PUBLIC SERVICES AND PROCUREMENT CANADA
ENVIRONMENTAL SERVICES – WESTERN REGION

Operations and Maintenance Manual Resolute Bay Landfill Remediation Project, Resolute Bay, Nunavut

PSPC Project R.095508.001

Final Report

December 9, 2020

DOJV Project No. P2017-06

Executive Summary

Dillon Consulting Ltd. and Outcome Consultants Inc in joint venture (DOJV) was contracted by Public Services and Procurement Canada (PSPC) Environmental Services to compose an Operations and Maintenance Manual (O&M Manual) for the Resolute Bay Airport Landfill. Work by DOJV was conducted according to the Terms of Reference *Specifications and Remedial Supervision – Resolute Bay Airport Landfill Remediation – Resolute Bay, Nunavut* dated December 2017. Work was completed under the Northern Contaminated Site Environmental Clean-up Work/Services Supply Arrangement EW699-170520-003 and in accordance with the Nunavut Water Board (NWB) Water License (WL) 1BR-RBL1419. This document is intended to abide to the requirements set out in the Nunavut Water Board (NWB) Water License (WL) 1BR-RBL1419.

The Resolute Bay Airport is five kilometres northwest of the Inuit hamlet of Resolute, adjacent to Resolute Bay on Cornwallis Island, Nunavut. Two historical landfills are located on the site and were previously identified along with a vehicle storage area (also referenced as metal storage area) as Areas of Environmental Concern (AEC) based on activities, historical and present, associated with the airport and local community. For reporting purposes, the AECs are referenced as the solid waste landfill (AEC 1), historical landfill (AEC 2), and the vehicle/metal storage area (AEC 3).

Site remediation is complete and took place over a two-year period from 2018 to 2019. The remedial objectives at the site included the removal of physical hazards (i.e., slope stabilization and capping at the landfills and debris removal), consolidation of waste and debris, off-site disposal of materials deemed hazardous by the NWB WL and the containment and control of contaminants in the surface water pathways prior to leaving the site and ultimately, discharging to receiving water bodies.

With remediation completed, operations and maintenance (O&M) activities will begin as outlined in this document. The goal of this O&M Manual is to ensure that during the lifespan of monitoring activities, the current and future risks to human health & environment are negligible from a physical standpoint. This will be achieved by ensuring that all design intents are met, and by revaluating risks during each monitoring event. The O&M Manual will be implemented immediately after the completion of construction.

The O&M Manual consists of specific monitoring elements, with descriptions of methodology and action levels based on observed impacts. The elements of the plan are as follows:

- Natural environment monitoring to assess trends in the use of the site by wildlife;
- Maintenance, temperature, and visual monitoring of landfill covers to assess performance and stability;
- Operational monitoring of the surface water swales including surface water/seep monitoring to address the potential for instability from surface drainage impacts.

Table of Contents

Appendices

Tables

Figures

1.0 Introduction

1.1 Purpose of the Manual

Dillon Consulting Ltd. and Outcome Consultants Inc in joint venture (DOJV) were contracted by Public Services and Procurement Canada (PSPC) Environmental Services to develop an Operations and Maintenance Manual for the Resolute Bay Landfill Remediation Program, as a requirement of the Water Licence (NWB Amended Renewal Water Licence No. 1BR-RBL1929).

The purpose of this manual is to assist responsible bodies with the proper operation and maintenance of remediated works during the post closure phase of the project lifecycle. This manual is intended to work as a companion document to the Long-Term Monitoring Plan (prepared under separate cover), and focuses on geophysical parameters and operational design features for the continued operation of the remediated works. In contrast, the Long-Term Monitoring Plan emphasizes chemical parameters for ensuring the protection of the natural environment and that the intent of the remedial design is being achieved.

DOJV prepared the manual in accordance with the "Guidelines for the preparation of an Operation and Maintenance Manual for Sewage and Solid Waste Disposal Facilities in the Northwest Territories, 1996" as referenced in the Water Licence. The general body of the manual is reflected as such:

1) Introduction
2) Site Description
3) Operation and Maintenance of AEC 1
4) Operation and Maintenance of AEC 2
5) Operation and Maintenance of AEC 3
6) Spills & Discharges – Contingency & Emergency Response Program
7) Monitoring Program
8) Reporting

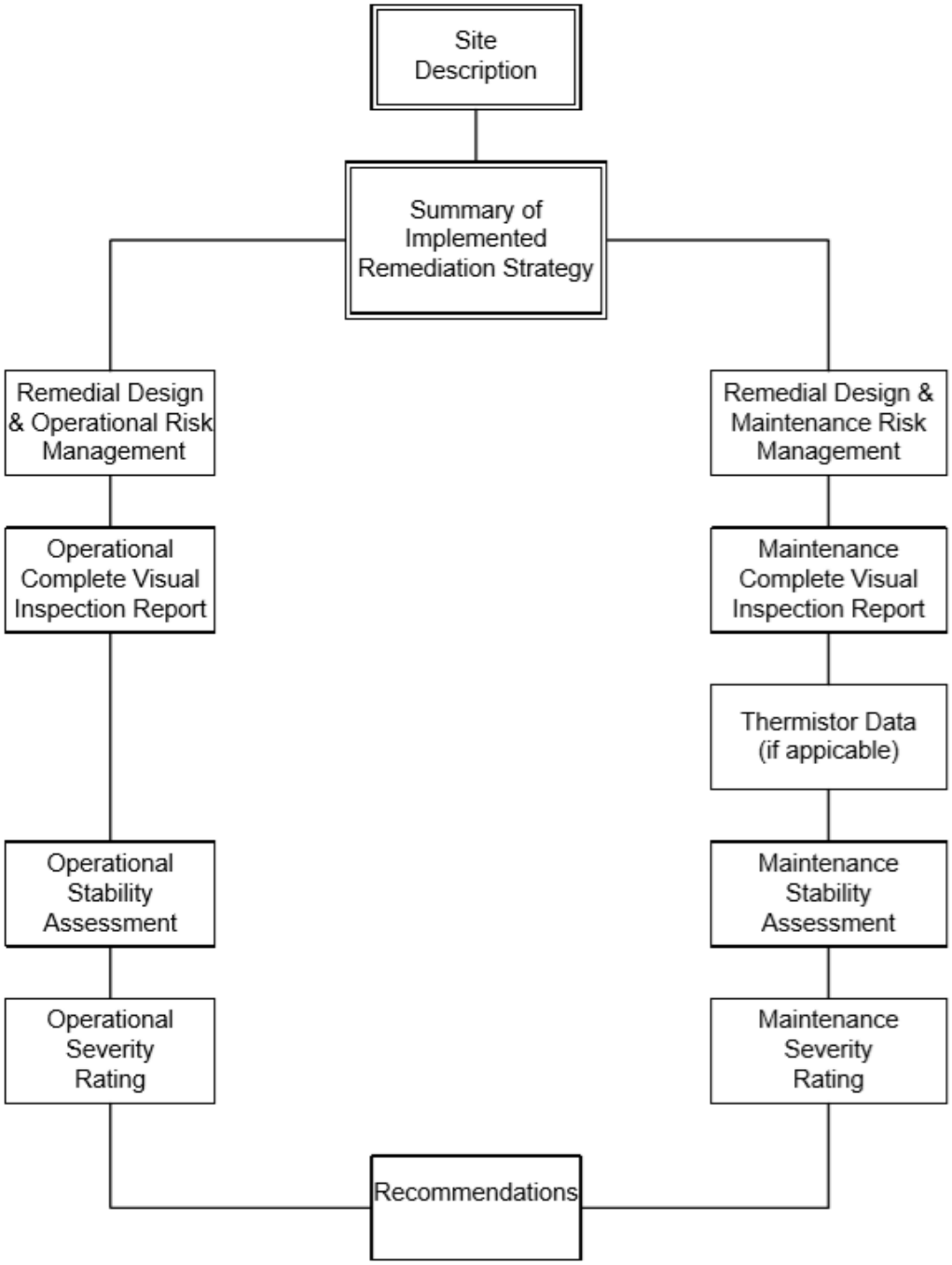
Appendix A – Proposed Thermistor Locations at AEC1

Appendix B – Design Tables

Appendix C – Field Templates

For each AEC, the Operation and Maintenance activities follow the elements presented in Figure 1 from the general guidelines set by the "Abandoned Military Site Remediation Protocol, 2008" (ASMRP).

FIGURE 1: FLOW CHART OF OPERATION AND MAINTENANCE ACTIVITIES BY AEC AS PER THE ASMRP



2.0 Site Background

The Resolute Bay Airport is five kilometres northwest of the Inuit hamlet of Resolute, adjacent to Resolute Bay on Cornwallis Island, Nunavut. Cornwallis Island is in the Qikiqtaaluk Region of Nunavut. Three Areas of Environmental Concern (AECs) were previously identified based on activities, historical and present, associated with the airport and local community. Two historical landfills referred to as the solid waste landfill (AEC 1), historical landfill (AEC 2) and a former vehicle storage area (AEC 3), are located on the site. AEC 3 is also referred to as the metal storage area. Two inactive soil land treatment units (LTUs) and a buried Asbestos waste pile owned by TC are also located onsite, however, these features were not included in the present Remediation scope of work nor covered within this O&M Manual. The sites cover an approximate area of 2025 hectares.

The Resolute Bay airport was originally constructed by the Royal Canadian Air Force and has been in operation since 1949 (PSPC, 2017). Transport Canada, on behalf of the Government of Canada, took ownership of the property in 1964 and continued operations until July 1, 1995. From July 1, 1995 to April 1, 1999 the Government of Northwest Territories had ownership and operations continued under the Arctic Airport Division of the Department of Transportation. The Government of Nunavut has owned the property since April 1, 1999.

Environmental audits and environmental site assessments have occurred at the Site since 1993. investigations between 1993 and 2005 were undertaken by TC. TC engaged PSPC since 2009 to assist with delineation of contaminants of concern, the development of remediation action plans for the site, and development of remediation specifications to tender for remediation contractor services.

