EXECUTIVE SUMMARY

This report is the twelfth annual report produced by the Analytical Services Unit (ASU) relating to the environmental assessment and remediation of the former military base at Resolution Island. The first three reports, pertaining to visits from 1994 to 1996, involved site assessment, remediation of critical areas and the development of cleanup plans and strategies. The work in these three years was managed by the ASU. From 1997 onwards, the management of the remediation work has been conducted by the Qikiqtaaluk Corporation. The ASU has provided analytical services and expertise to support this work and Dr. John Poland and Dr. Allison Rutter have acted as Scientific Advisors to Indian and Northern Affairs Canada (INAC) for the project. This report details the work undertaken by the ASU, Queen's University in 2005. This was the third and final year of the three year remediation plan designed to complete the cleanup of the site. The main accomplishments for the 2005 season were the excavation of all remaining Tier I and Tier II soils, the construction of the Tier II landfill and the off site disposal of remaining CEPA soil and other materials.

This year the field season lasted approximately 12 weeks and ASU personnel were on site for 75 days. Much of the work of the ASU involved the contaminated soil excavation; marking and mapping areas to be excavated, collecting and analyzing soils to ascertain if the excavation was successful and ensuring that the excavation was conducted properly. All coordinates were recorded with DGPS and all associated record keeping was completed. Monitoring wells and soil monitoring points established around the Tier II landfill, the airstrip dump and the maintenance dump were sampled and analysed for metals, PCBs and hydrocarbons; the Tier II landfill monitoring wells were sampled up to seven times. Annual tasks such as drinking water testing, barrier monitoring, background plant and water monitoring, air sampling and analysis and barrel analyses were completed.

The main problem at Resolution Island, confirmed by the 1993 site assessment, was the presence of large amount of PCBs both in the buildings within electrical equipment and on the ground mixed with soil. The site is unique given its remoteness, harsh weather conditions and topography. As a result the work has involved the development of new remediation protocols and novel monitoring plans.

At the start of the remediation project in 1994, there were approximately 5000 kg of PCBs as oil in electrical equipment and barrels, and 4030 kg of PCBs mixed with soil on the ground. All the PCBs as oils were shipped off site in 1999. Nearly all the PCB

contaminated soils have been excavated. About 97 % of the PCBs were present in CEPA soils which were shipped off site and destroyed by incineration. About 3 % or 150 kg of the PCBs were placed in the Tier II landfill.

Some PCBs still remain on the ground at the site in inaccessible locations. In order to contain these PCBs, three permanent barriers have been designed and constructed by the ASU at the site. Two of these are in the S1/S4 drainage pathway and one at the end of the furniture dump drainage pathway. In the S1/S4 drainage pathway the initial barrier was constructed at the top of the cliff in 2003. This has since been modified in light of field observations and laboratory experimentation. In 2005 the second major barrier was constructed at the S1/S4 beach location near to the sea. The S1/S4 barrier systems currently receive large quantities of sediment and have thus been modified to enhance their sediment trapping capability. As the sediment load decreases in the coming years, geotextiles with finer porosity will be re-introduced in order to trap the PCBs bound to finer particles. Research is on going to ensure that the optimal materials for the filter box are being used while maintaining good hydraulic conductivity.

The other area of research that the ASU has become involved in at Resolution Island is developing a strategy to deal with fuel contaminated soils in the Canadian Arctic by the landfarming technique. This technique involves addition of nutrient to the soil to promote bioremediation and aeration to accelerate volatilization. Methodology to maximize each remediation pathway is currently being developed by the ASU for DIAND using the Resolution Island site for these model studies. This work is being conducted in conjunction with a major laboratory experimental component.

This year at the site, further results were obtained from the initial experimental plots established in 2003; work at the experiment plots is now complete. The main landfarm established in 2004 was maintained and monitored. An in situ field experiment involving four plots with differing treatment protocols was established this year. In addition a barrier system comprising a pond and barrier system which was constructed in 2004 was inspected, maintained and monitored this year. A second major experiment was conducted in the laboratory in order to further understand the relative roles of aeration and bioremediation under various conditions. The work has demonstrated that landfarming can be successfully conducted in cold climates and it is planned to develop protocols for this under various climatic conditions. This work is continuing with further laboratory experiments currently underway and future ones planned to commence in the coming months.

