Resolution Island 2007

Monitoring and Research

Analytical Services Unit
Queen's University

Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada

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Prepared by

Analytical Services Unit
Queen's University
Kingston, Ontario

Canada

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EXECUTIVE SUMMARY

This was the first year after the completion of the remediation of the site. The work at the site, therefore, primarily involved monitoring activities. Research related to PCB barriers continued but this was conducted mostly at Queen's University. This report describes this work undertaken by the ASU at Queen's University in 2007 for Indian and Northern Affairs Canada.

The field work was managed by the ASU this year. This included logistics (travel, food and accommodation), the employment of a bear monitor as well as the actual on site monitoring. The ASU team of four personnel were on site for 9 days. The monitoring tasks comprised sampling and analysis of a) the thirteen monitoring wells and their adjacent soil monitoring points at three landfills, b) the ten plant monitoring points and c) the main landfarm and experimental in situ landfarm plots, and the maintenance and monitoring of the three PCB barriers. The resulting plant data was particularly interesting in that it demonstrated a significant reduction in the amount of aerial transport of PCBs at the site in comparison the previous years, both before and during remediation.

The maintenance of the three PCB barriers designed to stop PCBs from migrating to the sea involved excavating sediment by hand from the funnel areas of the barriers and placing it in overpack drums. These drums were left by the barriers in stable locations but will require removal next year along with similar sediment generated next year. The filters in the gate system were sampled and replaced. The new filters included several layers of geotextiles designed to trap finer particles which contain higher concentrations of PCBs. Research work reported this year relates to the retention and partitioning of PCBs between soil and granulated activated charcoal (GAC) and water.

Diesel fuel levels in the main landfarm have continued to decline. The level of 810 ppm found this year is considerably lower than the starting level of 3320 ppm. The in situ plots gave encouraging results but more time is needed to evaluate their performance. The main results of research related to the landfarms have been the development of an understanding of the relative roles of aeration and bioremediation in landfarming at cold temperatures, the isolation of the factors which promote these two pathways, and the optimization of parameters for the successful application of landfarming in cold climates and its limitations. This work formed the basis of a talk at ARCSAAC this year.

ACKNOWLEDGMENTS

The work was supported by Indian and Northern Affairs Canada through its office in Iqaluit, Nunavut. We would like to thank Lou Spagnuolo for making the project run so smoothly this year.

Allison Rutter of Queen’s University directed the project. The on site team leader, Indra Kalinovich was ably assisted by Nathan Manion, Justin Dee and Sarah Slater. Bear monitoring was provided by Simiga Korgak. Maps were done by Graham Cairns. This report was written by John Poland and edited by Allison Rutter.

Laboratory analyses were conducted by Queen’s University Analytical Services Unit, Kingston, Ontario. Thanks are due to Paula Whitley, Mary Andrews, Michele Pacey, Kevin McKenna and Kalam Mir, in addition to those listed above, who provided their usual high professional standards.

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A. Introduction

1. *General*

This is the first year since the completion of the remediation of the site at Resolution Island. Last year nearly all the equipment was removed from the island and therefore this year marks the start of the monitoring program operating at the site with minimal support. The Analytical Services Unit (ASU) has been contracted by Indian and Northern Affairs Canada (INAC) through a contribution agreement to conduct this work together with a continuation of the on-going research program centered at Resolution Island.

Over the period 1993-1996, environmental work at the site was detailed in a set of reports entitled "Environmental Study of a Military Installation at Resolution Island, BAF-5". These reports[1] fully described items such as site characteristics, history, and previous investigations. Scientific investigations have continued and have been reported annually[2]. From 1997 onwards, work at the site was managed by the Qikiqtaaluk Corporation (QC) through a contribution agreement with INAC. This work started in 1997 with infrastructure improvements and expanded from 1998 onwards to include remediation activities and training. The three year plan to complete the work at the site was initiated in 2003[3] and was essentially completed in 2005. The site was demobilized in 2006 with the removal of the heavy equipment relating to the remediation project, and the mobile laboratory and demolition of the camp. Map 1 shows the location and general layout of the site at Resolution Island.

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[1] Environmental Sciences Group (1994). Volume One, Analytical Services Unit (1995) Volume Two, Analytical Services Unit and Environmental Sciences Group (1996) Volume Three, and Analytical Services Unit (1997) Volume Four: Environmental Study of a Military Installation at Resolution Island. BAF-5. Prepared for Indian and Northern Affairs Canada.

[2] Analytical Services Unit (1998), (1999), (2000), (2001), (2002) (2003) (2004) (2005) (2006) and (2007). Resolution Island 1997: Scientific Investigations, Resolution Island 1998: Scientific Investigations: Resolution Island 1999: Scientific Investigations, Resolution Island 2000: Scientific Investigations: Resolution Island 2001: Scientific Investigations: Resolution Island 2002: Scientific Investigations: Resolution Island 2003: Scientific Investigations and Research: Resolution Island 2004. Prepared for Indian and Northern Affairs Canada: Scientific Investigations and Research: Resolution Island 2005. Prepared for Indian and Northern Affairs Canada Scientific Investigations and Research: Resolution Island 2006. Prepared for Indian and Northern Affairs Canada

[3] Analytical Services Unit (2003). Resolution Island Project Description and New Remediation Plan Revision 1 March 2003. Prepared for Indian and Northern Affairs Canada.

This report details the tasks carried out by the ASU in 2007 both on site and at the ASU laboratories at Queen's University. The report includes a section detailing research and activities relating to the design and construction of permanent barriers to intercept PCBs in drainage pathways. The appendix includes all QA/QC documentation.

2. On Site Scientific Investigations

The Queen's University team, composed of four ASU personnel and a bear monitor, Simiga Korgak, from Iqaluit, were on site from 30 July to 7 August 2007. Equipment and supplies used by the ASU were flown to Iqaluit and transported into and out of the site by Twin Otter aircraft (Photograph 1)**.** A helicopter was available for an hour on 1 August to move barrier supplies (GAC, gravel and overpack drums) to the beach site. The road to this location was completely removed in 2006 and impassable to even ATVs due to the soft ground conditions. This location was reached by walking from the beaching area near building B2. The road from the beach to the summit was passable by ATV though the steep area near the water lake showed considerable erosion.

The ASU managed all the logistics for this visit. The old training center worked well for accommodation (Photograph 2). The sewage pipe at the building became detached but was reconnected satisfactorily. Food was flown in via Iqaluit from Ottawa along with the team on 30 July. Drinking and cooking water was obtained in four 20 L jugs by ATV and trailer from the old water lake, while washing water was taken from a small pond above the road to the furniture dump. Polar bears were sited on 2 days.

The main tasks completed by the ASU this year are listed below:

- Sample the Tier II landfill monitoring wells and associated soil monitoring points. Collect one sample from each. Sample the monitoring wells and associated soil monitoring points at the airstrip and maintenance dumps.

- Inspect all landfills – note any subsidence, visible debris, leaching.

- Collect and analyse background plant samples.

- Record soil temperatures at the main landfarm and in situ plots while on site.

- Sample the main landfarm.

- Sample the in situ landfarm plots. Add fertilizer to control plot #2 (FAS2) after sampling.

- Inspect and sample the monitoring points along the imploded tank drainage pathway

- For each PCB barrier, inspect and photograph, sample soil in trap, excavate soil and sample monitoring points (soil and water), sample filters, refill filter cassettes and add geotextile filters as appropriate, re-establish clean cells.

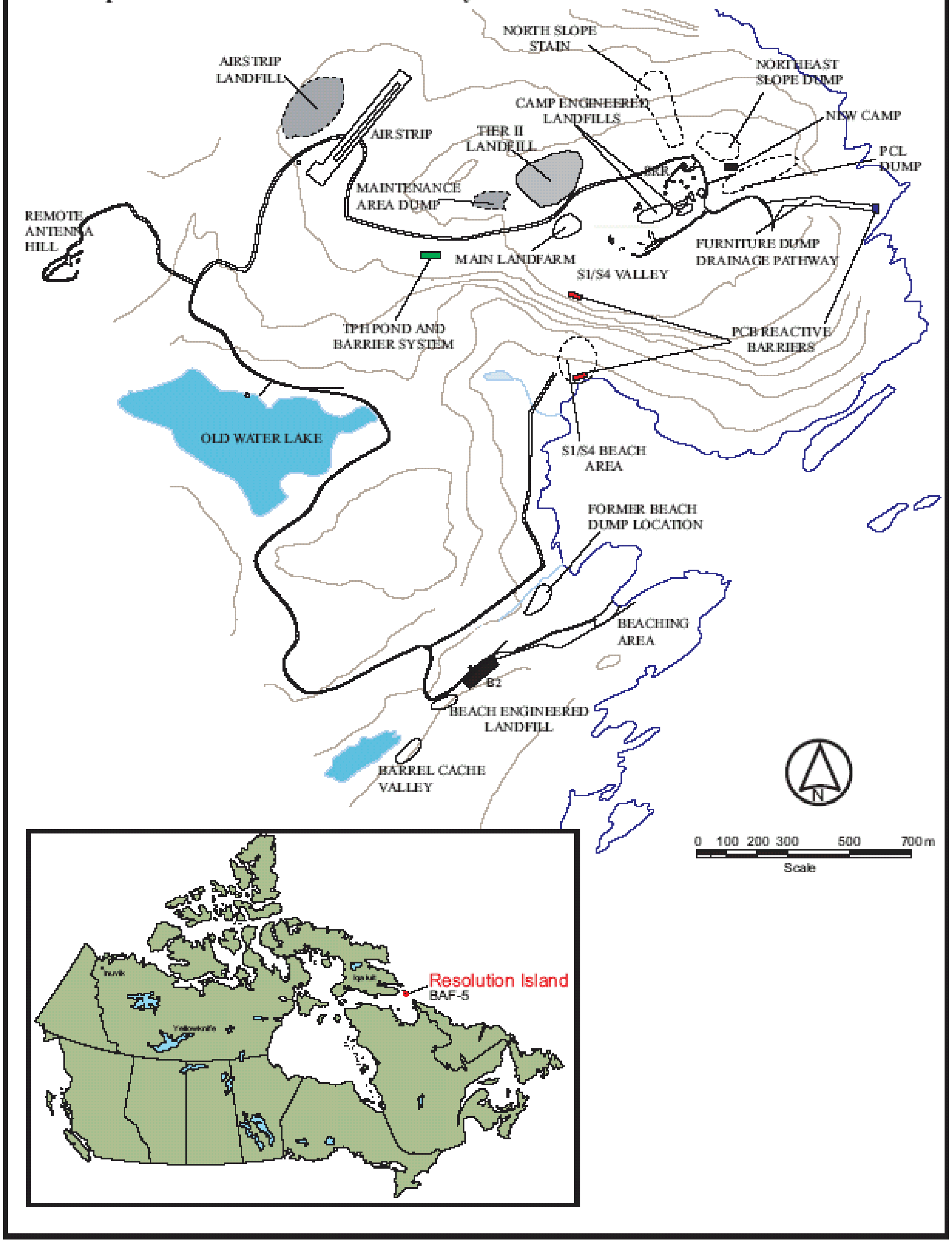
- Fill barrels with sediment from the barriers. Position the barrels such that they can be rolled on to a net for helicopter removal. Label barrels as per previous year.

- Refill filter cassettes with clean sand and GAC. Add geotextile filters as appropriate.

- Continue to conduct laboratory and field experiments with respect to the design and construction of permanent interceptor barriers.

- Continue research into barriers and TPH remediation. Liase with Australian Antarctic Division. Continue with the Canadian Antarctic Research Program (CARP) initiative.

Map 1: Location and General Layout of the Site at Resolution Island



Photograph 1: Preparing to Leave on the Twin Otter

Photograph 2: Loading ATVs for Work at the New Camp

3. Long Term Monitoring Plan

This is the first year of the long monitoring program. The plan recommends continuing annual monitoring for 5 years followed by a 3 year and then 5 year visit.

4. Other Activities

The two research projects were continued this year. These were related to the construction of permanent PCB barriers at the site and assessment and remediation of hydrocarbon contaminated soils. Indra Kalinovich is continuing her work towards a PhD related to the PCB barriers. A 4th Year student, Chen Liang, did some of the TPH laboratory work for his project.

Two papers were presented at ARCSACC in May 2007. "Remediation of Hydrocarbon Contaminated Soils in the Canadian Arctic with Landfarms" was presented by Dr Poland. Indra Kalinovich presented “The Relative Performance of Geotextiles and Granular filters for containing PCBs”. The paper “Remediation of Hydrocarbon Contaminated Soils in the Canadian Arctic by Landfarming” has been submitted. Collaboration continued with the Australian Antarctic Division. Dr Ian Snape and Dr John Radcliff visited Kingston in May 2007. Dr Rutter will be the chair of Contaminants in Freezing Ground (CFG7) in Kingston in June 2010. Three papers have been submitted to CFG6 which will be held in Vermont in June 2008. The TPH research will be presented by Dr Rutter, the barrier work by Indra Kalinovich and Dr Zeeb will present data from the Resolution Island plant monitoring in combination with data from other Arctic plant monitoring data.

B. Methodology

1. *Sampling*

Soil samples for metals and PCBs were collected using plastic scoops and placed in WhirlPak bags. Soil samples for TPH were placed in 250 mL glass amber jars which were completely filled to allow no headspace. Water samples for PCBs were collected in 1 L Teflon bottles or 1 L glass bottles with teflon lined lids. Water samples for metals were collected in 250 mL plastic bottles and water samples for TPH in 250 mL glass amber bottles with Teflon lined lids. Soil and Water samples were kept at 4 °C prior to analysis. Plant samples were wrapped in foil and placed in ziplock bags. Plant samples were not washed and were kept frozen prior to analysis.

Samples were shipped by air freight to Queen's University for testing. In order to conform with regulations regarding sample control, a rigorous chain of custody was maintained. Chain-of-custody forms were filled out and checked for each sample before shipment from the North, and the contents of shipments were verified upon receipt in the laboratory. The relevant documentation is available on request.

2. *Analysis*

a) <u>Metals</u>

Soil samples were air-dried and ground to a fine powder with a mortar and pestle; large stones were removed as they would not be expected to contain any anthropogenic environmental contamination. Approximately 0.5 g of this dried material was heated with 2 ml nitric acid and 6 ml hydrochloric acid overnight so that the volume was reduced to 1-2 ml. This solution was then made up to 25 ml, and analyzed by inductively coupled plasma atomic emission spectroscopy (ICP/AES). The ICP/AES analysis was conducted using a Varian Vista Pro Spectrophotometer with axial configuration. While it is recognized that the digestion procedure used may not bring all metals into solution (some metals may be locked into silicate minerals), it is felt that the metals released into solution are of greater environmental significance than true total metals.

Water samples were concentrated by evaporating 160 mL of sample, refluxing in acid and making the sample up to 10 mL. The resulting solution was run on the ICP spectrometer as for metals in soil. This is the method for total metals. For dissolved metals, 160 ml of sample was filtered through a filter paper and the procedure for total metals carried out without refluxing with acid.

b) Total TPH Analysis

Soil samples were homogenized and sub-samples dried for moisture determination. A wet sample (10 g dry equivalent weight) was mixed with anhydrous sodium sulphate and Ottawa sand in an Erlenmeyer flask. Pesticide grade hexane (40 mL) was added, and the flask ultrasonically agitated. For wet samples additional hexane and sodium sulphate was added. A 1-mL aliquot of the hexane extract was pipetted from the flask in a manner ensuring no transfer of solid material, and sealed in a gas chromatography (GC) vial.

For water samples, 100 mL was accurately measured and transferred to a clean, 125 mL glass separatory funnel. Hexane, 10 mL, was added and the mixture shaken vigorously and then allowed to separate. If emulsions formed, the funnel was briefly sonicated to ensure adequate phase separation. An aliquot of the hexane phase was then transferred to a GC vial. For low level detection the samples were concentrated by blowing down with nitrogen gas to about 0.5 mL before transfer to a GC vial; the final volume was determined accurately with a syringe.

The hexane extracts were analysed by GC/FID using a Hewlett Packard gas chromatograph with flame ionization detector. TPH was quantified by comparing the chromatogram peak area of the sample with that of the standard; standards of fuel oil and lubricating oil were prepared in hexane. Compound identity was determined by comparing the sample chromatogram with those of known hydrocarbon mixtures.

c) C_{17}/Pristane and C_{18}/Phytane Ratios

Diesel fuel contains two pairs of compounds with very similar boiling points but for each pair, one is a straight chain alkane while the other is branched. Because the straight chain alkane is volatilized at the same rate as its branched counterpart but the straight chain hydrocarbon is bioremediated faster than the branched counterpart, these two pairs of compounds can be used to discriminate between the two remediation pathways of volatilization and bioremediation. The four compounds are the two straight chain alkanes, heptadecane ($C_{17}H_{36}$; C_{17}) and octadecane ($C_{18}H_{38}$; C_{18}), and the two branched alkanes 2,6,10,14 tetramethylpentadecane ($C_{19}H_{40}$; pristane Pr) and 2,6,10,14-

tetramethylhexadecane ($C_{20}H_{42}$; phytane Ph). These branched alkanes are sometimes referred to as isoprenoids. The ratio of the masses of each pair in the hydrocarbon mixtures (equivalent to the ratio of the peak areas) are given as the mass of the straight chain alkane divided by the mass of the branched alkane; these are abbreviated as C_{17}/Pr and C_{18}/Ph in this report.

d) Nitrogen and Phosphorus

Total Kjeldahl nitrogen (TKN), total phosphorus and extractable phosphorus were analysed by RPC Laboratories, Fredericton NB. The methods used were colorimetric (ALPH 4500-NH3 G), ICP (EPA 3050) and sodium citrate extraction followed by ICP analysis respectively. For extractable ammonia, nitrate and nitrite, a 2M KCl solution was used. Moisture content was first determined and then a 5 g of dry equivalent sample of the wet soil weighed out and 25 ml of KCl added. Vials containing the resultant mixture were shaken for 30 min at 200 rpm, then filtered through P5 filter paper and analyzed on Technicon Autoanalyzers for each analyte.

e) PCBs

The standard analytical procedure for the analysis of PCBs, namely gas chromatography with an electron capture detector (GC/ECD) was used. These analyses were performed at the Analytical Services Unit, Queen's University by one of the two following procedures. For all procedures a separate sample (soil, gravel or GAC) was first taken for the determination of wet weight/dry weight ratio. The samples were analyzed by using approximately 10 g (dry weight equivalent), spiking with an internal standard solution (decachlorobiphenyl) and extracting. The soxhlet method used approximately 250 mL dichloromethane (DCM) in a soxhlet extractor for four hours. The DCM shaker method used 3 times 50 mL dichloromethane with agitation on a platform shaker for 20 minutes for each extract.

The shaker methods were used for most soil and gravel samples while the soxhlet method was generally used for other solid matrices. The solutions obtained from the soxhlet and DCM extraction methods were concentrated to 1-2 mL and the solvent exchanged for hexane. This concentrate was then applied to a Florisil column (Supelco SPE tube) and the resulting eluent analyzed using an Agilent 6890 chromatograph equipped with electron capture detector and a 30 m SPB-1 capillary column and calibrated with Aroclor 1260 standards.

Water was analyzed by using approximately 800 mL of sample, spiking with internal standard and extracting three times with dichloromethane. The extract was filtered through sodium sulphate and concentrated to 1-2 mL and the solvent exchanged for hexane. This concentrate was then applied to a Florisil column for cleanup of the extract and the resulting eluent analyzed by GC/ECD. For samples requiring a lower detection limit, extracts were concentrated to 0.5 mL before analysis on the GC.

For plants, a 1 - 5 g sample of dried material was accurately weighed and then ground in a mortar and pestle with sodium sulphate and Ottawa sand. The ground sample was transferred to a thimble, spiked with DCBP, and extracted by soxhlet for 6 hours at 4 - 6 cycles per hour using 250 mL of dichloromethane. The extract was then concentrated to 10 mL, and 5 mL of this extract was applied to a GPC column to separate the PCBs from the lipids. The PCB fraction was rotoevaporated, the solvent exchanged to hexane and the extract applied to a Florisil column for cleanup. This final extract was concentrated to 0.5 mL and run by GC/ECD. Values are reported on a dry weight basis.

f) Surface Water

Water samples were collected in one litre polyethylene bottles for general water quality parameters and inorganic elements analysis, and in one litre Teflon bottles for PCB analysis. For the analysis of phenols, a bottle containing an aliquot of phosphoric acid was used, for mercury, a bottle with an aliquot of sodium dichromate solution was used and, for bacteriological measurements, a sterile bottle was employed. Standard methods of analysis were employed.

3. Barrier Materials

a) Gravel

In previous years, gravel had been prepared for the filters by collecting the fraction of clean gravel on site that passed through a 8 mm sieve but not a 2 mm sieve. This year, in order to limit time spent on site, gravel was purchased in Kingston and shipped up north. A pea gravel with a particle size of roughly 6.4 – 9.5 mm was quarried locally near Kingston, Ontario and was distributed through Pyke Farms. Upon visual inspection, this material appears to be better quality than the material found on-site and perhaps less subject to freeze-thaw mechanical breakdown.

b) GAC

Two different grades of GAC were used: CNS 612, which has a particle size range of 2.00 to 3.35 mm, and BC 1240, which is sieved through a window screen prior to installation in a filter, and has a uniform particle size of 2.0 mm. Both activated charcoals were obtained through A.C. Carbone, Saint-Jean-Sur-Richelieu, Quebec.

c) Geotextiles

A vertical non-woven needle-punched geotextile, 1200R, was used in the barriers. It was supplied by Terrafix, Toronto and has a pore size between 0.05 and 0.15 mm.

d) Overpack drums

Standard metal overpack drums were used as the receptacles for the PCB contaminated soil from the barriers this year as opposed to the Waste Wranglers used last year. This was largely because no heavy equipment capable of moving the larger containers is now at the site.

4. Temperature Probes

These probes, which were used to determine the soil temperature at various depths in the landfarms, were manufactured for the project by Probes Unlimited Inc., Lansdale, PA. They have 4 or 7 temperature sensors that are spaced at 10 cm intervals with the first measuring the air or soil surface temperature. Temperatures were recorded every 30 minutes and later downloaded to a computer. Data can be stored on the probes for several months depending on the frequency of data collection.

