PUBLIC SERVICES AND PROCUREMENT CANADA
ENVIRONMENTAL SERVICES – WESTERN REGION

Post-Closure Monitoring Plan for the Resolute Bay Airport Landfill, Resolute Bay, Nunavut

PSPC Project R.112072.001

Final Report

R.1	December 2020	Number of thermistors revised

December 2020 DOJV Project No. P2020-21

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 a Post-Closure Monitoring Plan 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 and Amended Renewal Water License (WL) 1BR-RBL1929.

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 Inactive Solid Waste Landfill (AEC 1), Historical Landfill (AEC 2), and the Former Vehicle and Waste Metal Storage Area (AEC 3).

Site remediation took place over a two-year period from 2018 to 2019. The remedial tasks completed 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.

As of the creation of this report, the remediation is completed, post-closure monitoring, also known as long-term monitoring (LTM) will now begin. The goal of this LTM Plan is to ensure that present and future risks to human health and the environment from the site conditions post-remediation are negligible and that monitoring, at some point in the future, could be terminated with confidence, based on findings of no risk and no depreciation of the site's environmental status. The LTM Plan will be implemented post-closure to evaluate the sustained effectiveness of the remediation.

The LTM plan consists of specific monitoring elements, with descriptions of methodology and action levels based on observed impacts that may lead to further action or the cessation of LTM. The elements of the plan are as follows:

- Natural environment monitoring to assess trends in the use of the site by wildlife;
- Visual monitoring of landfill covers to assess performance and any signs of instability or potential risk of failure;
- Groundwater monitoring to address the potential for leaching of material from landfills;
- Surface water/seep monitoring to address the potential for surface drainage impacts from the landfills; and

- Thermal monitoring to track and confirm permafrost aggradation in the AEC 1 landfill cap.

The Nunavut Water Board (NWB) approved the LTM plan in late October 2020. The plan has been re-assessed with respect to the thermistors required to monitor permafrost aggradation at the Inactive Solid Waste Landfill (AEC 1), and the number recommended has been revised from five (5) to three (3). The relevant sections and figures in this version of the LTM plan have been updated accordingly.

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1.0 Introduction

Dillon Consulting Ltd. and Outcome Consultants Inc in joint venture (DOJV) were contracted by Public Services and Procurement Canada (PSPC) Environmental Services on behalf of Transport Canada (TC) as former site owner, to develop a Post-Closure Monitoring Plan for the Resolute Bay Airport Landfill site.

Site remediation was completed over a two Government of Canada fiscal-year (FY) period, FY 2018-2019 and FY 2019-2020. Field activities for FY 2018-2019 began August 14 and ended September 17, 2018. Remedial work which occurred in 2018 included consolidating and packaging hazardous materials, shipping hazardous waste to a licensed waste disposal facility, consolidating non-hazardous waste to the AEC 1 landfill, grading the AEC 1 slope, and preparing borrow sources. All remaining remediation work was completed in the summer of 2019 and included shipping hazardous material offsite, consolidating steel from AEC 2 to AEC 1, stabilizing landfill slopes, aggregate cover development and placement, constructing drainage swales, removing contaminated soil from AEC 3, capping AEC 1 and AEC 2 with gravel, and installing wells for groundwater monitoring.

This post-closure monitoring plan is based on the format outlined in the Federal Contaminated Sites Action Plan (FCSAP) document *FCSAP Long-Term Monitoring Planning Guidance* (Ministers of Fisheries and Oceans Canada, Environment Canada, and Health Canada, 2013).

The Nunavut Water Board (NWB) approved the LTM plan in late October 2020. The plan has been re-assessed with respect to the thermistors required to monitor permafrost aggradation at the Inactive Solid Waste Landfill (AEC 1), and the number recommended has been revised from five (5) to three (3). The relevant sections and figures in this version of the LTM plan have been updated accordingly.

1.1 Objectives of the LTM Plan

The goal of the long term monitoring (LTM) Plan is to ensure that present and future risks to human health and the environment from the site conditions post remediation are negligible and that monitoring, at some point in the future, could be terminated with confidence, based on findings of no risk and no depreciation of the site's environmental status.

The LTM Plan will be implemented post-closure to evaluate the sustained effectiveness of the Site remediation.

1.2 Scope of LTM at the Site

LTM at the site consists of the following activities:

- Natural environment monitoring,
- Visual monitoring of landfill cover and other remediated areas,
- Groundwater monitoring at wells,

- Surface water/seep monitoring at discharge points and
- Thermal monitoring at AEC 1 landfill.

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 Transport Canada (TC) are also located onsite, however, these features were not included in the present Remediation scope of work nor covered within this LTM Plan. The site location is shown in Figure 1 (Appendix A).

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.

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 and to support the tendering process such that the remediation work 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 was concluded in Summer 2019.

2.1 List of Documents

The following reports established existing site conditions prior to remediation. These reports identified the presence of contaminants of concern at the site, identified areas of potential and actual environmental contamination, and made assessments of risk to human health and ecological receptors.

- Arcadis, 2015. Remediation Program for AECs at Resolute Bay Airport. Prepared for Public Works Government Services Canada Environmental Services – Western Region on behalf of Transport Canada. Dated December 3, 2015.
- Franz Environmental Inc., 2013. Data Gap and Geotechnical Assessment Resolute Bay Airport Landfill, Nunavut. Prepared for Public Works and Government Services Canada Environmental Services – Western Region on behalf of Transport Canada. Dated December 10, 2013.
- Franz Environmental Inc., 2010. Phase II/III Environmental Site Assessment Final Report, Resolute Bay Airport Landfill Sites, Resolute Bay, Nunavut. Prepared for Public Works and Government Services Canada on behalf of Transport Canada. Dated March 2010.
- Franz Environmental Inc., 2010. Phase I and preliminary Phase II Environmental Site Assessment Upper Air Monitoring Station, Resolute Bay, Nunavut. Prepared for Public Works and Government Services Canada & Environment Canada on behalf of Transport Canada. Dated February 5, 2010.

2.2 Site Identification

Site information is presented in Table 1, below.

Table 1: 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

Site Characteristic	Description
Approximate site area	2025 hectares
Centre of site coordinates (in lat/long or UTM)	74.716944 N, 94.969444 W

2.3 Site Description

2.3.1 Physical Site Conditions

The airport property contains an airstrip, terminal building, hangars, warehouses, fuel storage, and other airport infrastructure.

Drinking water for the hamlet is supplied from Strip Lake, a naturally-occurring freshwater lake on the site immediately to the east of the main runway.

- 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.
- 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.
- 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 that resides on Territorial/Airport property boundary.

The “work areas” are shown in Figure 1, Appendix A. There are no buildings in the work areas. There are some utility poles with overhead wires located in the borrow source areas. Adjacent land use consists of a municipal sewage lagoon consisting of four separate containment cells, located southeast of AEC 1 and a fenced waste storage area located north of AEC 1 which are both operated by the hamlet and not addressed in this project. The open flat areas near AEC 1 have been reported by local contractors to be used by the hamlet to stockpile snow from snow removal activities. The open flat areas on the east side of AEC 2 has occasionally been used seasonally for large vehicle and or equipment/material storage by the airport authorities.

The work areas are characterized by flat to gently sloping terrain, although AEC 1 and AEC 2 are on slopes, with elevations that range from 35 to 66 m above sea level (asl). Where present, plant cover is sparse, irregular, and discontinuous.

2.3.2 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.

2.3.3 Elevation/Topography

Site elevation and topography is described in the SENES and Franz (2013) report. “The study areas are characterized, for the most part, by flat to gently sloping terrain. The Solid Waste Landfill (AEC 1) and Historic Landfill (AEC 2) are both characterized by gently sloping terrain, with elevations that range from 35 to 66 m above sea level (asl) and 40 to 60 m asl, respectively. The Vehicle Storage Area (AEC 3) is on the top of the south slope of the McMaster River Valley at an elevation of approximately 30 to 35 m asl.”

The loose, unconsolidated sediments at the site and the depth to permafrost mean that drainage in all areas is controlled by the topography. AEC 1 and AEC 3 discharge to the west.

According to SENES and Franz (2013), AEC 2 is “drained by a complex sequence of interconnected ponds and drainage channels that ultimately discharge towards the south into Resolute Bay. Three small ponded areas west of the landfill capture runoff and drainage from the landfill. These lakes drain approximately 1 km into Meretta Lake and then to Resolute Lake, and finally Resolute Bay. A patchy, discontinuous wetland has developed at the toe of the Historic Landfill (AEC 2) along its southern extent.”

2.3.4 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.

2.3.5 Geologic 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).

2.3.6 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.

2.3.7 Lines and Other Property Rights

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 the northern perimeter of the airport property/Territorial boundaries.

3.0 Summary of Remedial/Risk Management Activities

The remediation and risk management program was implemented from FY 2018-2019 to FY 2019-2020. The implemented program is based on risks identified in previous work, primarily the Conceptual Remedial Action Plan provided as part of the Phase II/III ESA (Franz, 2010), that were reviewed and accepted by the NWB during the Water License approval stage.

3.1 Risk Drivers

According to the Conceptual RAP, there are known and discrete impacted soils in the work areas associated with waste burial, vehicle dumping, and filling activities. Elevated concentrations of metals, PHCs, BTEX, and PAHs are present across the work areas. The evaluation of the Conceptual RAP indicated that "the buried and exposed debris imparts a slow release of contaminants into the environment. Contaminants originating from the source areas (landfill), are present in the groundwater, sediments, and surface water in the ponding areas beyond the landfills." The RAP also noted that the substances decrease to concentrations below the guidelines downgradient of the site.

The Conceptual RAP also identifies the potential for slope failure on the main slope of AEC 1 as a major physical hazard. According to the RAP, "slope failure could result in the sudden deposition of new debris in this area."

3.2 Summary of Remedial Objectives

The final RAP identified remedial objectives at the site 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 was completed:

- At AEC 1
    - regraded, cut/filled, and excavated non-stable soil and non-hazardous waste material located at the slope face to achieve the designed 3H:1V slope;
    - Segregated hazardous material unearthed during slope stability activities;
    - Filled voids with borrow material to stabilize the slope;
    - Constructed an aggregate cover over the top and slope of the landfill;
    - Constructed drainage swales to direct surface water around the landfill; and
    - Upgraded and maintained roads as necessary.

- At AEC 2
    - Consolidated non-hazardous wastes from AEC 2 within AEC 1;
    - Regraded the top and embankment of the landfill to direct surface water away from the slope face; and
    - Constructed surface drainage swales to promote drainage from existing culverts and to redirect surface water away from the top of the former landfill.
- At AEC 3
    - Consolidated non-hazardous wastes from AEC 3 within AEC 1;
    - Excavated and disposed of approximately 158 m^3 of PHC- and metals-contaminated soil at a licenced disposal facility; and
    - Backfilled and re-graded excavations with approved borrow material.

4.0 Regulatory Management

4.1 Nunavut Regulatory Process

Projects conducted in Nunavut are subject to review by various bodies as part of Nunavut's integrated regulatory process. Article 12 of the Nunavut Land Claims Agreement establishes the Nunavut Impact Review Board (NIRB) and outlines its responsibilities, as follows:

- to screen project proposals in order to determine whether a review is required;
- to gauge and define the extent of the regional impacts of a project, such definition to be considered by the Minister in making his or her determination as to the regional interest;
- to review the ecosystemic and socio-economic impacts of project proposals;
- to determine, on the basis of its review, whether project proposals should proceed, and if so, under what terms and conditions, and then report its determination to the Minister; in addition, NIRB's determination with respect to socio-economic impacts unrelated to ecosystemic impacts shall be treated as recommendations to the Minister; and
- to monitor projects in accordance with the provisions of Part 7 [of the agreement].

The NIRB screens all projects that are not exempt as determined by the Nunavut Planning Commission (NPC) and determines whether they require a full environmental review or if only licenses, permits and approvals are required.

On May 10, 2011, the NPC completed a review of the remediation project and determined that it conforms with the North Baffin Regional Land Use Plan. The NPC referred the project for further assessment to the NIRB (Aglukark, 2011). In March 2018, the NPC reviewed an updated project plan and reviewed it to the NIRB for further screening (Djalogue, 2018).

On June 22, 2018, the NIRB issued a Screening Decision Report indicating that an environmental review of the project was not required (Omilgoitok, 2018).

On July 11, 2014, the Nunavut Water Board (NWB) re-issued a water licence for the project based on the activities outlined in the conceptual RAP. The water licence, 1BR-RBL1419, was initially granted for a period of five years. A renewal application was submitted by Transport Canada on January 31, 2019, and later approved for a period of ten years on May 13, 2019 as NWB Amended Renewal Water Licence No. 1BR-RBL1929.

On June 15, 2020 on-site monitoring for 2020 was cancelled due to COVID-19 restrictions, as approved by NWB via email.

Specific requirements of the LTM plan are laid out in Section K of the Water Licence. A summary of the Section K requirements and their location in this report is provided in Table 2 below.

Table 2: Water Licence Section K Requirements

Section K Requirement Number	Description	Location In Report
1	Submission of post-closure monitoring plan, including a thermal monitoring plan	Entire report
2	Maintain monitoring stations	Section 7.3.1.1
3	Measure and record effluent at four monitoring locations	Section 0
4	Sample and analyze effluent at four monitoring locations	Section 0
5	Twice annually groundwater sampling	Section 7.3.1.2
6	GPS coordinates of waste deposit	Not applicable (see discussion below)
7	Effluent sampling during discharge	Section 0
8	Effluent sampling (composite)	Section 0
9	Petroleum hydrocarbon sampling in soil	Section 7.3.1.1
10	Sample preservation and analysis	Section 7.6.4
11	Laboratory accreditation	Section 7.6.1
12	Quality assurance and quality control	Section 7.6

Point 1 includes provisions for groundwater and surface water quality monitoring, site stability and thermal monitoring (AEC 1 landfill cap) as per Section J Monitoring Program of the water license.

Point 5 requires samples to be collected twice a year, once during spring freshet and a second sample collected during mid-summer.

Point 6 of the LTM requirements in Section K of the water licence requests “the GPS co-ordinates (in degrees, minutes and seconds of latitude and longitude) of all locations where wastes associated with camp operations are deposited.” No waste was deposited from camp operations, as lodging and board was be provided for the LTM program in the hamlet.

GPS coordinates for waste transported between the AECs will be provided under separate cover as part of the remediation report.

Improvements to the LTM Plan developed by the Canadian Council of Ministers of the Environment (CCME):

The LTM will compare environmental quality data with Environmental Quality Guidelines (EQGs) in accordance Canadian Council of Ministers of the Environment (CCME) where applicable. The following guidelines are proposed for moving forward:

- Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (CSQGs) (CCME, 1999, with updates).
- Canada-Wide Standards for Petroleum Hydrocarbons in Soil (CWS-PHC) (CCME, 2008).
- Canadian Soil Quality Guidelines (CSQG) Polycyclic Aromatic Hydrocarbons factsheet (CCME, 2010)
- Canadian Environmental Quality Guidelines. Canadian Sediment Quality Guidelines (CSedQG) for the Protection of Aquatic Life (CCME, 1999, with updates).
- Canadian Environmental Quality Guidelines. Canadian Water Quality Guidelines (CWQG) for the Protection of Aquatic Life (CCME, 2007, with updates).

