FINAL

CAM-E KEITH BAY LONG TERM MONITORING EVENT
2020 LONG TERM MONITORING REPORT

Submitted to:

Crown-Indigenous Relations and Northern Affairs Canada
Relations Couronne-Autochtones et Affaires du Nord Canada

Crown-Indigenous Relations and Northern Affairs Canada
Contaminants and Remediation Division

P.O. Box 2200
Iqaluit, Nunavut X0A 0H0

Prepared by:

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Yellowknife, NT X1A 1P3

Project Number: 200537
February 18, 2021

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EXECUTIVE SUMMARY

The CAM-E 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 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 demolition waste, a non-hazardous waste landfill (NHWL) and a Tier II landfill.

The field program including visual inspection, sampling and GPS surveying was carried out on August 28, 2020. A second site visit occurred on September 8, 2020 to collect thermistor data. A visual and environmental monitoring inspection was completed of the site and documented in the visual monitoring and environmental monitoring checklists. Photographic records were collected and documented.

No groundwater water samples were collected due to the monitoring wells being frozen. No soil or surface water samples were collected as there were no observed seepage points or staining. Thermistor data was collected and was submitted to CIRNAC. The data from the thermistors were analysed by Trek Geotechnical and results were presented in a letter report in Appendix D. A topographical survey was completed by RTK GPS surveying as well as RPA surveying. Video footage was taken of the site using the RPA. The raw data and video footage was submitted to CIRNAC.

The observations made during the 2020 long term monitoring event support that both the CAM-E non-hazardous waste landfill and Tier II Landfill are performing as expected. Visual monitoring shows that the NHWL and Tier II Landfill are in acceptable condition based on severity ratings presented in the Abandoned Military Site Remediation Protocol (AMSRP) Volume II (Indigenous and Northern Affairs Canada (INAC), 2009). The surface of the landfills did not show any evidence of frost action or erosion. There was a shallow disturbance from an attempted animal burrow at the Tier II Landfill but this feature does not appear to impact on the integrity of the landfill. Evidence of frost action approach the toe of the south berm at both landfills, therefore, these areas should be monitored closely in the next monitoring event to note any further settling. In the surrounding area, evidence of settlement and erosion are observed but occur a distance from the facilities and do not appear to have any negative impact.

The observations made regarding the natural environment monitoring showed evidence of wildlife on the site. A total of five (5) polar bears and a flock of snow geese were observed during the site visit. Caribou droppings and an attempted burrow on the landfill were noted. An interview with a resident from Kugaruuk reported that the area was used for hunting, fishing, and foraging. He commented that polar bears, snow geese, caribou, arctic foxes, and the occasional wolverine would frequent the area.

Water levels were taken at the seven (7) groundwater monitoring wells. All monitoring wells were frozen, thus no ground water samples were collected. No soil or surface water samples were collected as there was no evidence of any seepage or staining from either the NHWL or the Tier II Landfill.

Based on the results of the 2020 long term monitoring event, BluMetric recommends continuing the Phase I monitoring at the AMSRP recommended schedule. With no observable deterioration of the landfills observed at the CAM-E site in 2020, the site is in acceptable condition. The next monitoring event is recommended to occur in Year 3 (2022).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1 INTRODUCTION

BluMetric Environmental Inc. (BluMetric ™) was retained by Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) – Nunavut Regional Office to conduct long term monitoring (LTM) activities at the CAM-E site, Keith Bay, Nunavut (herein referred to as "the site"). This project was completed under CIRNAC Standing Offer Number 4600001830 and order number 4500413861. This report describes the monitoring activities completed for CIRNAC at the site.

1.1 OBJECTIVE

The objective of this project is to complete tasks for the long-term monitoring of the CAM-E site as described in the *CAM-E Keith Bay Long Term Monitoring Plan*, AECOM, 2019 (referred to as "the LTM Plan"). This work is Phase I, Year 1 of the LTM Plan.

1.2 SCOPE OF WORK

The scope of work for the 2020 long term monitoring activities includes the following:

- Produce and implement a Logistic Plan that complies with all federal, provincial/territorial and municipal health requirements, restrictions and guidance related to COVID-19.
- Produce and implement a Health and Safety Plan including risks and mitigations specific to COVID-19.
- Produce and implement a field sampling plan including Quality Assurance and Quality Control (QAQC) plan.
- Implement a field program including:
    - Provision of wildlife monitor (with firearm) from nearby community;
    - Complete a GPS survey of the site;
    - Monitoring of general site condition and natural environment;
    - Visual inspection of the Non-Hazardous Waste Landfill (NHWL) and Tier II Landfill documented by photographic record, visual monitoring checklist and a site map;
    - Purge and collect groundwater samples from the seven (7) monitoring wells;
    - Collect soil samples if seepage or staining is identified during the visual inspection;
    - Collect blind duplicates of at least 20% of samples;
    - Submit samples to a Canadian Association for Laboratory Accreditation (CALA) accredited laboratory for analysis of petroleum hydrocarbon (PHC) fractions F1 and F2, total and dissolved metals, major ions, hardness, total dissolved solids, total suspended solids, pH, conductivity, and polychlorinated biphenyls (PCBS)
    - Collect thermistor data from Tier II Landfill; and

- Submit a draft and final version of the CAM-E Keith Bay 2020 Long Term Monitoring Report to CIRNAC.