I. OVERVIEW

A. General

This is the twelfth year that the Analytical Services Unit (ASU) has conducted work at Resolution Island for Indian and Northern Affairs Canada (INAC). 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 has been 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 thus, the work described here, represents the final year of this plan. Map I-1 shows the location and general layout of the site at Resolution Island.

The work described in this report was conducted through a Contribution Agreement between Queen's University and INAC through their Nunavut Office. This report details the tasks carried out by the ASU in 2005 and outlines the progress made in the Resolution Island remediation project. The report includes a chapter detailing research and activities relating to the design and construction of permanent barriers to

---

[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) and (2004). 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.

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

intercept PCBs in drainage pathways. A separate chapter is also devoted to the remediation of hydrocarbon contaminated soils and the ongoing research supporting this.

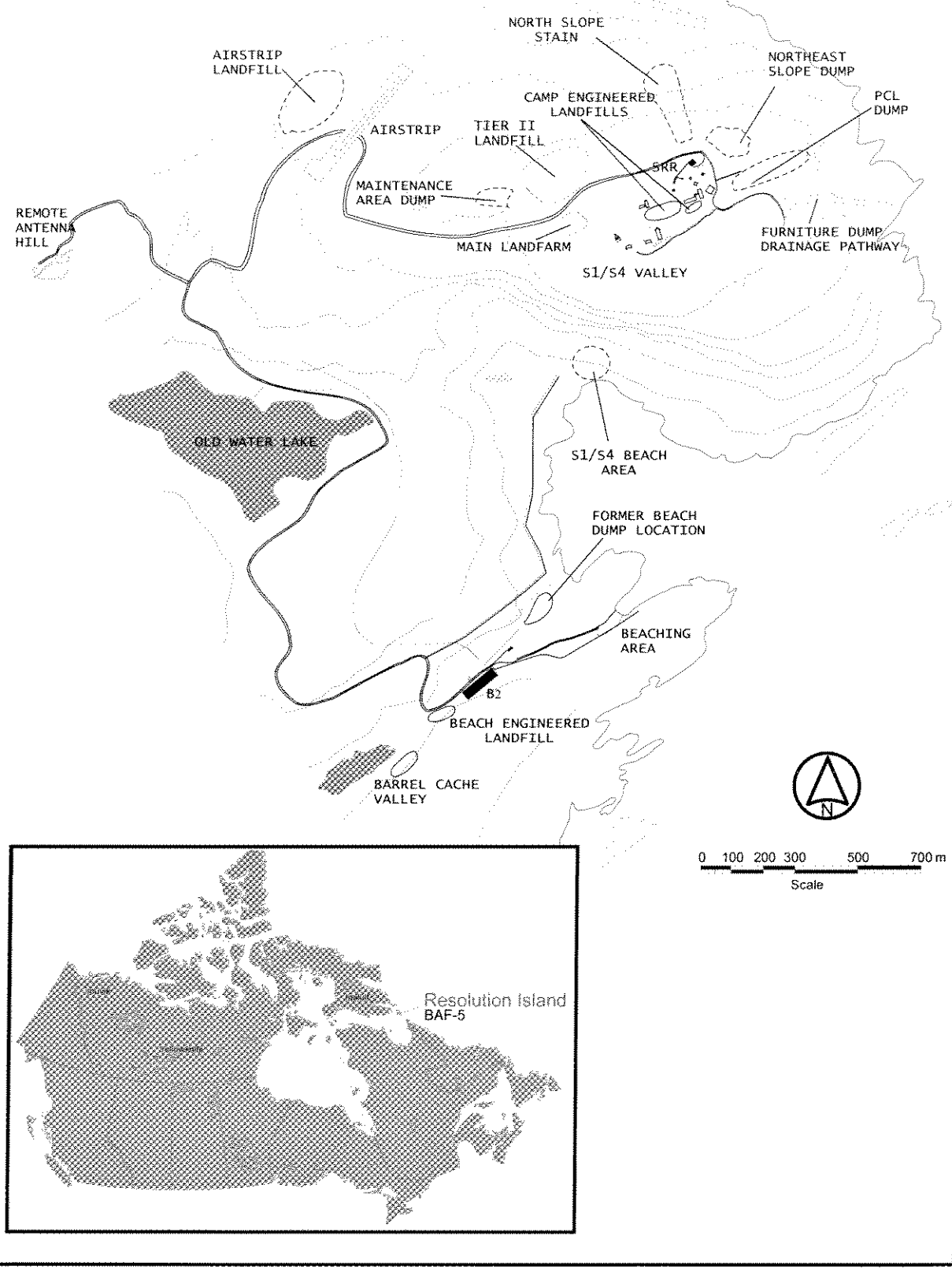
B. Site Activities

Most of the work conducted at Resolution Island this year was again managed by the Qikiqtaaluk Corporation (QC). QC managed the transportation to and from Iqaluit, provided meals and accommodation at the core camp, and provided personnel and equipment to assist with our work.

The main activities and accomplishments achieved this year are listed below:

- Excavation of the remaining CEPA soil from the S1/S4 beach area.
- Containerisation of all CEPA materials and their off site disposal. Southern disposal of other hazardous wastes.
- All accessible soils contaminated at the Tier II level were excavated and placed in the prepared Tier II landfill. All accessible Tier I soils were excavated and used in the construction of the Tier II landfill. Construction of the Tier II landfill was then completed by the addition of a top liner and gravel cap.
- Several structures were removed to the engineered landfills. These included the imploded tank and beach POL tanks, the downed antennae and buildings in its vicinity.

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



C. On Site Scientific Investigations

The Queen's University team was on site from 27 June to 9 September 2005.

The activities conducted at the site this year by the ASU and described in Chapters II-VI of this report are listed below. Between three and five ASU personnel were on site for most of the time this summer. Two people were generally required full time to operate the laboratory for the first half of the season. The successful operation of the mobile laboratory ensured the ability to analyze PCBs and other parameters promptly; this greatly facilitated the excavation and other activities on site. Equipment and supplies used by the ASU were flown to Iqaluit and transported into the site by helicopter or Twin Otter aircraft. Materials for the barrier installation and hydrocarbon migration control and solvents required by the laboratory were transported to the site by sea-lift.

