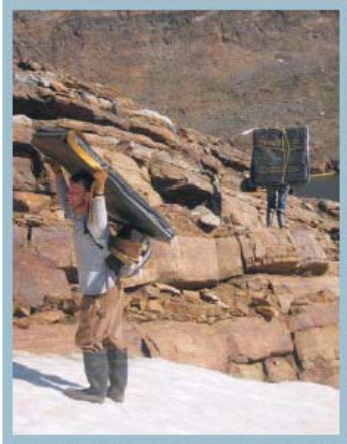
Appendix 1

Resolution Island 2008 Monitoring and Research

Resolution Island 2008

Monitoring and Research



Analytical Services Unit
Queen's University

Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada

Resolution Island 2008 Monitoring and Research

Prepared by

Analytical Services Unit
Queen's University
Kingston, Ontario

Canada

Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada

EXECUTIVE SUMMARY

This report describes this work undertaken by the ASU at Queen's University in 2008 for Indian and Northern Affairs Canada. The field work was again managed by the ASU. 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 main monitoring tasks comprised the sampling and analysis of a) the thirteen monitoring wells and their adjacent soil monitoring points at three landfills, b) the ten plant monitoring points c) the main landfarm, and the experimental in situ landfarm plots and d) the maintenance and monitoring of the three PCB barriers.

The most significant challenge this year related to the amount of sediment found in the PCB barrier systems. It had been expected that the amount of sediment trapped by the systems would have decreased again this year as the surface soil became more stable. However, since leaving the site in August 2007, a major storm or sudden spring melt had clearly occurred which caused significant erosion and movement of sediment in the drainage systems. This resulted in much more sediment having to be shoveled from the barriers. The containers of sediment were not moved from the barrier areas again this year as helicopter support was not able to reach the island and there is now very little room around the barriers. Furthermore, at the furniture dump barrier, the PCB level in the sediment and barrier materials exceeded the 50 ppm level set out in the CEPA regulations. Indian and Northern Affairs Canada will need to inform Environment Canada of the presence of the four barrels of sediment containing CEPA soil.

Monitoring data obtained from the PCB barriers, landfills and landfarms generally gave results in line with data obtained in previous years. Data from the analysis of plants again showed that the cleanup had significantly reduced the aerial transport of PCBs at the site. Geotextiles were added at the barrier systems last year; these filters trap finer materials which are known to contain higher concentrations of PCBs. Higher concentrations of PCBs were indeed found on these filters but the actual mass of PCBs was low, except at the furniture dump. Here the PCB levels were very high and thus more PCBs were trapped. The old training center was again used for accommodation but is now impregnated with mould and unsuitable for this purpose. In this report recommendations have been proposed concerning the logistics of future monitoring site visits as well as changes in the scope of work based on the results obtained over the last three years. Research continued on various aspects of the reactive barrier work.

ACKNOWLEDGMENTS

The work was supported by Indian and Northern Affairs Canada through its office in Iqaluit, Nunavut.

Allison Rutter of Queen's University directed the project. The on site team leader, Kevin McKenna was ably assisted by Nathan Manion, Rebecca McWatters and Sarah Jeswiet. Bear monitoring was provided by Pauloosie Atavak. The engineering monitoring was conducted by Rebecca McWatters, a final year PhD engineering student at Queen's University working with landfill liners. 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, Justin Dee, Rhonda Kristensen, Michele Pacey, Kevin McKenna and Kalam Mir, in addition to those listed above, who provided their usual high professional standards. Graham Cairns assisted with the maps.

Table of Contents

A. Introduction

1. General

This is the third year 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. In 2007 the monitoring program was conducted by the ASU[4]. Map 1 shows the location and general layout of the site at Resolution Island.

---

[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.

[4] Analytical Services Unit (2007). Resolution Island 2007: Monitoring and Research. Prepared for Indian and Northern Affairs Canada

This report details the tasks carried out by the ASU in 2008 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, Pauloosie Akavak, from Iqaluit, were on site from 14 July to 22 July 2008. Equipment and supplies used by the ASU were flown to Iqaluit and transported into and out of the site by Twin Otter aircraft**.** The ASU managed all the logistics for this visit. The old training center was used for accommodation but one window had blown out during the winter and mould was pervasive in the sleeping area. The sewage pipe was clogged and broken in one section so alternative arrangements were made. Drinking and cooking water was collected in five 20 L jugs and transported 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. One ATV trailer was damaged in trying to transport soil from the furniture dump to the airstrip and one ATV needs to be sent to Iqaluit for repairs. The remaining two ATVs are in poor condition especially the braking systems and require servicing. No polar bears were sited this year. Building B2 at the beach was severely damaged during the winter. The large front door buckled, the back door was missing, a panel was missing from the side and the roof was missing at one corner as shown in the photograph on the front cover. The overpack drums and waste wrangler containers were undamaged in the building but may require a more secure location.

The road to the beach barrier 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 but this was difficult due to soft ground and rock outcrops (see front cover photograph and photograph 17). The road from the beach to the summit was passable by ATV though the steep area near the water lake showed considerable erosion. On 20 July 2008 while the work was underway a group of approximately 60 tourists arrived by ship and came ashore at the beach. They assisted in transporting some waste wranglers to the beach area by zodiac. Suggestions for the operation of the monitoring program next year are made in the long term monitoring section 3 below.

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

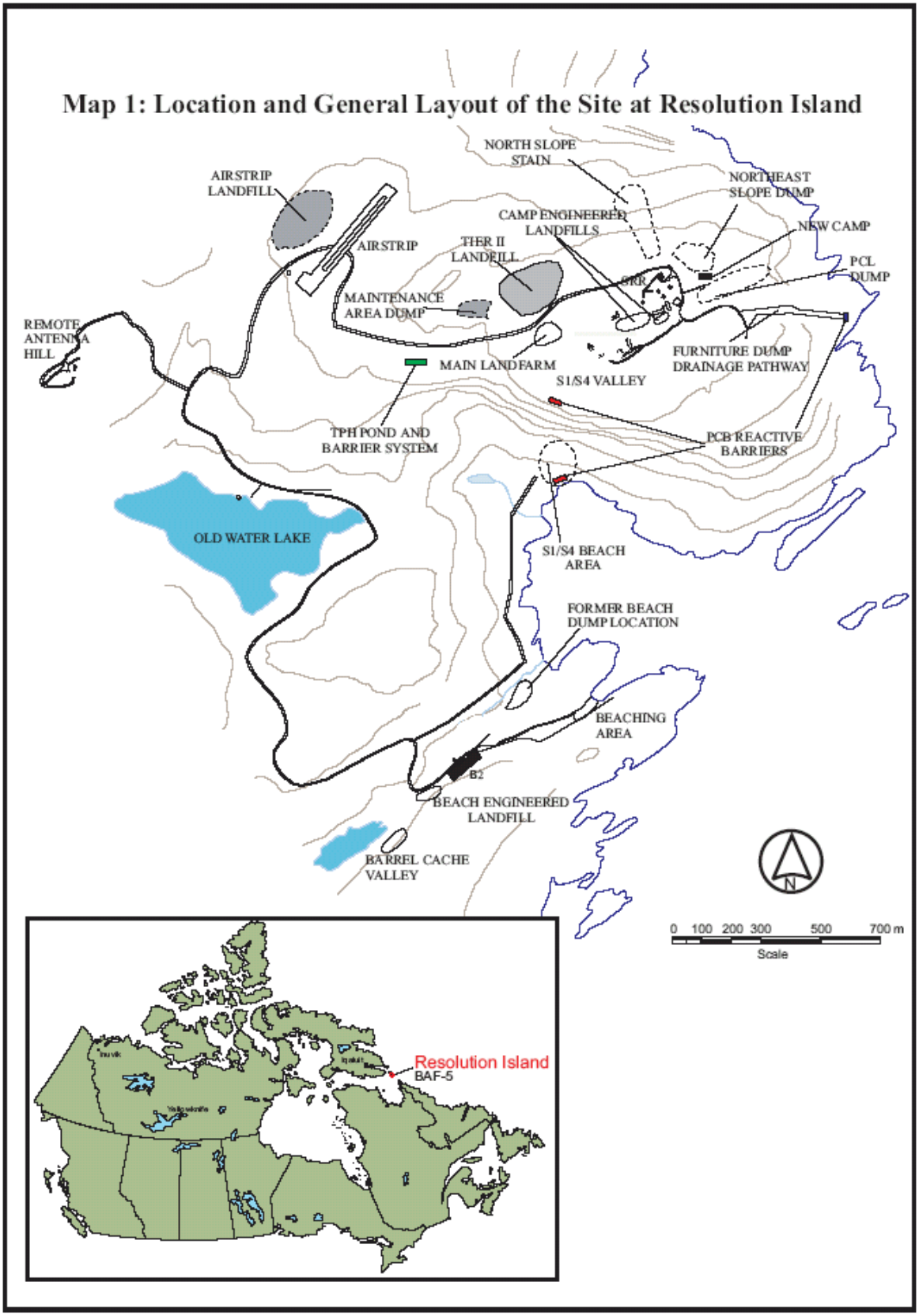
- Provide scientific and engineering support for the project as required
- Retain the services of a bear monitor for the duration of the site visit
- Charter a Twin Otter aircraft for transport to and from Iqaluit and Resolution Island.
- Sample the Tier II landfill monitoring wells and associated soil monitoring points. Sample the monitoring wells and associated soil points at the airstrip and maintenance dumps. Analyse water and soil samples for metals, TPH and PCBs with low detection limits.
- Download the data from the Tier II landfill thermisters and conduct an engineering inspection the Tier II landfill, the airstrip landfill, the maintenance dump and the two non-hazardous landfills.
- Collect and analyse background plant samples. Analyse for PCBs with low detection limits.
- Monitor the main and in situ landfarms on site and the two treatment ponds in the imploded tank drainage pathway.
- Inspect, monitor and modify the S1/S4 valley barrier, the furniture dump barrier and the S1/S4 beach barrier as appropriate. Continue to conduct laboratory and field experiments with respect to the design and construction of permanent interceptor barriers.
- Sample and analyze the sediment trapped in all three barriers. Manual excavation will be required for the sediment at all barriers. Sediment will be placed in barrels or waste wrangler containers for subsequent disposal. Sample and analyze water and soil monitoring points for all barriers.

- Revise proposals regarding barrier monitoring logistics and the long term monitoring plan as necessary.

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

- Attend the June 2008 CFG6 meeting in Vermont and present work on the fuel contaminated soils remediation and the PCB barrier work. Act as scientific resource to INAC and attend meetings as required. Initiate the planning of CFG7 to be held in Kingston in 2010.

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



3. Long Term Monitoring Plan

The long term monitoring plan recommends continuing annual monitoring for 5 years followed by monitoring in year 7, 10, 15 and 25. These time intervals were the same as those used by DND on their DEW Line sites and are based on the premise that after five years trends in the monitoring results should have been established. Clearly if any problems were noted the frequency of future visits might be increased. For the program described in this report, some measurements have become stable and predictable while others are no longer required.

There were some minor logistical difficulties this year and there are perceived problems for next year, in particular with regard to accommodation and on site transport. It would be very beneficial if conditions at the site were known before the site visit so that appropriate adjustments to the program could be made. To that end it is suggested that INAC contact the NWSO to see if it is possible to get a visit to the site on a scheduled NWSO visit prior to mid-July. Such a visit could enable an inspection of sediment levels in the barriers, an assessment on the status of the ATVs and the Kubota loader and of the road system. Depending on the length of this "recce" visit, other activities could be initiated. The old training center is no longer suitable for accommodation. Alternative accommodation could be at the NWSO module or possibly in the old cold storage building occupied by INAC personnel during the remediation program. Given the required changes a detailed logistics plan needs to be developed for next year's visit regarding, fuel, electricity generation, heating, food, sewage disposal etc.

It is getting harder to conduct the monitoring program as the roads, accommodation and ATVs have deteriorated. The status of the Kubota loader is unknown as it has not been operated for two or three years. As a result the monitoring program is getting more difficult to run. Since, as mentioned above, some of the elements of the monitoring program are now less important than in the past, and some produce predictable results, it would make operating the program more manageable if its scope were reduced. The following suggestions are therefore presented below regarding changes to the scope of the monitoring program for 2009; these are presented in the same order as they appear in this report.

- The monitoring of all landfills should remain unchanged. Batteries should be replaced in the 4 thermister units at the Tier II landfill.

- Sampling and analysis of drinking water should be dropped from the program. The same results have been obtained for over ten years. The most important parameters, those regarding bacteria levels cannot be undertaken due to the time delay between collection and analysis. The levels of these have not been a problem in the past.

- Sampling and analyses of the water near the Officer's mess should continue as it relates to possible leaching from the upper site and its non-hazardous landfill.

- Background plant sampling should be dropped from the list for one or two years.

- Sampling and analysis of the main landfarm should be suspended for two years. Levels have now become stable or are dropping slowly. One aspect of the operation of this landfarm which is particularly interesting relates to the periodic or annual addition of fertilizer. After the initial addition of fertilizer it was found by laboratory experimentation that a further addition would be beneficial and this proved to be the case. It is not known whether the fertilizer that has previously been added is available to the bacteria for the promotion of bioremediation. It is therefore proposed to test this in a cold room in the laboratory. If fertilizer is beneficial it would be added in 2010. One way to test this would be to add fertilizer to part of the landfarm for the next two years and then see if this results in a significant increase in diesel fuel decomposition relative to the untreated portion. Unfortunately the C_{17}/Pr ratios can no longer be used to test this as both compounds are now present at levels below the method detection limit. The current diesel fuel level of 1250 ppm is below the remediation criterion of 2500 ppm but the proposed tests would add to our knowledge for the operation of landfarms and also be environmentally beneficial

- Sampling and analysis of the in situ landfarm research experiment should continue as predictable levels have not yet been established .

- Sampling of the TPH ponding and barrier system should be stopped for two years. It has been difficult to assess whether the system is beneficial even though

logistically it seems very likely to be. If it is left in place for a longer time, results may show that the barrier is indeed preventing down stream migration.

- Maintenance and monitoring of the PCB barriers should continue. However, the sampling and analysis of gravel and GAC in the S1/S4 valley and beach systems should be reduced to a single composite sample. If only a little sediment was found in these two barriers it could be left in place for another year. The sampling of the geotextile filters should be also reduced.

- It is suggested the timing of the site monitoring visit be at the start of August rather than mid-July. It is possible that some results this year were different due to the earlier sampling date and also several wells were frozen.

4. Other Activities

The 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.

Four presentations were made at the 6th International Conference on Contaminants in Freezing Ground in Vermont (June 22-27, 2008). The titles were "Partitioning of PCBs between activated charcoal, soil and water in the Canadian Arctic" , "Biomonitoring of short-ranged aerial migration of PCBs during site remediation using Arctic plants", "Transport of volatile organic compounds through landfill cover systems in cold region environments" and "Landfarming fuel contaminated soils in the Canadian Arctic: mechanism and optimisation". John Poland and Allison Rutter were co-authors of two chapters in the book "Bioremediation of Petroleum Hydrocarbons in Cold Regions" published by Cambridge University Press, 2008. Two papers were published on research related to the project "Remediation of PCB contaminated soils in the Canadian Arctic: Excavation and surface PRB technology" in Science of the Total Environment, 407 (2008) 53-66 and "Remediation of hydrocarbon contaminated soils in the Canadian Arctic by landfarming" in Cold Regions Science and Technology 53 (2008), 102-114.

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. Chemical Analysis

a) Metals

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, the sample was filtered through a 0.45 um filter 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. 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. Geotextiles were air dried before analysis. 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 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

A pea gravel with a particle size of roughly 6.4 – 9.5 mm which was quarried locally near Kingston, Ontario and was distributed through Pyke Farms, was available on-site having been brought there by sea previously.

b) GAC

Granulated activated charcoal (CNS 612) which has a particle size range of 2.00 to 3.35 mm was obtained through A.C. Carbone, Saint-Jean-Sur-Richelieu, Quebec.

c) Geotextiles

A vertical non-woven needle-punched geotextile, 1200R, a woven geotextile 400W were used in the barriers. They were supplied by Terrafix, Toronto. The 1200R has a pore size between 0.05 and 0.15 mm while the 400W has a pore size of 0.6 mm.

d) Overpack drums

Standard metal overpack drums were used as the receptacles for the PCB contaminated soil from the barriers at the S1/S4 valley and furniture dump this year. Waste Wrangler containers purchased from Quatrex Inc. were used as well as the overpack drums at the beach barrier.

4. Landfill Monitoring Criteria

The Tier II landfill was assessed for its physical stability using the following indicators:

- Settlement
- Erosion
- Frost action
- Staining
- Seepage/Ponded Water
- Debris

The indicators were graded with the following descriptors for severity and extent as was carried out for assessments of the landfill in previous years.

a) Severity

- Acceptable – features noted are of little consequence, requires no attention
- Marginal – lower limits of acceptability for performance. Attention to areas in future inspections required. The potential for failure of the landfill is low to moderate.

- Significant – landfill stability is affected by significant or potentially significant changes, such as slope geometry, significant erosion or differential settlement. The potential for failure is imminent.

- Unacceptable – landfill stability is compromised, such that the ability to contain waste is compromised. Examples include slope failures, liner or debris exposure, erosion channels or areas of differential settlement.

b) Extent

- Isolated – singular feature

- Occasional – features of note occurring in irregular intervals/locations

- Numerous – many features of note, impacted less than 50% of the surface of the landfill

- Extensive – impacting greater than 50% of the surface area of the landfill.

C. Tier II Landfill Monitoring Program

The long-term, post-remediation monitoring program contained 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 was comprised of 7 wells and 6 associated soil monitoring points: soil monitoring point 5 is adjacent to both wells 5A and 5B. Four thermister strings were placed in the landfill during construction. The landfill was inspected on 17 July 2008 and data was downloaded from the thermister data loggers. Results of this aspect of the work are presented in the next two sections. Analytical results for the water and soil samples collected this year are presented in the next section in two tables which are followed by a discussion of these results including a comparison to the results obtained in previous years.

1. Visual Inspection

Photograph 1 shows the landfill in July 2008. The results of the physical inspection are presented in Table 1 and their location shown on Map 2. The same methodology for landfill assessment and reporting format that was used by EBA in 2006 and Earth Tech in 2007 have been followed here.

a) Settlement

Three small sinkhole pockets were noted as in previous years near the north west area of the landfill (close to the bedrock wall). These sinkholes had not increased in size from the previous years. Along the southwest berm there were a few small newly reported sinkholes of dimension 0.3 x 0.2 x 0.1. There was also a small area of settlement in the north east area of the landfill of dimensions 0.5 x 0.5 x 0.2 m.

b) Erosion

Previous observed areas of erosion E1-E3 did not appear to have increased in size. E4, a surface water runoff channel along the SW toe of landfill, has increased slightly in size. New areas of erosion were observed along east, west and south berms (Photograph 2); they were all about 8-10 m long, 1-15 m wide, but only 0.1-0.5 m deep and appear to be the result of surface water runoff. The stability of these numerous channels are in marginal condition and should be monitored in the future.

c) Staining

There was an isolated area of surface staining (rusty colour) observed near the west toe of the landfill which was approximately 30 m long, and extended to the service road. It was no larger than previous years and its severity is considered acceptable.

d) Seepage

In 2007 there was an area of seepage observed at the southeast toe of the landfill. This was absent this year.

