AECOM

CAM-E Keith Bay Long Term Monitoring

Year 3 Report

Crown-Indigenous Relations and Northern Affairs Canada

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Executive Summary

The CAM-E Keith Bay site was originally an intermediate Distant Early Warning (DEW) Line site implemented by the United States Air Force (USAF) in cooperation with the Canadian Department of National Defence (DND). Constructed in 1957, the site was taken out of service in 1963 and custody of the site was assumed by Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC). Remediation of the site began in 2016 and two landfill facilities were constructed to house the demolition waste: a non-hazardous waste landfill (NHWL) and a Tier II Landfill. As part of the construction work, the beach airstrip and access roads were also upgraded.

The field program was completed on August 7, 2022, including visual inspection and sampling. A visual and environmental monitoring inspection was completed for the Site and documented via checklist along with a photographic record.

Groundwater collection continues to be problematic; no groundwater samples were collected at either the NHWL or Tier II Landfill as the monitoring wells were dry within the active layer. Surface water or soil samples were also not collected as there was no observed seepage points or staining at the Site. Thermal data was collected from the thermistors and processed off-site. Significant wildlife damage and disturbance was observed in the vicinity of the thermistors. The data loggers and thermistor cables were found pulled from four of five casings, with thermistor VT-B-2's cable severed. The severed data logger was removed from Site and left with a CIRNAC representative. Claw and teeth marks on the casing and locks were identified by the Wildlife Monitor as originating from a polar bear. Data was successfully retrieved from VT-A-1, VT-A-2, VT-B-1, and VT-B-2 (up until severance) with a partial data download of VT-A-3 that was found to be corrupt. In-situ manual readings was also taken at each thermistor location following the initial data downloads with the exception of VT-B-2. New batteries were installed in all four remaining data loggers, set to expire July 2024, which will coincide with Year 5 monitoring activities.

Based on the results of the 2022 Year 3 activities, the remediation strategy for CAM-E appears to be meeting the objectives expected for Phase I of the Long-Term Monitoring Plan (LTMP). Physical stability criteria are the focus of Phase I; the thermistor data indicates the Tier II Landfill contents remain frozen and the visual inspection of both landfills found them to be in acceptable condition overall as per Abandoned Military Sites Remediation Protocol (AMSRP) severity ratings. The differential settlement observed at the landfills is presently not a concern but appears to have worsened since Year 1. The shape of the settlement features suggest it may be due to infilled pre-existing frost wedge cracks, in which case, the settlement should not progressively worsen.

Continuation of Phase I monitoring into Year 5 (2024) is recommended with subsequent evaluation for progression into Phase II at that time.

Table of Contents

Figures

Tables

Appendices

Acronyms and Abbreviations

AECOM	AECOM Canada Ltd.
ALS	ALS Environmental Laboratories
AMSRP	Abandoned Military Site Remediation Protocol
CALA	Canadian Association for Laboratory Accreditation
CCME	Canadian Council of Ministers of the Environment
CCUSBA	Communication Cable USB-A
COM	Communication Channel for Data Loggers
CIRNAC	Crown-Indigenous Relations and Northern Affairs Canada
DEW	Distant Early Warning
DND	Department of National Defense
DO	Dissolved Oxygen
GPS	Global Positioning System
HASP	Health and Safety Plan
INAC	Indigenous and Northern Affairs Canada (formerly AANDC)
LTM	Long Term Monitoring
LTMP	Long Term Monitoring Plan
NHWL	Non-Hazardous Waste Landfill
NU	Nunavut
ORP	Oxidative-Reduction Potential
PCBs	Polychlorinated Biphenyls
PHCs	Petroleum Hydrocarbons
POL	Petroleum, Oil, and Lubricants
QA	Quality Assurance
QC	Quality Control
QA/QC	Quality Assurance/Quality Control
RPD	Relative Percent Difference
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
ULA	Upper Limit of Acceptability
USAF	United States Air Force
UTM	Universal Transverse Mercator

1 Introduction

AECOM Canada Ltd. (AECOM) was retained by Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) to conduct the long term monitoring (LTM) activities at former Distant Early Warning (DEW) Line site CAM-E Keith Bay (herein referred to as "the site"). CAM-E is located at 68º 15.37'N, 88º 10.42'W on the eastern side of Simpson Peninsula, approximately 75 km east of Kugaaruk, Nunavut (NU). This report outlines Year 3 of the monitoring program.

1.1 Objective

The objective of the long term monitoring event was to complete Year 3 monitoring activities as described in the *CAM-E, Keith Bay Long Term Monitoring Plan* (AECOM, 2019). The program included visual monitoring of the Non-hazardous Waste Landfill (NHWL), visual inspection of general site conditions and the natural environment, collection and analysis of groundwater samples, and collection of thermal monitoring data. Analysis of field data and visual observations was conducted to satisfy the requirements of the *Abandoned Military Site Remediation Protocol* (INAC, 2009; AMSRP).

1.2 Scope of Work

The scope of work for the 2022 long term monitoring activities included the following:

- Prepare and submit a Logistics Plan detailing the work schedule.
- Prepare and submit a Work Plan detailing the work methodologies.
- Prepare and submit a detailed Health and Safety Plan (HASP).
- Mobilize to and from CAM-E Keith Bay via chartered Twin Otter aircraft, with one field day on site.
- Provision of a wildlife monitor (with firearm) from nearest community.
- Monitoring of general site conditions (i.e., access roads and airstrip, etc.) and natural environment as outlined in section 4.1 of the addendum to the Long Term Monitoring Plan (LTMP) along with visual inspection of the Non-Hazardous Waste Landfill (NHWL) and Tier II Soil Disposal Landfill.
- Visual inspection of the NHWL in accordance with Appendix B of the Addendum to the LTMP. Observations will be documented via a photographic record, visual monitoring checklist, and a site map.
- Purge monitoring wells, collect in situ field parameters, and collect groundwater samples from three (3) monitoring wells around the NHWL and from four (4) monitoring wells around the Tier II landfill.
- Collect soil samples if seepage or staining has been identified during visual inspection. Parameters to be analysed include: Polychlorinated Biphenyls (PCBs), petroleum hydrocarbons, and metals (As, Cd, Co, Cr, Pb, Ni, and Zn).
- Collect thermal monitoring data (both manually and through the download of thermistor data) from five (5) thermistors on the Tier II landfill. Re-set data loggers and replace batteries.
- Replace locks on monitoring wells and thermistors.
- Collect and analyse blind duplicates from at least 20% of samples.
- Submit water samples to a Canadian Association for Laboratory Accreditation (CALA) accredited laboratory for analysis of petroleum hydrocarbon fractions (F1 and F2), total and dissolved metals, major ions, hardness, total dissolved solids, total suspended solids, pH, conductivity, and polychlorinated biphenyls.
- Prepare a field report summarizing LTM activities within two weeks of fieldwork completion.
- Submit draft and final copies of the *CAM-E Long term Monitoring Report (Year 3)* Report to CIRNAC.

Details regarding specific methodology of each task are included in Section 4.

2 Background Information

2.1 Site Description

CAM-E is located approximately 75 kilometres (km) east of Kugaruuk, Nunavut, on the eastern edge of Simpson Peninsula at 68º 15.37' N, 88º 10.42' W. **Figure 1** in **Appendix A** shows the general site location. The CAM-E site was an intermediate DEW Line site constructed by the United States Air Force (USAF) in cooperation with the Canadian Department of National Defense (DND). Constructed in 1957, the site was decommissioned in 1963 and custody of the site was assumed by CIRNAC.

The site consists of the Main Station Area, Main airstrip, and Beach Area (AECOM, 2020). At the time of operation, the infrastructure at the Main Station included a garage, warehouse, petroleum, oil, and lubricant (POL) tanks and pipelines, a module train, antenna, and radar tower, three Quonset huts, drum caches, pallet storage line, a house for local Inuit workers ("Inuit house"), a small airstrip (North Airstrip), storage pads, a landfill, waste dumps, a sewage disposal area and discharge pipe, and a freshwater lake. The Main Airstrip and Beach Area, located about 5.6 km south, consisted of a larger beach airstrip, helicopter landing area, two Quonset huts, waste dumps, a barrel dump, a bunker, and a small shack.

Remediation of the site began in 2016 and included demolishing most of the infrastructure. As part of the construction work, the beach airstrip and access roads were upgraded. Two landfill facilities were constructed to house the non-hazardous waste from infrastructure and debris, and Tier II level contaminated soil: a NHWL and a Tier II Landfill, respectively.

2.2 Previous Reports and Monitoring Programs

AECOM reviewed the following reports prior to the field program:

- *CAM-E Keith Bay Long Term Monitoring Event 2020 Long Term Monitoring Report* (BluMetric, 2021)
- *CAM-E, Keith Bay Site Remediation Construction Summary Report* (AECOM, 2020)
- *Addendum to: CAM-E Long Term Monitoring Plan* (CIRNAC, 2020)
- *CAM-E, Keith Bay Long Term Monitoring Plan* (AECOM, 2019)
- *Abandoned Military Site Remediation Protocol* (AMSRP) (INAC, 2009)

The requirements for long term monitoring as laid out in the AMSRP include:

- **Phase I**: Years 1, 3, and 5
- **Phase II**: Years 7, 10, 15, and 25
- **Phase III**: Beyond Year 25, if required

Phase I monitoring is conducted to confirm landfill stability criteria are achieved, while Phase II is to verify that equilibrium conditions are established during Phase I. Phase III will be carried out if long term issues such as liner integrity, permafrost stability, or significant storm events occur.

3 Reference Guidelines

Review of the CAM-E LTMP and AMSRP identified the applicable guidelines for use in the LTM program. The following sections describe the reference guidelines selected for each type of sample collected at the site.

3.1 Groundwater

During the construction phase, monitoring wells were installed hydraulically upgradient and downgradient of the new landfills (MW17-01 – MW17-07). Due to the absence of appropriate groundwater criteria, the analytical data for groundwater should be compared to available historical data from the site. According to the AMSRP, if the analytical results are within the average +/- three standard deviations, the landfill is deemed acceptable and performing as expected. If the analytical results do not meet these criteria, further measures should be recommended ranging from increasing monitoring frequency to developing a new remedial plan.

For CAM-E, limited background data is available as the wells have been routinely dry within the active layer, with the water level probe hitting the frozen base at permafrost level. One baseline sample was collected during the two-year construction period in 2017, however this does not provide enough information to calculate Upper Limits of Acceptability (ULAs). Similarly, year 1 of the LTM Program was unable to collect samples due to wells being dry within the active layer. Further monitoring events must occur to calculate future ULAs.

3.2 Surface Water

Due to the absence of appropriate surface water criteria, the analytical data for surface water should be compared to available historical data from the site. According to the AMSRP, if the analytical results are within the average +/- three standard deviations, the landfill is deemed acceptable and performing as expected. If the analytical results do not meet these criteria, further measures should be recommended ranging from increasing monitoring frequency to developing a new remedial plan.

No baseline surface water samples exist for the site. Given the absence of appropriate reference guidelines or baseline reference data, the Canadian Council of Ministers of the Environment (CCME) guidelines for protection of aquatic life are used purely as a point of reference and are not meant to be interpreted as criteria. The CCME guidelines are a conservative reference as the closest surface water body is approximately 950 m from the Tier II Landfill or 1,100 m from the NHWL.

3.3 Soil

Baseline soil samples were collected in 2017 prior to the construction of the NHWL and Tier II Landfill and were analyzed for PHCs, PCBs and metals. The results can be used to calculate ULAs and used as criteria per the AMSRP, however no soil samples have been collected since 2017 and there has been no need to calculate ULAs. The baseline data can be found in the 2020 CAM-E (Keith Bay) Construction Summary Report (AECOM, 2020).

4 2022 Monitoring Program Methodology

The site investigation for the 2022 CAM-E Long Term Monitoring Program was completed on August 7, 2022 by AECOM personnel David Bugden and Alysha Selinger accompanied by CIRNAC representative Melanie Netser, wildlife monitor Noah Alookie, and a field technician Max Dubeau with Nunatta Environmental. The site was accessed by Twin-Otter aircraft provided by Kenn Borek Ltd. The team was to depart from Kugaaruk, but due to fuel shortages, departure was made from Gjoa Haven to the site.

4.1 Health and Safety Plan

In preparation for the field program, a site-specific HASP was produced and submitted to CIRNAC previously under a separate cover. The HASP identified risks and suspected hazards associated with work on the site. It specifically addressed any known or suspected hazards and provided mitigative measures including protocols for COVID-19. Included in the HASP were emergency contacts and procedures for medical, mechanical, or weather emergencies. Prior to the start of work, a review of the HASP was completed with all personnel involved in the field program.

4.2 Geotechnical Monitoring and Visual Inspection

The physical integrity of the NHWL and Tier II Landfill was inspected at the CAM-E site during the 2022 monitoring event. The purpose of the visual inspection was to look for evidence of the following:

- Erosion, ponding, frost action, settlement, and lateral movement
- Animal burrows, vegetation, vegetation stresses
- Staining or seepage

These features were documented by use of the visual monitoring checklist and through site photographs. Site features that were documented in the previous monitoring event were specifically inspected for any observed changes, and new features observed during the 2022 visual monitoring were documented.

4.3 Natural Environment Monitoring

Natural environment data was collected during the 2022 long term monitoring event. The specific observations that were noted included:

- Wildlife sightings (species, number, gender, juveniles)
- 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).

Additional observations or information were not collected from local residents due to logistical restraints that caused the field team to stage from Gjoa Haven in place of Kugaaruk.

4.4 Groundwater Sampling

There are seven groundwater monitoring wells (MW17-01 – MW17-07) around the NHWL and Tier II Landfill. There was no evidence of wildlife damage to the groundwater wells at the time of assessment. Well locations are provided in **Table 4-1** and shown in **Figure 2** of **Appendix A**.

Table 4-1 CAM-E Keith Bay Groundwater Well Locations

Well	UTM83-16 Northing (m)	UTM83-16 Easting (m)
MW17-01	7571319.8	452278.7
MW17-02	7571241.7	452304.4
MW17-03	7571294.9	452410.2
MW17-04	7571375.6	452341.8
MW17-05	7571447.2	452315.5
MW17-06	7571483.4	452366.8
MW17-07	7571432.7	452411.0

4.4.1 Groundwater Sampling Methodology

The following outlines the methodology that was prepared for this program in the event that the wells contained groundwater.