These guidelines contain numerical limits intended to maintain, improve or protect environmental quality and human health at contaminated sites. The limits come from models and are adjustable based on certain site characteristics, including land use, soil grain size, and whether groundwater is used as a source of drinking water. The guidelines are derived using toxicological data and aesthetic considerations.

For the site, DOJV will use the following characteristics:

- Land use: industrial
- Soil grain size: coarse
- Groundwater: not used as a source of drinking water
- Aquatic life: freshwater

Where federal guidelines are absent, provincial guidelines from Alberta will be used.

4.1.1 Surface Water and Groundwater

Analytical results will be compared over time. After each monitoring event, the results will be assessed as to whether they are statistically significant increasing or decreasing trends are observable at any location. It is recommended to use an analysis using a moving average approach with actionable decisions backed by Mann-Kendall analyses.

A moving average approach is the preferred primary method as it can identify statistical outliers by showing dominant statistical trend in results throughout the monitoring phase. This method is ideal for

avoiding any additional work that is not required, as it is more robust for identifying statistical outliers or seasonal variations that may affect results.

The moving average method also has the added benefit of producing an output for comparing trends after as little as two sampling rounds. The Mann-Kendall alternatively would take 4 years of sampling if one were to create two different regressions in order to account for seasonal variations.

The Mann-Kendall technique is non-parametric and does not consider concentration magnitudes or specific dates in the analysis. Instead, it considers the difference between samples collected earlier and later and assigns them a value of increasing (+1), decreasing (-1) or equal (0). These values are added, and a large positive number (where later values are mostly greater than initial values) indicates an increasing trend, and a large negative number (where later values are mostly less than earlier values) indicates a decreasing trend.

4.1.2 Thermal Monitoring

Thermistors will be installed at AEC 1 landfill cap and associated ground temperature monitoring will be completed as part of the long-term monitoring program. This monitoring is intended to verify certain engineering design parameters and assumptions related to permafrost aggradation (i.e. growth) in the new landfill cap upon which the landfill cover design was based on for the Resolute Bay Landfill project. Appendix D provides a technical memo which assisted in the design of the thermistor monitoring plan, as outlined in the following sections.

5.0 Authority and Accountability

Transport Canada, through PSPC, has contracted DOJV to provide construction supervision and regulatory support services for the Resolute Bay Landfill Remediation project. As part of the project, DOJV has developed this LTM plan, which will be implemented by PSPC for Transport Canada. PSPC may use a consultant to implement the plan. PSPC and Transport Canada, with their consultant, will continue to engage project stakeholders.

6.0 Site Stability

This serves to highlight performance and operational design features required for the continued operation of the remediated works. Site stability evaluation is provided in detail as part of the Operations and Maintenance Manual written under a separate cover, as a companion document to the LTM. Observations, results and recommendations related to design performance are included in the Operations and Maintenance Manual, meanwhile the LTM evaluates the chemical results and site observations for the purpose of centralizing data and environmental risk evaluations.

6.1 Operation & Maintenance Evaluation, Procedures and Reporting

The operation and maintenance evaluation and procedures will be conducted in a format that provides the desired 2008 Abandoned Military Site Remediation Protocol (AMSRP) reporting results. The report results are as follows with the associated procedures described:

6.1.1 Complete Visual Inspection Report

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

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 subsequent visit as part of the monitoring program.

Visual observations may be compiled in a table format.

See *Appendix B* for all inspection tables. Visual inspection tables are unique to each area of environmental concern.

6.1.2 Stability Assessment

Further to a Visual Inspection, the Stability Assessment serves to provide the current status of each AEC based on comparison to 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 was adapted from the AMSRP, although, the extent of the assessment protocol should only be limited to physical characteristics.

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 criteria.

6.1.3 Operation and Maintenance Severity Rating

Operation and maintenance features are to be evaluate for severity level based on tables largely adapted from *Table 4.1* of the AMSRP Volume 2. Each area of environmental concern is to be evaluated based on its determined risk factors establish in the Operations and Maintenance Manual. As such, each AEC shall be compared to different criteria.

All tables for Operation and Maintenance Severity Ratings can be found in *Appendix B*.

6.1.4 Recommendations

Based on the analyses and perceived severity ratings, a set of recommendations for each operation and maintenance activity will be given in the Operations and Maintenance Manual. In the event where there is no Operation and Maintenance Report for a site visit, recommendations should be provided in the LTM document, but shall still be in accordance with the recommendations outlined in the Operations and Maintenance Manual.

7.0 Long Term Monitoring

The LTM plan consists of natural environment monitoring, visual monitoring of the landfill, groundwater monitoring, surface water/seep monitoring and thermal monitoring at AEC 1. Proposed monitoring activities described in this report are based on the 2008 Abandoned Military Site Remediation Protocol (AMSRP) Volume 1 – Main report, developed by Indian and Northern Affairs Canada. This guidance document provides environmental protocols for lower northern arctic contaminated sites which could be applied for best practices purposes to the Resolute Bay landfill remediation site.

7.1 Environmental Quality Guidelines

For the use of this Monitoring Program, Environmental Quality Guidelines (EQGs) adopted will be from the federal guidance, also known as the Canadian Environmental Quality Guidelines (CCME). There are four sets of guidelines for soil and five sets of guidelines for water quality. The sets of guidelines used have been chosen in a manner to best protect the aquatic life downstream of the AECs. The chosen EQGs for the monitoring program are as follows:

- Canada-Wide Standards for Petroleum Hydrocarbons in Soil (CWS-PHC) (CCME, 2008).
- Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (CSQGs) (CCME, 1999, with updates).
- Canadian Environmental Quality Guidelines. Canadian Sediment Quality Guidelines (CSedQG) for the Protection of Aquatic Life (CCME,1999, with updates).
- Canadian Environmental Quality Guidelines. Canadian Water Quality Guidelines (CWQG) for the Protection of Aquatic Life (CCME, 2007, with updates).

The soil EQGs are further categorized by land use for soil (i.e., agricultural/wildland, residential/parkland, commercial and industrial) and soil properties (i.e., fine or coarse grained soil). As stated in *Section 4.1* of this document, for the site, DOJV will use the following characteristics:

- Land use: industrial
- Soil grain size: coarse
- Groundwater: not used as a source of drinking water
- Aquatic life: freshwater

Where federal guidelines are absent, provincial guidelines from Alberta will be used.

7.2 Natural Environmental Monitoring

7.2.1 Rationale

Natural environment data will be collected as part of the LTM Plan at the site. This will include observations of animal usage of the site (i.e., direct observation, tracks, scat, etc.) and discussions with locals knowledgeable with the site regarding site usage (i.e., fishing, hunting, gathering, etc.). This information may be helpful for future planning.

7.2.2 Monitoring Plan: Natural Environmental

Natural environment data will be collected during site visits as well as during community meetings with people who use or visit the site/area frequently. The purpose of collecting this data is to provide anecdotal information related to the presence of wildlife and changes over time.

The site-specific data to be collected will include:

- wildlife sightings (species, number, gender, juveniles);
- other evidence of recent presence of wildlife (droppings, tracks, feathers/fur, carcass remains, etc.);
- wildlife activity (summering/nesting/denning, migratory/passing through);
- qualitative assessment of relative numbers versus previous years (more, same, less); and
- revegetation of disturbed areas versus previous years (more, same, less).

Information regarding observations of the site by local people may also be collected through consultations with local community members. The type of information that may be collected includes:

- wildlife sightings;
- use by people for traditional activities;
- season(s);
- activities (hunting, fishing, trapping, camping, other harvesting);
- relative frequency versus previous years (more, same, less);
- wildlife species present (sightings or evidence);
- wildlife presence versus previous years (more, same, less);
- health of wildlife observed or harvested (good, average, poor); and
- relative health of wildlife versus previous years (better, same, worse).

7.3 Groundwater Monitoring

Federal groundwater EQG have been published by the CCME and under the Federal Contaminated Sites Action Plan (FCSAP); however, they have not been used in developing this monitoring plan. Exposure to contaminated groundwater have been deemed not applicable to the site (i.e., groundwater exposure pathway non-operable) for the following reasons:

1. Due to the shallow active layer, groundwater is typically intermixed with surface water- creating a zero-contaminant transport distance;
2. There is an active groundwater discharge within 10 m of surface water, further intermixing the two; and
3. Overland flow is the primary mode of water transport in the area, as groundwater flow is relatively stagnant.

Groundwater wells installed as per the Water License will, however, be used as an additional system for detecting pathways of exceedances in the EQGs.

7.3.1 Method

7.3.1.1 Monitoring Well Installation

The Water Licence requires the installation of monitoring wells as shown in Table 3 below. All required monitoring wells have been installed as part of remediation works.

The following monitoring wells have been installed at AEC 1:

Table 3: 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 have been confirmed by survey method.

The following monitoring wells have been installed at AEC 2:

Table 4: AEC 2 Monitoring Well Locations

Well ID	Northing	Easting	Elevation	AEC	Description
RBL-5	829250	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 have been confirmed by survey method.

The following monitoring wells have been installed at AEC 3:

Table 5: AEC 3 Monitoring Well Locations

Well ID	Northing	Easting	Elevation	AEC	Description
RBL-10	8296242	440493.031	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)

Well ID	Northing	Easting	Elevation	AEC	Description
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 have been confirmed by survey method.

7.3.1.2 Ground Water Sampling

At each monitoring well location ground water levels will be measured with a water level tape. As noted above, the wells are very shallow and water flow is expected to be quasi-surface water flow with permafrost as the base. Given the elevation gradient at the site, flow is expected to be coincident with topography.

Monitoring wells will be sampled with dedicated LDPE tubing and purged under low flow protocols using a peristaltic pump. During purging, ground water quality parameters including pH, EC, temperature, dissolved oxygen, and oxidation reduction potential (ORP) will be monitored; however, given the well depths and locations, it will not be possible to wait for parameter stabilization before sampling.

Sampling time, well water drawdown and qualitative observations for colour, turbidity, odour and sheen, if any, will be recorded.

Sample locations, sampling frequency and analyses are presented in *Table 6*.

Table 6: Groundwater Sampling Requirements

Station	Description	Analysis	Frequency
RBL-1	Monitoring Well installed up-gradient of the Solid Waste Landfill	See note below	Twice annually: freshet and mid-summer
RBL-2	Monitoring Well installed down-gradient of the Solid Waste Landfill	See note below	Twice annually: freshet and mid-summer
RBL-3	Monitoring Well installed down-gradient of the Solid Waste Landfill	See note below	Twice annually: freshet and mid-summer

Station	Description	Analysis	Frequency
RBL-5	Monitoring Well installed up-gradient of the Historic Landfill	See note below	Twice annually: freshet and mid-summer
RBL-6	Monitoring Well installed down-gradient of the Historic Landfill	See note below	Twice annually: freshet and mid-summer
RBL-7	Monitoring Well installed down-gradient of the Historic Landfill	See note below	Twice annually: freshet and mid-summer
RBL-10	Monitoring Well installed up-gradient of the Vehicle Storage Area (Site 1)	See note below	Twice annually: freshet and mid-summer
RBL-11	Monitoring Well installed down-gradient of the Vehicle Storage Area (Site 1)	See note below	Twice annually: freshet and mid-summer
RBL-12	Monitoring Well installed down-gradient of the Vehicle Storage Area (Site 1)	See note below	Twice annually: freshet and mid-summer
RBL-14	Monitoring Well installed up-gradient of the Vehicle Storage Area (Site 2)	See note below	Twice annually: freshet and mid-summer
RBL-15	Monitoring Well installed down-gradient of the Vehicle Storage Area (Site 2)	See note below	Twice annually: freshet and mid-summer

Analyses are to be performed on groundwater wells as per the Water License as follows:

Table 7: Groundwater Analyses

Group	Parameters
General chemistry	pH, conductivity, total suspended solids, ammonia nitrogen, nitrate-nitrite, oil and grease, total phenols, sulfate, total hardness, alkalinity, sodium, potassium, magnesium, calcium, chloride, phosphorus

Group	Parameters
Metals	aluminum, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, zinc
Fuel-related compounds	Petroleum hydrocarbons, polycyclic aromatic hydrocarbons, benzene, toluene, ethylbenzene and xylenes, visual oil & grease

7.3.2 Action Levels

Each groundwater result will be compared to the upgradient sample collected in the area, and to the time series trend at the same location.

For groundwater, time trends will be assessed with using a moving average approach with actionable criteria backed by a Mann-Kendall analysis.

A moving average approach is the preferred primary method as it can identify statistical outliers by showing dominant statistical trend in results throughout the monitoring phase. This method is ideal for avoiding any additional work that is not required, as it is more robust for identifying statistical outliers or seasonal variations that may affect results.

The moving average method also has the added benefit of producing an output for comparing trends after as little as two sampling rounds. The Mann-Kendall alternatively would take 4 years of sampling if one were to create two different regressions in order to account for seasonal variations.

The Mann-Kendall technique is non-parametric and does not consider concentration magnitudes or specific dates in the analysis, it considers the difference between samples collected earlier and later and assigns them a value of increasing (+1), decreasing (-1) or equal (0). These values are added, and a large positive number (where later values are mostly greater than initial values) indicates an increasing trend, and a large negative number (where later values are mostly less than earlier values) indicates a decreasing trend.

Action levels and responses are presented in *Table* 8.

Table 8: Action Levels for Groundwater

Event	Response
Increase in single detection monitored chemical concentrations	• Re-evaluate monitoring data through re-sampling • Consider possibility of impact by other sources • Increase sample frequency to determine absence/presence of statistical increase

Event	Response
but with concentrations remaining below Regulatory Limit	
Increase in single detection monitored chemical concentrations above the Regulatory Limit	• Re-evaluate monitoring data • Implement confirmatory sampling program • Consider possibility of impact by other sources
Increase in moving average monitored concentrations with results exceeding Regulatory Limit (all areas)	• Re-evaluate risks • Determine if the pathways and/or receptors identified in the risk have been modified or eliminated • Develop plan of action; possible plan could require the following: * Increase monitoring frequency * Development of additional risk management measures
Change in site conditions	• Re-evaluate validity of monitoring plan based on site usage • Re-evaluate changes in risk assumptions and active pathways. • Consider early termination of active monitoring program
Change in property exposure pathways	• Confirm operable vs. non operable pathways to receptors • Re-evaluate validity of monitoring plan • Re-evaluate changes in risk assumptions on site management

7.4 Surface Water/Seep Monitoring

7.4.1 Method

Surface water monitoring will provide valuable information on the on-going state of the down-gradient surface water bodies. This plan would effectively provide an early warning system that could be implemented in association with a Contingency Plan and could provide the decision criteria for termination. Surface water sampling will be conducted at pre-determined LTM sampling stations along the down-gradient drainage and surface water system. These sample stations were selected to correspond with previous surface water sampling conducted on site in order to maintain consistency and have comparable concentrations.