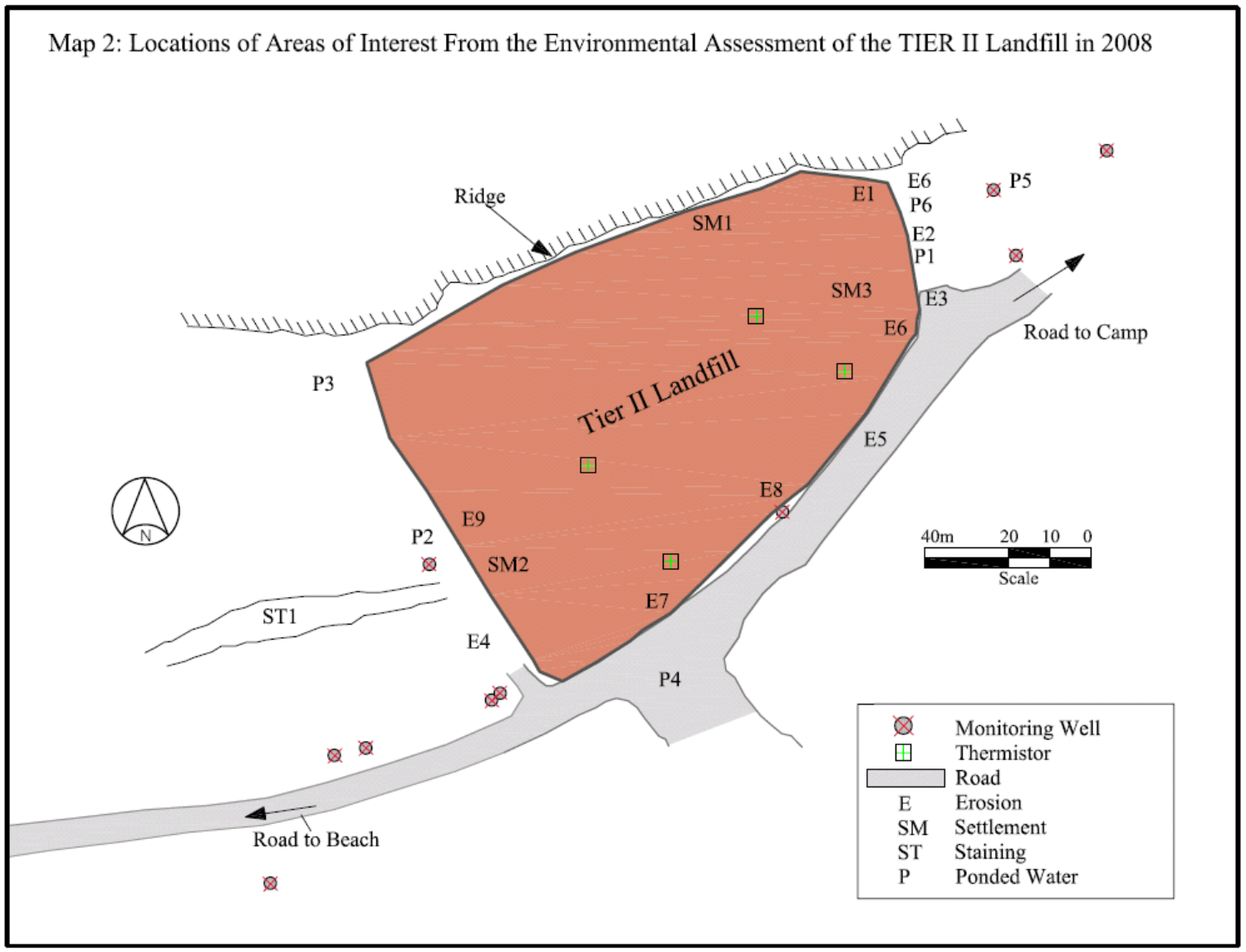
e) Ponded Water

Three previously observed areas of ponded water, P1-P3, were assessed; no water was present this year. However, evidence of ponding of water earlier in the season still existed. Small amounts of water at P4 were observed along the south berm (Photograph 2). A large area of ponded water was still present, P5, 30 m from the east berm at MW-1 (Photograph 3). A new area of ponded water was observed 4 m from the north east berm of the landfill (Photograph 3). Surface water runoff from the access road drained into this pond. In general, ponds were drier than previous years and were graded as acceptable with the exception of P5 which was graded as marginal.

f) Other Features

The mouth of the culvert near the service road at east corner of the landfill was crushed. The severity is marginal as the culvert does not drain surface water. Exposed liner near the east corner of the landfill as previously reported was found to be scrap material from the original construction and not part of the landfill.

Map 2: Locations of Areas of Interest From the Environmental Assessment of the TIER II Landfill in 2008



Photograph 1: View of the Tier II Landfill from the Service Road

Photograph 2: View of the South Berm Showing Areas of Erosion and Ponded Water

Photograph 3: Ponded Water at the East Berm

Photograph 4: The Tube Containing the Thermister String in the South Berm was Tilted: The Main Hydrocarbon Landfarm is Visible Across the Service Road

Table 1: Tier II Landfill Engineering Assessment Visual Check List

Item	Location	Previously Observed	Dimensions (L, W, D) (m)	Description	Comment
Settlement	SM1- north west area near bedrock wall	yes	0.2-1.0 x 0.2-0.5 x 0.2-0.5	pockets do not seem to be significant	acceptable
	SM2- south west berm	no	0.3 x 0.2 x 0.1	not significant	acceptable
	SM3- north east area	no	0.5 x 0.5 x 0.1	gradual sinking, maybe present from construction	acceptable
Erosion	E1- NE corner	yes	-	no additional erosion, from surface water runoff on road	acceptable
	E2- 3m from east toe	yes	-	no additional erosion	acceptable
	E3- SE toe next to road	yes	-	no additional erosion	acceptable
	E4- toe of SW corner	yes	30-40 x 0.3-2.0 x 0.2	several erosion channels from runoff. Increasing size	marginal
	E5- south side adjacent to road	yes	50 x 1.0 x 0.5	small channel from surface water runoff	acceptable
	E6-largest drainage gully near NE corner	yes	-	small amount of erosion on steep slope. Not large	acceptable
	E7- south berm area, near thermister 1311	yes	6 x 6 x 0.2-0.5	surface water runoff extends down landfill slope	acceptable
	E8- middle east berm	no	10 x 15 x 0.1 (top berm) 0.5 (bottom berm)	surface water runoff	acceptable
	E9- along west berm	no	8.0-10 x 1.0-2.0 x 0.1-0.2	water runoff from west middle of landfill to west berm. Small finger gullies.	marginal
Staining	ST1- west toe, adjacent to landfill berm	yes	30 x 0.5-1.0 x unknown	30 m rust stain, stable, same size as previous year	acceptable
Ponded Water	P1- middle of east berm, 1-3m from berm	yes	-	now 3m east of berm, no water observed but evidence of ponded water	acceptable
	P2-west toe of berm (near MW4)	yes	2.0 x .0 x 0.3 (dry pond)	no water observed	acceptable
	P3- NW corner	yes	6.0 x 10 x 0.1-0.2	no water observed, dry ponds	acceptable
	P4- south of landfill near landfarm	yes	1.0 x 1.0 (10 x 5 previously)	small water pond, dry pond larger	acceptable
	P5- 30 m east of landfill	yes	10 x 10	larger pond from surface water	marginal
	P6- north east berm, 4 m from berm	no	4 x 2 x 0.1 (9 x 5 x 0.1 dry pond)	small pond, evidence of larger pond	acceptable
Other	Culvert near service road at east corner	yes	-	culvert crushed	marginal

2. Thermal Monitoring

The locations of the four thermister strings is given in Map 3. All thermisters were in good working order. No 1311 was tilted slightly (Photograph 4), but it is unknown as to whether it has been like this since the time of construction. No 1318 was not downloaded last year, (the terminal was inverted in the housing) but results were obtained this year; data for last year was also obtained and this is reported, for completeness, as per last year's format at the end of the appendix. Batteries should have been replaced in August 2008 (as noted on the datalogger) however they were not. Memory of the data logger was 80 % full but the old data will erase to make room for new data automatically.

Temperatures were recorded every 12 hours. Temperature data for each month were averaged and these were plotted to give temperature curves for the 13 months from July 2007 to July 2008 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 also compiled. Both these are given at the end of the Appendix. They show that, for the top 3 m of soil, the September values were lower in 2007 than in 2006 which in turn were lower than the 2005 ones. A temperature regime has now become established with the 0 °C isotherm reaching its lowest penetration in late November for 2007. By close examination of the data, the lowest depths for the 0 °C isotherm were found to be 2.5 m, 2.8 m and 3.3 m from the surface of the landfill for the East Landfill, West Landfill and West Berm thermister locations respectively. Temperatures recorded at the East Berm where the depths of the thermisters are from 3.4 m to 6.9 m below grade, were all below zero for the whole year. For the East Landfill, West Landfill and West Berm thermister locations, the depth at which all temperatures were below zero in the autumn of 2006 were 2.9 m, 3.5 m and 3.55 m respectively. Thus the depth to permafrost in the landfill is decreasing. From the engineering design, the depth of fill above the Tier II contaminated material is 2.7 m whereas the lowest depths of the 0 ºC isotherms within the landfill were 2.5 m and 2.8 m. Thus the contents of the landfill are nearly all frozen.

3. *Water and Soil Monitoring*

The position of the monitoring wells and their associated soil monitoring locations is given in Map 3. Wells were all purged three times to dryness prior to sampling. 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 MW5A again this year. Wells MW1A and MW2 were frozen; the site visit was about two weeks earlier than last year when these two wells were not frozen. Soil and water samples were collected on 19 July 2008. Results of the analysis of the soil and water soil samples are given in Tables 2 and 3 respectively.

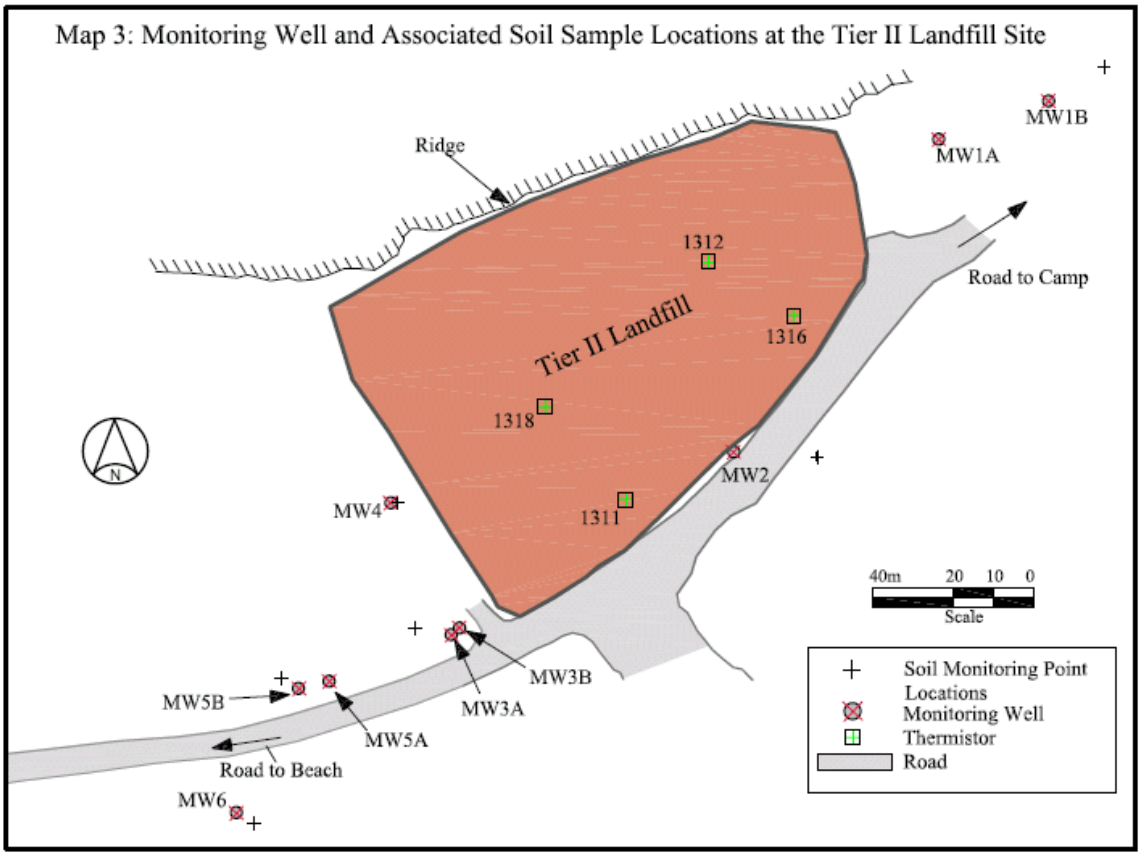


Table 2: Results of Analyses of Soil Samples Taken From Close to the Monitoring Wells at the Tier II Landfill Site

Location		MW1	MW2	MW3	MW4	MW5	MW6
Prefix RI08		001/053	002/054	003/055	004/056	005/057	010; 010D/058
Arsenic	ppm	<1.0	<1.0	<1.0	<1.0	1.2	1.5
Cadmium	ppm	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chromium	ppm	40	46	45	49	62	48
Cobalt	ppm	11.4	13.3	13.9	22	24	9.3
Copper	ppm	72	82	76	77	101	96
Lead	ppm	10.7	<10	16.7	14.1	25	<10
Nickel	ppm	60	60	61	91	104	43
Zinc	ppm	73	63	79	83	98	49
PCBs	ppb	44	47	86	7	79	14
TPH (lube)	ppm	<40	<40	<40	<40	<40	<40
TPH (fuel)	ppm	<40	<40	190	180	<40	<40

Table 3: 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 RI08-		frozen	frozen	008W	009W	dry	007W	004W
Arsenic	ppm	-	-	<0.003	<0.003	-	<0.003	<0.003
Cadmium	ppm	-	-	<0.001	<0.001	-	<0.001	<0.001
Chromium	ppm	-	-	<0.005	<0.005	-	<0.005	<0.005
Cobalt	ppm	-	-	<0.003	<0.003	-	0.023	0.047
Copper	ppm	-	-	<0.005	<0.005	-	<0.005	<0.005
Lead	ppm	-	-	<0.010	<0.010	-	<0.010	<0.010
Nickel	ppm	-	-	<0.005	<0.005	-	0.064	0.164
Zinc	ppm	-	-	<0.010	<0.010	-	0.129	0.080
PCBs	ppb	-	-	0.035	0.047	-	0.097	0.048
TPH (lube)	ppm	-	-	<1.0	<1.0	-	<1.0	<1.0
TPH (fuel)	ppm	-	-	<1.0	<1.0	-	1.6	<1.0

4. 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 4 summarizes the soil baseline sample data obtained in previous years while Table 5 summarizes the results for this year. Elements for all samples were within the baseline ranges developed in 2004 and 2005. Similar results were obtained in 2006 and 2007. Two results exceeded the DCC II criteria; one copper result (101 ppm) and one nickel level (104 ppm) were just above the 100 ppm criteria.

Table 4: 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 5: Summary of Elemental Levels Found in Soil Samples Collected From the Tier II Landfill Soil Monitoring Points in 2008 (ppm)

	Arsenic	Cadmium	Chromium	Cobalt
Mean	1.3	<1.0	48	15.7
Range	<1.0-1.5	<1.0	40-62	9.3-24
	Copper	Lead	Nickel	Zinc
Mean	84	16.7	70	74
Range	72-101	<10-25	43-104	63-98

Table 6 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, copper or lead were detected in any samples. Cobalt, nickel and zinc were detected wells MW5B and MW6. Only nickel in MW6 was outside the normal range (0.164 ppm as compared to <0.010 – 0.091 ppm); this well was dry in 2007.

Table 6: 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	<0.003-0.05	<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 fuel oil in two of the soil samples this year but no oil and grease were found. In the two wells, MW3 and MW4, fuel has sporadically been found in previous years. TPH was only detected in the water from Well 5B again this year at a similar level (1.6 ppm) to that found in 2007 (1.3 ppm). In 2005, fuel was detected in 10 of the 39 water samples analysed.

c) PCBs

PCB levels in the soil samples at the monitoring points ranged from 7 to 86 ppb which are somewhat lower than the values obtained in previous years. MW3 and MW5 gave the highest results and MW4 the lowest which is consistent with previous data. The average value found this year from the 6 samples was 46 ppb as compared to 78 ppb last year.

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. Last year PCBs were only detected above 0.020 ppb in one of 5 samples whereas this year all 4 samples contained measurable levels. However the PCB levels were low with an average value of 0.057 ppb. In previous years levels as high 0.3 ppb had been found. The earlier sampling date this year may have had some effect as levels of sediment in the samples was very high.

D. Airstrip Landfill Monitoring Program

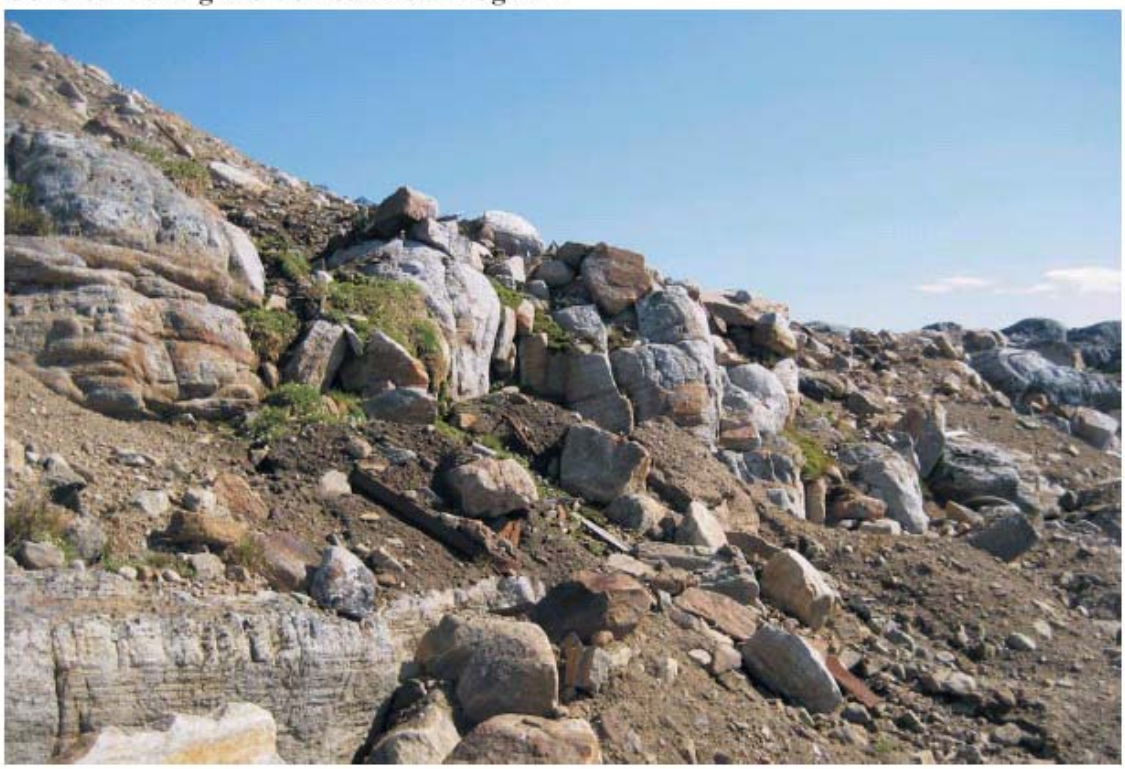
The remediation of the airstrip dump was completed in 2003. Four monitoring wells were placed around it, one above and three in the leachate channel leading away from it (Map 4). However, it should be noted that the drainage channel for MW12, MW13 and MW14 is extremely narrow and the staked area for the soil samples straddles the channel.

1. Visual Inspection

The surface of the main landfill is in good condition with minimal erosion. There was no ponding at the time of the site visit but there are small areas where water does accumulate as shown in Photograph 5. On the steep edge of the landfill between MW12 and MW13 there are several pockets of rusty debris which were never fully covered during the remediation of the site (Photograph 6). There are no visible signs of erosion on the steep edges of the landfill except in the main drainage pathway incorporation MW 14. There is a 2 m wide area of significant vegetation growth (Photograph 7) from the top of the edge of the landfill down to MW13 but this is not eroding.

Photograph 5: The Airstrip Landfill Showing the Surface in Good Condition with Minimal Erosion Pathways

Photograph 6: Some Visible Debris at the Steep Edge of the Airstrip Dump was Not Covered During the Remediation Program



Photograph 7: Vegetative Growth is Present in Some Areas at the Edge of the Airstrip Landfill

2. Water and Soil Monitoring

Monitoring well 11 was again dry this year and MW 14 was frozen. Results of the analyses are shown in Table 7 and Table 8 for water and soil respectively.

Elemental results in the soil samples were consistent with results found in 2005 and 2006 except for the sample from MW12 which contained elevated levels of all elements except chromium and arsenic. Presumably this sample contained metallic contamination from some solid material in the ground rather than from migration from the landfill. The metal levels in water were consistent with results from previous years and all within the normal ranges given in Table 6.

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 higher than previous years. In particular the value at MW11 was 112 ppb as opposed to 17 ppb in 2007 and 18 ppb in 2006. Similarly for MW 14 the level of 103 ppb this year contrasted with 20 ppb in 2007 and 26 ppb in 2006. For water samples, the PCB results levels of 0.049 ppb and 0.108 ppb were found. Again these were higher than in previous years. Last year the results ranged from 0.021 to 0.073 ppb PCBs.