C. Tier II Landfill Monitoring Program

The long-term, post-remediation monitoring program, which forms part of the remediation plan for the site, contains provisions for monitoring wells and associated soil points at the Tier II landfill. The landfill was constructed over the period 2003-2005 at a somewhat contaminated location as was evidenced by the discovery of TPH in the sub-surface soils at the site location. Four monitoring wells and associated soil monitoring points were established in 2003 and 5 additional monitoring wells added in 2004. These were sampled up to seven times during the 2004 and 2005 seasons in order to establish baseline data. No water could be obtained from the two wells, 1B and 3B, and thus the Tier II monitoring well system comprises 7 wells and six associated soil monitoring points: soil monitoring point 5 is adjacent to both wells 5A and 5B. The landfill appeared in good condition. Analytical results for the water and soil samples collected this year are presented in the next two sections. This is followed by a discussion of these results which includes a comparison to the results obtained in the previous seasons. The position of soil and water monitoring points together with the thermister locations are shown on Map 2.

1. Thermister Readings

The readings this year were recorded by Earth Tech (Canada) Inc. as their team was working at Radio Island and could readily visit the site. The temperatures were only collected for 3 of the 4 thermisters because the connector to one thermister string was different from the others and no adapter was available. Temperatures were recorded every 12 hours. Temperature data for each month was averaged and these were plotted to give temperature curves for the 13 months from July 2006 to August 2007 for each depth. Tables of data of the temperatures at midday on the 4 dates (15 September, 15 December, 15 March and 15 June 2007) were compiled along with similar tables for the previous year. These are given at the end of the Appendix. They show that, for the top 3 m of soil, the September values are lower in 2006 than in 2005 as the temperature regime became established. Otherwise the temperature profiles for the 2 years are similar indicating that the depth of the active layer has essentially been established. Temperatures recorded at the East berm where the depths of the thermisters are from 3.4 m to 6.9 m below grade, were now below zero for the whole year. For the West Berm and Landfill East, the depth at which all temperatures were below zero was 2.9 m and 3.55 m respectively.

2. Monitoring

Wells were all purged twice to dryness prior to sampling. Upon sampling, conductivity and pH readings were measured and recorded. Once three consistent readings were obtained sampling could begin, as well water was assumed to have reached a steady state. After sampling, the Waterra tubing was removed from the wells and discarded. Well caps and lids were replaced and secured with zip ties. No water was present in Wells 5A and 6 this year. Soil and water samples were collected on 30 July 2007. Results of the analysis of the soil and water soil samples are given in Tables 1 and 2 respectively.

Map 2: Monitoring Well and Associated Soil Sample Locations at the Tier II Landfill Site

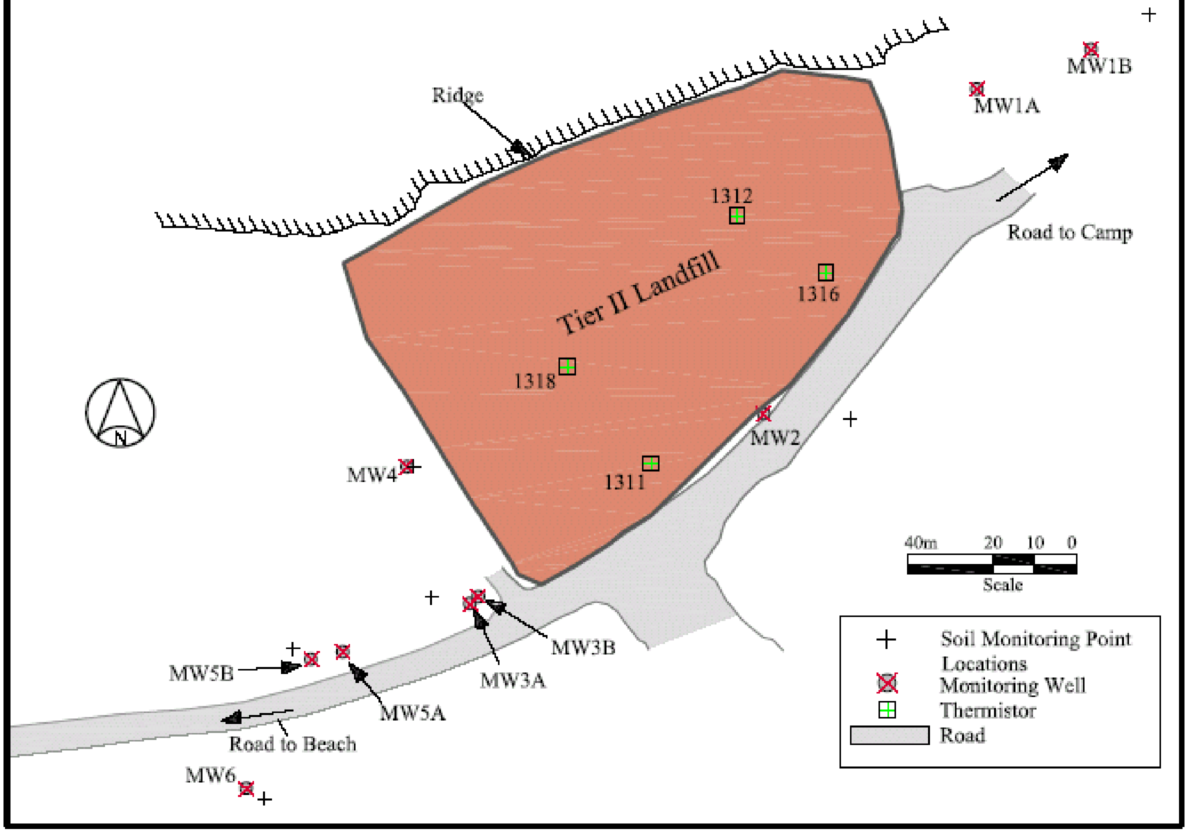


Table 1: Results of Analyses of Soil Samples Taken From Close to the Monitoring Wells at the Tier II Landfill Site

Location		MW1	MW2	MW3	MW4	MW5	MW6
Prefix RI07-		229/005	230/230D/ 006	231/007	232/008	233/009	234/010 /010D
Arsenic	ppm	1.0	1.1	1.1	1.0	1.2	1.2
Cadmium	ppm	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chromium	ppm	33	42	35	52	40	38
Cobalt	ppm	7.8	12.2	10.4	21	11.7	6.7
Copper	ppm	45	79	44	77	57	58
Lead	ppm	<10	11	36	12	17	<10
Nickel	ppm	43	57	44	89	51	29
Zinc	ppm	50	56	71	81	58	39
PCBs	ppb	29	43	140	11	230	14
TPH (lube)	ppm	1760	<40	740	<40	<40	<40
TPH (fuel)	ppm	<40	<40	1330	<40	<40	<40

Table 2: Results of Analyses of Water Samples Taken From the Monitoring Wells at the Tier II Landfill Site

Location	Unit	MW1A	MW2	MW3A	MW4	MW5A	MW5B	MW6
Prefix RI07-		-010W	-006W	-003W	-004W	Dry	-005W	Dry
Arsenic	ppm	<0.003	<0.003	<0.003	<0.003	-	<0.003	-
Cadmium	ppm	<0.001	<0.001	<0.001	<0.001	-	<0.001	-
Chromium	ppm	<0.005	<0.005	<0.005	<0.005	-	<0.005	-
Cobalt	ppm	0.028	0.024	0.008	0.011	-	0.006	-
Copper	ppm	0.018	<0.005	<0.005	<0.005	-	<0.005	-
Lead	ppm	<0.010	<0.010	<0.010	<0.010	-	<0.010	-
Nickel	ppm	0.034	0.081	0.017	0.017	-	0.020	-
Zinc	ppm	0.021	0.041	<0.020	<0.020	-	<0.020	-
PCBs	ppb	<0.020	<0.020	0.034	<0.020	-	<0.020	-
TPH (lube)	ppm	<1.0	<1.0	<1.0	<1.0	-	<1.0	-
TPH (fuel)	ppm	<1.0	<1.0	<1.0	<1.0	-	1.3	-

3. Discussion of Analytical Results

The objective of the monitoring wells and associated soils program was to initially establish baseline values for levels of parameters in the soil and water and thus any increases in the levels of these parameters in time might then be attributed to failure of the landfill to have contained the contaminants placed within it. Unfortunately the Tier II landfill site was situated on a site contaminated at levels that one might expect at an industrial site and the variability of some of the initial baseline levels was larger and more variable than desired.

a) Metals

Table 3 summarizes the soil baseline sample data obtained in previous years while Table 4 summarizes the results for this year. Elements for all samples were within the ranges developed in 2004 and 2005. None of the results exceeded any of the DCC II criterion.

Table 3: Summary of Baseline Results for Elemental Levels in Soil Samples Collected From the Tier II Landfill Soil Monitoring Points in 2004 and 2005 (ppm)

	Arsenic	Cadmium	Chromium	Cobalt
Mean	1.1	<1.0	40.0	11.1
Standard Deviation	0.4	0.0	9.4	4.9
Range	<1.0-2.0	<1.0	32-70	5.6-25
# samples > det limit	22	0	28	28
	Copper	Lead	Nickel	Zinc
Mean	61	13.4	48	57
Standard Deviation	19	14.0	19	18
Range	35-118	<10-63	24-106	33-103
# samples > det limit	28	11	28	28

Table 4: Summary of Elemental Levels Found in Soil Samples Collected From the Tier II Landfill Soil Monitoring Points in 2007 (ppm)

	Arsenic	Cadmium	Chromium	Cobalt
Mean	1.1	<1.0	40.0	11.6
Range	1.0-1.2	<1.0	33-52	6.7-21
	Copper	Lead	Nickel	Zinc
Mean	60	19	52	59
Range	44-79	<10-36	29-89	39-81

Table 5 summarizes the water baseline sample data obtained in previous years. Results from this year show values similar to those obtained in previous years. No arsenic, cadmium, chromium or lead were detected in any samples. Cobalt, nickel and zinc were detected in many samples but all were within the normal range. Copper was only detected in one sample.

Table 5: Baseline Summary of Elemental Levels in the 86 Water Samples Collected From the Tier II Landfill Monitoring Wells in 2004 and 2005 (ppm)

	Arsenic	Cadmium	Chromium	Cobalt
Mean*	<0.003	<0.001	<0.005	0.017
Standard Deviation*	0.000	0.000	0.000	0.019
Range	<0.003-0.050	<0.001	<0.005-0.367	<0.003-0.073
# samples > det limit	1	0	2	51
	Copper	Lead	Nickel	Zinc
Mean	0.006	0.006	0.037	0.021
Standard Deviation	0.006	0.003	0.042	0.027
Range	<0.005-0.033	<0.010-0.022	<0.010-0.091	<0.010-0.286
# samples > det limit	26	7	71	41

* Excluding outliers

b) TPH

TPH was detected both as lubricating oil and as fuel oil in two of the soil samples this year. Lubricating oil and grease was again found at MW1 above the landfill; none was found in 2005 but both fuel and lubricating oil and grease were found in 2004. The other soil which contained TPH was from MW3 which contained both oil and fuel as in previous years. The other wells had sporadically contained low levels of fuel in the past but this was absent this year. TPH was only detected in the water from Well 5B this year but at a low level of 1.3 ppm. In 2005, TPH was detected in 10 of the 39 water samples analysed as fuel. This site had historically been contaminated with various fuel and lubricating oils and levels of these can be found in soils near to the summit. One might expect to see these levels in the soil for many years but now there is less activity at the site, there may be less soil in the well water samples as per discussion below for PCBs.

c) PCBs

PCB levels in the soil samples at the monitoring points ranged from 11 to 230 ppb which are similar to the values obtained in previous years. Also MW3 and MW5 gave the highest results which is again consistent with previous data. The average value found this year from the 6 samples was 78 ppb with a standard deviation of 88. In 2005, the average value was 85 ppb and in 2004 was 62 ppb. As expected the standard deviations are high with values of 122 and 89 in 2004 and 2005 respectively.

Given the level of PCBs in the nearby soil, any soil contamination in the water is likely to give measurable PCB levels in the water. The water cannot be filtered since this process would remove the PCBs from the water. In the laboratory, the samples were allowed to stand for at least 24 hours and then the water to be analysed was carefully decanted. However several samples in the past contained soil particles floating on the surface and, in others, colloidal material was present. Thus, the results where PCBs were found in the water may well have been a measure of the soil contamination rather than actual levels in the water. This is particularly likely since PCB molecules tend to partition on to solid surfaces and to absorb on to particles rather than to dissolve in water. This argument has been used to explain anomalously high readings in previous years and the detection of PCBs in about half the samples collected. This year only one of the 5 samples was found to contain PCBs and this at 0.034 ppb. It may well be that the wells have now stabilized and the amount of soil incorporation decreased significantly.

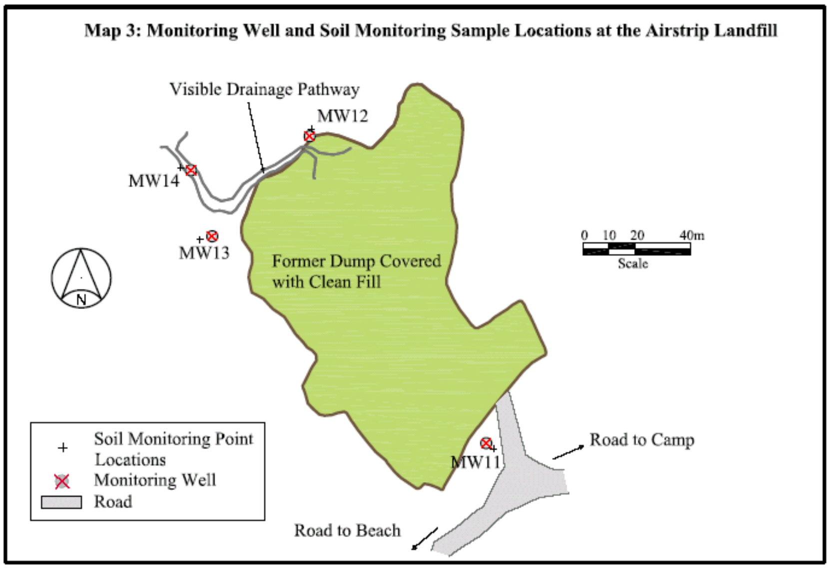
D. Airstrip Landfill Monitoring Program

The remediation of the airstrip dump was completed in 2003. Four monitoring wells were placed around it, one above and three in the leachate channel leading away from it. However, it should be noted that the drainage channel for MW12, MW13 and MW14 is extremely narrow and the staked area for the soil samples straddles the channel. Monitoring well 11 was again dry this year. Results of the analyses are shown in Table 6 and Table 7 for water and soil respectively. It should also be noted that the western slope of the airstrip dump was never fully covered and some partially buried material is still visible.

Elemental levels in soil are very similar this year to values obtained in previous years. Only chromium and nickel were detected in the well water in contrast to previous years when cobalt, copper and zinc had also been detected albeit at low levels.

For the soil samples this year, TPH (lubricating oil and grease) was high in MW 12 as usual. In contrast no TPH was found in the other soil samples and no TPH was found in the water samples. These results are consistent with results from previous years.

PCB levels in the soil samples were similar to previous years. An analytical interference was again encountered this year at MW 12 presumably due in part to the high levels of lubricating oil and grease. For water samples, the PCB results ranged from 0.021 to 0.073 ppb. Last year the results ranged from <0.020 to 0.037 ppb PCBs.



Map 3: Monitoring Well and Soil Monitoring Sample Locations at the Airstrip Landfill

Table 6: Results of Analyses of Water Samples Taken From the Monitoring Wells at the Airstrip Landfill

		MW11	MW12	MW13	MW14
Prefix RI07-		Dry	002W	009W	008W
Arsenic	ppm	-	<0.003	<0.003	<0.003
Cadmium	ppm	-	<0.001	<0.001	<0.001
Chromium	ppm	-	0.008	<0.005	<0.005
Cobalt	ppm	-	<0.003	<0.003	<0.003
Copper	ppm	-	<0.005	<0.005	0.005
Lead	ppm	-	<0.010	<0.010	<0.010
Nickel	ppm	-	<0.005	0.020	0.006
Zinc	ppm	-	<0.020	<0.020	<0.020
PCBs	ppb	-	0.027	0.021	0.073
TPH (lube)	ppm	-	<1.0	<1.0	<1.0
TPH (fuel)	ppm	-	<1.0	<1.0	<1.0

Table 7: Results of Analyses of Soil Samples Taken From Close to the Monitoring Wells at the Airstrip Landfill

		MW11	MW12	MW13	MW14
Prefix RI07-		228/004	225/001	226/002	227/003
Arsenic	ppm	1.1	1.0	1.6	1.3
Cadmium	ppm	<1.0	<1.0	<1.0	<1.0
Chromium	ppm	51	42	43	48
Cobalt	ppm	18.3	16.5	12.1	16.6
Copper	ppm	75	69	82	74
Lead	ppm	15	16	20	<10
Nickel	ppm	75	76	68	83
Zinc	ppm	76	118	201	118
PCBs	ppb	17	<100	48	20
TPH (lube)	ppm	<40	3240	<40	<40
TPH (fuel)	ppm	<40	<40	<40	<40

E. Maintenance Dump Monitoring Program

The remediation of the maintenance dump was completed in 2005 and two monitoring wells and two soil monitoring points established. Water and soil samples were collected this year and results of their analyses are shown in Table 8.

Elemental results in the soil samples were consistent with results found in 2005 and 2006. For the water samples, all results were low with only chromium, cobalt and nickel being detected in one of the samples and all just above the detection limit. This is consistent with the results from the previous two years.

No hydrocarbons were detected in either the water or soil samples again this year.

The PCB levels in the two soils were 70 and 86 ppm. Results from 2005 and 2006 were in the range of 9 to 67 ppm. Water from well MW21 was found to contain 0.042 ppb PCBs. For the previous 2 years only one of five water samples was found to contain PCBs above the 0.020 ppb detection limit; a level of 0.025 ppb was found in one of two samplings of MW22 in 2006.

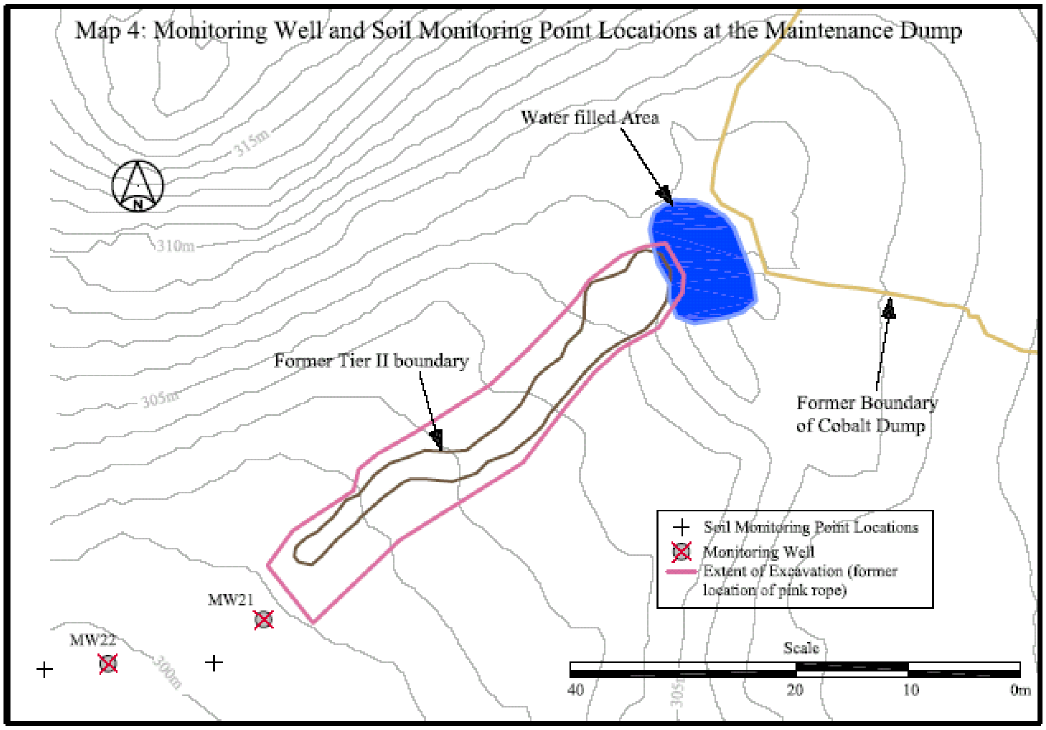

Map 4: Monitoring Well and Soil Monitoring Point Locations at the Maintenance Dump

Table 8: Results of Analyses of Water and Soil Samples Taken From the Monitoring Well Locations at the Maintenance Dump

Location	Units	Water		Soil	
		MW21	MW22	MW21	MW22
Prefix RI07-		011W/010DW	007W	235/012	236/011
Arsenic	ppm	<0.003	<0.003	<1.0	1.0
Cadmium	ppm	<0.001	<0.001	<1.0	<1.0
Chromium	ppm	<0.005	0.006	38	51
Cobalt	ppm	0.004	<0.003	13.3	15.6
Copper	ppm	<0.005	<0.005	50	82
Lead	ppm	<0.010	<0.010	<10	<10
Nickel	ppm	0.008	<0.005	60	78
Zinc	ppm	<0.020	<0.020	74	120
PCBs	ppb	0.042	<0.020	86	70
TPH (lube)	ppm	<1.0	<1.0	<40	<40
TPH (fuel)	ppm	<1.0	<1.0	<40	<40

F. Non-hazardous Landfills

Engineered non-hazardous landfills are located in the camp area, at the beach and at the north slope. The long term monitoring program includes an inspection of the non-hazardous landfills for any deterioration. No runoff was observed from any of the landfills. Water from below the landfill at the camp was sampled and analyzed as described in Section G below. All landfills were in good condition and no deterioration was observed.

G. Water Samples

1. Drinking Water

Analytical results are shown in Table 9. With two exceptions, none of the parameters measured were outside of the OME guidelines. The pH of the water was very low; this has been consistently so for the 10 years of the project. The drinking water was not buffered with sodium carbonate this year. Total Coliform was found in the water sample this year but this is likely because it was not possible to get the sample to the laboratory within the 24 hour holding time required for bacterial analysis. The short season precluded the repeating of the sampling and analysis.