When applicable, flow will be measured using the cross-sectional area (m^2) of the stream/ seep and then multiplying it by the steam/ seep movement in (m/s) to achieve a flow in (m^3/s). Flow will be documented during each site visit at the same locations with documentation as follows:

- photos of the cross-sectional area calculations
- field logs with flow calculations

A field assessor will collect surface water/seep samples using a peristaltic pump, as it is expected that large amounts of deep free-flowing water will not be present at the proposed sampling locations. The field assessor will submerge the dedicated LDPE or silicone tubing attached to the peristaltic pump in the water and transfer the sample to the lab-provided bottles. Because this method can volatilize some components and result in an under-measurement of these parameters, the field assessor will make an effort to collect low-volume volatile samples directly from the flowing water.

After the sample is collected, field parameters including pH, temperature, and conductivity will be measured using hand-held water quality meter (a Horiba U-52 or equivalent) with a flow-through cell and recorded in field logs for inclusion in the LTM report.

Table 9: Surface Water/Seep Sampling Requirements

Station	Description	Analysis	Frequency
RBL-4	Discharge from the Solid Waste Landfill	See below	Twice annually: freshet and mid-summer
RBL-8	Discharge from the Historic Landfill	See below	Twice annually: freshet and mid-summer
RBL-13	Discharge from the Vehicle Storage Area (Site 1)	See below	Twice annually: freshet and mid-summer
RBL-16	Discharge from the Vehicle Storage Area (Site 2)	See below	Twice annually: freshet and mid-summer

Each sample is to be analyzed for the following parameters.

Table 10: Surface Water Analysis

Group	Parameters
General chemistry	pH, conductivity, total suspended solids, ammonia nitrogen, nitrate-nitrite, oil and grease, total phenols, sulfate, total hardness, alkalinity, sodium, potassium, magnesium, calcium, chloride, phosphorus
Metals	aluminum, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, zinc

Group	Parameters
Fuel-related compounds	Petroleum hydrocarbons, polycyclic aromatic hydrocarbons, benzene, toluene, ethylbenzene and xylenes, visual oil & grease

7.4.2 Action Levels

The water licence stipulates the following maximum allowable concentrations.

Table 11: Surface Water Sampling Requirements

Event	Response
Increase in single detection monitored chemical concentrations but with concentrations remaining below Regulatory Limit	• Re-evaluate monitoring data through re-sampling • Consider possibility of impact by other sources • Increase sample frequency to determine absence/presence of statistical increase
Increase in single detection monitored chemical concentrations above the Regulatory Limit.	• Re-evaluate monitoring data • Implement confirmatory sampling program • Consider possibility of impact by other sources
Increase in moving average monitored concentrations with results exceeding Regulatory Limit (all areas).	• Re-evaluate risks • Determine if the pathways and/or receptors identified in the risk have been modified or eliminated • Develop plan of action; possible plan could require the following: * Increase monitoring frequency * Development of additional risk management measures
Change in site conditions	• Re-evaluate validity of monitoring plan based on site usage. • Re-evaluate changes in risk assumptions and active pathways. • Consider early termination of active monitoring program
Change in property exposure pathways	• Confirm operable vs. non operable pathways to receptors • Re-evaluate validity of monitoring plan • Re-evaluate changes in risk assumptions on site management

As with groundwater, surface water time trends will be assessed with using a moving average approach with actionable criteria backed by a Mann-Kendall analysis.

A moving average approach is the preferred primary method as it can identify statistical outliers by showing dominant statistical trend in results throughout the monitoring phase. This method is ideal for avoiding any additional work that is not required, as it is more robust for identifying statistical outliers or seasonal variations that may affect results.

The moving average method also has the added benefit of producing an output for comparing trends after as little as two sampling rounds. The Mann-Kendall alternatively would take 4 years of sampling if on were to create two different regressions in order to account for seasonal variations.

The Mann-Kendall technique is non-parametric and does not consider concentration magnitudes or specific dates in the analysis. Instead, it considers the difference between samples collected earlier and later and assigns them a value of increasing (+1), decreasing (-1) or equal (0). These values are added, and a large positive number (where later values are mostly greater than initial values) indicates an increasing trend, and a large negative number (where later values are mostly less than earlier values) indicates a decreasing trend.

7.4.3 Effluent Discharge Limits

No discharge of effluent will occur as part of remediation of the site or during the post remedial stage. Should seepage from the landfill be noted during long term monitoring, it will be tested and compared against the water quality criteria included in the Water Licence:

Table 12: Maximum Allowable Effluent Discharge Limits as per Part D, Condition 11 of Water Licence

Parameter	Maximum Allowable Concentration (mg/L)
pH	6 to 9 (pH units)
TSS	50
Oil and Grease	15 and no visible sheen
Total Lead	0.001
Benzene	0.37
Toluene	0.002
Ethylbenzene	0.090

Should seepage water quality exceed these allowable concentrations, water will be collected or treated in accordance with the WL.

7.5 Thermal Monitoring

The Water Licence in section J (Monitoring Program) has identified that the LTM evaluate the need for thermal monitoring. For this project, thermal monitoring has been included as this monitoring is intended to verify certain engineering design parameters and assumptions related to permafrost aggradation (i.e. growth) in the new landfill cap upon which the landfill cover design was based. As such, thermistors will be installed at AEC 1 landfill cap and associated ground temperature monitoring will be completed as part of the LTM program.

7.5.1 Method

7.5.1.1 Thermistor Locations and Installation

Thermistors have not yet been installed at the site. As shown in Table 13, thermistors will be installed at the following co-ordinates (in Table 13) and as shown on Figure 12.

Table 13: AEC 1 Thermistor Locations

Well ID	Northing	Easting	Depth	AEC	Description
THRMS-01	8295589.44	440966.89	3 m bg	AEC 1	On slope of new cap of the Solid Waste Landfill
THRMS-02	8295606.84	441054.99	3 m bg	AEC 1	Within new cap of the Solid Waste Landfill
THRMS-03	8295577.43	441013.96	3 m bg	AEC 1	Within new cap of the Solid Waste Landfill

Based on the data presented in Appendix D, it is proposed that a thermistor depth of 3.0 m or to the bottom of the capping material will be completed. This will ensure there is useable data for the remainder of the Monitoring Plan, while also allowing for this data to be correlated to Environment and Climate Canada data as required.

It is proposed that the thermistors be installed during the next scheduled field program associated with the LTM program. The thermistors will be installed using a hydraulic breaker/hoe pack or equivalent using locally sourced equipment. It should be noted that thermistor depths of 3.0 m may not be achievable based on the materials encountered beneath the aggregates at the top of the AEC-1 landfill cap. Thermistor excavations will be backfilled with similar aggregated materials as the landfill cap and finished with a bentonite surface seal to avoid any water infiltration.

7.5.1.2 Field Equipment and Thermistor Data Collection

Thermistors will be comprised of several temperature sensor nodes spaced along a “string”, connected to a programed data logger that remains at the thermistor location in a protected case. This string will be cased by a PVC pipe and grouted/backfilled in place. Node depths will be documented prior to installation, and temperature readings will be taken from a portable readout unit, as a baseline reading.

Based on the achievable depths of the thermistor excavation, up to 4-5 sensor nodes will be installed at 0.5 m depth intervals from the bottom depth at each location.

The field assessor will measure each thermistor and document the following during installation:

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

Data loggers will be programmed to take daily readings for the duration of the monitoring program. These readings will be downloaded from the data logger to a laptop computer during the site visits that are planned for the LTM program.

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.

The 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.

All thermistor readings collected during the site visits will 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”.

Table 14: AEC 1 Thermistor Readings

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

7.5.2 Action Levels

Based on the thermistor data for each time interval, a chart summarizing the soil temperature profile data results will be created to plot cumulative permafrost aggregation over time. Once readings are taken, node depths can be correlated with temperature readings to deduct the aggregation of permafrost. These results will be charted and analyzed appropriately.

For thermal monitoring, it is predicted that steady state permafrost aggradation will be reached after year 5 based on the maximum landfill vertical cover depth (See Appendix D). After this timeframe, the theoretical frost penetration front is expected to reach either the existing permafrost or the capped landfill waste.

Further statistical comparison to baseline expectations can be performed after the installation of thermistors. It is recommended that after year 5, subsequent monitoring events may be used for the statistical analysis to evaluate the steady state conditions of the permafrost, if required.

7.6 Quality Assurance and Quality Control

The water licence recommends the use of the guidance document *Quality Assurance (QA) and Quality Control (QC) Guidelines For Use by Class "B" Licensees in Collecting Representative Water Samples in the Field and for Submission of a QAQC Plan* (INAC, 1996) for the development of the QA/QC plan for the LTM program. In recent years, however, the CCME has published updated guidance for conducting environmental site characterization projects, which is relevant to the current LTM plan. As a result, it is recommended the adoption of this newer guidance (CCME, 2016) as the basis for this QA/QC plan.

7.6.1 Certification and Training

The laboratory selected for each year of the LTM project will be certified by the Canadian Association for Laboratory Accreditation Inc. (CALA). This accreditation program includes an initial site assessment and regular evaluation of laboratory performance. The laboratory will be certified for each of the analytes to be tested.

ISO/IEC 17025:2017 is the international standard for testing and calibration laboratories. It "specifies the general requirements for the competence, impartiality and consistent operation of laboratories" and is applicable to all organizations performing laboratory activities. The lab selected for the LTM program will be ISO/IEC 17025 certified.

Field personnel will be trained to perform each sampling task in accordance with written standard operating procedures.

7.6.2 Sampling Methods

Sampling methods to be performed as noted in sampling plan, above. Any deviations from the sampling plan will be noted in field notes and in the final report.

The field assessor will use fresh disposable nitrile gloves for the collection of each sample. Any non-dedicated sampling equipment will be decontaminated with Alconox sample detergent and rinsed with distilled water between uses.

7.6.3 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.

7.6.4 Sample Handling, Custody and Analysis

Analytical protocols will be selected by the lab for all analysis required for the LTM program. The field assessor will confirm that these analytical protocols are acceptable before the field program begins.

Samples will be collected in jars provided by the project laboratory. Preservation will be provided by the project lab, and the field staff will preserve samples in accordance with laboratory instructions. The field assessor will note hold laboratory hold times for all analytes and make every effort to have samples to the lab before the hold time expires. Given the project location and attendant logistical challenges, some short-hold time analytes (e.g., nitrate/nitrite) may come close to or exceed laboratory hold time requirements. In this case, the field assessor will discuss interpretation of data on a case-by-case basis with the lab.

Samples will be placed into coolers with ice for preservation during the field program and for shipment to the lab. Samples will be shipped to the lab accompanied by chain of custody forms identifying samples, volumes, dates, and other pertinent information. Sample identification labels on jars will be written clearly in ink and cross-checked before shipment with chain of custody forms. The field assessor will use consistent sample identification numbers so that mistakes can be identified quickly.

Field quality control will consist of the following samples:

- Field duplicates are collected in the field from the same location by placing aliquots of approximately ten percent of the total sample volume in both primary and duplicate sample containers alternately. Field duplicates should be “blind,” i.e., not identifiable as duplicates by their ID. This program proposes one duplicate sample be collected for every ten primary samples.
- A trip blank should be collected for volatile components for the program because volatile components can be introduced to samples from the atmosphere or from cross-contamination in transport. The trip blank is a laboratory-prepared sample of deionized water, known to contain no contaminants. The trip blank should be present during all sampling and returned to the

laboratory for analysis after the program is complete. One trip blank sample should be collected for each mobilization to the site.

Laboratory quality control will consist of the following methods:

- Laboratory duplicates will be analyzed by the lab based on their quality control program.
- Laboratory blanks, i.e., generic samples of a matrix prepared with known zero concentrations of analytes of concern, will be analyzed by the project lab based on its quality program.
- A Matrix spike is a sample of an analyte of concern with a known concentration in the matrix. Matrix spikes will also be included in the lab quality program.

Reportable detection limits for the program will be dependent on the capabilities of the project lab. A competent person will ensure that detection limits for all analytes are below relevant standards; however, it is possible that matrix interference, high concentrations of other analytes or limited sample volumes will result in increased detection limits in the program. A competent person will discuss each such event individually in the report.

7.6.5 Documentation and Record Keeping

The field assessor will record notes in a bound field book at the time of sampling. Some records (e.g., test pit logs) may be kept on dedicated forms. All records will be retained, and original forms will be used to transfer information to digital formats.

Sample details will be transmitted to the laboratory on chain of custody forms that will accompany samples. The lab will transmit sample analysis data to the departmental representative in electronic formats, both static (PDF) and manipulatable (Excel). The departmental representative will use electronic data to generate report tables.

Electronic data will be maintained on a secure, backed-up server. Field notes and forms will be scanned and retained in electronic format after use.

7.6.6 Data Validation

All sample identification will be cross-checked with field records, chain of custody forms and sample labels before shipping. Laboratory certificates of analysis will be cross-checked with field records to ensure that no errors were introduced by laboratory transcription. Where uncertainty is present, the report authors will make every effort to obtain and compare original bottles and labels from the lab for comparison with notes collected in the field.

Field and laboratory quality will be compared to industry standards as shown in Table 15 below. Evaluation methods are derived from the Site Characterization Guidance Manual (CCME, 2016).

Table 15: Data Quality Targets

Quality Control Measure	Evaluation and Mitigation
Field duplicate	Relative percent difference between the primary and duplicate sample should be less than 40 percent for water and 60 percent for soil. Where samples exceed the acceptable value, each analyte-matrix combination should be assessed across the program.
Trip blank	Concentrations of all analytes should be non-detect. Where this is not the case, an evaluation of sampling methodology, site conditions and shipping methods should be conducted.
Laboratory duplicate	Per laboratory quality program, but generally less than 20 percent for water and 30 percent for soil. If laboratory duplicates exceed acceptable range, discuss reasons for the exceedance with the laboratory and assess each analyte across the program.
Laboratory blank	Per laboratory quality program. If laboratory blanks contain detectable concentrations, discuss reasons for the detection with the laboratory and assess each exceeding analyte across the program.
Matrix spike	Per laboratory quality program. If laboratory spikes are outside the acceptable range, discuss reasons for the issue with the laboratory and assess each analyte across the program.

7.7 Reporting

Tabular summaries for all data and information are required annually by March 31 under Part B of the site water licence. A memo report is to be provided each year to describe the sampling methodology, quality assurance and quality control, and other relevant information collected in the field in addition to the tabular data summaries.

7.7.1 Nunavut Water Board Annual Reporting

The Nunavut Water Board Annual Reporting consists of the following:

- A summary report of Water use and Waste disposal activities;
- A list of unauthorized discharges and a summary of follow-up actions taken;
- A summary, including photographic records

- A summary of public consultation/participation, describing consultation with local organizations and residents of the nearby communities, if any were conducted;
- A summary of work done to address concerns or deficiencies listed in inspection reports and/or compliance reports prepared by an Inspector;
- An executive summary in English and Inuktitut of all plans, reports, or studies conducted under this Licence; and
- Any other details on Waste disposal requested by the Board by the 1st November of the year being reported.

