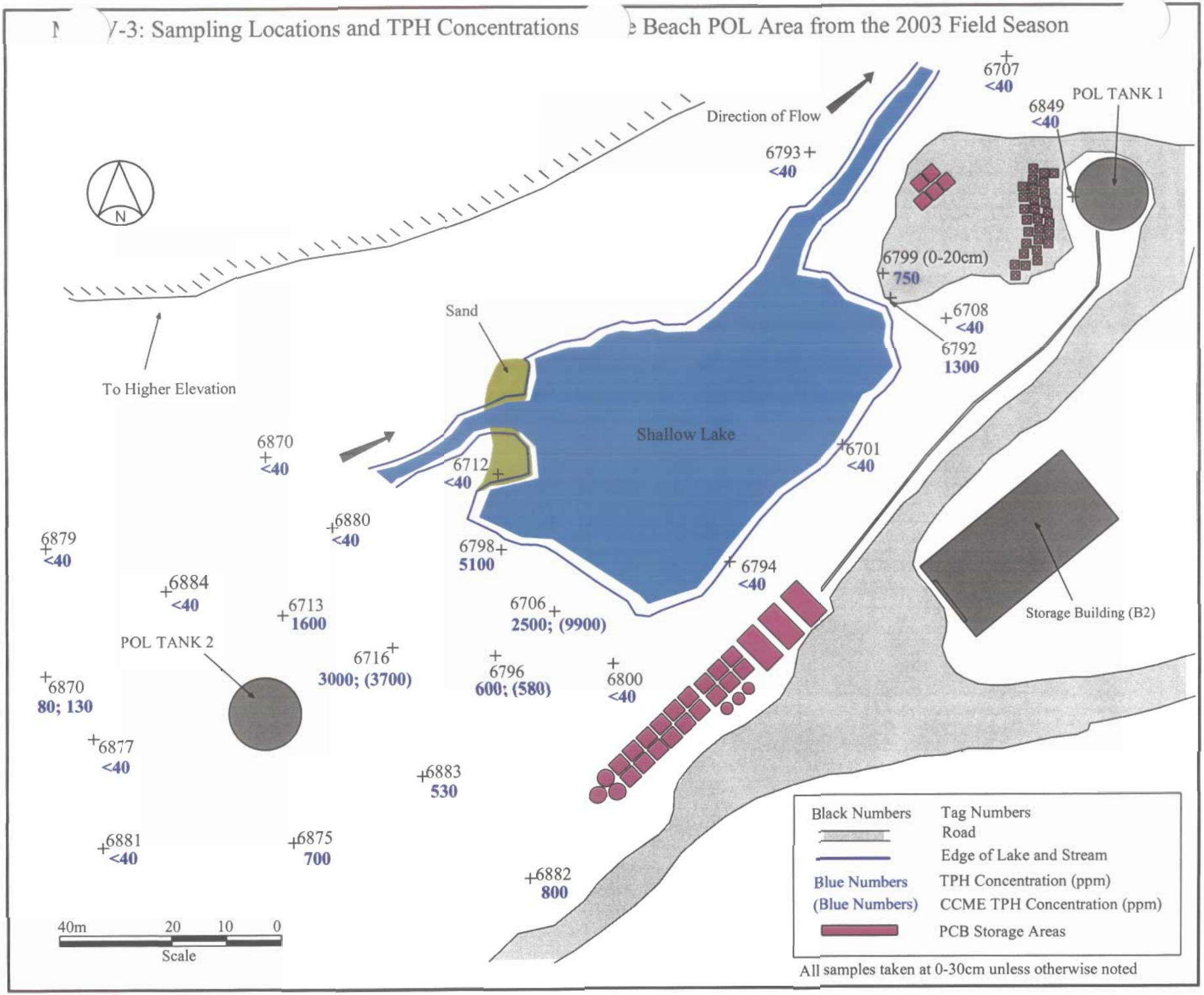