Water level and depth to bottom were to be recorded, and an approximate well volume calculated. A peristaltic pump and dedicated disposable polyethylene tubing was to be used to purge and sample using low-flow sampling methodology. The following recordings were to be taken prior to sampling; water level, total depth of water, height of well stick-up, presence of hydrocarbons, and hydrocarbon thickness (if appropriate). The monitoring well was then to be purged until water quality parameters stabilized, including dissolved oxygen (DO), oxidative-reduction potential (ORP), temperature, pH, conductivity, and turbidity were to be recorded prior to sampling. Parameter readings during the purging process would be recorded every 3 to 5 minutes, aiming for three consecutive readings within 5% prior to sampling. If stabilization could not be achieved before depletion of the water column, purging would stop, and sample collection would begin. Laboratory supplied containers were to be filled, packed with ice in coolers, and shipped to ALS Laboratories in Edmonton for analysis.

ALS is an accredited Canadian Association for Laboratory Accreditation (CALA), where samples were to be analyzed for:

- PHC Fractions F1 and F2;
- Total and dissolved metals;
- Major ions, hardness, total dissolved solids, total suspended solids;
- pH, conductivity; and
- PCBs.

4.5 Surface Water Sampling Methodology

The following outlines the methodology that was prepared for this program in the event that surface water was identified on site.

Following the collection of each water sample, temperature, pH, dissolved oxygen, and conductivity were to be recorded. Observations such as turbidity, evidence of groundwater indicators (surface sheen, vegetation), and presence or evidence of aquatic life, humans and/or animals on site were also to be noted.

All collected surface water samples were to be placed in appropriate laboratory-supplied, clean sample bottles, placed in insulated coolers (provided by ALS Laboratory) to be maintained between 0 and 10 degrees Celsius (ºC),

and shipped to the laboratory under a Chain of Custody. Global Position System (GPS) Universal Transverse Mercator (UTM) coordinates were to be documented for surface water sampling locations.

The following parameters were to be analyzed:

- PHC Fractions F1 and F2 (C6-C16);
- Total and dissolved metals;
- PCBs; and
- Total suspended solids (TSS), total dissolved solids (TDS), and routine parameters including major ions and hardness.

4.6 Soil Sampling Methodology

In the event that visual inspections identified the need for soil samples to be collected, samples were to be collected with a small trowel which will be decontaminated with a laboratory-grade biodegradable cleaner (Alconox®) and rinsed between sampling locations. Soils samples were to be collected to a maximum depth of 30 cm and packed into laboratory supplied jars with minimal to no headspace. Samples were to be kept cool and packed on ice for shipment to ALS laboratories.

The following parameters were to be analysed:

- PCBs;
- PHC Fractions F1-F4; and
- Metals.

4.7 Thermal Monitoring

Five thermistor strings, which measure temperatures at various depths below the ground surface, were installed in the Tier II Landfill in 2018 to provide a record of permafrost aggradation through the containment berms and landfill contents over time, and to provide an indication of the average active layer depth. The thermistor strings are equipped with Lakewood Systems RX16ML Data Loggers and include 11 to 13 beads spaced every 0.6 m for a general length of 5 to 7 m. Thermistor locations are listed in **Table 4-2** and shown on **Figure 2** of **Appendix A**.

Table 4-2 CAM-E Keith Bay Thermistor Locations

Thermistor	UTM83-16 Northing (m)	UTM83-16 Easting (m)
VT-A-1	7571335.8	452305.5
VT-A-2	7571274.0	452325.2
VT-A-3	7571300.7	452368.0
VT-B-1	7571319.5	452326.2
VT-B-2	7571294.4	452342.9

4.7.1 Thermal Data Collection Methodology

The thermistor casings were visually inspected for their condition and any damage documented. The Data Loggers were then connected to a laptop and downloaded with ProLog software using the designated CCUSBA Communication Cable and reset. Both the main battery and back-up 9-volt battery were replaced within each Data Logger. The Data Logger was then disconnected from the thermistor cable so manual readings could be taken as a backup in the event of malfunction. Once the Data Logger was reconnected, the cable was placed back in the casing with the Data Logger on top and locked.

The thermal data was then processed off-site to produce ground temperatures curves and rate plots for each thermistor, with clear indication of the 0°C isotherm. These graphs provided the basis for discussion of freeze back and active layer depth within the landfill during the period of maximum thaw.

4.8 Quality Assurance and Quality Control

A Quality Assurance/Quality Control (QA/QC) program was to be followed in the event that sampling occurred to check that sampling and analytical data collected are interpretable, defensible, and comparable. This would involve QA/QC measures in both the collection and analysis of environmental samples.

Quality Control (QC) measures apply to the collection, preservation, shipment, and analysis of samples and include the following:

- Sampling techniques performed in accordance with standard written AECOM protocols.
- Thorough field notes taken during the site visit.
- All samples collected in laboratory provided sample containers, and kept cool prior to shipment.
- Samples assigned unique sample control numbers and transported under chain of custody procedures.
- The analytical laboratory chosen with proficiency certification issued by CALA.

Quality Assurance (QA) measures include the collection of field duplicate samples. A blind duplicate sample consists of a second aliquot of an individual sample that is submitted to the analytical laboratory under a separate label such that the analytical laboratory has no prior knowledge that it is a duplicate. The CAM-E LTM program specifies that field duplicates be collected at a rate of minimum 10%.

The relative percent difference (RPD) between duplicate results is used to assess overall sampling precision. The RPD is a measure of the variability between two duplicate analyses and is calculated by the following equation:

$$RPD = 100 \times ((2 \times (x_1 - x_2))/(x_1 + x_2))$$

Where x_1 is the primary results and x_2 is the blind duplicate result.

Acceptable RPD values vary on the analytical parameters, the sample matrix and the concentrations of analytes in the sample. For metals in soils acceptable RPD values are 35%, and 50% for organics in soils (e.g., PHCs and PCBs). Only when concentrations are at least 10 times the method detection limit are RPD calculations considered valid.

5 Results

Drawings, with inspection feature markups, are provided on figures in **Appendix A.** Photographs of the site taken during the site monitoring program are presented in **Appendix B.** The Visual Inspection Checklist can be found in **Appendix C**.

It should be noted that frost wedge cracking on the surrounding tundra and encroaching towards the landfill was visible from the aerial approach, particularly to the east and south of the landfills. These natural permafrost terrain features were previously misidentified in the Year 1 monitoring event as erosion (BluMetric, 2021). Visual inspection markups on **Figure 2** in **Appendix A** have been updated accordingly.

5.1 Natural Environment

Observations of the natural environment were limited to the evidence of polar bear activity among the thermistors. No polar bears were spotted while on site, only evidence of past activity and knowledge of polar bear sightings during previous site visits. There was no evidence of establishment of vegetation on site at the time of the inspection. The complete Natural Environment Checklist is available in **Appendix C**.

5.2 Non-Hazardous Waste Landfill (NHWL)

5.2.1 Geotechnical Monitoring and Visual Inspection

The following subsections describe the results of the geotechnical monitoring visual inspections completed at the landfill and immediately surrounding area.

5.2.1.1 Settlement

Some differential settlement was noted on the west side of the NHWL extending 30-40 m out from the slope (see Photograph 13 in **Appendix B**). Differential settlement was also noted midway on the south slope extending approximately 10 m out from the slope with smaller settlement on the southeast corner (Photographs 17 and 18 in **Appendix B**). This settlement was noted in the previous Year 1 investigation in 2020 (BluMetric, 2021) and appears to have continued to develop. Currently, the features do not compromise the performance of the NHWL. The north and east slopes were found to be in good condition with no notable defects. Of note is that the mainly linear shape of the settlement and its position moving away from the landfill toe suggests that it may be due to pre-existing frost wedge cracks that were covered during construction. If this is the case, the settlement should not be expected to continue to worsen.

5.2.1.2 Erosion

The 2022 inspection did not identify any signs of erosion on site. The Year 1 features identified as erosion have been updated as frost wedge cracking and are naturally occurring features of the surrounding tundra. In their current condition, the frost wedge cracks do not compromise the performance of the NHWL and will only present a potential risk if new cracks develop proximate or within the landfill. These features are most clearly displayed in Photograph 3 of **Appendix B**.

5.2.1.3 Animal Presence

No evidence of wildlife activity was noted at the NHWL; no animals were sighted nor burrows noted during the investigation.

5.2.1.4 Debris

Minimal scattered surface debris was observed throughout the site but was not observed to be exposed or originating from the NHWL.

5.2.1.5 Staining

No staining was observed.

5.2.1.6 Vegetation Stress

No evidence of revegetation was noted.

5.2.1.7 Seepage and Ponding

Indicators of seepage or active seepage points were not observed.

5.2.1.8 Monitoring Instruments

The monitoring wells around the perimeter of the NHWL, MW17-04, MW17-05, MW17-06 and MW17-07, were found in good condition.

5.2.2 Groundwater Monitoring

All wells were found to be dry within the active layer again in 2022, so no samples were collected. The depth to ice values were recorded and are included in **Appendix D**.

5.2.3 Surface Water Monitoring

No surface water ponding or seepage were noted, consistent with baseline and previous monitoring events, so no samples were collected at the site during the 2022 long term monitoring event.

5.2.4 Soil Monitoring

No soil samples were collected at the time of the 2022 long term monitoring event as there was no evidence of seepage or staining.

5.2.5 Landfill Performance

The overall performance condition of the NHWL is rated as acceptable in 2022 based on the severity ratings presented in AMSRP Volume II (INAC, 2009). This is consistent with the condition documented in the Year 1 inspection (BluMetric, 2021). While some settlement features appear slightly larger since the 2020 inspection, the settlement does not appear to be affecting the stability, or performance, of the landfill. The consistent lack of active layer groundwater and surface water accumulation along the toe also indicate little to no risk associated with contaminant migration from the landfill.

5.3 Tier II Landfill

5.3.1 Geotechnical Monitoring and Visual Inspection

5.3.1.1 Settlement

The top of the Tier II landfill and the north and east slopes were observed to be in good condition. Minor differential settlement was noted on the northwest corner, and middle of the west and south slopes of the landfill (Photographs 25 and 30 in **Appendix B**). These settlement cracks from the south and west berms were noted in the previous Year 1 investigation in 2020 (BluMetric, 2021) and appear to have continued to develop. Currently, the features do not compromise the landfill performance. The north and east slopes were found to be in good condition with no notable defects. Similar to the NHWL, the mainly linear shape of the settlement and its position moving away from the landfill toe suggests that it may be due to pre-existing frost wedge cracks that were covered during construction. If this is the case, the settlement should not be expected to continue to worsen.

5.3.1.2 Erosion

The 2022 inspection did not identify any signs of erosion on site. The Year 1 features identified as erosion have been updated as frost wedge cracking and are naturally occurring features of the surrounding tundra. These features closest to the Tier II Landfill are displayed in Photographs 1 - 4 of **Appendix B**.

5.3.1.3 Animal Presence

Evidence of animal activity onsite included polar bear scratches and teeth marks on the thermistor casings and locks. Data Loggers from thermistors VT-A-1, VT-B-1, and VT-B-2 had been pulled from their casings with VT-B-2 severed and relocated to the vicinity of VT-B-1. Animal evidence was not observed around the groundwater wells, and no animal burrows were noted on site during the investigation. The field team did not actively see any wildlife while on site or during the aerial approach.

5.3.1.4 Debris

Minimal scattered surface debris was observed throughout the site but was not observed to be exposed or originating from the landfill.

5.3.1.5 Staining

No staining was observed.

5.3.1.6 Vegetation Stress

No evidence of revegetation was noted.

5.3.1.7 Seepage and Ponding

Indicators of seepage or active seepage points were not observed.

5.3.1.8 Monitoring Instruments

The monitoring wells on the perimeter of the Tier II Landfill, MW17-01, MW17-02, MW17-03 and MW17-04, were generally in good condition. A bailer was found frozen inside MW17-01, however a depth to ice measurement was still manageable. The five thermistor casings installed in the landfill berm and contents received some damage from polar bear activity. Damage to the thermistor casings was superficial with claw and teeth marks. All casings were found uncapped, except for VT-A-2 that was still capped, pinned, and dummy locked. The thermistor VT-B-2 Data Logger was severed from the cable and removed from site. Thermistor VT-A-3 was found with bite marks on the cable and water in the data logger. A clock reset error was also noted upon download.

5.3.2 Thermal Monitoring

5.3.2.1 Thermistor Inspection and Data Collection

Ground temperature data was retrieved by AECOM personnel during the 2022 field program at CAM-E. On August 7, 2022, data was successfully retrieved from VT-A-1, VT-A-2, VT-B-1, and VT-B-2 with a partial data download of VT-A-3. The VT-B-2 Data Logger was found severed from its thermistor string cable; the data logger was later removed from site and left with a CIRNAC representative. The data download from VT-B-2 was successful with the ProLog software generated rate plot indicating the date the connection had been severed. A clock reset error was incurred during the download of VT-A-3 resulting in the partial download. An in-situ manual reading was also taken at each thermistor location following the initial data downloads with the exception of VT-B-2. New batteries were installed in all four remaining data loggers, set to expire July 2024, which will coincide with Year 5 monitoring activities.

Significant wildlife damage and disturbance was observed in the vicinity of the thermistors. The data loggers and thermistor strings were found pulled from four of five casings, with thermistor VT-B-2's string cable severed. Claw and teeth marks on the casing and locks were identified by the Wildlife Monitor as originating from a polar bear. The previous LTM site visit in 2020 reported five polar bear sightings at the site, and polar bear sightings and encounters were documented during site construction. Therefore, a continued bear presence on site is expected.

Given the condition the thermistors were found in, it is possible the bead elevations may have shifted when the Data Loggers were pulled from the casings at VT-A-1, VT-A-3, VT-B-1 and VT-B-2. Since the caps were also removed from those thermistors, it is possible precipitation could have entered the casing and wet the containment sand. Moisture within the casing may damage the thermistor cables themselves or influence the thermal readings compared to those which remained dry. VT-A-2 was found capped and therefore could provide a dry reference in subsequent monitoring events if thermal data shows signs of interference.