7.7.2 Long Term Monitoring Annual Report

In addition to NWB Reporting, upon completion of each monitoring event, a Long-Term Monitoring report will be created. One annual monitoring report will be created for each monitoring year and will include:

In addition to the reporting requirements set out in the NWB Amended Renewal Water License No. 1BR-RBL-1929, the Long-Term Monitoring Annual Report will include the following:

- An executive summary outlining the main findings and any noteworthy trends that have been flagged as a potential concern.
- A brief explanatory section outlining the site visit. This will include the physical site conditions, weather during field work, field staff present, and the means and methods used for each sampling activity.
- An inspection of the current site stability will be included as outlined in *Section 6.0* of this document. This includes completed tables for each of the three areas of environmental concern.
- A photo log for documentation of observations including GPS coordinates of each photo.
- A list of figures outlining sampling locations.
- Supporting documentation on water quality including formal laboratory certificates, and a tabulated comparison between results, EQG limits, and previous samples. These should be found in separate appendices.
- A report to summarize water quality findings that will include: a discussion on QA/QC relating to analytic results, a discussion and comparison of current results, previous results and EQGs, and a trend analysis of increasing or decreasing concentrations when applicable.

- Logs of the thermistor and datalogger conditions, and any battery changes completed.
- A discussion on monitoring requirements moving forward.
- Recommendations for any required immediate or future actions.

7.8 Revisions

In the event where monitoring activities or methodology change, a new Long-Term Monitoring Plan will be completed and PSPC and TC will be notified of this change. If these changes affect the current Water License requirements in effect such as: changes in monitoring frequency, monitoring well numbering, or sample locations, then the proposed changes shall be submitted to the NWB for approval.

8.0 Monitoring Plan

The schedule, data collection and reporting for the Long-Term Monitoring Plan and Operations & Maintenance and (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 and thermal monitoring.

The proposed Monitoring Program schedule has yet to be confirmed, however, it is recommended that monitoring 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. Monitoring should continue as planned for the initial 5 years (to 2024). As of 2024, all monitoring reporting shall evaluate the need for further monitoring based on EQGs established and the ability to establish statistical trends from monitoring parameters.

The monitoring plan is proposed in 3 distinct phases where Phase 1 is recommended, and phases 2 and 3 will be treated as contingency and be implemented as necessary. The three phases are distinguished as follows:

- Phase I: Years 1, and up to Year 5
- Contingency -Phase II: Years 7 to 25
- Contingency -Phase III: beyond 25

The proposed program is based off INAC's Abandoned Military Site Remediation Protocol, AMSRP (2008) and review of other landfill sites throughout the arctic.

A table of the proposed monitoring schedule for is shown on the following table:

Table 16: Proposed Monitoring Schedule

Year	Years After Construction	Site Monitoring Event	Monitoring Phase
2019	0		
2020	1	X	Phase 1
2022	3	X	Phase 1

Year	Years After Construction	Site Monitoring Event	Monitoring Phase
2024	5	X	Phase 1
2026	7	X	Phase 2
2029	10	X	Phase 2
2034	15	X	Phase 2
2039	20	X	Phase 2
2044	25	X	Phase 2

The main purpose of the proposed program is to ensure no contamination pathways are observed following the implemented designs.

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

1. Natural Environment, Water Quality and Thermal Monitoring – Reported as *Section 7* of the Long-Term Monitoring Plan.
2. Site Stability – Reported as part of the Operations and Maintenance Report. Observations and Results to also be documented as discussed in *Section 6* of the Long-Term Monitoring Plan.

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.

8.1 Reduction or Termination of Site Monitoring

As part of the monitoring plan, a reduction or termination of specific locations will be developed and any recommendations for changes will be presented in the annual monitoring report. Results of the site monitoring would be compared against the regulatory limits to provide continuous feedback for hazard identification and compliance with the data analysis and response actions.

The reduction or termination of the site monitoring could be evaluated against the following criteria (as examples):

1) Outside of the source area, are the chemical results consistently below the appropriate Regulatory Limit over the predefined monitoring period?
2) Outside of the source area, do the chemical results demonstrate a trend of reduced, non-detectable or steady state concentrations over a predefined sampling period?
3) Do the natural attenuation processes at the site remain consistent and predictable with previous interpretations?
4) Have the pathways and/or receptors identified been modified or eliminated?

If these criteria have been met then the site monitoring could be reduced or terminated despite the fact that concentrations of contaminants of concern (COCs) within the source area could still remain above the Regulatory Limits.

8.2 Water Quality

The water quality section outlines the required water quality testing parameters as per the NWB Amended Renewal Water License No. 1BR-RBL-1929. For more information on the sampling methods, effluent quality limits, action levels, and general requirements for chemical parameters, please refer to Section 7 of the Long Term Monitoring Plan.

As a requirement for the Renewal Water License Renewal No. 1BR-RBL-1929, water quality will be analyzed as part of the Monitoring Program. This requirement is covered in Section 7 of this document as is further distinguished between groundwater monitoring and surface water/ seep monitoring.

8.3 Thermal Monitoring

It is predicted that steady state permafrost aggradation will be reached after year 5 based on the maximum landfill vertical cover depth (see Appendix D). After, this timeframe the theoretical frost penetration front is expected to reach either the existing permafrost or the capped landfill waste.

It is recommended that after year 5, subsequent monitoring events may be used for the statistical analysis to evaluate the steady state conditions of the permafrost, if required.

8.4 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. Similarly, Section 6 of this

document is intended to satisfy the Observations and Results of the site stability portion required for the Monitoring Program.

9.0 References

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10.0 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

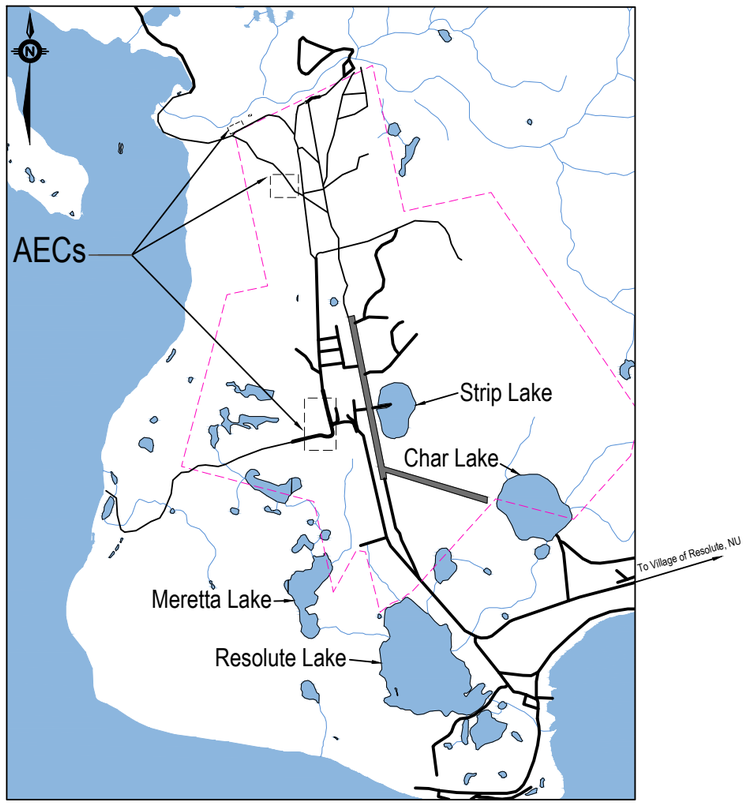
Mark Mathews, B.Eng
Junior Professional

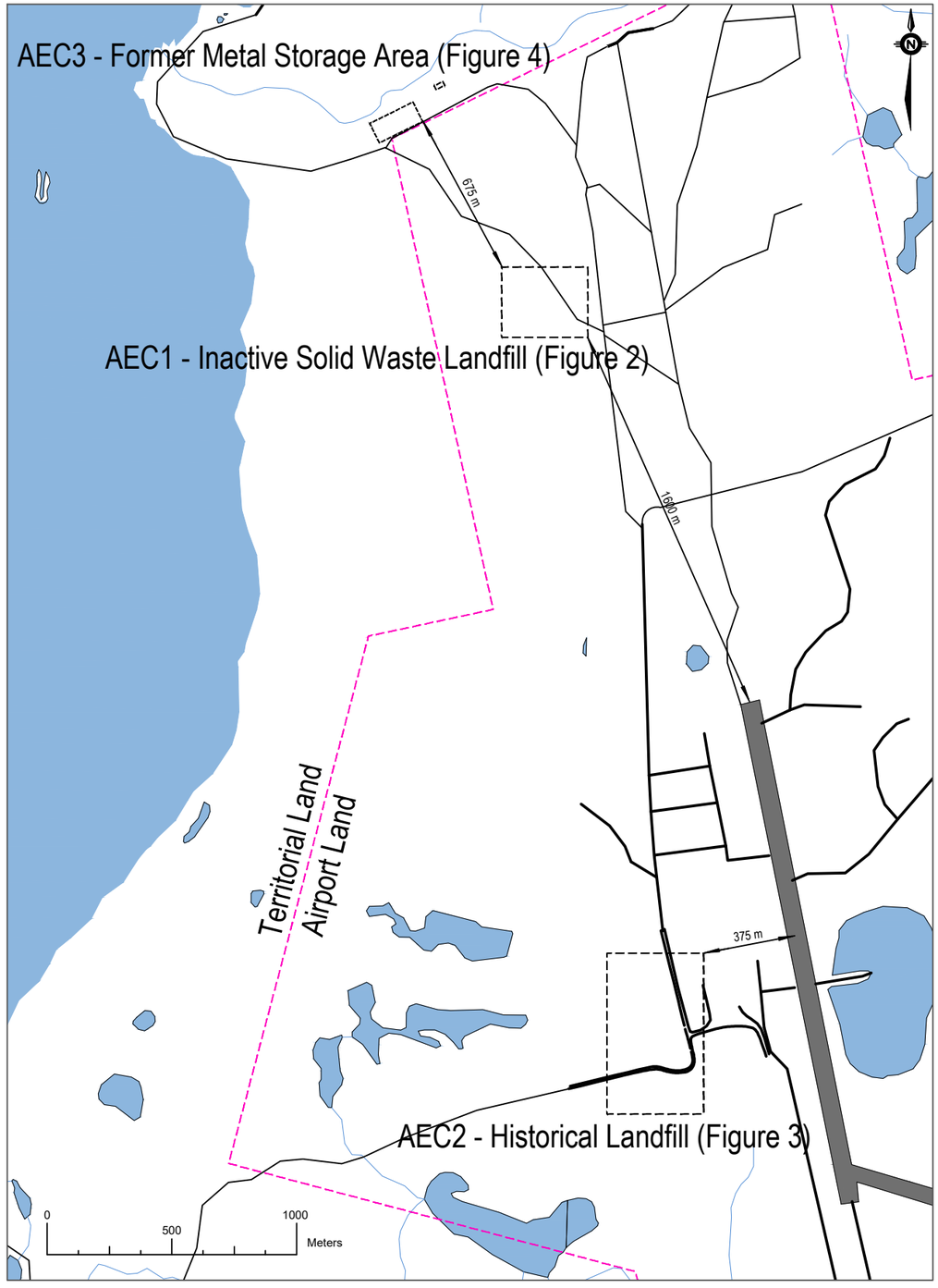
Steve Livingstone, M.Sc., P.Geo
Senior Professional

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

Appendix A

Figures





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

NOTES:

1 – Adapted from Preliminary Design prepared by Arcadis Canada Inc. on behalf of Public Works & Government Services Canada (March 2016)

LEGEND:

- Airport Property Line
- Area of Environmental Concern (AEC)

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C drawing no. – where detailed / dessin no. – ou detaille

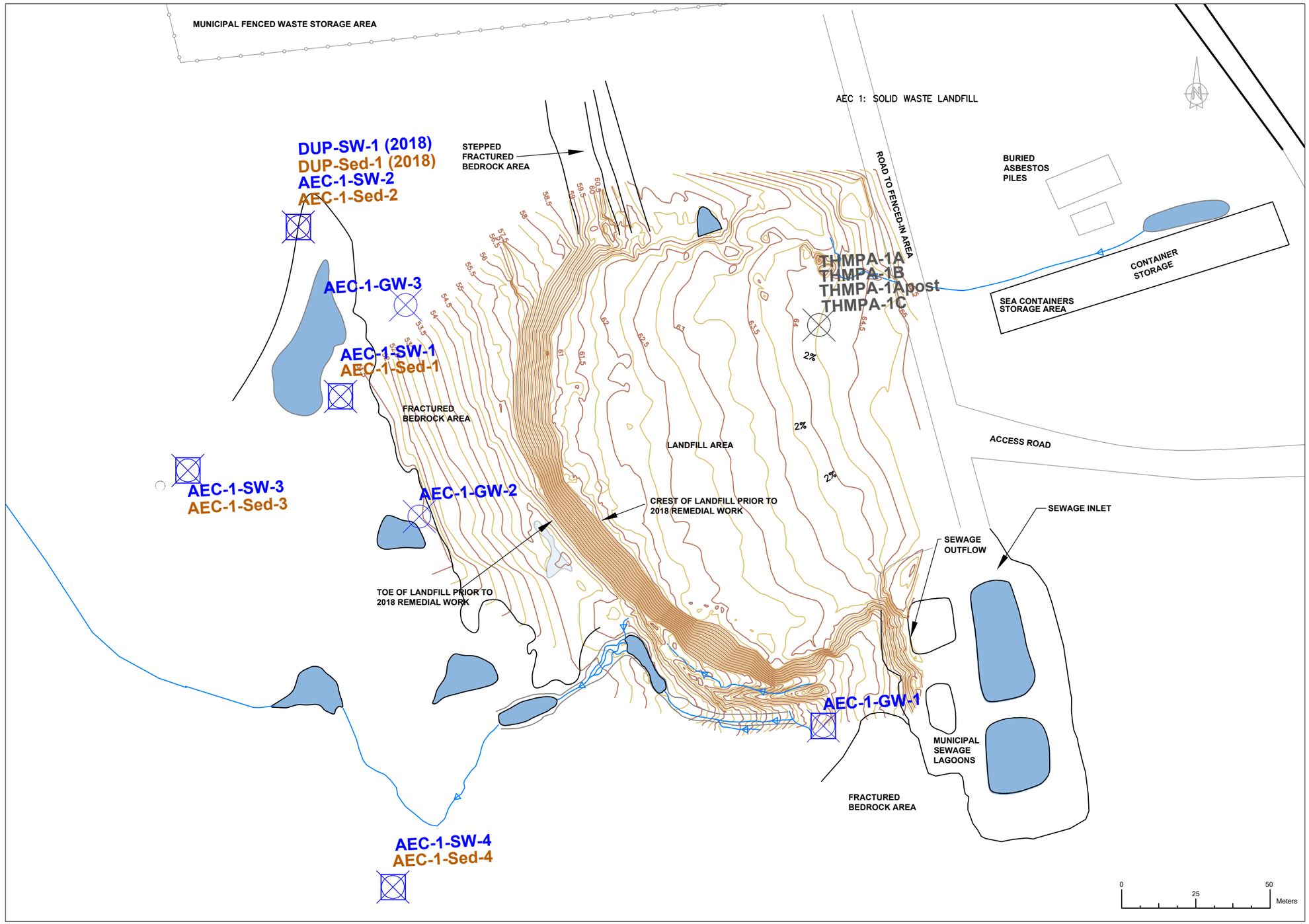
project title / titre du projet

RESOLUTE BAY NUNAVUT
PWGSC for TRANSPORT CANADA
REMEDIATION OF RESOLUTE BAY AIRPORT LANDFILLS

drawing title / titre du dessin

SITE LOCATION

drawn by / dessine par	C. SADLER
designed by / conc par	J. MAUCHAN
approved by / approuve par	M. BILLOWITS
bid / offre	N. ROBINSON (project manager / administrateur de projets)
project date / date du projet	SEPTEMBER 2020
project no. / no. du projet	R.095508.001
drawing no. / dessine no.	Figure 1



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

NOTES:

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

2 – Protected and maintained municipal fenced waste storage area. Kudlik Construction provided public access throughout work.