2 BACKGROUND INFORMATION

The CAM-E Keith Bay site is located at 68°15.37' N, 88°10.42' W, on the eastern side of the Simpson Peninsula. The site is approximately 75 km east of Kugaaruk, Nunavut. Figure 1 shows the general site location.

The CAM-E 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 CIRNAC.

According to the CAM-E, Keith Bay Site Remediation Construction Summary Report by AECOM (2020), the site consisted of the Main Station Area as well as the Main Airstrip and Beach Area. At the time of operation the infrastructure at the Main Station Area included a garage, warehouse, petroleum and lubricant (POL) tanks and pipelines, a module building 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 lagoon area and discharge pipe, and a freshwater lake. The Main Airstrip and Beach Area, located about 5.6km 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. This 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 demolition waste. A non-hazardous waste landfill (NHWL) and a Tier II landfill.

Construction of the NHWL occurred between 2017 and 2018. All non-hazardous wastes were placed into the landfill in 0.5m lifts with intermediate cover between layers. A final cap was installed in 2018 which was comprised of a 400 mm lift of Type 2 granular fill and an additional 700 mm of engineered granular fill material.

Construction of the Tier II landfill occurred between 2017 and 2018 for the disposal of Tier II contaminated soil and ash. The landfill was designed to encapsulate the contaminated soil using a geosynthetic liner system in the berms and base and was keyed into the underlying permafrost.

The base and berms were constructed and filled with the contaminated soil, with any airspace that was left being filled with a Type 1 Granular Fill. The landfill was then covered by the geosynthetic liner system and then capped with a Type 2 Granular Fill and a Type I Granular Fill.

2.1 Previous Reports and Monitoring Programs

BluMetric Environmental reviewed the following reports prior to the field program:

- CAM-E (Keith Bay) Site Remediation Construction Summary Report, AECOM, March 30 2020;
- CAM-E, Keith Bay Long Term Monitoring Plan, AECOM, December 2019;
- Addendum to CAM-E, Keith Bay Long Term Monitoring Plan, CIRNAC, December 2019.

The CAM-E Long Term Monitoring Plan outlines the proposed frequency of monitoring as follows (AECOM, 2019):

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

Phase I is conducted to confirm that physical stability criteria are achieved. Phase II is to verify that equilibrium conditions are established during Phase I, and Phase III is to monitor for long term issues, including integrity of facilities, permafrost stability and issues caused by significant storm events.

3 REGULATORY GUIDELINES

BluMetric reviewed the CAM-E LTM Plan as well as the Abandoned Military Site Remediation Protocol (AMSRP) to identify the applicable guidelines to be used in the LTM program. The following sections describe the regulatory guidelines selected for each type of sample collected at the site.

3.1 Groundwater

3.1.1 Baseline Samples

Due to the absence of groundwater criteria, the analytical data for groundwater should be compared to available historical data from the site. According to (AMSRP) issued by CIRNAC in 2008, 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.

Limited baseline groundwater data exists for the two landfills. As described in the 2020 CAM-E (Keith Bay) Construction Summary Report, baseline sampling attempted during construction near impossible as the wells were found to be frozen or dry. One sample was collected from MW17-01 over the two year construction period in 2017. This does not provide enough information to calculate Upper Limits of Acceptability (ULAs), however as more monitoring events occur, the data collected can be used to calculate ULAs in the future.

3.1.2 Federal Interim Groundwater Quality Guidelines

In addition to the ULAs, the analytical results could be compared to the Federal Interim Groundwater Quality Guidelines (FIGQG). Generally, federal contaminated sites are evaluated using the Canadian Environmental Quality Guidelines (CEQG) developed by the Canadian Council of Ministers of the Environment (CCME). There are comprehensive guidelines for various media including surface water and soil, however no CEGQ exists for groundwater. In recognizing the need for a nationally-consistent approach for assessing and managing groundwater, Environment Canada developed the Federal Interim Groundwater Quality Guidelines. These guidelines are intended as an interim measure until CEQGs for groundwater are available.