A Phase II/III ESA was completed by Franz Environmental Inc. (Franz) in March of 2010 and provided a conceptual remedial option plan (RAP). An informal RAP was later produced by Franz during the 2011-2012 fiscal year. The accepted design included an aggregate capping solution without an impermeable geomembrane. A data gap assessment was completed on the AECs by Franz in 2013-2014. The data gap assessment identified an adjacent municipal sewage lagoon which was a concern for overflowing effluent, a past contributor to leachate production at AEC-1. The sewage lagoon is owned by the Government of Nunavut and as such is not included in the project scope. Two landfills and a single metal storage area are located on the site and were previously identified as Areas of Environmental Concern based on activities, historical and present, associated with the airport and local community.

During the 2014-2015 government fiscal year, PSPC purchased and mobilized 26 marine shipping containers, 10 Liquid hazardous waste containers and 5 solid hazardous waste containers to site in anticipation of remedial activities.

DOJV was retained by PSPC during FY 2017-2018 to review and modify the existing remediation designs to provide an achievable scope of work that could be contracted and completed by the end of the FY 2019-2020.

The contract was awarded to Kudlik Construction Ltd under contract EW699-182827/A, in June 2018. Construction work began in Summer 2018 and is was completed in the Summer 2019.

2.1 Site Identification

Site information is presented in Figure 2below.

FIGURE 2: SITE IDENTIFICATION INFORMATION

Site Characteristic	Description
FCSI No. of Contaminated Site	N0017003
DFRP Number	NA (site is administered by Nunavut)
Exact Site Name as listed in IDEA	Old Landfill/Main Drum Cache
Site Address (street address, municipality, province/territory)	Resolute Bay, Nunavut
Reporting Organization	Transport Canada
Legal description or metes and bounds:	Lot 1001, Quad 58 F/11, Plan 77590, Resolute Bay, Nunavut with adjacent areas
Approximate Site area	2025 hectares
Centre of site coordinates (in lat/long or UTM)	74.716944 N, 94.969444 W

2.2 Overall Site Description

2.1.1 Regional Setting

The site is located on the southwestern edge of Cornwallis Island in the high arctic. Cornwallis Island is roughly in the centre of the Canadian arctic, north of the Arctic Circle. Resolute is accessible year-round by air and for three months in the summer by boat (Geological Survey of Canada, 1958).

Cornwallis Island is affected by plate tectonics, but this has not resulted in the formation of mountains. Instead, the island is relatively flat, with a maximum elevation of approximately 400 metres above mean sea level (Geological Survey of Canada, 1958).

The island is characterized by plains topography with relatively small hills and ridges, with intervening broad valleys.

2.1.2 Climate and Weather

The Resolute CARS weather station is approximately 2.5 km south of the landfill. Climate normals for the weather station indicate that the weather is typical of the high arctic: only June, July and August have average daily temperatures above zero. The highest temperature recorded at the station before 2010, the period for which climate normal data is available, was 18.5^{o}C.

The site is in the polar desert as indicated by annual precipitation of 161.2 mm, approximately 2/3 of which falls as snow. On average, there are only four days a year with rainfall of more than 5 mm.

2.1.3 Geological Setting

The site is on the boundary between two geologic units, separated by the sharp gradient that passes through AEC 1. The "upper site," i.e., the eastern portion of the site and the majority of the airport lands, consists of argillaceous and dolomitic limestone, calcerous shale and calcisilite, and shallow to deep subtidal outer shelf ramp.

The lower site area, between the upper site and the bay, consists of medium to thick-bedded light grey to yellow-brown dolostone as well as dolomitic limestone, minor flat pebble conglomerate, and local stromatoporoid bioherms in semi-arid to arid subtidal to supratidal settings (Natural Resources Canada, 2015).

Site overburden "is a mix of angular cobbles and boulders with variable amounts of sands and gravels, all a result of bedrock fracturing and weathering" (SENES and Franz, 2013) with local pockets of silt also noted. The site is in the zone of continuous permafrost. Permafrost was encountered in previous investigations at depths between 0.4 and 1 metres (SENES and Franz, 2013).

2.1.4 Demography

According to the Federal Contaminated Sites Inventory (FCSI) record for the site, there are five residents within a 1 km radius of the site; 131 within a 5 km radius of the site, and 312 within a 10 km radius of the site.

2.1.5 Lines and Other Property Lines

The Resolute airport is legally described as Lot 1001, Quad 58 F/11, Plan 77590 (Public Works and Government Services Canada, 1994). The total area of the site is 2,025 hectares. The work areas described in this report do not map directly onto the property – as noted above, AEC 3 is on Territorial land slightly outside the airport property boundaries.

3 Operation and Maintenance of Solid Waste Landfill (AEC 1)

3.1 Site Description

AEC 1 is a solid waste landfill developed in the 1960s and 1970s that has not been in official use since 1995. It is located on airport property approximately 2 km north of the north end of the airstrip.

3.2 Summary of Implemented Remediation Strategy

The RAP identified remedial objectives at the site as: (i) the removal of physical hazards (i.e., slope stabilization and debris removal and/or capping), (ii) consolidation of waste and debris, and (iii) the containment and control of contaminants in the surface water pathways that may discharge to receiving water bodies.

Specifically, the following remedial work was completed:

- Regrading, cutting/filling, and excavation of the non-stable soil and non-hazardous waste material located at the slope face to achieve the designed 3H:1V slope;
- Segregating contaminated soil and hazardous material unearthed during slope stability activities, packaging, and transporting the material to a licensed disposal facility off-site;
- Filling voids with borrow material to stabilize the slope;
- Constructing an aggregate cover over the top and slope of the landfill;
- Constructing drainage swales to direct surface water around the landfill; and
- Upgrading or maintaining roads as necessary.

3.3 Remedial Design and Risk Management

3.3.1 Remedial Design

The AEC1 landfill design was based on a soil barrier cover design. The soil barrier was placed and compacted during construction. The barrier construction along with the predicted ambient environment leads to the formation of permanently frozen ground over time (permafrost aggradation). The presence of permafrost within the soil barrier cover has the added benefit of reducing infiltration by an order of magnitude of three to five times[1] in comparison to a similar soil without permafrost present, thereby reducing the potential for leachate generation. Drainage swales were constructed to redirect surface water along the perimeter of the landfill from entering onto the surface of the landfill, thereby reducing the potential for landfill leachate production.

[1] Cold Regions Cover System Design Technical Guidance Document", MEND Report 1.61.5c (July, 2012)

For AEC1, previous conceptual landfill designs had a minimum of 1.0m total aggregate fill thickness to be placed, with the top 0.2 m being coarse fill. However, based on test pitting information carried out prior to construction and further analysis, it was found acceptable to have a reduced fill thickness for the final landfill design based on the possibility for change in material types and the overall landfill geometry (shallow top cover). The final implemented design used a 1.1m aggregate thickness on side slopes including a 0.3m Type 1 coarse layer. The top surface of the landfill was relatively flat and therefore capped with 0.6m of Type 2 fine aggregates. The installed landfill uses the Type 2 fine aggregates to avoid direct surface runoff contact, reduce water infiltration, promote permafrost aggradation, and reduce leachate generation. A sufficiently high degree of saturation of the barrier layer below the active zone was added to maintain the reduced infiltration capacity (voids within soil profile filled with ice, once frozen). Fine-textured soils were used since they have higher capillary suction, and field capacity (water content of a soil when gravity drainage ceases). The landfill top was sloped to 2% for positive drainage and side slopes cut and filled to a 3H:1V slope for improved slope stability. The cut and fill of side slopes was implemented to reduce safety risks of additional hauling and placement.

3.3.2 Risk Management

The following is all related information during the Design and Development phase of the project last updated on January 17, 2019. *Table 1* in *Appendix B* describes design features, issues, feasibility, and rational behind decisions. The following risks are interpreted from the design phase segregated based on the risk type and integrated into the site operation and maintenance:

Operational Risks:

- Ensuring landfill cover thickness is thicker than active layer. (min 1.0m)
- Snow cover duration
- Sun exposure
- Surface temperature
- Wind
- Surface water drainage and potential percolation into landfill cap
- Ensuring a sufficiently high degree of saturation of the barrier layer below the active zone
- Runoff diversion

Maintenance Risks:

- Surface drainage and municipal sewage lagoon overflow.

The sewage lagoon is owned by the Government of Nunavut and as such is not included in the project scope. Although any overflow, or general issue relating to the sewage lagoon is not the responsibility of Transport Canada, the sewage lagoon does pose a potential maintenance risk to the AEC 1 remedial works.

3.4 Operation & Maintenance Evaluation, Procedures and Reporting

The operation and maintenance evaluation and procedures will be conducted in a format that provides the desired AMSRP reporting results. The report results are as follows with the associated procedures described below:

3.4.1 Complete Visual Inspection Report

A field assessor will inspect the physical integrity of the capped areas at the site. The inspection will be conducted using photographs, sketches, and other notes.

A field assessor will make observations of the presence or absence of visual items in the table below. Operation and maintenance features will be distinguished from one another as shown, meanwhile general observations will be distinguished from site specific risk observations by means of separate tables.

The General Visual Inspection Matrix was largely adapted from the ASMRP *Table 7.2*.

3.4.2 Thermistor Data

Thermistor data will be summarized in a section and be included in a separate section labelled "Thermistor Data Logger Results", and a final table should for each monitoring period will summarize the following:

TABLE 1: AEC 1 SITE SPECIFIC RISKS VISUAL INSPECTION MATRIX

Thermistor ID	String No.	String Depth (m)	Reading (°C)	Date of Reading	Time of Reading

In the thermistor data for each O&M interval, a chart summarizing the soil temperature profile data results will be created to plot cumulative permafrost aggregation over time. These results will be analysed in the Stability Assessment.

TABLE 2: GENERAL AEC 1 VISUAL INSPECTION MATRIX

Observation Parameter	Operational Feature	Maintenance Feature	Observations from Previous Report	Current Observations
Settlement	✓			
Erosion	✓			
Frost Action	✓			
Animal Burrows		✓		
Vegetation	✓			
Staining		✓		
Vegetation Stress	✓			
Seepage Points	✓			
Exposed Debris		✓		
Condition of Monitoring Instruments		✓		
Grades/ Topography	✓			
Distance to downgradient surface water bodies	✓			
Distance to freshwater/marine habitat and habitat usage	✓			
Terrestrial Habitat		✓		
Land Uses		✓		
Debris		✓		

Site specific risks will also be visually inspected for, to the extent possible:

TABLE 3: SITE SPECIFIC AEC 1 RISKS VISUAL INSPECTION MATRIX

Observation Parameter	Operational Feature	Maintenance Feature	Observations from Previous Report	Current Observations
Ensuring landfill cover thickness	✓			
Snow cover, including measured depth	✓			
Sun exposure	✓			
Surface temperature	✓			
Wind effects	✓			
Surface Drainage	✓			
Municipal Sewage Lagoon Overflow		✓		
potential percolation into landfill cap	✓			
Ensuring a sufficiently high degree of saturation of the barrier layer below the active zone	✓			
Thermistor Condition		✓		
Runoff Diversion	✓			

A field assessor is to take measurements of any feature noted. In subsequent years, A field assessor will compare all previously identified features with current conditions. The field assessor will take photographs and make note of the location and direction of the photos so that they can be re-created in each year of the monitoring program.