Map 4: Monitoring Well and Soil Monitoring Sample Locations at the Airstrip Landfill

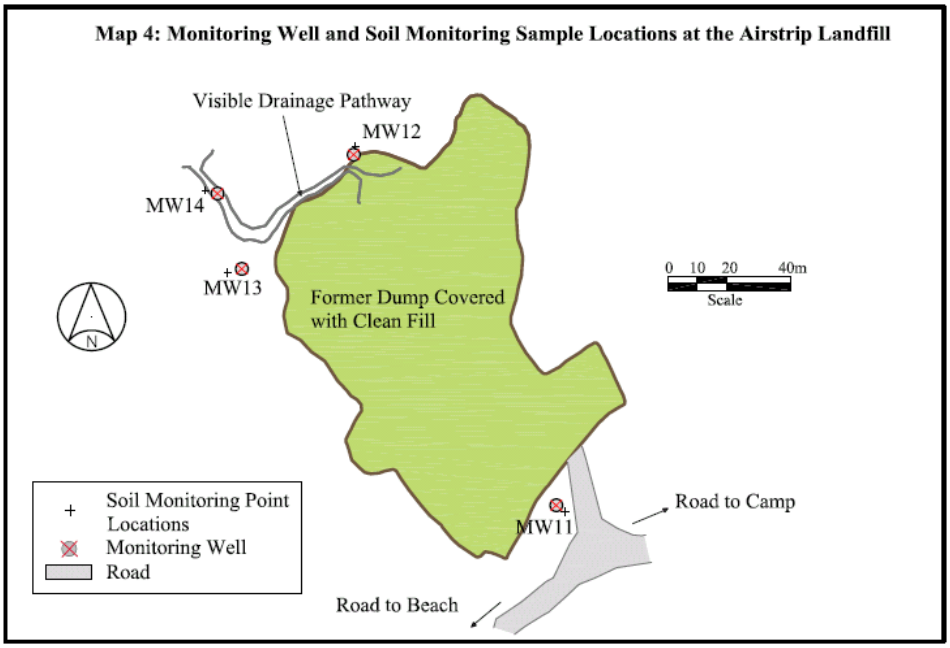


Table 7: Results of Analyses of Water Samples Taken From the Monitoring Wells at the Airstrip Landfill

		MW11	MW12	MW13	MW14
Prefix RI08-		Dry	005W	003W	Frozen
Arsenic	ppm	-	<0.003	<0.003	-
Cadmium	ppm	-	<0.001	<0.001	-
Chromium	ppm	-	0.010	<0.005	-
Cobalt	ppm	-	0.004	<0.003	-
Copper	ppm	-	0.016	0.006	-
Lead	ppm	-	0.013	<0.010	-
Nickel	ppm	-	0.021	0.007	-
Zinc	ppm	-	0.050	<0.010	-
PCBs	ppb	-	0.049	0.108	-
TPH (lube)	ppm	-	<1.0	<1.0	-
TPH (fuel)	ppm	-	<1.0	<1.0	-

Table 8: Results of Analyses of Soil Samples Taken From Close to the Monitoring Wells at the Airstrip Landfill

		MW11	MW12	MW13	MW14
Prefix RI08-		008/071	012/074	009/072	011/073
Arsenic	ppm	<1.0	1.2	1.5	<1.0
Cadmium	ppm	<1.0	1.5	<1.0	<1.0
Chromium	ppm	35	66	51	45
Cobalt	ppm	12.9	49	14.4	17.2
Copper	ppm	80	155	82	74
Lead	ppm	33	64	18	10
Nickel	ppm	57	154	80	86
Zinc	ppm	91	268	196	149
PCBs	ppb	112	<3	38	103
TPH (lube)	ppm	<40	4390	<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 (Map 5).

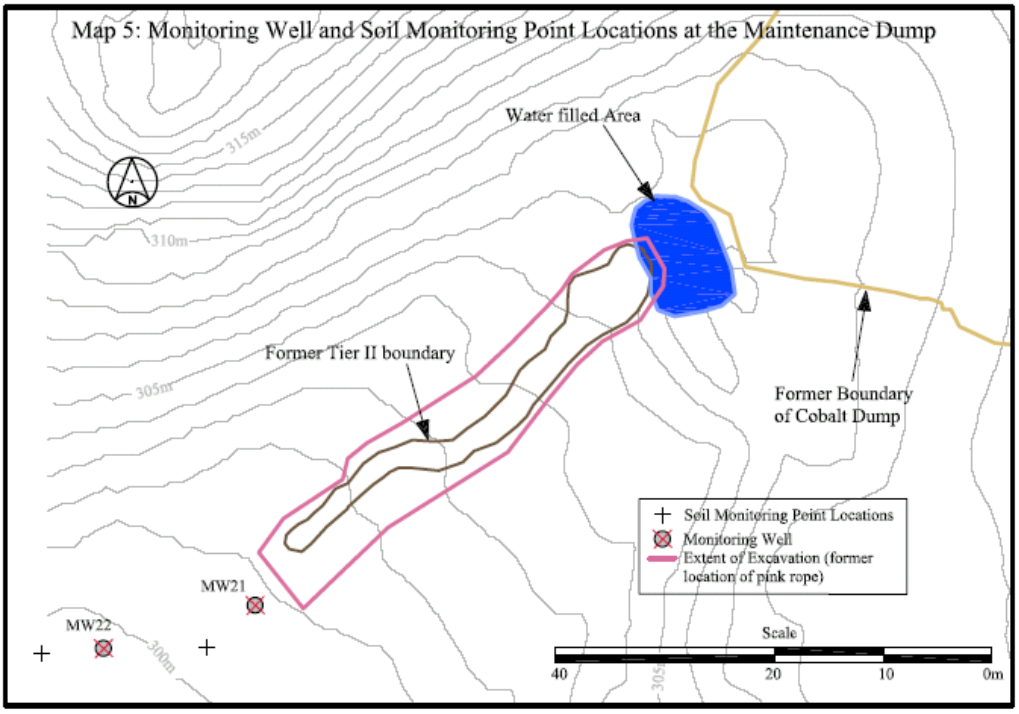
1. Visual Inspection

The area was regraded as part of the remediation program. There appears to be no erosion in the area which contains several pockets of vegetation.

2. Water and Soil Monitoring

Water and soil samples were collected this year and results of their analyses are shown in Table 9.

Elemental results from soil samples were consistent with those obtained in previous years. For the water samples, all metal results were below the method detection limit. Again these results are 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 consistent with results from previous years. Water from well MW21 was found to contain 0.024 ppb PCBs which again is consistent with results from previous years.

Table 9: 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 RI08-		Frozen	006W	006/059	007/060
Arsenic	ppm	-	<0.003	1.2	<1.0
Cadmium	ppm	-	<0.001	<1.0	<1.0
Chromium	ppm	-	<0.005	46	45
Cobalt	ppm	-	<0.003	17.5	45
Copper	ppm	-	<0.005	71	74
Lead	ppm	-	<0.010	<10	11
Nickel	ppm	-	<0.005	84	86
Zinc	ppm	-	<0.010	91	223
PCBs	ppb	-	0.024	4	56
TPH (lube)	ppm	-	<1.0	<40	<40
TPH (fuel)	ppm	-	<1.0	<40	<40

F. Non-Hazardous Landfills

The long term monitoring program includes an inspection of the non-hazardous landfills for any deterioration.

1. Station Landfill

The landfill was in good condition and no deterioration was observed. (Photograph 8). Beyond the lowest part of the landfill is a low area where water has collected between the troposphere and the Officer's mess (Photograph 9). However, no water was flowing out of the landfill. Water from the landfill may pass by the Officer's mess where water was again collected this year (section G2) but this water would also be impacted by contamination from the station area as a whole.

2. Beach Landfill

This landfill is situated near the junction of the road from the camp and the barrel cache valley. It was well graded and firmly packed. There are no signs of erosion, water ponding or any vegetative growth (Photographs 10 and 11).

Photograph 8: The Station Non-Hazardous Landfill was in Good condition

Photograph 9: The Lower Edge of the Station Non-Hazardous Landfill Where a Small Pool of Water Was Present; Note the Officer's Mess Further Down Gradient

Photograph 10:The Beach Non-Hazardous Landfill was in Good Condition

Photograph 11: The Edge of the Beach Non-Hazardous Landfill Adjacent to the Barrel Cache Valley

G. Water Samples

1. Drinking Water

Analytical results are shown in Table 10. With one exception, 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 14 years of the project. The drinking water was not buffered with sodium carbonate this year. Bacteria levels were not able to be measured due to the time taken between collection and analysis; a 24 hour holding time is the maximum allowed for bacterial analysis.

Table 10: Drinking Water Results and Guidelines

Parameter	Units	RI08-W001	OME Guidelines
Alkalinity	mg/L	5	30-500
Ammonia	mg/L	<0.10	-
Arsenic	mg/L	<0.003	
Cadmium	mg/L	<0.001	
Calcium	mg/L	5.0	-
Cobalt	mg/L	0.032	
COD	mg/L	<3	-
Conductivity	uS/cm	118	-
Copper	mg/L	0.053	<1.0
Chromium	mg/L	<0.005	
Hardness	mg/L	24	80-100
Iron	mg/L	<0.05	<0.30
Lead	mg/L	<0.010	<0.01
Nickel	mg/L	0.16	
Magnesium	mg/L	2.9	-
Mercury	mg/L	<0.0004	
PCB	ug/L	<3.0	<3
pH	-	4.6	6.5-8.5
Phenols	ug/L	<1.0	-

Parameter	Units	RI08-W001	OME Guidelines
Potassium	mg/L	0.43	-
Sodium	mg/L	4.0	<200
Sulphate	mg/L	43.8	<500
Nitrate	mg/L	<0.05	<10
Nitrite	mg/L	<0.05	<1.0
Chloride	mg/L	5.8	<250
TDS	mg/L	<5.0	<500
TKN	mg/L	<0.2	-
TSS	mg/L	<2.0	<500
Zinc	mg/L	0.088	5
Total Coliforms	Cts/100 mL	nd	0
Faecal Coliforms	Cts/100 mL	nd	0
Faecal Streptococci	Cts/100 mL	nd	0
E coli	Cts/100 mL	nd	0
Standard Plate Count (48 hrs)	Cts/1 mL	nd	500
Background	Cts/100 mL	nd	200

nd – not determined

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 11. Both nickel and zinc were somewhat higher than in previous years. The zinc level was within the normal site levels given in Table 6 but the nickel value of 0.12 ppm was outside of the normal range of <0.10 to 0.091 ppm. A trace amount of nitrate was detected this year.

Table 11: Results From Water Near the Officer's Mess

Parameter	Units	RI08-002W
Copper	mg/L	0.018
Iron	mg/L	<0.05
Lead	mg/L	<0.010
Manganese	mg/L	0.028
Cadmium	mg/L	<0.001
Nickel	mg/L	0.12
Chromium	mg/L	<0.005
Cobalt	mg/L	0.019
Zinc	mg/L	0.14
Phenols	ug/L	<1.0
PCBs	ug/L	<3.0
pH	-	6.4
TSS	mg/L	<2.0
Nitrate	mg/L	0.08
Nitrite	mg/L	<0.05

H. Background Plant Samples

Eleven background plant samples were collected this year; one was a field duplicate. The results from nine of the ten plant monitoring points (PMPs) and from an additional location in the imploded tank drainage area are presented in Table 12. At PMP 8 the whole area was very muddy and no plants could be found. Plants were collected but not washed and therefore dust and water droplets transferred to new growth, and which may contain PCBs, were analysed in the sample. Therefore results of these analyses are an indication of airborne PCB levels. All PCBs showed the Aroclor 1260 pattern.

Table 12: Results of Analyses of Background Plant Samples

Sample	Tag	Monitoring Point	PCBs (ppb)	Location
RI08-006P	6421	PMP1	166	Camp – old officer's mess
RI08-001P	6568	PMP2	37	NE of Tier II landfill
RI08-008P	6741	PMP3	6.0	Airstrip drainage pathway
RI08-004P	6746	PMP4	87	Imploded tank
RI08-009P	6887	PMP5	3.8	1000m NE of airstrip
RI08-010P D	6888	PMP6	3.1	Radio Hill
RI08-002P	6746	PMP7	7.7	S1/S4 Beach
No sample	-	PMP8	-	Beaching area
RI08-005P	6889	PMP9	6.9	1000m S of barrel cache valley
RI08-007P	6984	PMP10	4.5	New water lake
RI08-003P	6758	-	65	Imploded tank area

Results have now been obtained for 6 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. This year there was minimal soil disturbance as was the case in 2007. Table 13 and Figure 1 show the change in levels at the PMPs with time. 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 2006. 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.

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 7; 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 plants 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, Figure 1 and Map 6, 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. Generally the levels around the summit have dropped from values of 1000s of ppb to < 100 ppb PCBs whereas at other locations values have dropped from in the range of 50-1000 ppb to < 10 ppb PCBs.

Table 13: Results of Analyses of Background Plant Samples (2003-2007)

Monitoring Point		Year					
		2003	2004	2005	2006	2007	2008
PMP1	Camp – old officer's mess	1700	66	530	-	15.5	166
PMP2	NE of Tier II landfill	400	<3.0	250	97	38	37
PMP3	Airstrip drainage pathway	11000	250	4.3	8.0	<3.0	6.0
PMP4	Near imploded tank	3300	380	42	-	40	87
PMP5	1000m NE of airstrip	33	25	11.3	7.9	4.0	3.8
PMP6	Radio Hill	1090	<3.0	5.8	22	<3.0	3.1
PMP7	S1/S4 Beach	21	<3.0	18	-	6.6	7.7
PMP8	Beaching area	170	70	-	-	38	-
PMP9	S of barrel cache valley	26	67	54	-	6.1	6.9
PMP10	New water lake	43	<3.0	4.5	<3.0	3.4	4.5
Tag 6758	Imploded tank drainage	-	25	34	125	14.1	65

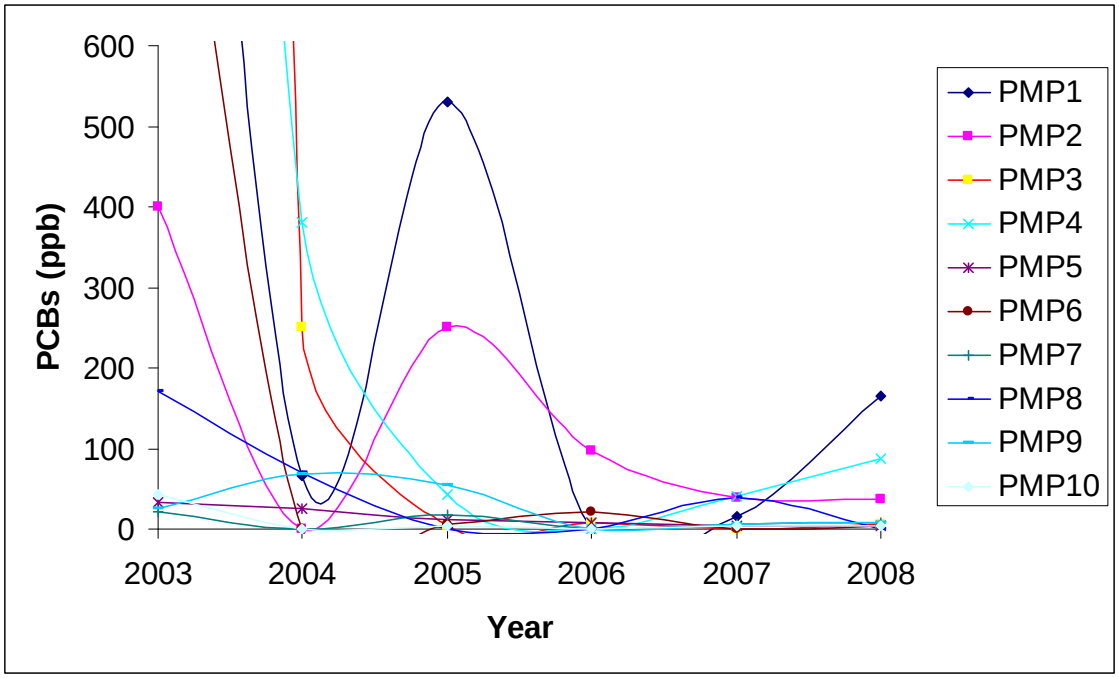
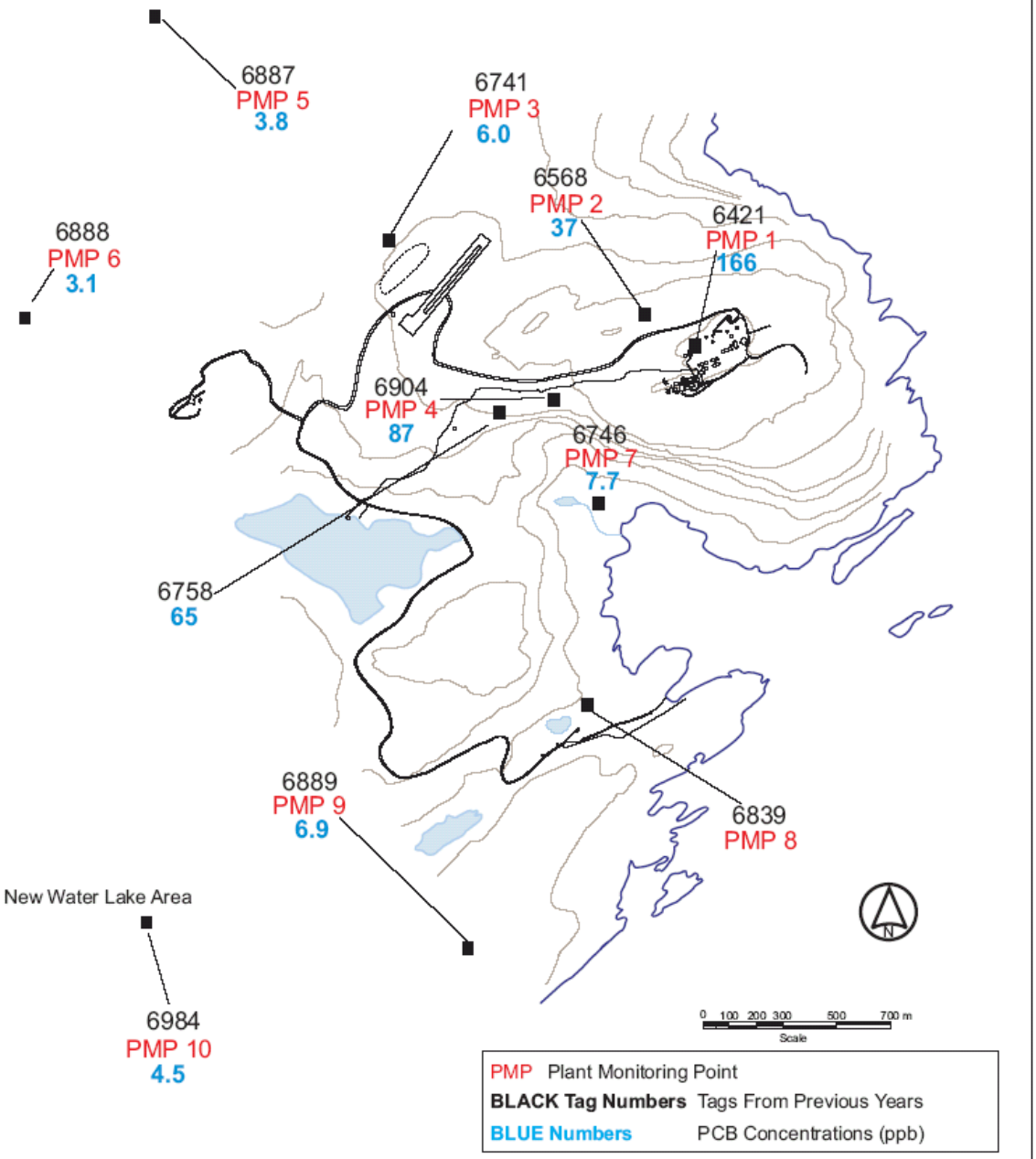
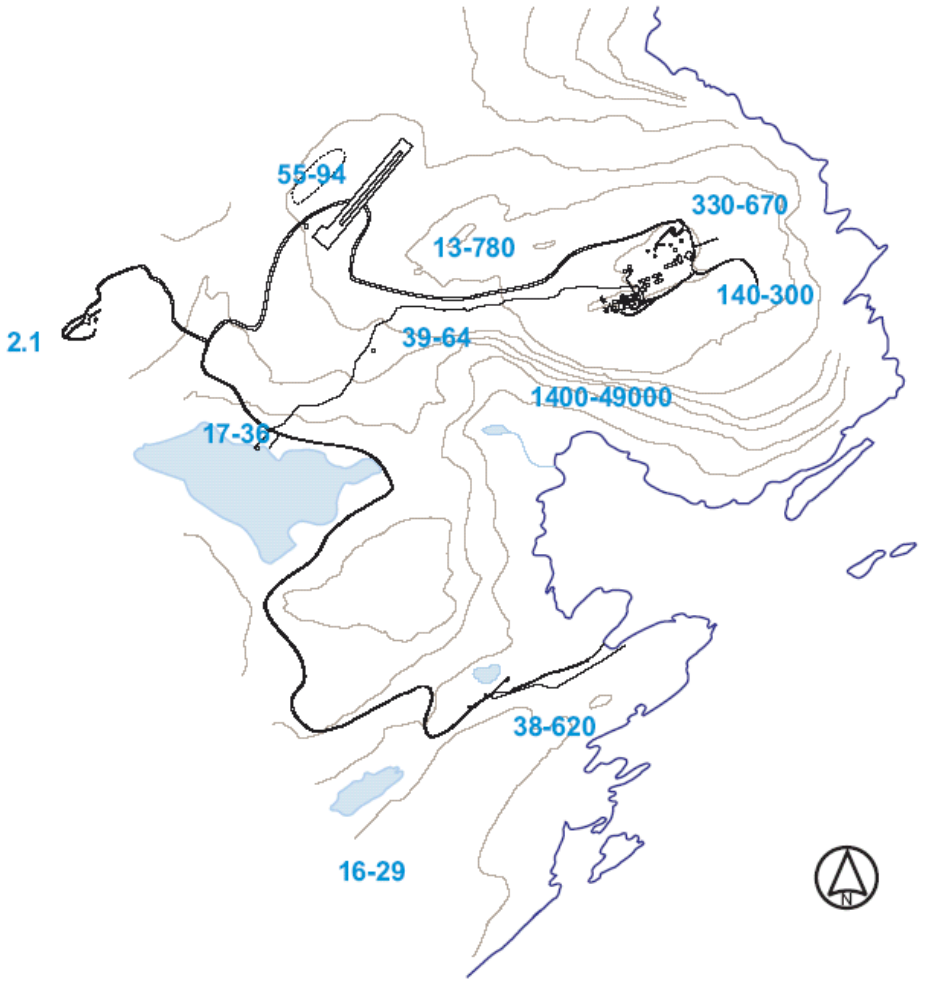


Figure 1: PCB Levels in Plants From Various Locations at the Site With Time

Map 6: Locations and PCB Concentrations of Background Plant Samples Collected in 2007



Map 7: 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 soil contaminated with > 2500 ppm fuel 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. 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 and 1510 ± 560 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. In 2007, the TPH level in the main landfarm was 810 ± 410 ppm while that of the untilled plot was 1690 ± 650 ppm. Also the value of the C_{17}/Pr ratio for the control plot was 0.27 ± 0.06 which was still not significantly different from the value obtained when the landfarm was constructed whereas for the main landfarm the ratio could not be determined since the two peaks involved were at concentrations below the method detection limit.

