2.4.2 Soil and Groundwater Monitoring

The results of the soil and groundwater monitoring program will be compared against baseline data established prior to the initial landfill development or remediation program. Results of the analysis of soil and groundwater samples that show decreasing trends of contamination at the perimeter of existing landfills typically indicate that the implemented landfill remediation has been effective.

Conversely, if monitoring results indicate increasing levels of contamination, then it may be necessary to implement one or all of the following:

- Increase the frequency of the monitoring program.
- Carry out a review and evaluation of the nature and extent of the contamination, including the incorporation of the results of the visual monitoring program. The major objective of this evaluation will be to determine the cause of the contaminant migration problem, and in particular to determine if it is the result of ineffective design, material (e.g. liner) failure, improper compaction, selection and use of inadequate granular material, poor grading, etc. This evaluation may require intrusive investigation into and around the landfill.
- Depending on the results of the above, it may be necessary to remove and replace liner material, reconstruct containment berms, etc.
- Assess the requirement to excavate and dispose of the contaminated soil; this would include the delineation of the vertical and horizontal extent of the contamination.
- Excavate and dispose of contaminated soil, as required.

The requirement for the specific scope and extent of remediation, as outlined above, should also incorporate an evaluation of the potential environmental impacts of the contamination.

2.4.3 Thermal Monitoring

The results of the thermal monitoring program will be compared against the parameters for freezeback that were incorporated into the geothermal design of the landfills. It is important that the overall assessment of these results consider the results of both the visual and soil/groundwater monitoring programs. If the thermal monitoring results indicate ground temperatures that are significantly higher than predicted during the geothermal analyses carried out as part of the design, then it may be necessary to implement one or more of the following:

- Increase the frequency of the recording and assessment of results from the thermal monitors.
- Establish, based on the results of the soil and groundwater monitoring programs, if groundwater and/or soil contaminant levels beyond the perimeter of the landfill have increased. Assess the environmental impacts to determine the appropriate remediation requirements.

- If it is established that a slower than expected freezeback period has resulted in the migration of contamination beyond the landfill and depending on the results of the above environmental impact assessment, then it may be necessary to implement one or more of the following:

  - determine if the rate of the freezeback progress is continuing, or if freezeback within the landfill has terminated;
  - excavate and dispose of contaminated soil, as required;
  - place additional granular cover material or other insulating material (Styrofoam insulation, vegetation) over the landfill to provide an increased insulation barrier over the landfill;
  - reconstruct and/or re-saturate the perimeter berms of the landfill.

2.5 *REVIEW OF MONITORING RESULTS*

An Environmental Working Group (EWG) has been established to provide technical support to the DEW Line Cleanup Steering Committee. This working group is comprised of qualified engineers and/or environmental scientists with expertise in environmental remediation and cleanup in northern climates. The EWG has two designated representatives from each of the Parties, Owner and NTI.

During the monitoring program, the EWG will review the results of the monitoring program in accordance with the methodology as described in the previous section. The results of the review and any recommendations regarding changes to the monitoring plan and/or remediation requirements will be reported to the Steering Committee.

The requirement for Phase III monitoring will be evaluated at the end of the 25 years (end of Phase II). Monitoring may be terminated if the performance of the landfill was satisfactory over the period of monitoring from an environmental, geotechnical and thermal perspective, as appropriate. The assessment of satisfactory performance will be carried out by jointly by the NTI and DND.

At the termination of the monitoring period, a decision on the disposition of the above ground installations of monitoring wells and thermistors, and associated marker posts, should be made. The decommissioning of monitoring installations shall be carried out in a manner such that, if required, they may be reactivated. Electronic equipment shall be returned to DND for re-use or disposal as appropriate, and other non-hazardous materials shall be removed from site and disposed of in an appropriate landfill area.

ANNEX DEW LINE Cleanup-Landfill Monitoring Checklist

LANDFILL TYPE	Visual	Soil	Water	Thermal
New Landfill (Non-Hazardous Wastes)	X	X		
Landfill requiring Regrading - Class C	X	X		
Landfill requiring Leachate Containment - Class B	X	X	X	X
DCC Tier II Soil Facility	X	X	X	X

SITE: _____

LANDFILL DESIGNATION: _____

LANDFILL TYPE: _____

DATE: _____

MONITORING EVENT NO: _____

NAME: _____

WEATHER CONDITIONS: _____

VISUAL INSPECTION CHECKLIST

Date: _____

Site: _____

Landfill: _____

Carry out a visual inspection of the landfill surface, berms, toe of berms and identify potential areas of distress as follows:

1. Settlement:
   a) Is there differential settlement occurring on the surface?
      i) low areas or depressions;
      ii) voids forming

   b) What is the extent of settlement?
      i) percent of surface area affected;
      ii) localized areas or continuous;
      iii) how deep;

   c) Where is the settlement occurring?
      i) near berms, center of facility, etc.

   d) Explain:
      i) evidence of significant surface infiltration,
      ii) water ponding on surface
      iii) snow drifting

2. Erosion
   a) Is there erosion occurring on the surface or berms of the landfill?
      i) preferred drainage channels;
      ii) sloughing of material;

   b) What is the extent of erosion?
      i) percent of surface area affected;
      ii) localized areas or continuous;

   c) Where is the erosion occurring?
      i) along the toe, on the surface, through the berms;

   d) Explain:
      i) evidence of significant surface water run-off ;
      ii) poor material type;

Date: _____

Site: _____

Landfill: _____

3. Frost Action
   a) Is there frost action/damage to the landfill?
      i) exposure of debris due to uplift;
      ii) tension cracking along berms;
      iii) sorting of granular fill;

   b) What is the extent of frost action?
      i) percent of surface area affected;
      ii) localized areas or continuous;

   c) Where is the cracking, frost heaving occurring?
      i) along the toe, on the surface, through the berms;

   d) Explain?
      i) poor material gradation;
      ii) poor compaction;
      iii) high water content, silt content in cover material;

4. Condition of Other Monitoring Instruments, as applicable:

5. Provide detailed sketch and photographic record of landfill.

Date: _____

Site: _____

Landfill: _____

PRELIMINARY ASSESSMENT – VISUAL MONITORING

PHOTOGRAPHIC RECORDS

Signature: _____

Name: _____

GROUNDWATER MONITORING FIELD CHECKLIST

Date: _____

Site: _____

Landfill: _____

Sample No: Well No.:	
Field Measurements:	Ph Conductivity Temperature Color, Odor
Well Processing	Water level (from top of pipe)
	Height of water in well?
	Depth to bottom of well
	Apparent Freezing/Siltation?
	Purged well or standing water sampled.
	Presence of Hydrocarbons
	Thickness of Hydrocarbon Layer
	Purging Procedure
	Recovery Rates
Analyses Requested	

Comments:

_____

_____

_____

SOIL MONITORING FIELD CHECKLIST

Date: _____

Site: _____

Landfill: _____

Sample No: Location:	
Analyses Requested	

Comments:

_____

_____

_____

THERMAL MONITORING CHECKLIST

Date: _____

Site: _____

Landfill: _____

Thermistor Number:

Location:

Prior to retrieving data, ensure that personnel are grounded.

1. Download data and save data to hard drive and disk.
2. Translate and view data in the field to ensure completeness.
3. Replace battery pack
4. Check condition of connections and instrumentation, repair as necessary
5. Take manual readings of the thermistor using a digital readout.
6. Reset datalogger memory to zero, and re-start readings.
7. Monitor to ensure system operational.
8. Re-lock cap

3. NUNAVUT SETTLEMENT AREA

This section provides an overview of the landfill monitoring program for the DEW Line sites in the Nunavut Settlement Area. This section is to be updated, as required, following the completion of pre-tender site investigations.

The cleanup of sites in the Nunavut Settlement Area is anticipated to be carried out generally according to the schedule outlined in Figure 3.1. Also indicated on this figure is the proposed monitoring event schedule until the completion of Phase II Monitoring. Table 3.1 summarizes the landfills and monitoring requirements for each of the existing and proposed landfills at the DEW Line sites. The classification of each landfill as presented in Table 3.1, with the exception of those landfills at CAM-M and FOX-4, is preliminary and will be reviewed following the pre-tender site investigation at that site. The classification of each landfill will be reviewed with the Environmental Working Group, in accordance with the Terms of the Cooperation Agreement.

As indicated in Section 2.0, an important component of the monitoring program is the baseline/background assessment to be completed for each landfill. Preliminary information on the environmental status of the landfills was obtained during the initial environmental investigations. As part of the site investigations to be carried out in the two year period prior to cleanup, a more detailed sampling and testing program will be carried out to collect sufficient information to establish baseline conditions for comparison to subsequent monitoring events. Recommended sampling locations for specific landfills are outlined on the accompanying figures.