5.3.2.2 Thermal Data Evaluation

Five thermistors were installed within the Tier II Landfill to document the active layer depth fluctuation over time as the thermal conditions stabilize on site. During the site visit, temperature measurements, recorded in degree Celsius (°C) from February 6, 2020, to August 7, 2022, were downloaded from all five thermistors. The data was processed to analyze annual temperature patterns and trends over time. Rate Plots, Figures 1 through 4 in **Appendix E**, present the temperature fluctuation recorded for each thermistor bead at 4 of the 5 thermistor locations. The Ground Temperature Curves, Figures 5 through 8 in **Appendix E**, depict the temperature depth profiles mid-month over the last two years. Due to corruption of the VT-A-3 data, neither a Rate Plot nor Ground Temperature Curve could be plotted.

The primary means of containment for the Tier II landfill is within berms constructed of saturated, compacted, low permeability granular fill that become largely impermeable once permafrost has aggraded into them. Three thermistors were installed in the berms of the landfill, VT-A-1, VT-A-2 and VT-A-3, and two within the landfill contents, VT-B-1 and VT-B-2, to measure the active layer depth. Ideally, the landfill berms and soil contents become consistently frozen. Secondary (shorter term) containment is provided via geomembrane installed at the landfill base, along the containment berms, and over the top the landfill contents. A thick granular surface cover is placed at a design thickness of 3 m that is intended to keep the containment berms, and ideally contents, consistently frozen. The maximum active layer depths recorded during monitoring events are compared to the cover thickness, top of berm and top of landfill contents to confirm that the thermal containment design is performing as intended. These depths are included on the Ground Temperature Curves to visualize the thermal conditions with respect to the various landfill layers (see **Appendix E**).

Interpolation of the results allowed for determination of the per annum maximum thaw at each thermistor location. As shown in **Table 5-1**, between 2019 and 2022 the maximum active layer depth has generally decreased, although not consistently. Some variability is expected, in line with climatic variability over different years, and climatic variability (including climate change) is included within derivation of the cover thickness design. However, the key information shown in **Table 5-1** is that the landfill contents have been consistently frozen since 2019, with the maximum active layer depth limited to within the surface cover since 2020. This is consistent with design predictions and monitoring results from other sites which have freeze-back occurring within 2-5 years following construction.

Table 5-1 Maximum Thaw Depth by Year (shown in metres below ground surface)

Thermistor	Thermistor Location	2019	Year 1 of LTM 2020	Year 3 of LTM 2022
		Surface Cover is 3 m thick [a] Depth to Waste from Cap Surface is 4 m [a]		
VT-A-1	West Berm	1.9	1.7	1.8
VT-A-2	South Berm	2.2	2.0	2.0
VT-A-3	East Berm	2.3	2.0	- [b]
VT-B-1	Central for Contents	2.8	1.9	2.1
VT-B-2	Central for Contents	3.0	1.9	1.9 [c]

[a] *– Based on design and as-built information (AECOM, 2020)*

[b] *– Thermistor VT-A-3 was found with bite marks on the cable and water in the Data Logger, a clock reset error was also noted upon download. The data is corrupt and unable to be processed.*

[c] *– Reflective of data up to November 6, 2021. Data logger records indicate this is the day the data logger was severed from the thermistor cable.*

Figures 1 through 4, below, are a simplification of the Ground Temperature Curves in **Appendix E** and provide the maximum freeze (depicted with annual data from January 15) and maximum thaw (August 15 annually) with respect to the landfill cap surface, top of waste, bottom of waste, and 0°C isotherm. The range of temperature variability narrows from approximately 5-degrees at the top of the landfill contents, to approximately 2-degrees at the end of the thermistor strings. The low variability demonstrates an approach towards steady-state conditions indicating the containment method is performing as designed. Intersection of the curves with the 0°C isotherm provides the maximum thaw depth presented in **Table 5-1** and informs the active layer depth. The active layer remains 2 m above the top of waste at all thermistor locations and shows that the Tier II soil has been frozen continuously since 2019.