The FIGQGs follow a tiered framework as follows:

- Tier 1: direct application of generic numerical guidelines, specifically, application of the lowest guideline for any pathway.
- Tier 2: allows for the development of site-specific remediation objectives through the consideration of site-specific conditions, by modifying (within limits) the numerical guidelines based on site-specific conditions and focusing on exposure pathways and receptors that are applicable to the site
- Tier 3: use of site-specific risk assessment to develop Site-Specific Remediation Objectives

From the FIGQGs, the criteria from Table 2, Generic Guidelines for Residential/Parkland Land Uses, Tier 1 Lowest Guideline for coarse-grained soil (Table 2, Tier 1) were to be referenced for this report as they were deemed most representative of current site use and soil conditions. The FIGQGs typically do not apply to total metals, they have been applied to both total and dissolved metals to evaluate potential for transport of contaminants with colloidal materials in groundwater. As per FIGQG for certain metals (aluminum, copper, lead, and nickel) without

criteria, *Canadian Water Quality Guidelines for the Protection of Aquatic Life* (CCME 1999) were to be used. Though typically only applied to total metals, due to the absence of applicable guidelines for dissolved metals, these were to be applied to both.

3.2 SOIL

3.2.1 Baseline Samples

As reported in the CAM-E (Keith Bay) Construction Summary Report, baseline soil samples were collected in 2017 prior to the construction of the NHWL and Tier II Landfill. The samples were analysed for PHCs, PCBs and metals. The results can be used to calculate ULAs and used as criteria as per the AMSRP. The baseline data for the CAM-E site can be found in the 2020 CAM-E (Keith Bay) Construction Summary Report, Appendix B, Table B.1.

3.2.2 Canadian Environmental Quality Guidelines – CCME

No soil samples were collected at the site during the 2020 long term monitoring event, however previous monitoring reports reference the following CCME guidelines for soil analytical results:

- Canadian Soil Quality Guidelines (CSQG) *for the Protection of Environmental and Human Health* (CCME, 1999, with updates) for residential/parkland use, including fact sheets for benzene, toluene, ethylbenzene and xylene (BTEX), non-potable water, coarse-grained soil.
- Canada-Wide Standard (CWS) for Petroleum Hydrocarbons in Soil (CCME, 2008) – Tier 1 Residential/Parkland, non-potable water, coarse-grained soil.

The rationale for choosing these criteria are that the groundwater at CAM-E will not be used for drinking (non-potable) and coarse-grained material is found on site. If seepage or staining occurs and soil samples are taken in future monitoring activities, the above guidelines should be used for comparison.

3.3 SURFACE WATER

There were no surface water samples collected at the site during the 2020 long term monitoring event. No baseline surface water samples exist for the site.

In similar monitoring program reports at other DEW line sites, the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQG-PAL) (CCME, 1999) is referenced for surface water. The CWQG-PAL were developed to provide basic scientific information about the effects of water quality variables and natural and anthropogenic substances on aquatic life.

The guidelines that should be used to compare surface water analytical results are the freshwater, long term exposure guidelines. This set of criteria is chosen as the landfills are permanent structures.

4 METHODOLOGY

The field program including visual inspection and sampling was carried out on August 28, 2020 by Matthew Kitchen, EIT and Jeff Rosnawski. They were accompanied by CIRNAC representative Selma Al-Soweydawi, and by a wildlife monitor, Fred Qavvik, a resident of Kugaruuk, NU who also provided knowledge of the site. The site was accessed by Twin Otter, chartered by Kenn Borek Air. Logistics were carried out as per the Logistics Plan provided under a separate cover. The thermistors data was not downloaded during this site visit as the data cable was misplaced during the program. A second site visit to download thermistor data was conducted on September 8, 2020 by Kim Carlton, of BluMetric Environmental. She was accompanied by a wildlife monitor, Simon Curley of Hall Beach, NU. The summaries of daily activities and notes can be found in Appendix B.

4.1 HEALTH AND SAFETY PLAN

In preparation for the field program, a Health and Safety Plan (HASP) was produced and submitted to CIRNAC under a separate cover. The HASP identifies risks and suspected hazards associated with work on the site. It specifically addresses any known or suspected hazards and provides mitigative measures including protocols for COVID-19. Included in the HASP are 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 LANDFILL VISUAL MONITORING

The physical integrity of the NHWL was inspected at the CAM-E site during the 2020 long term monitoring event. The visual inspection looked for evidence of:

- erosion, ponding, frost action, settlement, and lateral movement;
- animal burrows, vegetation, vegetation stresses,
- staining or seepage

This was documented by the visual monitoring checklist and through site photographs.

4.3 NATURAL ENVIRONMENT MONITORING

Natural environment data was collected during the 2020 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); and
- qualitative assessment of relative numbers versus previous years (more, same, less).

Observations and additional information on land use and wildlife activity was provided by Fred Qavvik, the wildlife monitor, and a resident of Kugaruuk.