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

- Provided scientific and engineering support at the site.
- Conducted analyses at the mobile laboratory. The analyses were mainly for PCB by the GC/ECD method in soil, water, and other matrices. The GC/ECD equipment and associated equipment for PCB analysis is complex. This year two GCs were on site to increase the throughput and in case of equipment breakdown. Additional backup was provided by provision of test kits (on-site) and another GC/ECD at Queen's (off-site); One GC was also used for the analysis of soil samples for TPH. Tested miscellaneous materials such as used decontamination supplies for PCBs, water, daily pH testing of drinking water, and identity of unknown materials.
- Confirmatory testing, mapping and roping at the S1/S4 Buildings and Valley areas (Tier II and Tier I) was conducted. Queen's had a person assigned to oversee these remediation operations.
- Confirmatory testing, mapping and roping at the S1/S4 Beach area (CEPA, Tier II and Tier I) was carried out. Queen's had a person assigned to oversee these remediation operations.

- Confirmation testing, mapping and roping at the PCL dump and DND Helipad. These required testing for PCBs only.
- Confirmation testing, mapping and roping at the Maintenance dump, North Slope dump and Beach dump. These required testing for metals and PCBs.
- Investigated the area below the Beach dump in order to locate gasoline leak.
- Barrels were tested, sorted and labelled as required.
- PCB Storage facilities – added materials to, and kept an inventory of, the Beach facility as required – reported records of the contents of the PCB storage facility and off site disposal to INAC at the end of the field season
- Drinking water and lake water were tested. pH was tested daily, and the potability of the site drinking water was tested three times during the summer and lake water once in mid-season.
- Collected and analysed air samples for PCBs and chlorinated hydrocarbons.
- Sampled the Tier II landfill monitoring wells and associated soil monitoring points. Collected and analysed water samples every week and soil samples twice during the season. Permanently marked the soil monitoring points.
- Sampled the monitoring wells and associated soil monitoring points at the airstrip (4 wells) and maintenance dumps (2 wells). Analysed samples for metals, TPH and PCBs.
- Sampled new borrow pits established this year and analysed for TPH, metals and PCBs.
- Tested black stains at the barrel cache valley and analysed by the CCME TPH method.
- Took concrete samples at B2 and analysed for PCBs.
- Background plant and water samples. Collected water samples and analysed them for metals and PCBs at ultra-low levels. Collected plant samples and analysed them for PCBs at ultra-low levels
- Monitored and maintained the two landfarms on site. For the trial plots, these were sampled twice. For the main landfarm, approximately 16 quadrants were set up and each