Visual observations may be compiled in a table format.

3.4.3 Stability Assessment

Further to a Visual Inspection, the Stability Assessment serves to provide an analysis of the current status of the AEC. The stability assessment was adapted from the AMSRP, although, the extent of the assessment protocol should only be limited to physical characteristics. The assessment will serve to analyze established risks. This will be done by comparing current observations to previous observations and/ or baseline conditions. From this comparison, appropriate severities and action levels will be concluded as identified in following sections. Any additional risks identified should also be established in this section to be implemented for future operation and maintenance activities.

The Stability Assessment will include the following:

- A general interpretation of findings
- A comparison to between previous conditions and/or baseline conditions and as-built drawings
- Expected findings
- Any additional risks identified and its impact

Based on the above criteria, the severity of each observation should be established as part of the analysis. Tables in the following sections are for the evaluation of analyzed observations. Operational and Maintenance features are to be evaluated based on separate matrices.

3.4.4 Operation and Maintenance Severity Rating

The following tables are to be used for interpreting the severity level of operational features. The following tables were adapted from *Table 4.1* of the AMSRP Volume 2. *Table 4* represents a *Severity Rating of Operation Features*, meanwhile *Table 5* represents *a Severity Rating for Maintenance Features*.

TABLE 4: SEVERITY RATINGS OF AEC 1 OPERATIONAL FEATURES

Severity Rating	Description
Not observed	No issues identified
Acceptable	Noted features are of little consequence. The landfill is performing as designed. Minor deviations may be observed, such as isolated areas of erosion or settlement, drainage system is performing well.

Severity Rating	Description
Marginal	Physical/environmental performance appears to be deteriorating with time. Observations may include an increase in number or size of features of note, such as differential settlement, erosion or cracking; drainage systems are showing increased sedimentation reducing surface flow. No significant impact on landfill stability to date, but potential for failure is assessed as low or moderate.
Significant	Significant or potentially significant changes affecting landfill stability, such as significant changes in slope geometry, significant erosion, or differential settlement; scarp development, collapsed or slumped surface water drainage systems. The potential for failure is assessed as imminent.
Unacceptable	The stability of the landfill is compromised to the extent that waste materials are exposed in areas of erosion, or differential settlement, cap is not functional and/or slope failure, surface water is not draining as designed with overflows or breakouts.

TABLE 5: SEVERITY RATINGS OF AEC 1 MAINTENANCE FEATURES

Severity Rating	Description
Not observed	No issues identified
Acceptable	Noted features are of little consequence. The landfill is performing as designed. Minor deviations may be observed such as terrestrial habitat use on the landfill, signs of thermistor functionality being reduced, surface debris from non-project related landfill activities, or visual changes noted in the sewage lagoon.
Marginal	Physical/environmental performance appears to be deteriorating with time. Observations may include an increase in number or size of features of note, such as small animal burrows on the landfill caps or slopes, sewage lagoon overflow, a thermistor no longer operational, signs of tampering, or significant amounts of debris on-site. No significant impact on landfill stability to date, but potential for failure is assessed as low or moderate.
Significant	Significant or potentially significant changes affecting landfill stability, such as large animal burrows on the landfill caps or slopes, sewage lagoon overflow impeding near AEC1, or significant amounts of debris heaving the landfill. The potential for failure is assessed as imminent.
Unacceptable	The stability of the landfill is compromised to the extent that waste materials are exposed in areas of erosion, the landfill cap is not functional and/or slope failure. Observations may include sewage lagoon overflow onto the landfill.

3.4.5 Recommendations

Based on the analyses and perceived severity ratings, a set of recommendations for each operation and maintenance activity will be given. The following action matrix below which was adapted from the ASMRP will be used as guide for creating recommendations. Once the severity of observations is established, recommendations should be further elaborated on, either in the current section, or as part of a separate document as seen appropriate.

TABLE 6: ACTION LEVELS FOR AEC 1 LANDFILL MONITORING OR REHABILITATION

Severity Rating	Action
Not observed	Monitoring to continue as planned
Acceptable	Monitoring to continue as planned
Marginal	Analyze potential causes of instability. Continue monitoring plan with any potential recommendations for future operation and maintenance.
Significant	Assess current and future impact to implemented remedial works, develop a remedial plan.
Unacceptable	Develop and Implement a site-specific remedial plan (in coordination with the LTM).

Action levels are to be separated into unique sections for operational and maintenance features.

4 Operation and Maintenance of Historical Landfill (AEC 2)

4.1 Site Description

AEC 2 is a historic landfill that operated between 1947 and 1996. The landfill was used by the military, Transport Canada, and other airport tenants. It is 0.5 km immediately west of the airstrip and in close proximity to restricted access airport activities.

4.2 Summary of Implemented Remediation Strategy

The Conceptual RAP identified remedial objectives at the site such as the removal of physical hazards (i.e., slope stabilization and debris removal and/or capping), consolidation of waste and debris, and the containment and control of contaminants in the surface water pathways prior to leaving the site and ultimately, discharging to receiving water bodies.

Specifically, the following remedial work was completed:

- Consolidation of non-hazardous wastes from AEC 2 within AEC 1;
- Regrading the top and embankment of the landfill to direct surface water away from the slope face; and
- Constructing surface drainage swales to promote drainage from existing culverts and to redirect surface water away from the top of the former landfill.

4.3 Remedial Design and Associated Risks

4.3.1 Remedial Design

The AEC2 landfill design was based on a barrier cover design. Surface debris was removed from AEC 2 and brought to AEC 1 if non-hazardous. Hazardous materials were packaged and shipped off-site. The implemented design has a cap and slopes graded, using a cut/fill approach, with aggregates used to fill in voids or low spots on the top to promote surficial flow.

4.3.2 Associated Risks

The following is all related information during the Design and Development phase of the project. *Table 2* in *Appendix B* describes design features, issues, feasibility, and rational behind decisions. The following risks were interpreted from the design phase for AEC 2 or similar features from AEC1:

Operational Risks:

- Permafrost Degradation
- Snow cover duration
- Sun exposure
- Surface temperature
- Wind
- Surface water drainage and potential percolation into landfill cap
- Runoff diversion

Maintenance Risks:

- N/A

4.4 Operation & Maintenance Evaluation, Procedures, and Reporting

4.4.1 Complete Visual Inspection Report

A field assessor will inspect the physical integrity of the capped areas at the site. The inspection will be conducted using photographs, sketches, and other notes.

A field assessor will make observations of the presence or absence of visual items in the table below. Operation and maintenance features will be distinguished from one another as shown, meanwhile general observations will be distinguished from site specific risk observations by means of separate tables.

The General Visual Inspection Matrix was largely adapted from the ASMRP *Table 7.2*.

TABLE 7: GENERAL AEC 2 VISUAL INSPECTION MATRIX

Observation Parameter	Operational Feature	Maintenance Feature	Observations from Previous Report	Current Observations
Settlement	✓			
Erosion	✓			
Frost Action	✓			
Animal Burrows		✓		
Vegetation	✓			
Staining		✓		
Vegetation Stress	✓			
Seepage Points	✓			
Exposed Debris		✓		
Condition of Monitoring Instruments		✓		
Grades/ Topography	✓			
Distance to downgradient surface water bodies	✓			
Distance to freshwater/marine habitat and habitat usage	✓			
Terrestrial Habitat		✓		
Land Uses		✓		
Debris		✓		

Site specific risks will also be visually inspected for to the extent possible:

TABLE 8: AEC 2 SITE SPECIFIC RISKS VISUAL INSPECTION MATRIX

Observation Parameter	Operational Feature	Maintenance Feature	Observations from Previous Report	Current Observations
Permafrost Degradation	✓			
Snow cover duration	✓			
Sun exposure	✓			
Surface temperature	✓			
Wind	✓			
Surface water drainage and potential percolation into landfill cap	✓			
Runoff Diversion	✓			
Permafrost Degradation	✓			
Snow cover duration	✓			

A field assessor is to take measurements of any feature noted. In subsequent years, A field assessor will compare all previously-identified features with current conditions. The field assessor will take photographs and make note of the location and direction of the photos so that they can be re-created in each year of the monitoring program.

Visual observations may be compiled in a table format.

4.4.2 Stability Assessment

Further to a Visual Inspection, the Stability Assessment serves to provide an analysis of the current AEC. The stability assessment was adapted from the AMSRP, although, the extents of the assessment protocol should only be limited to physical characteristics. The assessment will serve to analyze established risks. This will be done by comparing current observations to previous observations and/ or baseline conditions. From this comparison, appropriate severities and action levels will be concluded in

following sections. Any additional risks identified should also be established in this section to be implemented for future operation and maintenance activities.
The Stability Assessment will include the following:

- A general interpretation of findings
- A comparison to between previous conditions and/or baseline conditions and as-built drawings
- Expected findings
- Any additional risks identified and its impact

Based on the above criteria, the severity of each observation should be established as part of the analysis. Tables in the following sections are for the evaluation of analyzed observations. Operational and Maintenance features are to be evaluated based on separate matrices.

4.4.3 Operation and Maintenance Severity Rating

The following tables are to be used for interpreting the severity level of operational features. This tables were largely adapted from *Table 4.1* of the AMSRP Volume 2. *Table 4* represents a *Severity Rating of Operation Features*, meanwhile *Table 5* represents *a Severity Rating for Maintenance Features*.