2. Results for 2008

No tilling of any part of the landfarm took place again this year. Soil samples were collected from the main area of the landfarm and from the control plot. Sampling locations were marked with a rock cairn as shown on the report cover. Results of analyses for diesel fuel are given in Table 14. Data for the fertilized and tilled main portion of the

landfarm is shown graphically along with data from previous years in Figure 2. The average soil fuel level found was higher than last year but the results were within the range showing a continuing trend indicating loss of hydrocarbon. Data displayed in Figure 3 show that the average C_{17}/Pr ratios obtained from the landfarm also rose slightly but was not statistically different from last year. Several results for the ratio were very low and below the detection limit of 0.10. In calculating the average value, half the detection limit was used. For the control plot to which no fertilizer had been added, the fuel levels were higher than the main landfarm (2470 ppm versus 1250 ppm) as were the C_{17}/Pr ratios (0.44 versus 0.08). The C_{17}/Pr ratios show that bioremediation was essentially absent when no fertilizer was added.

Table 14: 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	RI08-029	1090
	30-60	RI08-030	525
	0-60	RI08-026, 027, 028, 031, 032, 033	855, 1370, 1780, 617, 1860, 1960
Control plot	0-30	RI08-024	1970
	30-60	RI08-025	2130
	0-60	RI08-023	3300

Soil nitrogen and phosphorus data are presented in Table 15. The total and extractable phosphorus and TKN values are similar to those seen in 2005 and 2006. Ammonia levels of up to 485 ppm were found after the application of fertilizer in 2006. Last year they dropped to 64 ppm. This year's results show that there is still residual ammonia and nitrate in places.

Table 15: 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	RI08-001N	ppm	370	<5.0	<2.0	<2.0	170	10
Main landfarm	RI08-002N	ppm	440	138	57	<2.0	160	20
	RI08-003N	ppm	310	<5.0	<2.0	<2.0	160	20

Hydrocarbon degraders levels for the control plot were 3.0×10^5, while two samples from the main landfarm gave values of 7.3×10^4 and 1.8×10^5.

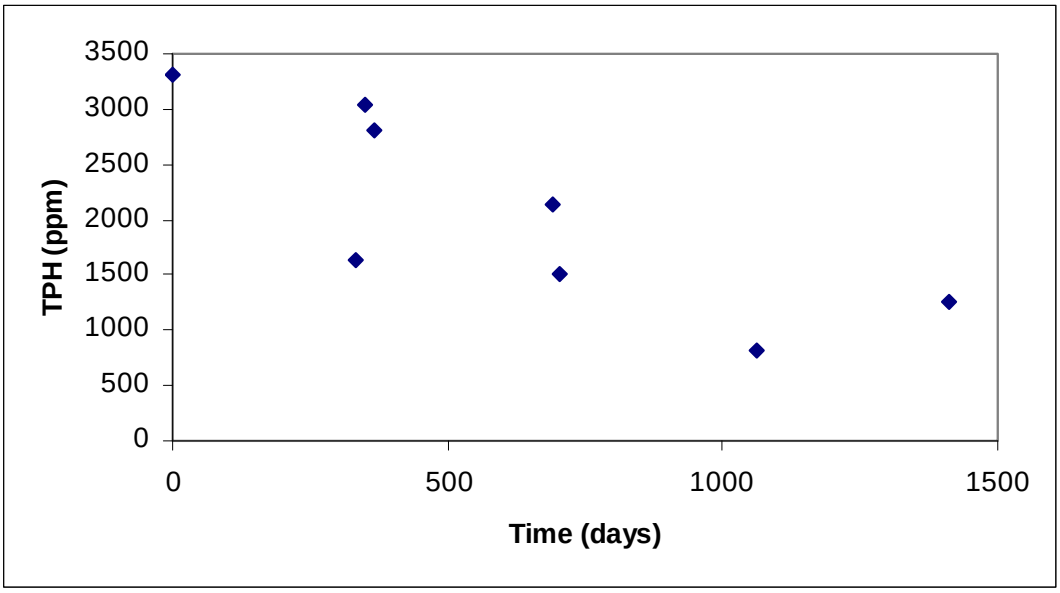


Figure 2: Change of TPH with Time at the Main Landfarm

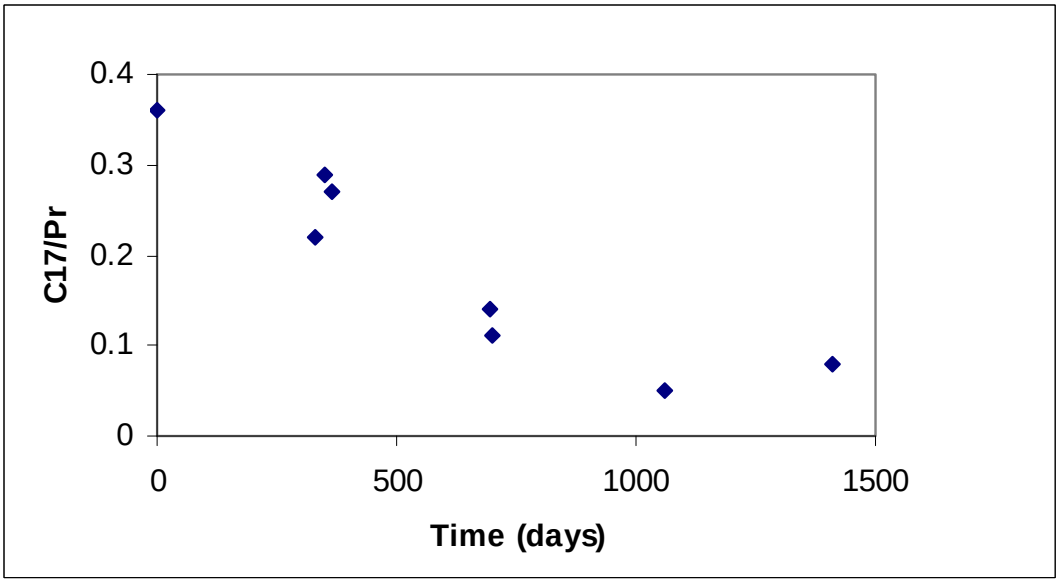


Figure 3: Change of C_{17}/Pr Ratios with Time at the Main Landfarm

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 until the soil had settled for 2 years – 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. In 2007, fertilizer was added to plot CP2: FAS2 in the form of urea (1600 g) and DAP (250 g). Analytical results for the 4 plots showed a decrease with time for the fertilized plots but these were not statistically different. The C_{17}/Pr ratios however exhibited a significant difference between the plots fertilized in 2005/2006 and unfertilized plots.

2. 2008 Field Activities

All 4 plots were sampled on 18 July 2008 with 2 soil samples per plot. 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. 2008 Results

Analytical results obtained from the four landfarm plots in 2008 are given in Table 16 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 data are consistent with results and trends from previous years. In 2007, fertilizer was added to FAS2 which was previously left for two years in order to give it time to stabilize. TPH levels found in 2007 were anomalously low for both CP1 and FAS 2. This year however the CP1 level was virtually unchanged from that in 2005 whereas

the FAS1 level had fallen to roughly half the initial value. The C_{17}/Pr ratio for the CP1 plot is not significantly different from the 2005 value. The C_{17}/Pr ratio for the FAS2 is slightly less (Figure 5) but not significantly different from the control plot. This is surprising given the lowering of the TPH level. The C_{17}/Pr ratio for FAS1 and FAM plots are much lower showing that a significant amount of bioremediation is taking place.

Table 16: Results of Analyses of Soil Samples for TPH From the In Situ Landfarm

Plot Regime	Sample Number	Depth (cm)	TPH (ppm)
CP1	RI08-035	0-30	830
CP1	RI08-036	30-60	1460
CP1	RI08-034	0-60	1240
Control Plot 1 average ± sd			**1178 ±317**
FAS2	RI08-038	0-20	390
FAS2	RI08-039	20-30	940
FAS2	RI08-037	0-45	490
Control Plot 2 average ± sd			**608 ± 295**
FAS1	RI08-040	0-30	310
FAS1	RI08-040D	30-60	460
FAS1	RI08-041	0-60	580
FAS plot average ± sd			**450 ± 136**
FAM	RI08-044	0-30	440
FAM	RI08-043	30-60	280
FAM	RI08-042	0-60	340
FAM plot average ± sd			**355 ± 82**

sd = standard deviation

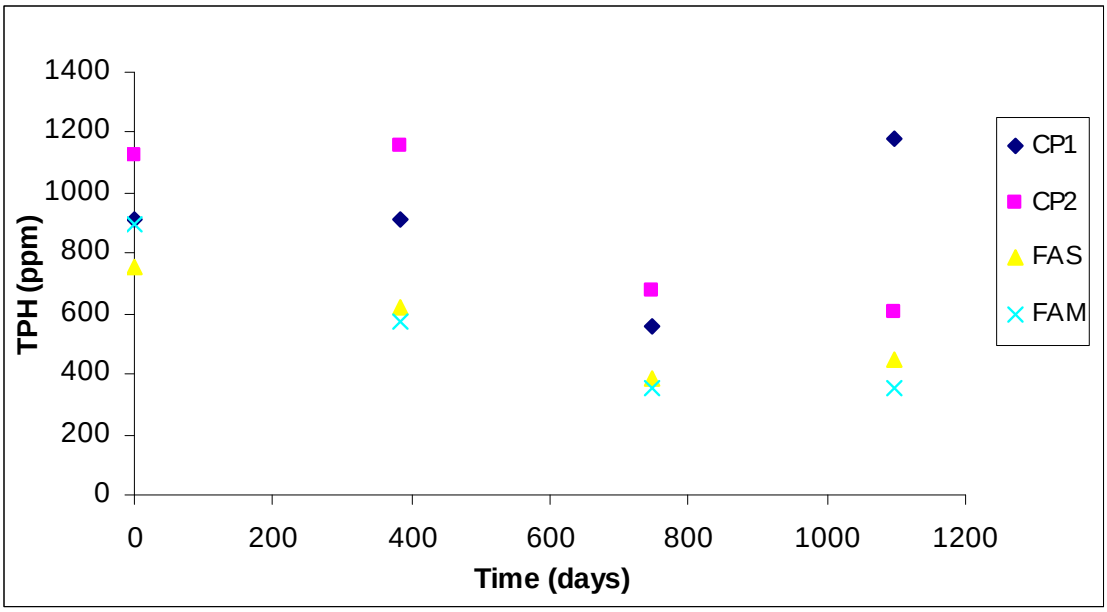


Figure 4: Change of TPH with Time at the In Situ Landfarm

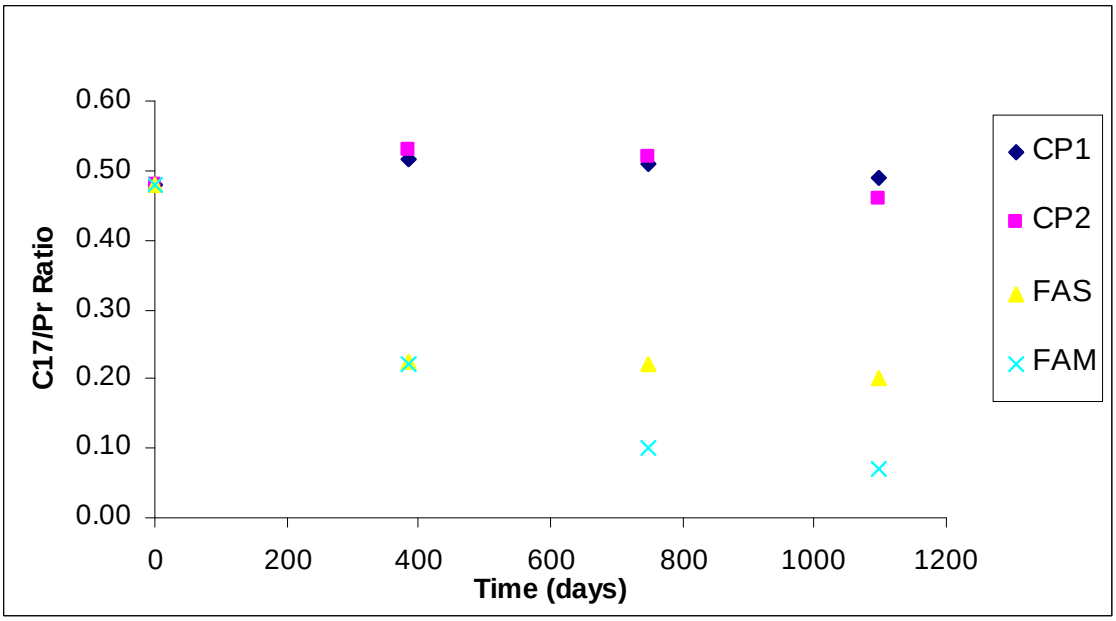


Figure 5: Change of C_{17}/Pr Ratios with Time at the In Situ Landfarm

Nutrient analysis results given in Table 17 show the presence of low levels of ammonia and nitrate FAM plot where fertilizer was added in 2006. The FAS1 plot was treated similarly but no nutrients were found this year. Last year nutrients were added to the FAS2 plot but surprisingly no ammonia or nitrate were found in the sample from this location.

Table 17: Soil Nitrogen and Phosphorus Levels (ppm) at the In Situ Landfarm

Sample	Plot	TKN	Ext. Ammonia	Ext. Nitrate	Ext. Nitrite	Total P	Ext P
RI08-004N	CP1	340	<5.0	<2.0	<2.0	220	20
RI08-005N	FAS2	240	<5.0	<2.0	<2.0	210	20
RI08-006N	FAS1	360	<5.0	<2.0	<2.0	220	20
RI08-007N	FAM	390	6.1	4.8	<2.0	210	30

Hydrocarbon degraders levels in the four samples CP1, FAS2, FAS1 and FAM were <100, 9.0×10^4, 5.0×10^4, and 7.3×10^4 respectively. These numbers of biodegraders clearly show the effect of adding fertilizer to the different plots.

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 8. 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. In 2007 the system was found to be in good repair and water and soil samples collected and analysed.

2. 2008 Field Activity

No major repairs were needed on the system again this year. Build up of sediment found at the PCB barriers was not found at this barrier probably due to the smaller catchment area involved. The second boom had however washed over the dam between the two ponding areas but was undamaged and easily repositioned. The PVC liner forming the first pond was damaged above the water line but the seal on the pond was intact (Photographs 12, 13) This was not entirely unexpected since the pond liner is subject to uv-degradation and is much thinner than the HDPE liners used on the second

barrier and the PCB barriers. However, beneath the pond level the liner was undamaged since here it is covered with a layer of sediment and is not subject to weather damage. The pond liner is very economical, light weight and easy to manipulate and was used here as an experiment to see how well it would perform. It will be interesting to see whether it continues to seal the upper pond during the next few years.

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 8. The filter box system was in good condition with no indication of overflow and therefore materials were again not replaced this year. The filters were however sampled this year together with the boom material.

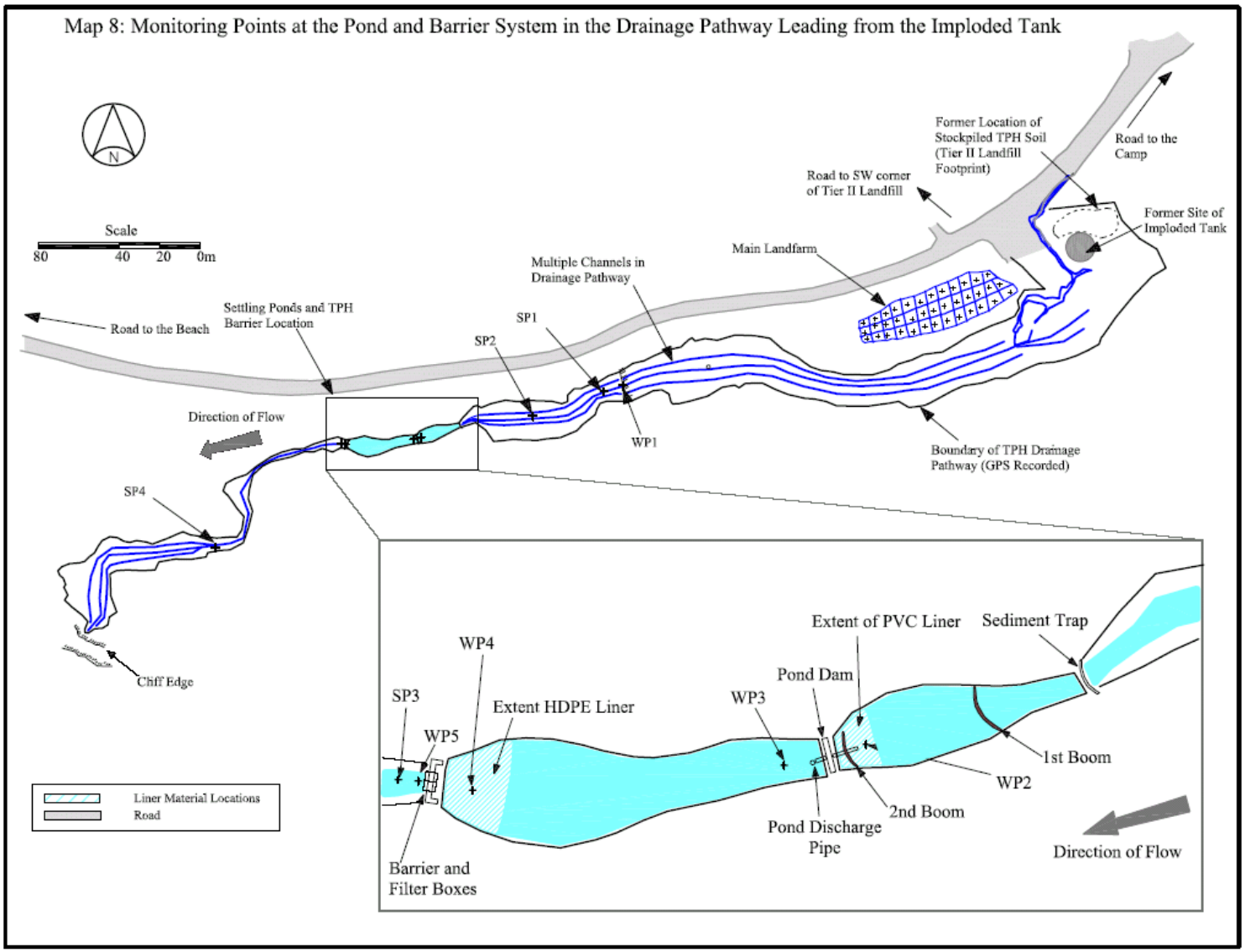
3. Monitoring Results

Results of analyses of soil samples collected this year are shown in Table 18 along with those for the previous 4 years. Results for SP2 and SP4 were surprising high. However, the variability of TPH levels found in field samples is well known.

Table 18: 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	2008
SP1	Below waterfall	950	710	310	370	430
SP2	Between waterfall and barrier	1190	<40	<40	<40	400
SP3	Just beyond barrier	290	600	182	290	310
SP4	Between barrier and cliff	160	100	<40	100	850

Map 8: Monitoring Points at the Pond and Barrier System in the Drainage Pathway Leading from the Imploded Tank



Photograph 12:The PVC Pond Liner Did Not Survive the Arctic Winter Above the Pond Level: Note the Damage Due to UV-Radiation and Weather

Photograph 13:The PVC Pond Liner Was Intact Below the Water Line Where it Was Covered With a Layer of Sediment

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 19 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 as was the case in 2007.

Table 19: Results of Water Analyses for TPH at the Imploded Tank Drainage Area Ponds and Barriers

Water Monitoring Point	Location	TPH (ppm)				
		2004	2005	2006	2007	2008
WP1	Small Waterfall Upstream of Pond	0.09	0.19	<0.20	<0.10	<0.10
WP2	Pond #1	0.11	0.31	<0.20	<0.10	<0.10
WP3	Pond #1 Discharge Pipe	-	0.16	<0.20	<0.10	<0.10
WP4	Pond #2	0.09	0.29	<0.20	<0.10	<0.10
WP5	Filter System Discharge	0.09	0.23	<0.20	<0.10	<0.10

Nutrient levels at the four soil sampling points are given in Table 20. Total N and P levels are similar to those from previous years. In previous years the levels of extractable ammonia, nitrate and nitrite were all below the method detection limits. The trace level of ammonia in SP4 may indicate some run off from the landfarm.