4.4 GROUNDWATER SAMPLE COLLECTION

The site has seven (7) monitoring wells located around the NHWL and Tier II Landfill (MW17-01 to MW17-07). During the process of assessing the wells for sampling, all seven (7) well locks were cut and replaced with new locks. The new keys were given to the CIRNAC representative. Monitoring well locations are listed in Table 1 below.

Table 1: CAM-E Keith Bay Monitoring Well Locations

Monitoring Well	Northing	Easting
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

The following is the methodology that was prepared for the groundwater sampling and a similar methodology should be used for future monitoring events. The water level and depth were to be recorded, and an approximate well volume calculated. A peristaltic pump and dedicated, disposable polyethylene tubing were to be used to purge and sample the wells using a low-flow sampling methodology. The monitoring well was to be purged of three well volumes prior to sampling. Water quality parameters including dissolved oxygen (DO), oxidation-reduction potential (ORP), temperature, pH, conductivity, turbidity and total dissolved solids were measured and recorded prior to sampling. Prior to shipping, samples were packed in a laboratory

provided cooler and ice packs were to be replaced daily as necessary. The samples were to be shipped by Canadian North to the ALS Laboratories depot in Yellowknife where they were received and forwarded for analysis.

Any groundwater samples collected were to be sent to the ALS Laboratories, a Canadian Association for Laboratory Accreditation (CALA) accredited laboratory to be analysed for:

- Petroleum Hydrocarbons (PHCs);
- Total and Dissolved Metals;
- Major Ions, Hardness, Total Dissolved Solids, Total Suspended Solids;
- pH, Conductivity;
- Polychlorinated biphenyls (PCBs).

The QA/QC plan for this program included the following:

- **field duplicates** (20% of program) as per AMSRP to provide a measure of precision/repeatability of the sampling procedure, analytic technique and heterogeneity of the sample.
- **analytical method blanks** give a measure of any contamination that may be introduced during sample handling and processing and can indicate whether results are falsely inflated.
- **analytical control spike** is used to identify analytical interference associated with the sample matrix. Control spikes are evaluated by calculating a percent recovery as follows:

$$Recovery\ (\%) = \left(\frac{measured\ concentration}{certified\ concentration}\right) * 100$$

- **analytical duplicates** provide a measure of the precision and repeatability of the analytical method.
- **travel blanks** to test for background contaminants, contamination from transport and handling or presence of container or preservative contamination.
- **field blanks**, to provide a measure of the sampling procedure and whether cross-contamination or contamination from exposure to air has occurred.

For field and analytical duplicates, the precision is measured by the relative percentage difference (RPD) for duplicate samples. RPD is calculated for contaminant concentrations greater than 5 times the reportable detection limit (RDL), concentrations results less than 5 times the RDL become increasingly imprecise. RPD is calculated as follows:

$$RPD\ (\%) = \left(\frac{Dup_1 - Dup_2}{average\ of\ Dup_1 + Dup_2}\right) * 100$$

The guidance Manual for Environmental Site Characterization in Support of Human Health Risk Assessment, Volume I (CCME, 2016) recommends that RPDs for parameters of field duplicate groundwater samples not exceed 40% and RPDs for laboratory groundwater duplicates not exceed 20%. RPDs for soil sample field duplicates should not exceed 60% and RPDs for laboratory soil duplicates should not exceed 30%.

4.5 SOIL SAMPLING

No soil samples were collected at the time of the 2020 long term monitoring event as there was no evidence of seepage or staining. The following outlines the methodology that was prepared for this program in the event that soil sampling was required.

Soil 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 30cm and pack 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
- F1-F4 PHCs and
- Metals

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4.6 THERMISTORS DATA COLLECTION

Five (5) thermistors with a Lakewood Systems RX16ML data logger are installed at the Tier II landfill to collect ground temperature data. The data from the logger is downloaded via a USB cable and then the logger is reset and batteries replaced as required. Thermistor locations are listed in Table 2 and shown on Figure 2.

Table 2: CAM-E Keith Bay Thermistor Locations

Monitoring Well	Northing	Easting
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 GPS Survey of Landfills and RPA Topography

The site survey was completed using Real-Time Kinematic Global Position System (RTK-GPS) equipment. Two Hemisphere S320 units were used which are each equipped with a 400 MHz radio and Bluetooth.

A remote pilot aircraft (RPA) topography survey was conducted using a Parrot Anafi drone. The survey covered the NHWL and the Tier II Landfill. The drone survey was conducted by a licensed drone pilot with two observers to ensure safety. To tie the two survey methods together, six (6) garbage bags were placed on the ground as temporary ground controls and shot with the RTK GPS.