TABLE 9: SEVERITY RATINGS OF AEC 2 OPERATIONAL FEATURES

Severity Rating	Description
Not observed	No issues identified
Acceptable	Noted features are of little consequence. The landfill is performing as designed. Minor deviations may be observed, such as isolated areas of erosion or settlement.
Marginal	Physical/environmental performance appears to be deteriorating with time. Observations may include an increase in number or size of features of note, such as differential settlement, erosion or cracking. No significant impact on landfill stability to date, but potential for failure is assessed as low or moderate.
Significant	Significant or potentially significant changes affecting landfill stability, such as significant changes in slope geometry, significant erosion, or differential settlement; scarp development. The potential for failure is assessed as imminent.
Unacceptable	The stability of the landfill is compromised to the extent that waste materials are exposed in areas of erosion, or differential settlement, cap is not functional and/or slope failure.

TABLE 10: SEVERITY RATINGS OF AEC 2 MAINTENANCE FEATURES

Severity Rating	Description
Not observed	No issues identified
Acceptable	Noted features are of little consequence. The landfill is performing as designed. Minor deviations may be observed such as terrestrial habitat use on the landfill, or surface debris from non-project related landfill activities.
Marginal	Physical/environmental performance appears to be deteriorating with time. Observations may include an increase in number or size of features of note, such as small animal burrows on the landfill caps or slopes, signs of tampering, or significant amounts of debris on-site. No significant impact on landfill stability to date, but potential for failure is assessed as low or moderate.
Significant	Significant or potentially significant changes affecting landfill stability, such as large animal burrows on the landfill caps or slopes, or significant amounts of debris heaving the landfill. The potential for failure is assessed as imminent.
Unacceptable	The stability of the landfill is compromised to the extent that waste materials are exposed in areas of erosion, the landfill cap is not functional and/or slope failure.

4.4.4 Recommendations

Based on the analyses and perceived severity ratings, a set of recommendations for each operation and maintenance activity will be given. The following action matrix below which was adapted from the ASMRP will be used as guide for creating recommendations. Once the severity of observations is established, recommendations should be further elaborated on, either in the current section, or as part of a separate document as seen appropriate.

TABLE 11: ACTION LEVELS FOR AEC 2 LANDFILL MONITORING

Severity Rating	Action
Not observed	Monitoring to continue as planned
Acceptable	Monitoring to continue as planned
Marginal	Analyze potential causes of instability. Continue monitoring plan with any potential recommendations for future operation and maintenance.
Significant	Assess current and future impact to implemented remedial works, develop a remedial plan.
Unacceptable	Develop and Implement a site-specific remedial plan (in coordination with the LTM).

Action levels are to be separated into unique sections for operational and maintenance features.

5 Operation and Maintenance of Vehicle Storage Area (AEC 3)

5.1 Site Description

AEC 3, the historical vehicle storage area, is a metal storage area previously used for vehicle and airport metal waste storage. It is northwest of the Resolute Airport airstrip and 2.75 km north-west of AEC 1. It is an inactive area on Territorial property directly adjacent to the northern Resolute Airport property limit.

5.2 Summary of Implemented Remediation Strategy

The Conceptual RAP identified remedial objectives at the site such as the removal of physical hazards (i.e., slope stabilization and debris removal and/or capping), consolidation of waste and debris, and the containment and control of contaminants in the surface water pathways prior to leaving the site and ultimately, discharging to receiving water bodies.

Specifically, the following remedial work was completed:

- Consolidation of non-hazardous wastes from AEC 3 within AEC 1;
- Excavate and dispose of approximately 179 m^3 of PHC- and metals-contaminated soil at a licenced disposal facility; and
- Backfill and re-grade excavations with approved borrow material.

5.3 Remedial Design and Associated Risks

5.3.1 Remedial Design

The remedial design called for a backfill and surface grading of Type 2 material following the removal of surface non-hazardous waste materials to AEC 1. Any hazardous materials were packaged and transported offsite for disposal at a licensed facility. *Table 3* summarized in *Appendix B* describes design features, issues, feasibility, and rational behind decisions.

5.3.2 Associated Risks

There were no additional risks identified in addition to typical construction activities.

5.4 Operation and Maintenance Procedures

5.4.1 Complete Visual Inspection Report

A field assessor will inspect the physical integrity of the backfilled and graded areas at the site. The inspection will be conducted using photographs, sketches, and other notes.

A field assessor will make observations of the presence or absence of visual items in the table below. Operation and maintenance features will be distinguished from one another as shown, meanwhile general observations will be distinguished from site specific risk observations by means of separate tables.

The General Visual Inspection Matrix was largely adapted from the ASMRP *Table 7.2*.

TABLE 12: GENERAL AEC 3 VISUAL INSPECTION MATRIX

Observation Parameter	Operational Feature	Maintenance Feature	Observations from Previous Report	Current Observations
Settlement	✓			
Erosion	✓			
Frost Action	✓			
Animal Burrows		✓		
Vegetation	✓			
Staining		✓		
Vegetation Stress	✓			
Seepage Points	✓			
Exposed Debris		✓		
Condition of Monitoring Instruments		✓		
Grades/ Topography	✓			
Distance to downgradient surface water bodies	✓			
Distance to freshwater/marine habitat and habitat usage	✓			
Terrestrial Habitat		✓		
Land Uses		✓		
Debris		✓		

Site specific risks will also be visually inspected for to the extent possible:

A field assessor is to take measurements of any feature noted. In subsequent years, A field assessor will compare all previously-identified features with current conditions. The field assessor will take photographs and make note of the location and direction of the photos so that they can be re-created in each year of the monitoring program.

Visual observations may be compiled in a table format.

5.4.2 Stability Assessment

Further to a Visual Inspection, the Stability Assessment serves to provide an analysis of the current AEC. The stability assessment was adapted from the AMSRP, although, the extents of the assessment protocol should only be limited to physical characteristics. The assessment will serve to analyze established risks. This will be done by comparing current observations to previous observations and/ or baseline conditions. From this comparison, appropriate severities and action levels will be concluded in following sections. Any additional risks identified should also be established in this section to be implemented for future operation and maintenance activities.

The Stability Assessment will include the following:

- A general interpretation of findings
- A comparison to between previous conditions and/or baseline conditions and as-built drawings
- Expected findings
- Any additional risks identified and its impact

Based on the above criteria, the severity of each observation should be established as part of the analysis. Tables in the following sections are for the evaluation of analyzed observations. Operational and Maintenance features are to be evaluated based on separate matrices.

5.4.3 Operation and Maintenance Severity Rating

The following tables are to be used for interpreting the severity level of operational features. This tables were largely adapted from *Table 4.1* of the AMSRP Volume 2. *Table 4* represents a *Severity Rating of Operation Features*, meanwhile *Table 5* represents *a Severity Rating for Maintenance Features*.

TABLE 13: SEVERITY RATINGS OF AEC 3 OPERATIONAL FEATURES

Severity Rating	Description
Not observed	No issues identified
Acceptable	Noted features are of little consequence. Performing as designed. Minor deviations may be observed, such as isolated areas of erosion or settlement.
Marginal	Physical/environmental surface grading performance appears to be deteriorating with time. Observations may include an increase in number or size of features of note, such as differential settlement, erosion or cracking.
Significant	Significant or potentially significant changes affecting site regrading such as significant differential settlement or water erosion features. Regrading is not consistent with remedial design.
Unacceptable	Significant settlement or erosion.

TABLE 14: SEVERITY RATINGS OF AEC 3 MAINTENANCE FEATURES

Severity Rating	Description
Not observed	No issues identified
Acceptable	Noted features are of little consequence. Minor deviations may be observed such as planned grading settlement.
Marginal	Physical/environmental performance appears to be deteriorating with time. Observations may include settlement or erosion

Severity Rating	Description
Significant	Significant or potentially significant changes such as significant settlement affecting permafrost, active layer or site water drainage.
Unacceptable	Backfilling and grading is not performing as designed.

5.4.4 Recommendations

Based on the analyses and perceived severity ratings, a set of recommendations for each operation and maintenance activity will be given. The following action matrix below which was adapted from the ASMRP will be used as guide for creating recommendations. Once the severity of observations is established, recommendations should be further elaborated on, either in the current section, or as part of a separate document as seen appropriate.

Action levels are to be separated into unique sections for operational and maintenance features.

TABLE 15: ACTION LEVELS FOR AEC 3 MONITORING

Severity Rating	Action
Not observed	Monitoring to continue as planned
Acceptable	Monitoring to continue as planned
Marginal	Analyze potential causes of instability. Continue monitoring plan with any potential recommendations for future operation and maintenance.
Significant	Assess current and future impact to implemented remedial works, develop a remedial plan.
Unacceptable	Develop and Implement a site-specific remedial plan (in coordination with the LTM).

6 Spills & Discharges - Contingency & Emergency Response Plan

This section is intended to describe the measures to be used to prevent, warn of, prepare for, respond to, and recover from any emergency that may cause harm to the environment or danger to human life or health. As a result, DOJV has prepared a Spills Discharge Contingency and Emergency Response Plan.

Planning for an emergency is imperative due to the remoteness of the site.

To prevent any spills or discharges, the following procedures will be followed by on-site personnel during the Monitoring Program:

- Ensure staff are familiar with regulations
- Always ensure equipment is shut 'Off' when not required
- Seal all outlets of fuel storage containers
- Ensure there is no smoking or open flames in the vicinity
- All equipment that may be parked for two hours or more, will have a haz-mat/drip tray under it or be sufficiently diapered
- Leaky equipment shall be repaired immediately
- Report any spills immediately to the site lead
- No fueling on-site

The flow chart depicted in *Figure 3* identifies the response. An immediately reportable spill (Major Spill) is defined as a release of a substance that is likely to be an imminent environmental or human health hazard or meets or exceeds the maximum volumes. It must be reported to the Nunavut 24-Hour Spill Report Line at 867-975-8130. Any spills less than these quantities (Minor Spill) will be tracked and documented by DOJV. Information about minor spills will be communicated to the project management team during monthly reports and immediately upon request of an Authority Having Jurisdiction. In all cases, discussions with the Project Team will be initiated to confirm and document the level of effort required.

Following reporting of the spill to the Project Lead, the Project Lead will report spills to the NWT 24-Hour Spill Line as necessary.