sampled three times during the summer. Determined the nitrogen and phosphorus levels at the main landfarm in order to check if the addition of more fertilizer was appropriate. Recorded soil temperature frequently at both landfarms. Inspected and monitoring the two treatment ponds in the imploded tank drainage pathway.

- At the beach POL area, oversaw the remediation as appropriate. Designed and set up an in situ landfarm with soil from this area at the barrel cache valley.
- Continued to conduct laboratory and field experiments with respect to the design and construction of permanent interceptor barriers. Inspected, sampled, monitored and modified the initial trial barrier installed in 2003.
- Designed and installed a permanent barrier at S1/S4 beach area. Sampled the barrier and surrounding area and established a monitoring program.
- Replaced the barrier in furniture dump pathway and continued with monitoring.
- Set forward proposals regarding barrier monitoring logistics and revised the site long term monitoring plan.
- Continued research into barriers and TPH remediation. The PCB barrier laboratory work focussed on optimising the particle size and gradient for the GAC filters. The gate design was adapted to the S1/S4 beach. The TPH research in the laboratory was designed to support the in situ landfarm at the barrel cache valley and further investigated the effects of aeration on soil temperature.
- Liased with Australian Antarctic Division and continued with the Canadian Antarctic Research Program (CARP) initiative.
- Acted as scientific resource to INAC and attend meetings as required.
- Hired two Inuit students as part of the Queen's team; this included a three week training period at the laboratory in Kingston.

D. Long Term Monitoring Plan

A long term post-remediation monitoring program (LTMP) formed part of the three year final remediation plan for Resolution Island. This plan is concerned primarily with the landfills, former dumps and the permanent interceptor barriers. The remediation plan was based largely on the agreement between NTI and DND for the cleanup and restoration of DEW line sites within the Nunavut settlement area (Environmental Provisions, 1998). The ASU has been requested to up-date this plan in light of the current conditions that now exist at the site. The remainder of this section is devoted to this task.

1. Landfills

Three new landfills for non-hazardous wastes were constructed as part of the cleanup, two near the camp and the other near the barrel cache valley. Their construction will be completed in 2006. As part of the LTMP these will be inspected visually for stability only. This visual inspection will look for any major settling, ponding, erosion or frost action that may have occurred. If there are signs of instability at these landfills such that buried material becomes exposed, then remedial action may be required. Monitoring samples will be taken from the Tier II landfill, the airstrip dump and the maintenance dump. All other remaining dumps on site have never been observed to leach. These dumps are therefore considered low risk and will only be monitored visually.

For the Tier II landfill, visual water and soil monitoring are proposed as well as the recording of temperatures with thermisters buried in the landfill. Nine monitoring wells and six associated soil monitoring points have been established. Monitoring of these locations started in 2004. Soil points were sampled twice a year while the wells were sampled on a weekly basis. It is proposed that they be sampled twice in 2006 and once a year on the subsequent annual visit. Water from the wells should be tested for the 8 elements of the DCC (As, Cd, Cr, Co, Cu, Pb, Ni and Zn), TPH and PCBs. Soil collected from the six locations close to the monitoring wells will be analysed for the same set of parameters. Remediation steps may be required if the analytical results show a significant increase in contamination over a period of three or more years. Three thermister strings were placed at the landfill during 2005. Temperatures should be recorded several times in 2006 and once during the subsequent annual site visits. This landfill is designed to ensure that all the buried Tier II material should remain frozen. This steady state should be reached within 3-4 years. Remedial action could be required if all the buried material is not frozen permanently.

The airstrip and maintenance dumps should be visually monitored for stability and have a water and soil sampling program similar to the Tier II landfill. Four monitoring points have been established at the airstrip dump and two at the maintenance dump. Soil and water samples will be taken annually for the 8 DCC metals, TPH and PCBs.