5 RESULTS

5.1 Photographic Records

The photographic record of the CAM-E site NHWL and Tier II Landfill were taken as per the scope of work. The complete photographic record (Photos 1-133) have been provided electronically to CIRNAC via a file transfer protocol (FTP) Site. The photographs referenced in the text of the document are found in Appendix B. Note that the photographs referenced in CAM-E Keith Bay NHWL and Tier II Feature Summary Table 9 reference photos from the complete photo record. Photo viewpoints (which reference the complete photo record) have also been depicted on Figure 2 CAM-E Non-hazardous Waste Landfill and Tier II Landfill Plan.

5.2 Landfill Visual Monitoring

The visual monitoring checklist was completed to document the inspection of the NHWL and Tier II Landfill. See Appendix A for the visual monitoring checklist and notes collected on site. Table 3 summarizes the notable features at the CAM-E site. .

Table 3: CAM-E NHWL and Tier II Feature Summary

Feature Letter	Feature Type	Location	Extent	Description/Change Comments	Photos
A	Erosion	Unworked Areas surrounding NHWL	<1%	Erosional channels were observed around the site in non-compacted areas.	94-103
B	Settlement	S of the Tier II Landfill	<1%	Horizontal crack, running from the toe of the Tier II Landfill.	66, 67
C	Settlement	By NW corner of Tier II landfill	<1%	Horizontal crack, 0.27 m wide and approximately 3 m long running NE.	11
D	Erosion	S of NHWL	<1%	Small washboard, south of the NHWL.	20
E	Settlement	S of NHWL	<1%	Horizontal crack, running south in contact with the NHWL.	26
F	Settlement	W of NHWL	<1%	Two horizontal cracks. Smaller crack 0.4 m wide by approximately 2m long, and larger crack 0.44 m wide at the west end, 0.84 m wide at the east end and approximately 5 m long, both to the west of the NHWL.	47, 48, 49, 50
G	Settlement	W of the Tier II Landfill	<1%	Narrow depression that appears to be a pothole or crack, small 0.27 m wide by 1 m long depression to the west of the Tier II Landfill. Does not appears to have any effect on the integrity of the landfill.	58, 59, 60
H	Settlement	SW of the Tier II Landfill	<1%	Narrow depression that appears to be a pothole or crack. small 0.25m wide by 1 m long depression to the south west of the Tier II Landfill. Does not appears to have any effect on the integrity of the landfill.	61, 64
I	Animal Burrow	E Berm of Tier II Landfill	<1%	Attempted burrow 0.85 m in diameter.	72, 73

[1]Photograph numbers listed in this table reference photograph numbers from the complete photo record.

Visual monitoring shows that the NHWL and Tier II Landfill are in acceptable condition based on severity ratings presented in the AMSRP Volume II (INAC, 2009). The surface of the landfills did not show any evidence of frost action or erosion.

Erosion and settlement were noted in the uncompacted areas around the landfills (Photo 1). At the Tier II landfill, a frost crack leads up to the toe of the south berm but does not appear to affect the landfill (Photo 2). Another crack was found approximately 10 m from the northwest corner of the landfill (Photo 3). Two narrow depressions that appear to be small cracks or potholes were also observed nearby, Photo 4 shows the depression found to the west and Photo 5 shows the depression found by the southwest corner. At the NHWL, there is a frost crack that leads up to the toe of the south berm but does not appear to affect the landfill (Photo 6). To the west of the landfill, there are two more cracks shown in Photo 7 and 8. A washboard was noted south of the NHWL (Photo 9)

An attempted animal burrow was located on the east berm of the Tier II landfill. The disturbance was shallow and does not appear to impact the landfill (Photo 10). Natural re-vegetation has not yet begun at the site. Seepage and staining were not present and the site was clear of any debris.

An inspection of the groundwater wells was done during groundwater sampling. The wells were found to be in good condition. They appeared not to have any changes due to frost heaving though the wells were frozen, and no groundwater samples could be collected.

5.3 Natural Environment Monitoring

Site observations and an interview with a local resident were conducted to document the status of the natural environment. The natural environment monitoring checklist can be found in Appendix A.

Three (3) polar bears were observed from the plane prior to landing, and two (2) more polar bears were observed while on site (Photo 11). During monitoring activities, a flock of snow geese flew overhead (Photo 12). Evidence of other wildlife on site was observed in the form of caribou droppings (Photo 13).

The interview with Fred Qavvik revealed that wildlife expected to be in the area include polar bears, caribou, arctic foxes, geese and rarely wolverines. He provided an estimate on the number of wildlife that would frequent the area: five (5) polar bears, about fifty (50) snow geese, less than five (5) caribou, and an unknown number of arctic foxes. Other uses of the area that were noted include caribou hunting, fishing for lake trout, and berry picking.