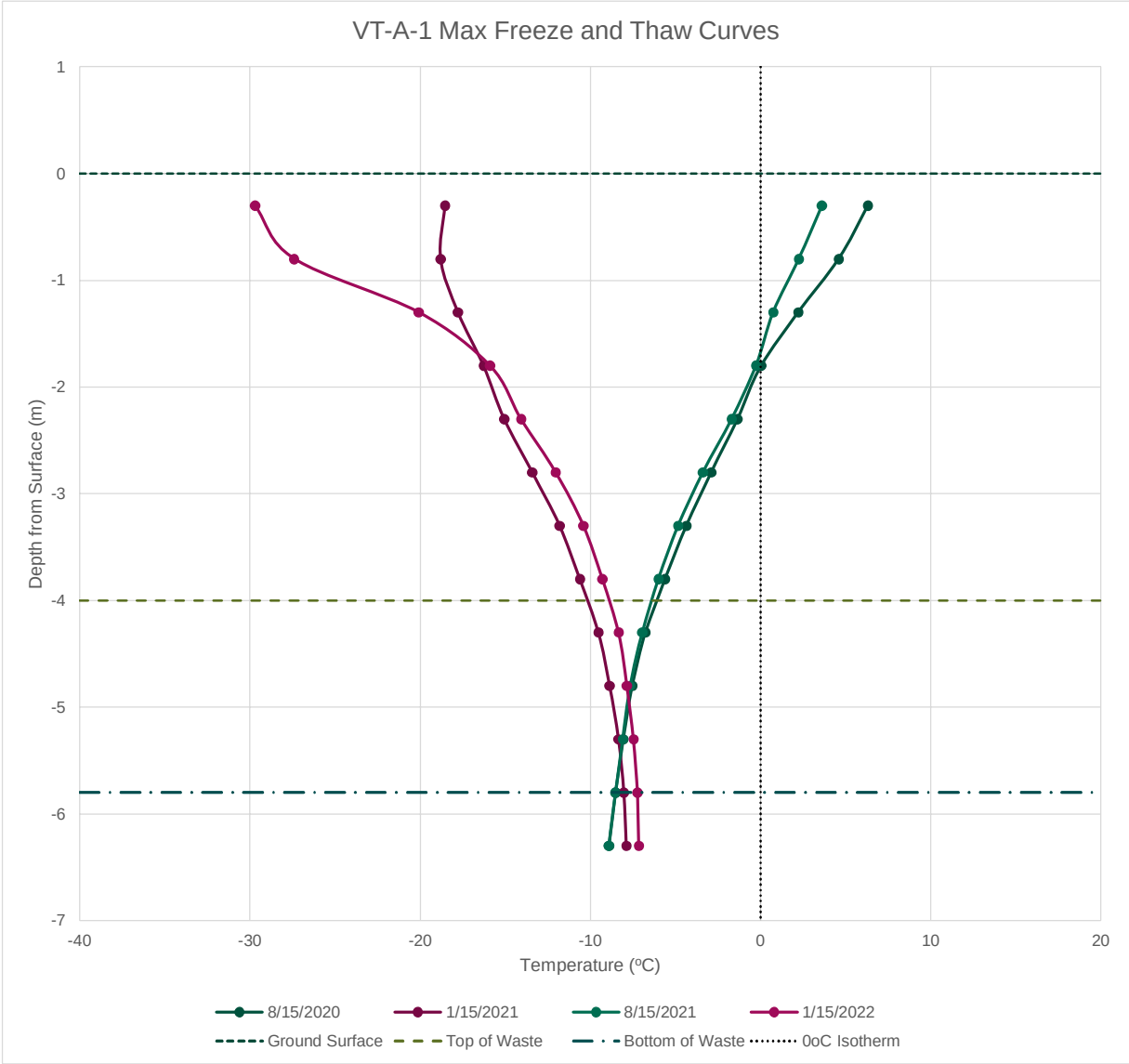


Figure 1. VT-A-1 Max Freeze and Thaw Curves

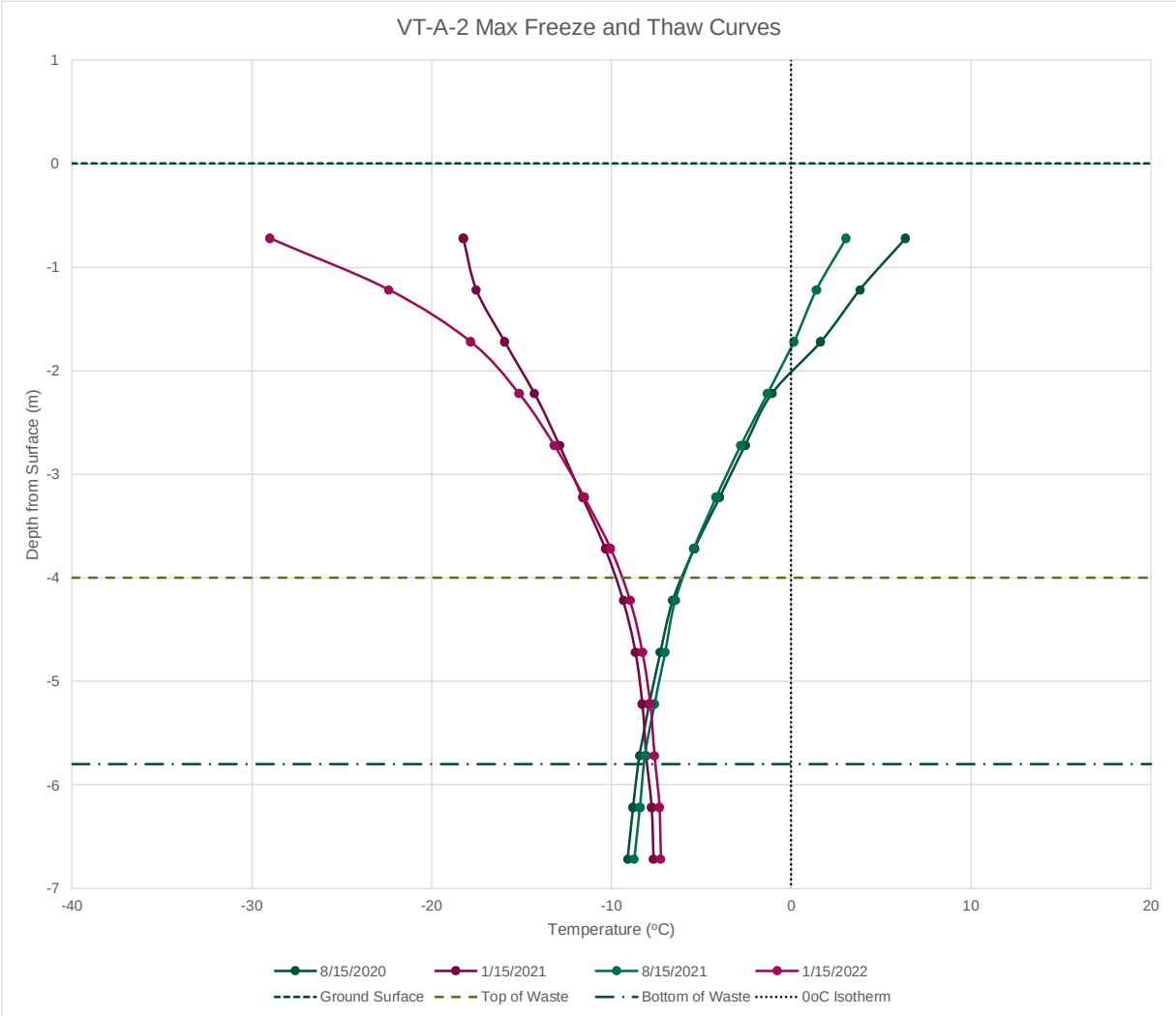


Figure 2. VT-A-2 Max Freeze and Thaw Curves

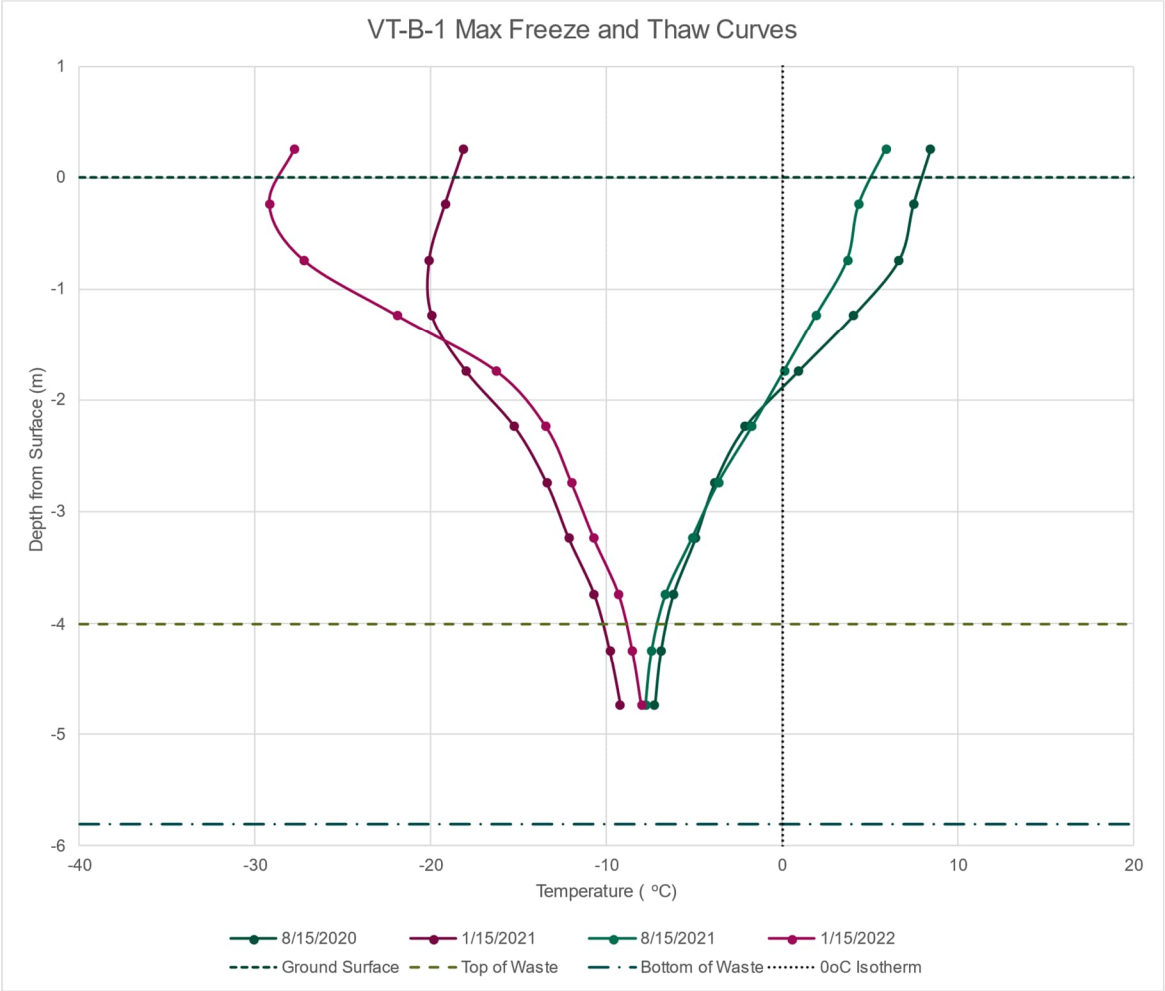


Figure 3. VT-B-1 Max Freeze and Thaw Curves

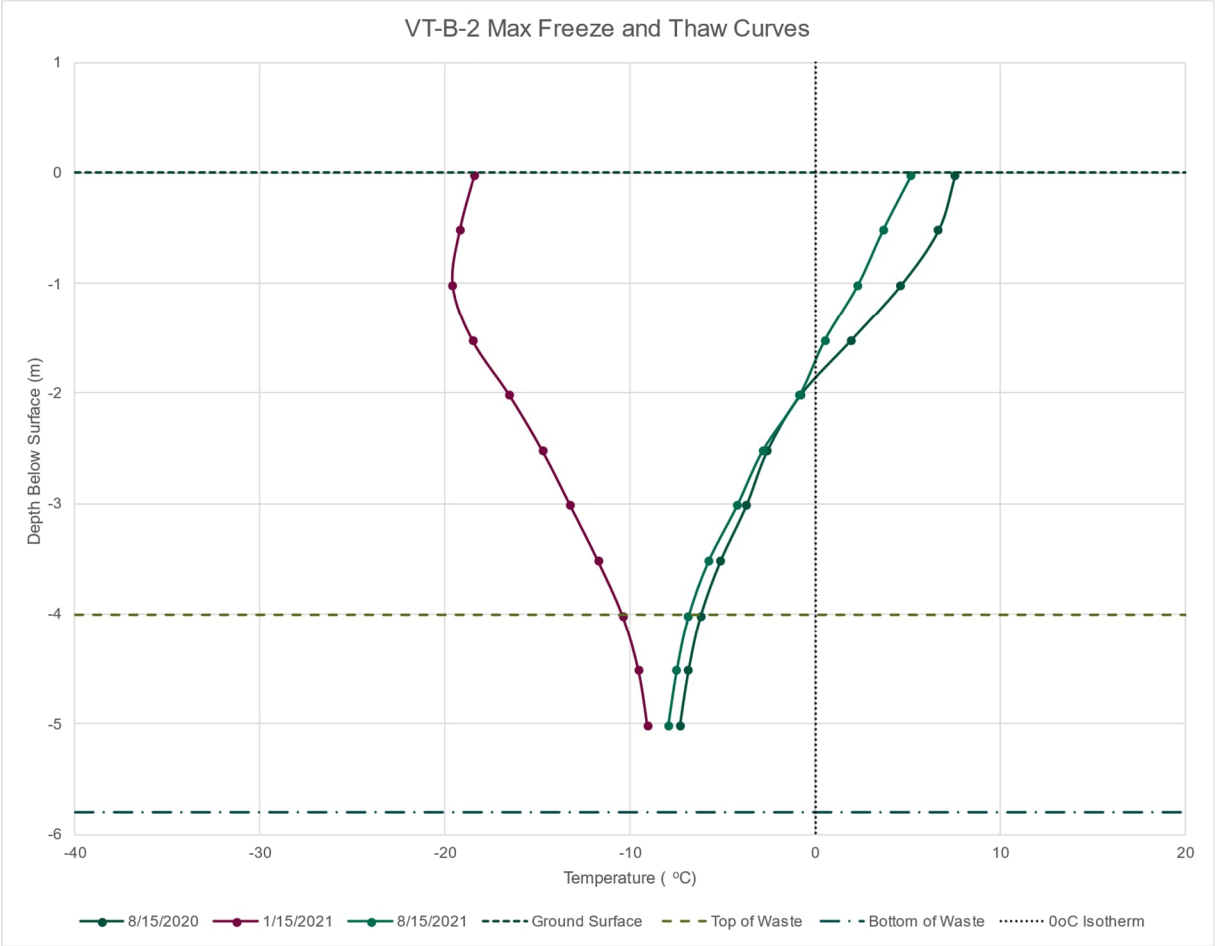


Figure 4. VT-B-2 Max Freeze and Thaw Curves

Note: 2022 data unavailable due to severance on November 6, 2021. Data Logger has been removed from site.

5.3.3 Groundwater Monitoring

All wells were found to be dry within the active layer again in 2022, so no samples were collected. The depth to ice values were recorded and are included in **Appendix D**.

5.3.4 Surface Water Monitoring

No surface water ponding or seepage were noted, consistent with baseline and previous monitoring events, so no samples were collected at the site during the 2022 long term monitoring event.

5.3.5 Soil Monitoring

No soil or surface water samples were collected at the time of the 2022 long term monitoring event as there was no evidence of seepage or staining.

5.3.6 Landfill Performance

The overall performance condition of the Tier II Landfill is considered acceptable in 2022 based on the severity ratings presented in AMSRP Volume II (INAC, 2009). This is consistent with the condition documented in the Year 1 inspection (BluMetric, 2021). While some settlement features appear slightly larger since the 2020 inspection, the settlement does not appear to be affecting the stability, or performance, of the landfill and the landfill surface did not show any evidence of settlement or erosion. The thermal data demonstrate that permafrost containment of the Tier II soil has been in place since 2019. The thermal data, combined with consistent lack of active layer groundwater and surface water accumulation along the toe, support the conclusion that there has been no contaminant migration from the landfill.

6 Conclusion and Recommendations

Based on the results of the 2022 Year 3 activities, the remediation strategy for CAM-E appears to be meeting the objectives expected for Phase I of the LTMP. Physical stability criteria are the focus of Phase I; the thermistor data indicates the Tier II Landfill contents remain frozen and the visual inspection of both landfills found them to be in acceptable condition overall. The differential settlement observed at the landfills is presently not a concern but appears to have worsened since Year 1. The shape of the settlement features suggest it may be due to infilled pre-existing frost wedge cracks, in which case, the settlement should not progressively worsen. Continuation of Phase I monitoring into Year 5 is recommended with subsequent evaluation for progression into Phase II at that time.

Groundwater collection continues to be problematic. Collection of soil samples, beyond the current LTMP specification of seepage and staining, could provide a data source to supplement the lack of groundwater data. This approach was used for landfill monitoring by DND at their DEW Line sites.

It is paramount that all instrument casings are locked to prevent further damage to the thermistors and make the instruments more secure from unauthorized access. This would work to mitigate against the recurring polar bear activity on site and act as a deterrent for possible human vandalization or interference. Thermistors and groundwater wells were locked with Guard Key 111 and additional key sets were left with a CIRNAC representative. It is recommended keys are provided for the next monitoring event to avoid cutting and replacement of locks on site. Further, it is recommended additional locks are brought to site during future visits in the event locks are found missing or damaged.

Repair or reinstallation of severed thermistor VT-B-2 is not yet recommended at the site given the associated cost and VT-B-1 remaining functional within the contents of the Tier II Landfill. The data obtained from thermistor VT-A-3 was corrupt. Standing water found in the VT-A-3 Data Logger case was removed, dried, and a fresh moisture indicator pad was placed inside prior to properly storing the case in the thermistor housing. It is recommended this thermistor is assessed during the next monitoring event to determine if the issue is rectified, or if the thermistor is irreparably damaged. Fortifying the thermistor casings may become necessary to protect the remaining functional instruments; alterations may include installing metal casing caps in place of the current plastic caps and using heavy-duty locks on each end of the pin.

7 References

AECOM Canada Ltd. (AECOM). 2020. CAM-E, Keith Bay - Site Remediation - Construction Summary Report. Submitted to Public Services and Procurement Canada. March 30, 2020.

AECOM. 2019. CAM-E, Keith Bay – Long Term Monitoring Plan. Submitted to Public Services and Procurement Canada. December 17, 2019.

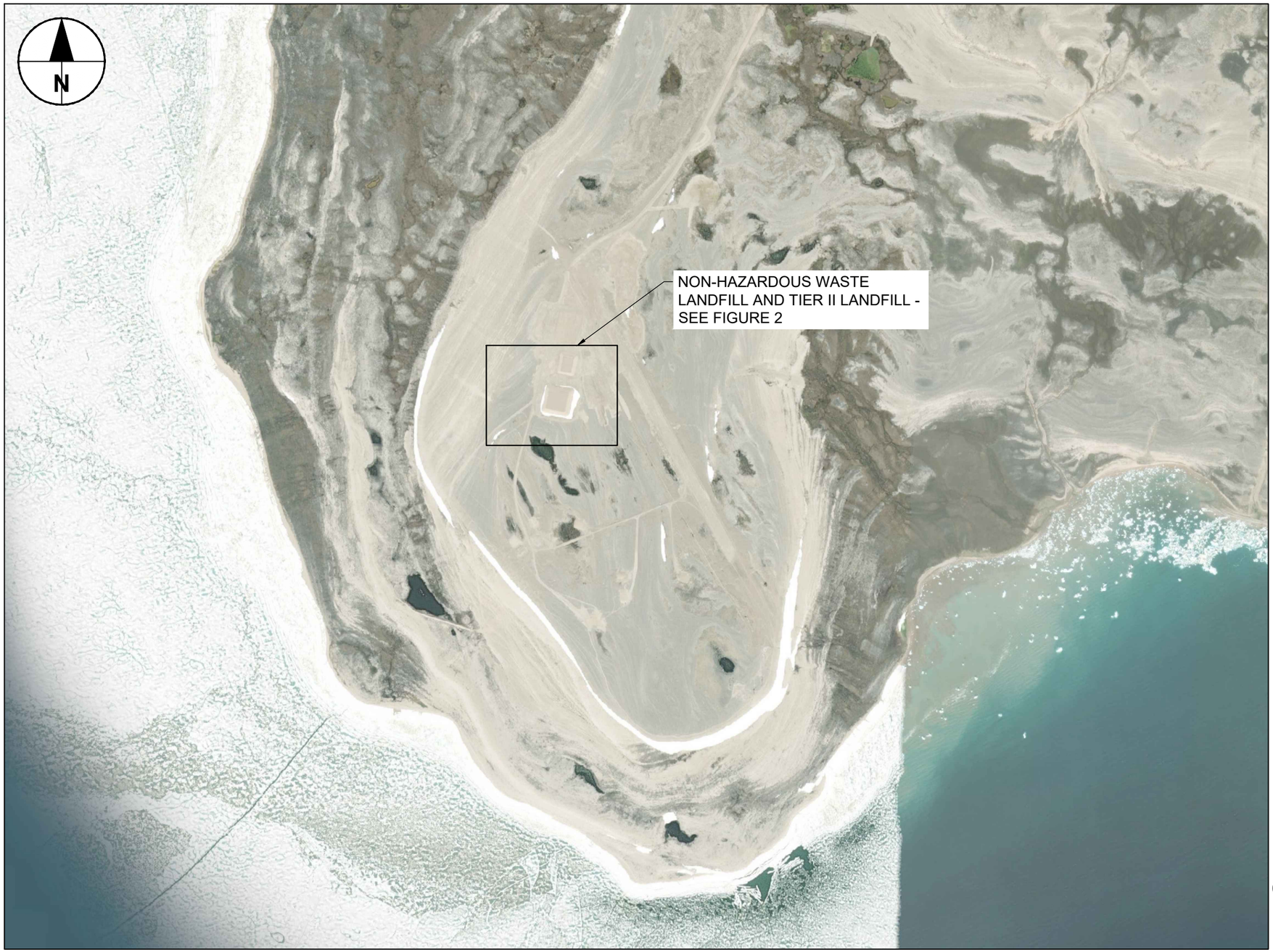
BluMetric Environmental Inc. (BluMetric). 2021. CAM-E Keith Bay Long Term Monitoring Event – 2020 Long Term Monitoring Report. Submitted to Crown-Indigenous Relations and Northern Affairs Canada. February 18, 2021.

Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC). 2020. Addendum to: CAM-E Long Term Monitoring Plan. Submitted to Crown-Indigenous Relations and Northern Affairs Canada.

Indigenous and Northern Affairs Canada (INAC). 2009. Abandoned Miliary Site Remediation Protocol (AMSRP).

Appendix A

Figures



NOTES:
1. ALL COORDINATES ARE REFERENCED TO NAD83 UTM ZONE 16.
2. IMAGERY FROM ARCGIS DATAMAP.

Issue Status: FINAL

2022 Nunavut Sites Long-Term Monitoring
CAM-E Keith Bay (Year 3)
Crown-Indigenous Relations and Northern Affairs Canada
Project No.: 60686962 Date: 2023-01-11

NON-HAZARDOUS WASTE LANDFILL AND TIER II LANDFILL
LOCATION PLAN

AECOM

Figure 1

SITE LOCATION PLAN
N.T.S.

No.	NORTHING	EASTING
VT-A-1	7571335.80	452305.50
VT-A-2	7571274.00	452325.20
VT-A-3	7571300.70	452368.00
VT-B-1	7571319.50	452326.20
VT-B-2	7571294.40	452342.90
MW17-01	7571319.80	452278.70
MW17-02	7571241.70	452304.40
MW17-03	7571294.90	452410.20
MW17-04	7571375.60	452341.80
MW17-05	7571447.20	452315.50
MW17-06	7571483.40	452366.80
MW17-07	7571432.70	452411.00

LEGEND

- WILDLIFE EVIDENCE
- MW — MONITORING WELL
- VT — THERMISTOR
- VT — THERMISTOR - DATA LOGGER SEVERED; REMOVED FROM SITE
- FROST WEDGE CRACKING
- SETTLEMENT
- 50 — EXISTING CONTOURS (0.5 m INTERVAL)

NOTES:
1. ALL COORDINATES ARE REFERENCED TO NAD83 UTM ZONE 16.
2. IMAGERY FROM ARCGIS DATAMAP.