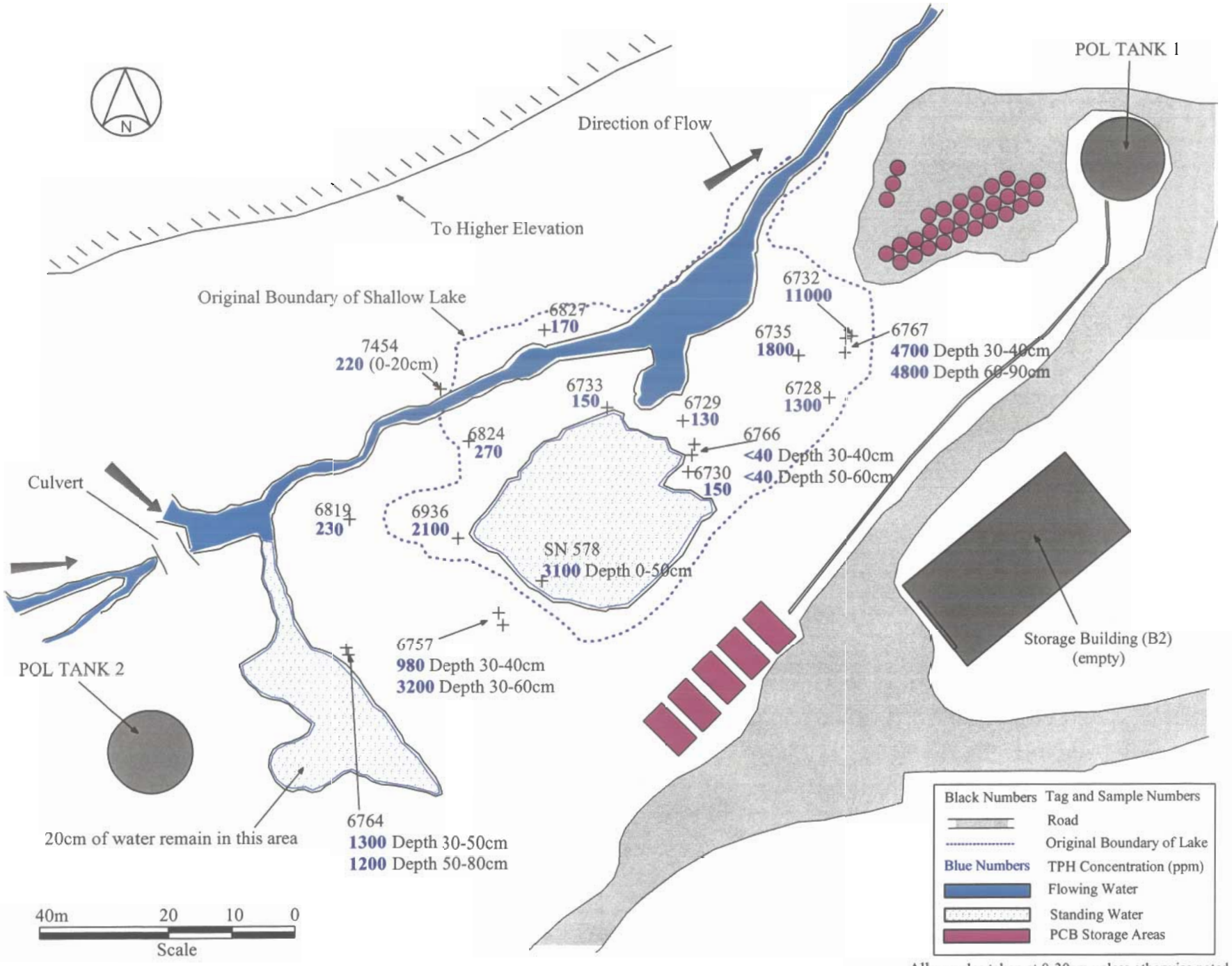