2. PCB Barriers

The three permanent PCB interceptor barriers should be inspected and repaired, if necessary, at each monitoring visit. Any silt collected by the barriers should be excavated into suitable containers and sub-samples collected for PCB analysis. In addition, soil samples should be collected from the clean cells which will be established beyond barriers in order to assess their performance. Water flowing through the barriers and materials in the filter box system should also be collected and analysed for PCBs. The nature of the materials in the filter box are expected to be changed with time due to decreased sediment loading and also as a result of laboratory research findings. Initially all filter materials will be sampled and replaced each year. As PCB levels decrease and sediment stabilizes, filter materials may not need to be replaced annually.

3. Landfarms and TPH Barrier System

The TPH level in the landfarm is already below the cleanup criterion of 8000 ppm diesel fuel. The main landfarm at the site will be aerated several times in 2006 in order to reduce the TPH level, to take advantage of the heavy equipment on site and to be proactive. All other activities related to TPH are associated with research. At the main landfarm, a section has been left undisturbed since its construction. It is proposed that a small area of the landfarm will be rototilled each year. The levels in these two sub-plots will be compared to the landfarm as a whole in order to gain insight into landfarming in the Arctic. The barrier system established below the landfarm will be maintained and monitored so as to assess its performance and to judge its usefulness in this type of application and for excavations in general in cold climates.

Work at the experimental plots established in 2003 is now complete. New experimental plots were established in 2005 in order to study the potential use of in situ bioremediation. Annual sampling and maintenance of these plots will be undertaken.

4. Background PCB in Plants

Plant samples have been collected from various locations at the site for the past four years. Plants are good biological indicators of airborne PCBs. It is therefore

expected that a decrease in PCB levels should now be seen since both the PCB levels and the level of physical activity at the site have been reduced. Thus one would expect, particularly by 2007, substantially lower PCB levels than during in the period 2002-2005.

5. Monitoring Frequency

Monitoring at the landfills should initially be conducted once a year in early to mid-August from 2006 onwards. The frequency of the program should be each year for 5 years. Then year 7, 10, 15 and 25 if no problems are encountered and approval is obtained from the Nunavut Water Board. Some modifications to the program may be undertaken during the initial 5 years. Such modifications may be to reduce the analytical suite or the number of wells being analysed at the Tier II landfill. These modifications would be contingent on obtaining similar results from the wells for at least two more years. Also, for example, the maintenance dump was leaching cobalt only; if no PCBs, TPH or other metals are found these additional parameters could be removed from the list of analyses required for the two wells at the maintenance dump.

The frequency of all other activities should be the same as for the landfills. The level of these other activities will likely be reduced during the first 5 years. Much of the landfarm research activities, for example, are expected to be completed before the end of the five year period.

A full review of all the data is proposed after 5 years in 2010.

6. Infrastructure and Logistics

Logistics are often the most difficult part of environmental remediation planning in the Canadian Arctic and one can never over-plan for such activities. For the LTMP at Resolution Island these comments are particularly relevant given the climate, terrain and the uncertainty of the scope of the work. This latter statement particularly refers to the amount of sediment in the PCB barrier traps and the PCB level in this material.

Infrastructure has been put in place for the LTMP. The old training center building, which has its own generator, will be able to accommodate up to 10 people. In an emergency the NWSO module can be used. For 2006, the remediation of the site will be completed and most of the equipment shipped off site. It is expected that the ASU will send a team on site for about 2 weeks to complete its work this year. It is expected that QC will be on site with helicopter support for about 4 weeks. The remainder of this section deals with 2007 and subsequent years.

a) Transportation to the Site

Helicopter support was used for the remediation of the site from 1997-2005. It is expected that a helicopter will be required to move containers of sediment from the barrier sites, at least for the first few years. Prior to 1997 all work was done using Twin Otter transportation. Once the sediment volume in the barriers is reduced it may be possible to use Twin Otter aircraft for the LTMP work. It also may be possible to approach NWSO regarding the use of their helicopter at the site for a day each year to move the containers of sediment.

b) Barrier Sediment

The volume of sediment in the S1/S4 barriers at the valley and beach areas is expected to be several cubic meters (2-10 m^3 for each location) at least for 2007 and 2008. This material needs to be placed in either barrels or waste wranglers and their PCB levels established. The plan is to transport this sediment off site by Twin Otter or helicopter. A Twin Otter can transport approximately 0.6 m^3 of sediment. Waste wranglers are light weight and many can be transported on site in a single Twin Otter flight. However once they are filled with sediment they may be more difficult to handle on site than barrels.