The emergency procedure for initial actions, that will be followed, are listed as:

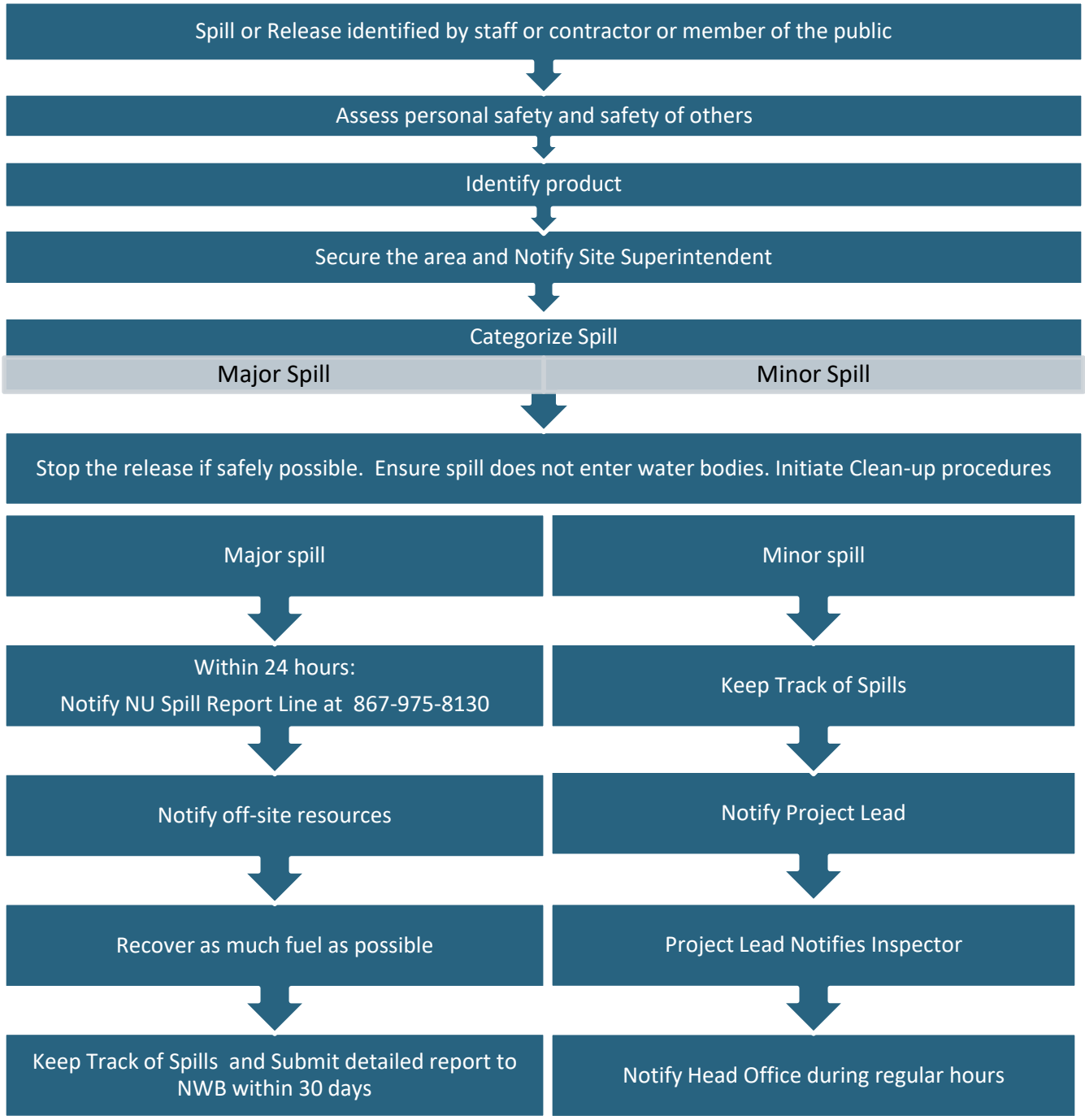
- Ensure safety of all personnel
- Wear appropriate PPE
- Assess spill hazards and risks
- Remove all sources of ignition
- Stop the spill if safely possible e.g. shut of pump, replace cap, tip drum upward, patch leaking hole. Use the contents of the nearest spill kit to aid in stopping the spill if it is safe to do so
- No matter what the volume is, notify the Project Lead

- Contain the spill – use contents of spill kits to place sorbent materials on the spill, or use shovel to dig dike to contain spill. Methods will vary depending on the nature of the spill

Procedures for Containing and Controlling a Spill

- Initiate spill containment by first determining what will be affected by the spill.
- Assess speed and direction of spill and cause of movement (water, wind, and slope).
- Determine best location for containing spill, avoiding any water bodies.

FIGURE 3: FLOW CHART OF RESPONSE ORGANIZATION



7 Monitoring Plan

The schedule, data collection and reporting for Operations & Maintenance and Long-Term Monitoring (provided under separate cover) will work in conjunction to create the Monitoring Program. The Operations and Maintenance activities will serve to observe and analyze physical parameters related to site operations, whereas, the Long Term Monitoring Plan will serve to provide an overall evaluation including the analysis of Water Quality (chemical) parameters.

The proposed Monitoring Program schedule is that monitoring will be conducted in years 1, 3, 5, 7, 10, 15, 20 and 25. Monitoring can be scheduled after year 10 as deemed necessary; however, the current LTM duration is assumed to be 25 years. The actual inspection years may vary slightly. The LTM is scheduled to begin in 2020.

The main purpose of the proposed program is to ensure no contamination pathways are observed following the implemented designs. Additionally, it must be confirmed that adequate permafrost aggregation in the AEC 1 landfill is present, and that the function of the two landfills meet design intents in terms of stability.

As such, the Monitoring Plan will focus on two main parameters:

1. Water Quality – Reported as part of the Long Term Monitoring Plan
2. Site Stability – Reported as part of the Operations and Maintenance Report

For site stability, observational parameters are to be analyzed immediately for variances from as-built drawings and compared accordingly. Recommendations will be summarized in the Operations and Maintenance Report, and categorized by specific AEC, as outlined in the O&M manual.

Due to the remote nature of the site, method and frequency of the O&M activities will work in conjunction with the Long-Term Monitoring Plan and any Remedial Plans that have been developed.

Monitoring is scheduled to commence in 2020. This visit will prioritize data collection for baseline conditions following remedial works, as well as the observation of differential landfill cap settlement.

7.1 Water Quality

The following section outlines the required water quality testing parameters as per the NWB Amended Renewal Water License No. 1BR-RBL-1929. The following is a summary of the current testing parameters and monitoring wells that have been installed at each AEC with the associated discharge point nomenclature. For more information on the sampling methods, effluent quality limits, action levels, and general requirements for chemical parameters, please refer to the Long Term Monitoring Plan.

7.1.1 Testing Parameters:

As per the Water License, the following chemical parameters will be tested as shown below, at locations outlined in Section 7.1 *Monitoring Wells*.

- pH
- Total Suspended Solids (TSS)
- Nitrate – Nitrite
- Total Phenols

- Total Hardness
- Sodium
- Magnesium
- Chloride
- Total Copper
- Total Iron
- Total Mercury
- Total Zinc
- Total Aluminum
- Total Cobalt
- Polycyclic Aromatic Hydrocarbons (PAH)
- Benzene, Toluene, Ethylbenzene, Xylene (BTEX)
- Conductivity
- Ammonia
- Nitrogen
- Oil and Grease (visual)
- Sulphate
- Total Alkalinity
- Potassium
- Calcium
- Total Cadmium
- Total Chromium
- Total Lead
- Total Nickel
- Total Phosphorous
- Total Manganese
- Total Arsenic
- Total Petroleum Hydrocarbons (TPH)

7.1.2 AEC 1 Monitoring Wells

The following monitoring wells have been installed at AEC1:

TABLE 16: AEC 1 MONITORING WELL LOCATIONS

Well ID	Northing	Easting	Elevation	AEC	Description
RBL-1	8295630	441147	66.2	AEC 1	Monitoring Well installed up-gradient of the Solid Waste Landfill
RBL-2	8295551	440943	52.2	AEC 1	Monitoring Well installed down-gradient of the Solid Waste Landfill
RBL-3	8295608	440901	51.5	AEC 1	Monitoring Well installed down-gradient of the Solid Waste Landfill

Well ID numbers are as per NWB Amended Renewal Water License No. 1BR-RBL-1929. In the event there is a discharge from AEC 1, a monitoring well with the well ID RBL 4 is to be installed at the discharge point and daily discharge volumes are to be recorded as per the Water License.

The X,Y,Z coordinates are represented under UTM Zone 15N and are confirmed by survey method.

7.1.3 AEC 2 Monitoring Wells

The following monitoring wells have been installed at AEC1:

TABLE 17: AEC 2 MONITORING WELL LOCATIONS

Well ID	Northing	Easting	Elevation	AEC	Description
RBL-5	8292509	441662	53.1	AEC 2	Monitoring Well installed up-gradient of the Historic Landfill
RBL-6	8292566	441420	42.7	AEC 2	Monitoring Well installed down-gradient of the Historic Landfill

RBL-7	8292634	441384	43.2	AEC 2	Monitoring Well installed down-gradient of the Historic Landfill

Well ID numbers are as per NWB Amended Renewal Water License No. 1BR-RBL-1929. In the event there is a discharge from AEC 2, a monitoring well with the well ID RBL 8 is to be installed at the discharge point and daily discharge volumes are to be recorded as per the Water License.

The X,Y,Z coordinates are represented under UTM Zone 15N and are confirmed by survey method.

7.1.4 AEC 3 Monitoring Wells

The following monitoring wells have been installed at AEC1:

TABLE 18: AEC 3 MONITORING WELL LOCATIONS

Well ID	Northing	Easting	Elevation	AEC	Description
RBL-10	8296242	440493	43.8	AEC 3	Monitoring Well installed up-gradient of the Vehicle Storage Area (Site 1)
RBL-11	8296265	440383	41.6	AEC 3	Monitoring Well installed down-gradient of the Vehicle Storage Area (Site 1)
RBL-12	8296335	440450	42.6	AEC 3	Monitoring Well installed down-gradient of the Vehicle Storage Area (Site 1)
RBL-14	8296449	440682	55.4	AEC 3	Monitoring Well installed up-gradient of the Vehicle Storage Area (Site 2)
RBL-15	8296468	440635	52.7	AEC 3	Monitoring Well installed down-gradient of the Vehicle Storage Area (Site 2)

Well ID numbers are as per NWB Amended Renewal Water License No. 1BR-RBL-1929. In the event there is a discharge from AEC 3 – Site 1, a monitoring well with the well ID RBL 13 is to be installed at the discharge point. In the event there is a discharge from AEC 3 – Site 2, a monitoring well with the well ID RBL 16 is to be installed at the discharge point and daily discharge volumes are to be recorded as per the Water License.

