Mitigation of PCBs using Permeable Reactive Barrier Technology at Resolution Island from 2005 to 2013

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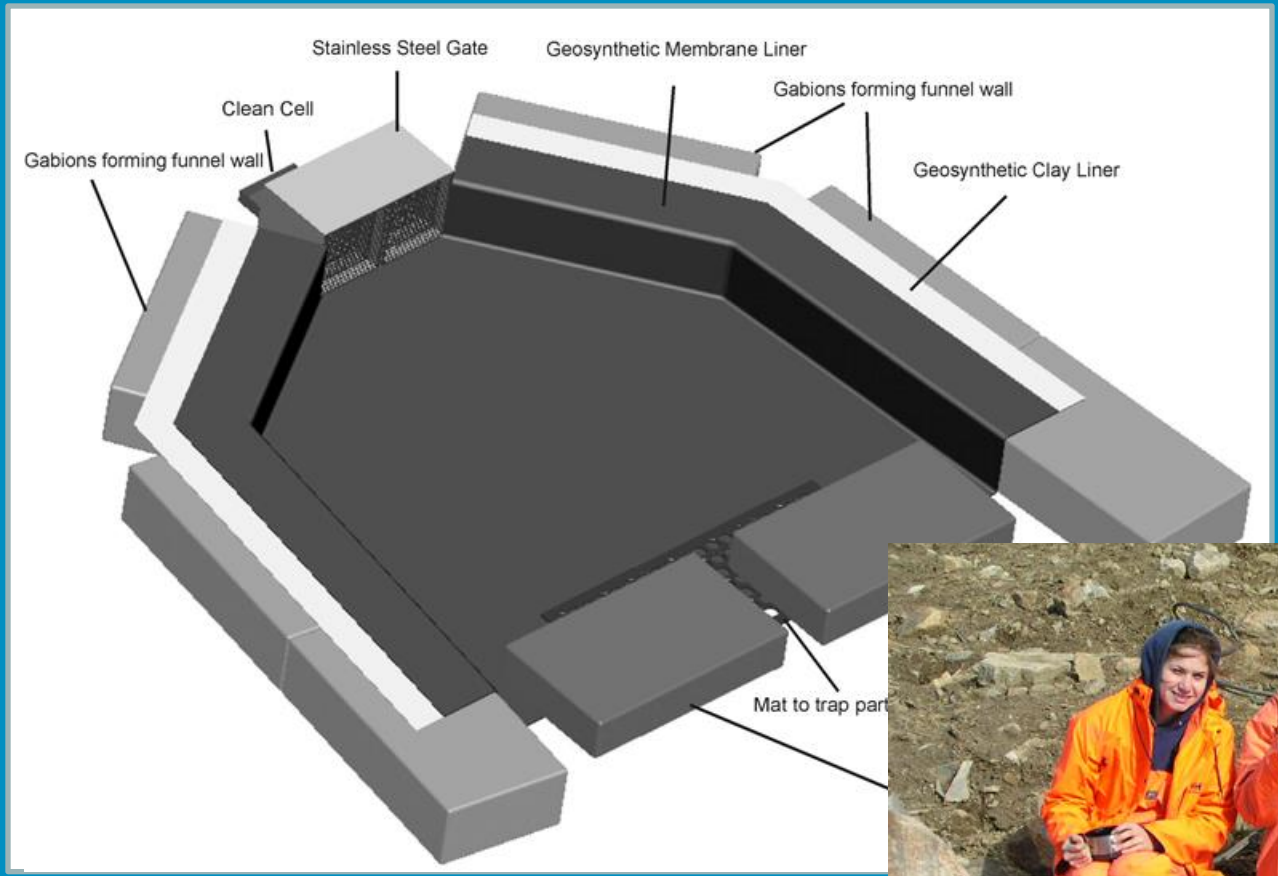
Surface Permeable Reactive Barriers for cold climates



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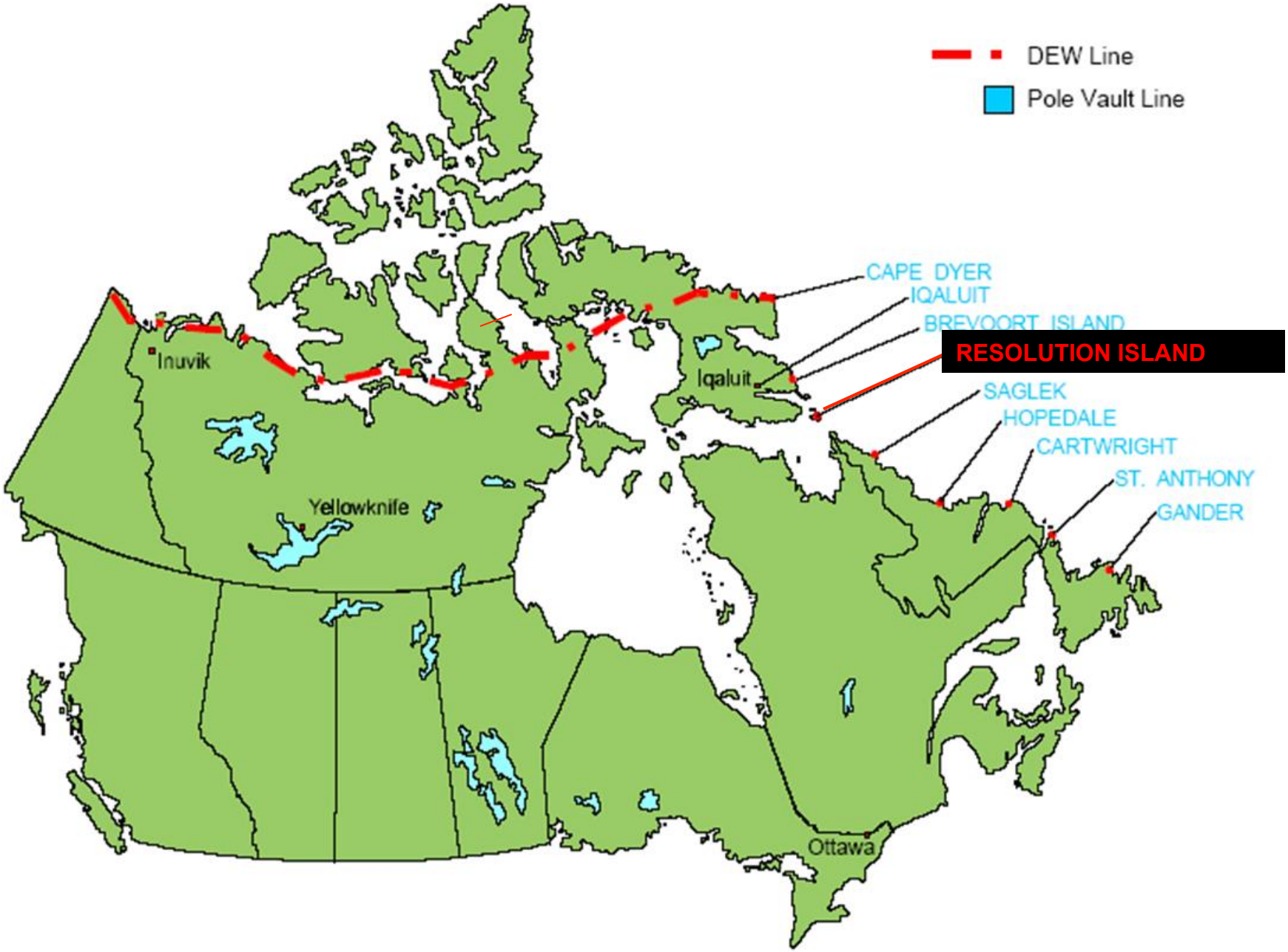
Sci Total. Env. (2008) 407: 53-66.