Figure V-4: Chromatograms of Hydrocarbon Contamination at the Beach POL Area



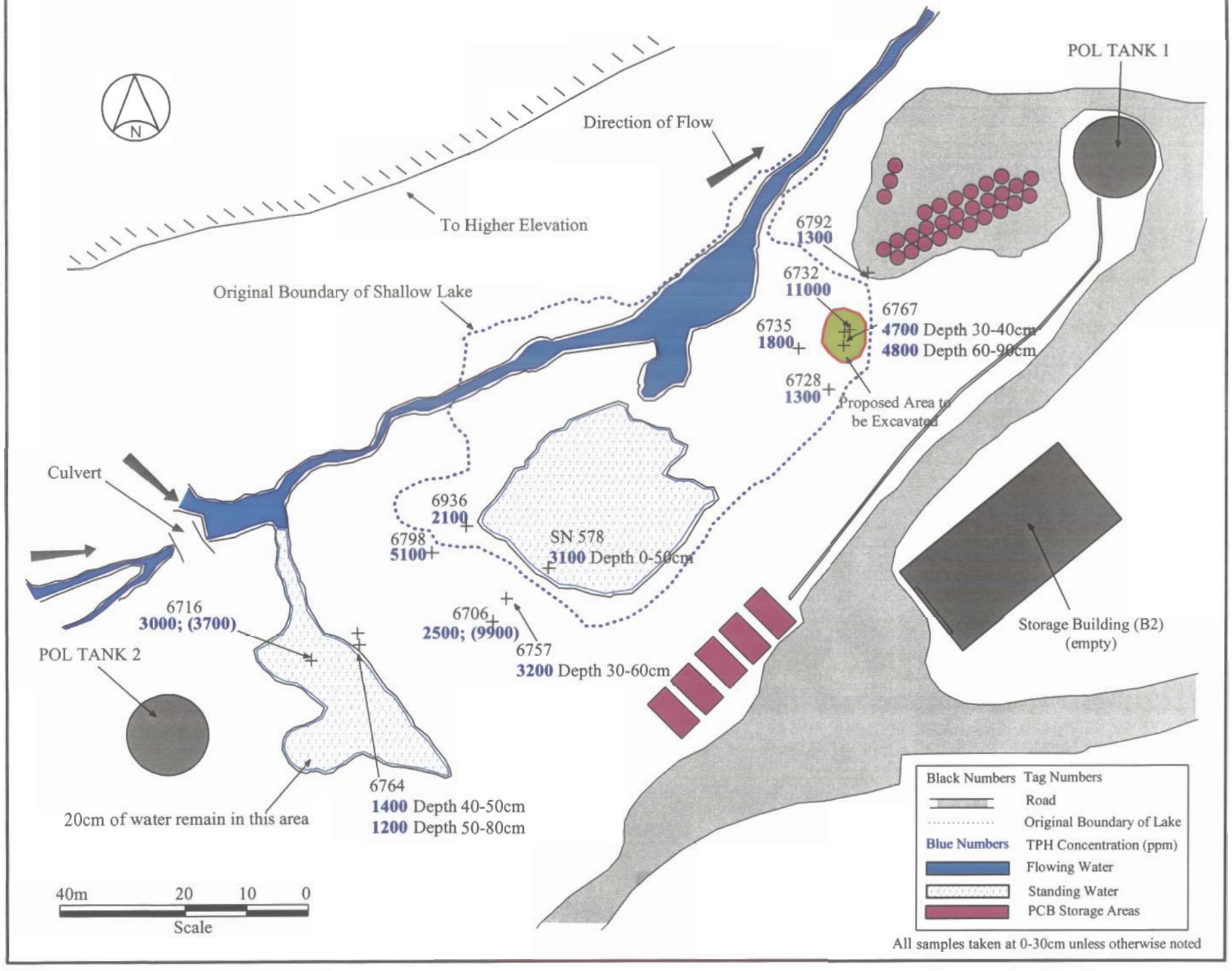

Y-3: Sampling Locations and TPH Concentrations
e Beach POL Area from the 2003 Field Season
N
Direction of Flow
To Higher Elevation
Sand
Shallow Lake
POL TANK 1
POL TANK 2
Storage Building (B2)
6707 <40
6849 <40
6793 <40
6799 (0-20cm) 750
6708 <40
6792 1300
6701 <40
6794 <40
6870 <40
6712 <40
6880 <40
6879 <40
6798 5100
6884 <40
6713 1600
6706 2500; (9900)
6716 3000; (3700)
6796 600; (580)
6800 <40
6870 80; 130
6877 <40
6883 530
6881 <40
6875 700
6882 800
40m 20 10 0
Scale
Black Numbers Tag Numbers
Road
Edge of Lake and Stream
Blue Numbers TPH Concentration (ppm)
(Blue Numbers) CCME TPH Concentration (ppm)
PCB Storage Areas
All samples taken at 0-30cm unless otherwise noted

N -4: Sampling Locations, Tag and Sample Numbers and Concentrations at the Beach POL Area for the 2004 Field S n



All samples taken at 0-30cm unless otherwise noted

V-5: Soil TPH Concentrations >1000 ppm at th ach POL Area and the Proposed Area to be Excav



All samples taken at 0-30cm unless otherwise noted

Photograph V-9: The Pond Between the Two POL Tanks After Draining: The Original Boundary of the Pond is Outlined by the Brown Staining

Photograph V-10: Collecting a Soil Sample From a Pit in the Previously Ponded Area

Table V-4: Results of Analyses of Delineation Samples for CCME-TPH at the Beach POL Area Obtained in 2003