Table 9: Drinking Water Results and Guidelines

Parameter	Units	RI07-W001	OME Guidelines
Alkalinity	mg/L	<2.0	30-500
Ammonia	mg/L	0.1	-
Arsenic	mg/L	<0.003	
Cadmium	mg/L	<0.001	
Calcium	mg/L	6.8	-
Cobalt	mg/L	0.032	
COD	mg/L	<3	-
Conductivity	uS/cm	141	-
Copper	mg/L	0.046	<1.0
Chromium	mg/L	<0.005	
Hardness	mg/L	35	80-100
Iron	mg/L	0.065	<0.30
Lead	mg/L	<0.010	<0.01
Nickel	mg/L	0.16	
Magnesium	mg/L	4.4	-
Mercury	mg/L	<0.0005	
PCB	ug/L	<3.0	<3

Parameter	Units	RI07-W001	OME Guidelines
pH	-	4.4	6.5-8.5
Phenols	ug/L	<1.0	-
Potassium	mg/L	0.69	-
Sodium	mg/L	5.5	<200
Sulphate	mg/L	55	<500
Nitrate	mg/L	<0.05	<10
Nitrite	mg/L	<0.05	<1.0
Chloride	mg/L	7.7	<250
TDS	mg/L	100	<500
TKN	mg/L	<0.2	-
TSS	mg/L	<4.0	<500
Zinc	mg/L	0.10	5
Total Coliforms	Cts/100 mL	3	0
Faecal Coliforms	Cts/100 mL	0	0
Faecal Streptococci	Cts/100 mL	0	0
E coli	Cts/100 mL	0	0
Standard Plate Count (48 hrs)	Cts/1 mL	6	500
Background	Cts/100 mL	38	200

2. *Surface Water*

Water from near the Officer's Mess was again collected this year as it would be required under the monitoring plan if it were landfill leachate. This water is below the engineered landfill at the camp but not in its direct drainage pathway. This water has also been affected by sewage discharge from the camp in previous years and from the general contamination at the site. Result for the water sample are presented in Table 10. Cobalt, copper, nickel and zinc were detected in the water this year but within the normal site levels given in Table 5. No nitrate was detected this year; the value of 0.37 ppm last year was attributed to historical sewage discharges which are no longer occuring.

Table 10: Results From Water Near the Officer’s Mess

Parameter	Units	RI07-031W
Copper	mg/L	0.012
Iron	mg/L	<0.05
Lead	mg/L	<0.010
Manganese	mg/L	0.009
Cadmium	mg/L	<0.001
Nickel	mg/L	0.074
Chromium	mg/L	<0.005
Cobalt	mg/L	0.010
Zinc	mg/L	0.087
PCBs	ug/L	<3
pH	-	6.8
Nitrate	mg/L	<0.05
Nitrite	mg/L	<0.05
TPH (fuel)	mg/L	<1.0
TPH (oil)	mg/L	<1.0

H. Background Plant Samples

Fourteen background plant samples were collected this year; the three samples from the radio hill area were combined prior to analysis. The twelve results are from the 10 plant monitoring points (PMPs) and from two locations near the summit. Plants were collected but not washed and therefore dust and water droplets transferred to new growth, and which may contain PCBs, are analysed in the sample. Therefore results of these analyses are an indication of airborne PCB levels.

The data presented in Table 11 and on Map 5 shows a marked decrease in PCB levels from previous years. All PCBs showed the Aroclor 1260 pattern.

Table 11: Results of Analyses of Background Plant Samples

Sample	Tag	Monitoring Point	PCBs (ppb)	Location
RI07-014P	6421	PMP1	15.5	Camp – old officer's mess
RI07-001P	6568	PMP2	38	NE of Tier II landfill
RI07-009P	6741	PMP3	<3.0	Airstrip drainage pathway
RI07-002P	6746	PMP4	40	Imploded tank (TPH drainage area)
RI07-007P	6887	PMP5	4.0	1000m NE of airstrip
RI07-004/5/6P	6888	PMP6	<3.0	Radio Hill
RI07-012P	6746	PMP7	6.6	S1/S4 Beach
RI07-013P	-	PMP8	38	Beaching area – 20m from tag 6839
RI07-011P	6889	PMP9	6.1	1000m S of barrel cache valley
RI07-010P/10D	6984	PMP10	3.7; <3.0	New water lake
RI07-008P	6739	-	3.5	100 m N of airstrip drainage pathway
RI07-003P	6758	-	14.1	Imploded tank (TPH drainage area)

Results have now been obtained for 5 successive years. During the first three years (2003-2005) there was considerable remediation activity at the site particularly in 2003 when CEPA soil was being excavated. Last year there was reduced activity since equipment was being used only for a few weeks and no contaminated soils were handled. This year there was minimal soil disturbance as the ASU team of 5 people was only on site for 9 days. Table 12 shows the change in levels at the 10 PMPs and two additional sampling points for the 5 years of the current monitoring program.

The level of PCBs in the plants in the areas removed from remediation action had already dropped in 2005 presumably due to the removal of the high level CEPA soil. The results may show that vehicular traffic, which produces considerable dust, was still important up to last year. Also not just the new growth was analysed in the samples but some older woody material which would reflect levels from previous year's activity. These results indicate that the removal of the PCB contaminated soils has greatly reduced the airborne transport of PCBs.

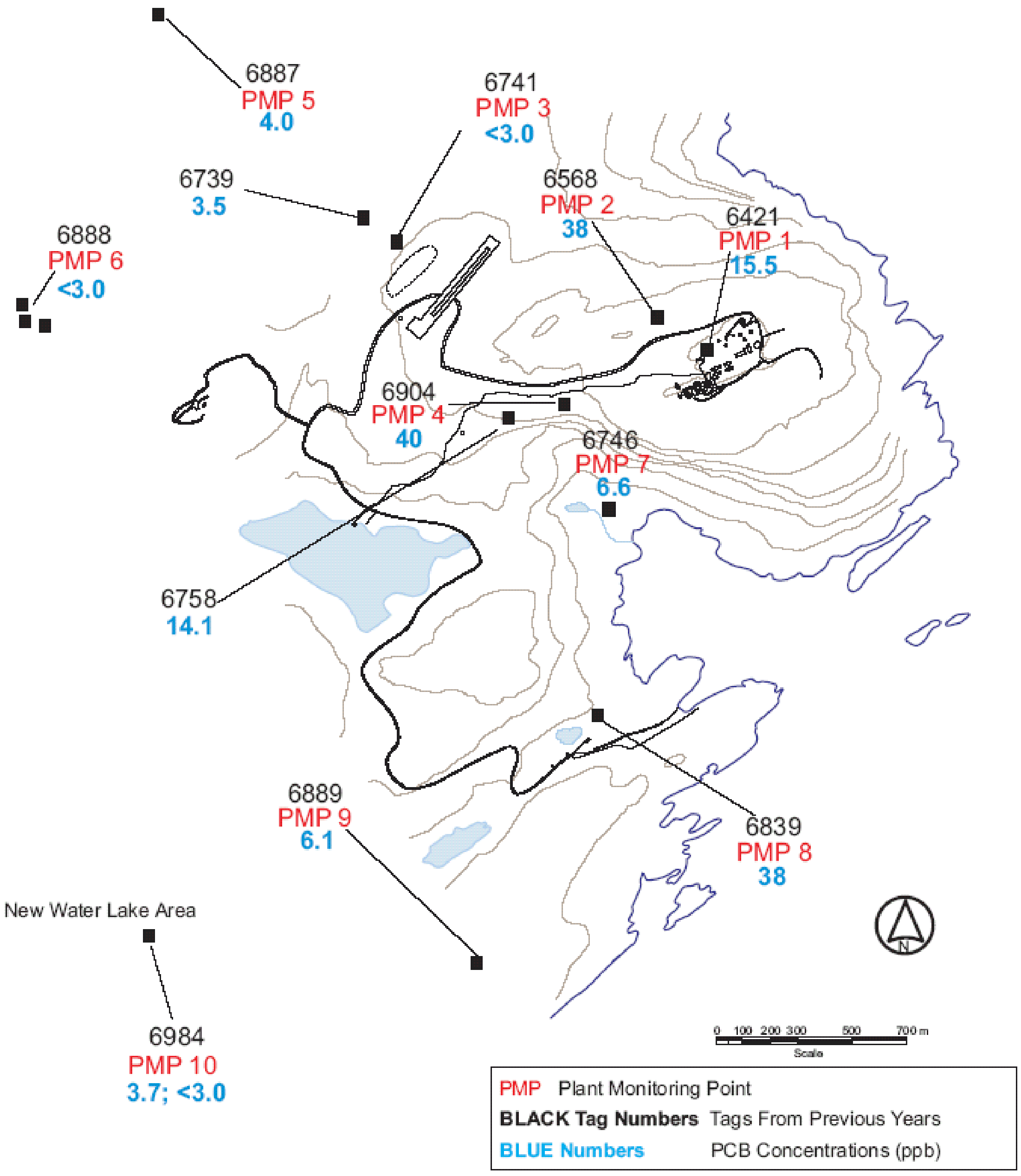
Table 12: Results of Analyses of Background Plant Samples (2003-2007)

Monitoring Point	Location	PCBs (ppb)				
		2003	2004	2005	2006	2007
PMP1	Camp – old officer's mess	1700	66	530	-	15.5
PMP2	NE of Tier II landfill	400	<3.0	250	97	38
PMP3	Airstrip drainage pathway	11000	250	4.3	8.0	<3.0
PMP4	Near imploded tank	3300	380	42	-	40
PMP5	1000m NE of airstrip	33	25	11.3	7.9	4.0
PMP6	Radio Hill	1090	<3.0	5.8	22	<3.0
PMP7	S1/S4 Beach	21	<3.0	18	-	6.6
PMP8	Beaching area	170	70	-	-	38
PMP9	S of barrel cache valley	26	67	54	-	6.1
PMP10	New water lake	43	<3.0	4.5	<3.0	3.4
Tag 6739	100 m N of airstrip	130	-	6.2	-	3.5
Tag 6758	Imploded tank drainage	-	25	34	125	14.1

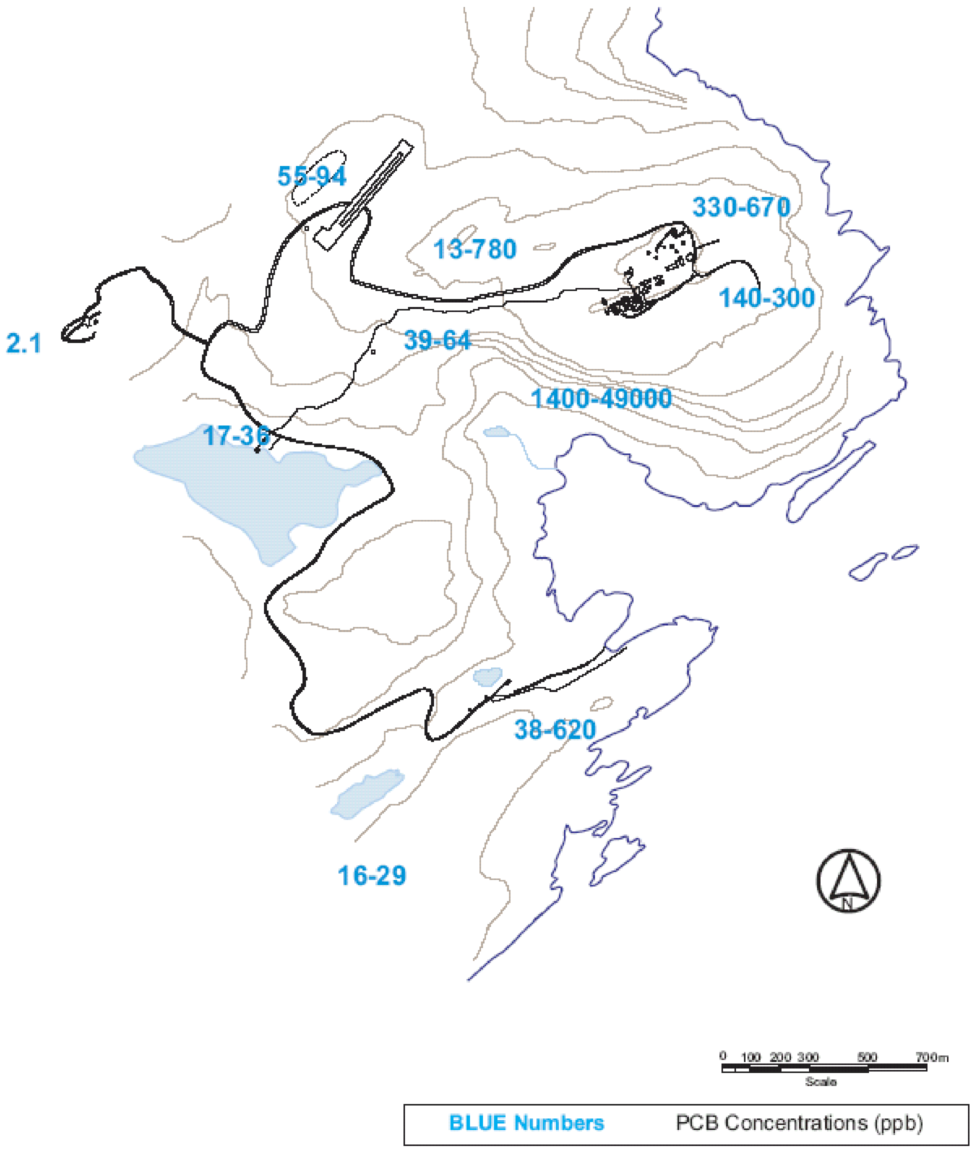
Plant samples were analysed as part of the environmental assessment in 1993. Results of these determinations are shown as ranges for various areas on Map 6; results were for various Arctic plants, as opposed to Willow (*Salix Polaris)* used in this study; remote background plant samples from > 1.5 km from the site all contained < 4 ppb PCBs. At this time some would have been growing in PCB-contaminated soils and might therefore reflect uptake as well as aerial transport.

As can be seen by comparison to the data in Table 12 and Map 5, there has been a large decrease in the level of PCBs in plants which reflects the significant reduction in aerial transport of PCBs as a result of the site remediation. Typically the levels around the summit have dropped from values of 100s to 1000s of ppb to 10-50 ppb PCBs whereas at other locations values have dropped from in the range of 50-1000 ppb to < 10 ppb PCBs.

Map 5: Locations and PCB Concentrations of Background Plant Samples Collected in 2007



Map 6: Locations and PCB Concentrations of Background Plant Samples Collected in 1993



I. Main Landfarm

1. *Background*

A major landfarm was set up in 2004 in order to remediate the high fuel contaminated soil at the site. The approximate size of the landfarm was 76 m by 21 m with a depth of about 0.6 m. The area was therefore 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 (DAP) per m^2. in 2004 and the whole area was then rototilled and 39 representative samples taken on 3 September 2004 and analysed. The concentration of the TPH in the landfarm was found to be 3320 ± 970 ppm. In 2005, one quadrant was marked off and designated as a control plot. This control plot was not fertilized or aerated. In 2006 a second quadrant marked off and was rototilled frequently. Analytical results obtained from three samplings of the main landfarm in 2005 showed that the mean TPH concentration was 2450 ± 1150 ppm The C_{17}/Pr ratios showed little change also indicating that TPH losses due to bioremediation were very low. Laboratory experiment in the winter of 2005 showed that more fertilizer was required and therefore urea and MAP were added at the rate of 252 g Urea and 19 g MAP per m^2 on 24 July 2006. The main landfarm (excluding the control plot) was thoroughly mixed three times in 2006 using the 315 excavator. Analytical results obtained from the landfarm in 2006 gave results of 2140 ± 690 ppm and 1510 ± 560 ppm from the two samplings. The C_{17}/Pr ratios showed a significant reduction in 2006 indicating that TPH losses due to bioremediation were occurring. Results for the control plot show higher TPH levels for the two samplings of 2280 ppm and 3000 ppm and an average C_{17}/Pr ratio of 0.28. The ratio is not statistically different from the starting value of 0.36. No significant results were obtained from the frequently rototilled plot.

2. *Results for 2007*

No tilling of any part of the landfarm took place this year. Soil samples were collected from the main area of the landfarm and from the two sub-plots. Results of analyses for diesel fuel are given in Table 13. Data for the fertilized and tilled main portion of the landfarm is shown graphically along with data from previous years in Figure 1. The graph shows a continuing trend indicating loss of hydrocarbon. Data in Table 13 show that the TPH level in the main landfarm as 810 ± 410 ppm while that in the untilled plot was 1690 ± 650 ppm. The C_{17}/Pr ratios were also determined for all samples. For the main fertilized landfarm and the tilled plot all results were below the detection limit of 0.10. In most cases the peaks for the two compounds were visible but the area beneath was too small to quantify. Figure 2 shows the trend in C_{17}/Pr ratios over the lifetime of the landfarm using a value of half the detection limit for 2007. The value of the C_{17}/Pr ratio for the control plot was 0.27 ± 0.06 which is unchanged from last year and not significantly different from the value obtained when the landfarm was constructed showing that no significant bioremediation had taken place in the absence of added nutrient.

Table 13: Results of Analyses of Soil Samples for TPH from the Main Landfarm

Quadrant type	Depth (cm)	Sample Numbers	TPH diesel fuel (ppm)
Main Landfarm	0-30	223HC	<40
	30-60	218HC	360
	0-60	217HC, 220HC, 220HCD, 221HC, 222HC, 224HC	1150, 1430, 800, 360*, 610, 500. **Mean = 810**
Control plot	0-30	212HC	1830
	30-60	211HC	980
	0-60	216HC	2260
Tilled plot	0-30	214HC	340
	30-60	215HC	1090
	0-60	219HC	750

* sample also contained 760 ppm lube oil

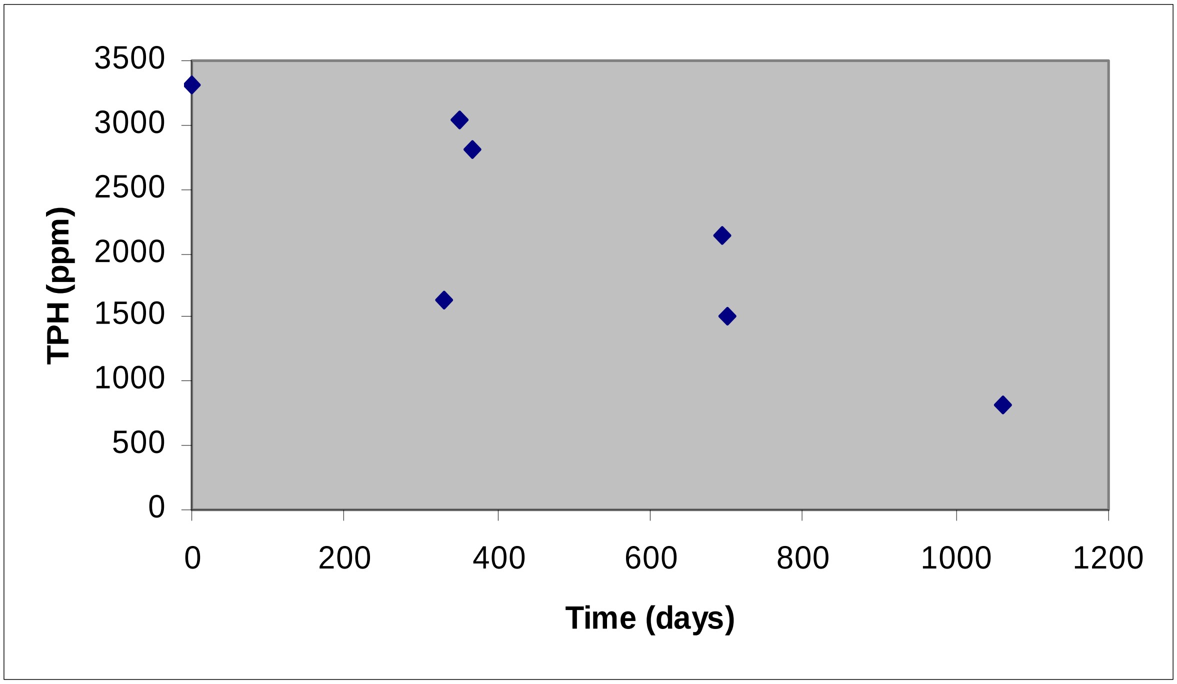


Figure 1: Change of TPH with Time at the Main Landfarm

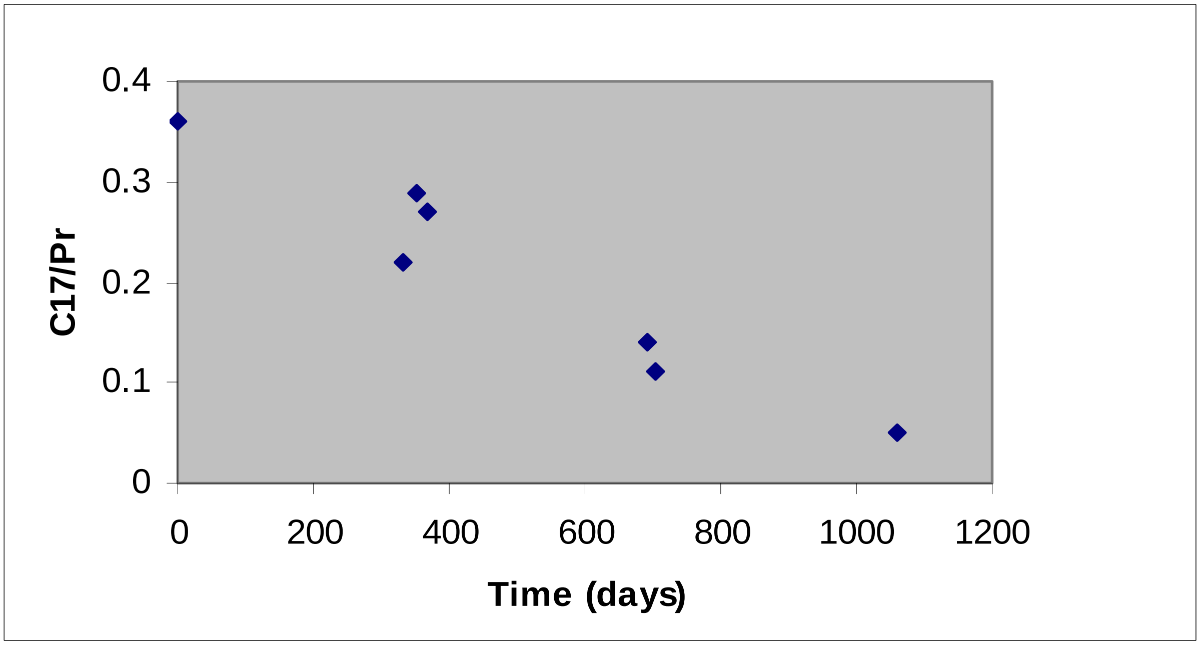


Figure 2: Change of C_{17}/Pr Ratios with Time at the Main Landfarm

a) Temperature probe

Three probes were placed in the landfarm on 31 July and removed on 5 August 2007. One 30 cm probe was placed in the tilled plot while 60 cm probes were placed in the control plot and main landfarm. All three probes recorded similar temperatures. These were averaged and are presented in Figure 3. This graph shows the fluctuation in daily temperatures of soil at depths of 10, 20, 30, 40, 50 and 60 cm. Even at 60 cm there is a fluctuation slight response to the changing air temperature. This fluctuation is slightly delayed. The weather on the first 3 days of August was unusually hot while on August 4 it was cold and foggy. Soil temperatures below 30 cm were fairly constant with a mean temperature of 8.3 ºC. This is similar to the soil temperatures recorded in previous years but the data for depths below 30 cm had not been obtained with these more accurate probes before.