DEW Line
Pole Vault Line
CAPE DYER
IQALUIT
BREVOORT ISLAND
RESOLUTION ISLAND
SAGLEK
HOPEDALE
CARTWRIGHT
ST. ANTHONY
GANDER
Inuvik
Iqaluit
Yellowknife
Ottawa

BAF-5: Resolution Island

- Main base 1300 ft above sea level
- Part of the Pole-vault line
- Logistically challenging site

Canadian

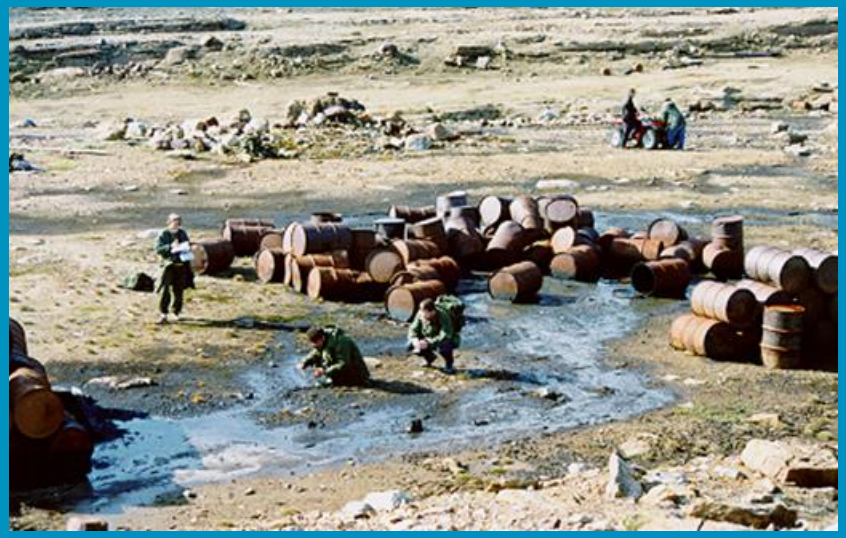
Operational 1954 - 72

- 100-200 military workers on site working on a six month rotation

Initial Investigations

- Site ownership to AANDC 1976
- Short Range Radar construction 1985
- Preliminary investigations 1987
- Queen's University ASU and Environmental Sciences Group at Royal Road Military College 1993

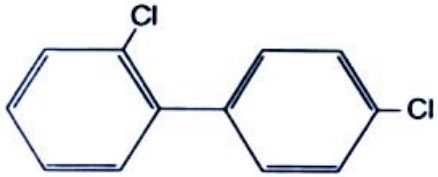
Multiple Dump Sites, Hydrocarbons, Metals



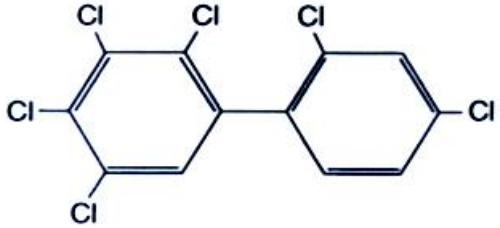
PCB Contamination at BAF-5

- 18 large transformers in **S1/ S4** buildings plus 14 excavated from **furniture dump**
- 80 to 300 L of PCBs (36% to 72%) each
- Total of 4000 kg pure PCBs in oil
- Plus 5000 kg pure PCBs in soil in over 25,000 m^3