Samples	F1 (C6-C10)	F2 (C10-C16)	F3 (C16-C34)	F4 (C34-C50)	Total
RI03-334	<10	3630	70	<40	3700
RI03-342	13	420	150	<40	580
RI03-343	200	8100	1600	<40	9900

Table V-5: Results of Analyses of Delineation Samples for TPH at the Beach POL Area

Sample Number	Tag Number	Depth (cm)	TPH (ug/g)
578	-	0-50	3100
592	6728	0-30	1300
590	6729	0-30	130
589	6730	0-30	150
593	6732	0-30	11000
588	6733	0-30	150
591	6735	0-30	1800
603	6757	30-40	980
576	6757	30-60	3200
598	6764	30-50	1300
580	6764	50-80	1200
582	6766	50-60	<40
602	6766	30-40	<40
575	6767	60-90	4700
596	6767	30-40	4600
583	6819	0-30	230
585	6824	0-30	270
587	6827	0-30	170
586	6936	0-30	2100
584	7454	0-20	220

F. Landfarming

1. General

The term landfarming generally refers to the process where TPH contaminated soils are spread out in a layer about 0.5 m thick, nutrients are added and periodically the soils are mixed. During landfarming TPH can be lost through volatilization or bioremediation and thus landfarming refers to the combination of the two processes. The main concern regarding the viability of landfarming in the Canadian Arctic is the low temperatures. Both volatilization and bioremediation are affected by temperature and the rate of removal of TPH will decrease with decreasing temperature for both mechanisms. Trials involving landfarming or bioremediation have been conducted in both the Arctic and Antarctic with mixed results. Research has shown the presence of organisms adapted to cold conditions at sites where hydrocarbon contamination is present in the soils in polar regions. However, as far as we know, no definitive research has been conducted to determine the relative contributions of aeration and bioremediation at different temperatures. Neither has the practicality of conducting landfarming at reduced temperatures been demonstrated adequately. The soil temperatures at which the rate of removal of TPH is too slow to be useful is unknown.

In order to address some of these knowledge gaps and to try to decide what approach to take to deal with TPH contaminated soils at Resolution Island, it was decided to set up a small trial landfarm experiment at the site in 2003. In addition, laboratory experiments have been conducted at Queen's University and these are ongoing (see Section G).

2. Trial Plots Constructed in 2003

a) Construction and Monitoring

Four trial plots were established on 6 August 2003 and these have been operated and monitored both in 2003 and 2004. Soil was excavated from both the imploded tank drainage site and the beach POL area and was mixed, rocks were removed and the soil spread out into four plots. Each plot measured 5 m by 5 m with a depth of 0.3 m. The four plots were each subjected to a different regime.

- Control plot, no action except the three sample collections
- Daily rototilling in 2003, rototilling every fine day in 2004
- Rototilling every four days in 2003, every four fine days in 2004
- Rototilling every four days and addition of fertilizer

In 2004 it was decided to rototill only when the weather was dry as experiences in 2003 had shown that rototilling under very wet conditions was not productive. Fertiliser addition was based on a C:N:P ratio of 100:7.5:0.5 and was not applied until 24 August 2003. Rototilling was carried out (Photograph V-11) to the approximate depth of the plots. Samples were collected periodically for analysis from each plot (Photograph V-12). For each sampling time for each plot, five soil samples were collected. These were from towards the four corners of the plot plus one from the central area. At each location a hole was dug to about 25 cm and a soil profile from the edge of the hole collected with a clean scoopula.

b) Analytical Results

Analytical results obtained from the four plots at three different times in 2003 and 2004. Results are given in Table V-7, summarized in Table V-6 and presented graphically in Figure V-5.

Table V-6: Summary of Results of Analyses of Soil Samples for TPH from the Landfarm Plots in 2003 and 2004

Plot Regime	TPH – Weathered Diesel Fuel (ppm)					
	08-Aug-03	24-Aug-03	08-Sep-03	7-Jul-04	8-Aug-04	28-Aug-04
Control	3060	1600	2400	1950	1780	990
Everyday	2820	1120	1430	1050	700	260
Every 4 days	2780	1840	2380	1550	1050	690
Fertilised	2680	1450	1240	520	310	100

These results show a dramatic decrease in the TPH levels with time. The final results from samples collected on 28 August 2004 were all low for all plots, including the control plot in which TPH level which fell from 1780 to 980 ppm. A similar trend was

seen in second sampling in 2003. The explanation for this is unknown but may relate to weather conditions at the time of sampling. It is also possible that the disturbance of the soil in the construction of the landfarm created conditions that promote TPH loss through aeration or leaching. TPH levels in all plots have decreased over the two year period. The fertilized plot shows a striking decrease in TPH levels by over 90 %. The daily aerated plot similarly shows losses in excess of 80 %, while the aerated every 4 days shows lower reduction in TPH levels.