The X,Y,Z coordinates are represented under UTM Zone 15N and are confirmed by survey method.

7.2 Site Stability

As a requirement for the Renewal Water License Renewal No. 1BR-RBL-1929, site stability will be analyzed as part of the Monitoring Program. Site stability should be broken out by AEC and analyzed as outlined in the Operations and Maintenance Manual's sections 3 through 5. *Figure 1* of this Document outlines the general procedures for analyzing site stability.

7.3 Thermal Monitoring

Thermal monitoring is to be used in order to measure ground temperatures at AEC1 where the design basis for the landfill cover included the use of permafrost aggradation to lower the permeability of the soil fill, thereby reducing infiltration. There are no thermistor requirements in AEC 2 or AEC 3 as permafrost aggradation did not form part of the design basis for the remediation of these areas. As such, thermistors should be installed in multiple locations on-site to track the aggradation of permafrost in order to create a profile for ensuring uniform aggradation. It is predicted that the 3H:1V slopes will

have very little snow cover and hence have a much higher permafrost aggradation in comparison to the landfill cap, due to the insulating properties of snow. It is proposed to install three (3) thermistors at AEC 1, in the general configuration depicted in the plan drawing including in Appendix A. This method of installation will provide adequate spatial distribution and provide adequate instrumentation such that if one thermistor ceases to function, there will still be data available for analysis.

A baseline permafrost aggradation prediction for the AEC 1 landfill has been created based on a simple mathematical model based on the Stefan Equation. The model is as summarized in "A simple heat-conduction method for simulating the frost-table depth in hydrological models" (Hayashi, Goeller, Quinton, & Wright, 2007). The equation is shown below:

$$z(m) = \left[\frac{2n\lambda_b t T_{av}}{\rho f L}\right]^{1/2}$$

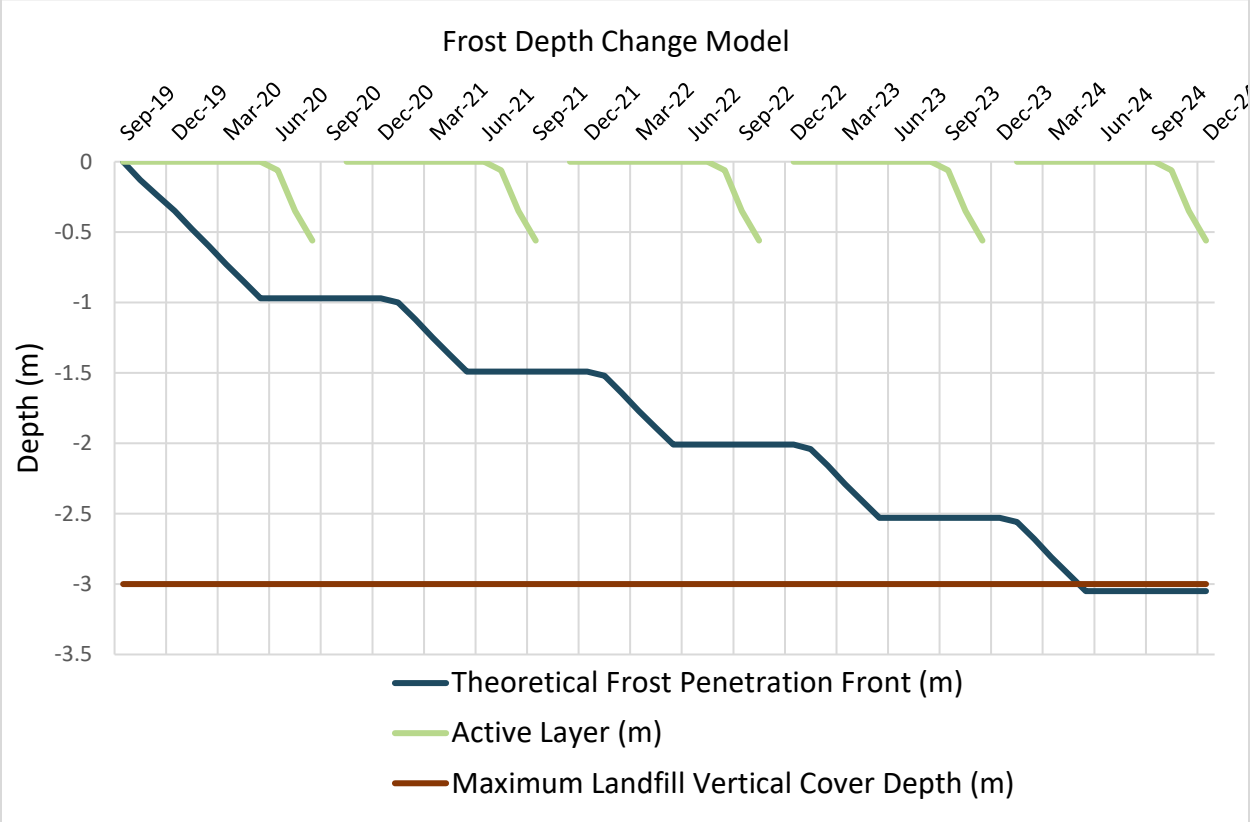
Where:

$$z = \ Depth\ of\ Permafrost\ (m)$$
$$\lambda_b = Thermal\ Conductivity\ \left(\frac{W}{m\ K}\right)$$
$$t = \ Eplasted\ Time\ (s)$$
$$\rho = Density\ of\ Ice\ (\frac{kg}{m^3})$$
$$f = Volumetric\ Fraction\ of\ Ice\ in\ Frozen\ Soil$$
$$L = Latent\ Heat\ of\ Fusion\ (\frac{Wx\ s}{kg})$$
$$T_{av} = Average\ Temperature\ ^\circ C$$
$$n = Ground\ Temperature\ to\ Air\ Temperature\ Factor$$

The following assumptions/ values were made for inputs to the model:

- Thermal conductivity of 0.37 $\left(\frac{W}{m\ K}\right)$ was used, based on a weighted average of 0.3 $\left(\frac{W}{m\ K}\right)$ for Type 1 and 0.4 $\left(\frac{W}{m\ K}\right)$ for Type 2.
- Ice density of 997$(\frac{kg}{m^3})$
- Volumetric fraction of ice in frozen soil of 0.2 based on sieve analyses and field reports of rain records
- Latent heat of fusion of 334,000 $(\frac{Wx\ s}{kg})$
- Average Temperature during freezing cycles of -1$^\circ C$ based on a conservative estimate of the insulating factors of snow
- Ground temperature to air temperature factor of 3, based on a conservative estimate of the summertime radiation effects in the arctic region.

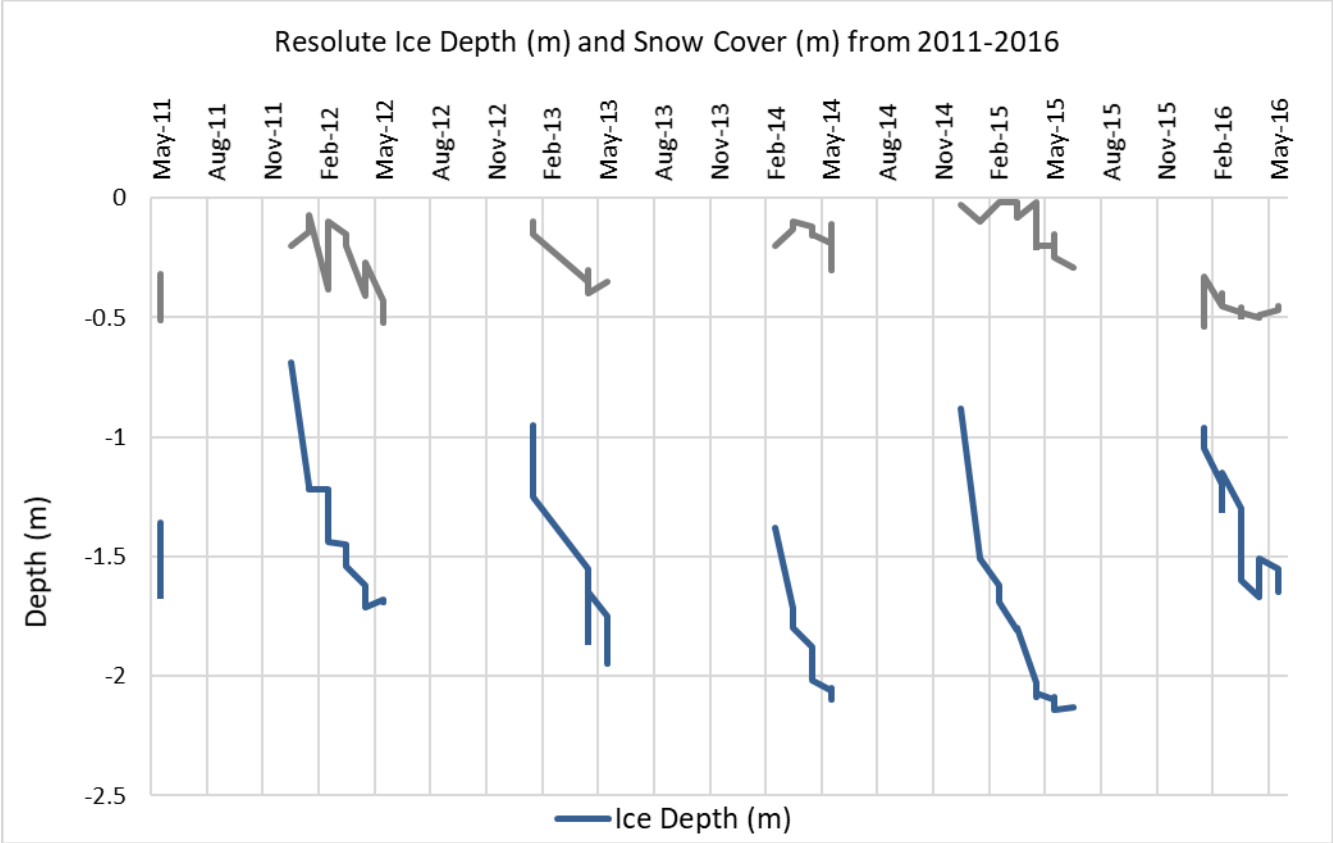
FIGURE 4: **PERMAFROST AGGRADATION MODEL**



It should be noted that the average permafrost maximum depth between data retrieved between 2011 and 2015 was found to be 1.95m in depth. As such a lower limit for the model was set to this value. Furthermore, empirical data from test pitting was incorporated to this model. The average test pit depth from previous on-site test pitting outlined in the Phase 3 Site Assessment identified 5 test pits in AEC 1 with an average active layer of 0.56m in depth before permafrost was encountered. An upper bound for permafrost was established based on this data.