Polychlorinated Biphenyls



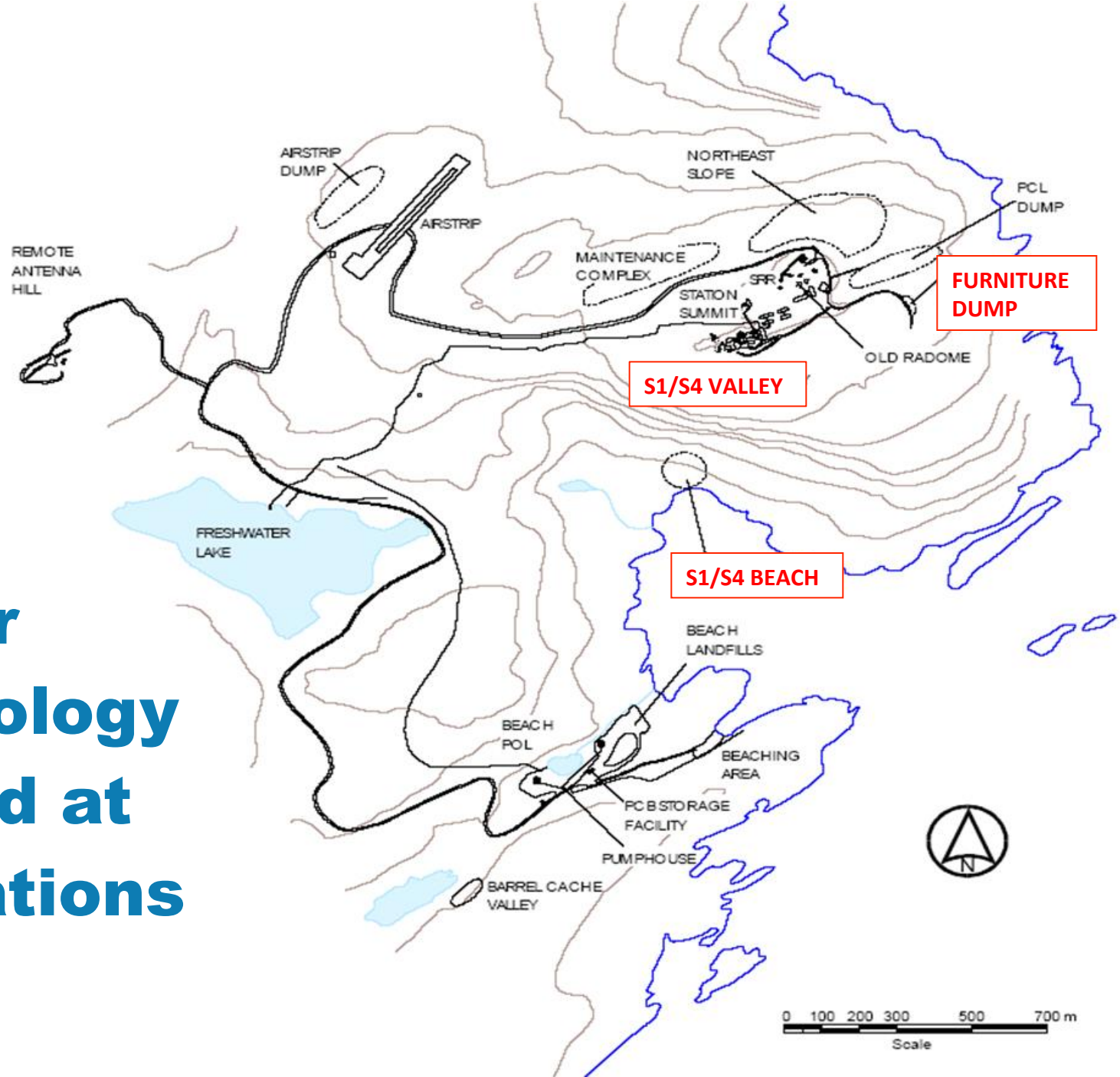
2,4'-dichlorobiphenyl



2,2',3,4,4',5-hexachlorobiphenyl

- Good electrical insulating properties very stable reduced fire risk
- Persistent organic pollutant
- Soluble in fat therefore bio-accumulates
- Some congeners carcinogenic in rats
- Create dioxins and furans when burnt in uncontrolled conditions
- Estrogenic effects other health issues

Barrier Technology Applied at 3 Locations



PCB Source Furniture Dump

PCB Source S1/S4 Valley and Beach

Beginning of Drainage Pathway

S1/S4 Valley drainage pathway

End of Drainage Pathway

PCB Cleanup main site 1995 to 2006

1995

2006

Contractor: Qikiqtaaluk Corporation

Soil Remediation > 50 ppm 1997-2006

- Soil Excavation
- Containerization
- Ship South for incineration

Excavation and Engineered Landfill (5 to <50 ppm)

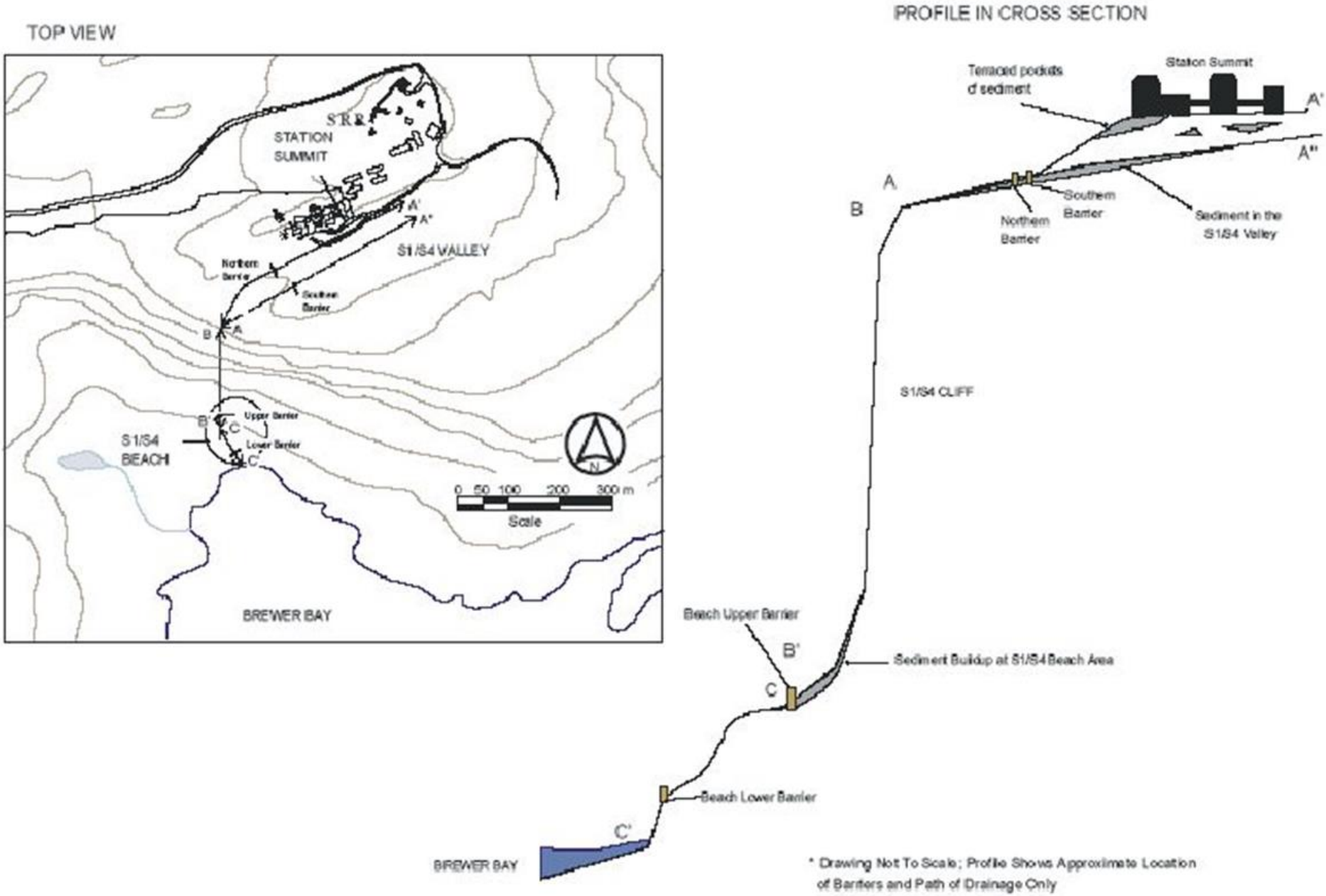
Why is barrier technology necessary?