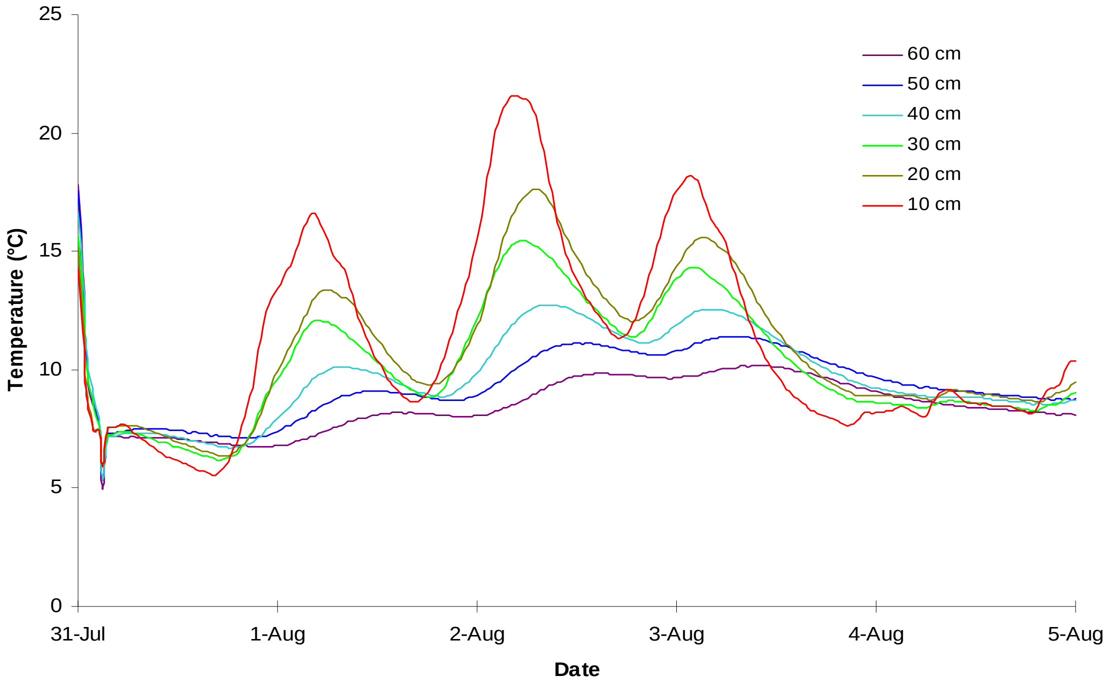


Figure 3: Soil Temperatures Recorded Using a Temperature Probe at the Main Landfarm

Soil nitrogen and phosphorus data are presented in Table 14. The total phosphorus and TKN values are similar to those seen in 2005 and 2006. The extractable phosphorus levels are now below the detection limit of 10 ppm whereas in 2006 they were generally in the 10-20 ppm range after the addition of more fertilizer last year. Similarly the ammonia values have dropped from last year's levels of up to 485 ppm to 27 and 64 ppm for the tilled and main landfarm respectively. The nitrate values were mostly <2 ppm last year with a high of 4 ppm. The main landfarm this year gave a value of 11 ppm. No nitrite was seen in either year. Extractable ammonia and nitrate would be expected to be present as a result of breakdown of the urea and subsequent reactions in the soil matrix. Much of the nitrogen added as urea is now in different forms within the soil, some available for bioremediation purposes and some not. The extractable value of 9 ppm in the control plot may have been caused by runoff from the main plot.

Table 14: Soil Nitrogen and Phosphorus Levels (ppm) at the Main Landfarm

Sample location	Date	Unit	TKN	Ext. Ammonia	Ext. Nitrate	Ext. Nitrite	Total P	Ext P
Control plot	31 Jul 07	ppm	290	<5	9	<2	159	<10
Tilled plot	31 Jul 07	ppm	380	27	<2	<2	154	<10
Main landfarm	31 Jul 07	ppm	380	64	11	<2	149	<10

Hydrocarbon degraders results for the control plot, tilled plot and main landfarm were 3.1×10^5, 6.8×10^5, <100 respectively. The first two results are similar to the those obtained in 2005. The very low value for the main landfarm is strange since it was the same sample in which nitrate and ammonia were found.

J. In Situ Landfarm

1. Background

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 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 two years before nutrients were added so that the soil would be more settled and oxygen levels stabilized.

Four holes measuring 5 m by 5 m and with a depth of 0.6 m were excavated in the ground in the barrel cache valley. Excavated, screened and mixed TPH contaminated soil was then placed in each hole and compacted. For one plot, fertilizer was mixed with the soil prior to filling the hole. At another plot fertilizer was sprinkled on top. The amount of fertilizer added was 124 g of urea and 21 g of DAP per plot. Thus the four plots were as follows:

- Control Plot 1 (CP1) – no fertilizer added
- Control Plot 2 (CP2: FAS2) – no fertilizer added – fertilizer was added to this plot in 2007

- Fertilizer added to the surface (FAS1)
- Fertilizer mixed with the soil (FAM)

The four plots were then sampled twice in August 2005. 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. In 2006, more fertilizer was sprinkled on the top of the FAS1 and FAM plots in the form of urea (1.6 kg) and DAP (0.25 kg) on 27 July 2006. More fertilizer was added to both plots because much less fertilizer was added in 2005 than required. Essentially both plots were then the same. Average TPH levels in the 4 plots in 2006 were found to be 910, 1150, 620 and 670 ppm for CP1, CP2:FAS2, FAS1 and FAM respectively. The C_{17}/Pr ratios in the FAS1 and FAM plots had been reduced to 0.20 while for the CP1, CP2:FAS2 they remained unchanged 0.50, indicating that bioremediation was taking place in the two fertilized plots. Average soil temperatures were 7.9 to 8.9 ºC in the top 30 cm but 6.1 – 7.3 ºC at depths between 40-80 cm.

2. 2007 Field Activities

Fertilizer was added to plot CP2: FAS2 this year in the form of urea (1600 g) and DAP (250 g). All 4 plots were sampled on 31 July 2007. All samples were taken by hand excavation as they were found to be very wet at depth. Soil was returned to the sampling location and this was marked so that the location would not be sampled in subsequent years.

3. 2007 Results

Analytical results obtained from the four landfarm plots in 2007 are given in Table 15 and Figure 4. C_{17}/Pr ratios were determined again this year and are shown in Figure 5 together with results from the previous year; C_{18}/Ph ratios showed a similar result.

The TPH results show a decrease with time as illustrated in Figure 4 but these are not statistically different as shown by the errors given in Table 15; the ± values are one standard deviation. There is however, a very clear difference in C_{17}/Pr ratios again this year between the fertilized plots and unfertilized plots as shown in Figure 5. This indicates that the fertilizer added to the surface of the plots permeated through the soil and essentially accelerated the bioremediation activity to a significant and measurable level.

Table 15: Results of Analyses of Soil Samples for TPH From the In Situ Landfarm

Plot Regime	Sample Number	Depth (cm)	TPH (ppm)
CP1	205HC	0-60	500
CP1	207HC	0-30	650
CP1	208HC	0-43	520
Control Plot 1 average ± sd			**557 ± 81**
CP2: FAS2	200HC, 200HCD	0-28	610
CP2: FAS2	209HC	0-45	860
CP2: FAS2	213HC	0-42	570
Control Plot 2 average ± sd			**680 ± 157**
FAS1	203HC	0-45	200
FAS1	206HC	0-55	770
FAS1	210HC, 210HCD	0-40	180
FAS plot average ± sd			**383 ± 335**
FAM	201HC	0-60	230
FAM	202HC	0-60	360
FAM	204HC	0-60	480
FAM plot average ± sd			**357 ± 125**

sd = standard deviation

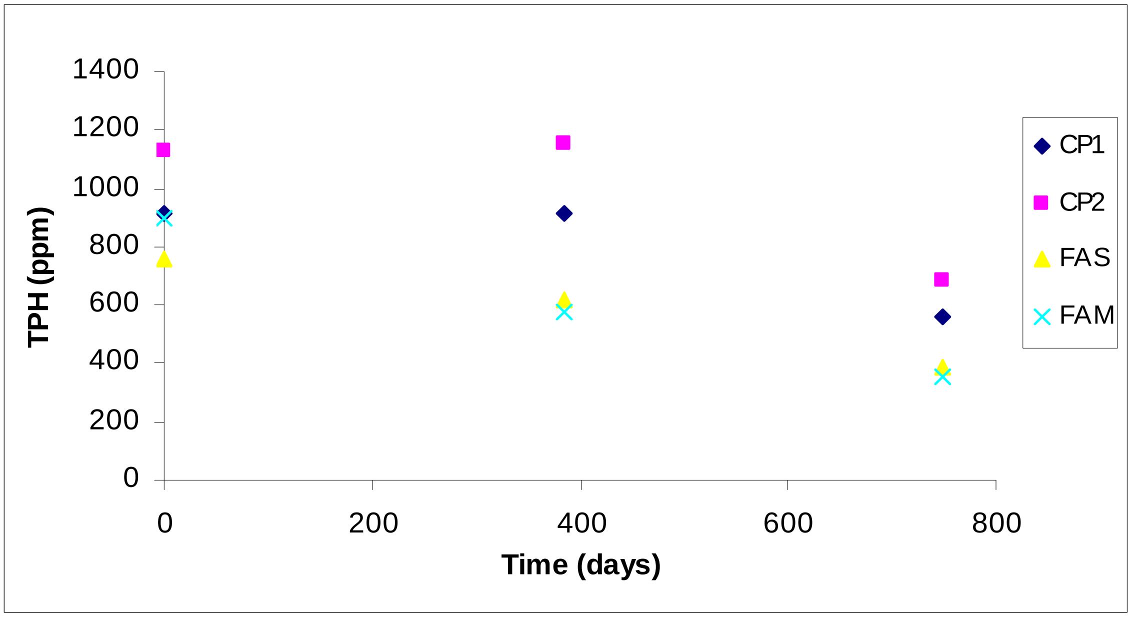


Figure 4: Change of TPH with Time at the In Situ Landfarm

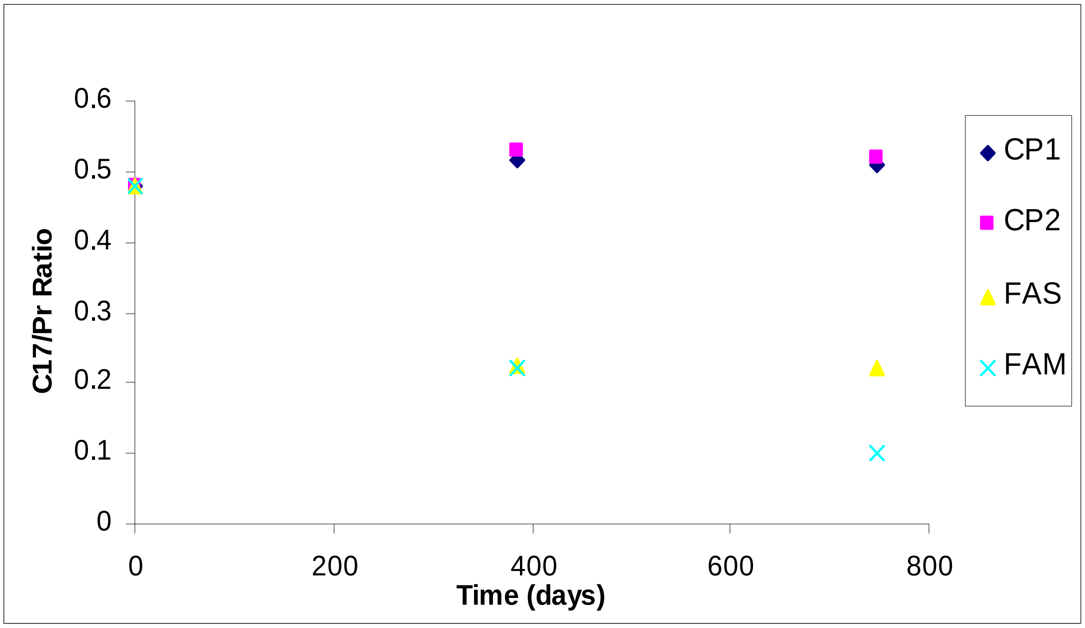


Figure 5: Change of C_{17}/Pr Ratios with Time at the In Situ Landfarm

Temperature probes were placed in all four plots. Three were to a depth of 30 cm, while one in the FAM plot was of a 60 cm length. The 4 probes gave similar results and these were averaged and are displayed in Figure 6. Data is similar to that of the main landfarm but varies slightly since the two locations are at different altitudes.

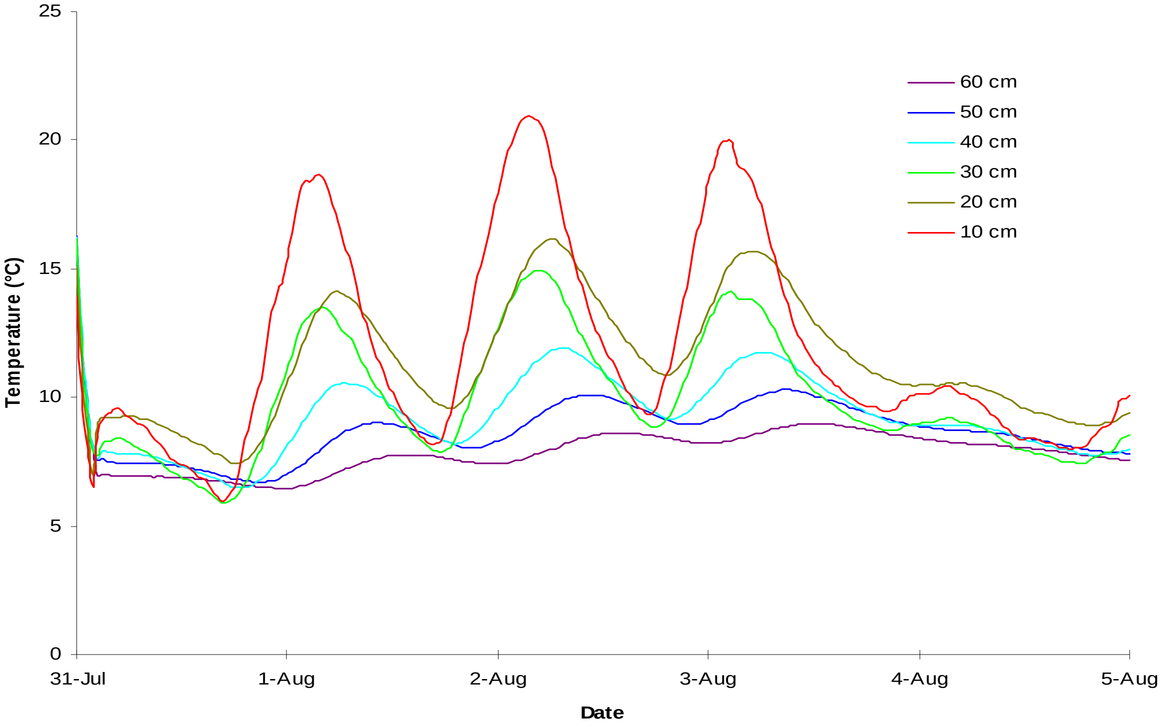


Figure 6: Soil Temperatures Recorded Using Temperature Probes at the In Situ Landfarm Plots

Nutrient analysis results given in Table 16 show the presence of ammonia in the FAS1 and FAM plots where fertilizer was added this year. Last year the FAM and FAS1 plots contained extractable ammonia as urea had been added in 2006. No extractable nitrate or nitrite was found in the soil this year or last year.

Table 16: 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
RI07-001N	31 Jul 07	CP1	220	<5	<2	<2	255	<10
RI07-002N	31 Jul 07	FAS2	200	<5	<2	<2	163	<10
RI07-003N	31 Jul 07	FAS1	320	22	<2	<2	181	<10
RI07-004N	31 Jul 07	FAM	290	7	<2	<2	213	<10

Hydrocarbon degraders levels in the four samples CP1, FAS2, FAS1 and FAM were 1.1×10^3, 9.0×10^2, 1.68×10^4, 5.04×10^4 respectively. These had not previously been determined.

K. Ponding and Barrier Research

1. *General*

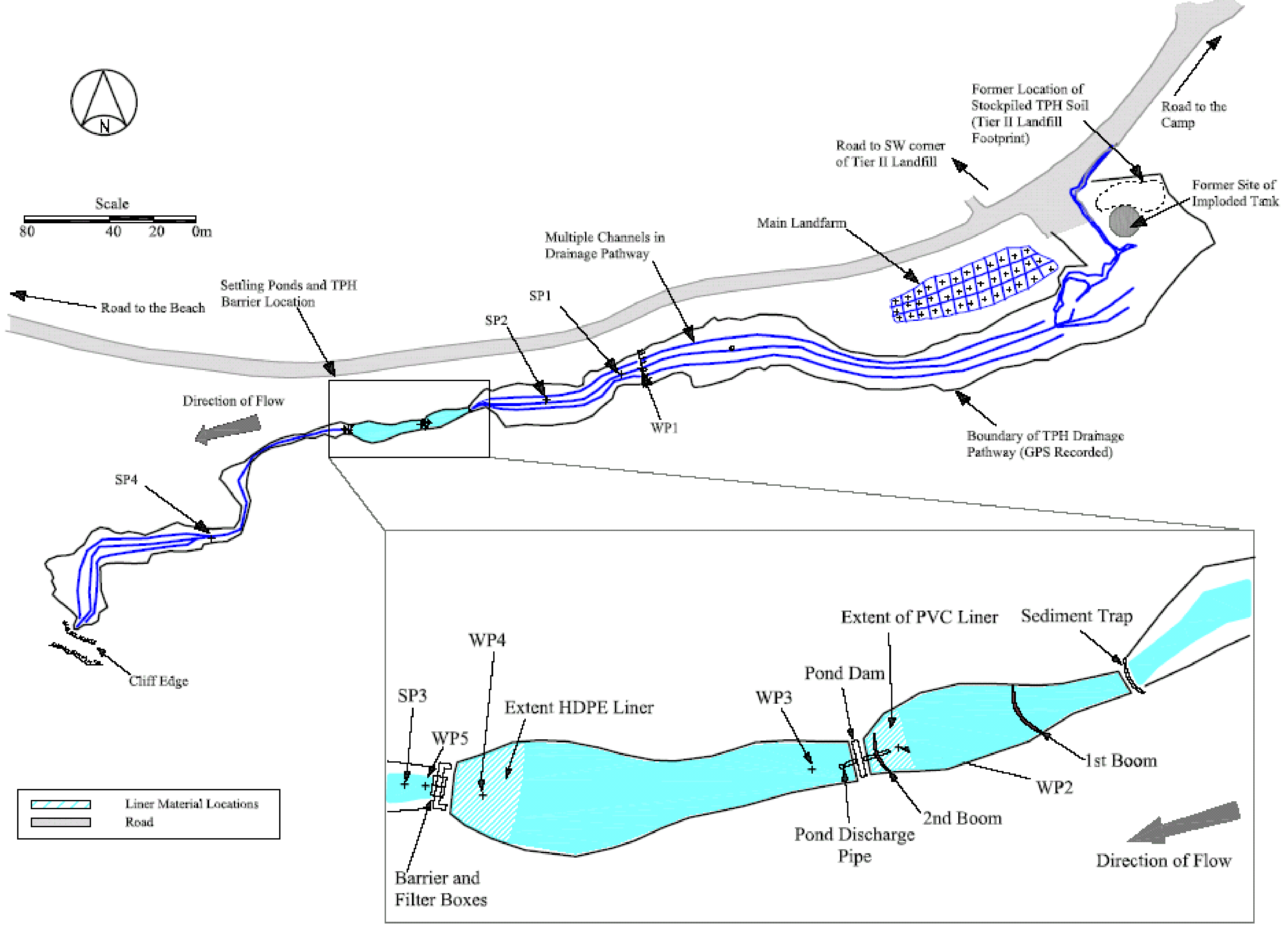
A pond and barrier system was constructed in 2004. This novel system was installed to examine its effectiveness in removing TPH from a drainage pathway under Arctic conditions. It was reasoned that a pond would help in the removal of volatile TPH by adding a large surface area for evaporation and the use of an oil absorbent boom on the surface of the pond would remove any hydrocarbon on the water surface. Additionally, the placement of a barrier system incorporating materials to absorb TPH from water would remove any TPH from the water or entrapped particles.

In 2005 and 2006, the various components of the barrier system were sampled and analysed and the filter materials and booms replaced. This required the testing of soil and water monitoring points and the components of the system (sand, GAC and boom material) to determine whether TPH was being removed. The soil and water monitoring points were established at locations upstream, downstream and within the system reservoirs in 2004 as shown on Map 7. Results of analyses of the soil and water samples probably reflected upstream remediation activity rather than barrier performance. Measurable levels of TPH was found in two sections of the GAC filters but this corresponded with only a small amount of TPH (0.75 g). Samples from the boom material were collected each year but interference from the material precluded analysis for TPH. Nitrogen and phosphorus levels determined in soil samples from monitoring points in 2004, 2005 and 2006 suggested that there had been little or no leaching of fertilizer from the main landfarm. Inspection of the whole system in each year showed no deterioration as a result of erosion or ultraviolet light.