One of the major areas of interest that it was hoped that this experimental landfarm would shed some light on concerned the viability of aeration and bioremediation as separate mechanisms to remediate TPH in the Canadian Arctic and their relative contributions under certain conditions. The data in Table V-6 show a clear and dramatic reduction over time and it would seem that the addition of fertilizer had a significant effect. This idea can further be explored by examination of the C_{17}/Pr ratio in the chromatograms. Figure V-6 shows that for the 3 plots with no fertilizer added, the C_{17}/Pr ratios remained unchanged indicating that no measurable bioremediation was occurring. Moreover the figure shows that, for the plot which had fertilizer applied on the C_{17}/Pr ratios was dramatically reduced indicating significant bioremediation had occurred. This data therefore demonstrates that bioremediation is viable at the site but shows that aeration can also achieve very significant reductions in TPH. Obviously the addition of fertilizer is much easier and cheaper to implement than is a daily rototilling regime. The fertilized plot was rototilled every four days so it is not yet known how necessary this soil aeration step was in assisting the bioremediation; oxygen is necessary for bioremedition of TPH to occur. The laboratory experiments that are underway should help to answer this question and lead to an optimal landfarm operation protocol.

Soil temperatures were measured periodically in July and results are presented in Table V-8. Temperatures were recorded at 10 cm depth for each of the four plots and the mean temperature calculated. The average soil temperature found was 14 °C. This high soil temperature is the result of solar heating and the albedo effect. It is also probable that the rototilling of the soil helped to raise the soil temperature at depth. As a result it is not yet clear whether the fertilized plot would have been so successful if it had not been rototilled every four days. Without rototilling a more uniform temperature gradient within the soil would have resulted with the soil being colder at depth. This could have resulted in a much slower bioremediation rate. It is hoped to answer this very important question through additional laboratory experiments and field trials.

Figure V-5: Change of TPH with Time for the Trial Landfarm

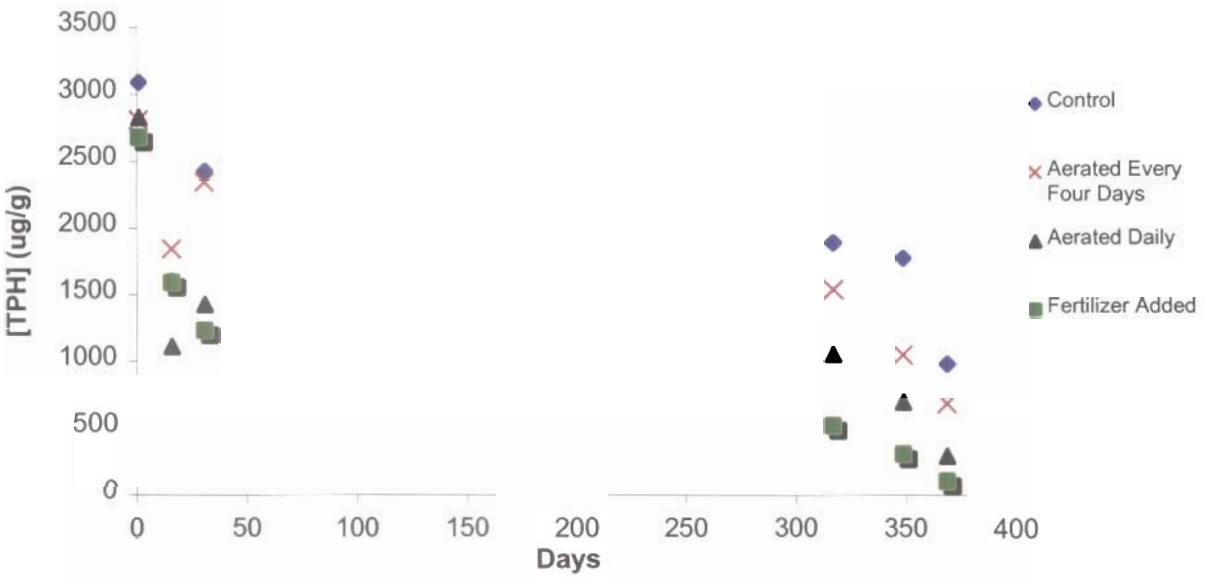
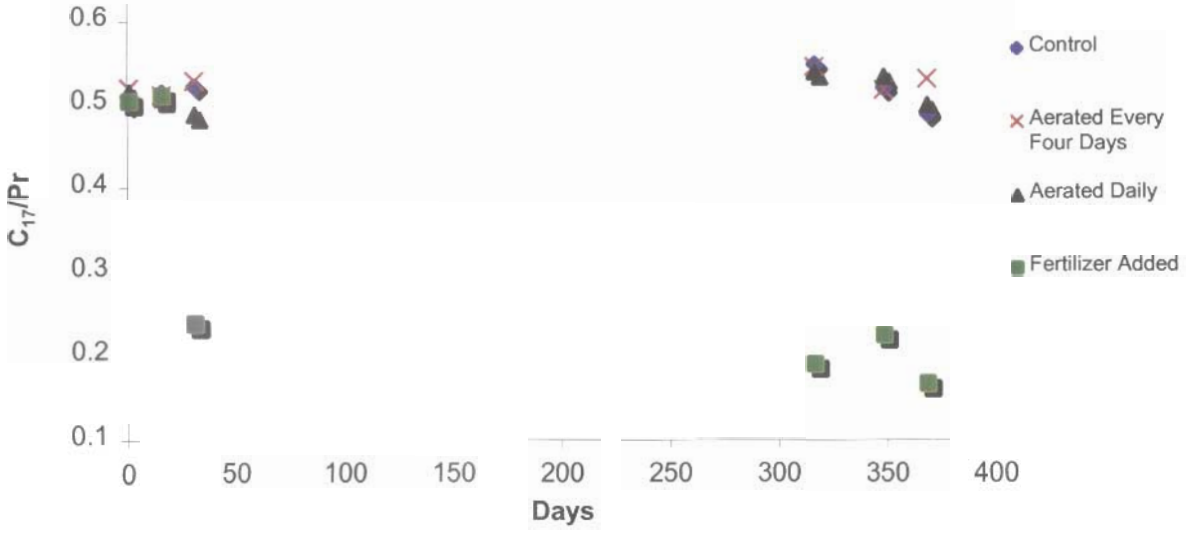