3 – Protected, maintained and left buried Asbestos piles As-Is

4 – Protected and maintained sewage lagoons. Kudlik Construction provided public access throughout work

5 – Buried Asbestos Piles were not disturbed during work

6 – (2018) and (2019) indicate year that sample was collected.

LEGEND:

- Major Topographic Contour
- Minor Topographic Contour
- Topographic Elevation (approx. metres above sea level)
- Surface Water Drainage Pathway
- Surface Flow Direction
- Water
- Road
- Photo Number and Loction
- Buried Asbestos Piles
- Sample collected in 2018
- THMPA – Temporary Hazardous Materials Processing Area (soil Sample)
- SW – Surface Water Sample
- SED – Sediment Sample
- GW – Groundwater Sample
- DUP – Duplicate Sample
- Sample collected in 2018 and 2019
- Sample collected in 2019

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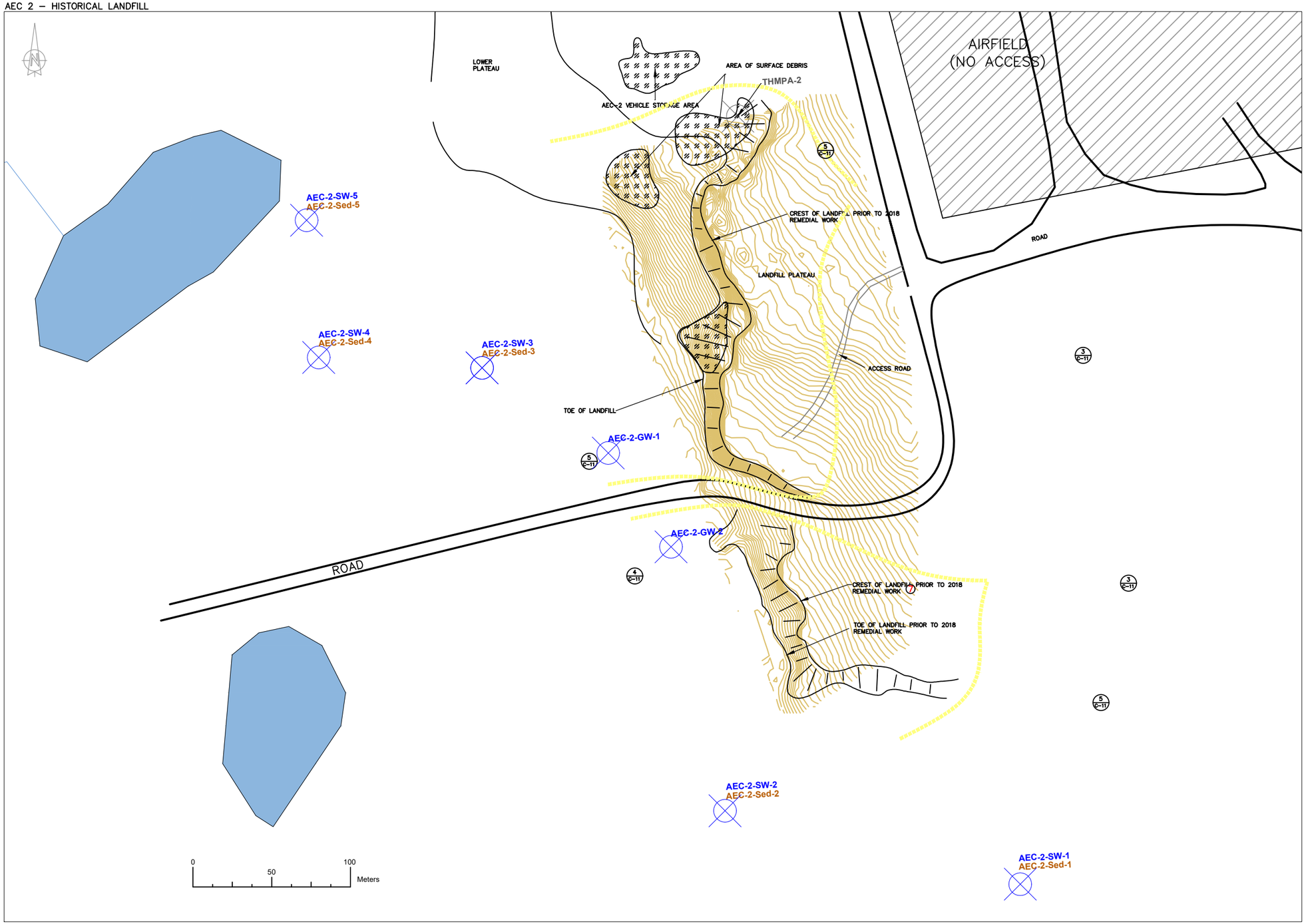
C drawing no. – where detailed / dessin no. – ou detaille

project title / titre du projet
RESOLUTE BAY NUNAVUT
PWGSC for TRANSPORT CANADA
REMEDIATION OF RESOLUTE BAY AIRPORT LANDFILLS

drawing title / titre du dessin
AEC1 Construction Monitoring Sample Locations

drawn by / dessine par	C. SADLER
designed by / conc par	J. MAUCHAN
approved by / approuve par	M. BILLOWITS
bid / offre	N. ROBINSON (project manager / administrateur de projets)
project date / date du projet	SEPTEMBER 2020
project no. / no. du projet	R.095508.001
drawing no. / dessine no.	Figure 2

AEC 2 – HISTORICAL LANDFILL



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Notes:

1 – Adapted from Preliminary Design prepared by Arcadis Canada Inc. on behalf of Public Works & Government Services Canada (March 2016)

LEGEND:

- Major Topographic Contour
- Minor Topographic Contour
- Topographic Elevation (approx. metres above sea level)
- Airfield
- Surface Waste
- Road
- Embankment
- Sample collected by DOJV in 2018 and 2019

THMPA – Temporary Hazardous Materials Processing Area (soil Sample)
SW – Surface Water Sample
SED – Sediment Sample
GW – Groundwater Sample
DUP – Duplicate Sample

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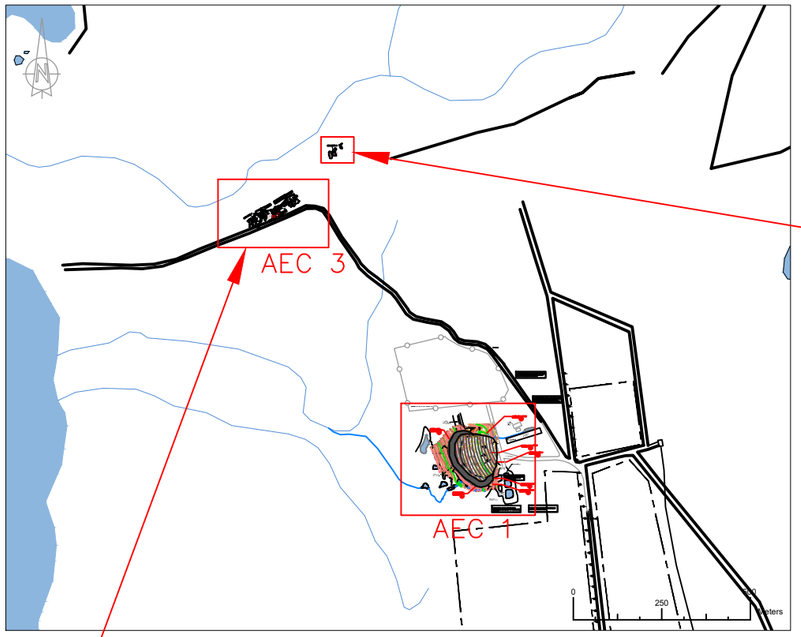
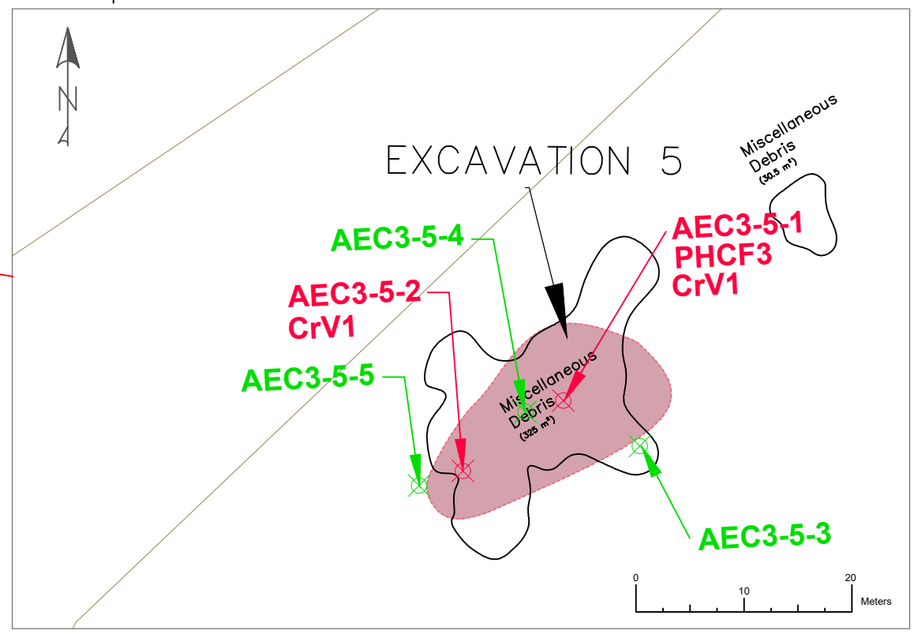
RESOLUTE BAY NUNAVUT
PWGSC for TRANSPORT CANADA

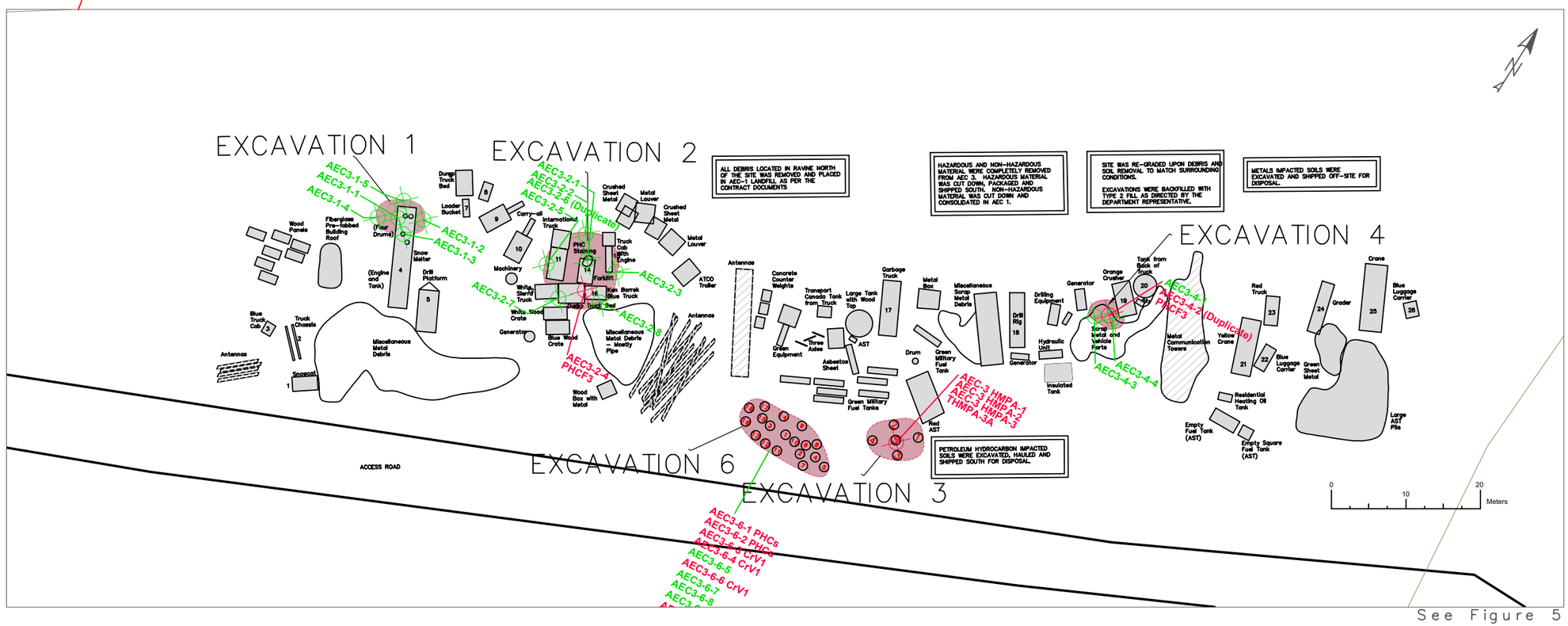
REMEDIATION OF RESOLUTE BAY AIRPORT LANDFILLS

drawing title / titre du dessin
AEC2 Construction Monitoring Sampling Locations

drawn by / dessine par	C. SADLER
designed by / conc par	J. MAUCHAN
approved by / approuve par	M. BILLOWITS
bid / offre	N. ROBINSON (project manager / administrateur de projets)
project date / date du projet	SEPTEMBER 2020
project no. / no. du projet	R.095508.001
drawing no. / dessine no.	Figure 3







See Figure 5

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1 – Adapted from Preliminary Design prepared by Arcadis Canada Inc. on behalf of Public Works & Government Services Canada (March 2016)

LEGEND:
- Major Topographic Contour
- Minor Topographic Contour
- Topographic Elevation (approx. metres above sea level)
- Airfield
- Surface Waste
- Road
- Embankment
- 2019 Soil Sample Below Criteria
- 2019 Soil Sample Above Criteria

THMPA – Temporary Hazardous Materials Processing Area (soil Sample)
SW – Surface Water Sample
SED – Sediment Sample
GW – Groundwater Sample
DUP – Duplicate Sample