1. High level PCBs trapped in fractured bedrock, loose soil despite vacuuming

Why is barrier technology necessary?

2. PCBs >50 ppm in inaccessible areas all in a pathway directly leading to the ocean

Figure 1: Drainage Flow Profile from the S1/S4 Valley and Beach Area to Brewer Bay, Resolution Island



Technological Requirements

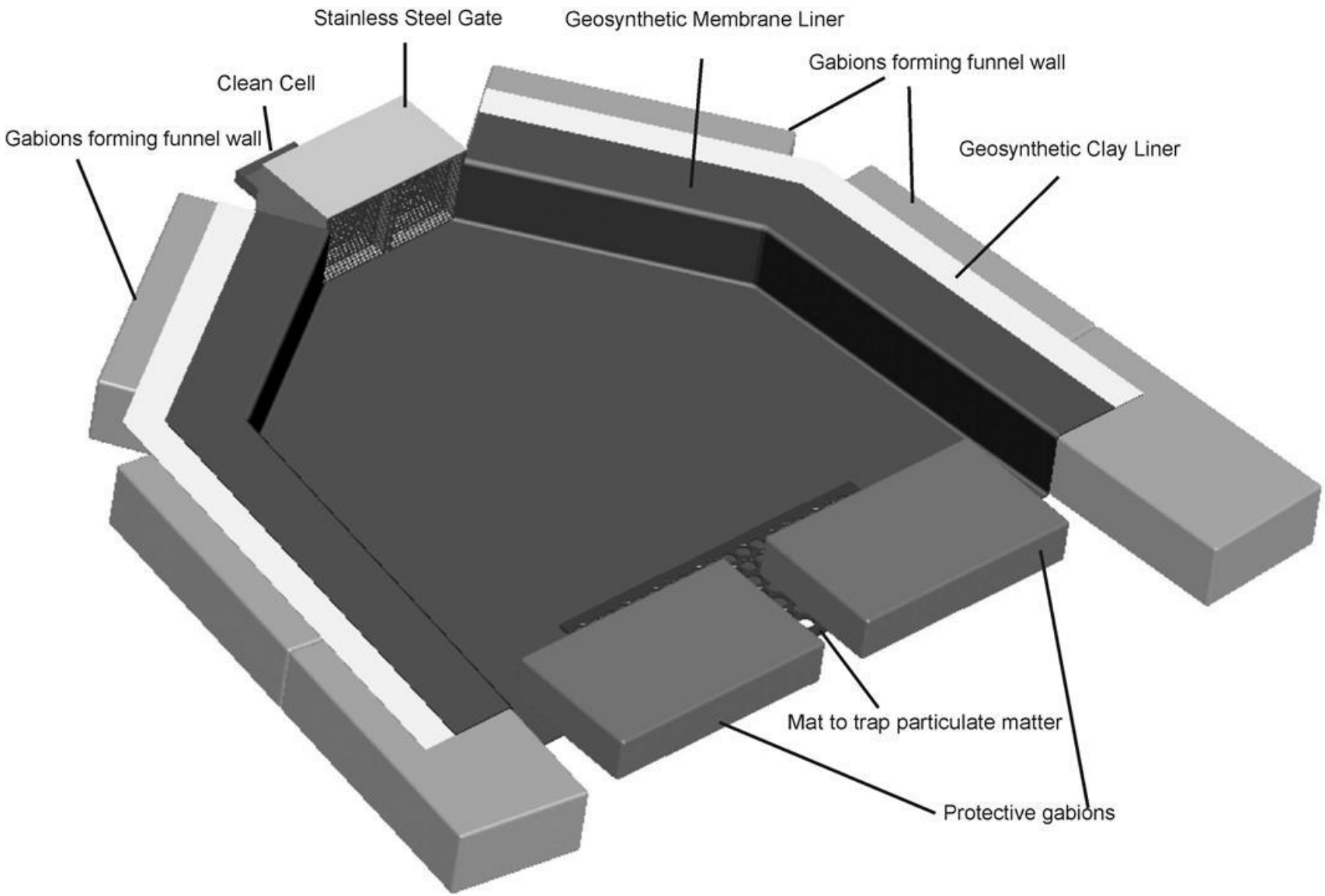
- 85% of PCB mass are sorbed on to soil particles < 0.5 mm
- System must trap silt and fines but allow treated water to flow through unhindered i.e. not clog
- PRB must function in Arctic climate

Kalinovich I, Rutter A, Rowe RK, McWatters R and Poland JS, "The Application of Geotextile and Granular Filters for PCB Remediation, *Geosynthetics International* (2007) Vol 15, No. 3. pp 173-183.