2. *2007 Field Activity*

No repairs were needed on the system this year. The filter box system was in good condition with no indication of overflow and therefore materials were not replaced. Monitoring samples were taken for both soil and water at the established monitoring points along the pathway, both upstream and downstream from the barrier at locations indicated on Map 7.

Map 7: Monitoring Points at the Pond and Barrier System in the Drainage Pathway Leading from the Imploded Tank



3. *Monitoring Results*

Results of analyses of this year's soil samples are shown in Table 17 along with those for the previous 3 years. The soil results for all four years generally show the established trend of a decrease in TPH levels as the distance from the source at the imploded tank increases. This year the TPH levels results showed the same trend as in previous years. As there is only slow lateral movement of the TPH in the pathway it will likely be some time before levels below the barrier show a decrease.

Table 17: Results of Soil Analyses for TPH at the Imploded Tank Drainage Area Ponds and Barriers

Soil Monitoring Point	Location	TPH (ppm)			
		2004	2005	2006	2007
SP1	Below waterfall	950	710	310	370
SP2	Between waterfall and barrier	1190	<40	<40	<40
SP3	Just beyond barrier	290	600	182	290
SP4	Between barrier and cliff	160	100	<40	100

Water samples taken in the imploded tank drainage channel during the assessment phase all gave results of <1.0 mg/L TPH. Water samples were collected in 2004 from four points within the barrier system to determine low-level concentrations of TPH in water. Results given in Table 18 show that TPH levels were in the range from 0.09 - 0.11 ppm. In 2005 one additional monitoring point was added. Results of the analysis for TPH in water from these five points gave values in the range 0.16 – 0.31 ppm TPH. In both 2004 and 2005 there was considerable disturbance of the surface soil and water interface in and around the imploded tank area. The results for these years may therefore represent elevated background levels associated with this activity. The samples collected this year were analysed with a detection limit of 0.10 ppm and no TPH was detected.

Table 18: Results of Water Analyses for TPH at the Imploded Tank Drainage Area Ponds and Barriers

Water Monitoring Point	Location	TPH (mg/L)			
		2004	2005	2006	2007
WP1	Small Waterfall Upstream of Pond	0.09	0.19	<0.20	<0.10
WP2	Pond #1	0.11	0.31	<0.20	<0.10
WP3	Pond #1 Discharge Pipe	-	0.16	<0.20	<0.10
WP4	Pond #2	0.09	0.29	<0.20	<0.10
WP5	Filter System Discharge	0.09	0.23	<0.20	<0.10

Nutrient levels at 3 of the soil sampling points are given in Table 19. As in previous years the levels of extractable ammonia, nitrate and nitrite were all below the method detection limits indicating no leaching of these from the main landfarm. Total N and P levels are similar to those from previous years.

Table 19: Nitrogen and Phosphorus Levels (ppm) in Soil at the Imploded Tank Drainage Area Ponds and Barriers

Sample	Plot	TKN	Ext. Ammonia	Ext. Nitrate	Ext. Nitrite	Total P	Ext P
RI07-008N	SP1	270	<5	<2	<2	145	<10
RI07-009N	SP2	190	<5	<2	<2	121	<10
RI07-010N	SP4	180	<5	<2	<2	116	<10

Hydrocarbon degrader levels in the 3 soils from SP1, SP2 and SP4 were found to be 4.5×10^4, 4.2×10^3, 2.2×10^3 respectively. These are typical levels found at the site.

L. PCB Barriers

The excavation of PCB contaminated soils at Resolution Island was carried out in the same manner as would be done elsewhere in Canada. However, it was not possible to excavate all the PCB contaminated soil because some soil was trapped in fractured bedrock, or located on very steep terrain that could not be accessed for logistical and safety reasons. The soil surface prior to the cleanup was stabilized by lichens and dwarf plants or by compaction. The soil remaining after excavation is now loose and subject to erosion, particularly during runoff. In order to control the PCB migration from these two factors, it was decided in 2002 that permanent barrier systems were required as a long term solution. The ASU was contracted to conduct the necessary research, design and development of these barrier systems.

In 2003, the first barrier was installed at the top of the cliff in the S1/S4 valley. Laboratory studies were conducted by the ASU in order to support the design and construction of this barrier system. As a result of these studies and field observations, the barrier was modified and two others were constructed at the S1/S4 beach adjacent to the shore and at the end of the furniture dump drainage channel. The barriers consist of a lined funnel formed by rock gabions through which all drainage must flow and a gate which contains various filters. Coarse sediment is trapped in the funnel while finer material is collected by the filters in the gate which also may remove dissolved material. This year all three barrier systems were inspected, sampled and maintained as necessary. This maintenance involved excavating sediment from the “funnel” traps and replacing the filters in the filter boxes. The overpack drums containing the PCB-contaminated sediment were not removed from near the barriers this year. They will require moving next year together with those generated next year. They could be conveniently stored in building B2. Work at each of the three barriers is discussed in detail below followed by a section which summarises the results.

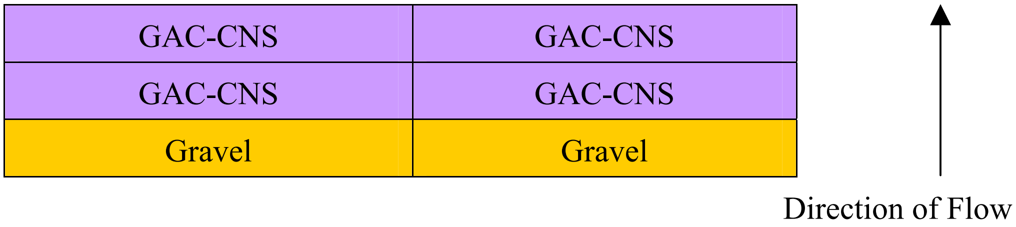
Additional laboratory work continued in support of the barrier system study and is presented in Section M.

1. *S1/S4 Valley Barrier*

a) General

Filters containing fresh gravel and GAC only were placed in the filter box in 2006. Only three of these 3 inch filters could be accommodated in this box. One GAC filter and two gravel filters were placed in each half of the filter box as shown in Figure 7.

Figure 7: Arrangement of Filters and Sorbents in the S1/S4 Valley Filter Box at the End of the 2006 Field Season



GAC-CNS	GAC-CNS
GAC-CNS	GAC-CNS
Gravel	Gravel

b) 2007 Field Work

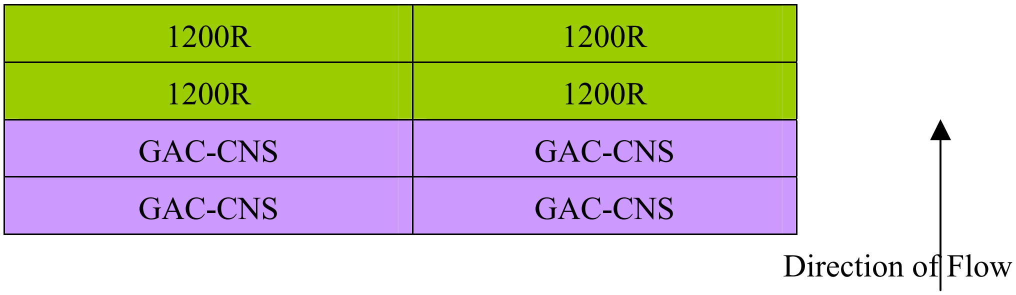
Upon preliminary inspection of the valley barrier it was noted that the sediment loading was about half that of 2006 and much less than 2005 (Photograph 3). A decrease was expected since the soil excavation in the valley had been completed in 2005 and this made the task of maintaining the barrier system less arduous this year. Moss has started to grow along the bottom side of the chevrons (Photograph 4). The chevrons are constructed of a geosynthetic that is primarily used for hydroseeding so this was quite interesting to see. Water was flowing through the filter gates, but no leakage was visible around the filters. The uncontaminated sediment in the first clean cell had been washed away but the second cell was in good condition. No repairs were necessary at the barrier. The material in the first clean cell was not replaced as it would likely be washed out as in previous years.

Photograph 3: The Barrier at the S1/S4 Valley at the Start of Field Work

Photograph 4: The Curlex Trap

Composite samples were taken from the funnel areas of the barrier and sent to the ASU laboratory for quick analyses. Sediment was shoveled out of the areas from specific sections into overpack drums. Eight drums were half-filled with sediment and labeled Valley 1 to 8. The first 5 were from sediment in front of the chevrons while Valley 6 to 8 were filled with material from between the chevrons and the filter box. After removing the contaminated sediment, filters were sampled and material from the old filters was placed into an overpack drum labeled Valley 9. The filter cassettes were filled with new GAC and Geotextile. The valley barrier was charged with 4 GAC filters and 4 geotextile filters as shown in Figure 8. Since there was now much less sediment loading, charcoal and geotextile were considered appropriate.

Figure 8: Arrangement of Filters and Sorbents in the S1/S4 Valley Filter Box at the End of the 2007 Field Season



1200R	1200R
1200R	1200R
GAC-CNS	GAC-CNS
GAC-CNS	GAC-CNS

c) Monitoring Results

(1) Water

Water was collected from 5 locations in the valley. Their locations and PCB concentrations are given in Table 20 and Map 8. These results are generally lower than in previous years; no water was collected in 2005 as none was flowing. The higher value downstream of the barrier is expected as some pockets of soil containing high levels PCBs could not be excavated here for safety and logistical reasons.

Table 20: PCB Concentration (ppb) in Water From the S1/S4 Valley

Sample Number	Monitoring Point	PCB Concentration	Location
RI07-019W	VWP1	0.078	In front of chevrons
RI07-020W/20D	VWP2	0.031	In front of filter box
RI07-028W	VWP3	0.071	After filter box
RI07-021W	VWP4	0.023	20 m downstream of barrier
RI07-025W	VWP5	0.080	Near cliff

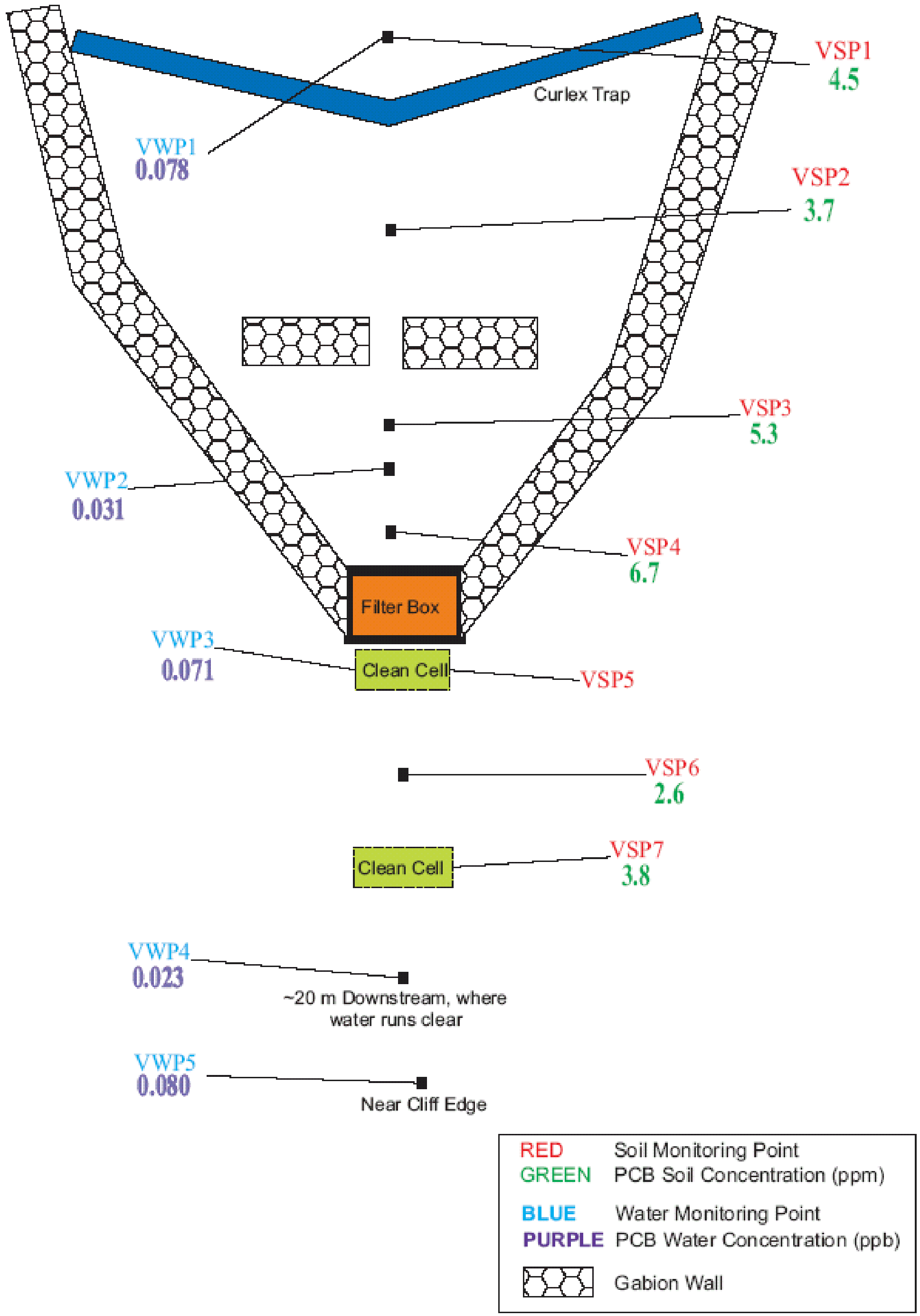
(2) Sediment

Results of the analysis for PCBs from sediment collected from within the barrier are shown in Table 21 and Map 8. The PCB level within the barrier was Tier II in all sections. Total amount of soil removed from the funnel this year was 0.75 m^3. Last year the volume of soil removed was 2.25 m^3 with an average concentration of 6.1 ppm while 7.0 m^3 of sediment was removed in 2005. The calculated amount of pure PCB trapped by the barrier in front of the filter box between 2 August 2006 and 3 August 2007 was 8.6 g as compared to 25 g for a similar period in the previous year.

Table 21: PCB Concentration of Sediment From the S1/S4 Valley Barrier

Sample Number	Monitoring Point	PCB Concentration (ppm)	Location
RI07-071	VMP1	4.5	In front of chevrons
RI07-072	VMP2	3.7	Between chevrons and first gabion fence
RI07-073	VMP3	5.3	Between first gabion fence and filter box
RI07-074	VMP4	6.7	In front of filter box
RI07-077	VMP6	2.6	Between the two clean cells
RI07-078	VMP7	3.8	Second clean cell

Map 8: Locations and PCB Concentrations of Soil and Water Samples at the S1/S4 Valley Barrier in 2007



(3) Filters

The filters were removed from the filter box on 3 August 2007. Samples were collected from each filter and analysed for PCBs. Results of analysis are presented in Table 22, which also gives the location from which the sample was taken. Composite samples were taken from some filters while in others, top, middle and bottom samples were taken. The PCB concentration found in the filters was low in all samples and the levels in the gravel were less than last year. The average amount of PCB trapped by the filters was calculated to be 8 mg per filter pair in the gravel row, 64 mg per filter in the first pair of GAC filters and 72 mg per filter on the GAC filters in the second row. Thus the total amount of pure PCBs collected by the filter box this year was 289 mg. This compares to 128 mg in 2006 and 474 mg in 2005. One GAC and two gravel filters were used in 2006 and, as can be seen, the gravel filters were less efficient than the GAC filters this year. In fact the amount of 8 mg of PCBs on each gravel filter this year is much less than the 24 mg and 31 mg collected on the gravel filters in 2006. This year the GAC filters trapped much more than in 2006 when only 10 mg of PCBs were trapped by each filter cartridge. It seems likely that as the soil in the excavated areas stabilize, the amount of coarser sediment transported to the barrier decreases relative to the finer material. This argument would also fit in with the decrease in sediment loading in the funnel of the barrier. In 2005 excavation was still proceeding which would account for the higher level in that year. The barrier is functioning as designed since the contaminant is being removed as water passes through the barrier system. This year the gravel filter was not replaced. The re-introduction of two geotextile filters to trap the finer particles as the final step is hoped to increase the efficiency of the barrier and remove the finer material being transported from the drainage area.

Table 22: PCB Concentration of Filter Box Materials From the S1/S4 Valley Barrier System in Operation From 2 August 2006 to 3 August 2007

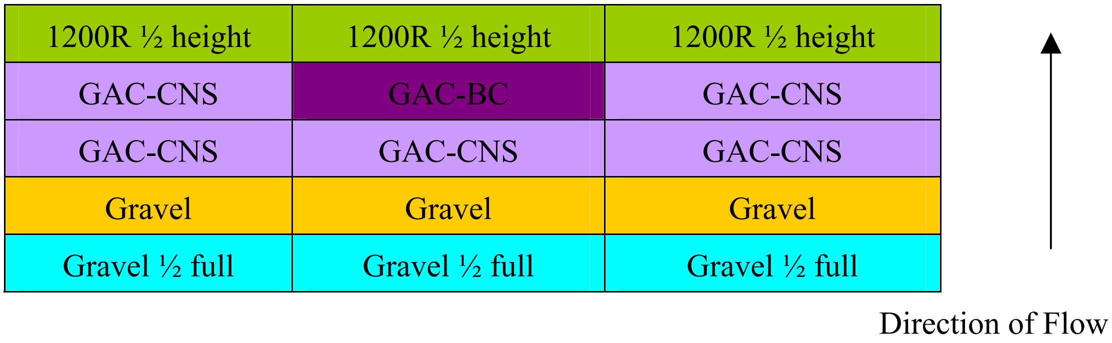
Sample No	Medium	Location	PCB (ppm)
RI07-079	Gravel	Left first filter top third	0.4
RI07-080	Gravel	Left first filter middle third	0.2
RI07-080D	Gravel	Left first filter bottom third	0.1
RI07-076	Gravel	Right first filter	0.2
RI07-058	GAC-CNS	Left second filter	1.7
RI07-059	GAC-CNS	Right second filter top third	2.8
RI07-060	GAC-CNS	Right second filter middle third	1.3
RI07-060D	GAC-CNS	Right second filter bottom third	0.8
RI07-055	GAC-CNS	Left third filter top third	3.3
RI07-056	GAC-CNS	Left third filter middle third	1.6
RI07-057	GAC-CNS	Left third filter bottom third	2.2
RI07-043	GAC-CNS	Right third filter	1.4

2. *S1/S4 Beach Barrier*

a) General

An interceptor barrier was designed and constructed at the bottom edge of this area adjacent to the sea in 2005. Figure 9 shows the arrangement of filters in the filter box at the end of the 2006 field season.

Figure 9: Arrangement of Filters and Sorbents in the S1/S4 Beach Filter Box at the End of the 2006 Field Season



1200R ½ height	1200R ½ height	1200R ½ height
GAC-CNS	GAC-BC	GAC-CNS
GAC-CNS	GAC-CNS	GAC-CNS
Gravel	Gravel	Gravel
Gravel ½ full	Gravel ½ full	Gravel ½ full

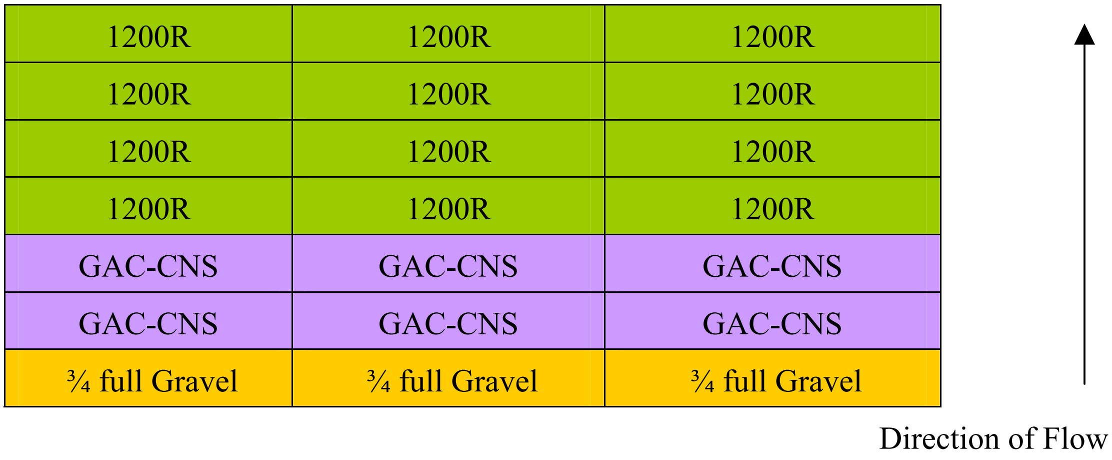
b) 2007 Field Work

The area was reached by walking from the beach landing area adjacent to building B2 (Photograph 5). The S1/S4 beach barrier was found to be in good condition upon arrival (Photograph 6). Six sediment samples were taken from in and adjacent to the barrier. Five overpack drums labeled Beach 1 to 5 were completely filled with sediment shoveled out of the funnel area. The filter cassettes were then sampled and their contents placed in an overpack drum labeled Beach 6. The filters were then recharged and replaced within the filter box. These comprised one gravel and two GAC filters, for a total of 3 gravel and 6 GAC filters as shown in Figure 10. In the last filter slot in each box, four layers of a non-woven geotextile (1200R) were placed one after the other with about a 2 cm gap between each. The height of each decreased approximately 2 cm from front to back so that if the first were to clog it would not prevent the next from functioning properly. The top black wooden plate was replaced securely on top of the filters.

Photograph 5: Transporting Supplies to the S1/S4 Beach Barrier

Photograph 6: The Three Cassettes of the S1/S4 Beach Barrier Before Their Removal

Figure 10: Arrangement of Filters and Sorbents in the S1/S4 Beach Filter Box at the End of the 2007 Field Season



1200R	1200R	1200R
1200R	1200R	1200R
1200R	1200R	1200R
1200R	1200R	1200R
GAC-CNS	GAC-CNS	GAC-CNS
GAC-CNS	GAC-CNS	GAC-CNS
¾ full Gravel	¾ full Gravel	¾ full Gravel

c) Monitoring Results

(1) Water

Water was collected from 3 locations in the beach area. Their locations and PCB concentrations are given in Table 23 and Map 9. These values are generally lower than those obtained last year. No PCBs (<0.020 ppb) had generally been detected in the water below the cliff at the sea edge prior to the construction of the barrier. The higher values in the last two years are likely caused by the major disturbance of soils during excavation.