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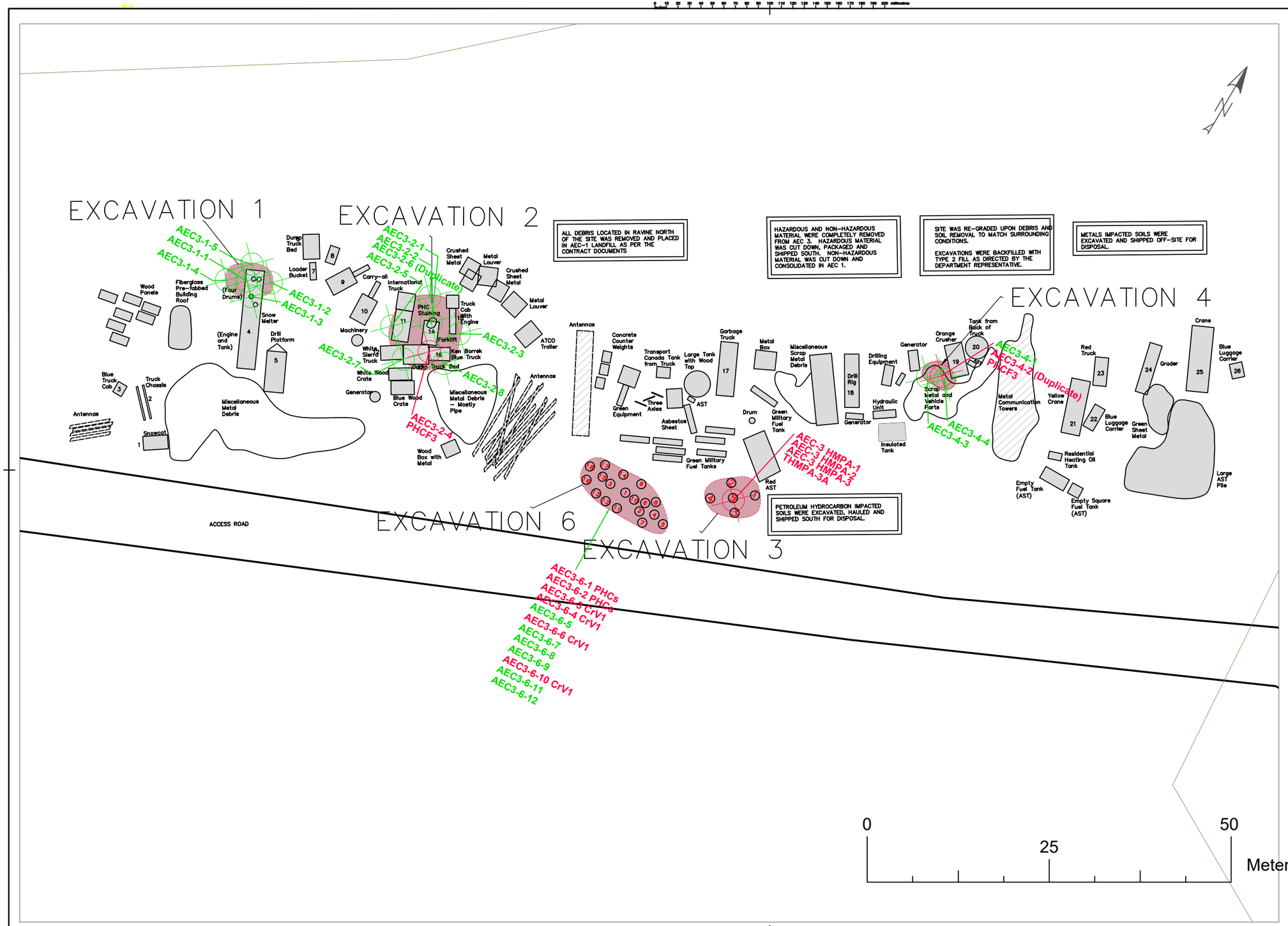
C drawing no. – where detailed / dessin no. – ou detaille

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

REMEDIATION OF RESOLUTE BAY AIRPORT LANDFILLS

drawing title / titre du dessin: AEC3 SOIL EXCAVATION LOCATIONS

drawn by / dessine par	C. SADLER
designed by / conc par	J. MAUCHAN
approved by / approuve par	M. BILLOWITS
bid / offre	N. ROBINSON (project manager / administrateur de projets)
project date / date du projet	SEPTEMBER 2020
project no. / no. du projet	R.095508.001
drawing no. / dessine no.	Figure 4



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Notes:

1 – Adapted from Preliminary Design prepared by Arcadis Canada Inc. on behalf of Public Works & Government Services Canada (March 2016)

2 – All Non-hazardous debris moved to AEC1 landfill.

3 – All Hazardous Materials Transported off-site for disposal.

LEGEND:

- Major Topographic Contour
- Minor Topographic Contour
- 245 Topographic Elevation (approx. metres above sea level)
- Airfield
- Surface Waste (removed)
- Road
- Embankment
- 2019 Soil Sample Below Criteria
- 2019 Excavation Area

THMPA – Temporary Hazardous Materials Processing Area (soil Sample)
SW – Surface Water Sample
SED – Sediment Sample
GW – Groundwater Sample
DUP – Duplicate Sample

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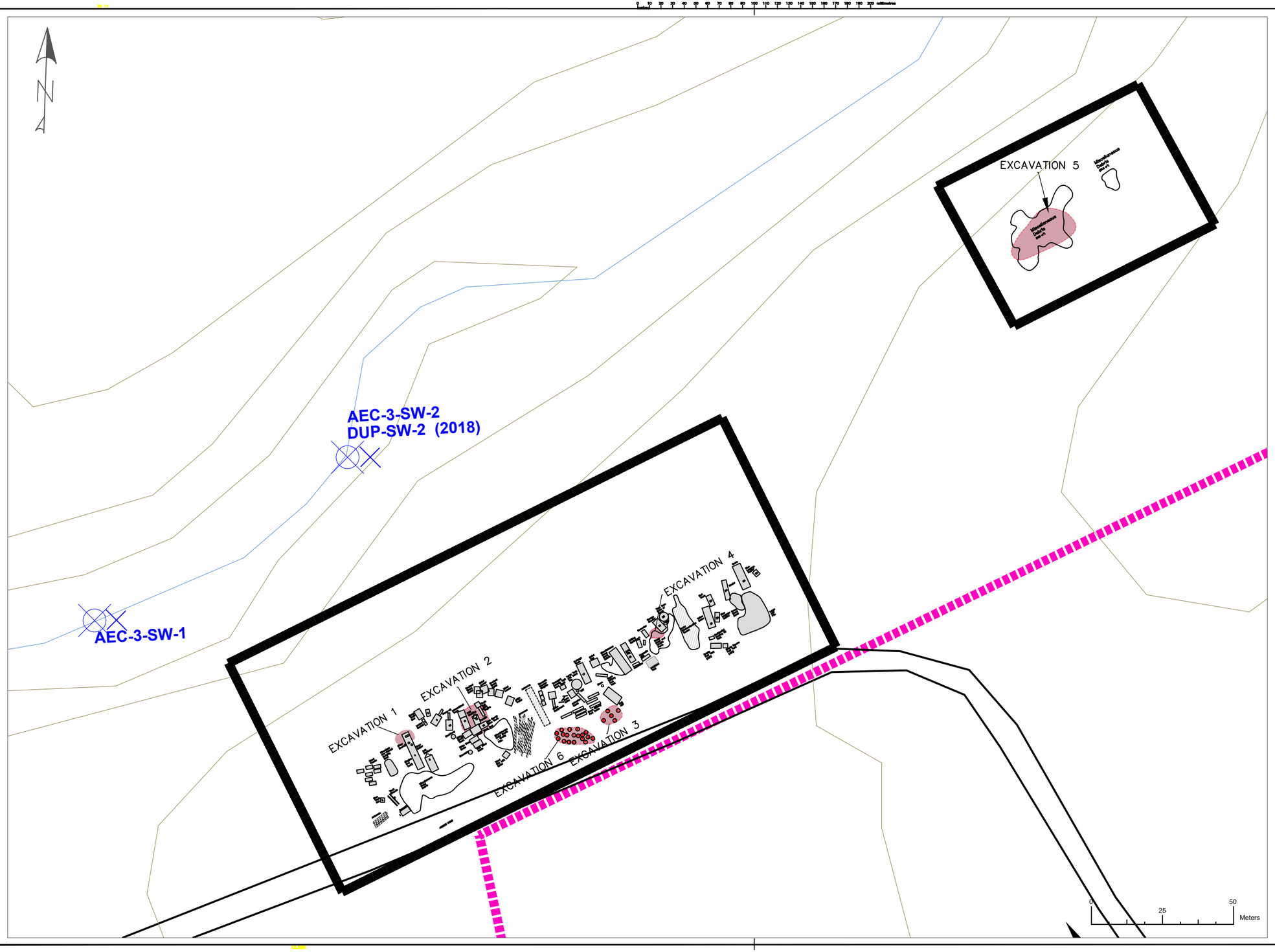
C drawing no. – where detailed / dessin no. – ou detaille

project title / titre du projet: RESOLUTE BAY NUNAVUT — PWGSC for TRANSPORT CANADA
REMEDIATION OF RESOLUTE BAY AIRPORT LANDFILLS

drawing title / titre du dessin: AEC3 EXCAVATIONS

drawn by / dessine par	C. SADLER
designed by / conc par	J. MAUCHAN
approved by / approuve par	M. BILLOWITS
bid / offre	N. ROBINSON — project manager / administrateur de projets
project date / date du projet	SEPTEMBER 2020
project no. / no. du projet	R.095508.001
drawing no. / dessine no.	Figure 5



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LEGEND:

- Road
- Gravel Road
- Embankment
- Fenced Area
- Water
- Airstrip
- Surface Waste
- Area Identification
- Topographic Elevation (approx. metres above sea level)
- Surface Water Drainage Pathway
- Surface Flow Direction
- Vehicle/Debris/Structure
- Property Boundary
- Sample collected in 2018
- Sample collected in 2019
- Major Topographic Contour
- Minor Topographic Contour

THMPA – Temporary Hazardous Materials Processing Area (soil Sample)
SW – Surface Water Sample
SED – Sediment Sample
GW – Groundwater Sample
DUP – Duplicate Sample

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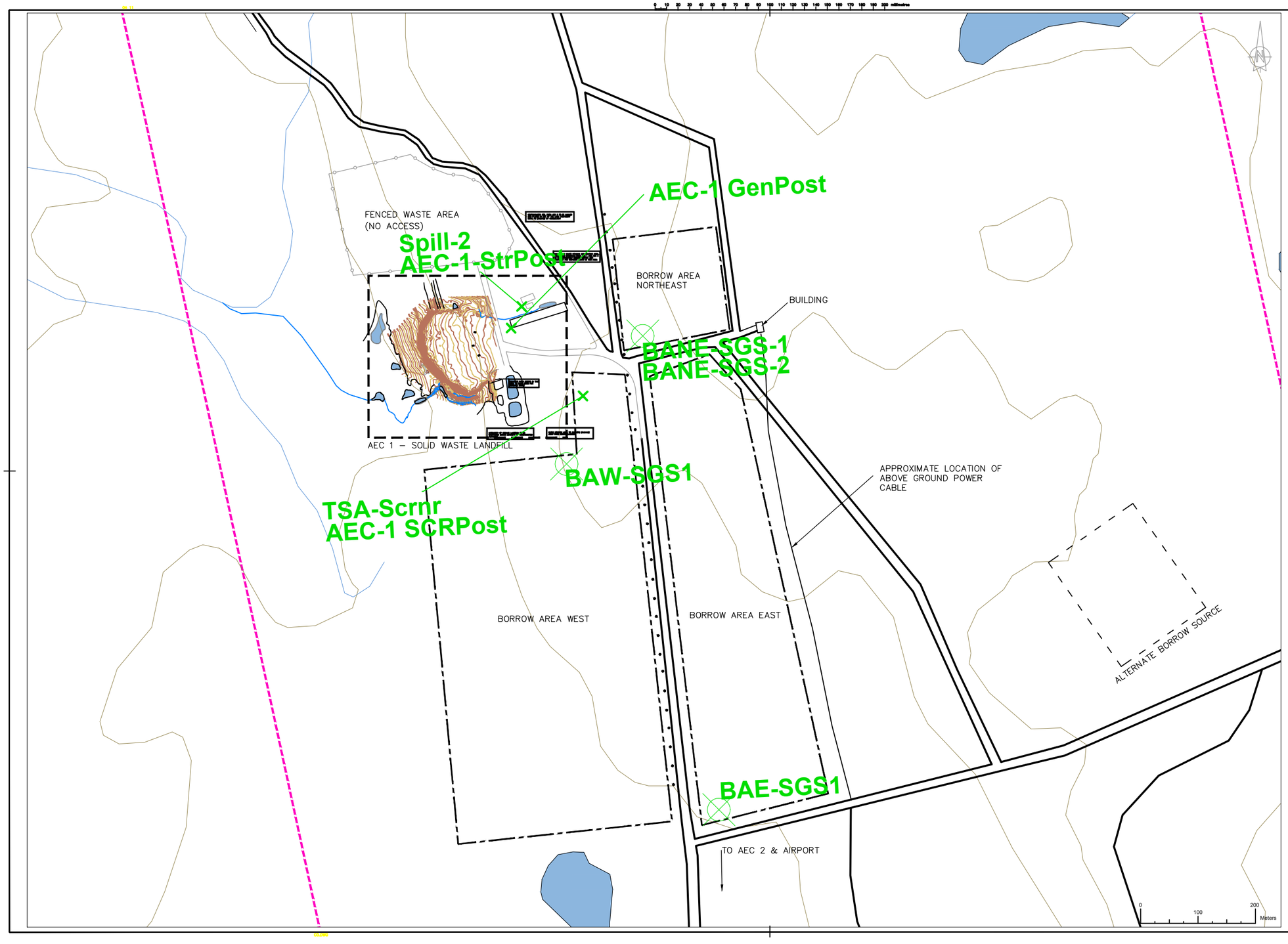
PWGSC for TRANSPORT CANADA
REMEDIATION OF RESOLUTE BAY AIRPORT LANDFILLS

drawing title / titre du dessin
AEC-3 CONSTRUCTION MONITORING SAMPLING LOCATIONS

drawn by / dessine par	C. SADLER	
designed by / conc par	J. MAUCHAN	
approved by / approuve par	M. BILLOWITS	
bid / offre	N. ROBINSON	project manager / administrateur de projets
project date / date du projet	SEPTEMBER 2020	
project no. / no. du projet	R.058019.001	
drawing no. / dessine no.	Figure 6	



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LEGEND:

- Major Topographic Contour (Background – from NTS)
- Major Topographic Contour
- Minor Topographic Contour
- Topographic Elevation (approx. metres above sea level)
- Surface Water Drainage Pathway
- Water
- Borrow Source Area
- Property Boundary
- Area Identification
- Road
- Fenced Area
- Hydro Pole
- Sample collected in 2018
- Sample collected in 2019

THMPA – Temporary Hazardous Materials Processing Area (soil Sample)
SW – Surface Water Sample
SED – Sediment Sample
GW – Groundwater Sample
DUP – Duplicate Sample