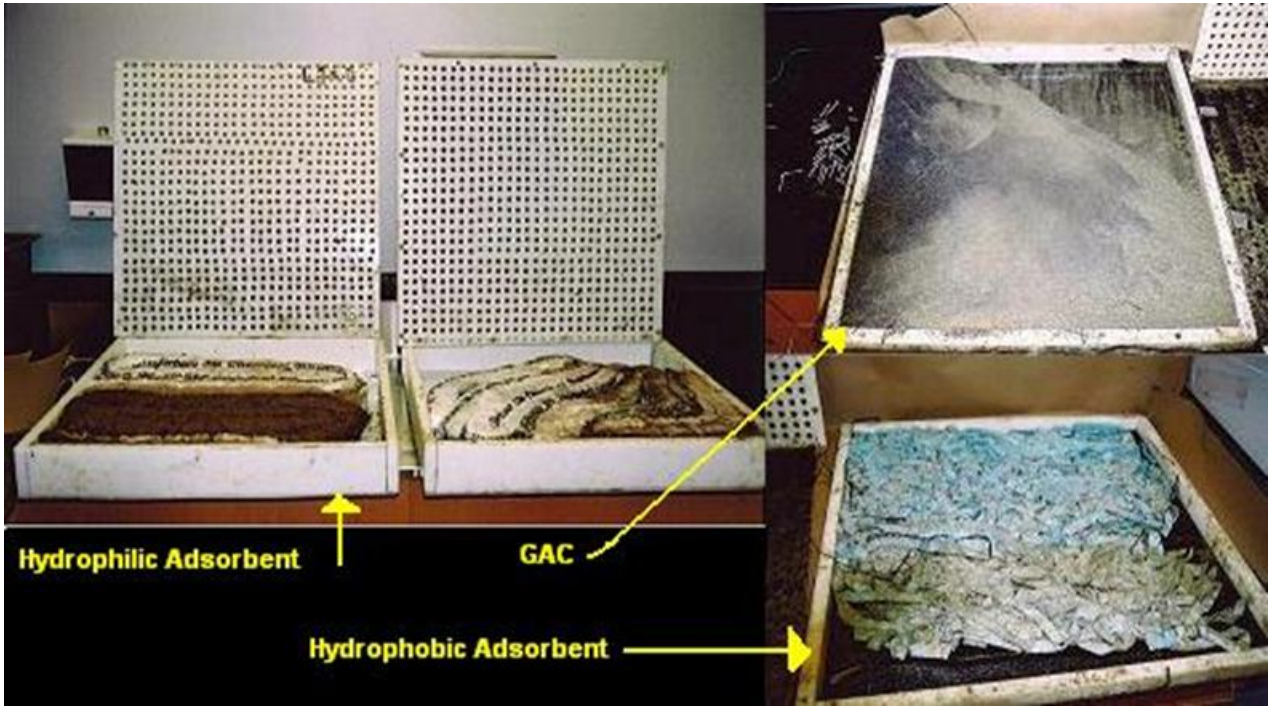
Kalinovich I., Rutter, A., Poland, J.S., Cairns, G., Rowe, R.K., Remediation of PCB Contaminated Soils in the Canadian Arctic: Excavation and Surface PRB Technology. *Sci Total. Env*. (2008) 407: 53-66.

Kalinovich. I. K., Rutter, A., Rowe, R. K. and Poland, J. S. Design and application of surface PRBs for PCB remediation in the Canadian Arctic, J. of Env. Management, 101:124-133 (2012)