Figure V-6: Change of C_{17}/Pr Ratio with Time For the Trial Landfarm



Photograph V-11: Rototilling the Trial Landfarm Plots

Photograph V-12: Collecting Soil Samples From the Trial Landfarm Plots

Table V-7: Results of Analyses for TPH from the Landfarm Plots in 2003 and 2004

Plot Regime	TPH – Weathered Diesel Fuel (ppm)					
	08-Aug-03	24-Aug-03	08-Sep-03	7-Jul-04	8 Aug-04	28-Aug-04
Control	4400	2200	2100	1750	1470	830
Control	2800	1200	2400	2100	1860	1250
Control	2800	1800	2200	1700	2350	930
Control	2600	1300	3100	2250	1840	940
Control	2700	1500	2200	nd	1390	nd
Everyday	3700	1200	1300	1100	900	120
Everyday	2900	1400	1500	1050	550	220
Everyday	3000	820	2300	840	750	280
Everyday	2100	1400	960	1200	490	425
Everyday	2400	760	1100	nd	820	nd
Every 4 days	4100	2600	3900	1600	1430	710
Every 4 days	2500	1600	2100	1400	1470	860
Every 4 days	2500	1700	2200	1700	1000	730
Every 4 days	2000	1800	1600	1500	740	450
Every 4 days	2800	1500	2100	nd	610	nd
Fertilised	3400	1800	940	640	290	130
Fertilised	1700	740	910	440	340	89
Fertilised	2700	1500	1900	460	270	99
Fertilised	2600	1200	1500	550	270	95
Fertilised	3000	2000	960	nd	380	nd