Table 20: Results of Analyses for Nutrient in Soil at the Imploded Tank Drainage Area Ponds and Barriers (ppm)

Sample	Plot	TKN	Ext. Ammonia	Ext. Nitrate	Ext. Nitrite	Total P	Ext P
RI08-011N	SP1	370	<5.0	<2.0	<2.0	140	<10
RI08-010N	SP2	250	<5.0	<2.0	<2.0	105	<10
RI08-009N	SP3	220	<5.0	<2.0	<2.0	130	10
RI08-008N	SP4	200	6.2	<2.0	<2.0	90	<10

Hydrocarbon degrader levels in the 4 soil samples from SP1, SP2, SP3 and SP4 were found to be 4.5×10^3, 2.2×10^3, 3.9×10^4, and 3.4×10^3 respectively. The two SP2 values found in field duplicates were 4.2×10^3 and 3.0×10^4 thus there is considerable variation from sample to sample in a small area. These are typical levels found at the site.

Results given in Table 21 show that no diesel fuel was detected in samples of gravel or GAC from the filter box.

Table 21: TPH Concentration of Filter Box Materials From 2005. to 18 July 2008

Sample No	Medium	Location	TPH (ppm)
RI08-020HC	Gravel	Left filter	<40
RI08-019HC	Gravel	Right filter	<40
RI08-017HC	GAC	Left filter	<40
RI08-018HC	GAC	Right filter	<40

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 was loose and subject to erosion, particularly during runoff. In order to control the PCB migration from these two factors, it was decided 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.

The surprise this year was the large volume of sediment in the barriers particularly in the beach barrier which had five times the amount collected in the previous two years. Clearly there had been a major precipitation event and/or rapid snow melt which had caused considerable runoff and associated sediment entrainment. Both the S1/S4 barriers were clogged which had not occurred in the previous two years. The furniture dump barrier has a much smaller catchment area as well as less disturbance within the catchment area, so that it was not greatly impacted by the rapid runoff.

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. Geotextiles 1200R and 400W were placed in the filter boxes this year as outlined below. The overpack drums and waste wranglers

containing the PCB-contaminated sediment were not removed from near the barriers again this year so there is now no room around the barriers for any more containers. They will require moving if the process is to continue. Table 22 lists the locations of the containers of PCB contaminated soil and their volumes.

Table 22: Data Summary of the Containers of PCB Contaminated Soils Obtained From the Barriers in 2007 and 2008.

	S1/S4 Beach		S1/S4 Valley		Furniture Dump		Total
	2007	2008	2007	2008	2007	2008	
Number of Overpack Barrels	5	2	8	12	2	3	32
Number of Waste Wranglers	-	7	-	-	-	-	7
Total Volume of Soil (m^3)	1.3	5.3	0.75	2.6	0.25	0.6	10.8
Number of Barrels of Filters	1	1	1	1	1	1	6
Barrels with PCB <1.0 ppm	6		-		-	-	6
Barrels with Tier I	-	3 + 7 WW	9*	12	-	-	24 + 7 WW
Barrels with Tier II	-	-	-	1	3	-	4
Barrels with CEPA > 50 ppm	-	-	-	-	-	4	4
PCB level of used GAC, gravel and geotextile	Tier I	Tier I	Tier II	Tier II	Tier II	CEPA	-

* PCB concentration is 4.8 ppm, therefore might be considered Tier II: Soil volumes do not directly correlate to barrel numbers as these were filled to various depths.

Current Location of Waste: Airstrip: 4 drums (3 from furniture dump in 2007 and one from 2008): Building B2 – one drum waste from furniture dump in 2008: Furniture Dump Barrier, 2 drums: Valley Barrier, 22 drums: Beach Barrier, 9 drums plus 7 waste wranglers. Estimated mass of the 7 waste wranglers = 2900 lbs each

Work at each of the three barriers is discussed in detail below followed by a section which summarises the results. Not all the samples collected were analysed. Analysis of samples was continued until PCB levels in the various matrices were established. All samples are stored should their analysis be deemed desirable.

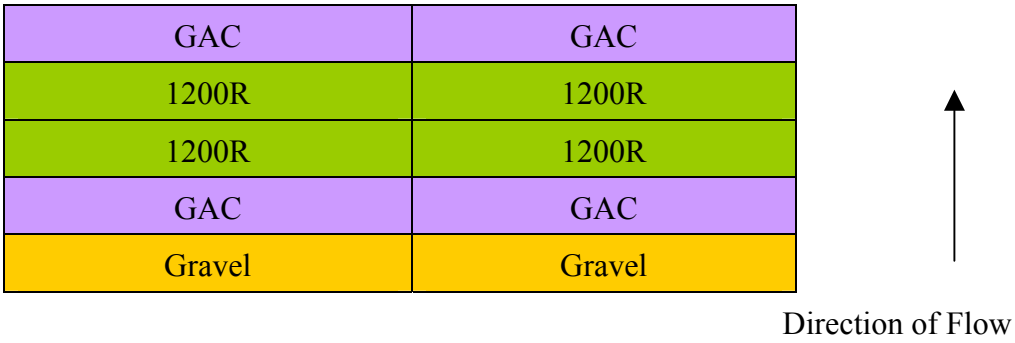
Additional laboratory work continued in support of the barrier system study and is presented in Section M.

1. S1/S4 Valley Barrier

a) General

Filters containing fresh gravel, GAC and 1200R geotextile were placed in the filter box in 2007 as shown in Figure 6.

Figure 6: Arrangement of Filters and Sorbents in the S1/S4 Valley Filter Box at the End of the 2007 Field Season



b) 2008 Field Work

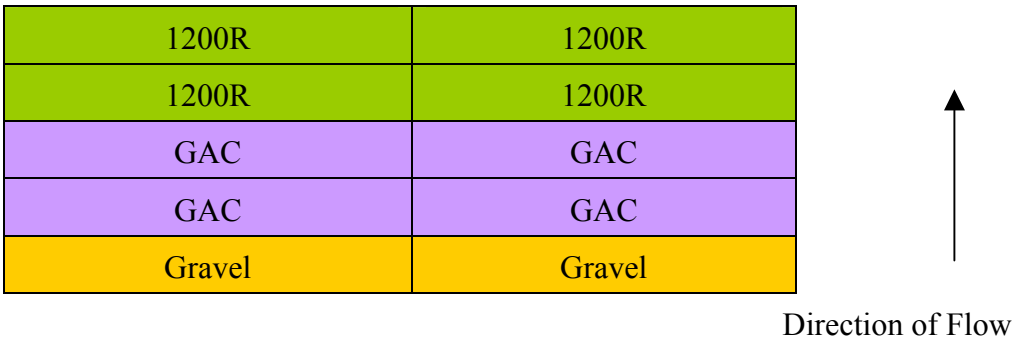
Upon preliminary inspection of the valley barrier it was noted that the sediment loading was greater than that of 2006. A decrease was expected again this year since the soil excavation in the valley had been completed in 2005 and therefore it was thought that the remaining soil would be stabilized to a greater degree. However, the barrier was clogged and water was up to about 80 % the height of the filters (Photograph 14). Initially all filters except the last GAC were removed and the barrier left for 2 days after which time the water level had dropped to about 20 % of the height of the filters. The uncontaminated sediment in the first clean cell had been mostly washed away but the second cell was in good condition. No repairs were necessary at the barrier.

Sediment and water samples were taken from the various monitoring points around the barrier. Sediment was then shoveled out of the catchment areas within the barrier system into overpack drums (Photograph 15). Twelve drums were filled 7/8 full with sediment and labeled "Valley 2008 Barrel # PCBs". Filters were sampled and material from the old filters was placed into an overpack drum labeled #13 together with some additional sediment. The filter cassettes were filled with new gravel, GAC and geotextile 1200R. The valley barrier was charged with 2 gravel filters, 4 GAC filters and 4 geotextile filters as shown in Figure 7. Material from on site was used to regenerate both clean cells.

Photograph 14: The Valley Barrier at the Start of the Site Visit; Much More Sediment Was Present Than Last Year and the Filter Box was Clogged

Photograph 15: The Valley Barrier After the Sediment Was Shoveled Out Into Thirteen Overpack Drums:

Figure 7: Arrangement of Filters and Sorbents in the S1/S4 Valley Box at the End of the 2008 Field Season



c) Monitoring Results

(1) Water

Water was collected from 5 locations in the valley. Their locations and PCB concentrations are given in Table 23 and Map 9. These results are at similar levels to those obtained in the last two years; no water was collected in 2005 as none was flowing. Several water samples collected this year contained considerable amounts of sediment which may well have affected the PCB levels that were found.

Table 23: PCB Concentration in Water From the S1/S4 Valley

Sample Number	Monitoring Point	PCB (ppb)	Location
RI08-023W	VWP1	0.063	In front of chevrons
RI08-022W	VWP2	0.124	In front of filter box
RI08-021W	VWP3	0.067	After filter box
RI08-020W	VWP4	0.084	20 m downstream of barrier
RI08-019W	VWP5	0.022	Near cliff

(2) Sediment

Results of the analysis for PCBs from sediment collected from within the barrier are shown in Table 24 and Map 9. Sediment samples were also taken from 12 of the thirteen drums and their results are given in Table 25. The average PCB level within the barrier was 2.9 ppm (Tier I). This is significantly lower than the concentrations (4.8 ppm and 6.1 ppm) in the previous two years. Total amount of soil removed from the funnel this year was 2.6 m^3. Last year the volume of soil removed was 1.0 m^3 with an average concentration of 4.8 ppm while 2.3 m^3 was removed in 2006. The calculated amount of pure PCB trapped by the barrier in front of the filter box between 3 August 2007 and 17 July 2008 was 13.6 g as compared to 8.6 g for a similar period in the previous year.

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

Sample	Monitoring Point	PCB (ppm)	Location
RI08-040	VSP1	4.1	In front of chevrons
RI08-038	VSP2	2.9	Between chevrons and first gabion fence
RI08-122	VSP3	2.2	Between first gabion fence and filter box
RI08-121	VSP4	5.5	In front of filter box
RI08-037	VSP5	3.8	First clean cell
RI08-036	VSP6	13.8	Between the two clean cells
RI08-035	VSP7	2.9	Second clean cell
RI08-034	VSP8	nd	20 m downstream
RI08-033	VSP9	nd	Cliff edge
RI08-044	-	nd	Near VMP1 (0-40cm)
RI08-124	-	11.1	Between filters in barrier
RI08-070	-	nd	New material in first clean cell
RI08-152	-	nd	New material in second clean cell

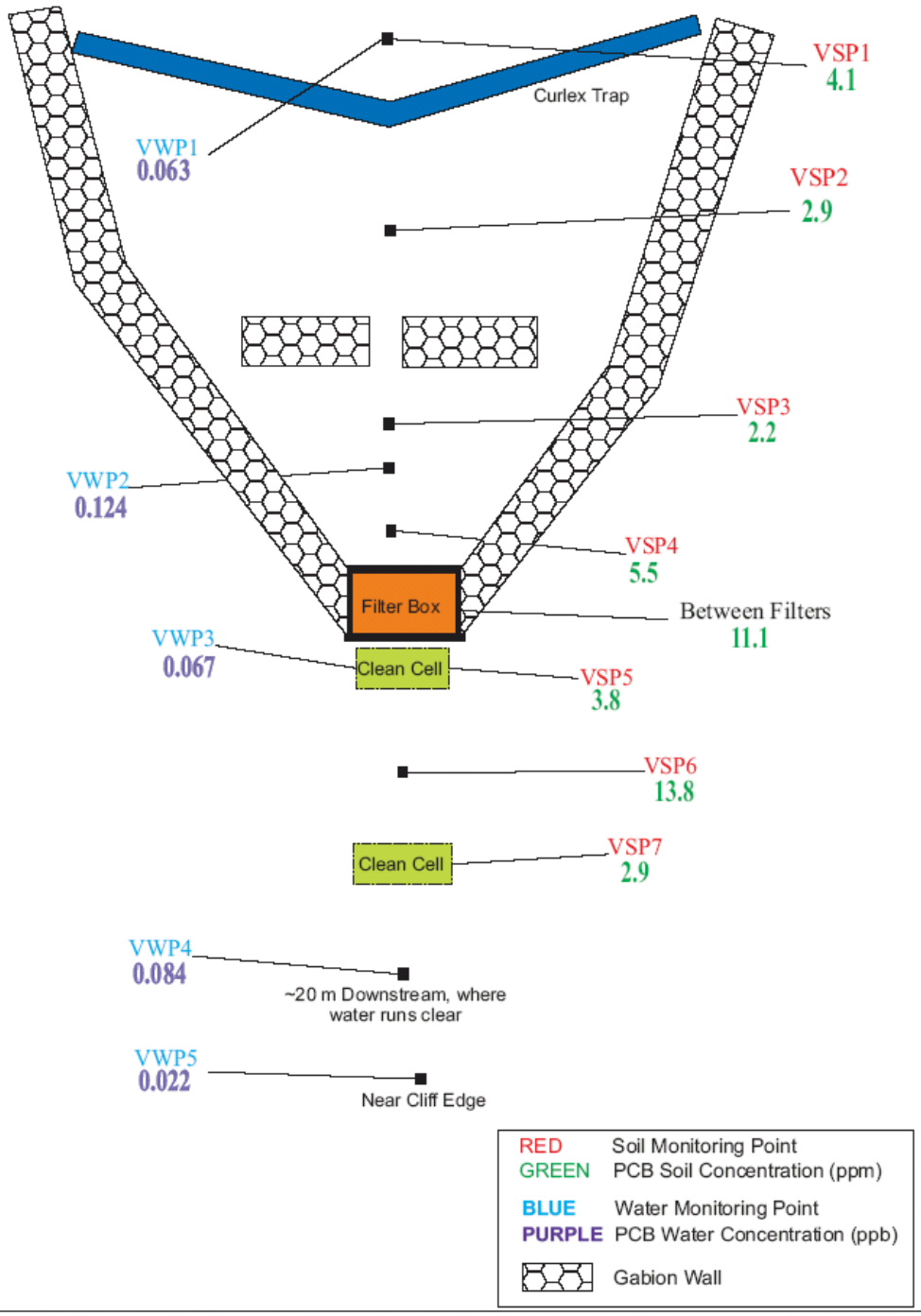
nd – not determined

Table 25: PCB Concentration of Sediment in Drums Filled from the S1/S4 Valley Barrier

Barrel number	Sample number	PCB (ppm)
1	RI08-125	2.7
2	RI08-062	1.9
3	RI08-123	1.4
4	RI08-061	2.0
5	RI08-064	2.6
6	RI08-065	2.2
7	RI08-066	2.8
8	RI08-126	1.4
9	RI08-063	2.1
11	RI08-067	7.7
12	RI08-068	3.2
13	RI08-069	2.1*

* Soil from drum also containing barrier filter box material

Map 9: Locations and PCB Concentrations of Soil and Water Samples at the S1/S4 Valley Barrier in 2008



(3) Filters

The filters were removed from the filter box on 16 July 2008. Samples were collected from each filter and analysed for PCBs. Results of analysis are presented in Tables 26 and 27, 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. Samples were analysed until the PCB level was established based on variability and results from previous years. The PCB concentration found in the gravel and GAC filters was low and similar to the levels found in 2007. The amount of PCB trapped by the gravel and GAC filters was calculated to be 65 mg and 83 mg respectively for a total of 148 mg. This compares to 289 mg in 2007, 128 mg in 2006 and 474 mg in 2005. Two layers of 1200R geotextile filters were placed in the box last year and results of analysis of these is given in Table 27. The levels found were similar to those in the gravel and GAC. The amount of pure PCBs trapped by the geotextile filters was 8 mg.

Table 26: PCB Concentration of Filter Box Materials From the S1/S4 Valley Barrier System in Operation From 3 August 2007 to 16 July 2008

Sample No	Medium	Location	PCB (ppm)
RI08-048	Gravel	Left first filter	1.3
RI08-050, 051, 052	Gravel	Right first filter (top, middle and bottom thirds combined)	0.4
RI08-045, 046, 047	GAC	Left second filter (top, middle and bottom thirds combined)	0.7
RI08-049	GAC	Right second filter	nd
RI08-130	GAC	Left last filter	2.7
RI08-127	GAC	Right last filter top third	0.9
RI08-128	GAC	Right last filter middle third	0.8
RI08-129	GAC	Right last filter bottom third	0.5

nd - not determined

Table 27: PCB Concentration of the Geotextile Materials From the S1/S4 Valley Barrier System in Operation From 3 August 2007 to 16 July 2008

Sample No	Medium	Location	PCB (ppm)
RI08-041	1200R	Left first (¼ height)	1.8
RI08-042	1200R	Right first (¼ height)	1.3
RI08-039	1200R	Left second (2/3 height)	1.2
RI08-043	1200R	Right second (2/3 height)	2.5

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 8 shows the arrangement of filters in the filter box at the end of the 2007 field season.

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

b) 2008 Field Work

The S1/S4 beach barrier was found to be in good condition upon arrival but the whole space behind the filter box was filled with sediment and water (see front cover photograph). Sediment and water samples were first taken from in and adjacent to the barrier. Then the geotextile filters and GAC filters were removed and sampled. As the

level of water and sediment did not become lower, some sediment was removed immediately in front of the filter box, and the lids of the filter boxes were then used to block the barrier and the gravel filters removed (Photograph 16). The area is reached by walking from the beach landing area adjacent to building B2. Three empty drums were carried to the barrier but this was deemed to be too dangerous due to the terrain (Photograph 17). Since the volume of sediment was so large it was decided to switch to waste wrangler containers. The sediment was then shoveled into the 2 drums and seven overpacks which were filled to approximately 7/8th capacity. The drums were labeled "Beach 2008 Barrel #2 and #3 PCBs" and the 7 waste wranglers "Beach 2008 Waste Wrangler # PCBs". After sampling the cassettes (Photograph 18), the used GAC, gravel and geotextile were placed in Barrel #1. Sediment samples were also taken from between the geotextile filters (Photograph 19). 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 9. In the last filter slot in each box, three layers of a non-woven geotextile (1200R) were placed one after the other with about a 2 cm gap between each. In front of these a woven geotextile 400W was placed. 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.

Figure 9: Arrangement of Filters and Sorbents in the S1/S4 Beach Filter Box at the End of the 2008 Field Season

1200R	1200R	1200R
1200R	1200R	1200R
1200R	1200R	1200R
400W	400W	400W
GAC	GAC	GAC
GAC	GAC	GAC
¾ full Gravel	¾ full Gravel	¾ full Gravel

Direction of Flow

Photograph 16: Replacing the Lids on the Filter Box After Recharging the Filters With Fresh Materials

Photograph 17: Carrying Empty Drums to the Beach Barrier From Building B2 Was Deemed to be Too Dangerous

Photograph 18: Sampling a Cassette Containing GAC by Depth (Top, Middle and Bottom) and by Composite in Duplicate

Photograph 19: Sampling Sediment From Between the Geotextile Filters After Having First Sampled the Filter

c) Monitoring Results

(1) Water

Water was collected from 3 locations in the beach area. Their locations and PCB concentrations are given in Table 27 and Map 10. These values are generally higher than in the previous years. This is probably the result to the major movement of sediment to the trap and the fact that the barrier was overflowing.

Table 27: PCB Concentration (ug/L) in Water From the S1/S4 Beach Area

Sample Number	Monitoring Point	PCB Concentration	Location
RI08-024W	BWP1	0.075	Effluent from barrier filter box
RI08-025W	BWP2	0.105	Effluent from barrier filter box
RI08-026W	BWP3	0.135	Below cliff at the sea edge

(2) Sediment

Four sediment samples were collected in and around the barrier and samples taken from four of the waste wranglers. Results of analysis of these for PCBs and their locations are given in Tables 28, 29 and Map 10. The volume of sediment removed was 5.3 m^3. This is much more than the 1.3 m^3 and 2.0 m^3 removed from the barrier in 2007 and 2006 respectively. The average PCB level in the sediment removed from the barrier was 1.6 ppm. This is higher than in the previous two years (0.6 ppm and 0.7 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 15.3 g PCB. This was much greater than the 1.2 g removed in 2007 and 2.5 g in 2006.