There was no evidence of revegetation observed on the landfill (Photo 14).

5.4 Analytical Results

When water level and depth were measured, it was determined that all seven (7) wells were frozen. The water levels in each monitoring well are recorded in the groundwater monitoring log found in Appendix C. No other information could be collected.

No soil samples were collected as no staining or seepage points were observed on site. No surface water samples were collected as there were no surface waterbodies in the immediate area.

5.5 Thermistor Data Collection

BluMetric was successful at downloading the raw data from the thermistors after which they were reset. It was noted that the key to open the thermistors was not the correct one and the locks were cut to access the thermistors. The security pins were put back in place after the data was downloaded to prevent thermistor exposure to rain, snow, and sunlight and to allow future access (see Photos 15 through 17). Replacement locks should be brought to site during the next monitoring event to secure the thermistors.

Appendix D contains the letter report from Trek Geotechnical who analyzed the thermistor data. This report summarizes the findings and plots ground temperature versus depth with indication of the 0 degree isotherm. Table 4 summarizes the conclusions of maximum thaw depth from the letter report. The results found the maximum thaw over the two years of monitoring is between 1.9 to 3.0 m below ground surface in 2019 and 1.7 to 2.9 m below ground surface in 2020. This indicates that the Tier II facility has started to freeze over however, the thermistor loggers were downloaded at the beginning of September 2020 and may not have captured the maximum thaw that occurred in 2020.

Table 4: Maximum Thaw Depth by Year

Thermistor ID	Year 2019 (metres below ground surface)	Year 2020 (metres below ground surface)
VT-A-1	1.9	1.7
VT-A-2	2.2	2.0
VT-A-3	2.3	2.0
VT-B-1	2.8	1.9
VT-B-2	3.0	1.9

The RAW data was submitted to CIRNAC electronically through an FTP site due to the size of files. The USB cable to download the data, the incorrect thermistors' key and USB key with software were provided to CIRNAC personnel in Iqaluit shortly after the site visit.

5.6 GPS Survey of Landfills

The NHWL and Tier II landfills were surveyed using RTK GPS. The elevations are geodetic and using the HT2 Canadian geoid model. The GPS base was averaged for 2 hours. The raw data was processed using NRCAN's Precise Point Positioning (PPP) software to ensure geodetic results in northing, easting and elevation. Topographic contours (at 25cm intervals) were derived from the 3D model from the RPA survey.

The results were used to generate Figure 2 CAM-E Non-Hazardous Waste Landfill and Tier II Landfill. The figure shows the locations in the Universal Transverse Mercator coordinate system, 1983 North American Datum (UTM NAD83), Zone 16.

In addition to the topography survey, the RPA was used to collect aerial footage that provide a 360° view of the site. The RAW data and video footage was submitted electronically to CIRNAC due to the large file size.

6 CONCLUSION

The observations made during the 2020 long term monitoring event support that the CAM-E non-hazardous waste landfill and Tier II Landfill is performing as expected. Visual monitoring shows that the NHWL and Tier II Landfill are in acceptable condition based on severity ratings presented in the AMSRP Volume II (INAC, 2009). The surface of the landfills did not show any evidence of frost action or erosion. There was a shallow disturbance from an attempted animal burrow at the Tier II Landfill but this does not appear to impact the landfill. Evidence of frost action approach the toe of the south berm at both landfills, these areas should be monitored closely in the next monitoring event to note any further settling. In the surrounding area, evidence of settlement and erosion are observed but occur at a distance from the facilities and do not appear to have any negative impact.

The observations made regarding the natural environment monitoring showed evidence of wildlife on the site. A total of five (5) polar bears and a flock of snow geese were observed during the site visit. Caribou droppings and an attempted burrow on the landfill was noted. An interview with a resident from Kugaruuk reported that the area was used for hunting, fishing, and foraging. He commented that polar bears, snow geese, caribou, arctic foxes, and the occasional wolverine would frequent the area.
Water levels were taken at the seven (7) groundwater monitoring wells. All monitoring wells were frozen, thus no ground water samples were collected. No soil or surface water samples were collected as there was no evidence of any seepage or staining from the NHWL.

Thermistor data was collected and the data provided to Trek Geotechnical for analysis. The data was processed to determine the active layer during the two-year period. Their results were summarized in a letter report in Appendix D.

A topographical survey was completed by RTK GPS surveying as well as RPA surveying. Video footage was taken of the site using the RPA. The RAW data and video footage was submitted to CIRNAC.

Based on the results of the 2020 long term monitoring event, BluMetric recommends continuing the Phase I monitoring at the AMSRP recommended schedule. With no observable deterioration of the landfills observed at the CAM-E site in 2020, the site is in acceptable condition. The next monitoring event is recommended to occur in Year 3 (2022).