Table 23: PCB Concentration (ppb) in Water From the S1/S4 Beach Area

Sample Number	Monitoring Point	PCB Concentration	Location
RI07-023W	BWP2	0.011	Effluent from barrier filter box
RI07-018W	BWP2	0.041	Effluent from barrier filter box
RI07-022W	BWP3	0.031	Below cliff at the sea edge

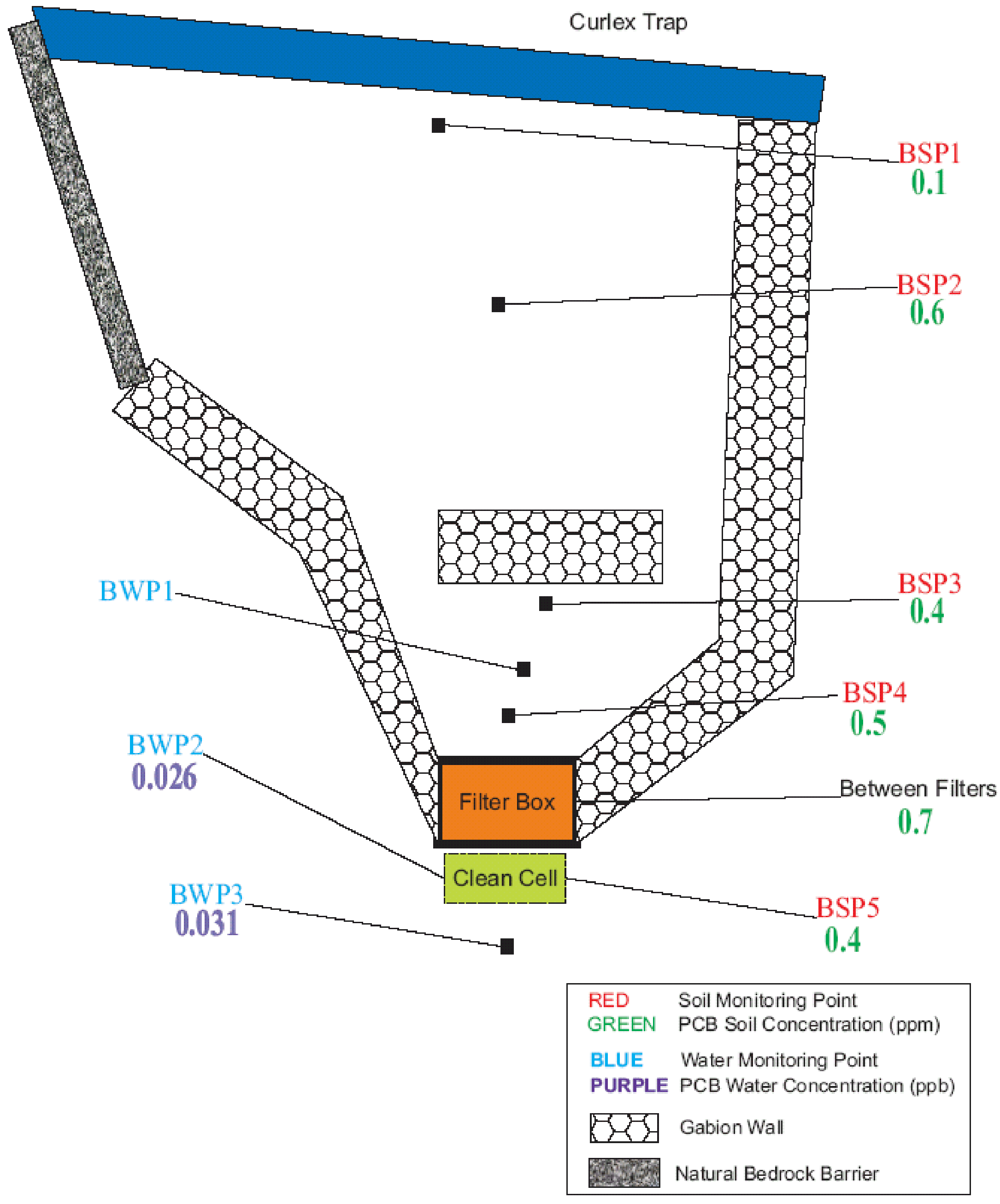
(2) Sediment

Six sediment samples were collected in and around the barrier. Results of analysis of these for PCBs and their locations are given in Table 24 and Map 9. The levels were very low with the highest being 0.8 ppm and the average 0.45 ppm. The soil along the main drainage pathway leading up to the funnel was not removed due to its quantity and difficulty in excavating it. The amount of pure PCBs removed in the sediment from the barrier was calculated to be 1.2 g PCB. The volume of sediment and the mass of PCBs was approximately half that obtained in 2006.

Table 24: PCB Concentration of Sediment From the S1/S4 Beach Barrier

Sample Number	Monitoring Point	PCB Concentration (ppm)	Location
RI07-091	BMP1	0.1	Between top gabions and Curlex trap
RI07-092	BMP2	0.6	In front of Curlex trap
RI07-093	BMP3	0.4	Between edge of liner and central gabion
RI07-094	BMP4	0.5	In front of filter box
RI07-095	BMP5	0.4	Below filter box outside of barrier
RI07-088	-	0.7	Between filters

Map 9: Locations and PCB Concentrations of Soil and Water Samples at the S1/S4 Valley Barrier in 2007



(3) Filters

The filters were removed from the filter box on 4 August 2007. Samples were collected from each filter and analysed for PCBs. Results of analysis are presented in Table 25 for GAC and gravel and Table 26 for the geotextile 1200R, which also give the location from which the samples was taken. Very low concentrations of PCBs were found again this year with only 36 mg collected on the 6 gravel filters and 28 mg on the 6 GAC filters. No difference between the two GAC grades was observed. These values compare with 29 mg and 16 mg found of the gravel and GAC filters respectively last year.

Table 25: PCB Concentration of Filter Box Materials From the S1/S4 Beach Barrier System in Operation From 29 July 2006 to 4 August 2007

Sample No	Medium	Location	PCB (ppm)
RI07-21	Gravel	Left first filter top half	0.5
RI07-22	Gravel	Left first filter bottom half	0.1
RI07-29	Gravel	Central filter	0.1
RI07-87	Gravel	Right filter	0.6
RI07-23	Gravel	Left second filter	0.1
RI07-96	Gravel	Central second filter	0.1
RI07-97	Gravel	Right second filter top third	0.1
RI07-98	Gravel	Right second filter middle third	0.1
RI07-99	Gravel	Right second filter bottom third	0.2
RI07-24	GAC-CNS	Left third filter top third	0.6
RI07-25	GAC-CNS	Left third filter middle third	0.3
RI07-26	GAC-CNS	Left third filter bottom third	0.2
RI07-30, 30D	GAC-CNS	Central third filter	0.2
RI07-100, 100D	GAC-CNS	Right third filter	0.4
RI07-28	GAC-CNS	Left fourth filter	0.3
RI07-81	GAC-CNS	Central fourth filter top third	0.8
RI07-82	GAC-CNS	Central fourth filter middle third	0.2
RI07-83	GAC-BC	Central fourth filter bottom third	0.1
RI07-86	GAC-CNS	Right fourth filter	0.2

The concentration of PCBs found on the three half-height geocomposite filters is given in Table 26. While these are also low they are higher than the concentrations in the GAC and gravel filters. The average mass of PCBs collected per filter (0.1 mg) is however low due to the lower mass of the cloth filters as compared to the 3 inch GAC and gravel filters. Four geocomposite filters have been placed in the barrier this year.

Table 26: PCB Concentration of the Geotextile Materials From the S1/S4 Beach Barrier System in Operation From 29 July 2006 to 4 August 2007

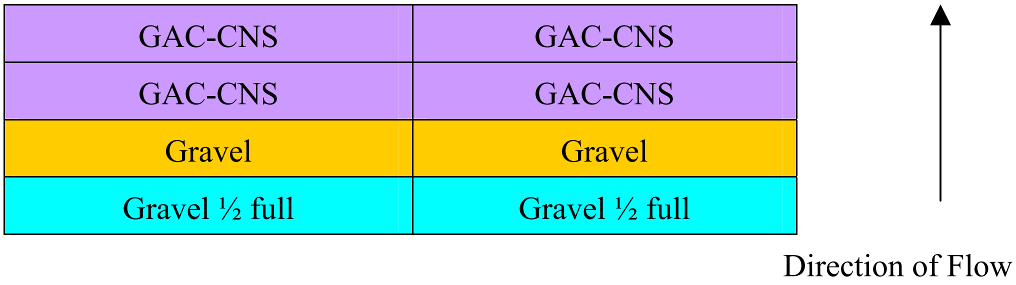
Sample No	Medium	Location	PCB (ppm)
RI07-027	1200R	Left	1.6
RI07-084	1200R	Central	2.4
RI07-085	1200R	Right	2.5

3. Furniture Dump Barrier

a) General

The furniture dump and its drainage pathway were excavated in 1999. Transformers containing nearly pure PCBs were removed from the dump. All soil containing > 1 ppm PCB was removed from the original dump and its drainage pathway and large areas of exposed boulders were washed and vacuum cleaned. In 2003, a wooden experimental barrier was designed and constructed. This was replaced by a stainless steel one in 2005. Results of analyses of barrier sediment and filters in the period 2004-2006 showed that PCBs were being transported in the drainage pathway and were still present in the area previously occupied by the furniture dump and in the drainage pathway leading from it. This was despite considerable effort to remove any soil found to contain < 1 ppm PCBs with the vacuum truck; normally vacuuming was only undertaken for CEPA areas. Figure 11 shows the arrangement of filters in the filter box at the end of the 2006 field season.

Figure 11: Arrangement of Filters in the Furniture Dump Filter Box at the End of the 2006 Field Season



GAC-CNS	GAC-CNS
GAC-CNS	GAC-CNS
Gravel	Gravel
Gravel ½ full	Gravel ½ full

b) 2007 Field Work

Upon inspection, there was again little sediment in the furniture dump barrier. Water was flowing above the barrier but not through it; a water sample was collected. Five soil samples were collected from in and around the barrier. Approximately 0.25 m^3 of material was then removed from the silt fence up gradient from the barrier and from the barrier funnel. This was placed in two overpack drums which were half filled and labeled FD1 and FD2. The four charcoal and four gravel filters were removed from the barrier, sampled. The remains of the gravel filters were placed into an overpack drum labeled FD3. The three drums were transported to beside the airstrip by ATV and trailer. One gravel filter cassette was then refilled with new gravel and four geotextile sheets were placed in the fourth slot as shown in Figure 12. Since the two GAC filters showed little sign of sediment contamination they were not refreshed but moved from slots 3 and 4 to slots 2 and 3. No modifications or repairs were deemed necessary for the barrier.

Figure 12: Arrangement of Filters in the Furniture Dump Filter Box at the End of the 2007 Field Season

1200R	1200R
1200R	1200R
1200R	1200R
1200R	1200R
GAC-CNS	GAC-CNS
GAC-CNS	GAC-CNS
¾ full Gravel	¾ full Gravel

c) Monitoring Results

(1) Water

A high level of 0.535 ppb PCBs was found in water above barrier this year; no water was passing through the barrier at the time of the site visit. In 2005 a level of 0.89 ppb was recorded but generally water has been absent during the summer sampling season. These high levels are consistent with the high sediment levels and slow water movement.

(2) Sediment

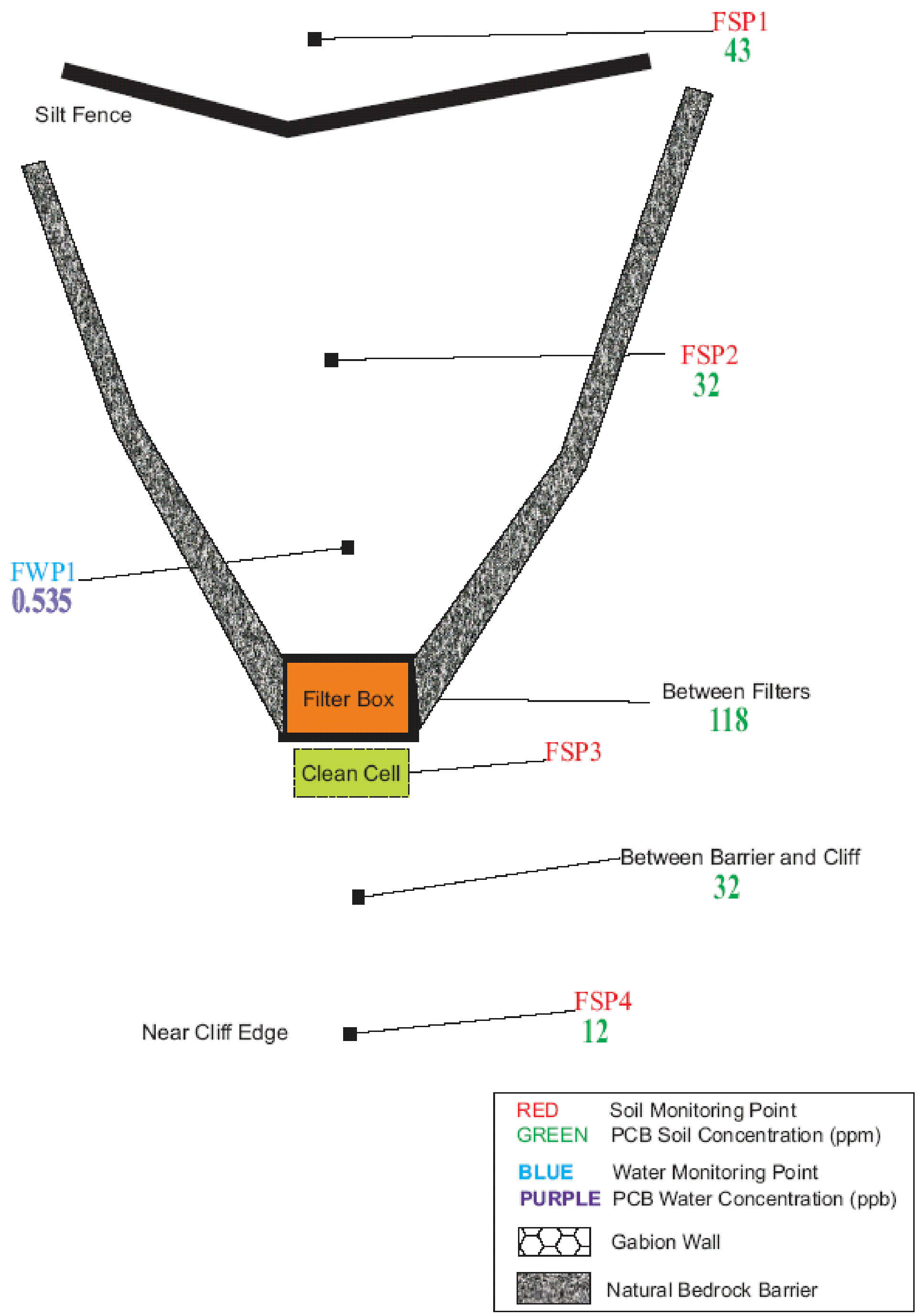
Five sediment samples were collected for analysis from the locations given in Table 27 and Map 10. The high values found paint a similar picture to the results obtained in previous years, that is, that there are small quantities of sediment contaminated at higher concentrations than found in the S1/S4 valley or beach areas. This is likely due to the very highly contaminated soils that were found in the furniture dump. The total amount of pure PCBs removed with the sediment was approximately 16.9 g in 0.25 m^3 of sediment. This is very similar to the 15.4 g of PCBs in 0.3 m^3 of sediment found in 2006, indicating that a steady state seems to have been reached at this location.

The level of 118 ppm PCBs that was found in the very small volume of soil between the filter cartridges in the box indicates that this finer material contains higher PCB concentrations than in the sediment.

Table 27: PCB Concentration of Sediment Samples From the Furniture Dump Barrier System After Spring Runoff

Sample Number	Monitoring Point	PCB Concentration (ppm)	Location
RI07-032	FMP1	43	In front of silt fence
RI07-034	FMP2	32	In funnel of barrier
RI07-033	FMP3	32	Between the barrier and the cliff
RI07-031	FMP4	12	Near cliff edge to the south of the barrier
RI07-039	-	118	Between filters

Map 10: Locations and PCB Concentrations of Soil and Water Samples at the Furniture Dump Barrier in 2007



(3) Filters

Results of analyses of the contents of the filters are given in Table 28. The mass of PCB collected in the gravel filters was 79 mg and by GAC filters was 209 mg for a total of 288 mg. These values are approximately two and a half times less than in 2006. The lower third of the GAC filters collected significantly more material than the upper two thirds suggesting that the water flow through the box is predominantly through the lower portion in contrast to the S1/S4 valley barrier. The catchment area for the furniture dump barrier is very much less than that of the S1/S4 drainage basin.

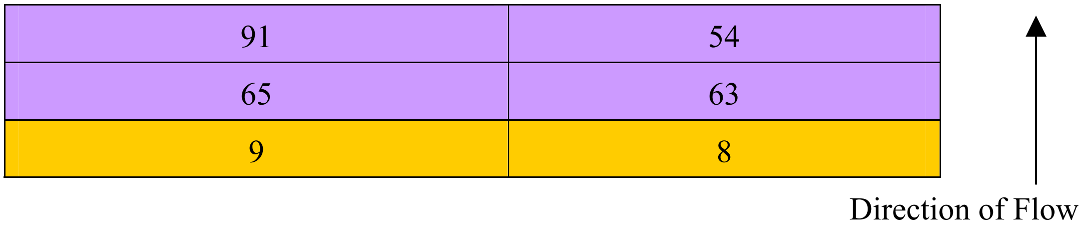
Table 28: PCB Concentration of Filter Box Materials From the Furniture Dump Barrier System in Operation From 5 August 2006 to 2 August 2007

Sample No	Medium	Location	PCB (ppm)
RI07-041	Gravel	Left first filter top half	0.2
RI07-042	Gravel	Left first filter bottom half	2.4
RI07-054	Gravel	Right first filter	0.6
RI07-040, 40D	Gravel	Left second filter	0.5
RI07-051	Gravel	Right second filter top third	0.1
RI07-052	Gravel	Right second filter middle third	0.2
RI07-053	Gravel	Right second filter bottom third	1.5
RI07-036	GAC-CNS	Left third filter top third	1.8
RI07-037	GAC-CNS	Left third filter middle third	2.7
RI07-038	GAC-CNS	Left third filter bottom third	15
RI07-050	GAC-CNS	Right third filter	3.5
RI07-035	GAC-BC-CNS	Left fourth filter	3.7
RI07-047	GAC-BC-CNS	Right fourth filter top third	0.1
RI07-048	GAC-BC-CNS	Right fourth filter middle third	0.7
RI07-049	GAC-CNS	Right fourth filter bottom third	9.9

4. *Summary of Barrier Results*

Figures 13, 14 and 15 give the mass of pure PCBs in mg collected on the individual filters in the barriers at the S1/S4 valley barrier, S1/S4 beach barrier and furniture dump barrier respectively.

Figure 13: Mass of Pure PCBs (mg) Found in the Various Sections of the S1/S4 Valley Barrier Filter Box

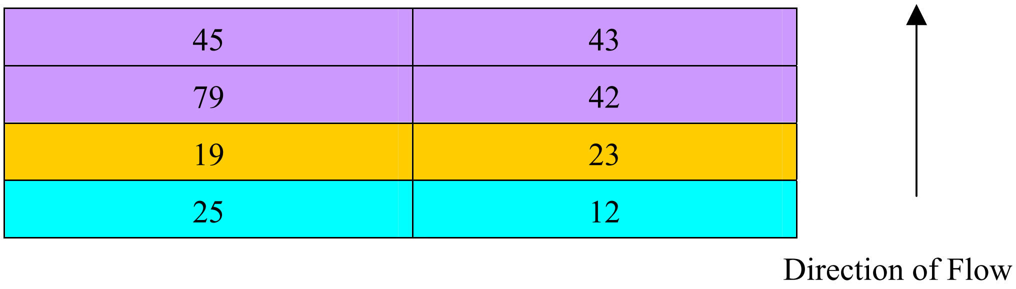


91	54
65	63
9	8

Figure 14: Mass of Pure PCBs (mg) Found in the Various Sections of the S1/S4 Beach Barrier Filter Box

0.1	0.1	0.1
4	4	2
4	2	5
4	4	5
11	4	8

Figure 15: Mass of Pure PCBs (mg) Found in the Various Sections of the Furniture Dump Barrier Filter Box



45	43
79	42
19	23
25	12

Legend

🟪 GAC CNS 612
■ GAC BC 1240
🟩 Geotextile 1200R
🟨 Gravel
🟦 ½ Filled with Gravel

Table 29 summarises the amounts of pure PCBs collected in the three barrier systems in the sediment and filter systems in 2007 and 2006 while Figure 16 illustrates the change in sediment loading at the barriers with time.