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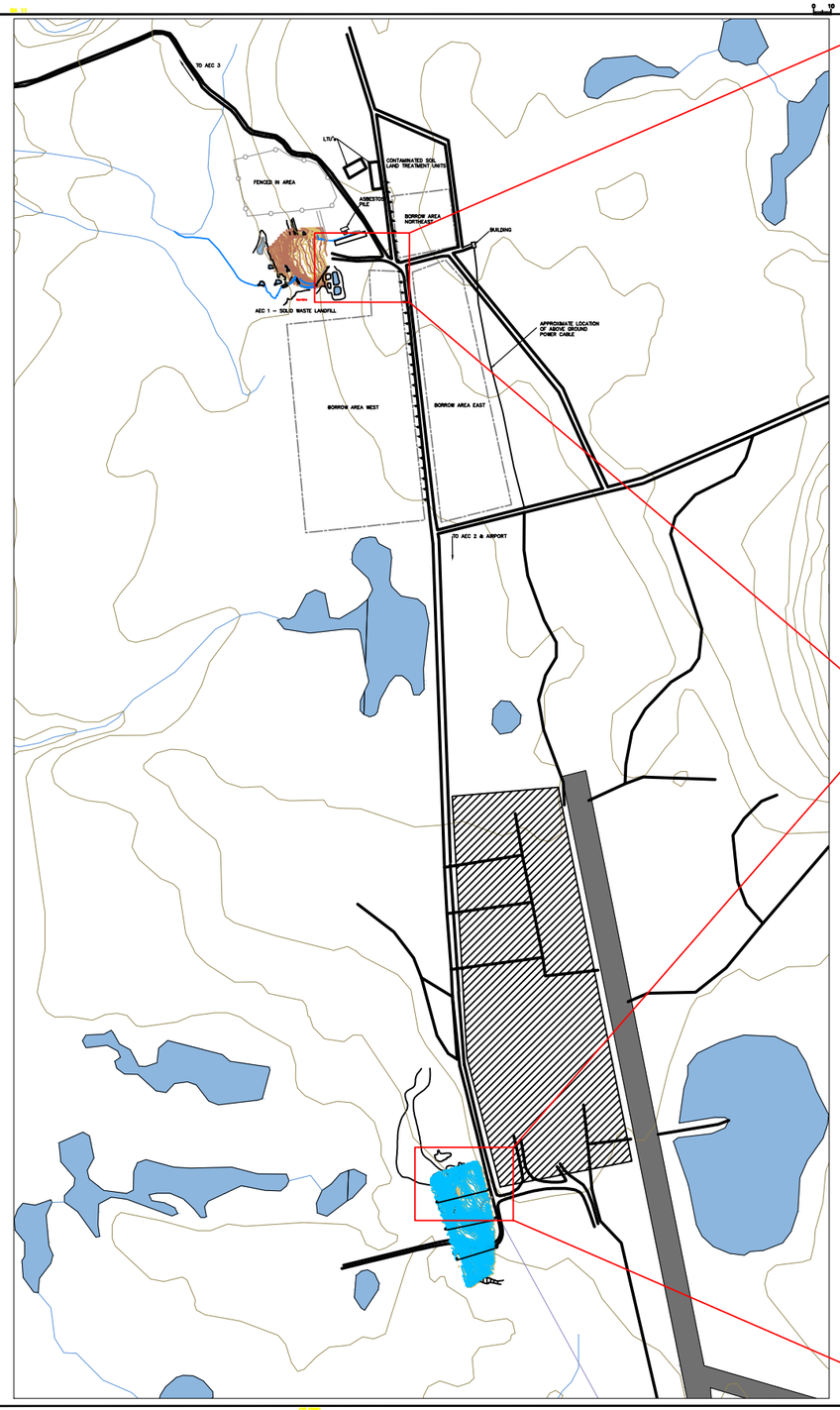
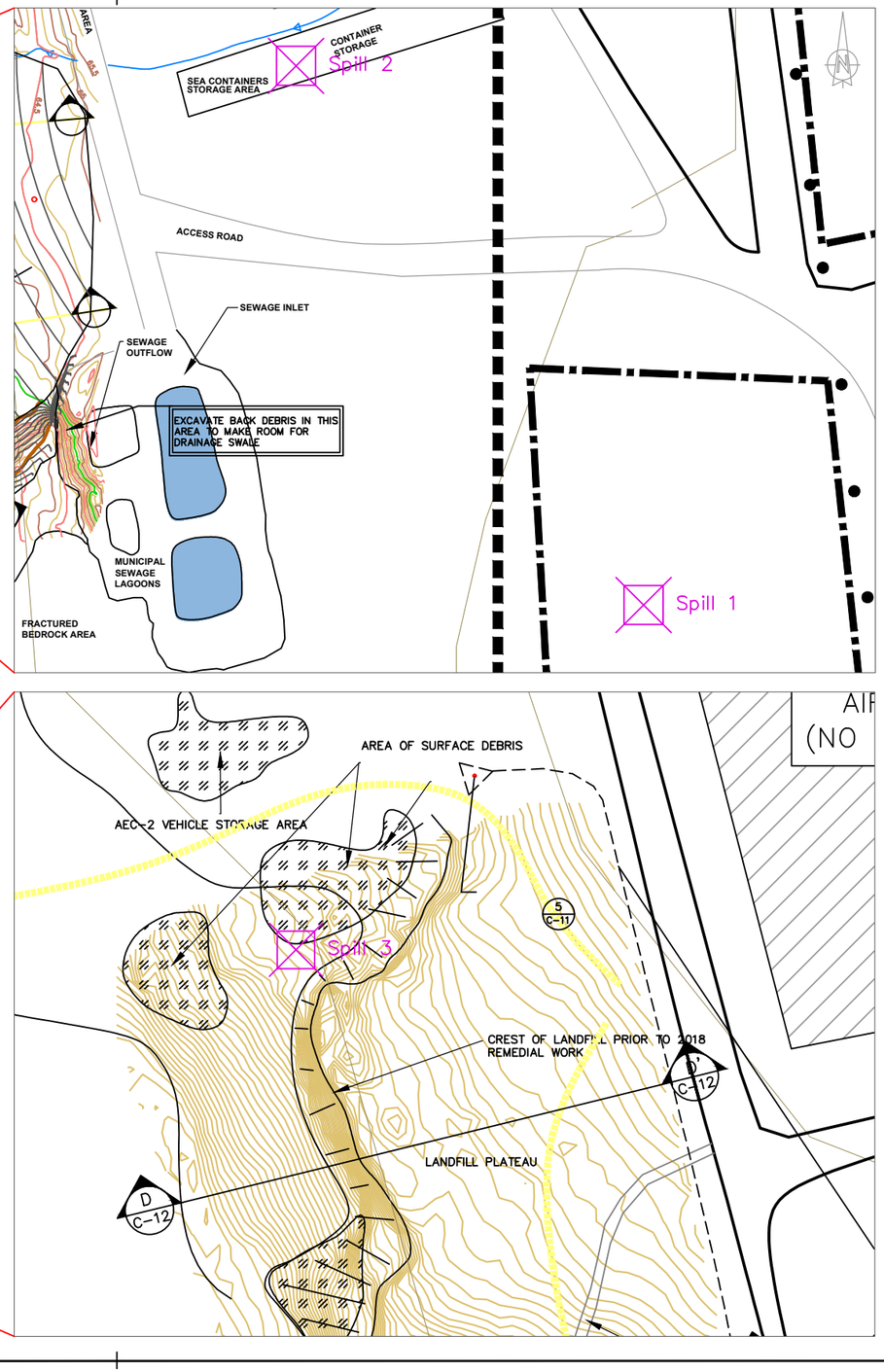
project title / titre du projet: RESOLUTE BAY NUNAVUT
PWGSC for TRANSPORT CANADA
REMEDIATION OF RESOLUTE BAY AIRPORT LANDFILLS

drawing title / titre du dessin: BORROW AREAS

drawn by / dessine par	C. SADLER
designed by / conc par	J. MAUCHAN
approved by / approuve par	M. BILLOWITS
bid / offre	N. ROBINSON (project manager / administrateur de projets)
project date / date du projet	SEPTEMBER 2020
project no. / no. du projet	R.095508.001
drawing no. / dessine no.	Figure 7





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Travaux publics et Services gouvernementaux Canada

NOTES:

1 – Adapted from Preliminary Design prepared by Arcadis Canada Inc. on behalf of Public Works & Government Services Canada (March 2016)

2 – Spills were cleaned up by Kudlik as per their Spill Contingency Plan.

3 – Spill locations were sampled by DOJV

LEGEND:

- Water
- Road
- Fenced Area
- Hydro Pole
- Major Topographic Contour (Background – from NTS)
- Major Topographic Contour
- Minor Topographic Contour
- Topographic Elevation (approx. metres above sea level)
- Surface Water Drainage Pathway
- Borrow Source Area
- Property Boundary
- Area Identification
- Spill Location and sample location
- Sample collected in 2018
- Sample collected in 2019

THMPA – Temporary Hazardous Materials Processing Area (soil Sample)
SW – Surface Water Sample
SED – Sediment Sample
GW – Groundwater Sample
DUP – Duplicate Sample

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PWGSC for TRANSPORT CANADA
REMEDIATION OF RESOLUTE BAY AIRPORT LANDFILLS

drawing title / titre du dessin
SPILL LOCATIONS

drawn by / dessine par	C. SADLER
designed by / conc par	J. MAUCHAN
approved by / approuve par	M. BILLOWITS
bid / offre	N. ROBINSON (project manager / administrateur de projets)
project date / date du projet	SEPTEMBER 2020
project no. / no. du projet	R.095508.001
drawing no. / dessine no.	Figure 8

AEC 1 – SOLID WASTE LANDFILL

FRACTURED BEDROCK AREA

BURIED ASBESTOS PILES

ROAD TO FENCED-IN AREA

CONTAINER STORAGE

SEA CONTAINERS STORAGE AREA

RBL–1

RBL–3

FRACTURED BEDROCK AREA

LANDFILL AREA

ACCESS ROAD

2%

2%

2%

CREST OF LANDFILL PRIOR TO 2018 REMEDIAL WORK

SEWAGE INLET

SEWAGE OUTFLOW

TOE OF LANDFILL PRIOR TO 2018 REMEDIAL WORK

RBL–2

EXCAVATE BACK DEBRIS IN THIS AREA TO MAKE ROOM FOR DRAINAGE SWALE

MUNICIPAL SEWAGE LAGOONS

FRACTURED

0 20 40 Meters

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

Notes:

1 – Adapted from Preliminary Design prepared by Arcadis Canada Inc. on behalf of Public Works & Government Services Canada (March 2016)

LEGEND:

- Major Topographic Contour
- Minor Topographic Contour
- Topographic Elevation (approx. metres above sea level)
- Airfield
- Surface Waste
- Road
- Embankment
- Sample collected in 2018
- Sample collected in 2019
- Monitoring Well installed in 2019

THMPA – Temporary Hazardous Materials Processing Area (soil Sample)
SW – Surface Water Sample
SED – Sediment Sample
GW – Groundwater Sample
DUP – Duplicate Sample

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revision		date

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

A Detail No. / No. du detail
B drawing no. – where detail required / dessin no. – ou detail exige
C drawing no. – where detailed / dessin no. – ou detaille

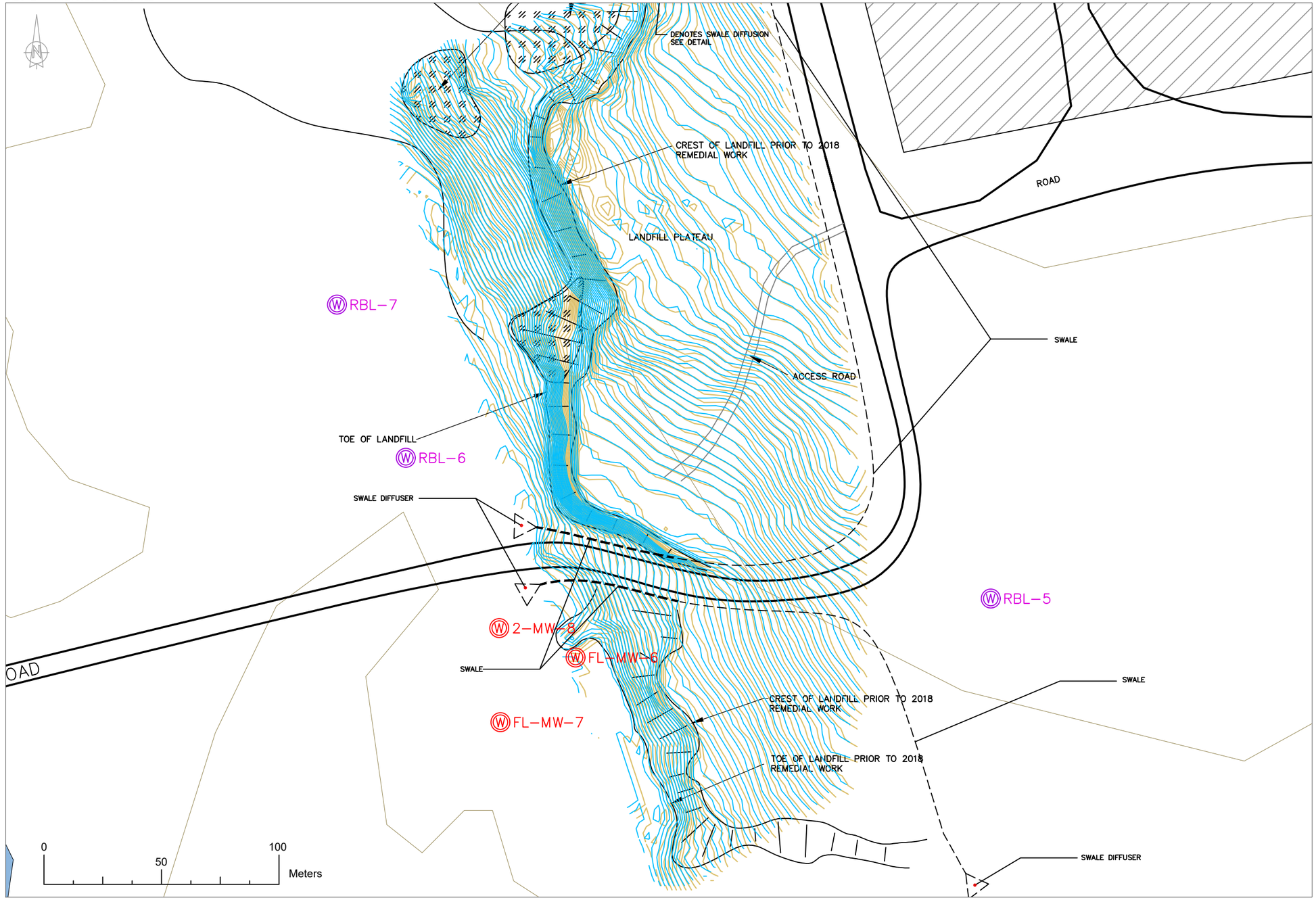
project title / titre du projet
RESOLUTE BAY NUNAVUT
PWGSC for TRANSPORT CANADA

REMEDIATION OF RESOLUTE BAY AIRPORT LANDFILLS

drawing title / titre du dessin
AEC1 MONITORING WELLS INSTALLED IN 2019

drawn by / dessine par	C. SADLER
designed by / conc par	J. MAUCHAN
approved by / approuve par	M. BILLOWITS
bid / offre	N. ROBINSON (project manager / administrateur de projets)
project date / date du projet	SEPTEMBER 2020
project no. / no. du projet	R.095508.001
drawing no. / dessine no.	Figure 9

AEC 2 – HISTORICAL LANDFILL



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

Notes:

1 – Adapted from Preliminary Design prepared by Arcadis Canada Inc. on behalf of Public Works & Government Services Canada (March 2016)

LEGEND:

- Major Topographic Contour
- Minor Topographic Contour
- 845 Topographic Elevation (approx. metres above sea level)
- Airfield
- Surface Waste
- Road
- Embankment
- Sample collected in 2018
- Sample collected in 2019
- Monitoring Well installed in 2019
- Existing Monitoring Well