nd: not determined, reserved for CCME-TPH, biograder, N and P analysis

Table V-8: Soil Temperatures (°C) Recorded at the Trial Landfarm Plots in 2004

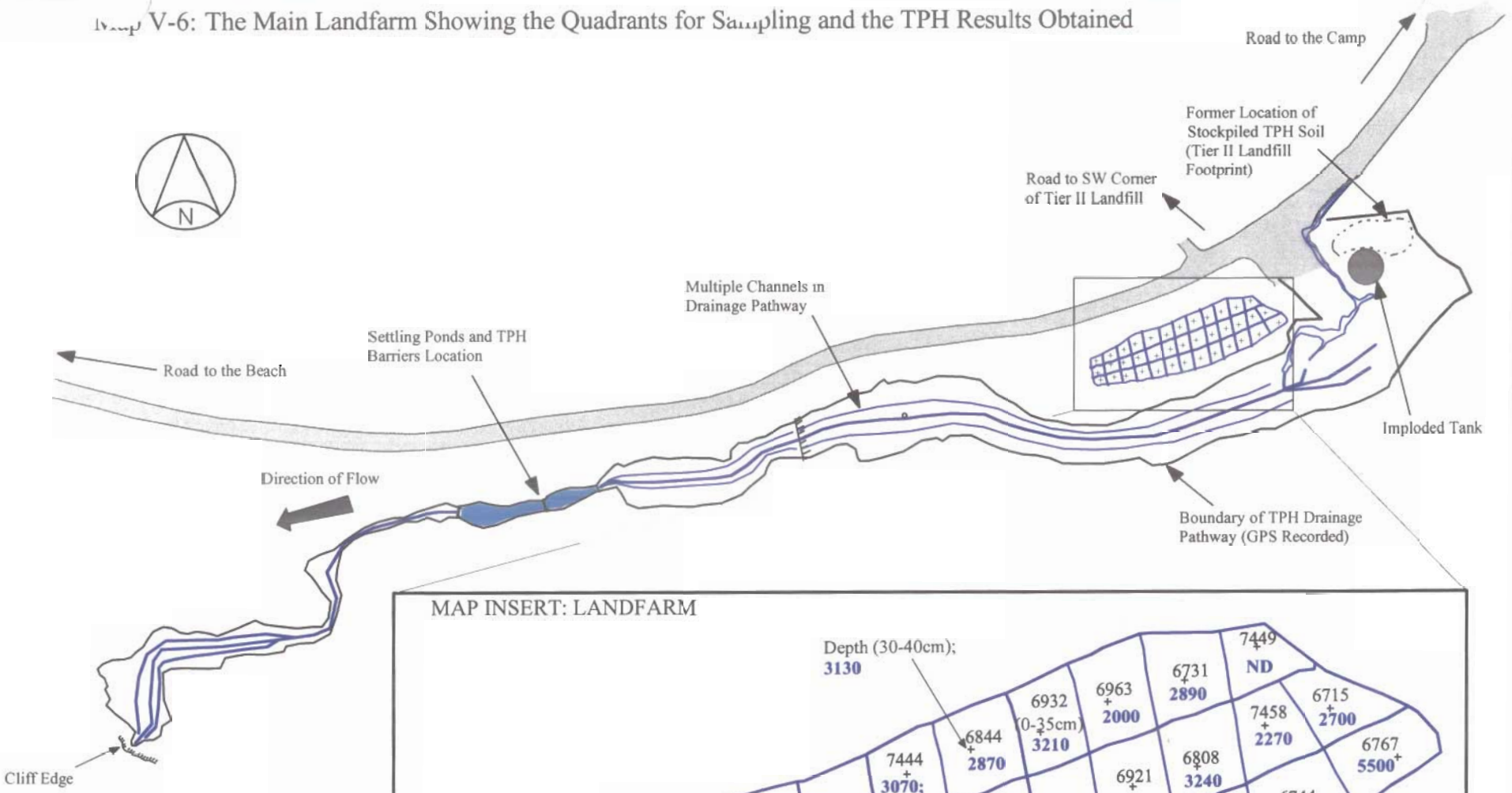
Date	Temperature	Date	Temperature	Date	Temperature	Date	Temperature
Jul 03	16.4	Jul 05	13.7	Jul 07	12.2	Jul 11	13.4
Jul 13	13.7	Jul 14	17.9	Jul 15	25.5	Jul 17	10.7
Jul 18	11.0	Jul 20	10.3	Jul 21	11.5	Jul 25	15.5
Jul 26	14.6	Jul 28	12.7	Jul 29	12.6	Jul 30	13.1