6.1 CLOSURE

The conclusions presented in this report are based upon the analysis of historical information made available to BluMetric Environmental Inc. Any additional information received after the date of delivery of this report will be analysed and submitted in a timely manner in the form of an addendum or a memorandum.

BluMetric Environmental Inc, makes no warranty as to the accuracy or completeness of the information provided by others, or of conclusions and recommendations predicated on the accuracy of that information.

This report has been prepared for CIRNAC. Any use a third party makes of this report, any reliance on the report, or decisions based upon the report, are the responsibility of those third parties unless authorization is received from BluMetric Environmental Inc. in writing.

Respectfully Submitted,
BluMetric Environmental Inc.

Karen Phong, B.Eng., EIT (ON)
Engineering Intern

Yannick Lanthier, M.Sc. (ON)
Geomatics Manager

REGISTERED PROFESSIONAL ENGINEER
A.D. JENNEY
LICENSEE
18-Feb-2021
NT/NU

Andrea Jenney, B.Sc., P.Eng (NU/NT)
Senior Engineer

7 REFERENCES

AECOM. 2020. "CAM-E (Keith Bay) Construction Summary Report."

CCME. 1999. "Canadian Water Quality Guidelines for the Protection of Aquatic Life."

CCME. 2008. "Canada-Wide Standard (CWS) for Petroleum Hydrocarbon in Soil, Tier 1 Residential/Parkland, non-potable water, coarse-grained soil."

CCME. 1999 with updates. "CSQGs for the Protection of Environment and Human Health for residential/parkland use, non-potable coarse-grained soil."

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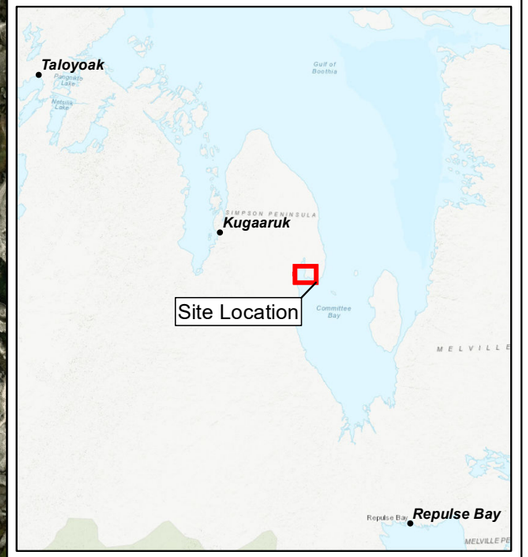
INAC. March 2009. "Abandoned Military Site Remediation Protocol (AMSRP)."

FIGURES

LEGEND



REV.	DESCRIPTION	YY/MM/DD	BY	CHK
1				

REFERENCES

N, W, E, S

0 500 1,000 Metres

1:50,000

CLIENT

Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC)