Historic ice thickness and snow cover was analyzed during the baselining of the model. Results from May 2011 to May 2016 are depicted in Figure 5.

FIGURE 5: RESOLUTE ICE DEPTH (M) AND SNOW COVER (M) FROM 2011-2016



Monthly predictions of permafrost aggradation were generated using Environment and Climate Change Canada historic weather station data of the Resolute. As stated previously, a conservative correlation was made between air temperature and ground temperature for cases above $0^{\circ} C$. The model was then cross referenced with the historic ice thickness data in the figure above to provide confidence. Upon the presence of thermistor data for ground temperatures, more accurate calibrations of the model can be made.

Based on the analysis of data, it is proposed that a thermistor minimum depth of 3m be used to collect ground temperatures over time to verify the permafrost aggradation formation.

7.4 Field Equipment

For each piece of field equipment, the field assessor will note instrument type and model number in the field notes. Each piece of field equipment will be traceable and identifiable with a unique name or number, so that any equipment errors not noted in the field can be traced after the fact.

A field assessor will maintain calibration records for all equipment requiring calibration. Instrument inspection and maintenance records (whether internal or provided by an equipment supplier) will be retained and referenced where necessary.

7.4.1 Thermistors

Thermistors are comprised of several temperature sensor nodes along a "string". This string is cased by a PVC pipe and grouted. Node depths are documented prior to install, and temperature readings taken from a portable readout unit. Once readings are taken, node depths can be correlated with temperature readings to deduct the presence of permafrost. Data loggers are to be programmed to take temperature readings at regular intervals of several times an hour. These readings are recorded in the data logger which can be downloaded during the LTM site visits. These results are to be charted and analyzed along with other data collected as part of the long-term monitoring (LTM) program.

The field assessor is to collect data from each thermistor during the LTM site visit and document the following:

- Thermistor ID
- String No.
- String Depth (m)
- Data collection from Data Logger (temperature readings over time)
- Date and time of Data Collection

All thermistor readings should be accompanied by a photograph and included in an appendix labeled "Photographic Records". Field notes will also be included in a separate appendix labelled: "Handwritten Field Notes".

Thermistors will all require an isolated battery source such as a car battery during continuous operation. These batteries are to be charged or replaced as required during the monitoring program.

8 Reporting Procedures

8.1 Annotated Drawings on Tabloid Paper, indicating all visual inspection features

For each site visit, annotated drawings on tabloid paper should indicate all noteworthy features identified. Annotations shall include the following information:

- Approximate 3D position (in table format)
- Reference to relevant photos
- A unique identifier or point number

8.2 Photographic Records

For documentation of on-site photos, the photo log template from Appendix C is to be used. The following will ensure that the following are captured:

- Area of Environmental Concern

- Provide a Unique Identifier

- Description

- Photo Direction

- Date

See *Appendix C* for a Photo Log Template.

All photos should be included in a separate appendix when compiling future Operation and Maintenance Reports.

Any noteworthy observations should also have approximate GPS locations for inclusion in the section “Annotated Drawings on Tabloid Paper, indicating all visual inspection features”.

9 References

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10 Closure

This report was prepared exclusively for the purposes, project, and site location outlined in the report. The report is based on information provided to, or obtained by Dillon-Outcome as indicated in the report, and applies solely to site conditions and the regulatory and planning frameworks existing at the time of the site supervision Dillon-Outcome's report represents a reasonable review of available information and environmental monitoring efforts within an established work scope and schedule.

This report was prepared by Dillon-Outcome for the sole benefit of our client. The material in it reflects Dillon-Outcome's best judgment in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibilities of such third parties. Dillon- Outcome accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

We trust that this information is satisfactory for your requirements.

Sincerely,

DILLON-OUTCOME JOINT VENTURE

Mark Mathews, B.Eng
Junior Professional

Steve Livingstone, M.Sc., P.Geo
Senior Professional

Michael Billowits, MSc.(Eng), P.Eng.
Engineer of Record
President, Outcome Consultants Inc.

Appendix A

Proposed Thermistor Locations at AEC1

AEC 1 – SOLID WASTE LANDFILL

STEPPED FRACTURED BEDROCK AREA

FRACTURED BEDROCK AREA

ROAD TO FENCED-IN AREA

BURIED ASBESTOS PILES

CONTAINER STORAGE

SEA CONTAINERS

ACCESS ROAD

SEWAGE INLET

SEWAGE LAGOONS

FRACTURED BEDROCK AREA

THRMS–01

THRMS–02

THRMS–03

2%

2%

2%

51.5 52 52.5 53 53.5 54 54.5 55 55.5 56 56.5 57 57.5 58 58.5 59 59.5 60 60.5 65 65.5

0 20 40 Meters

Thermistor Coordinates		
Thermistor ID	Northing	Easting
THRMS–01	8295589.44	440966.89
THRMS–02	8295606.84	441054.99
THRMS–03	8295577.43	441013.96

Public Works and Government Services Canada
Travaux publics et Services gouvernementaux Canada

Notes:
1. Adapted from Preliminary Design prepared by Arcadis Baker Inc. on behalf of Public Works & Government Services Canada (March 2018)

LEGEND:
- 0.25m Topographic Contour
- 0.50m Topographic Contour
- 1.0m Topographic Contour
- 5.0m Topographic Contour
- 65.5 Topographic Elevation (approx. metres above sea level)
- Road
- Thermistor

DILLON CONSULTING

outcome CONSULTANTS

PROFESSIONAL SEALS

DO NOT SCALE DRAWINGS

04		
03		
02		
01		
revision		date

Do not scale drawings. Verify all dimensions and conditions on site and immediately notify the Departmental Representative of all discrepancies.

A/B/C A Detail No. No. de détail; drawing no. – where detail required dessin no. – au détail exige
B drawing no. – where detailed dessin no. – au détaillé
C

project title titre du projet
RESOLUTE BAY NUNAVUT
PWGSC for TRANSPORT CANADA

REMEDIATION OF RESOLUTE BAY AIRPORT LANDFILLS

drawing title dessin
AEC1 THERMISTOR LOCATIONS

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Appendix B

Design Tables

The tables in this section were adapted from "RBL Design Development Summary Table".

TABLE 1: AEC 1 DESIGN DEVELOPMENT FEATURES AND RISKS

Date/ Approximate Timeline	Discussion Participants	Design Feature	Description of Design Issue	Rationale/Outcome
October 2013 - Various	Discussions between Arcadis/Senes, TC, PWGSC	Capping landfill option: granular material cap design promotes permafrost encapsulation of existing former landfills and an accepted industry design for arctic environments. Aggregate material used for final cover. Cover thickness must be thicker than active layer. Anticipated minimum landfill thickness is 1.0 m. Active layer thickness primarily influenced by air temperature, and soil moisture content. Major factors that affect these two main factors at the site are snow cover duration, topographical aspects to sun exposure, surface temperature, wind, surface drainage and sewage lagoon overflow.	Franz /Senes identifies potential concerns of omission of "liner" based on interpretation of historical approval and application documentation (i.e. a regulatory not a technical issue). Concern generates further discussion to evaluate cap design option requirement and whether current design is compliant with Approval.	TC clarifies and evaluates benefit of liner with Consultant assistance. Based on comparison of aggregate material vs aggregate material plus full cover liner. It is PWGSC's understanding that TC considers the aggregate capping option, more cost effective to implement and maintain, and represents a more sustainable solution.
October 2013 - Various	Arcadis/Senes, TC, PWGSC Internal Arcadis/Senes discussions to evaluate liner recommendation to client.	Capping option of landfill: granular cap and HDP (geomembrane) liner that covers entire landfill area. HDP liner design enhances surface water drainage concerns, and mitigates leachate production by preventing percolation of water into landfill.	Franz /Senes identifies potential concerns of omission of "liner" based on interpretation of historical Approval and application documentation. Concern generates further discussion to evaluate if design component is a valid requirement and compliant with Approval. Evidence of detectable concentrations of lead above guidelines suggests the presence of buried lead amended paint waste in the landfill AEC 1.	TC/PWGSC discussions with consultant to clarify technical benefit, concluded cost to implement out-weighs technical benefit to meet remediation goal given granular cap and limited geotextile coverage option, with drainage mitigation work is a viable design option that meets remediation goals. Arcadis/Senes recommends the development of a risk management plan to address sediment and surface water impacts at the site, if a liner is not to be considered in scope by TC. Similarly the development of a long term monitoring plan.4 Neither recommendations have been implemented to date.
September 2014	Arcadis/PWGSC/ TC Discussions with AANDC Water Resource Enforcement Officer and Internal Memo (PWGSC-Franz)	Capping option of landfill: Geomembrane liner that covers entire landfill area.	PWGSC and consultant attended a September meeting with AANDC water resources inspector to outline TC remediation plan. AANDC raised concerns about some of the design aspects regarding a landfill liner, thermal monitoring, and methane collection. The	PWGSC requests TC to seek clarification, as this is identified as a project risk from contractual perspective with significant cost ramifications.