THMPA – Temporary Hazardous Materials Processing Area (soil Sample)
SW – Surface Water Sample
SED – Sediment Sample
GW – Groundwater Sample
DUP – Duplicate Sample

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C drawing no. – where detailed / dessin no. – ou detaille

project title / titre du projet: RESOLUTE BAY NUNAVUT
PWGSC for TRANSPORT CANADA
REMEDIATION OF RESOLUTE BAY AIRPORT LANDFILLS

drawing title / titre du dessin: AEC2 MONITORING WELLS INSTALLED IN 2019

drawn by / dessine par	C. SADLER
designed by / conc par	J. MAUCHAN
approved by / approuve par	M. BILLOWITS
bid / offre	N. ROBINSON (project manager / administrateur de projets)
project date / date du projet	SEPTEMBER 2020
project no. / no. du projet	R.095508.001
drawing no. / dessine no.	Figure 10

AEC 3 – VEHICLE STORAGE AREA

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

Notes:

1 – Adapted from Preliminary Design prepared by Arcadis Canada Inc. on behalf of Public Works & Government Services Canada (March 2016)

LEGEND:

- Major Topographic Contour
- Minor Topographic Contour
- 953 Topographic Elevation (approx. metres above sea level)
- Airfield
- Surface Waste
- Road
- Embankment
- Sample collected in 2018
- Sample collected in 2019
- Monitoring Well installed in 2019

THMPA – Temporary Hazardous Materials Processing Area (soil Sample)
SW – Surface Water Sample
SED – Sediment Sample
GW – Groundwater Sample
DUP – Duplicate Sample

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revision		date

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A Detail No. / No. du detail
B drawing no. – where detail required / dessin no. – ou detail exige
C drawing no. – where detailed / dessin no. – ou detaille

project title / titre du projet
RESOLUTE BAY NUNAVUT
PWGSC for TRANSPORT CANADA
REMEDIATION OF RESOLUTE BAY AIRPORT LANDFILLS

drawing title / titre du dessin
AEC3 MONITORING WELLS INSTALLED IN 2019

drawn by / dessine par	C. SADLER
designed by / conc par	J. MAUCHAN
approved by / approuve par	M. BILLOWITS
bid / offre	N. ROBINSON, project manager / administrateur de projets
project date / date du projet	SEPTEMBER 2020
project no. / no. du projet	R.095508.001
drawing no. / dessine no.	Figure 11

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

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

0 20 40 Meters

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

Notes:
1. Adapted from Preliminary Design prepared by Golder Associates Ltd. 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

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

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

REMEDIATION OF RESOLUTE BAY AIRPORT LANDFILLS

drawing title dessin
AEC1 THERMISTOR LOCATIONS

drawn by dessiné par M. MATHEWS
designed by conc par J. MAUCHAN
approved by approuvé par M. BILLOWITS
bid offre N. ROBINSON project manager administrateur de projet
project date date du projet DECEMBER 2020
project no. no. du projet R.112072.001
drawing no. dessin no. Figure 12

Appendix B

Site Stability Tables

Solid Waste Landfill (AEC 1)

TABLE 1: 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		✓		

TABLE 1: 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	✓			
Sewage Lagoon Overflow		✓		
potential percolation into landfill cap	✓			
Ensuring a sufficiently high degree of saturation of the barrier layer below the active zone	✓			
Runoff Diversion	✓			

TABLE 2: 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.
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 3: 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, 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, 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.

Historical Landfill (AEC 2)

TABLE 4: 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		✓		

TABLE 5: 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	✓			

TABLE 6: 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 7: 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.

Vehicle Storage Area (AEC 3)

TABLE 8: 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		✓		

TABLE 9: 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 10: 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
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.

Appendix C

Photo Log

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.

Appendix D

Thermal Monitoring - Technical Memo

Appendix D

Resolute Bay Landfill Remediation – Technical Memo

Thermal Monitoring

The purpose of this memo is to outline the recommended thermistor installation and associated ground temperature monitoring during the long-term monitoring (LTM) program following the Resolute Bay Landfill Remediation (RBLR) project. This monitoring is intended to verify certain assumptions related to the permafrost aggradation approach and upon which the landfill cover design for the RBLR program was based. This memo provides a summary of the thermal modelling carried out for the design of the thermistors, the thermistor data to be collected, and monitoring proposed during the LTM program.

Thermal Modelling

A baseline permafrost aggradation model for the AEC 1 landfill has been created to assist with the design of the thermistor depth, and to theoretically predict the timing of frost penetration as it relates to the monitoring period. The thermal modelling is based on a simple mathematical model from the Stefan Equation. The model is summarized in "A simple heat-conduction method for simulating the frost-table depth in hydrological models" (Hayashi, Goeller, Quinton, & Wright, 2007). The Stefan equation is as shown below:

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

Where:

$$z = \ Depth\ of\ Permafrost\ (m)$$

$$\lambda_b = Thermal\ Conductivity\ \left(\frac{W}{m\ K}\right)$$

$$t = \ Eplasted\ Time\ (s)$$

$$\rho = Density\ of\ Ice\ (\frac{kg}{m^3})$$

$$f = Volumetric\ Fraction\ of\ Ice\ in\ Frozen\ Soil$$

$$L = Latent\ Heat\ of\ Fusion\ (\frac{Wx\ s}{kg})$$

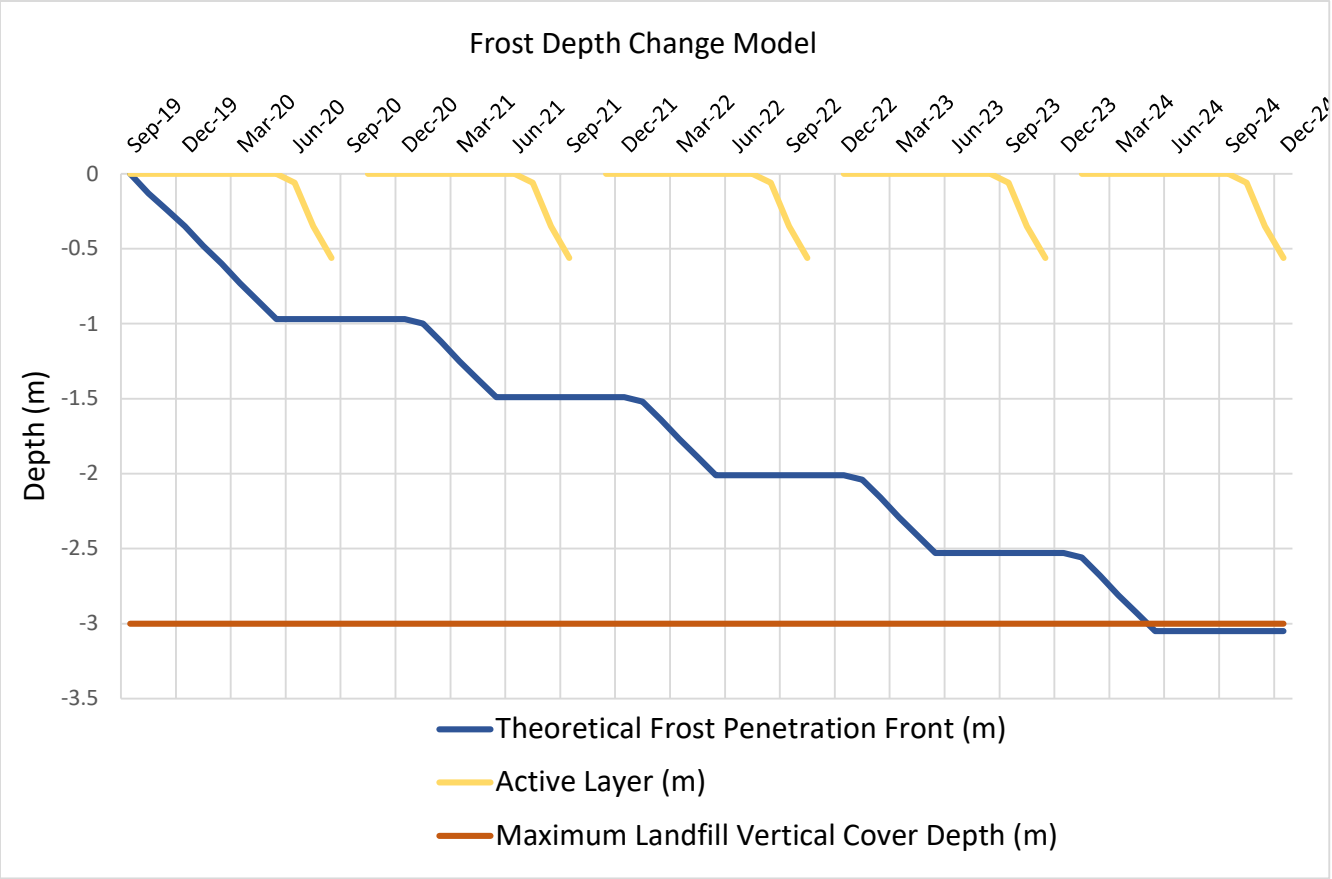
$$T_{av} = Average\ Temperature\ ^\circ C$$

$$n = Ground\ Temperature\ to\ Air\ Temperature\ Factor$$

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

- Thermal conductivity of 0.25 $\left(\frac{W}{m\ K}\right)$ was used, based on typical values for a gravel material.
- Ice density of 997$(\frac{kg}{m^3})$
- Volumetric fraction of ice in frozen soil of 0.1 based on conservative calculations from 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 1.35, based on correlations between the model and average test pitting active layer depths.

FIGURE 1: FROST DEPTH CHANGE MODEL



This model provides an average distribution of what each thermistor shown in *Appendix A: Figure 1* should represent over time.

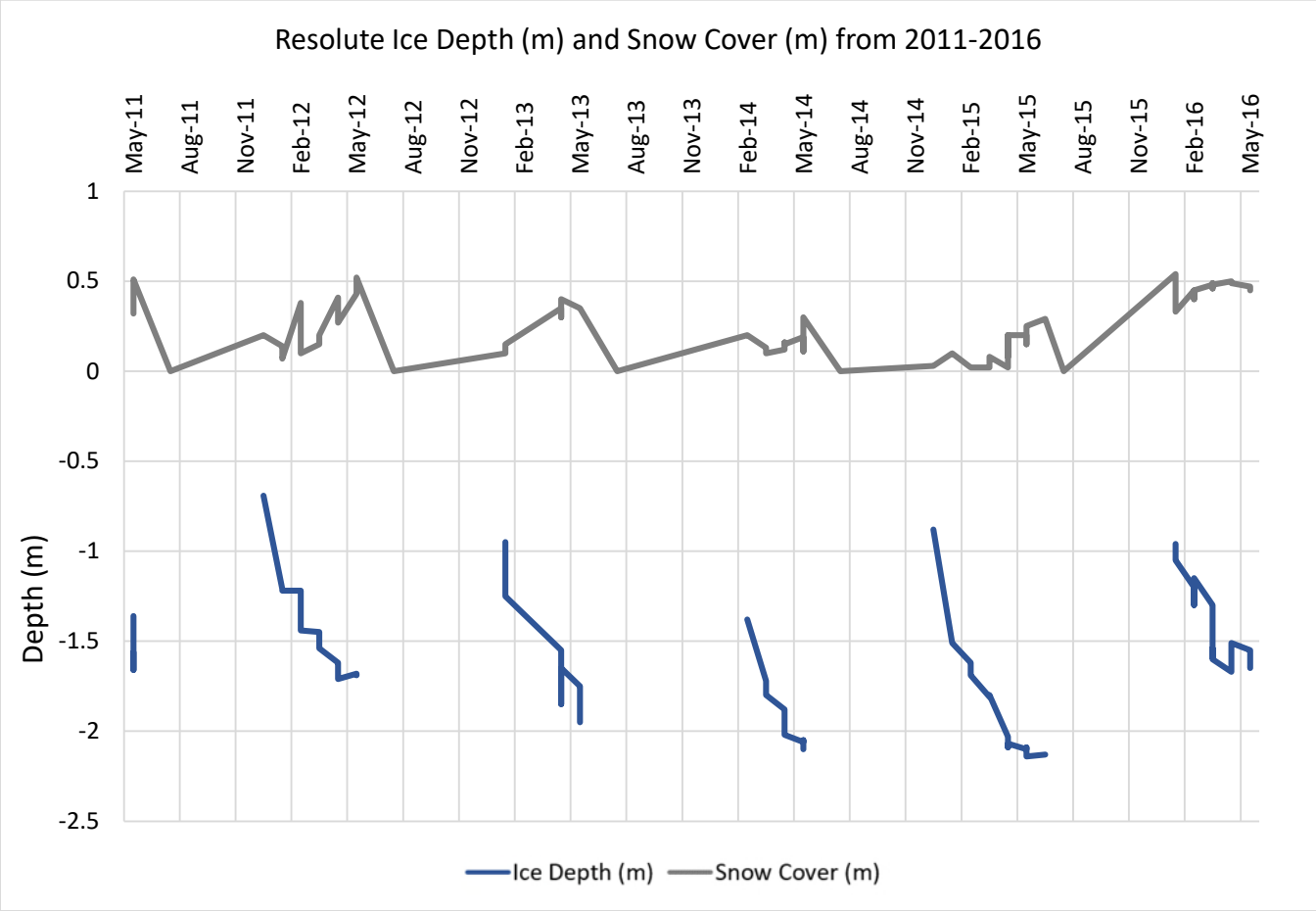
Previous on-site test pitting outlined in the *Phase 3 Environmental Site Assessment* identified 5 test pits in AEC 1 with an average active layer of 0.56m in depth before permafrost was encountered. The maximum active layer depth for *Figure 1* above was established based on this data. The active layer depth was also used to correlate the relationship between air temperature and ground temperature (factor n). It should be noted, however, the installation of thermistors will allow for actual average ground temperatures to be used into the *Frost Depth Change Model*, which will increase its overall precision.

For thermal monitoring, it is predicted that steady state permafrost aggradation will be reached after year 5 based on the *maximum landfill vertical cover depth* shown *in Figure 1*. After, this timeframe the theoretical frost penetration front is expected to reach either the existing permafrost or the capped landfill waste.

Further statistical comparison to baseline expectations can be performed after the installation of thermistors. It is recommended that after year 5, each subsequent monitoring event be used for the statistical analysis to evaluate the steady state conditions of the permafrost.

In order to confirm the validity of the *Frost Depth Change Model*, historic Ice thickness and snow cover depths were analyzed. Results from May 2011 to May 2016 are shown below:

FIGURE 2: RESOLUTE ICE DEPTH (M) AND SNOW COVER (M) FROM 2011-2016



Monthly ice depth was confirmed using Environment and Climate Change Canada historic weather station data of Resolute. The depth of accumulated ice in this model further confirms that the *Frost Depth Change Model* can reach steady state in a 5-year span.

Based on the data from the two previous figures, it is proposed that a thermistor depth of 3.0 m be used moving forward, or to the bottom of the capping material. This will ensure there is useable data for the remainder of the Monitoring Plan, while also allowing for this data to be correlated to Environment and Climate Canada data as required. It should be noted that thermistor depths of 3.0 m may not be

achievable based on the materials encountered beneath the aggregates at the top of the AEC-1 landfill cap.