Table 28: PCB Concentration of Sediment From the S1/S4 Beach Barrier

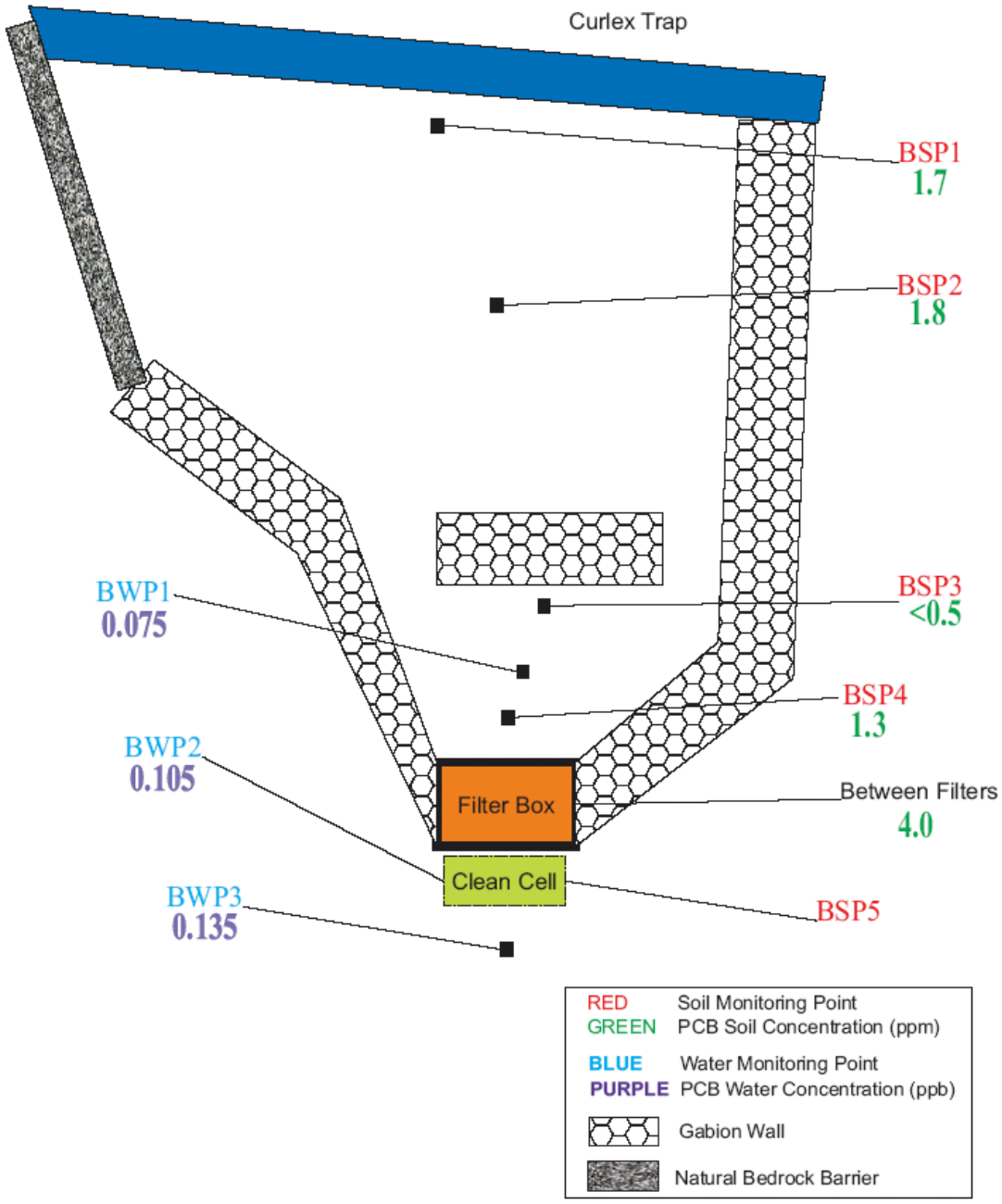
Sample Number	Monitoring Point	PCB Concentration (ppm)	Location
RI08-075	BSP1	1.7	Between top gabions and Curlex trap
RI08-076	BSP2	1.8	In front of Curlex trap
RI08-077	BSP3	<0.5	Between edge of liner and central gabion
RI08-078	BSP4	1.3	In front of filter box
RI08-097	-	nd	Between 3rd and 4th 1200R filters
RI08-089	-	nd	Between 1st and 2nd 1200R filters
RI08-100	-	4.0	Composite of material within the filter box
RI08-151	-	nd	Material placed clean cell

nd – not determined

Table 29: PCB Concentration of Sediment in Waste Wranglers Filled from the S1/S4 Beach Barrier

Waste Wrangler number	Sample number	PCB (ppm)
1	RI08-120	2.0
2	RI08-153	2.0
3	RI08-154	2.6
4	RI08-155	1.1

Map 10: Locations and PCB Concentrations of Soil and Water Samples at the S1/S4 Beach Barrier in 2008



(3) Filters

The filters were removed from the filter box on 17 July 2008. Samples were collected from each filter and analysed for PCBs. Results of analysis are presented in Table 31 for GAC and gravel and Table 32 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 in the gravel and GAC filters. The total PCBs collected were 12 mg on the gravel and 59 mg on the GAC. These values compare with 36 mg and 28 mg found of the gravel and GAC filters in 2007 and 29 mg and 16 mg 2006.

Table 31: PCB Concentration of Filter Box Materials From the S1/S4 Beach Barrier System in Operation From 4 August 2007 to 17 July 2008

Sample No	Medium	Location	PCB (ppm)
RI08-113	Gravel	Left first filter	0.1
RI08-114, 115, 116	Gravel	Central first filter (top, middle and bottom thirds combined)	0.1
RI08-117	Gravel	Right first filter	nd
RI08-102	GAC	Left second filter	nd
RI08-104, 105, 106	GAC	Central second filter (top, middle and bottom thirds combined)	0.3
RI08-112	GAC	Right second filter	0.8
RI08-03	GAC	Left third filter	0.7
RI08-107, 108, 109	GAC	Central third filter (top, middle and bottom thirds combined)	1.8
RI08-111	GAC	Right third filter	0.6

nd - not determined

The concentration of PCBs found on the geocomposite filters were also similar to those found last year. These are higher than the concentrations in the GAC and gravel filters and increase from the front to back of the filter box. The mass of PCBs collected by the 12 geotextile filters was 22 mg. This compares with 0.3 mg collected last year on six geotextile filters. The large increase is likely due to the increased volume of sediment on the filters this year. The level of PCBs found on the filters is similar to that of the sediment (4.0 ppm) trapped between the filters in the filter box.

Table 32: PCB Concentration of the Geotextile Materials From the S1/S4 Beach Barrier System in Operation From 4 August 2007 to 17 July 2008

Sample No	Medium	Location	PCB (ppm)
RI08-081	1200R	Left first top (1/2 height)	1.3
RI08-082	1200R	Left first bottom (1/2 height)	0.5
RI08-079	1200R	Central first top (1/2 height)	nd
RI08-088	1200R	Right first top (1/2 height)	2.5
RI08-090	1200R	Right first bottom (1/2 height)	nd
RI08-083	1200R	Left second top (5/8 height)	nd
RI08-080	1200R	Central second top (5/8 height)	nd
RI08-092	1200R	Right second top (5/8 height)	3.3
RI08-091	1200R	Right second bottom (5/8 height)	2.8
RI08-087	1200R	Left third top (3/4 height)	nd
RI08-086	1200R	Left third bottom (3/4 height)	nd
RI08-099	1200R	Central third top (3/4 height)	2.4
RI08-098	1200R	Central bottom (3/4 height)	3.1
RI08-100	1200R	Right third top (3/4 height)	nd
RI08-101	1200R	Right third bottom (3/4 height)	nd
RI08-085	1200R	Left fourth top (7/8 height)	3.6
RI08-084	1200R	Left fourth bottom (7/8 height)	1.5
RI08-094	1200R	Central fourth top (7/8 height)	5.7
RI08-093	1200R	Central fourth bottom (7/8 height)	8.6
RI08-096	1200R	Right fourth top (7/8 height)	nd
RI08-095	1200R	Right fourth bottom (7/8 height)	nd

nd – not determined

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 10 shows the arrangement of filters in the filter box at the end of the 2007 field season.

Figure 10: 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	GAC
GAC	GAC
¾ full Gravel	¾ full Gravel

Direction of Flow

b) 2008 Field Work

Upon inspection, there was again relatively little sediment in the furniture dump barrier though the volume was almost twice that of the previous two years. Water was flowing above the barrier but not through it; it presumably ran below the surface into fissures in the rock. A water sample was collected above the barrier. Five soil samples

were collected from in and around the barrier. Approximately 0.54 m^3 of material was then removed from the silt fence up gradient from the barrier and from just in front of the barrier funnel. This was placed in three overpack drums which were 3/4 filled and labeled 2008 Furniture Dump Barrel # PCBs. The filters were then removed from the barrier and sampled. The remains of the filters were placed into an overpack drum labeled 2008 Furniture Dump Barrel # 4 PCBs together with some sediment. One of the drums was transported to beside the airstrip by ATV and trailer but attempts to transport a second resulted in damage to the trailer, so the last two drums were left near the barrier. Barrel #4 was taken to building B2. The gravel and GAC cassettes were then refilled with new gravel and GAC and four geotextile sheets (one 400W followed by three 1200R) were placed in the fourth slot as shown in Figure 11. No modifications or repairs were deemed necessary for the barrier.

Figure 11: Arrangement of Filters in the Furniture Dump Filter Box at the End of the 2008 Field Season

1200R	1200R
1200R	1200R
1200R	1200R
400W	400W
GAC	GAC
GAC	GAC
¾ full Gravel	¾ full Gravel

Direction of Flow

4. Monitoring Results

(1) Water

A level of 0.125 ppb PCBs was found in water above barrier this year. This is lower than the high levels of 0.535 ppb found in 2007 and 0.89 ppb found in 2005; in other years water has been absent during the summer sampling season.

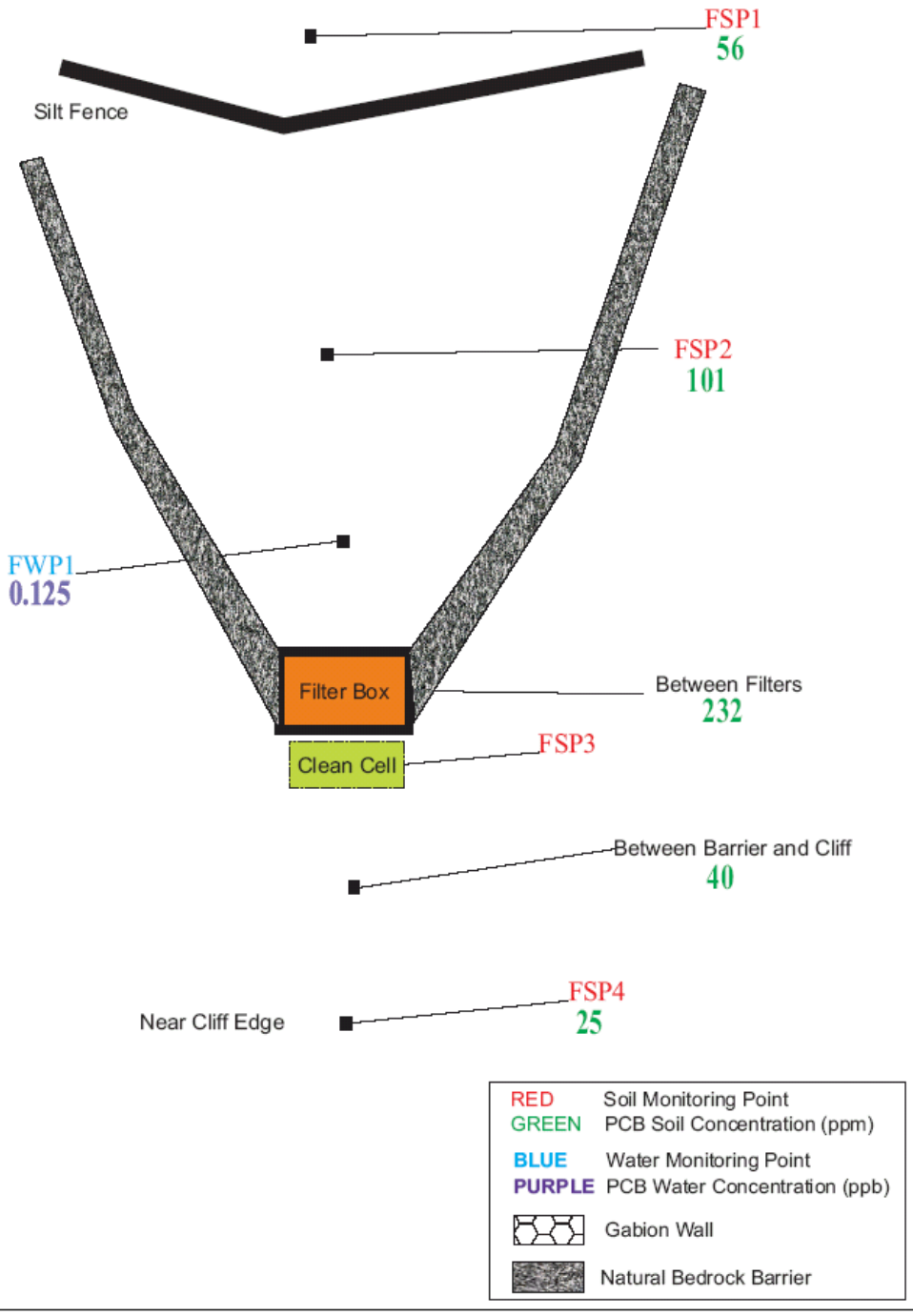
(2) Sediment

Five sediment samples were collected and analysed from the locations given in Table 32 and Map 11. The high values found paint a similar picture to the results obtained in previous years, that is, that there are relatively small quantities of sediment contaminated at much 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 within the furniture dump. This year, however, more sediment was collected and the PCB concentation (78 ppm) was higher. The total amount of pure PCBs removed with the sediment was 76 g in 0.6 m^3 of sediment. This is higher than the 16.9 g removed in 2007 and 15.4 g in 2006. The levels of PCBs beyond the barrier however did not increase showing that the barrier is performing well and preventing PCBs from reaching the ocean. The level of 232 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 as a whole.

Table 32: PCB Concentration of Sediment Samples From the Furniture Dump Barrier System After Spring Runoff

Sample Number	Monitoring Point	PCB Concentration (ppm)	Location
RI08-002	FMP1	56	In front of silt fence
RI08-001	FMP2	101	In funnel of barrier
RI08-003	-	40	Between the barrier and the cliff
RI08-004	FMP4	25	Near cliff edge to the south of the barrier
RI08-005	-	232	Between filters
RI08-158	-	nd	New clean cell material

Map 11: Locations and PCB Concentrations of Soil and Water Samples at the Furniture Dump Barrier in 2008



(3) Filters

Results of analyses of the contents of the gravel and GAC filters are given in Table 34. The levels in the gravel are similar to those found in 2006 and higher than those for 2007. The total mass of PCBs collected by the gravel filters was 400 mg as compared to 79 mg in 2007 and 223 mg in 2006. The GAC filters were not refilled last year as the PCB levels were low (average 4.7 ppm). The levels found this year in the GAC filters are much higher. The mass of PCB collected in the GAC filters was 1320 mg (after subtraction of the amount collected in 2007). This compares to 209 mg collected on the GAC filters in 2007 and 507 mg in 2006. These big increases in the amount of PCBs trapped by the filters are most likely due to the increase in the amount of sediment reaching the filter box.

Table 34: PCB Concentration of Filter Box Materials From the Furniture Dump Barrier System in Operation From 5 August 2006 to 15 July 2008

Sample No	Medium	Location	PCB (ppm)
RI08-020	Gravel	Left first filter top (2/3 full)	0.4
RI08-021	Gravel	Left first filter bottom (2/3 full)	4.1
RI08-006	Gravel	Right first filter middle	8.9
RI08-022	GAC	Left second filter top	nd
RI08-007	GAC	Right second filter middle	nd
RI08-023, 024, 025	GAC	Left third filter (top, middle and bottom thirds combined)	8.4
RI08-012	GAC	Right third filter top	33
RI08-013	GAC	Right third filter middle	nd
RI08-014	GAC	Right third filter bottom	50

nd - not determined

The PCB levels found in the geotextile filters are presented in Table 35. All values are greater than the 50 ppm level as regulated by CEPA. The average level was 190 ppm. The total amount of PCBs collected by the eight filters was 540 mg.

Table 35: PCB Concentration of the Geotextile Materials From the Furniture Dump Barrier System in Operation From 2 August 2007 to 15 July 2008

Sample No	Medium	Location	PCB (ppm)
RI08-026	1200R	Left first top (1/2 height)	145
RI08-027	1200R	Left first bottom (1/2 height)	285
RI08-009	1200R	Right first top (1/2 height)	nd
RI08-008	1200R	Right first bottom (1/2 height)	nd
RI08-028	1200R	Left second (5/8 height)	156
RI08-011	1200R	Right second top (5/8 height)	158
RI08-010	1200R	Right second bottom (5/8 height)	244
RI08-030	1200R	Left third top (3/4 height)	nd
RI08-031	1200R	Left third middle (3/4 height)	nd
RI08-032	1200R	Left third bottom (3/4 height)	nd
RI08-016	1200R	Right third top (3/4 height)	202
RI08-017	1200R	Right third middle (3/4 height)	229
RI08-018	1200R	Right third bottom (3/4 height)	283
RI08-029	1200R	Left fourth (7/8 height)	82
RI08-015	1200R	Right fourth (7/8 height)	121

nd – not determined.

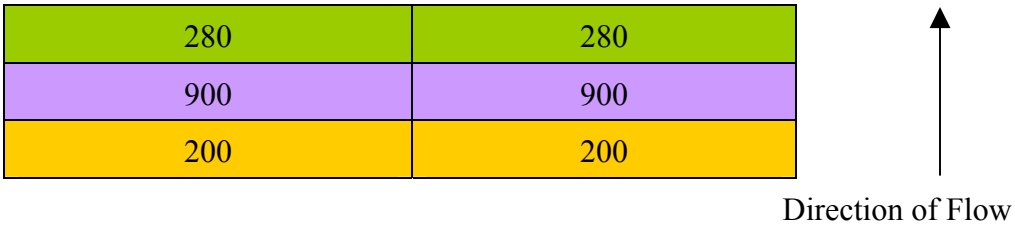
5. Summary of Barrier Results

Figures 12, 13 and 14 summarise the masses of pure PCBs in mg collected on each filter type in the barriers at the S1/S4 valley barrier, S1/S4 beach barrier and furniture dump barrier respectively.

Figure 12: Mass of Pure PCBs (mg) Found in the Various Sections of the S1/S4 Valley Barrier Filter Box

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

Figure 14: Mass of Pure PCBs (mg) Found in the Various Sections of the Furniture Dump Barrier Filter Box



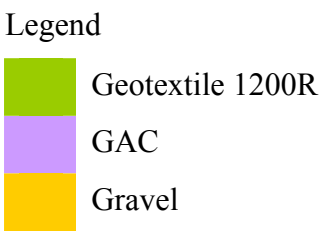


Table 36 summarises the PCB levels in the components of the barrier systems at the three locations this year. Table 37 summarises the amounts of pure PCBs collected in the three barrier systems in the sediment and filter systems in 2008, 2007 and 2006 while Figure 15 illustrates the change in sediment loading at the barriers with time.

Table 36: PCB Levels in Components of the Barrier Systems in 2008

Barrier	PCB Concentration (ppm)			
	Sediment	Gravel	GAC	1200R
S1/S4 Valley	2.9	1.2	1.4	1.7
S1/S4 Beach	1.6	0.1	0.8	3.2
Furniture Dump	78	4.5	30	190

Table 37: Mass of PCBs Removed From the Three Barrier Systems into Containers in 2008 (2007, 2006)

Barrier	Volume of Sediment	Mass of PCBs in Sediment	Mass of PCBs in Gravel and GAC	Mass of PCBs in Geotextiles
	m^3	g	g	g
S1/S4 Valley	2.6 (1.0, 2.2)	13.6 (8.5, 25)	0.15 (0.29, 0.13)	0.01
S1/S4 Beach	5.3 (1.3, 2.0)	15.3 (1.2, 2.5)	0.07 (0.06, 0.04)	0.02
Furniture Dump	0.6 (0.25, 0.3)	76 (16.9, 15)	1.7 (0.29, 0.73)	0.54

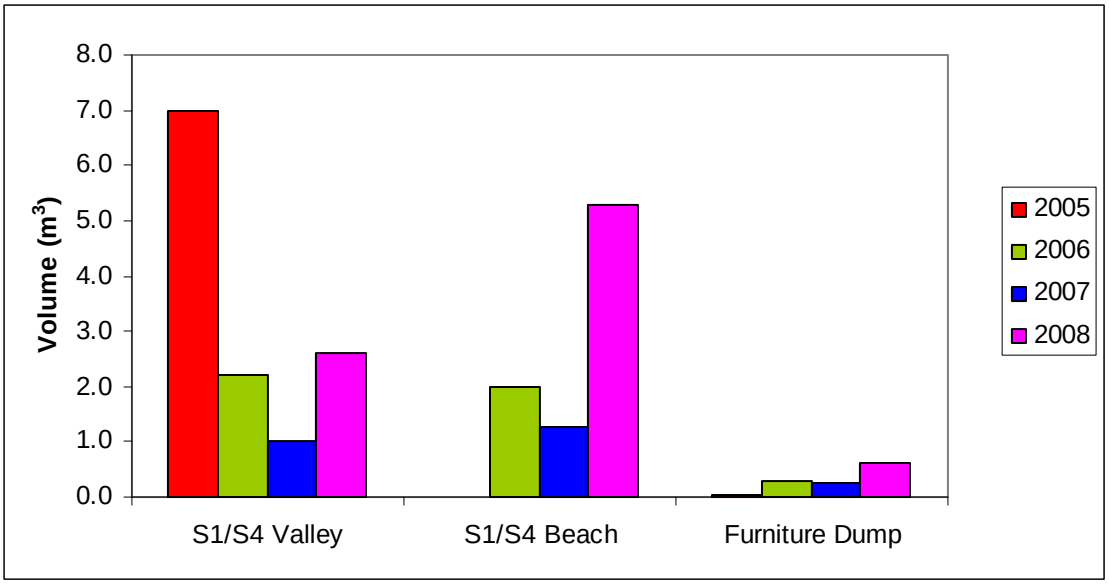


Figure 15: Change in Volume of Sediment Collected at the Three Barriers With Time

The volume of sediment in the traps indicated that a quick thaw or major rain event had occurred during the past 12 months resulting in a large increase in sediment in the barriers over previous years. The sediment levels had been decreasing with time as the material remaining after the excavation became stabilized but clearly a major event had mobilized more material in the drainage pathway.