0 37.5 75 m

1:1500

Issue Status: FINAL

2022 Nunavut Sites Long-Term Monitoring
CAM-E Keith Bay (Year 3)
Crown-Indigenous Relations and Northern Affairs Canada
Project No.: 60686962 Date: 2023-01-11

NON-HAZARDOUS WASTE LANDFILL AND TIER II LANDFILL
VISUAL INSPECTION

AECOM

Figure 2

Appendix B

Photographic Record

PHOTOGRAPHIC RECORD

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
1	8/7/2022

Direction Photo Taken

East

Area

Site Condition

Description

Aerial view of main station overlooking NHWL and Tier II Landfill. Various frost wedge cracks were visible on the east side from aerial view. Cracks are natural permafrost terrain features. Landfills visible in photo (boxed).

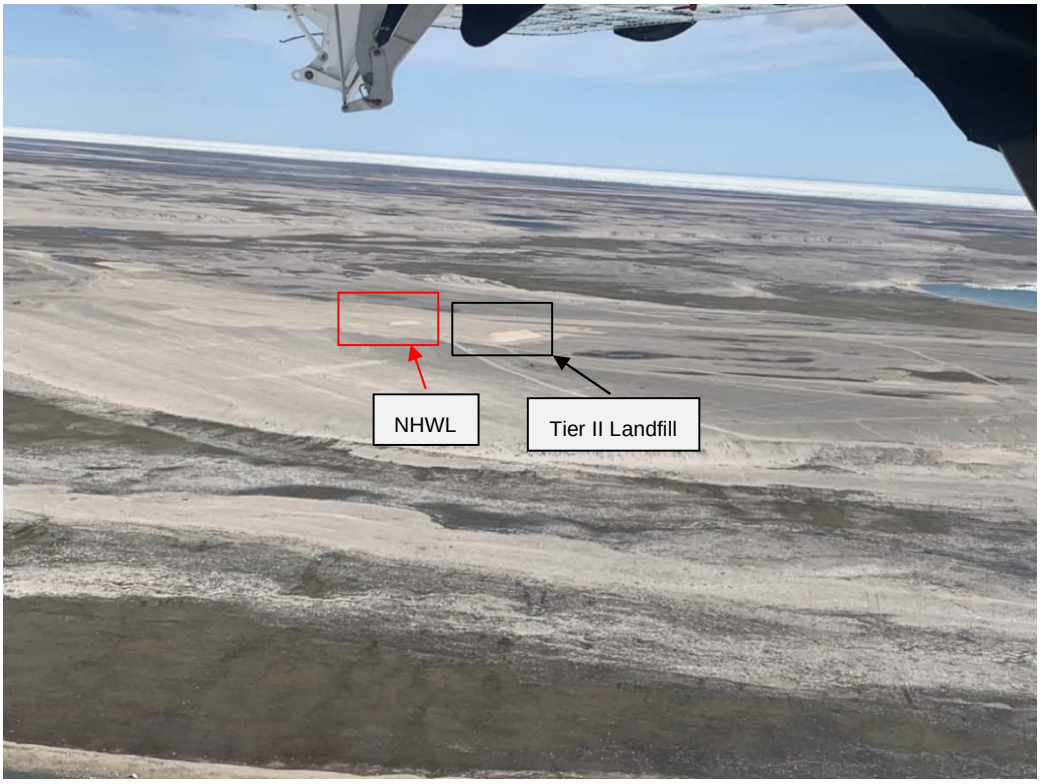


Photo No.	Date
2	8/7/2022

Direction Photo Taken

East

Area

Site Condition

Description

Frost wedge cracking visible on the south side from aerial view (circled).

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
3	8/7/2022

Direction Photo Taken: Northwest

Area: Site Condition

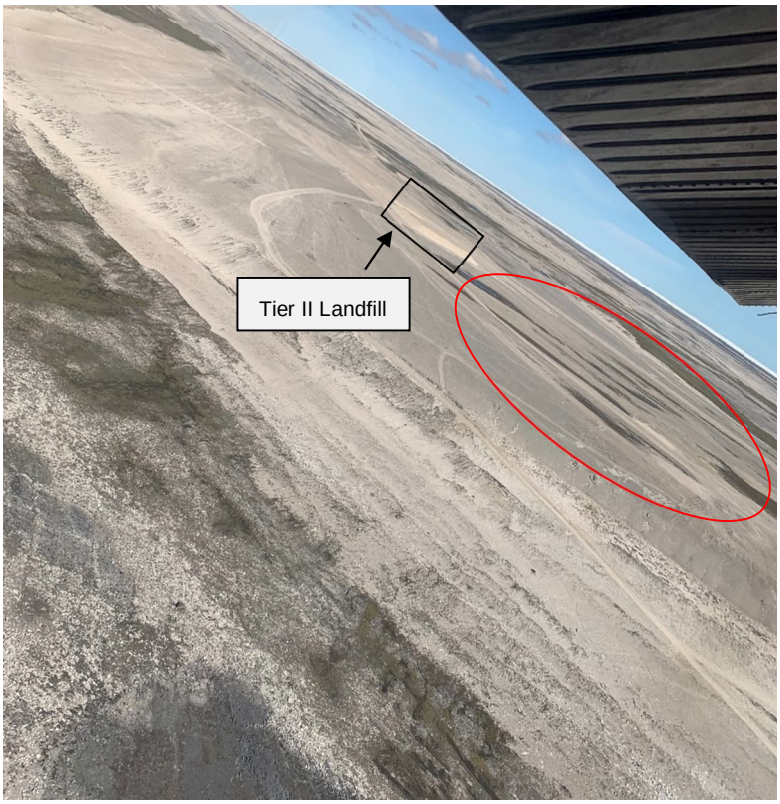
Description: Frost wedge cracks on east side of site.

Photo No.	Date
4	8/7/2022

Direction Photo Taken: Northeast

Area: Site Condition

Description: A closer aerial view of natural permafrost terrain features: thermokarst terrain (circled) on southside of the site. Tier II Landfill visible (boxed).



Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
5	8/7/2022

Direction Photo Taken

N/A

Area

Tier II Landfill

Description

Thermistor VT-A-2. Bite marks on casing from polar bears.

Photo No.	Date
6	8/7/2022

Direction Photo Taken

N/A

Area

Tier II Landfill

Description

Thermistor VT-A-1. Data logger found hanging out of casing.

AECOM

PHOTOGRAPHIC RECORD

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
7	8/7/2022

Direction Photo Taken

N/A

Area

Tier II Landfill

Description

Thermistor VT-B-1. Cable on ground approximately 2.17 m from casing.

Photo No.	Date
8	8/7/2022

Direction Photo Taken

Southwest

Area

Tier II Landfill

Description

Thermistor VT-B-1. Cable on ground is approximately 2.17 m from casing. Data Logger severed from thermistor VT-B-2 and found near VT-B-1 casing (circled). Severed Data Logger removed from site and left with CIRNAC representative.

AECOM

PHOTOGRAPHIC RECORD

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
9	8/7/2022

Direction Photo Taken

Southeast

Area

NHWL

Description

Northwest corner of NHWL in good condition. Tier II Landfill in distance.

Photo No.	Date
10	8/7/2022

Direction Photo Taken

South-southwest

Area

NHWL

Description

MW17-06. North slope of NHWL in good condition.

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
11	8/7/2022

Direction Photo Taken: South

Area: NHWL

Description: West slope of NHWL in good condition.

Photo No.	Date
12	8/7/2022

Direction Photo Taken: N/A

Area: NHWL

Description: Minor differential settlement on west side of NHWL.

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
13	8/7/2022

Direction Photo Taken

East

Area

NHWL

Description

Differential settlement from west slope of NHWL out 30 - 40 m. Continuation shown in Photo 14.

Photo No.	Date
14	8/7/2022

Direction Photo Taken

East-southeast

Area

NHWL

Description

Continuation of apparent settlement from west slope as shown on left side of photo. Settlement extends 30 – 40 m away from cell.

Additional settlement is visible on right side of photo.

The shape and orientation of the settlement cracks suggest they may be due to underlying frost-wedge cracks that were covered with fill during construction.

AECOM

PHOTOGRAPHIC RECORD

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
15	8/7/2022

Direction Photo Taken: Northeast

Area: NHWL

Description: Southwest corner of NHWL in good condition.

Photo No.	Date
16	8/7/2022

Direction Photo Taken: East

Area: NHWL

Description: South slope of NHWL in good condition.

AECOM

PHOTOGRAPHIC RECORD

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
17	8/7/2022

Direction Photo Taken: North

Area: NHWL

Description: Differential settlement midway on south side of NHWL, extending approximately 10 m.

Photo No.	Date
18	8/7/2022

Direction Photo Taken: Northwest

Area: NHWL

Description: Southeast corner of NHWL, differential settlement extending out.

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
19	8/7/2022

Direction Photo Taken: Northwest

Area: NHWL

Description: East side of NHWL in good condition.

Photo No.	Date
20	8/7/2022

Direction Photo Taken: Southwest

Area: NHWL

Description: Northeast corner of NHWL in good condition.

AECOM

PHOTOGRAPHIC RECORD

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
21	8/7/2022

Direction Photo Taken

West

Area

NHWL

Description

North slope of NHWL in good condition.

Photo No.	Date
22	8/7/2022

Direction Photo Taken

South

Area

NHWL

Description

Top of NHWL facing Tier II Landfill in good condition.

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
23	8/7/2022

Direction Photo Taken: East

Area: NHWL

Description: Frost wedge cracking off west side of NHWL viewed from top of cell. This may be source of observed linear settlement features moving away from the landfill toe.

Photo No.	Date
24	8/7/2022

Direction Photo Taken: South

Area: Tier II Landfill

Description: MW 17-04. North side of Tier II Landfill in good condition.

AECOM

PHOTOGRAPHIC RECORD

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
25	8/7/2022

Direction Photo Taken: Southeast

Area: Tier II Landfill

Description: Northwest corner of Tier II Landfill, differential settling at base extending out.

Photo No.	Date
26	8/7/2022

Direction Photo Taken: North

Area: Tier II Landfill

Description: West slope of Tier II Landfill in good condition.

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
27	8/7/2022

Direction Photo Taken

Southwest

Area

Tier II Landfill

Description

Differential settlement off west side of Tier II Landfill.

Photo No.	Date
28	8/7/2022

Direction Photo Taken

Northeast

Area

Tier II Landfill

Description

Southwest corner of Tier II Landfill in good condition.

AECOM

PHOTOGRAPHIC RECORD

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
29	8/7/2022

Direction Photo Taken: West

Area: Tier II Landfill

Description: South slope of Tier II Landfill in good condition.

Photo No.	Date
30	8/7/2022

Direction Photo Taken: West

Area: Tier II Landfill

Description: Differential settlement off south side of Tier II Landfill, extending outward.

Again, shape and position of features suggests pre-existing frost wedge cracks that were covered during construction.

AECOM

PHOTOGRAPHIC RECORD

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
31	8/7/2022

Direction Photo Taken: Northwest

Area: Tier II Landfill

Description: Southeast corner of Tier II Landfill in good condition.

Photo No.	Date
32	8/7/2022

Direction Photo Taken: South

Area: Tier II Landfill

Description: East slope of Tier II Landfill in good condition.

AECOM

PHOTOGRAPHIC RECORD

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
33	8/7/2022

Direction Photo Taken: Southwest

Area: Tier II Landfill

Description: Northeast corner of Tier II Landfill in good condition.

Photo No.	Date
34	8/7/2022

Direction Photo Taken: South

Area: Tier II Landfill

Description: Top of Tier II Landfill in good condition.

AECOM

PHOTOGRAPHIC RECORD

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
35	8/7/2022

Direction Photo Taken

Southeast

Area

Tier II Landfill

Description

Top of Tier II Landfill in good condition. Severed Data Logger from VT-B-2 (circled), pulled cable from VT-B-1 (boxed).

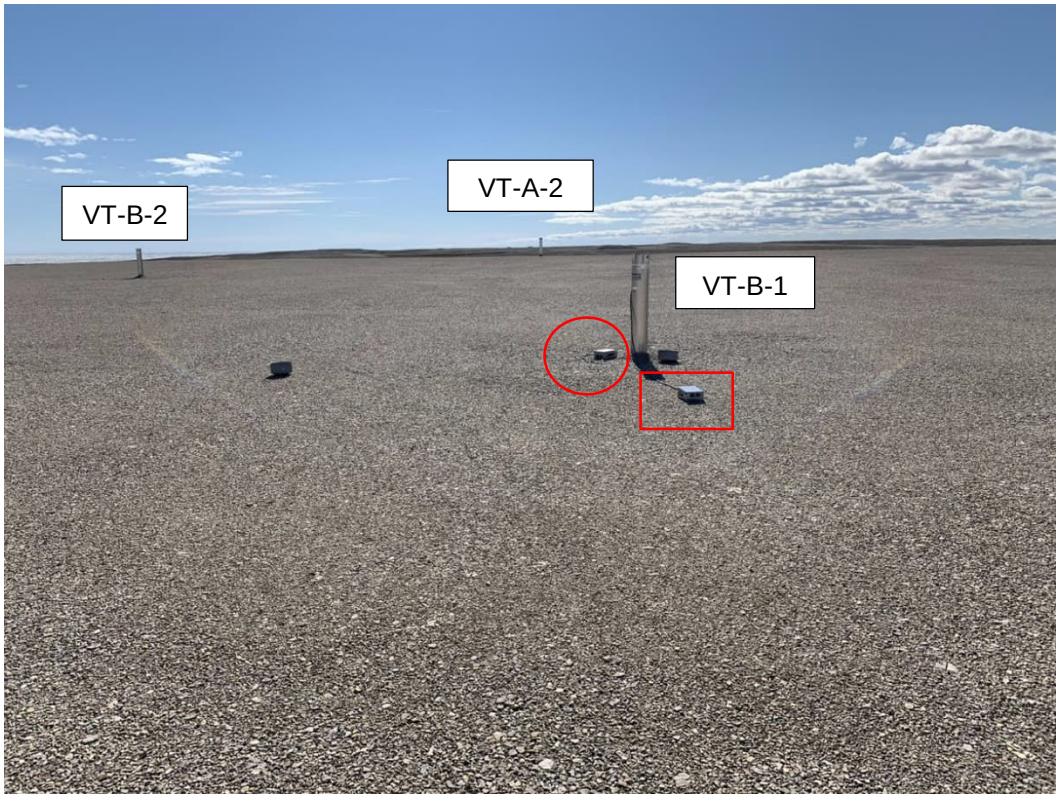


Photo No.	Date
36	8/7/2022

Direction Photo Taken

South

Area

Groundwater Wells

Description

MW17-06. Frozen, unable to sample. Depth to ice recorded. Well in good condition.