Required analyses for the baseline monitoring program are to be consistent with the monitoring criteria, as outlined in Section 2.0.

In the remaining annexes to this report, a brief summary of the environmental status and corresponding remediation design of each of the DEW Line landfills in the NSA is provided. The information provided is consistent with the outline of the Landfill Risk Assessment Matrix. Baseline and long term monitoring program is detailed.

Proposed Cleanup Schedule - DEW Line Sites - Nunavut Settlement Area

SITE	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
FOX-4 CAPE HOOPER																																						
Construction																																						
Monitoring																																						
CAM-M CAMBRIDGE BAY																																						
Construction																																						
Monitoring																																						
FOX-5 BROUGHTON ISLAND																																						
Construction																																						
Monitoring																																						
CAM-4 PELLY BAY																																						
Construction																																						
Monitoring																																						
FOX-M HALL BEACH																																						
Construction																																						
Monitoring																																						
CAM-5 MACKAR INLET																																						
Construction																																						
Monitoring																																						
CAM-3 SHEPHERD BAY																																						
Construction																																						
Monitoring																																						
DYE-M CAPE DYER																																						
Construction																																						
Monitoring																																						
CAM-2 GLADMAN POINT																																						
Construction																																						
Monitoring																																						
FOX-2 LONGSTAFF BLUFF																																						
Construction																																						
Monitoring																																						
FOX-3 DEWAR LAKES																																						
Construction																																						
Monitoring																																						
CAM-1 JENNY LIND ISLAND																																						
Construction																																						
Monitoring																																						
PIN-4 BYRON BAY																																						
Construction																																						
Monitoring																																						
PIN-3 LADY FRANKLIN POINT																																						
Construction																																						
Monitoring																																						
PIN-2 CAPE YOUNG																																						
Construction																																						
Monitoring																																						

MONITORING LEGEND	
BASELINE/BACKGROUND	
PHASE 1	
PHASE 2	

FIGURE 3.1

TABLE 3.1 NUNAVUT SETTLEMENT AREA - SUMMARY OF DEW LINE CLEANUP LANDFILL MONITORING PROGRAM

Site (Year of Landfill Closure)	Landfill Designation	Landfill Classification	Pre-tender Investigation/ Baseline Monitoring (year)	Post Construction Landfill Monitoring Program				Comments
				Visual	Soil	Groundwater	Thermal	
PIN-2 Cape Young (2007/2008)			2005/2008	2009, 2010, 2011, 2012, 2013, 2015, 2018, 2023, 2033				
	Station Area Landfill	New Non-Hazardous Waste Landfill		√	√	√		Location to be confirmed
	South Landfill - East and West	Class C - Regrading		√	√			
	Beach Landfill	Class C - Regrading		√	√			
	Tier II Soil Disposal Facility			√	√	√	√	Requirement for and location of to be confirmed.
	USAF Closure Landfills							to be confirmed.
PIN-3 Lady Franklin Point (2006/2007)			2004/2007	2008, 2009, 2010, 2011, 2012, 2014, 2017, 2022, 2032				
	Main Landfill & Extension	Class C - Regrading and Extension to existing landfill		√	√	√		Location of extension to be confirmed.
	Main NWS Landfill	Class C - Regrading		√	√			
	North Landfill	Class C - Regrading		√	√			
	South Area Landfills	Class C - Regrading		√	√			
	Tier II Soil Disposal Facility			√	√	√	√	Requirement for and location of to be confirmed.
PIN-4 Byron Bay (2005/2006)			2003/2006	2007, 2008, 2009, 2010, 2011, 2013, 2016, 2021, 2031				
	Station Area Landfill - East	New Non-Hazardous Waste Landfill		√	√	√		Location to be confirmed.
	Station Area Landfill - West	Class C - Regrading		√	√			
	North Landfill	Class C - Regrading		√	√			
	Northwest Landfill	Class B - Leachate Containment Class C - Regrading		√ √	√ √	√	√	One lobe of buried material to be provided with leachate containment.
	South Landfill Area	Class C - Regrading		√	√			
	Airstrip Landfill	Class C- Regrading		√	√			
	Beach Landfill	Class C - Regrading		√	√			
	Tier II Soil Disposal Facility			√	√	√	√	Requirement for and location of to be confirmed.
	USAF Closure Landfills							