Table 29: Mass of PCBs Collected at the Three Barrier Systems From Sampling in 2007 (2006)

Barrier	Volume of Sediment	PCB Concentration in Sediment	Mass of PCBs in Sediment	Mass of PCBs in Filters
	m^3	ppm	g	g
S1/S4 Valley	1.0 (2.2)	4.8 (5.0)	8.5 (25)	0.29 (0.13)
S1/S4 Beach	1.25 (2.0)	0.55 (0.7)	1.2 (2.5)	0.06 (0.04)
Furniture Dump	0.25 (0.3)	37.5 (29)	16.9 (15)	0.29 (0.73)

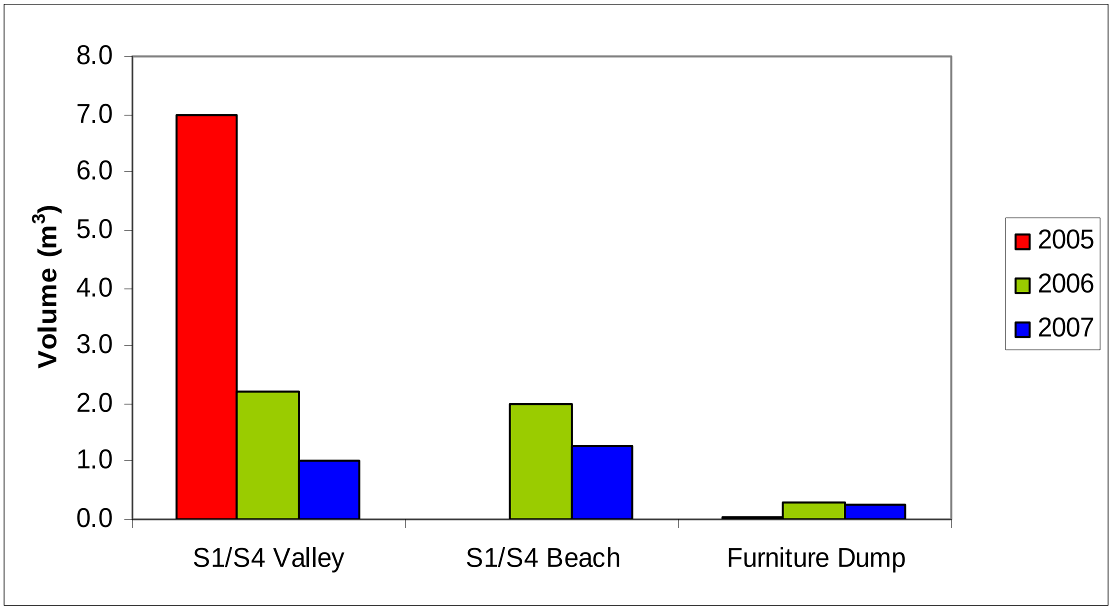


Figure 16: Change in Volume of Sediment Collected at the Three Barriers With Time

Similar quantities of sediment were collected in the two barriers in the S1/S4 drainage pathway in 2006 and 2007 but the PCB concentration in the valley sediment was higher in both years than the beach sediment. This year the volume of sediment and mass of PCBs was lower than 2006 and even lower than for 2005 at the S1/S4 valley barrier; the S1/S4 beach barrier was constructed in 2005 and so no data is available for that year. The furniture dump shows very different characteristics since it has a different history and a much smaller catchment area. The volume of sediment and mass of PCBs collected appears to have reached a steady state.

More PCBs were trapped in the gravel than the GAC for the two S1/S4 barriers in 2005 while the situation was reversed this year for the valley barrier and similar quantities were found in GAC and gravel at the beach barrier. More PCBs were again found in the GAC than the gravel at the furniture dump barrier. In the S1/S4 valley, filtering out of larger particles would appear to have been more important than small ones in 2006 but as the soil and sediment in the pockets in the catchment area have stabilized, less coarse material has been transported in the run-off. This trend should continue with a higher proportion of material being of a finer particle size as time passes and eventually mosses, lichens and vascular plants will develop in the area disturbed by excavation. At the furniture dump, which was excavated in 1999, the results show that the stabilization of soil is more advanced.

The concentration of PCBs found in the ½ height geotextile filters at the S1/S4 beach barrier was between 1.6 and 2.5 ppm PCBs as compared to 0.1 to 0.8 ppm PCBs in the GAC filters although the actual amount of PCBs retained was less. This year, two to four geotextile filters have been added to the barriers at between ¾ to full height. As the sediment at the site stabilizes the barriers will be gradually modified to increase their ability to trap finer particles.

M. Retention and Partitioning Laboratory Study

1. *Soil/Water/GAC Batch Tests*

Desorption from PCB contaminated soil into water is thought to be a very slow process. Previous batch tests have shown that GAC will adsorb PCBs from PCB-contaminated water. In the field and barrier system, most PCBs travel as suspended contaminated particles in a water column with a small proportion of dissolved PCBs present. In order to better understand the mechanisms involved it was decided to study how GAC might affect the desorption of PCBs from contaminated soil into water or, in other words, the partitioning of PCBs in the three component system GAC/soil/water. Previous literature has not investigated the combined system of GAC, water and PCB-contaminated soil together.

Batch tests were set up as follows: 1 g of GAC-CNS612 and 1 g of PCB contaminated soil were placed in a 1L Teflon bottle with 800 mL DDI water. The bottle was placed into a rotating apparatus and rotated at 50 ± 2 rpm for varying periods of time: 1h, 12 h, 24 h, 72 h, 168h, 336h. The samples were then poured out through a sieve (fine enough to trap GAC, large enough holes to let soil fall through) and filtered through a 0.45μm filter paper. The three fractions were then extracted and analyzed for Aroclor 1260. The GAC fraction was split in half previous to extraction and half the sample was placed in a vial for future extraction for congener analysis.

Results from last year demonstrated that the uptake of PCB by GAC was limited by the desorption of PCB from soil to water. It was not certain if the presence of GAC in the system inhibited the amount of PCB being desorbed, or whether the GAC was also partitioning in equilibrium with the water. Soil water batch tests were conducted to discern if GAC played any influencing role with respect to PCB partitioning into the water from the soil.

2. Partitioning Studies

In this work, three systems were studied:

1) GAC, PCB contaminated soil and water (GSW)
2) PCB contaminated soil and water (SW)
3) Sand (same particle size and shape as GAC), PCB contaminated soil and water.

Each of these studies was conducted as a series of batch tests as described above. In study 1 and 2, each fraction (soil, GAC, water) was analyzed to evaluate the proportion of PCBs in the components. Results are shown in Table 30 (GWS) and Table 31 (SW).

Table 30: Partitioning of PCB Between Soil, GAC and Water at Various Times

Time	Initial PCB content in Soil		PCB in GAC		PCB in Water	
h	ug	±	ug	±	ug	±
1	76	0.2	0.4	0.1	0.5	0.0
12	82	3.5	2.6	0.5	1.0	0.1
24	76	0.2	1.4	0.5	1	0.2
72	76, 82	0.2, 3.5	2.8	1.8	1.0	0.1
168	72, 76,	0.3, 0.2	1.9	0.3	1.3	0.5
336	76	0.2	2.1	0.3	1.3	1.0

Table 31: Partitioning of PCB Between Soil and Water at Various Times

Time	Initial PCB content in Soil		PCB in Water	
h	ug	±	ug	±
1	82	3.5	0.3	0.0
24	82	3.5	1.0	0.2
72	72	0.3	1.4	1.0
168	72	0.3	1.0	0.1
336	72	0.3	1.3	1.1

The total amount of PCB desorbed from the soil was plotted versus time and is shown in Figure 17.

This figure examines the two systems

$PCB_{(soil)} \rightarrow PCB_{(GAC)} + PCB_{(water)}$ and $PCB_{(soil)} \rightarrow PCB_{(water)}$

It can be seen from Figure 20 that a greater amount of PCB is desorbed over time in the GSW than in the SW system. This indicates that the following reaction is occurring:

$PCB_{(soil)} \rightarrow PCB_{(water)} \rightarrow PCB_{(GAC)}$

It can also be concluded from the overall amount of PCB that is desorbed from the soil (only 4% of total PCB has desorbed by one week), that the first desorption reaction (PCB(soil) → PCB(water)) is the rate-limiting step. Previous laboratory studies have shown that GAC has the potential to adsorb within an hour, 92 ± 6% of PCBs (initial concentrations ranging from 25 to 1000 ppb in water) within an aqueous system (ASU, 2004). This data also agrees with previous soil/water desorption/partitioning studies with PCBs in sediments that show slow and very slow desorption (ASU, 2006). This very slow desorption begins around 72 hours and can be seen by the shape of the curves in Figure 17

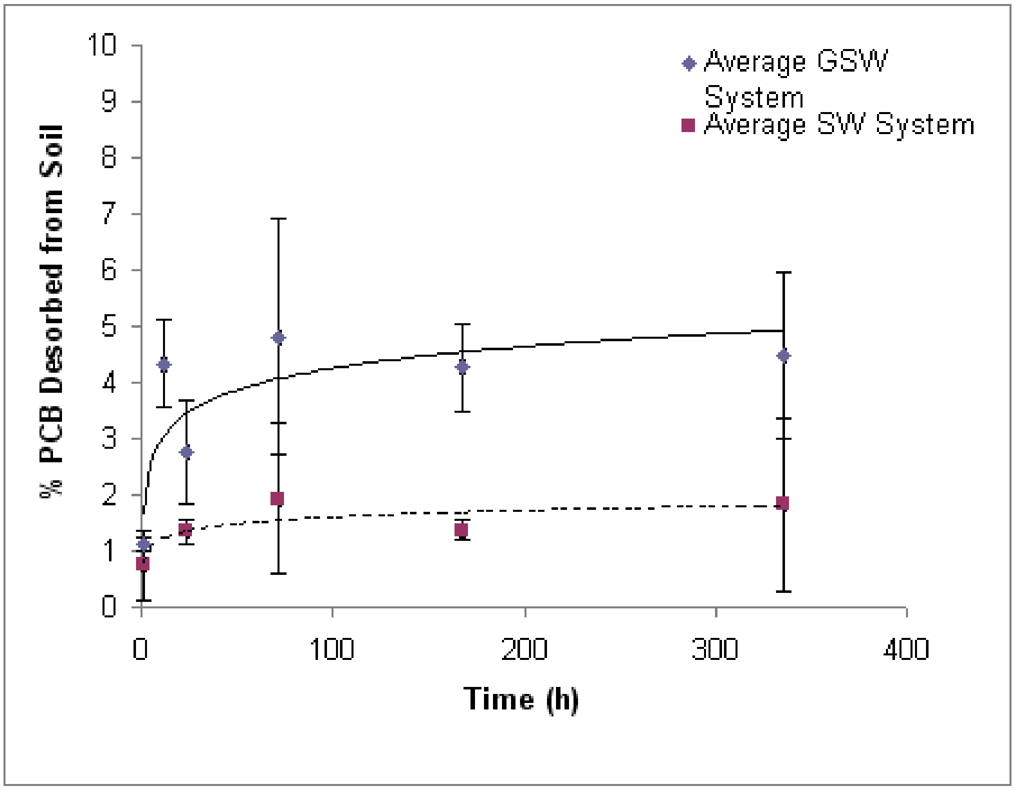


Figure 17: % Desorption of PCBs from Soil Over Time

In study 3 it was found that even after two months, no PCBs partitioned onto the sand particles from the soil (0.03 ± 0.05 ug/g, where the blank was also equal to 0.03 ug/g). This is in contrast to the soil/GAC/water system where PCBs did partition to the GAC. Particle retention in the PCB barrier system on Resolution Island is an important mechanism and sand can replace GAC in this respect. However, adsorption does occur within the barrier system and in terms of trapping and storing the PCB, this adsorption mechanism (unlike the particle retention) is irreversible and therefore much more desirable in the long term.

Analysis of field samples and column samples investigates this relationship in the following section.

3. *Column Tests*

a) Particle Retention Testing

The filter system put in place in the summer of 2007 was tested in the laboratory using a column apparatus (Figure 18) in a horizontal configuration.

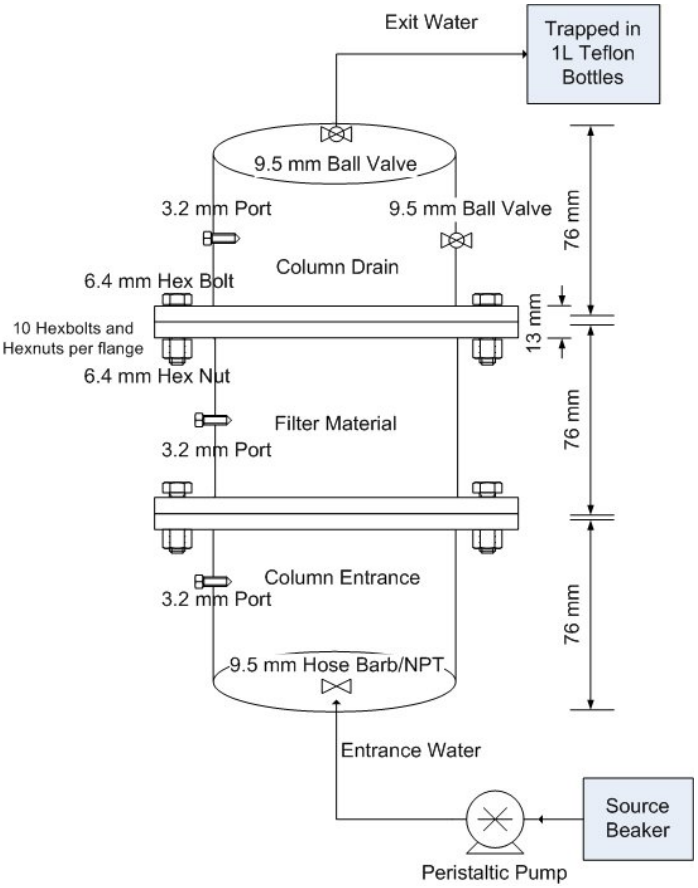


Figure 18: Schematic Diagram of the Laboratory Testing Apparatus

This filter system consisted of a half-height gravel filter, a full gravel filter, two full CNS612 GAC filters and four non-woven geotextiles with subsiding heights. Results from these column experiments showed that the loss of PCBs from the system totals 3.6 %. These are similar results to previous experiments with two charcoal filters and one nonwoven geotextile. It is important to keep in mind that these studies represent a worst-case scenario, as the column apparatus is a closed system, while the system in the field is open and therefore not subject to the same amount of pressure. This excess pressure in the closed system may drive PCB contaminated fines through the system.

Over time, granular filter materials can be washed out (Locke et al., 2001). In the field, one of the key questions was whether PCBs may be rinsed off/out of the filter materials. A longer-term column study conducted that flushed 100 L over 25 minutes and showed that further PCBs were not lost by increasing the volume of water flushing through the system. Results are shown below in Figure 19.

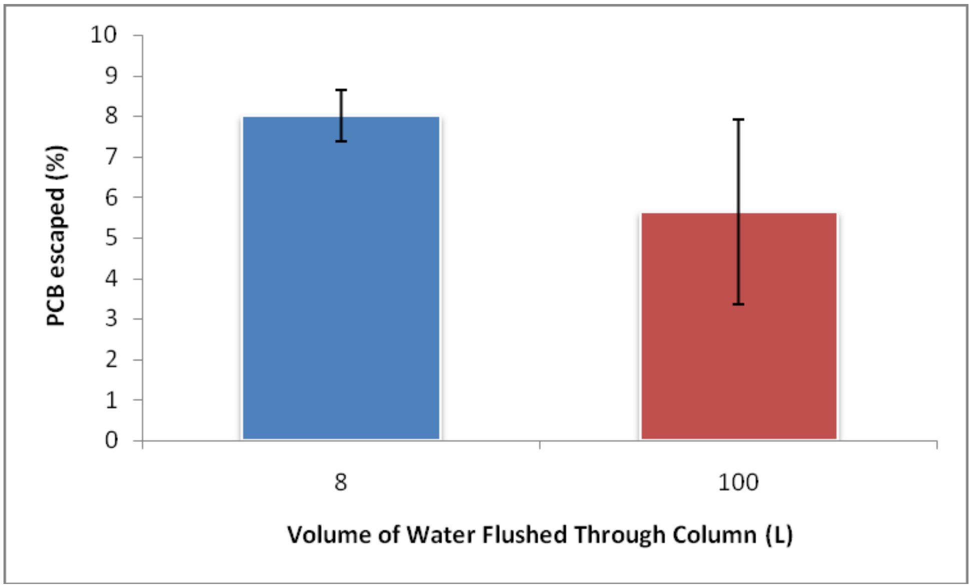


Figure 19. Loss of PCBs From the Column System: Long-Term versus Short-Term

b) <u>Adsorption</u> <u>versus</u> <u>Particle</u> <u>Retention</u> <u>Testing</u>

Column studies from last spring (ASU, 2006) demonstrated that sand trapped roughly the same amount of PCB as GAC in column runs. If sand proved to be as effective as GAC in trapping PCBs, it would be possible to replace the GAC with a more cost-effective material.

These column tests were conducted using the same stainless steel column apparatus described earlier in this report. The tests were run while the apparatus was horizontal, to mimic field conditions. In this section filter materials were analysed by themselves – the particles they trapped were removed. This was done through a wet-sieving process. To reduce the amount of wet-sieving, a 2.54 cm thickness of filter was used. A second filter material (sand) was introduced that allowed the comparison of a relatively non-sorptive material to GAC. This sand was of similar particle shape and size to the GAC. A known quantity of the previously mentioned PCB contaminated soil was flushed through the column at a constant flow rate as a slurry, sourced from a glass beaker. The solution was pumped through continuously at 4 L/min for 2 min (i.e waste water was re-circulated through the system).

The column was then carefully taken apart to ensure that each fraction of PCB contaminated soil remained within the sections (i.e. entrance drain, filter section, exit drain; see Figure 18). The filter portion was removed and the material was poured onto a 1 mm sieve. The filter material was flushed with 5 L of double de-ionized water and laid out to dry on a metal tray. Column runs were conducted in triplicate for each material used. In cases where outliers were present, further column runs were conducted. The material was sampled for soxhlet analysis. After analysis, Light Electron Microscope photographs of the filter material were taken to make certain that no soil grains remained on the wet-sieved GAC and/or sand material. All PCBs found on the GAC or sand material could therefore be attributed to adsorption.

Results of this wet-sieved GAC were compared to wet-sieved sand and are shown below in Figure 20. Non-sieved GAC column runs were also completed for comparison, to evaluate the extent of PCBs trapped through particle retention versus adsorption. Wet-sieved GAC retained 0.37 ± 0.29 % whereas non wet-sieved GAC retained 18 ± 8.2%. This clearly indicated that although some adsorption was occurring, particle retention was the most important factor in terms of capturing PCBs. There was no statistical difference between the sand and GAC materials for adsorption. These tests demonstrate that sand could be used instead of GAC for a filter material in the barrier system. However, these results are different than those from the partitioning experiment in section 2 using sand. In the partitioning study the sand/soil/water system showed no adsorption of PCBs to sand whereas the GAC did show adsorption of PCBs. In this case the batch test studies are more consistent with the field samples described in the next section.

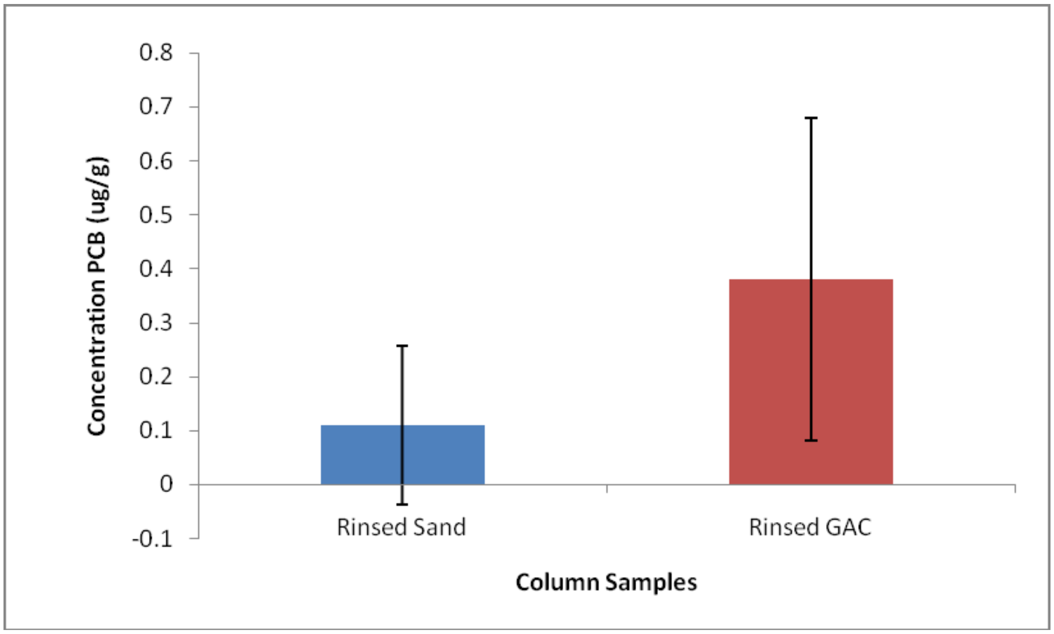


Figure 20: PCB Results of Rinsed Materials in Column Testing

4. *Field Samples*

It was seen from field samples at the furniture dump that although very little soil was present in the filters, high concentrations of PCBs were evident. Laboratory studies were undertaken to evaluate whether the PCB was in the soil, or was adsorbed onto the GAC. Several samples from the furniture dump barrier (RI07-038, RI06-059, RI06-076) and the S1/S4 Valley (RI07-055, RI07-057, RI07-059) with higher PCB concentrations were selected for analysis.

These samples were rinsed with distilled water to remove all soil particles from the GAC and left to dry prior to soxhlet extraction and GC/ECD analysis. Results of initial and final partitioned concentrations are shown below in Figure 21:

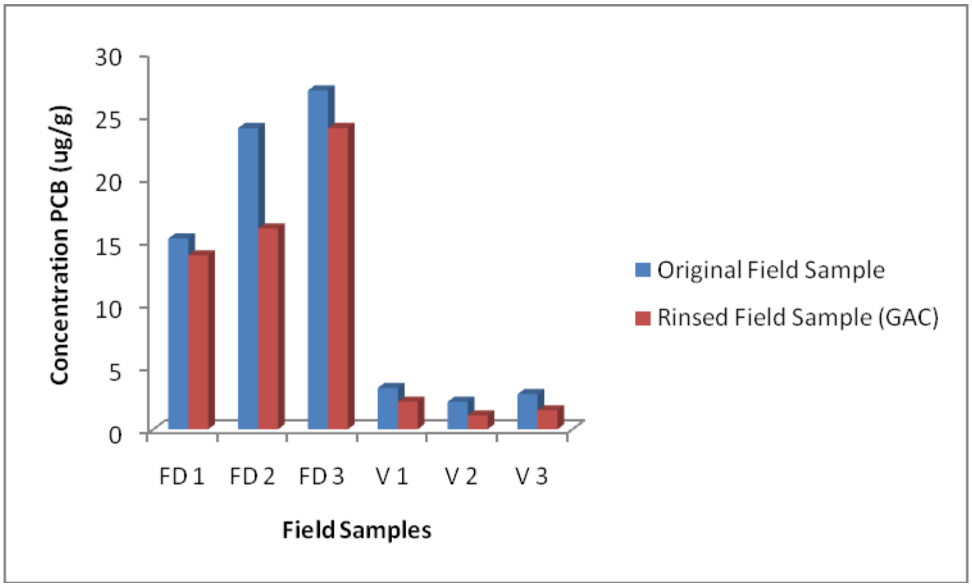


Figure 21: PCB Concentrations of Rinsed Field Samples.