AECOM

PHOTOGRAPHIC RECORD

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
37	8/7/2022

Direction Photo Taken

Southeast

Area

Groundwater Wells

Description

MW17-05. Frozen, unable to sample. Depth to ice recorded. Well in good condition. West slope of NHWL in background.

Photo No.	Date
38	8/7/2022

Direction Photo Taken

N/A

Area

Groundwater Wells

Description

MW17-04. Frozen, unable to sample. Depth to ice recorded. Well in good condition.

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
39	8/7/2022

Direction Photo Taken

N/A

Area

Groundwater Wells

Description

MW17-01. Frozen, unable to sample. Bailer frozen inside well. Depth to ice recorded. Well in good condition. West slope of Tier II Landfill in background.

Photo No.	Date
40	8/7/2022

Direction Photo Taken

West

Area

Groundwater Wells

Description

MW17-02. Frozen, unable to sample. Depth to ice recorded. Well in good condition. Southwest toe of Tier II Landfill on far right side. Frost wedge cracking visible on natural ground to the left.

AECOM

PHOTOGRAPHIC RECORD

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
41	8/7/2022

Direction Photo Taken

West

Area

Groundwater Wells

Description

MW17-03. Frozen, unable to sample. Depth to ice recorded. Well in good condition. East slope of Tier II Landfill in background.

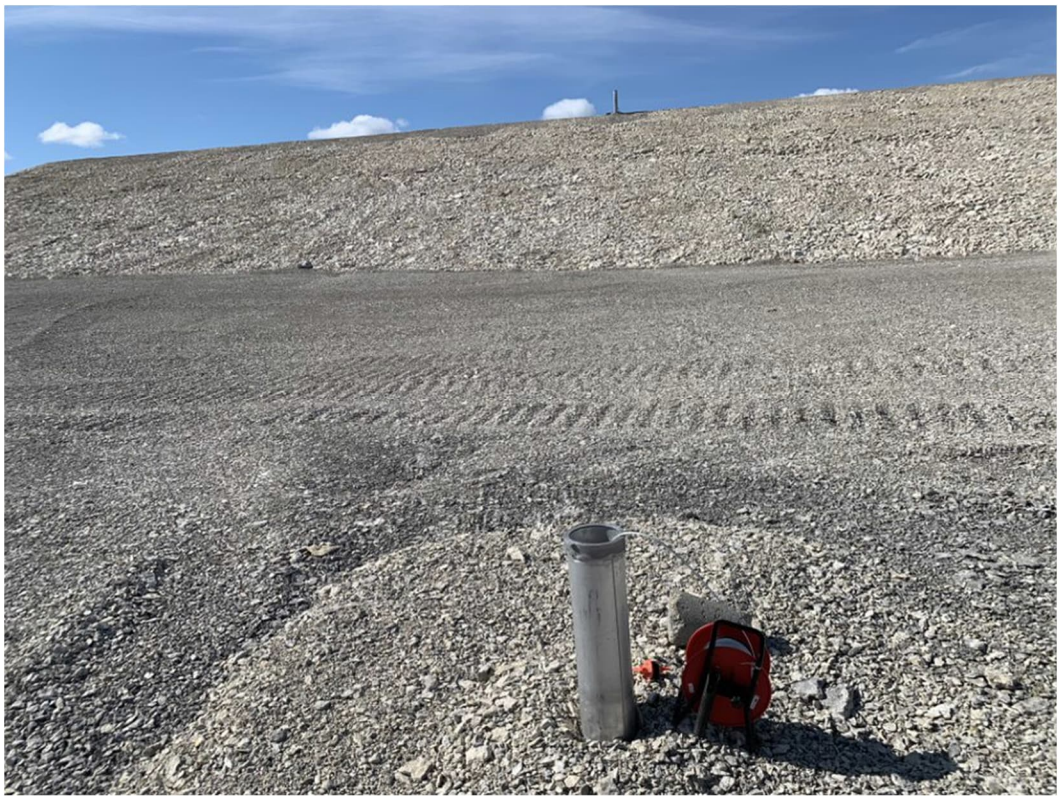


Photo No.	Date
42	8/7/2022

Direction Photo Taken

West

Area

Groundwater Wells

Description

MW17-07. Frozen, unable to sample. Depth to ice recorded. Well in good condition. East slope of NHWL in background.

PHOTOGRAPHIC RECORD

Site Name:	Site Location	Project No.
CAM-E Long-Term Monitoring – Year 3	Keith Bay, Nunavut	60686962

Photo No.	Date
43	8/7/2022

Direction Photo Taken

East

Area

Groundwater Wells

Description

MW17-07 in foreground. Frost wedge cracking throughout east portion of site visible in background.

Appendix C

Monitoring Checklists and Daily Field Report

VISUAL MONITORING CHECKLIST

ITEM	PRESENCE / ABSENCE	EXTENT	DESCRIPTION / PHOTOGRAPHIC REFERENCE
Settlement	Yes	No settling on landfill caps.	Some settling in areas around cells. West side of Tier II and NHWL cells show settlement. Appears to have increased since Year 1. 
Erosion	No		
Frost Action	No	Not on landfills, but in surrounding area.	Frost cracking on west side / between landfills. Natural features. Photos 1 – 4, 12-14, 17-18, 23, 25, 27, 30
Animal Burrows	No		
Vegetation	No		
Staining	No		
Vegetation Stress	No		
Seepage Points	No		
Exposed Debris	No		
Condition of Monitoring Instruments		Monitoring wells in good condition, all frozen, bailer frozen in MW17-01.	Thermistors disturbed by bears, some damage. Photos 5-8
Other Features of Note	N/A		

NATURAL ENVIRONMENT CHECKLIST

ITEM	PRESENCE / ABSENCE	EXTENT	DESCRIPTION / PHOTOGRAPHIC REFERENCE
Wildlife Sightings	No		
Evidence of Wildlife	Yes		Teeth and claw marks on thermistor casings from polar bears. Photos 5, 35
Wildlife Activity	Yes		Exploration of site and interaction with monitoring instruments. Photos 5 - 8
Relative Number	N/A		
Evidence of Revegetation	No		

AECOM

Project Daily Report			
Client:	CIRNAC	**Date:**	7-Aug-22
Project:	Nunavut Sites LTM	**Weather:**	10°C mostly sunny, consistent wind
Project No.:	60686962		
Location:	Gjoa Haven / CAM-E	**Number of Personnel On-Site :**	7
Departure Time:	10:15 AM MST	**Return Time:**	5:00 PM MST

Company			Total # Workers
AECOM	David Bugden	Alysha Selinger	2
CIRNAC	Melanie Netser		1
Nunatta	Max Dubeau	Noah Alookie	2
Kenn Borek	Brian Good	Travis Fawcett	2
Total			**7**

Health and Safety

Observations/Near Misses/Incidents/H&S Issues

Given the polar bear activity on site, and an abundance of ice bergs in the bay on both the east and west sides of the site, the team stayed close to the landfill cells and did not approach the water in the beach area.

Technical Scope

Geotechnical Inspection

Both the NHWL and Tier II cells were visually inspected. Some frost settlement and cracks were observed around the base of the cells, but the cells themselves were in good condition. Minimal debris was observed throughout the site and no animal burrows were found.

Aquatic Monitoring

All seven wells were frozen. The depth to ice level was recorded. There was no sign of wildlife damage to the groundwater wells.

Temperature Monitoring

Upon arrival, the thermistor casings were open and the data loggers strewn across the top of the Tier II cell. Evidence of polar bear claw marks were found on the casings and caps, as well as teeth marks on the thermistor cords and some of the plastic lock housings. One of the data loggers (VT-B-2) was severed from the thermistor. Data was downloaded from VT-B-2 and the graph indicates the day the connection was severed. This data logger was removed from site. One of the five casings was still capped (VT-A-2). One of the data loggers had water in the case (VT-A-3); the data was downloaded, however an error was incurred so it may be corrupt. For data loggers that were pulled out of the casing and had the thermistor cord on the ground, the length was measured to try to adjust the height of the data nodes. Overall, data was successfully downloaded from 4 of the 5 thermistors but will require further inspection for validity given the circumstances. Batteries were replaced, recapped, and locked.

Communications or Deviation from Work Plan

Another trip will need to be made to site to collect groundwater samples, if required.

Other:

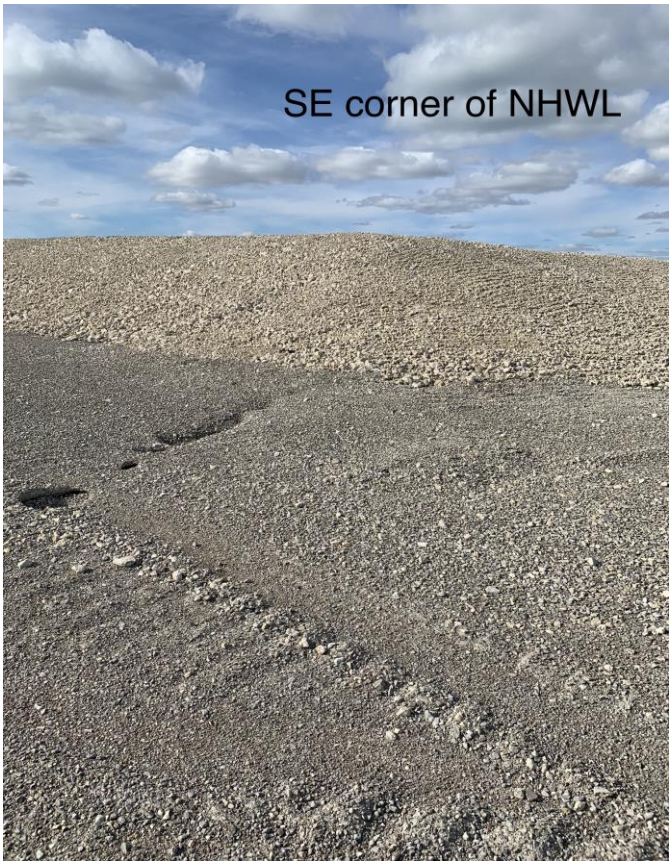
Pilots found the airstrip to be in good condition and were able to taxi right up to the NHWL cell.

Project Daily Photo Record

Photograph 1: Evidence of Polar Bear Claw Marks on Thermistor Casings

Photograph 2: VT-B-1 Pulled from Casing with VT-B-2 Severed Nearby

Photograph 3: Severed Data Logger (VT-B-2)



Photograph 4: Frost Settlement off Southeast Corner of NHWL

Appendix D

Groundwater Sampling Logs

Groundwater Sampling
Field Data

CAM-E
Year 3 2022

AECOM

Aquatics Monitoring										
Time	**Temperature (°C)**	**Conductivity (µs/cm)**	**pH**	**ORP**	**NTU**	**ODO (mg/L)**	**Water Level (m)**	**Depth to Water (m)**	**Depth to Bottom (m)**	**Stick Up (m)**
MW17-01										
Frozen - bailer frozen in well								0.48	-	0.51
MW17-02										
Frozen								1.15	-	0.56
MW17-03										
Frozen								1.18	-	0.47
MW17-04										
Frozen								1.165	-	0.45
MW17-05										
Frozen								1.145	-	0.37
MW17-06										
Frozen								1.185	-	0.39
MW17-07										
Frozen								1.19	-	0.535

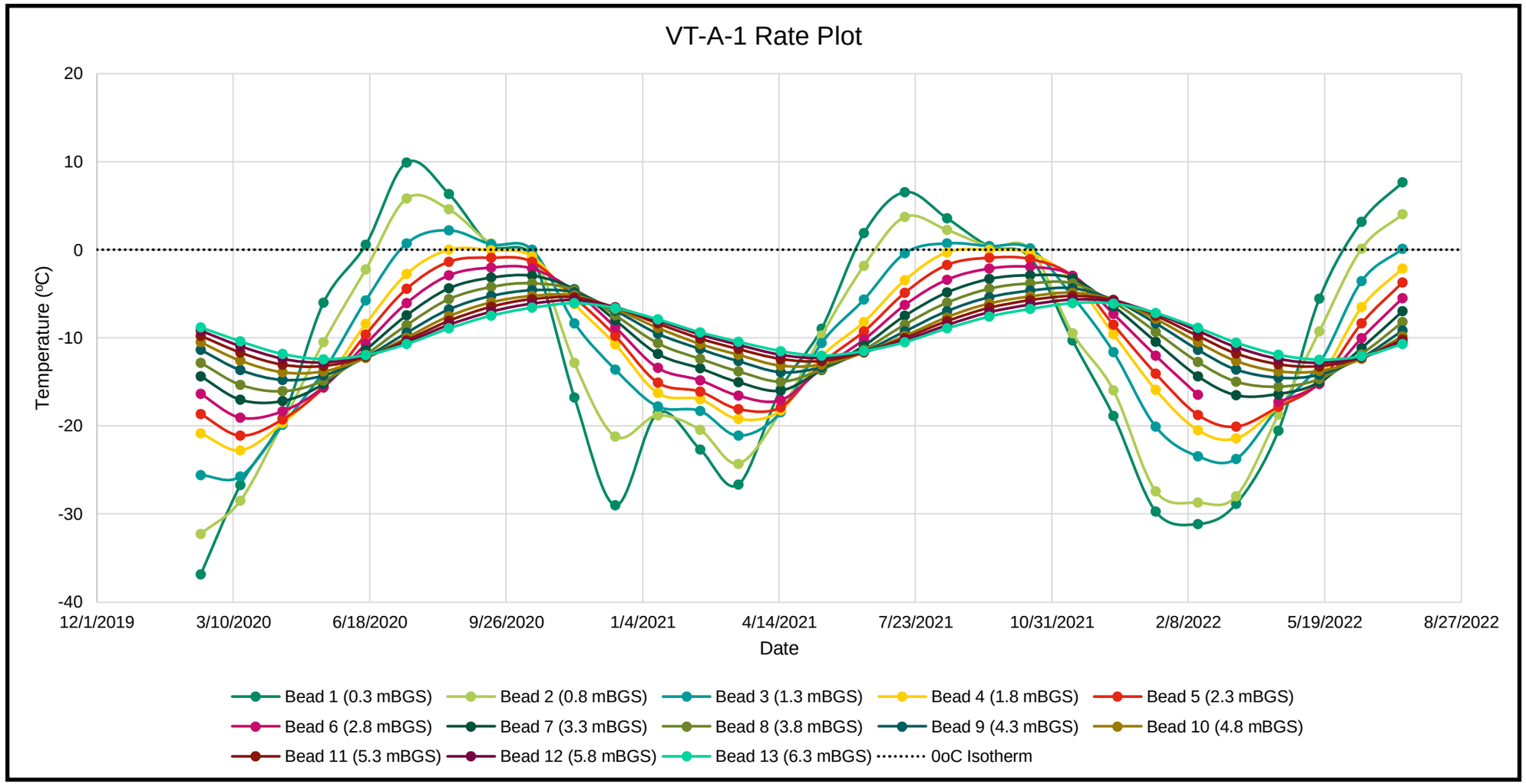
Notes:
ORP - Oxidative-Reduction Potential
NTU - Nephelometric Turbidity Units
ODO - Optical Dissolved Oxygen
Stick Up - Height of well casing from ground surface to top of casing