RESOLUTION ISLAND PCB BARRIERS



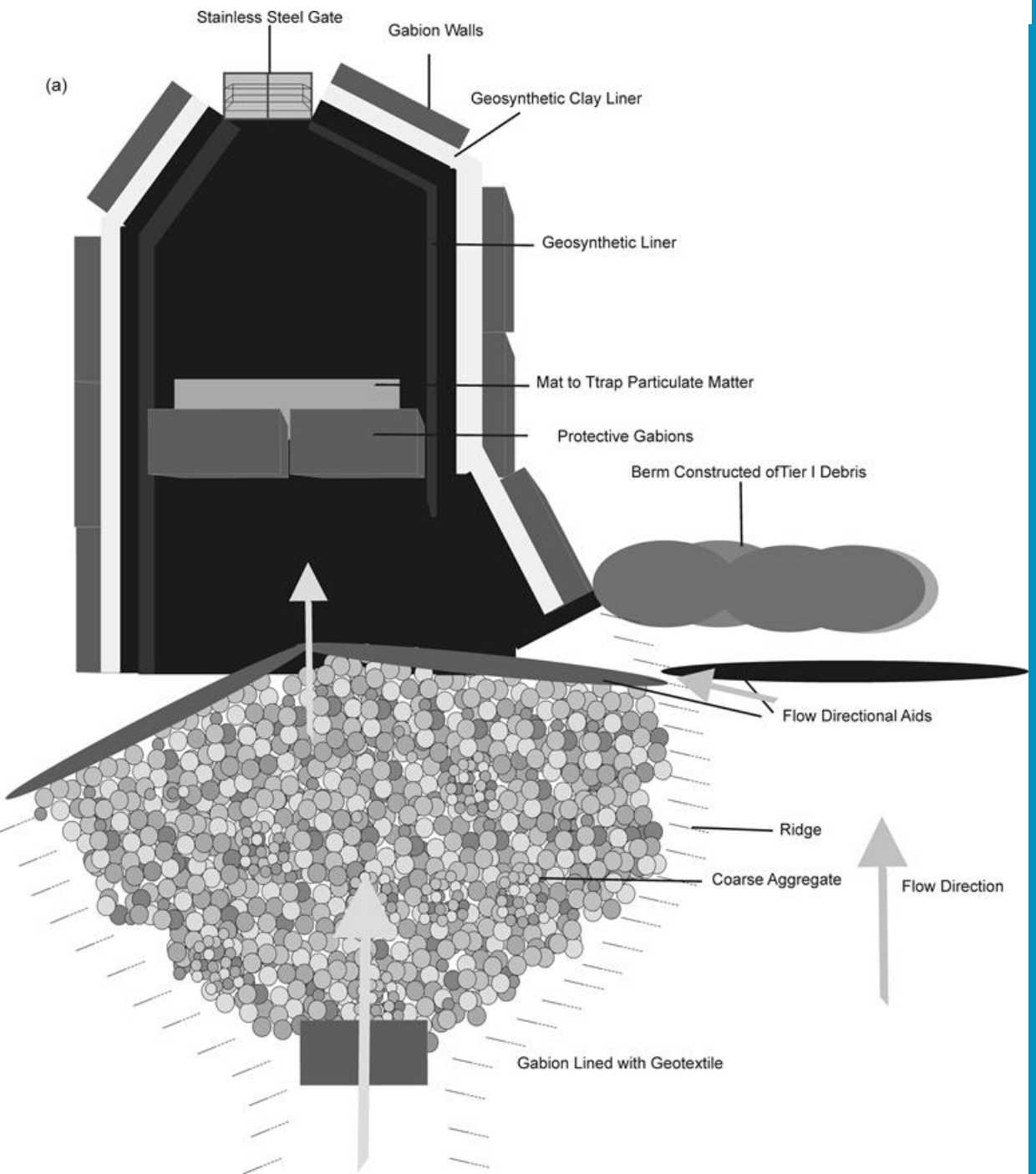
PRB Filter Materials



PCB Retention of Filters

Filter	PCB retained (mg)
Woven Geotextile 400W	0.4
Woven Geotextile 800W	0.2
Nonwoven Geotextile 1200R	6.5
Hydrophobic Geosorbent	2.7
GAC2	360

Various filter materials and PCB retained (µg) by the 2003 Barrier System. GAC2 stands for Granulated Activated Carbon, Type 2.



Final Barrier Design

Final Filter System

Half-height Nonwoven Geotextile	Half-height Nonwoven Geotextile
GAC	GAC
Gravel	Gravel
Half-height Gravel	Half-height Gravel

Direction of Flow

Annual Monitoring

S1/S4 Valley PRB Monitoring Results 2006-12

- Concentration of PCBs < 5ppm and trending down
- Currently planning to phase out gate and remove geosynthetics

	2006	2007	2008	2009/2010	2011	2012
Volume (m^3)	2.2	1.0	2.6	2.5	0.5	2.5
Concentration (ppm)	5.0	4.8	2.9	3.1	3.7	1.9
PCB Mass (g)	25	8.5	13.6	14	3.3	10.3

S1/S4 Valley PRB 2015/2016

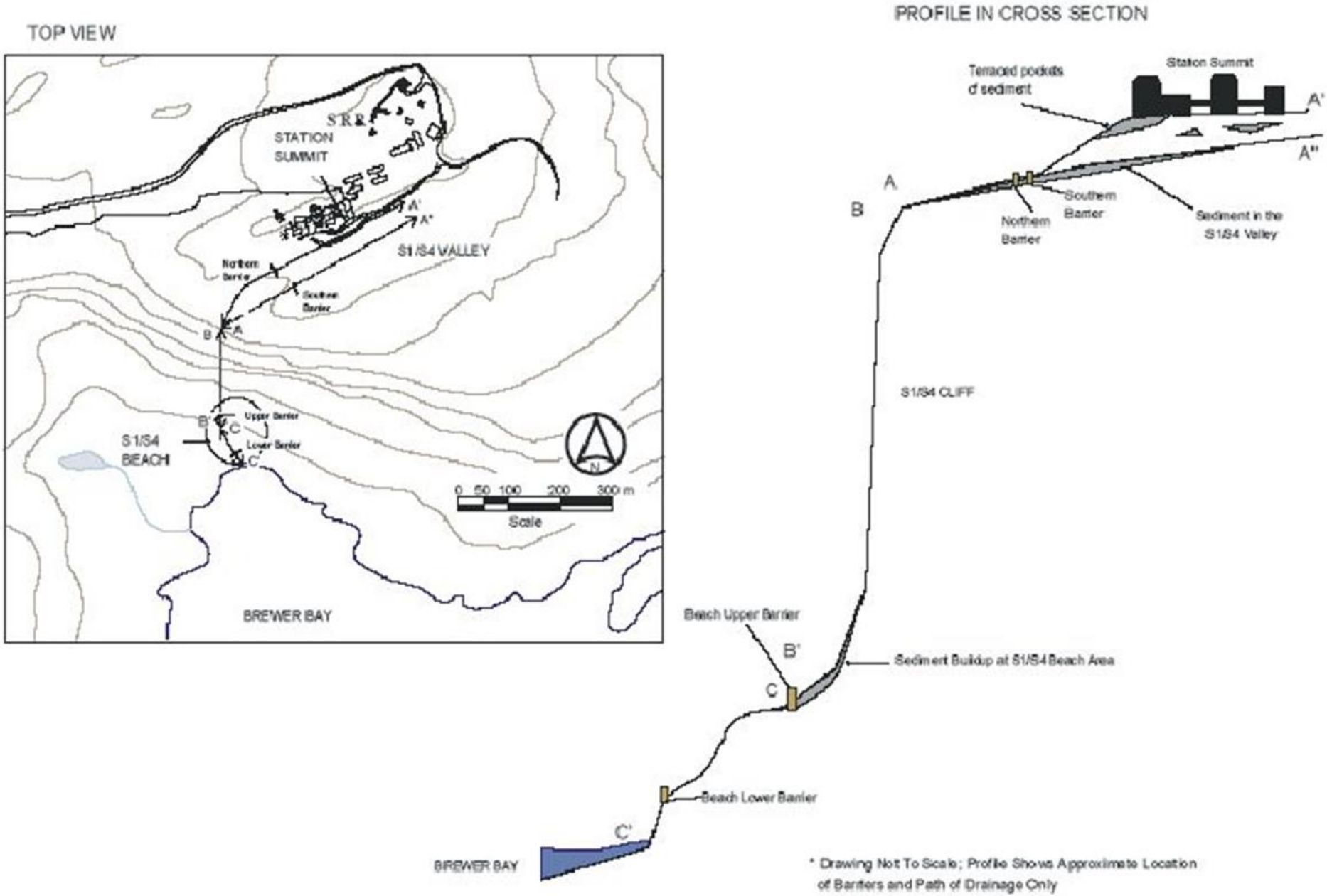
- Remove liner system
- Excavate sediment
- Gabions left intact
- Gravel only in gate
- Natural re-vegetation