3. *Main Landfarm Construction*

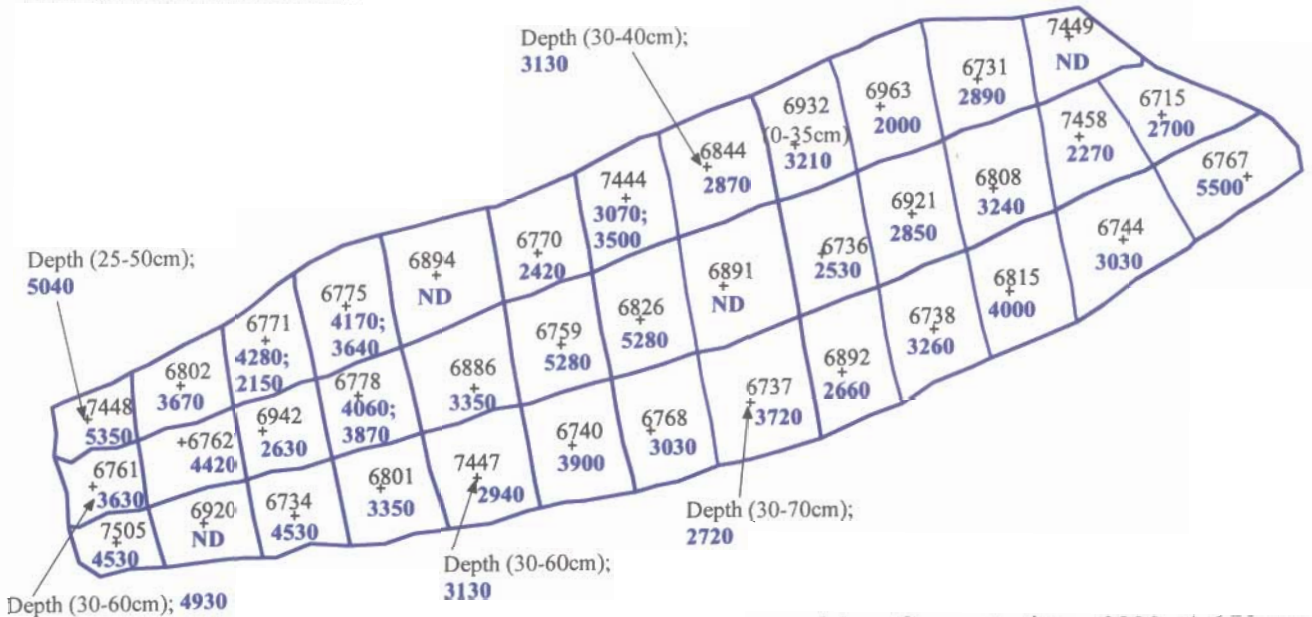
A major landfarm was set up this year in order to remediate the high fuel contaminated soil at the site. This soil came from two sources, the area around the imploded tank and material removed from beneath the Tier II landfill site. The areas identified around the imploded tank and drainage pathway as containing > 8000 ppm diesel fuel as specified in the 2003 ASU report were marked out with rope. These areas were then excavated and the resulting soil, together with that from the Tier II landfill excavation, were passed through a two inch screener (Photograph V-13). The screened soil was then spread out in an area near the imploded tank as shown in Map V-6. The approximate size of the area was 76 m by 21 m with a depth of about 0.5 m. The area was 1390 m^2 and a volume of 700 m^3. Fertilizer was then added at a rate of 117 g urea and 1.8 g diammonium phosphate per m^2. The whole area was then rototilled (Photograph V-14). A grid was then set up over the landfarm with an approximate quadrant size of 7 m by 7 m as shown in the inset of Map V-6 and Photograph V-15. Soil samples were collected from each quadrant of the grid as in the trial landfarm and analysed for total TPH. Results are shown in Table V-9 and on Map V-6. The concentration of the TPH in the landfarm was 3320 ± 970 ppm. This average is from the 39 samples analysed. Five samples were reserved for further analysis of CCME-TPH, nitrogen, phosphorus and biodegraders. The landfarm as shown in Photograph V-16 was completed on 30 August and soil samples taken on 3 September 2004.

Urea was added such that the nitrogen level was < 2000 mg/kg soil water. More urea may be added next year depending on the carbon, nitrogen moisture levels. The aeration regime for the landfarm will be based on the results from the laboratory studies currently underway. It is planned that the harrow that was purchased in 2003 will be used to aerate the landfarm as rototilling the large area will take about 5 hours.

Map V-6: The Main Landfarm Showing the Quadrants for Sampling and the TPH Results Obtained



MAP INSERT: LANDFARM



	Road
Black Numbers	Tag Number
Blue Numbers	TPH Concentration (ppm)
(Blue Numbers)	CCME TPH Concentration (ppm)
ND	Not Determined

All samples taken at 0-30cm unless otherwise noted

Photograph V-13: The Hydrocarbon Contaminated Soil Was Screened Prior to the Construction of the Main Landfarm

Photograph V-14: Rototilling the Main Landfarm