Appendix E

Thermal Monitoring Graphs

FIGURE E-1

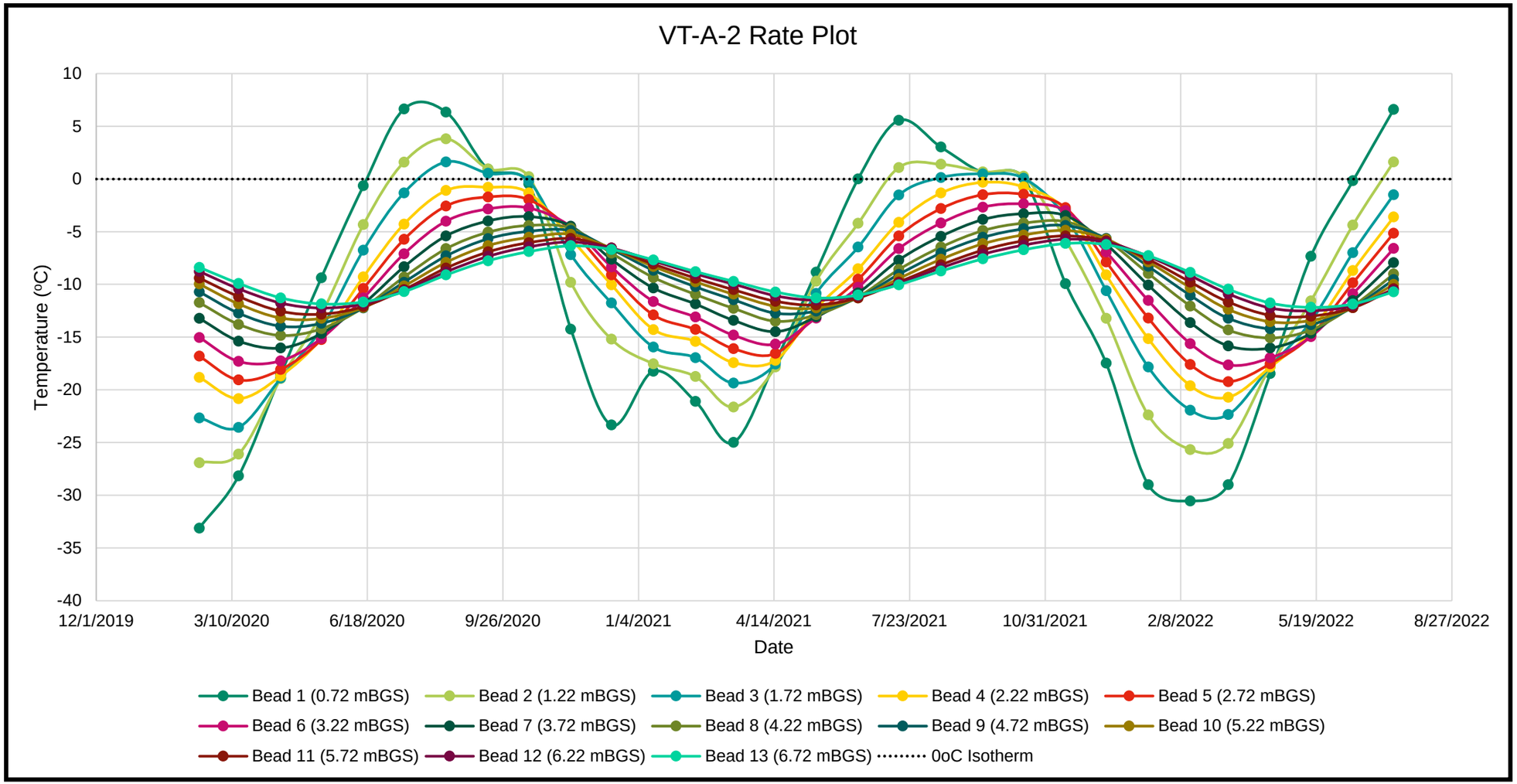
CAM-E
Year 3 2022



Notes:
mBGS = Metres Below Ground Surface

FIGURE E-2

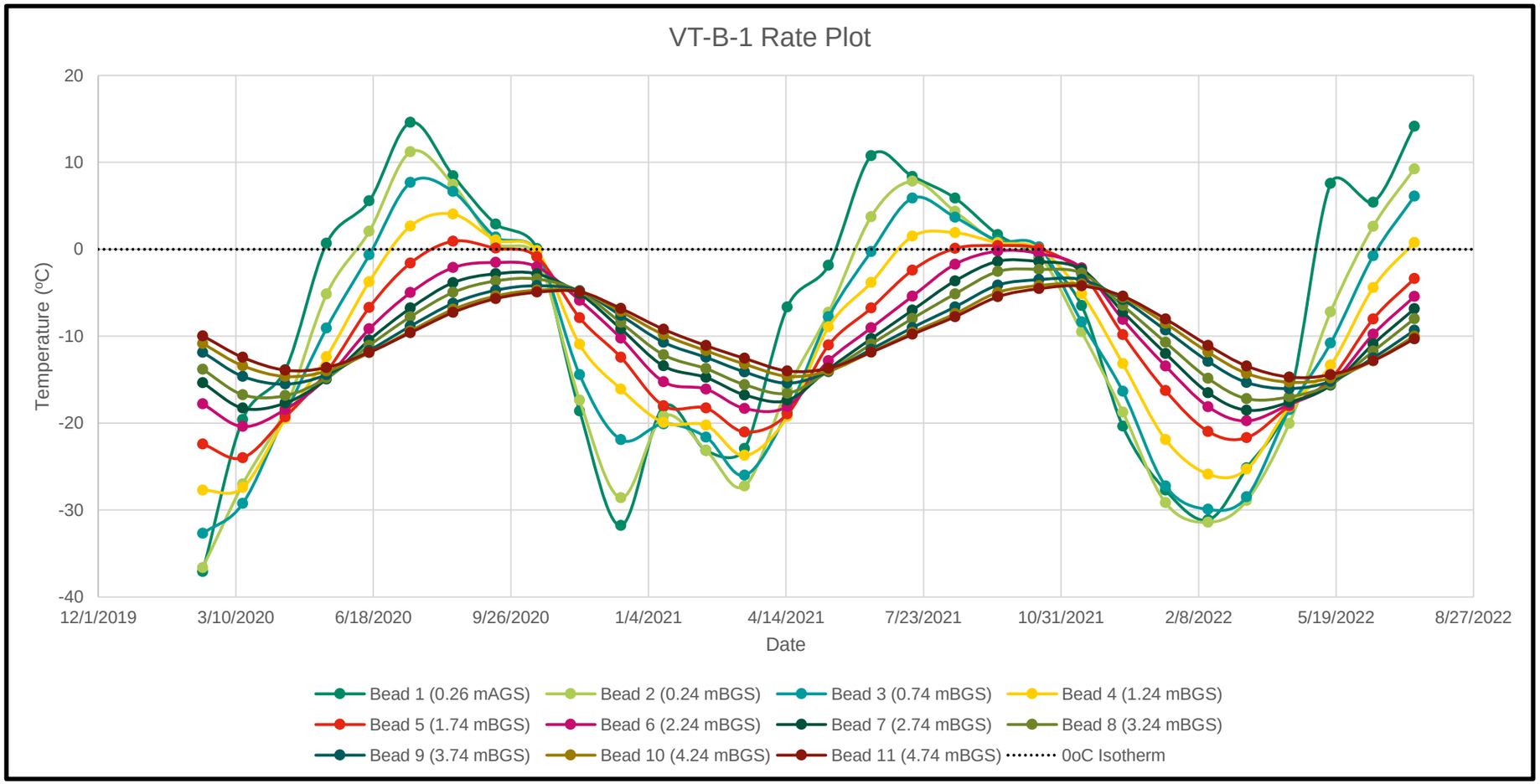
CAM-E
Year 3 2022



Notes:
mBGS = Metres Below Ground Surface

FIGURE E-3

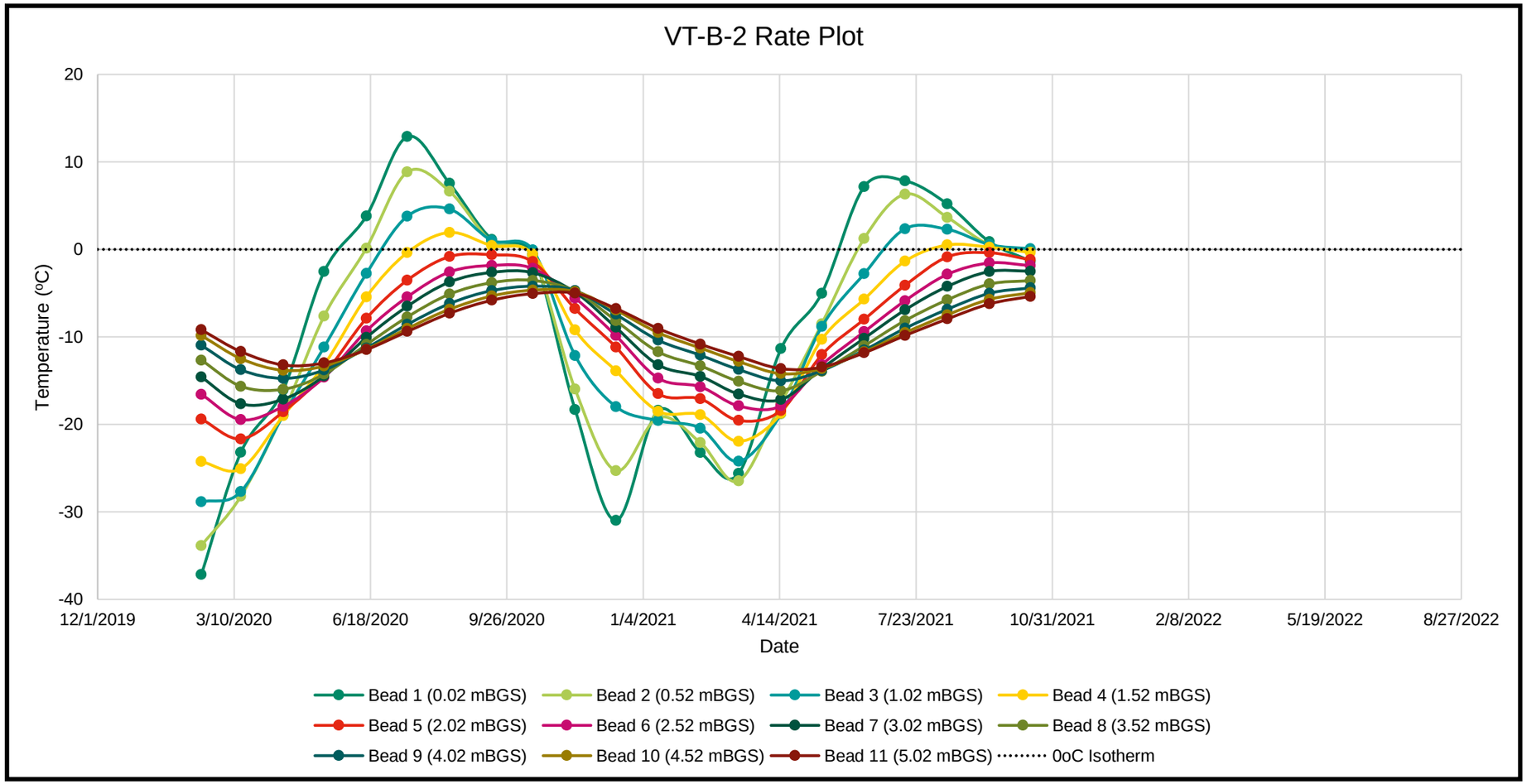
CAM-E
Year 3 2022



Notes:
mAGS = Metres Above Ground Surface
mBGS = Metres Below Ground Surface
Bead 1 is located above ground surface.