If the volumes of sediment are large it may be useful to consider alternatives to transporting the soil off site by air. If the sediment contains < 5 ppm PCBs (Tier I), then it could be placed at a suitable location on site and subsequently buried. A stockpile of gravel may be useful to have on site in an appropriate location if this option is being considered. If the level is between 5 and 50 ppm PCBs (Tier II), then the sediment needs to be isolated from the Arctic environment in accordance with the DLCU protocol. Containers filled with Tier II sediment could be stored at building B2 and ultimately removed by barge. Tier I soil could also be removed by barge rather than be buried on site. A few 205 L overpack barrels (UN approved) should be placed on site in case sediment or barrier material containing > 50 ppm PCBs is found.

The annual site visit would take place in early August each year. The sediment would be placed in containers adjacent to the barriers. At the S1/S4 valley barrier the Kabota can be used to excavate much of the soil from the barrier. Some shoveling will be necessary in the two settling ponds to ensure the liner is not breached. Filled containers can be transported on site using the Kabota and/or ATVs and trailers. At the S1/S4 beach barrier, all containers will be filled manually because the barrier is not accessible by the Kabota or ATVs. Once filled, the containers will be moved by helicopter. In subsequent

years, if the sediment volume is reduced to less than 1 m^3, it may be possible to move the sediment without the use of a helicopter.

If possible sediment samples would be sent to the laboratory and analyzed before the end of the site visit. Sediment could be sampled in place on day one of the visit and the samples sent to the laboratory the same day. The containers could then be labeled as either Tier I or Tier II before the site visit is complete.

c) Ground Transportation and Equipment

A Kubota 310 loader plus 2-4 ATVs and trailers should be left at the site to assist in the monitoring which would be expected to take 4-7 days. The Kubota would be used for transporting materials, water and fuel. The ATVs and trailers would be needed for personnel, supplies and barrier sediment. Ideally two would be stored at B2 and two at the upper station site. It is hoped that the road linking the beach with the camp would be open in early August, but the large snow field above the old water lake may pose a problem and erosion at this location may make the road impassable.

d) Personnel

It is proposed that the ASU conduct the LTMP at least for the first 5 years. The ASU can collect the monitoring samples and inspect and maintain the barriers in one site visit. The ASU would employ at least 2 workers from the Arctic as part of the team. The workers would be needed to run the camp (food, water, generator etc), keep the ATVs and Kubota running and to act as bear monitors. In year 5 an engineer would also be brought on site for a complete appraisal of the landfills. The ASU would have 3-4 of its personnel on site for the 4-7 day visit and would produce a check list prior to the site visit outlining all the monitoring requirements. A monitoring report on the visit would be produced by December 31 each year.

E. Other Activities

Two research projects were continued this year. These were related to the construction of permanent PCB barriers at the site and assessment and remediation of hydrocarbon contaminated soils. Two graduate students are involved in these project, Indra Kalinovich with the PCB barrier work, and Krysta Paudyn with the hydrocarbon study. The work is described in detail in Chapters V and VI.

Krysta Paudyn and Dr Rutter attended the 8th International Conference on In Situ and On Site Bioremediation in Baltimore, Maryland in May 2005. Krysta presented her poster entitled "Remediation of Hydrocarbon Contaminated Soils in the Canadian Arctic: Laboratory Investigations". Dr Poland, and Krysta Paudyn attended the ARCSAAC conference in Edmonton in May 2005 and Krysta presented a paper on the trial landfarm. The paper "Remediation of Hydrocarbon Contaminated Soils in the Canadian Arctic with Landfarms" has been accepted for the Federal Contaminated Sites National Workshop and will be presented by Dr Rutter. Two abstracts, "Remediation Of Hydrocarbon Contaminated Soils In The Canadian Arctic With Landfarms" and "Design and Application of a Funnel and Gate Barrier System for PCB Containment and Remediation in the Canadian Arctic" have been submitted to the Fifth International Conference on Contaminants in Freezing Ground in Oslo, Norway.