The increase in the sediment load had some effect on the PCB levels. At the S1/S4 valley the decrease in PCB levels is likely due to the an increase in uncontaminated soil from higher in the drainage pathway whereas at the S1/S4 beach barrier the increase in PCB levels can be attributed to erosion of higher contaminated soils from the upper reaches of the beach area. At the beach barrier the levels were still Tier I and well below 5 ppm. At the furniture dump PCB levels also increased causing them to be above the 50 ppm CEPA criterion. This requires that they be reported to Environment Canada under current regulations.

The PCB levels given in Table 36 show that levels are generally highest in the geotextile filters for each barrier. This confirms the findings of laboratory experiments and supports the result that PCBs levels increase with decreasing particle size. PCB levels are low on the gravel and GAC at the two barriers in the S1/S4 dranage pathway. They have consistently been so and therefore detailed sampling and analysis of these two components is no longer useful. The PCB levels in sediment collected between the filters in the box was similar to those found in the geotextile barriers at the beach and furniture dump. At the valley the level was higher perhaps due to the different particle size distribution.

There is now little room for more containers at the S1/S4 barriers and helicopter support will be required before or at the start of the 2009 monitoring season.

M. Retention and Partitioning Laboratory Study

Initial batch and column tests using site contaminated soil from Resolution Island and GAC indicated that particle retention was far more important than adsorption of PCBs onto GAC[5]. After 72 h in column tests, only 8.7 ± 2.4% of the PCBs was found adsorbed to the GAC. However, this finding was not consistent with field observations. In comparing two of the barrier sites in the laboratory, GAC samples were found to have 34-77 % PCB absorbed onto the GAC – after the PCB contaminated soil had been rinsed off the GAC. This indicates that particle-particle partitioning is occurring. Three significant differences were noted between the conditions in the field and the column studies: temperature, amount of water, and residence time. In order to better model the field results, the effect of these parameters on the mechanisms of partitioning were further investigated and a comprehensive conceptual model for sorption was developed.

1. Batch Tests

Two types of batch tests were conducted to evaluate system kinetics. The first used a traditional set up (Type A) to compare a system containing GAC, soil and water (GSW) to a system containing only soil and water (SW). Both tests were conducted using 1 L Teflon bottles with 800 mL double de-ionized water, 1 g of soil and, in the case of the GSW system, 1 g of GAC. Batch tests were placed into a revolving box and rotated at 30 ± 2 rpm for time periods ranging from 1 hour to 336 hours. Each test was conducted in triplicate to account for variance from soil heterogeneity. At the end of the chosen time period, materials were separated. The bottle contents were poured through a 1 mm sieve, which retained the GAC particles and the sieve was rinsed to flush the soil through.

The second type of batch test (Type B) used smaller bottles (250 mL amber glass bottles with a Teflon lined lid), and described as 'small batch tests'. These tests were performed to compare GS (GAC-Soil) to GSW (GAC-Soil-water) systems and to explore the effects of temperature and length of contact time. Analysis was performed only on the GAC from these batch tests. PCB analysis for all matrices was performed as described in section B: Methodology.

---

[5] Kalinovich I, Rutter A, Rowe RK, Poland JS. Surface Permeable Reactive Barriers for PCB Remediation in the Canadian Arctic. Sci Tot. Environ. Submitted 19 Aug 2008.

2. Results for Type A Batch Tests

Figure 16 shows results from batch studies conducted for both SW and GSW systems. Soil concentration at time t (C_t) is calculated from subtracting amounts in water and GAC from the initial soil concentration (C_o). From these results, it can be seen that there is a difference in initial desorption rates ($t = 2.937$, $p < 0.05$, $df = 36$) and overall desorption when GAC is introduced into the system ($t = 7.48$, $p < 0.05$, $df = 62$). For both these systems, an initial rapid desorption phase and a slower desorption phase can be seen – indicating that the system is biphasic in terms of rate constants (Figure 16). Overall, very little PCB is partitioned from the weathered soil ($4.5 \pm 2.9e^{-5}$ % for GSW, 1.8 ± 0.04 % for SW). It is suspected that some of the loss is likely attributable to colloidal interferences. This is particularly likely in the GSW system where colloidal GAC fines can be observed.

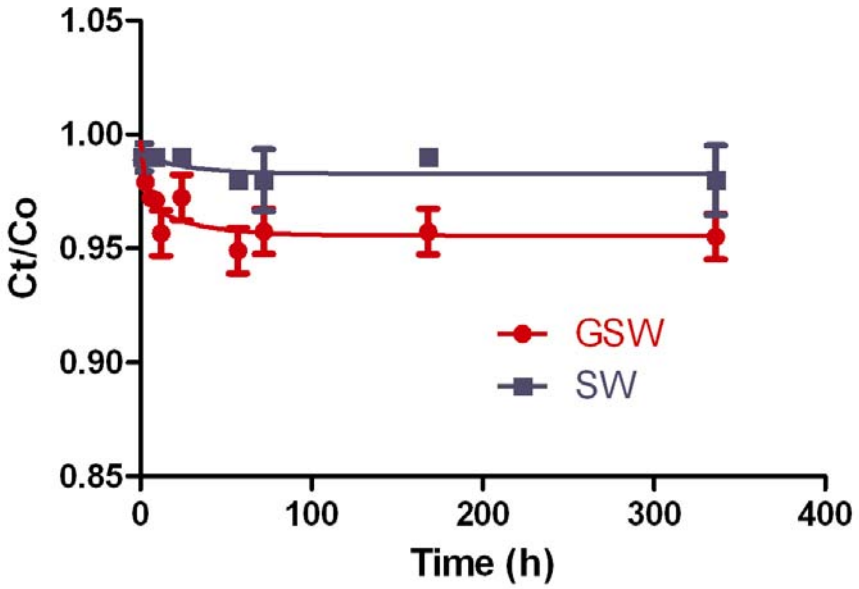


Figure 16: Batch Test Type A Results SW and GSW. Solid lines obtained by exponential curve fitting.

3. *Results for Type B Batch Tests*

The conventional batch and column laboratory testing indicated that particle retention was the primary mechanism of trapping PCB in a GAC filter within the barrier system. However, this did not fit with field data – GAC field samples indicated that at some locations, up to 77 % of PCB had partitioned onto the GAC, after the contaminated soils had been rinsed off of the GAC particles. Field parameters such as amount of water, temperature and length of contact between GAC and soil particles were not being accurately replicated in the laboratory. In the field, the ratio of water: soil: GAC is different in the barrier system than replicated in the initial batch tests. On average there is much less water in the field than in the laboratory batch tests. The temperature in the field is much colder than in the previous laboratory studies. In the new batch tests (Type B), the effect of temperature was investigated.

PCB contaminated soil particles sit in the charcoal filters for months, up to 1 year before sampling. Column and batch tests have been short term predictors by comparison. New batch tests were created to more readily replicate field conditions. The amount of water was reduced in the new batch tests, cold temperature was investigated and a 1 month particle-particle batch test was conducted. These batch tests were also used as quick screening tools to evaluate the effects of various parameters (such as amounts of diesel present in the system) upon desorption. Results are depicted in Figure 17.

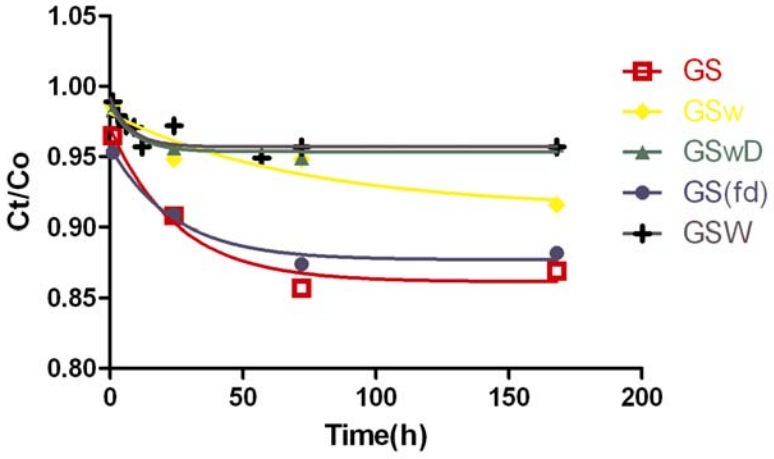


Figure 17: Small Batch Tests. GS denotes GAC-Soil, GSw denotes GAC-Soil-50mL water, GSwD denotes GAC-Soil-50mL water, Diesel, GS (fd) denotes GAC-Soil (furniture dump soil), GSW denotes GAC-Soil-800mL water. Solid lines obtained by exponential curve fitting.

These batch tests indicated that there is a difference in desorption behavior when even small amounts of water is present (50 mL) and that particle-particle partitioning is the more rapid process – within 72 hours. 14 % of PCB had mass transferred to the GAC via particle-particle partitioning, whereas with water present only 5.2 % of PCB was sorbed onto the GAC. In the field, high levels of PCB adsorb onto the GAC. This large mass transfer indicates that particle-particle partitioning occurs in the barrier system. In the field, contaminated particles are transported to the filter in times of high flow (and get trapped there). The water levels then drop, allowing for GAC-soil particle interaction without significant water interferences. These results, however, cannot confirm how water affects the mechanism of transfer of PCBs from soil to GAC in the barrier or whether particle-particle partitioning is occurring in the barrier system itself.

4. Temperature Studies

Large batch tests (system volume of 1 L) for both SW and GSW systems were conducted in triplicate for 1, 12 and 24 h at 3 ^{o}C. This temperature was chosen as the average temperature for the summer months (June – September) where temperatures would be above zero on site (2.4 ± 1.8 ºC). Small batch tests comprised S1/S4 valley soil with GAC (no water and small amounts of water – 50 mL, as opposed to 1 L) and furniture dump soil with GAC (no water and little water – 50 mL) were also performed to evaluate differences in particle-particle partitioning as well as small amounts of water.

There was no significant difference in behavior of the large batch test systems when temperature was altered (Table 38) for either the SW or the GSW systems. However, in the absence of water, (batch tests B) the particle-particle partitioning for both the valley and furniture dump soils appeared to be hindered by a decrease in temperature, as at 3 ^{o}C only 2 % of PCB is sorbed onto GAC compared with 14 % at 21 ºC (Table 39). In the field, the lids of the stainless steel boxes were painted black. This was to increase absorption of heat from the sun to promote earlier thawing in the spring. In the field the number of days with average daily air temperatures greater than 10 ºC for July and August during the period 2005-2008 is 22.3 ± 4.6 days. In comparison the laboratory column studies in which 8.7 ± 2.4 % PCBs were adsorbed in 72 hours.

Table 38: Normalized Soil Concentration GSW and SW Results for Kinetic Batch Tests at 3°C and 21°C at t = 1, 12 and 24h.

	GSW				SW			
	3°C		21°C		3°C		21°C	
Time (h)	Ct/Co	σ	Ct/Co	σ	Ct/Co	σ	Ct/Co	σ
1	0.994	0.001	0.989	0.001	0.994	0.006	0.993	0.006
12	0.971	0.014	0.957	0.008	0.995	0.002	-	-
24	0.956	0.010	0.972	0.009	0.992	0.004	0.993	0.002

Results in triplicate. σ denotes standard deviation.

Table 39: Small Bottle Batch Test Results. Percent PCB adsorbed to GAC at Temperatures 3°C and 21°C.

Test	% PCB adsorbed to GAC	
	3 °C	21 °C
SG	2 %	14 %
SGw	6 %	13 %
S(fd)G	2 %	9 %
S(fd)Gw	12 %	-

SG denotes Soil-GAC, SGw denotes Soil-GAC 50mL water, S(fd)G denotes (soil from the furniture dump)-GAC, S(fd)Gw denotes S(fd) denotes (soil from the furniture dump)-GAC-50mL water.

5. Column Tests

Column tests are used to more readily replicate or mimic barrier processes in the field. Column tests were conducted using a horizontal stainless steel column described in previous ASU reports. Site contaminated soil and water was recirculated through a 3.54 cm GAC filter for adsorption studies. The GAC filters were removed, air-dried and subsequently analysed by soxhlet extraction and GC-ECD. Twenty-four hour column tests were performed in triplicate and the amount of PCB adsorbed onto GAC compared to regular (21 °C) temperature conditions.

The 24 hour column tests performed in the cold room at 3 °C showed that GAC adsorbed less PCB (2.1 ±0.9 %) than those performed at room temperature of 21 ºC (8.7

±0.02 %). Since the large batch tests showed no change with temperature, and the particle-particle partitioning tests appeared to be affected by the decrease in temperature, these results indicate that particle-particle partitioning is the main mechanism for adsorption for PCB to GAC within a permeable reactive barrier system. The column testing mimics what occurs in the field (contaminated soil and water flowing through a GAC filter), therefore this data confirms that particle retention is an important mechanism to the barrier. The GAC functions as a granular filter, trapping contaminated soil particles. However, once the PCB contaminated soil particles are trapped within the granular structure of the filter, irreversible sequestration of PCBs onto the GAC is occurring via particle-particle partitioning, a mechanism that could be indicated by temperature effects.

Solid-solid partitioning is much faster than desorption and re-adsorption processes that occur when water is present in the system. Even though laboratory tests indicated that solid-solid partitioning was hindered by temperature, field results clearly indicated that the length of time that these particles were trapped by the granular media was adequate for the sequestration of PCBs by GAC to occur. In the field this particle-particle partitioning without water likely takes place after spring run-off and storm events, when large, volumes of water flow through the barrier, depositing PCB contaminated soil particles. These results have significant implications for the design of future adsorption barriers – by taking into account particle retention and length of time a particle of a particular size will be 'trapped' in a filter system, barriers can be designed for retaining a particle, sequestration the contaminant from the soil particle, and finally allowing the now 'clean' soil particle to be washed out of the filter system. Partitioning and particle retention are much more important processes than solute transport when dealing with hydrophobic organic contaminants like PCBs since the mechanism of transport of PCBs will be by movement of particles (such as soil), or colloids to which they are attached. Further studies are required, but it may be possible to design granular filters (permeable reactive barriers - PRBs) with retention criteria that would trap a particle for the required time that would allow mass transfer of PCBs to the GAC. The design would be based on the particle-particle partitioning coefficient and using particle transport in granular filter models similar to that developed by others[6].

[6] Locke M, Indraratna B, Adikari G. Time-dependent particle transport through granular filters. J Geotech and Geoenviron Eng 2001; 6: 521-529.

6. Conclusions

In the field, it was noted that mass transfer of PCB in the soil to the GAC occurred at sufficient levels (up to 77 %) to warrant further investigation. Initial laboratory studies in the form of batch and column tests could not confirm why or how this was happening. Batch tests were altered to account for differences between the field and the laboratory, chiefly, by altering the amount of water (it was found that the presence of water in the batch systems severely limited the capabilities of GAC to sequester PCBs) and temperature. Temperature studies confirmed that the main mechanism for mass transfer of PCB in soil to GAC within a barrier system was through particle-particle contact, a mechanism that is irreversible and effectively removes the PCB from the surrounding ecosystem. Kinetic studies showed that particle-particle partitioning is a rapid process in comparison to varying amounts of water present in the system, again indicating that this mechanism is preferable. In a PRB granular filter system, contact between contaminated soil particle and GAC is made when the granular structure retains the soil particle in its pore network.

Batch tests introduced diesel into the system in order to compare whether particle-particle partitioning was still relevant when PCB mobility in the aqueous phase was increased. At levels of hydrocarbons in the water seen in the field at the site, particle-particle retention remained the dominant mechanism. At higher levels of diesel, the uptake of PCB by the GAC was facilitated in water, resulting in a much greater mass transfer of PCBs. These results indicate that when designing a comprehensive model for these systems, solute transport may be relevant as a transport mechanism only when large quantities of hydrocarbons are present at the site.

N. Appendix

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

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 quality of the results. The number of results for each parameter are small so no average numbers have been calculated. Most experiments discussed in section M, were conducted multiple times in order to verify the results.

In general the field duplicates gave poorer precision than the laboratory ones due to the greater heterogeneity of the field samples. Results of water samples were also complicated by the presence of sediment. For TPH and PCB analyses filtering is not desirable since analytes in solution would be lost to the filter medium. This accounts for the poor precision in the field duplicates for low level PCBs in water (Table 46).

Table 40: PCB Concentrations in Blank and Spiked QA/QC Soil and Other Solid Samples

Sample	Units	PCB Concentrations
Blank	ppm	<0.5, <0.5, <0.5, <0.5, <0.5, <0.5, <0.5, <0.5, <0.5
Control	ppm	4.9, 5.6, 5.9, 5.6, 4.4, 4.2, 5.4, 4.0, 4.9
Control Target	ppm	5.0

Table 41: PCB Concentrations in Laboratory Duplicate Soil and Other Solid Analysis

Sample Number (prefix: RI08-)	PCB Concentrations (ppm)	Standard Deviation	Relative Standard Deviation (RSD) (%)
125	2.6; 2.8	0.14	5
154	2.0; 3.2	0.84	33
107,108,109	1.4; 2.4	0.71	37

Table 42: PCB Concentrations in Field Duplicate Soil and Other Solid Analysis

Sample Number (prefix: RI08-)	PCB Concentrations (ppm)	Standard Deviation	Relative Standard Deviation (RSD) (%)
10	272; 217	38	16
110	4.0; 3.9	0.07	2
120	2.2; 1.8	0.28	14
40	4.1; 4.1	0	0
20	0.4; 0.4	0	0

Table 43: PCB Concentrations in Blank and Spiked Low Level Soil Analyses

Sample	Units	PCB Concentrations
Blank	ppb	<3.0; <3.0
Control	ppb	13.9; 12.8
Control Target	ppb	10

Table 44: PCB Concentrations in Low Level Laboratory Duplicate Soil Analysis

Sample Number (prefix: RI08-)	PCB Concentrations (ppb)	Standard Deviation	Relative Standard Deviation (RSD) (%)
009HC	40; 35	3.5	9
006HC	3.5; 3.9	0.28	8
003HC	94; 78	11	13

Table 45: PCB Concentrations in Blank and Spiked QA/QC Water Samples

Sample	PCB Concentration (ppb)			
Blank	<0.02	<0.02	-	-
Control	0.077	0.206	0.069	0.186
Control Target	0.100	0.200	0.100	0.200

Table 46: PCB Concentrations in Field Duplicate Water Samples

Sample Number	Type	PCB Concentrations (ppb)	Standard Deviation	Relative Standard Deviation (RSD) (%)
RI08-020W	Field	0.142; 0.026	0.082	98
RI08-009W	Field	0.029; 0.066	0.026	55

Table 47: PCB Concentrations in Blank and Spiked QA/QC Plant Samples

Sample	Unit	PCB Concentrations
Blank	ppb	<3.0; <3.0
Control	ppb	11.0; 12.7
Control Target	ppb	10.0

Table 48: PCB Concentrations in Laboratory and Field Duplicate Plant Samples

Sample Number	Type	PCB Concentrations (ppb)	Standard Deviation	Relative Standard Deviation (RSD) (%)
RI08-009P	laboratory	3.7; 3.9	0.14	4
RI08-010P	field	3.4; <3.0	0.28	9

Table 49: TPH Concentrations in Blank and Spiked QA/QC Soil Samples

Sample	Units	TPH Concentrations			
Blank	ppm	<40	<40	<40	<40
Control	ppm	211	206	187	205
Control Target	ppm	195	195	195	195

Table 50: TPH (Fuel) Soil Concentrations in Laboratory and Field Duplicates

Sample Number	Type	TPH Concentrations (ppm)	Standard Deviation	Relative Standard Deviation (RSD) (%)
RI08-010HC	field	<40; <40	0	0
RI08-030HC	field	700; 350	247	47

Sample Number	Type	TPH Concentrations (ppm)	Standard Deviation	Relative Standard Deviation (RSD) (%)
RI08-017HC	laboratory	<40; <40	0	0
RI08-027HC	laboratory	1150; 1590	311	23
RI08-035HC	laboratory	854; 815	27	3
RI08-044HC	laboratory	434; 453	13.4	3

Table 51: TPH Concentrations in Blank and Spiked QA/QC Water Samples

Sample	TPH Concentrations (ppm)		
Blank	<1.0	<1.0	<0.1
Control	22.8	-	1.5
Control Target	19.5	-	2.0

Table 52: TPH Water Concentrations in Laboratory Duplicate Analysis

Sample Number	TPH Concentrations (ppm)	Standard Deviation	Relative Standard Deviation (RSD) (%)
RI08-009W	<1.0; <1.0	0	0
RI08-05HCW	<0.1; <0.1	0	0

Table 53: Metal Water Concentrations in Laboratory Blank Determinations and QC Control Samples