TABLE 3.1 NUNAVUT SETTLEMENT AREA - SUMMARY OF DEW LINE CLEANUP LANDFILL MONITORING PROGRAM

Site (Year of Landfill Closure)	Landfill Designation	Landfill Classification	Pre-tender Investigation/ Baseline Monitoring (year)	Post Construction Landfill Monitoring Program				Comments
				Visual	Soil	Groundwater	Thermal	
CAM-M Cambridge Bay (1998-1999)			1996/1999	2000, 2001, 2002, 2003, 2004, 2006, 2009, 2014, 2024				
	Main Landfills North and South	Class B - Leachate Containment (extension for non-hazardous waste materials)		√	√	√	√	
	South Shore Landfill	Class C - Regrading		√	√			
	West Landfill	Class C - Regrading		√	√			
	Airstrip	Class A/C-excavation of select areas of buried debris, regrading of other areas.		√	√			
	Tier II Soil Disposal Facility			√	√	√	√	
CAM-1 Jenny Lind Island (2004-2005)			2002/2005	2006, 2007, 2008, 2009, 2010, 2012, 2015, 2020, 2030				
	Main Landfill & Extension	Class C - Regrading & Extension for Non-Hazardous Waste		√	√	√		
	Tier II Soil Disposal Facility			√	√	√	√	Requirement for and location of to be confirmed.
CAM-2 Gladman Point ((2003-2004)			2001/2004	2005, 2006, 2007, 2008, 2009, 2011, 2014, 2019, 2029				
	West Landfill - North	Class C - Regrading		√	√			
	West Landfill - South	Class C - Regrading		√	√			
	Station Area Landfill	New Non-hazardous waste landfill		√	√	√		Location to be confirmed
	Airstrip Landfill	Class C - Regrading		√	√			Status of Landfill to be confirmed.
	Tier II Soil Disposal Facility			√	√	√	√	Requirement for and location of to be confirmed.
	USAF Closure Landfills							Requirements to be confirmed

TABLE 3.1 NUNAVUT SETTLEMENT AREA - SUMMARY OF DEW LINE CLEANUP LANDFILL MONITORING PROGRAM

Site (Year of Landfill Closure)	Landfill Designation	Landfill Classification	Pre-tender Investigation/ Baseline Monitoring (year)	Post Construction Landfill Monitoring Program				Comments
				Visual	Soil	Groundwater	Thermal	
CAM-3 Shepherd Bay (2002/2003)			2000/2003	2004, 2005, 2006, 2007, 2008, 2010, 2013, 2018, 2028				
	North Landfill	Class C - Regrading		√	√			
	Station Area Landfill	Class C - Regrading		√	√			
	Northeast Landfill & Extensions	Class C- Regrading & Extension for non-hazrdous waste materials		√	√	√		
	USAF /NWS Landfill	Class C - Regrading		√	√			Status of Landfills to be confirmed.
	Tier II Soil Disposal Facility			√	√	√	√	Requirement for and location of to be confirmed.
CAM-4 Pelly Bay (2001-2003)			1997-1999/2003	2004, 2005, 2006, 2007, 2008, 2010, 2013, 2018, 2028				
	Upper Site Landfill	Class A - Excavation						If complete excavation is carried out, no monitoring is required. Consideration is being given to partial excavation and leachate containment.
	Station Area Landfill	New Non-Hazardous Waste Landfill		√	√	√		Location to be confirmed.
	Tier II Soil Disposal Facility			√	√	√	√	Requirement for and location of to be confirmed.
	Abandoned Camp Landfill	Class C - Regrading		√	√			
	Airstrip Landfill	Class C - Regrading		√	√			
	Lower Site Landfill	Class B - Leachate Containment of portions of the landfill						Confirmation of leachate to be confirmed in 1999. Monitoring requirements to be confirmed.
	Barrow Lake Landfill	Class B						Evaluation of excavation to be carried out. If excavated no additional monitoring is required.
	USAF Closure Landfills	Class C						Environmental status to be confirmed in 1999. It is anticipated that no additional fill material is required.
CAM-5 Mackar Inlet (2003-2005)			2001/2004	2005, 2006, 2007, 2008, 2009, 2011, 2014, 2019, 2029				
	Upper Site Landfill	Class B - Leachate Containment		√	√	√	√	
	Station Area Landfill	New Landfill for Non-Hazardous Wastes		√	√	√		
	Lower Site Landfill - South	Class C - Regrading		√	√			Status of Landfill to be confirmed.
	Lower Site Landfill - North	Class C - Regrading		√	√			Status of Landfill to be confirmed.
	USAF Closure Landfills	to be confirmed						
	Tier II Soil Disposal Facility			√	√	√	√	Requirement for and location of to be confirmed.