Re-vegetation and Soil Stabilization 2011

Moss is naturally re-vegetating the valley

Curlex traps will help stabilize soils.

Figure 1: Drainage Flow Profile from the S1/S4 Valley and Beach Area to Brewer Bay, Resolution Island



S1/S4 Beach barrier

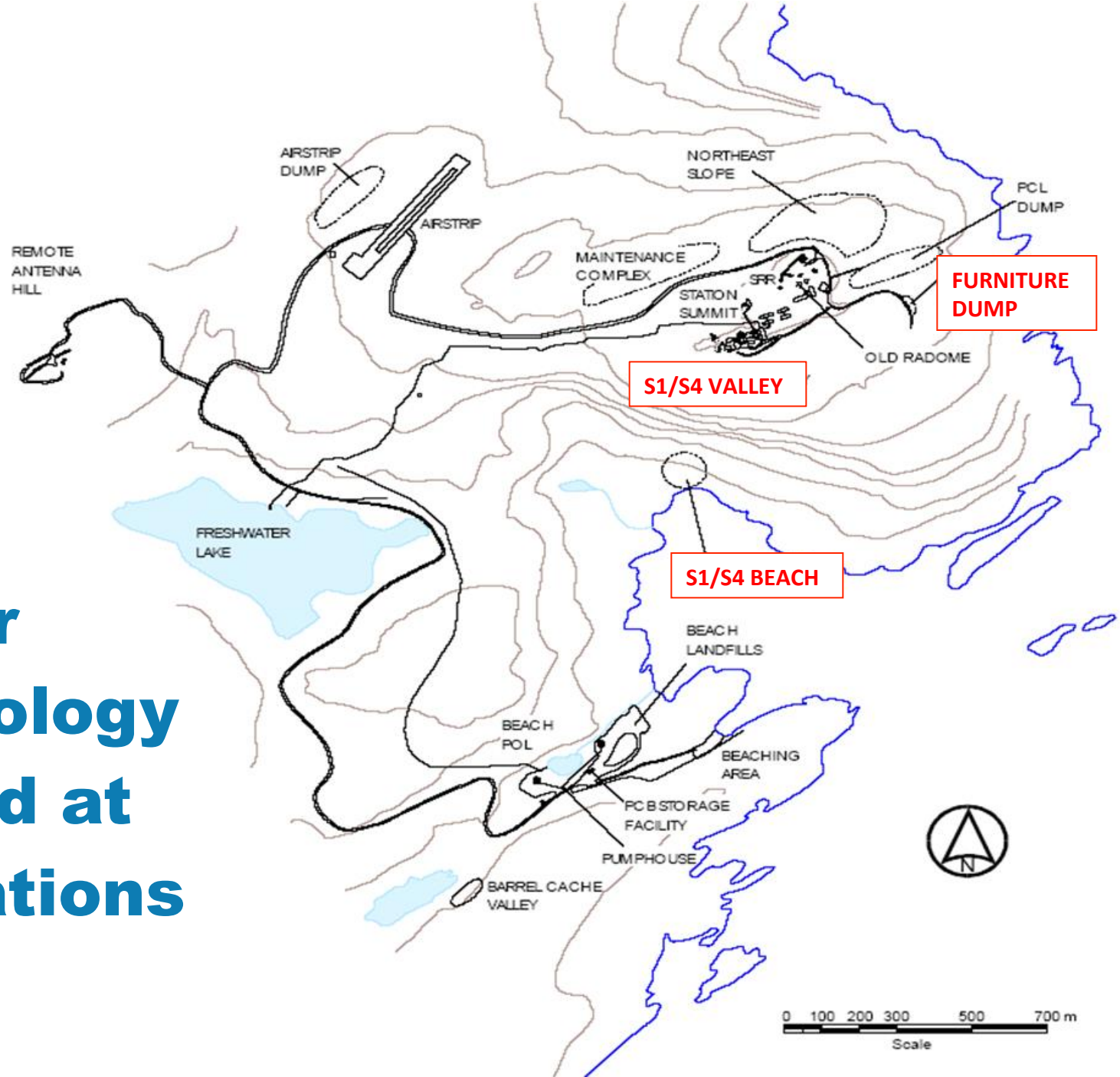
Beach Barrier Monitoring Results 2006-2013

	2006	2007	2008	2009/2010	2011-2013
Volume (m^3)	2.0	1.2	5.3	2.3	6.0
Concentration (ppm)	0.7	0.6	1.6	1.5	0.62
Mass (g)	2.5	1.2	15.3	6.1	6.7

Beach Barrier 2015/2016

- Excavate sediment from barrier
- Replace filters in gate
- Monitor sediment movement for 5 years