FIGURE E-4

CAM-E
Year 3 2022



Notes:
mBGS = Metres Below Ground Surface
Data Logger severed on November 6, 2021

FIGURE E-5

CAM-E
Year 3 2022

AECOM

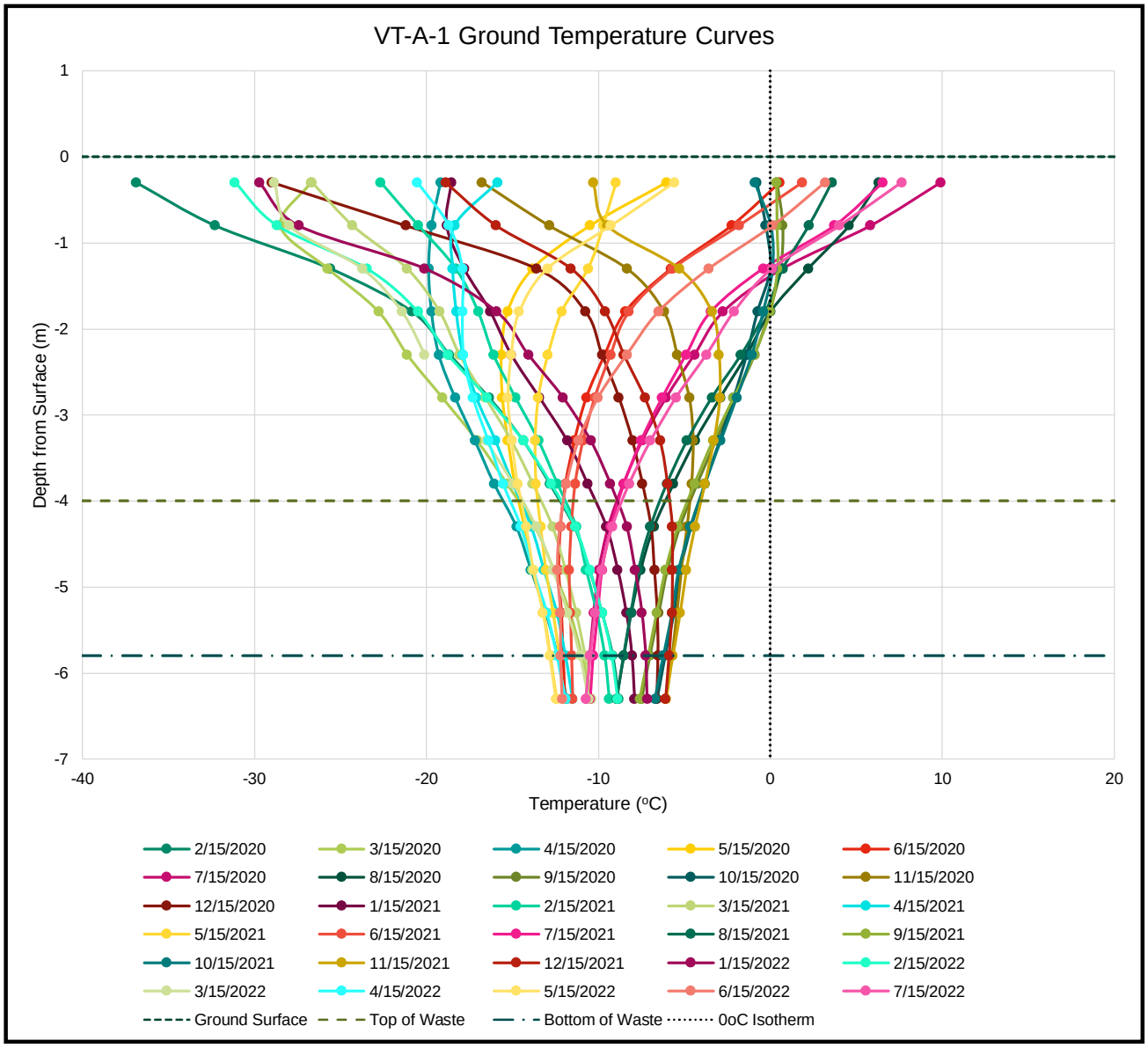


FIGURE E-6

CAM-E
Year 3 2022

AECOM

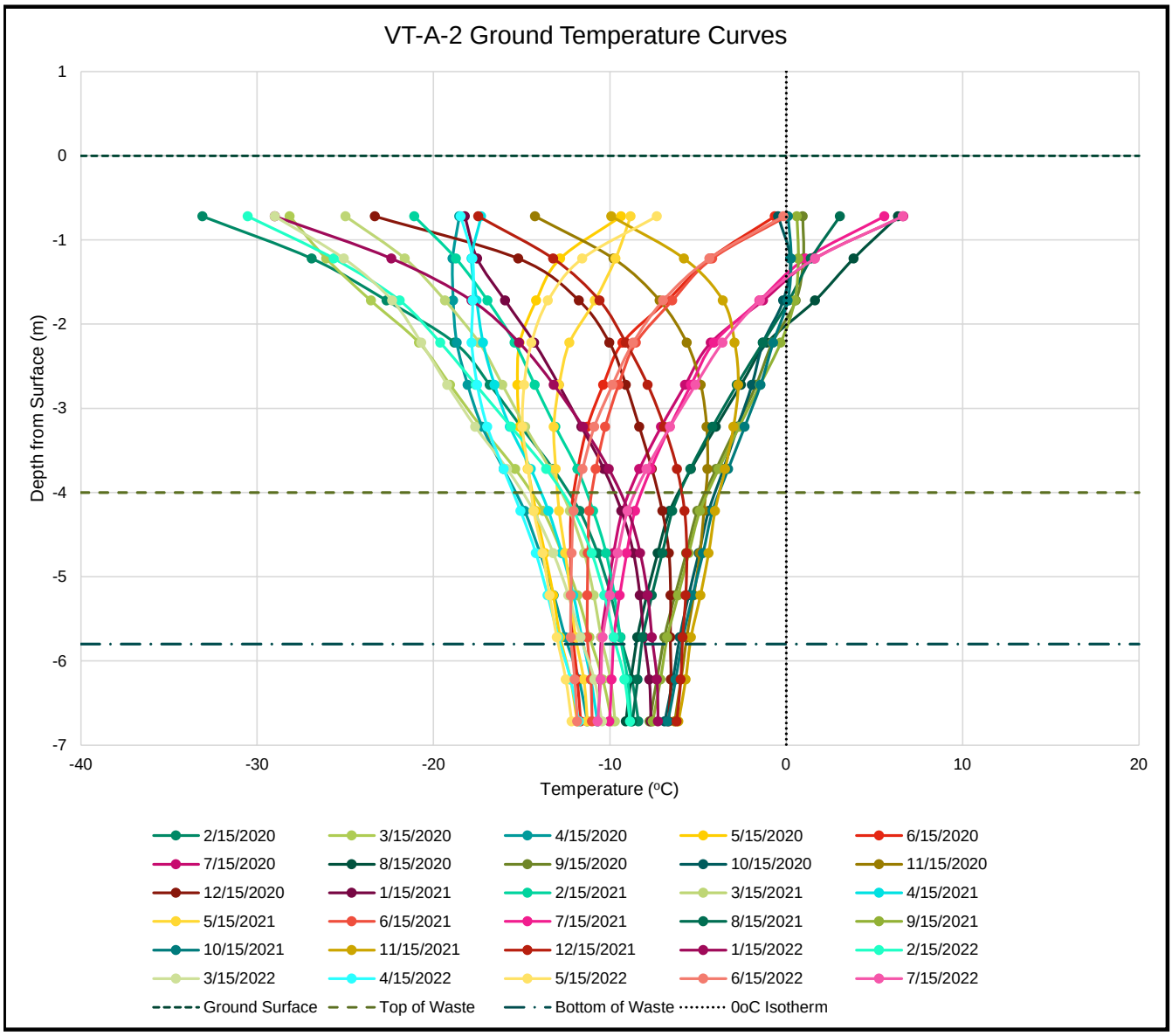


FIGURE E-7

CAM-E
Year 3 2022

AECOM

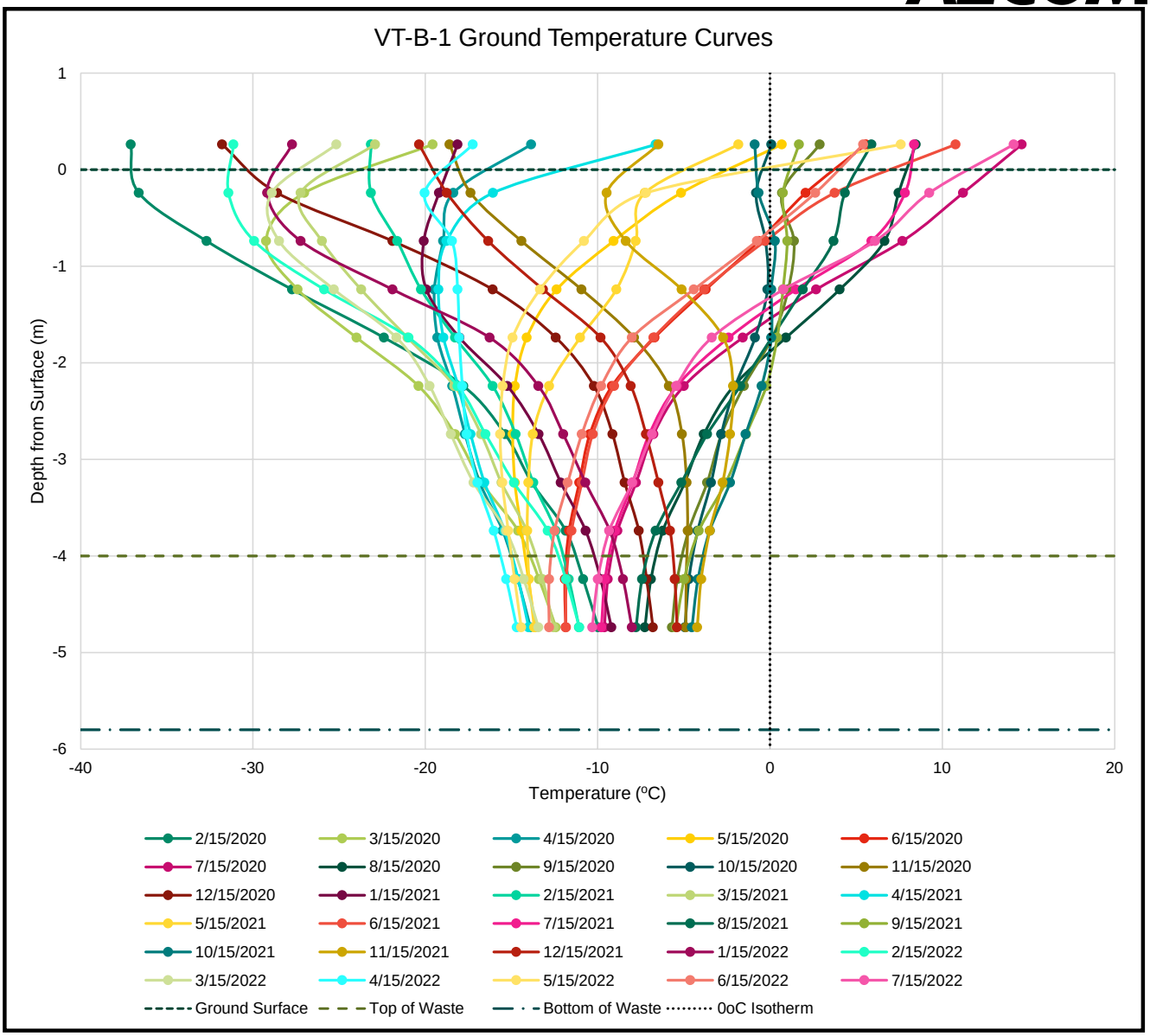
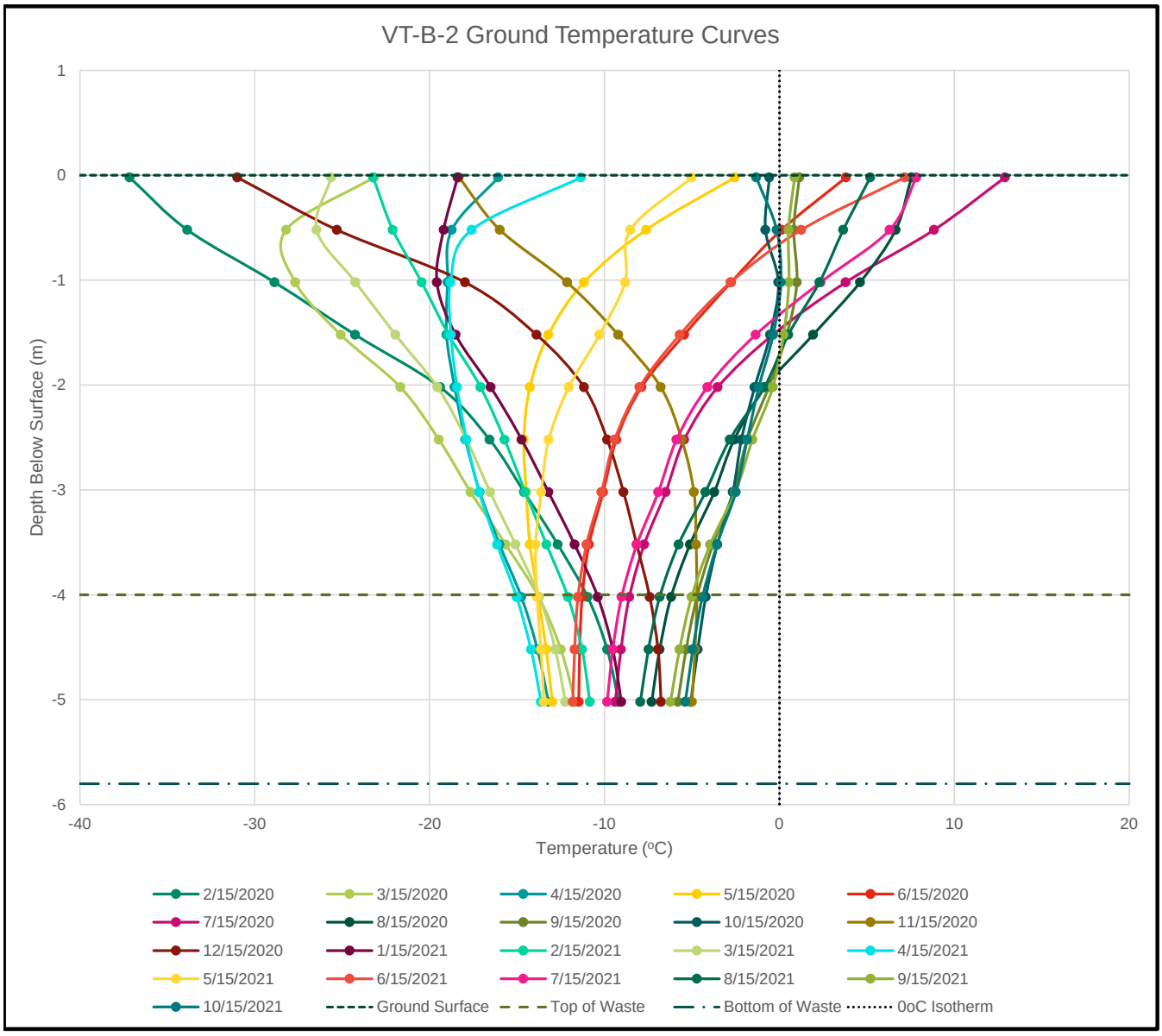


FIGURE E-8

CAM-E
Year 3 2022

AECOM



Appendix F

Thermal Sampling Data

Available on USB.

aecom.com