TABLE 3.1 NUNAVUT SETTLEMENT AREA - SUMMARY OF DEW LINE CLEANUP LANDFILL MONITORING PROGRAM

Site (Year of Landfill Closure)	Landfill Designation	Landfill Classification	Pre-tender Investigation/ Baseline Monitoring (year)	Post Construction Landfill Monitoring Program				Comments
				Visual	Soil	Groundwater	Thermal	
FOX-M Hall Beach (2002-2004)			1997&2000/ 2004	2005, 2006, 2007, 2008, 2009, 2011, 2014, 2019, 2029				
	South Beach Landfill	Class B/ C		√	√			Status of Landfill to be confirmed.
	Barrel Dump Areas - North and South	Class C - Regrading		√	√			Status of Landfill to be confirmed
	West Beach Landfill	New Landfill for Non-Hazardous Wastes		√	√	√		Location of Landfill to be confirmed.
	Tier II Soil Disposal Facility			√	√	√	√	
FOX-2 Longstaff Bluff (2004-2006)			2002/2006	2007, 2008, 2009, 2010, 2011, 2013, 2016, 2021, 2031				
	Upper Site Landfill	Class B - Leachate Containment		√	√	√	√	
	West Landfill	Class C - Regrading		√	√			
	Beach Landfill	Class C - Regrading		√	√			
	Airstrip Landfill	Class C - Regrading		√	√			
	Station Area Landfill	New Landfill - Non-Hazardous Wastes		√	√	√		Location to be confirmed.
	Hangar Landfill	New Landfill - Non-Hazardous Wastes		√	√	√		Location to be confirmed.
	Tier II Soil Disposal Facility			√	√	√	√	Requirement for and location of to be confirmed.
FOX-3 Dewar Lakes (2005-2007)			2002/2007	2008, 2009, 2010, 2011, 2012, 2014, 2017, 2022, 2032				
	Main Landfill and Extension	Class B - Leachate Containment and Extension of Non-Hazardous Wastes		√	√	√	√	
	Station Landfills - East and West	Class C - Regrading		√	√			
	Airstrip Landfills	Class C - Regrading		√	√			Status of Landifills to be confirmed
	West Landfill	Class C - Regrading		√	√			
	Tier II Soil Disposal Facility			√	√	√	√	Requirement for and location of to be confirmed.
FOX-4 Cape Hooper (1996-1999)			1999	1999, 2000, 2001, 2002, 2003, 2005, 2008, 2013, 2023				Cleanup of this site started prior to NTI/DND agreement. As a result additional monitoring wells placed at this site, including at those landfills where only regrading required.
	Upper Site Dump	Excavation						No monitoring required.
	Station Area Landfill	New Landfill - Non-Hazardous Waste		√	√	√		
	Helipad Landfills	Regrading		√	√	√		

TABLE 3.1 NUNAVUT SETTLEMENT AREA - SUMMARY OF DEW LINE CLEANUP LANDFILL MONITORING PROGRAM

Site (Year of Landfill Closure)	Landfill Designation	Landfill Classification	Pre-tender Investigation/ Baseline Monitoring (year)	Post Construction Landfill Monitoring Program				Comments
				Visual	Soil	Groundwater	Thermal	
	Barrel Dump	Regrading		√	√			
	Upper Site Landfill - West	Debris Removal, Contaminated Soil Excavation						No monitoring required as bedrock exposed during debris and contaminated soil removal operations.
	Lower Site Landfill	New Landfill - Non-Hazardous Waste		√	√	√		
	Airstrip Landfill	Regrading		√	√			
	Tanner Bay Landfill	Regrading		√	√			
	Tier II Soil Disposal Facility			√	√	√	√	
FOX-5 Broughton Island (2001-2003)			1998 2003	2004, 2005, 2006, 2007, 2008, 2010, 2013, 2018, 2028				
	Main Landfill	Class B - Leachate Containment		√	√	√	√	
	Existing Airstrip Landfill	Class A - Excavation						No monitoring required following excavation
	Station Area Landfill	New Landfill - Non-Hazrdous Wastes		√	√	√		Location to be confirmed.
	Lower Site Landfill	New Landfill - Non-Hazardous Wastes		√	√	√		Location to be determined.
	Tier II Soil Disposal Facility			√	√	√	√	Requirement for and location of to be confirmed.
DYE-M Cape Dyer	Not included in this draft.							

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