Barrier Technology Applied at 3 Locations



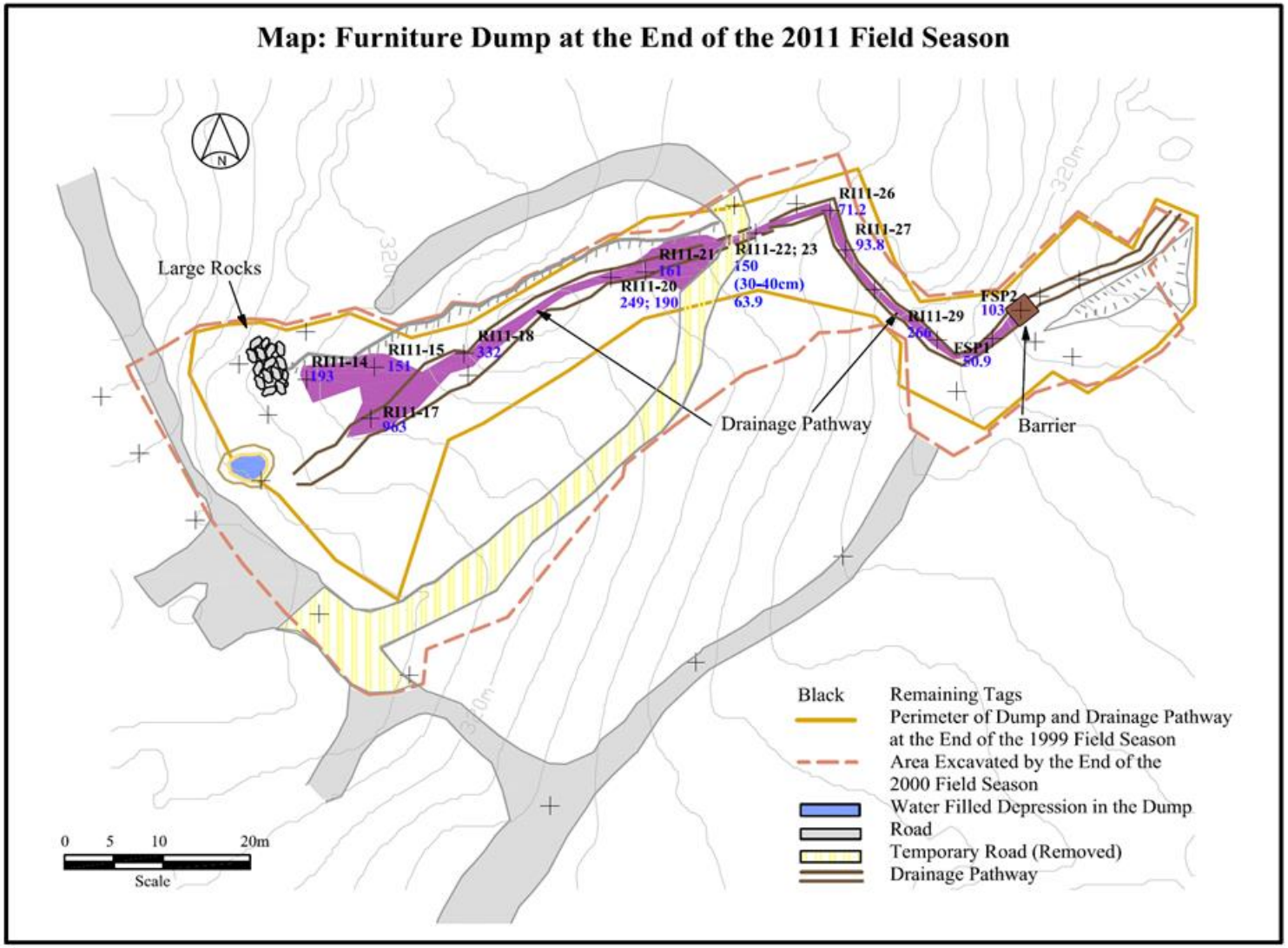
Furniture Dump Barrier

FURNITURE DUMP BARRIER

- ~1000 kg of CEPA soil trapped each year
- Concentrations >50 ppm
- Barrier will be rebuilt 2015

	2006	2007	2008	2009/2010	2011	2012
Volume (m^3)	0.3	0.25	0.6	0.5		
Concentration (ppm)	29	37	**78**	**53**	**101**	**77**
Mass (g)	15.5	16.9	76	48		

FD Drainage pathway 2011



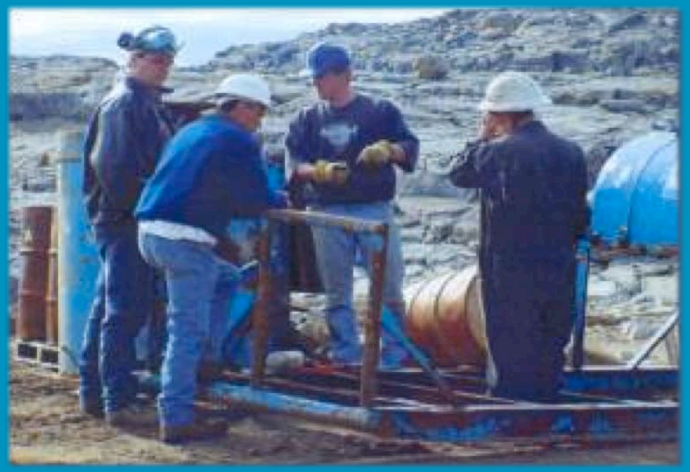
FD Barrier Liner Investigations 2011

Samples	Mass of Bentonite	Hydraulic Conductivity
	(g/m^2)	(m/s)
Virgin GCL	4100	4.7×10^{-11}
Furniture Dump Top Layer	3290	8.2×10^{-9}
Furniture Dump Bottom Layer	2850	3.7×10^{-8}

Holes in the geomembrane due to tensile stresses
Significant decreases in bentonite mass
Significant increases in hydraulic conductivity

Furniture Dump Barrier 2015/2016

- Excavate sediment from barrier and drainage pathway
- Replace entire barrier
- Further delineation to identify source
- Leave in place and monitor for 5 years



Thank you!