Date/ Approximate Timeline	Discussion Participants	Design Feature	Description of Design Issue	Rationale/Outcome
	GN Engineer responsible for sewage lagoon also present.		inspector disagrees with Water Board approval decision.	
2014	Arcadis/PWGSC/TC	Thermistor monitoring network: confirms that permafrost encapsulation in place by monitoring ground temperature fluctuations surrounding landfill to ensure encapsulation of landfill waste	Thermistor monitoring system recommended to monitor permafrost encapsulation. A technical review memorandum issued July 19, 2011 by the AANDC water resources, Nunavut regional office supported the licence application request and recommended the development of a detailed monitoring program that included thermal monitoring. It is PWGSC/TC's understanding that this is a recommendation outlined in an AANDC Water Resources technical review memorandum of the application, not a requirement.	PWGSC/Consultant recommends client remove this monitoring recommendation or confirm if there is a licence requirement. TC agrees with this recommendation. The status of this potential design requirement is unknown at the time this document was developed.
January 2018	DOJV/PSPC/TC	AEC-1 Main Landfill Side Slope Design Changes: Change in approach to crush/place wastes at toe of AEC-1 Main landfill	The original design called for loose wastes to be excavated at the toe, transported to the top, cut/crushed and then placed back at the toe. It is difficult for the contractor to estimate level of efforts verses a simple cut and fill method.	Using a cut/fill method for managing the 22,795m3 of slope side wastes will allow for wastes to be cut from the top and compacted in place, minimizing safety and environmental protection concerns associated with excavating and transporting such a large volume of wastes. The cut/fill approach will reduce the fill volumes that would be required to achieve a stable 3h:1v slope, thereby reducing the expected increase of AEC-1 footprint.
January 2018	DOJV/PSPC/TC	AEC-1 Main Landfill Cap Design Changes: Removal of coarse aggregate materials on top and increased thickness of fine aggregates	The aggregate cover is to prevent contact with the wastes by flora, fauna and humans and minimize water infiltration through permafrost aggradation. Any aggregate material can be placed to eliminate contact with wastes, however saturated fine aggregates are required to promote permafrost aggradation	A sufficiently high degree of saturation of the barrier layer below the active zone is required to maintain the reduced infiltration capacity (voids within soil profile filled with ice once frozen). Fine-textured soils preferred since they have higher capillary suction and field capacity (water content of a soil when gravity drainage ceases) The previous cover design will be updated to remove the separate 'bedding sand' and a 'fine fill' aggregate layers and to replace this with 'Type 2' material (same as fine fill) and spec will be updated for compaction and moisture addition To saturate the cover the contractor will need to source water from off-site as presently the Water License does not allow for the use of water, which is presently restricted.

Date/ Approximate Timeline	Discussion Participants	Design Feature	Description of Design Issue	Rationale/Outcome
January 2018	DOJV/PSPC/TC	AEC-1 Main Landfill Cap Design Changes: - Change in aggregate gradations for coarse fill	Coarse Aggregate gradation in specification had too high of a % of fines that could complication Contractors ability to meet the requirement and is ill-suited for coarse fill erosion control features (side slope, swales, etc.)	A 'coarse fill' surface layer is only necessary on the side slopes and within 10 m of the landfill crest where erosion is more likely (not required on the landfill top with just 2% grade) Proposed to use an industry standard 'Type 1' Fill Sieve (mm) % Pass by Weight 300 100 150 40 to 80 50 0 The side slopes would be covered with 0.8m fine aggregate "Type 2" layer, overlaid by a 0.3m Type 1 fill. The combined thickness of 1.1m matches the previous design thickness but removes the "Bedding Sand" layer and increases the Type 1 fill layer to 0.3m which the smallest thickness that can be obtained with 300-mm minus aggregates. The same Type 1 fill would be used for swales and erosion protection.

TABLE 2: AEC 2 DESIGN DEVELOPMENT FEATURES AND RISKS

Date/ Approximate Timeline	Discussion Participants	Design Feature	Description of Design Issue	Rationale/Outcome
2010 Resolute Bay Landfill Project transferred from ES Pacific Region to ES Western Region for 2011-12 Fiscal year.	TC Superintendent for Contaminated Sites, Darryl Pederson	Recoverable metal waste to be shipped south for recycling. Exposed waste to be covered, Surface solid waste to be consolidated into AEC 1. Drainage and geotechnical mitigation work carried out at AEC 1 and 2. Referred to as Option 3 in March 2010 Franz Phase II/III ESA (Also referred to as 2010 ESA Report) [1]	Remediation goals are to remove physical hazards (slope stabilization, debris), consolidation of waste and scattered debris, and containment and control of contaminants in the surface water pathways prior to leaving the site and discharging to receiving water bodies. [1]	Anecdotal information from M Molinski indicates TC Superintendent for Contaminated Sites, Darryl Pederson approved Option 3: Off-Site Recycling and Disposal of Waste at Solid Waste Landfill AEC 1. No TC records available for rationale. Anecdotal information suggests decision for Resolute Bay Landfill remediation solution based on March 2010 Franz Phase II/III ESA (2010 ESA Report) information provided in Conceptual Remedial Or Risk Management Action Plans Section of report which supports this option.
2011-12	TC, PWGSC, Franz Environmental	At AEC 2 (Option 2& 3 Table 10.1 in 2010 ESA Report[1]) removal of hazardous waste for off-site disposal will be limited to accessible waste exposed at or near surface. Surface waste debris to be removed and transferred to AEC 1. Subsequently re-engineer for closure and re-capping where required. At AEC 1 (Option 2& 3 Table 10.1 in 2010 ESA Report[1]) will receive surface debris from AEC 2 and 3. Subsequently to be re-engineered to mitigate geotechnical hazards for continued operation. No surface water management options are required for any AECs at the site.	Additional Data Gap work undertaken and results can be found in the December 10, 2013 Data Gap and Geotechnical Assessment, Resolute Bay Airport Landfill, Nunavut by Franz Environmental/Senes. PWGSC identified need for Remediation Action Plan (RAP) in order to develop specifications and provide revised cost estimates associated with remediation program.	Email from PWGSC to TC outlines TC design specification requirements and receives confirmation from TC Feb 16, 2012. No records available for TC managerial decision to support TC Project Manager rationale or directive. Based on the decision above, an informal Remedial Action Plan (RAP) was developed. The RAP was based on Option 3, and PWGSC and TC consultation with Franz to confirm correct technical details and sequence of tasks referenced in RAP.

Date/ Approximate Timeline	Discussion Participants	Design Feature	Description of Design Issue	Rationale/Outcome
January 2018	DOJV/PSPC/TC	AEC-2 Historical Landfill Design Changes: Cut/Fill with no cap	The present design indicates that the top and slope be graded using a cut/fill approach with aggregates used to fill in voids or low spots on the top to promote surficial flow. Cutting the slope or top could unnecessarily expose wastes or reduce the current active layer causing permafrost degradation.	

TABLE 3: AEC 3 DESIGN DEVELOPMENT FEATURES AND RISKS

Date/ Approximate Timeline	Discussion Participants	Design Feature	Description of Design Issue	Rationale/Outcome
2011-12	Mike Molinski (TC), Natalie Robinson (PWGSC), Franz Environmental	New landfill construction as close as possible to AEC 1 and AEC3. Surface waste materials would be placed in engineered landfill and covered, with geotextile (or equivalent), soil and if possible re-vegetated. (2010 ESA Report)	Conceptual design option presented in 2010 ESA report, based on remediation goals to remove physical hazards (slope stabilization, debris), consolidation of waste and scattered debris, and containment and control of contaminants in the surface water pathways prior to leaving the site and discharging to receiving water bodies	Anectodal information from PWGSC. PRO- good environmental stewardship, construction of landfill built to modern day standards to minimize future environmental impacts to environment CON – Extra barges would be required to handle significantly large volume of waste. Investigation of engaging barges outside of scheduled sailing times were identified to be significantly cost prohibitive, and likely could only be done cost effectively as joint venture with Govt. Nunavut (who lack funds). In addition to administrative burden to arrange joint funding between territorial and federal agencies. High likelihood, all hazardous waste could not be shipped out in one year, resulting in interim storage measures required to mitigate potential impact to environment, and health and safety concerns with potentially exposed hazardous waste. Most costly solution and not considered viable option. No records available for TC rationale.
2011-12	TC, PWGSC, Franz Environmental	Refined design included: At AEC 3 (waste metal storage areas) (Option 2& 3 Table 10.1 in 2010 ESA Report[1]) off-site recycling of selected metal debris and remaining waste to be transported to the AEC 1 (Solid Waste Landfill) to be consolidated with existing waste at this landfill. Impacted soil from AEC 3 to be transferred to existing TC Resolute landfarm.	Additional Data Gap work undertaken and results can be found in the December 10, 2013 Data Gap and Geotechnical Assessment, Resolute Bay Airport Landfill, Nunavut by Franz Environmental/Senes. PWGSC identified need for Remediation Action Plan (RAP) in order to develop specifications and provide revised cost estimates associated with remediation program.	Email from PWGSC to TC outlines TC design specification requirements and receives confirmation from TC Feb 16, 2012. No records available for TC managerial decision to support TC Project Manager rationale or directive. Based on the decision above, an informal Remedial Action Plan (RAP) was developed. The RAP was based on Option 3, and PWGSC and TC consultation with Franz to confirm correct technical details and sequence of tasks referenced in RAP.

Date/ Approximate Timeline	Discussion Participants	Design Feature	Description of Design Issue	Rationale/Outcome
2012	Mike Molinski (TC), Natalie Robinson (PWGSC), Franz Environmental	Metal recycling transportation and disposal. Option 1 considers the use of sea containers in the transportation of the metal south to an approved recycling facility. Option 2 involves crushing and bundling the metal to avoid the use of sea containers to transport the metal south to an approved recycling facility.	Recycling Feasibility Study based on cost recovery model to recycle high value metals present at site.	PRO- Recover costs by recycling non-hazardous waste at site. CON- Associated cost for level of effort is significantly greater than recycling recovery cost for 2012 known volumes. Risks associated with shipping due to weather could result in high but difficult to quantify costs. Unable to quantify added value of public perception and environmental stewardship but unlikely to outweigh net cost for this item.[3] PWGSC evaluates risk as high for shipping delays based on past experience with Arctic projects. In 2014, PWGSC discussions with contracting department identified potential liability associated with renting containers if not returned decontaminated. It was understood by PWGSC that TC considers recycling cost prohibitive. No records available for TC managerial decision to support TC Project Manager rationale or directive.

Appendix C

Field Template

TEMPLATE 1: PHOTO LOG TEMPLATE

Insert Photo	**Photo AEC and Point** Example: “AEC1-1” (For non- AEC’s, use “General”) **Date** Example: December 12, 2019 **Description** Example: “Sediment Runoff Observed at East AEC1 Slope” **Viewing Direction** Example: “NE”

Alternatively, embedding the date and viewing directed on the photo is acceptable. A description and photo point using the Photo Log Template would still be required.