These results show that there seems to be a significant difference in how the GAC is behaving in the field versus what is being seen in the laboratory column tests. Rinsed field samples showed that adsorption plays a much larger role than previously thought. GAC field samples showed an adsorption of 35 ± 2% (valley) and 62 ± 11% (furniture dump) of the total amount of PCBs, whereas experimental column data in the laboratory shows an adsorption of 0.4 ± 0.3 %. There is also a noted difference between how the different areas are behaving; adsorption clearly plays a much more integral role in the furniture dump barrier.

Further studies were required to evaluate the following questions:

1. How much time must the soil be in contact with GAC for adsorption to occur?
2. What was causing the different behavior between the furniture dump and valley barriers?

A preliminary column test was run for 8 hours to see if the time difference changed the adsorption behavior. It was seen that with an 8 hour column run, 3.6 % of the PCBs adsorbed onto the GAC, compared to 0.37 % over a two minute period. The soil used in these experiments was soil that in previous years had been excavated from the valley area so results were expected to be more similar to those of the rinsed valley field samples. This column run shows that although partitioning is happening, 8 hours of dynamic flow is not enough time.

It was also realized that although what occurs in batch studies is relevant to some part of adsorption in the barrier, they were unable to entirely explain the results found from the field samples. This may be due to long contact time in the field or increased particle-to-particle (soil-to-GAC) contact. As a result, several new batch studies are being developed in order to attempt to explain mechanisms. These further studies include: comparing furniture dump to valley samples; introducing hydrocarbons into the system to see how PCBs partition; comparing PCB in methanol to PCB in oil results; and changing the ratios of soil to water in the soil/GAC/water partitioning studies. These last can be compared with the results from the furniture dump and valley barrier. With these results, it may be possible to tailor each barrier system to suit the needs of its unique hydrogeological location.

5. *References*

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N. Appendix

This appendix contains the QA/QC data for this report and is followed by the field progress report of 8 August 2007 and summary plots of the thermister data.

The ASU is accredited by the Canadian Association for Environmental and Analytical Laboratories (CAEAL), for specific tests listed in the scope of accreditation. Quality control was maintained through the analysis of standards, duplicates, and blanks.

Most of the tables given below are self explanatory and show good control of the quality of results. The number of results in Table 32 exceeds those in the following tables relating to duplicate analyses. This is because most the results in Table 32 relate to analyses involving research where most experiments were done in triplicate and therefore no duplicate analyses were necessary.

Results in Tables 33 and 34 are for soil in the barrier sediment traps and for filter gravel and GAC. As expected the field duplicates give poorer precision than the laboratory ones due to the greater heterogeneity of the field samples. A similar result is seen in Tables 42 and 43 for the TPH results in soil.

Table 32: PCB Concentrations in Blank and Spiked QA/QC Soil and Other Solid Samples

Sample	Units	PCB Concentrations (ppm)
Blank	µg/g	<0.5, <0.5, <0.5, <0.5, <0.5, <0.5, <0.5, <0.5, <0.5
Control	µg/g	5.2, 4.6, 5.3, 5.6, 5.2, 5.2, 4.9, 5.3, 5.5
Control Target	µg/g	5.0

Table 33: PCB Concentrations in Laboratory Duplicate Soil and Other Solid Analysis

Sample Number (prefix: RI07-)	PCB Concentrations (ppm)	Standard Deviation	Relative Standard Deviation (RSD) (%)
037	2.5, 2.9	0.3	9.8
060	1.3, 1.1	0.1	12
095	0.4, 0.4	0	0
099	0.1, 0.2	0.1	53
100D	0.4, 0.3	0.1	29
Average RSD	-	-	21

Table 34: PCB Concentrations in Field Duplicate Soil and Other Solid Analysis

Sample Number (prefix: RI07-)	PCB Concentrations (ppm)	Standard Deviation	Relative Standard Deviation (RSD) (%)
030, 030D	<0.5, <0.5	0	0
040, 040D	0.8, <0.5	0.2	31
100, 100D	0.3, 0.4	0.7	20
Average RSD	-	-	17

Table 35: PCB Concentrations in Blank and Spiked Low Level Soil Analyses

Sample	Units	PCB Concentrations
Blank	ppb	<3.0; <3.0
Control	ppb	9.0; 8.8; 9.1; 9.4; 9.5
Control Target	ppb	10.0

Table 36: PCB Concentrations in Low Level Laboratory Duplicate Soil Analysis

Sample Number (prefix: RI07-)	PCB Concentrations (ppb)	Standard Deviation	Relative Standard Deviation (RSD) (%)
010	18.0; 10.0	5.6	40
012	4.8; 3.3	1.0	26
005	28.5; 28.7	0.14	0.5
Average RSD	-	-	22

Table 37: PCB Concentrations in Blank and Spiked QA/QC Water Samples

Sample	PCB Concentrations (ppb)		
Blank	<0.02	<0.02	<0.02
Control	0.127	0.112	0.112
Control Target	0.125	0.125	0.100

Table 38: PCB Concentrations in Laboratory and Field Duplicate Water Samples

Sample Number (prefix: RI06-)	Type	PCB Concentrations (ppb)	Standard Deviation	Relative Standard Deviation (RSD) (%)
020W	laboratory	0.040; 0.022	0.01	32

Table 39: PCB Concentrations in Blank and Spiked QA/QC Plant Samples

Sample	Unit	PCB Concentrations
Blank	ppb	<3.0
Control	ppb	10.5
Control Target	ppb	10.0

Table 40: PCB Concentrations in Laboratory and Field Duplicate Plant Samples

Sample Number	Type	PCB Concentrations (ppb)	Standard Deviation	Relative Standard Deviation (RSD) (%)
RI07-007P	laboratory	4.5; 3.4	0.78	20
RI07-010P	field	3.7; <3.0	0.50	15

Table 41: TPH Concentrations in Blank and Spiked QA/QC Soil Samples

Sample	Units	TPH Concentrations					
Blank	ppm	<40	<40	<40	<40	<40	<40
Control	ppm	134	138	123	128	-	-
Control Target	ppm	163	163	163	163	-	-

Table 42: TPH (Fuel) Soil Concentrations in Laboratory Duplicate Analysis

Sample Number (prefix: RI07-)	TPH Concentrations (ppm)	Standard Deviation	Relative Standard Deviation (RSD) (%)
218	336; 392	39	11
224	345; 365	14	4
205	531; 464	47	10
213	572; 561	8	1
237	299; 447	104	28
236	<40; <40	0	0
Average RSD	-	-	9

Table 43: TPH (Fuel) Soil Concentrations in Field Duplicate Analysis

Sample Number (prefix: RI07-)	TPH Concentrations (ppm)	Standard Deviation	Relative Standard Deviation (RSD) (%)
220	1430; 802	444	40
200	771; 452	225	37
210	214; 141	52	29
240	154; 40	81	83
230	<40; <40	0	0
Average RSD	-	-	38

Table 44: TPH Concentrations in Blank and Spiked QA/QC Water Samples

Sample	TPH Concentrations (ppm)		
Blank	<1.0	<1.0	<0.1
Control	11.3	16.8	1.31
Control Target	15.9	15.9	1.59

Table 45: TPH Water Concentrations in Laboratory and Field Duplicate Analysis

Sample Number (prefix: RI07-)	Type	TPH Concentrations (ppm)	Standard Deviation	Relative Standard Deviation (RSD) (%)
005W	laboratory	<1.0; 1.8	0.56	40
010W	field	<1.0; <1.0	0	0

Table 46: Metal Water Concentrations in Laboratory Blank Determinations and QC Control Samples

		Blank	QC	QC Target
Arsenic	mg/L	<0.003	1.14	1.20
Cadmium	mg/L	<0.001	0.38	0.40
Chromium	mg/L	<0.005	0.38	0.40
Cobalt	mg/L	<0.003	2.15	2.20
Copper	mg/L	<0.005	2.12	2.20
Lead	mg/L	<0.010	2.04	2.20
Nickel	mg/L	<0.005	2.09	2.20
Zinc	mg/L	<0.010	1.13	1.20

Table 47: Metal Water Concentrations in Field Duplicate Analysis (ppm)

Parameter	RI07-010W	
Arsenic	<0.003	<0.003
Cadmium	<0.001	<0.001
Chromium	<0.005	<0.005
Cobalt	0.008	<0.003
Copper	<0.005	<0.005
Lead	<0.010	<0.010
Nickel	0.017	<0.005
Zinc	<0.020	<0.020

Table 48: Metal Soil Concentrations in Blank and Reference Material (ppm)

	Blank	Blank	Mess-3	QC Control	SS2	QC Control
As	<1.0	<1.0	16.7	13.9-17.3	75.4	54.8-103
Cd	<1.0	<1.0	<1.0	-	1.7	0.1-3.0
Co	<5.0	<5.0	12.0	10.7-13.7	14.9	11.5-17.2
Cr	<20	<20	42	31-49	49	35.8-55.5
Cu	<3.0	<3.0	30.0	29.8-37.4	190	158-225
Ni	<5.0	<5.0	37.9	35.0-40.8	56.5	49.2-60.8
Pb	<10	<10	17	16.6-20.5	125	99.4-130
Zn	<15	<15	130	125-147	478	392-544

Table 49: Metal Soil Concentrations in Laboratory Duplicate Analysis (ppm)

	RI07-007	
Arsenic	1.3	<1.0
Cadmium	<1.0	<1.0
Chromium	35	34
Cobalt	11.3	9.6
Copper	47.1	40.4
Lead	40	32
Nickel	46.9	40.3
Zinc	77	65

Analytical Services Unit
School of Environmental Studies
Biosciences Complex
Queen's University, Kingston, Ontario, Canada K7L 3N6
Tel 613 533-2642 Fax 613 533-2897

14 September 2007

Lou Spagnuolo,
Indian and Northern Affairs Canada
Nunavut Regional Office
Iqaluit, Nunavut
X0A 0H0

Resolution Island 2007 – Field Report

Dear Lou,

Our team left Resolution Island on 7 August after a very busy but successful field season. Nearly all tasks this year involved monitoring.

Tier II Landfill and Airstrip and Maintenance Dump

All wells at the Tier II landfill, airstrip dump and maintenance dump were sampled once. To start with, conductivity readings were measured and recorded. Once three consistent readings were obtained sampling began, as well water was assumed to have reached a steady state. Several of the wells were purged to dryness prior to reaching a stable state. These wells were purged to dryness twice prior to sampling. Some wells were dry. Background soil samples were also collected while water was being sampled. Waterra tubing was removed from the wells and well caps and lids were replaced and secured with zip ties. Upon inspection, no leachate was found emanating from any of the landfills or dumps and no deterioration was observed except at the airstrip dump where the western slope shows debris on the surface, as was noted last year.

Diesel Fuel Remediation

Main landfarm
One 40 cm probe and two 60 cm probes were installed to determine soil temperatures at various depths. The large landfarm was sampled once for TPH and nutrients, with depth profiles in all 3 sections to ensure a good comparison of results.

In situ landfarm
Three data recording probe devices were installed at a depth of 40 cm and one at 60 cm. Fertilizer was added to the top of the one of the control plots. The in situ landfarm was sampled once for TPH and nutrients, shortly after arrival on site. Areas sampled were marked with tags to ensure a different area of the plot is sampled in the upcoming years.

Drainage pathway ponds and barrier
The imploded tank drainage pathway was inspected and monitoring samples were taken for both soil and water at various points along the pathway, both upstream and downstream from the barrier.

PCB Barriers

All barriers held up well over the winter and no further repairs were deemed necessary this field season.

S1/S4 Valley
Sediment loading was less this year than in previous years. Water was flowing through the filter gates, with no visible leakage on either side of the gate. The gates seemed to be performing well but needed to be replaced with new filters. Moss has continued to grow along the south side of the chevrons. The chevrons are constructed of a geosynthetic that is primarily used for hydroseeding embankments, so this was quite interesting to see.

Eight overpack drums were each half filled with sediment collected in the barrier funnel, five from in front of the chevrons and 3 from between the chevrons and the filter box. A ninth overpack was used for the materials in the gate. The valley barrier was sampled for both soil and water at several points along the drainage pathway both upstream and downstream from the barrier. Composite samples were taken from the funnel areas of the barrier and analysed quickly to ensure that timely results could be obtained for shipping the overpack drums.

After removing the contaminated sediment, filters were sampled and replaced with new filter material. The valley barrier was refilled with 4 charcoal filters and geotextiles. Geotextiles were re-introduced for capturing of highly contaminated fines.

Furniture Dump
Upon inspection, there was little sediment or water in the furniture dump barrier. A small quantity of sediment was shoveled into 2 overpack drums. Four charcoal and four gravel filters were removed from the barrier, sampled, and the remains of the filters were placed into a third over pack drum. These 3 drums were taken to the airstrip. The charcoal filters appeared to be in good condition and were not replaced. Two new gravel filters were installed. Geotextile filters were installed at the back of the barrier to capture highly contaminated fines. The area behind the barrier was again sampled this year.

S1/S4 Beach
Soil samples were taken both upstream and downstream from the barrier as well as from within the barrier. Five drums were completely filled with sediment shoveled from the funnel area of the barrier. A sixth drum was also filled in this area, comprising filter materials from the beach barrier. Barrels will need to be removed by helicopter and sling. Filters were replaced with each filter box containing 1 gravel and 2 charcoal

filters, for a total of 4 gravel and 6 charcoal filters. In the last slot, four nonwoven geotextile filters were placed to trap highly contaminated fines.

Other Activities

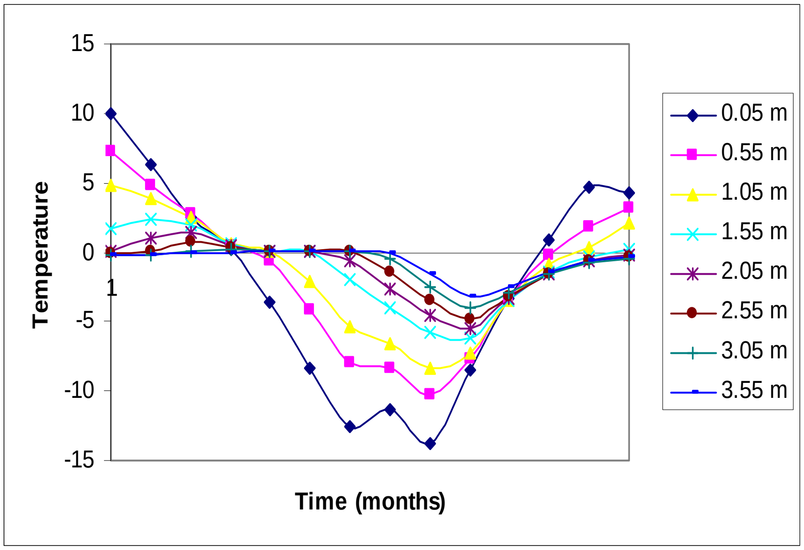
Plant samples were taken at remote locations on the island as well as near to the camp to monitor aerial contaminant migration. One set of drink water sampling was taken from old water lake and a background water sample was obtained near the officer's mess area. This was to establish background levels since this water could be affected by leaching from the camp landfill.

Sincerely,

Allison Rutter Indra

Allison Rutter and Indra Kalinovich

Thermister Data from Landfill East - Cable 1312 - Data Logger 61



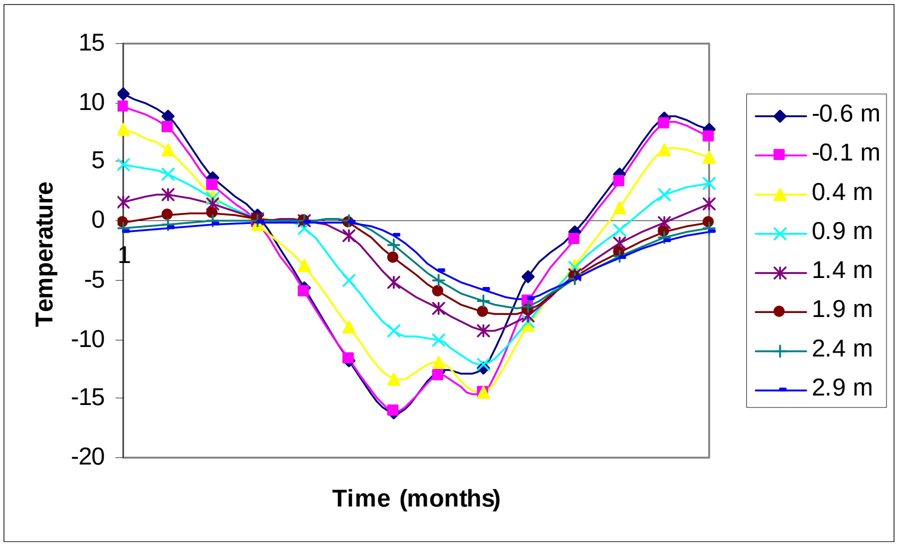
Landfill East Soil Temperature Data for 4 days in the period 22-Jul-06 to 23-Aug-07

Depth Below Finishing Grade(m)	15-Sep-06	15-Dec-06	15-Mar-07	15-Jun-07
0.05	3.3	-5.3	-16.7	0.4
0.55	3.3	-4.0	-11.2	0.3
1.05	2.8	-2.2	-8.4	-0.6
1.55	2.1	0.1	-5.5	-1.4
2.05	1.4	0.1	-4.3	-1.5
2.55	0.7	0.1	-3.2	-1.6
3.05	0.0	0.0	-2.3	-1.6
3.55	-0.1	-0.1	-1.4	-1.5

Landfill East Soil Temperature Data for 4 days in the period 24-Aug-05 to 21-Jul-06

Depth Below Finishing Grade(m)	15-Sep-05	15-Dec-05	15-Mar-06	15-Jun-06
0.05	3.7	-10.9	-15.1	10.4
0.55	2.4	-4.2	-10.2	1.7
1.05	4.3	-2.4	-7.8	-0.2
1.55	5.2	0.0	-5.4	-0.5
2.05	5.7	0.3	-4.4	-0.7
2.55	5.9	0.6	-3.3	-0.7
3.05	6.0	0.7	-2.3	-0.7
3.55	6.0	0.9	-1.2	-0.6

Thermister Data from Berm West - Cable 1311 - Data Logger 40



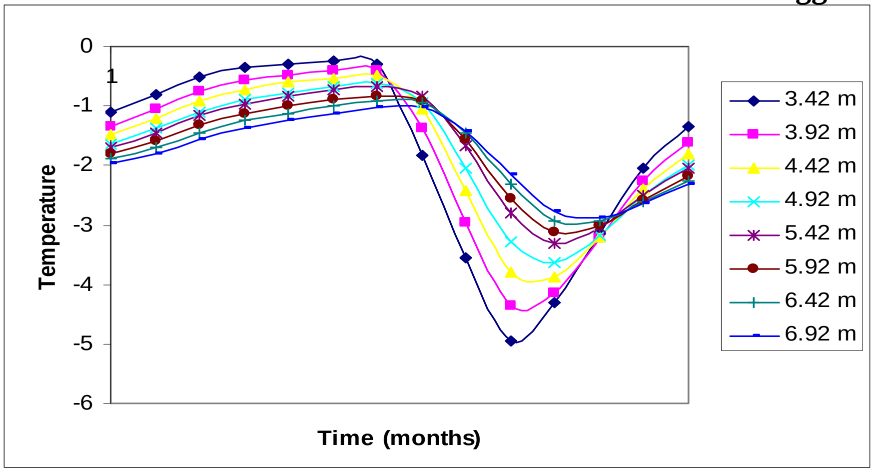
Berm West Soil Temperature Data for 4 days in the period 22-Jul-06 to 23-Aug-07

Depth Below Finishing Grade(m)	15-Sep-06	15-Dec-06	15-Mar-07	15-Jun-07
-0.6	5.3	-2.5	-11.8	1.7
-0.1	4.8	-2.5	-16.5	6.3
0.4	2.3	-4.2	-16.7	3.9
0.9	2.6	-4.2	-13.4	-0.4
1.4	1.6	-1.1	-9.3	-1.8
1.9	0.8	0.1	-7.5	-2.5
2.4	0.1	0.0	-6.4	-3.0
2.9	-0.2	-0.1	-5.6	-3.2

Berm West Soil Temperature Data for 4 days in the period 24-Aug-05 to 21-Jul-06

Depth Below Finishing Grade(m)	15-Sep-06	15-Dec-06	15-Mar-07	15-Jun-07
-0.6	7.6	-10.7	-9.2	13.1
-0.1	4.2	-10.1	-14.9	10.9
0.4	2.3	-7.3	-13.0	5.3
0.9	3.4	-4.3	-9.4	-0.3
1.4	3.1	-1.0	-6.5	-0.9
1.9	2.6	0.1	-5.3	-1.4
2.4	2.0	0.0	-4.6	-1.6
2.9	1.2	0.1	-3.9	-1.8

Thermister Data from Berm East - Cable 1316 - Data Logger 1



Berm East Soil Temperature Data for 4 days in the period 22-Jul-06 to 23-Aug-07

Depth Below Finishing Grade(m)	15-Sep-06	15-Dec-06	15-Mar-07	15-Jun-07
3.42	-0.5	-0.2	-3.4	-2.7
3.92	-0.7	-0.4	-2.8	-3.3
4.42	-0.9	-0.5	-2.4	-3.3
4.92	-1.1	-0.7	-2.0	-3.2
5.42	-1.2	-0.7	-1.6	-3.1
5.92	-1.3	-0.9	-1.5	-3.0
6.42	-1.5	-1.0	-1.4	-3.0
6.92	-1.5	-1.1	-1.4	-2.9

Berm East Soil Temperature Data for 4 days in the period 24-Aug-05 to 21-Jul-06

Depth Below Finishing Grade(m)	15-Sep-06	15-Dec-06	15-Mar-07	15-Jun-07
3.42	0.5	0.1	-2.5	-2.1
3.92	-0.1	-0.1	-1.9	-2.2
4.42	-0.5	-0.2	-1.5	-2.3
4.92	-0.9	-0.5	-1.3	-2.3
5.42	-1.2	-0.6	-1.1	-2.3
5.92	-1.5	-0.8	-1.1	-2.3
6.42	-1.8	-1.0	-1.2	-2.3
6.92	-2.1	-1.2	-1.2	-2.3