		Blank	QC	QC Target
Arsenic	mg/L	<0.003	0.75	0.80
Cadmium	mg/L	<0.001	0.76	0.80
Chromium	mg/L	<0.005	0.74	0.80
Cobalt	mg/L	<0.003	1.5	1.6
Copper	mg/L	<0.005	1.5	1.6
Lead	mg/L	<0.010	7.6	8.0
Nickel	mg/L	<0.005	1.5	1.6
Zinc	mg/L	<0.010	2.9	3.0

Table 54: Metal Water Concentrations in Laboratory and Field Duplicates (ppm)

Parameter	Laboratory duplicate RI08-007W	
Arsenic	<0.003	<0.003
Cadmium	<0.001	<0.001
Chromium	<0.005	<0.005
Cobalt	0.023	0.023
Copper	<0.005	<0.005
Lead	<0.010	<0.010
Nickel	0.064	0.063
Zinc	0.130	0.128

Table 55: Metal Soil Concentrations in Blank and Reference Material (ppm)

	Blank	Blank	Mess-3	QC Control	SS2	QC Control
Arsenic	<1.0	<1.0	16.5	13.9-17.3	81.8	54.8-103
Cadmium	<1.0	<1.0	<1.0	-	1.9	0.1-3.0
Chromium	<5.0	<5.0	44.9	31-49	45.7	35.8-55.5
Cobalt	<20	<20	13.1	10.7-13.7	15.6	11.5-17.2
Copper	<3.0	<3.0	30.9	29.8-37.4	186.2	158-225
Lead	<5.0	<5.0	18.3	16.6-20.5	116.4	99.4-130
Nickel	<10	<10	40.5	35.0-40.8	58.4	49.2-60.8
Zinc	<15	<15	147.3	125-147	499.2	392-544

Table 56: Metal Soil Concentrations in Laboratory Duplicate Analysis (ppm)

Parameter	RI08-053		RI08-060	
Arsenic	<1.0	<1.0	1.0	<1.0
Cadmium	<1.0	<1.0	<1.0	<1.0
Chromium	45.1	35.0	40.6	44.3
Cobalt	12.5	10.3	48.8	49.6
Copper	79.3	64.6	73.1	76.3
Lead	11.6	<10	10.8	11.6
Nickel	64.8	55.1	86.7	88.1
Zinc	79.3	67.1	226.3	235.0

Table 57: Metal Soil Concentrations in Field Duplicate Analysis (ppm)

Parameter	RI08-060	
Arsenic	<1.0	<1.0
Cadmium	<1.0	<1.0
Chromium	42.4	47.2
Cobalt	49.0	39.7
Copper	74.7	73.5
Lead	11.2	10.0
Nickel	87.4	84.8
Zinc	230	215

Table 58: Thermister Data from Landfill East – Cable 1312 – Data Logger 61

Average Monthly Temperatures From July 2007 to July 2008

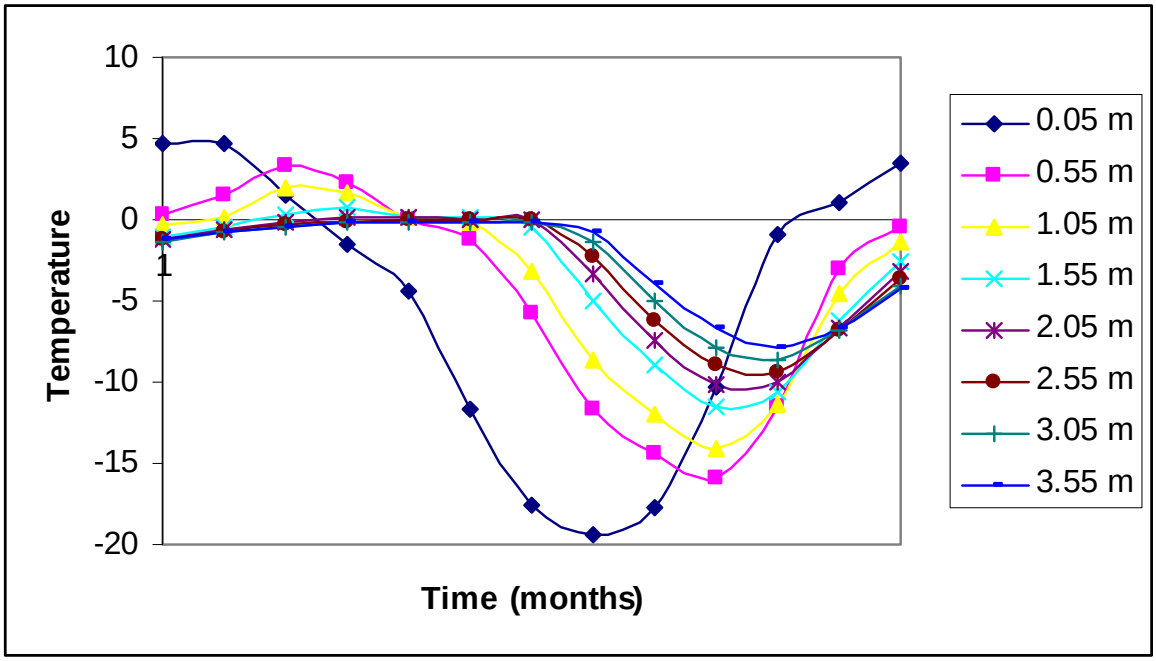


Table 59: Landfill East Soil Temperatures for 4 Days Between July 2007 and July 2008

Depth Below Finishing Grade (m)	15-Sep-07	15-Dec-07	15-Mar-08	15-Jun-08
0.05	1.7	-12.1	-20	0.0
0.55	1.9	-6.0	-16.2	-0.3
1.05	1.6	-3.2	-14.4	-1.1
1.55	0.8	0.0	-11.9	-2.3
2.05	0.1	0.0	-10.6	-2.8
2.55	-0.1	0.0	-9.3	-3.3
3.05	-0.2	-0.1	-8.2	-3.7
3.55	-0.2	-0.1	-7.1	-3.8

Table 60: Thermister Data from Landfill West – Cable 1318 – Data Logger

Average Monthly Temperatures From July 2007 to July 2008

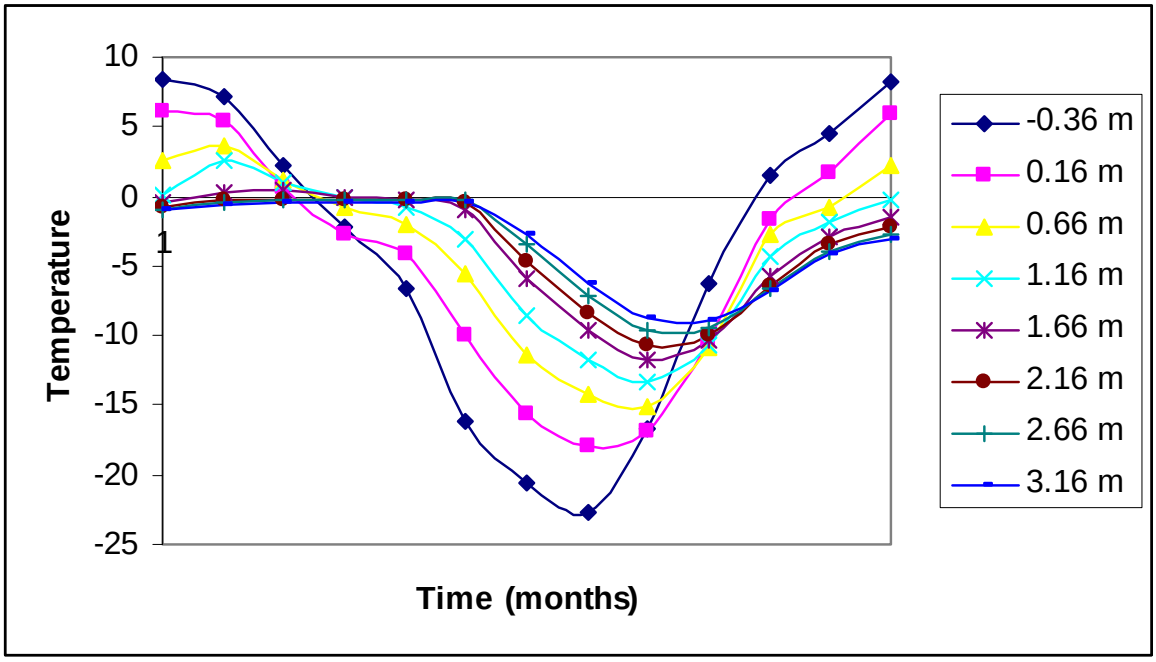


Table 61: Landfill West Soil Temperatures for 4 Days Between July 2007 and July 2008

Depth Below Finishing Grade (m)	15-Sep-07	15-Dec-07	15-Mar-08	15-Jun-08
-0.36	1.0	-18.4	-24.3	-0.7
0.16	1.0	-10.5	-18.7	-0.4
0.66	1.0	-5.3	-15.8	-0.6
1.16	1.0	-2.7	-13.9	-1.7
1.66	0.5	-0.5	-12.0	-2.8
2.16	-0.1	-0.2	-10.9	-3.5
2.66	-0.3	-0.3	-9.8	-3.9
3.16	-0.5	-0.4	-8.8	-4.2

Table 62: Thermister Data from Berm West – Cable 1311 – Data Logger 40

Average Monthly Temperatures From July 2007 to July 2008

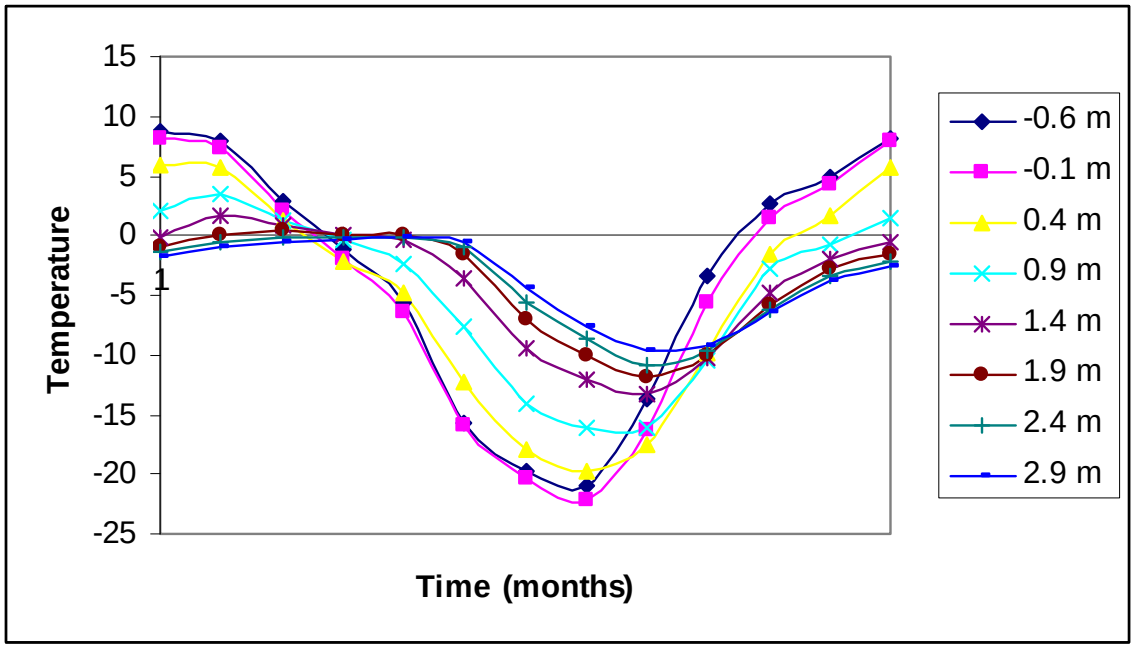


Table 63: Berm West Soil Temperatures for 4 Days Between July 2007 and July 2008

Depth Below Finishing Grade (m)	15-Sep-07	15-Dec-07	15-Mar-08	15-Jun-08
-0.6	1.4	-18.5	-24.6	-0.5
-0.1	1.3	-17.7	-23.8	-0.6
0.4	1.2	-12.7	-20.2	-0.5
0.9	1.3	-7.2	-17.0	-0.7
1.4	1.0	-3.0	-13.8	-2.1
1.9	0.4	-1.1	-12.1	-2.8
2.4	-0.1	-0.4	-10.9	-3.4
2.9	-0.5	-0.3	-9.8	-3.8

Table 64: Thermister Data from Berm East – Cable 1316 – Data Logger 1

Average Monthly Temperatures From July 2007 to July 2008

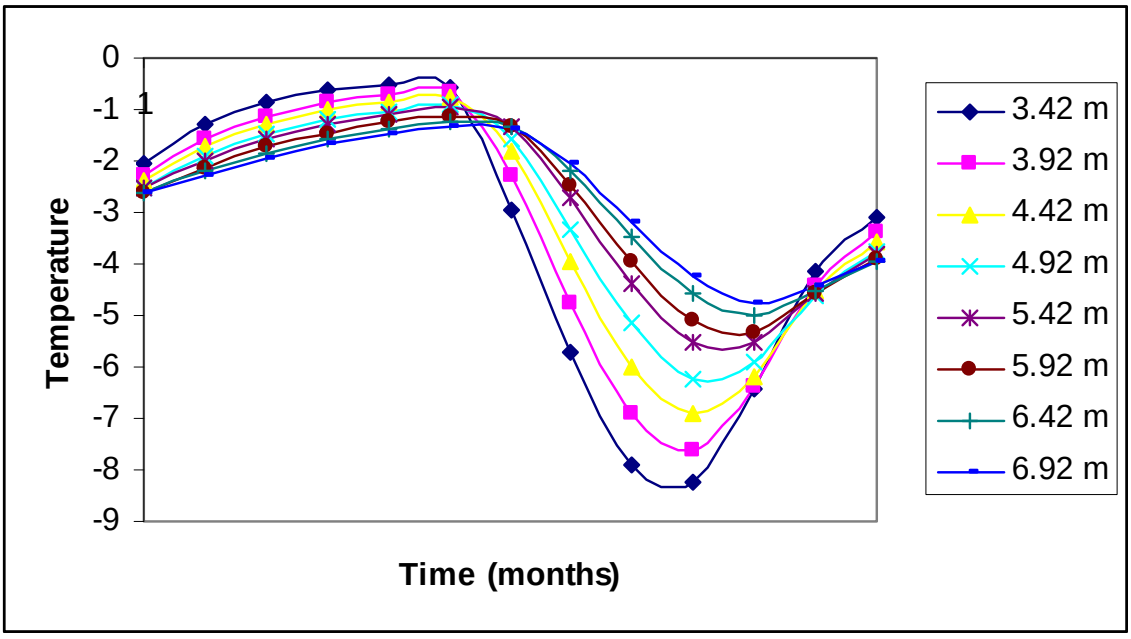


Table 65: Berm East Soil Temperatures for 4 Days Between July 2007 and July 2008

Depth Below Finishing Grade (m)	15-Sep-07	15-Dec-07	15-Mar-08	15-Jun-08
3.42	-0.9	-0.5	-7.9	-4.2
3.92	-1.1	-0.6	-6.9	-4.4
4.42	-1.3	-0.7	-6.0	-4.5
4.92	-1.5	-0.9	-5.1	-4.7
5.42	-1.6	-1.0	-4.3	-4.6
5.92	-1.7	-1.1	-3.9	-4.6
6.42	-1.8	-1.2	-3.5	-4.5
6.92	-1.9	-1.3	-3.1	-4.5

Table 66: Thermister Data from Landfill West – Cable 1318 – Data Logger

Average Monthly Temperatures From July 2006 to July 2007

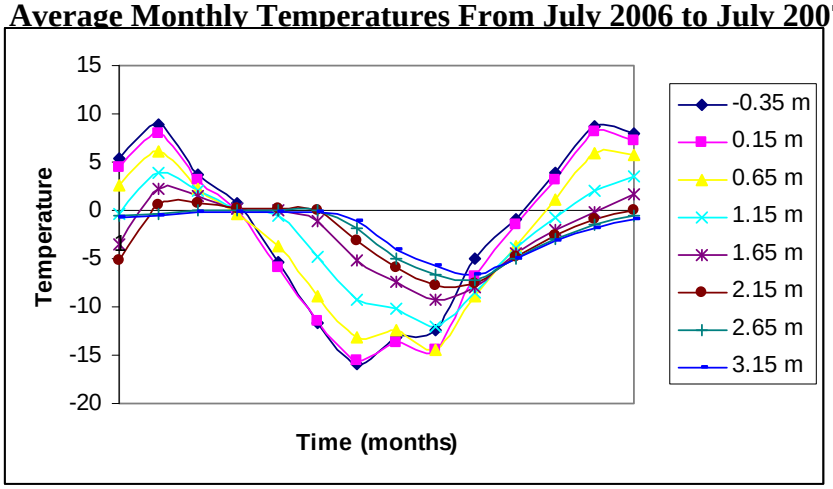


Table 67: Landfill West Soil Temperatures for 4 Days Between Jul 06 and Aug 07

Depth Below Finishing Grade (m)	15-Sep-06	15-Dec-06	15-Mar-07	15-Jun-07
-0.36	0.8	-3.1	-21.6	7.0
0.16	0.8	-3.3	-21.2	7.1
0.66	1.7	-4.8	-17.7	5.3
1.16	2.8	-4.5	-13.3	-0.5
1.66	1.6	-1.0	-9.2	-1.9
2.16	0.8	0.1	-7.4	-2.6
2.66	0.1	0.0	-6.4	-3.0
3.16	-0.2	-0.1	-5.5	-3.3

Table 68: Landfill West Soil Temperatures for 4 Days Between Aug 05 and Jul 06

Depth Below Finishing Grade (m)	15-Sep-05	15-Dec-05	15-Mar-06	15-Jun-06
-0.36	4.0	-11.6	-15.0	12.0
0.16	2.0	-7.3	-12.8	5.0
0.66	3.5	-3.1	-8.0	0.0
1.16	4.5	-1.4	-6.6	-0.5
1.66	5.0	0.0	-4.0	-0.9
2.16	5.7	0.3	-3.3	-1.0
2.66	6.0	0.6	-2.1	-1.2
3.16	6.8	0.7	-1.7	-1.2

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

17 September 2008

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

Resolution Island 2008 – Field Report

Dear Lou,

Our team left Resolution Island on 22 July 2008 after a very busy but successful nine day field season. Nearly all tasks this year involved monitoring.

Logistics

The old training center which was used for accommodation had one window blown out and mould was found throughout but particularly in the sleeping area. The sewage line was broken. The three ATVs are now in poor condition. One did not work and could not be repaired by our bear monitor and one of the two trailers was damaged in trying to transport a drum of contaminated sediment. Building B2 at the beach had been severely damaged over the winter. Both front and rear doors had been blown off, a side panel was missing and the roof was missing in one corner.

Tier II Landfill, Airstrip Landfill, Maintenance Dump and the Two Non-Hazardous Landfills

An engineering assessment was made at all locations. Only the Tier II landfill was assessed in the previous two years; the format and numbering system used in the previous reports was followed for continuity. No significant or unacceptable stability indicators were found. All wells at the Tier II landfill, airstrip dump and maintenance dump were sampled once. One well was dry and two were frozen. Background soil samples were also collected while water was being sampled. Waterra tubing was removed from the wells and discarded. Well caps and lids were replaced and secured with zip ties.

Diesel Fuel Remediation

The main landfarm was sampled once for TPH and nutrients, with depth profiles in both the control and main section to ensure a good comparison of results. 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. 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. The pond liner had deteriorated above the waterline but was intact below where it was covered in sediment and therefore not subject to uv degradation.

PCB Barriers

All the barriers were found to contain larger amounts of sediment than in previous years. Both of the S1/S4 barriers were clogged and overflowing. This was attributed to a major storm or rapid snow melt event. All barrier held up well over the winter and no further repairs were deemed necessary this field season. Hopefully the drums and waste wranglers filled with contaminated sediment and barrier material from this year and from 2007 can be removed by helicopter and sling to the beaching area later this year.

S1/S4 Valley
Sediment loading was much greater this year than in previous years. Water was flowing over the filter gates. All filters were replaced and geotextile filters incorporated. 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. Twelve overpack drums were each filled with sediment collected in the barrier funnel. An additional drum 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 12 of the 13 drums were also sampled. After removing the contaminated sediment, filters were sampled and replaced with new filter material.

S1/S4 Beach
This barrier was also overflowing and clogged. Soil samples were taken both upstream and downstream from the barrier as well as from within the barrier. It was difficult and dangerous to transport drums to the site from building B2. Moreover the volume of sediment involved was very large and therefore it was decided to switch to waste wrangler containers. Fortunately a group of 60 tourists arrived at the site and transported three of the seven waste wranglers in their zodiac. Two drums and seven waste wranglers were filled with sediment shoveled from the funnel area of the barrier. A third drum was also filled in this area, comprising filter materials from the beach barrier. 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.

Furniture Dump
Upon inspection, more sediment than usual was found behind the silt fence upgradient from the barrier. This sediment and that immediately in front of the barrier was shoveled into 3 overpack drums. Four charcoal and four gravel filters were removed from the barrier, sampled, and the remains of the filters were placed into a fourth over pack drum. This drum was transported to building B2. One of the other 3 drums was taken to the airstrip but attempts to transport a second one resulted in damage to one of the ATV

trailers so the last two were left at the barrier. The gravel and charcoal in the filters was replaced with fresh material. 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.

Other Activities

Plant samples were taken at remote locations on the island as well as near 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