PROJECT

Long-Term Monitoring 2020
CAM-E, Keith Bay, Nunavut

TITLE

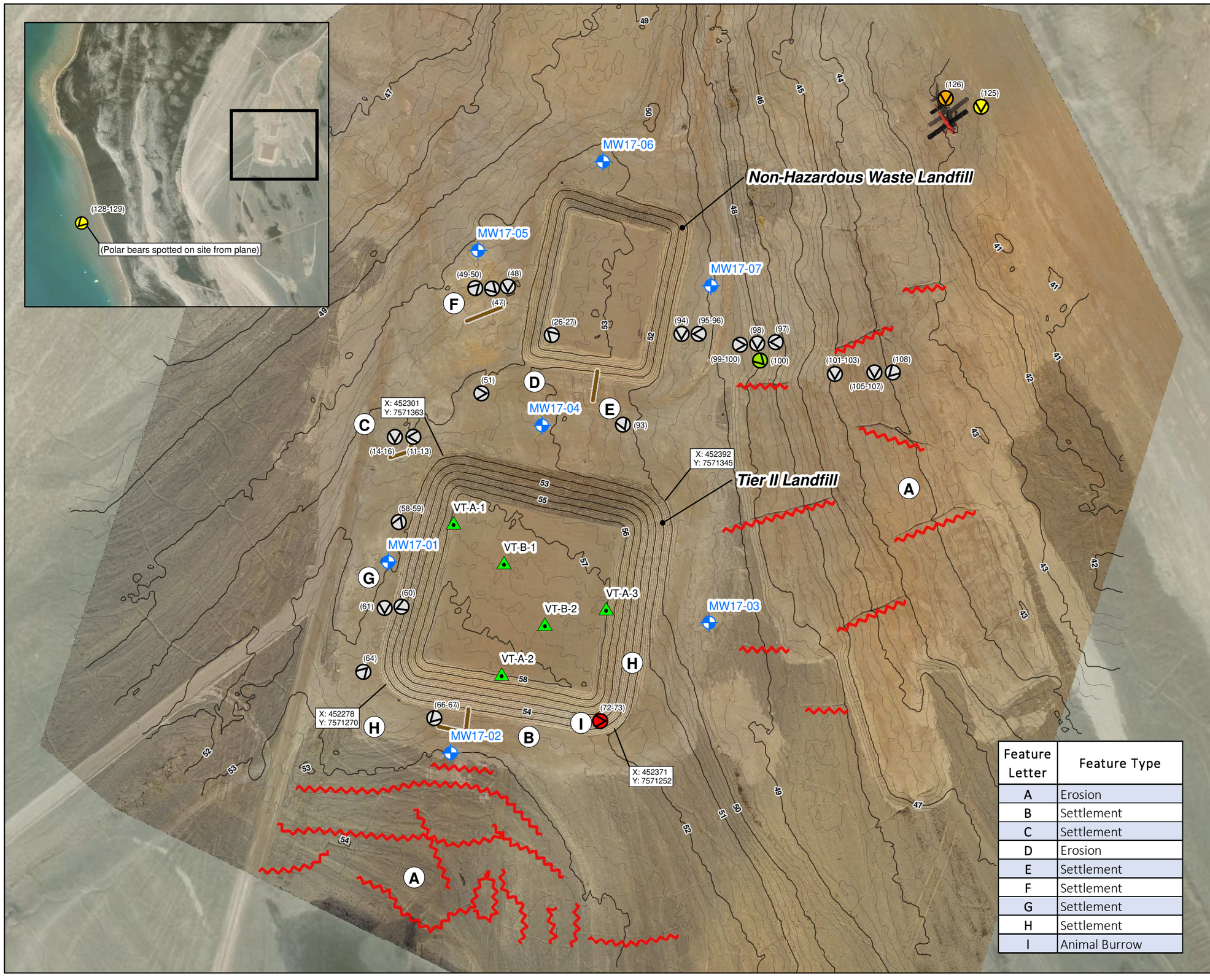
Site Location

BluMetric™ Environmental
4916 49th Street,
PO Box 11086
Yellowknife, NT, X1A 1P3
TEL: (867) 873-3500
FAX: (867) 873-3499
Email: info@blumetric.ca
Web: http://www.blumetric.ca

PROJECT #	DATE
200537	February 12, 2021

DRAWN	CHECKED	FIG NO.	REV
KH	KP	01	0

N:\GIS_PROJECTS\200000\200537 - PSPC - CIRNAC - LTM\Work Material\MXD\Report2_CAM-E\2021-02-12\200537-R2CAME-Fig01_SLM.mxd



Feature Letter	Feature Type
A	Erosion
B	Settlement
C	Settlement
D	Erosion
E	Settlement
F	Settlement
G	Settlement
H	Settlement
I	Animal Burrow

LEGEND

Photo Location and Evidence Type

- Evidence of Frost Action
- Evidence of Limited Vegetation
- Shallow Animal Burrow
- Wildlife Evidence
- Wildlife Sighting
- Monitoring Well
- Thermistor
- Erosion
- Settlement
- Major Topographic Contour (1 masl)
- Intermediate Topographic Contour (0.25 masl)

FIELD OF VIEW

NOTES:
ALL COORDINATES ARE IN METERS AND IN UTM NAD83 ZONE 16.
ALL ELEVATIONS ARE IN METERS AND IN THE CGVD28 GEOID.
TOPOGRAPHIC AND AERIAL RPA SURVEY FROM BLUMETRIC ON 2020/08/28.

REV.	DESCRIPTION	YY/MM/DD	BY	CHK
1				

REFERENCES

N, W, E, S

0 50 100 m

1:1,500

CLIENT

Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC)

PROJECT

Long-Term Monitoring 2020
CAM-E, Keith Bay, Nunavut

TITLE

CAM-E Non-Hazardous Waste Landfill

BluMetric Environmental
4916 49th Street,
PO Box 11086
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Email: info@blumetric.ca
Web: http://www.blumetric.ca

PROJECT #	DATE
200537	February 12, 2021

DRAWN	CHECKED	FIG NO.	REV
KH	KP	02	0

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APPENDIX A

Monitoring Checklists and Daly Field Report

Daily Activities

Date:	Friday August 28, 2020
Project Name:	2020 Long Term Monitoring
BluMetric Project #	200537
Client:	CIRNAC
BluMetric Personnel on site:	Matt Kitchen Jeff Rosnawski
Client personnel on site:	Selma Al-Soweydawi
Site Visited:	CAM-E and CAM-D
Start time (on site):	11:00 and 15:30
End time (off site):	15:00 and 19:00
Weather conditions:	10 C, partly cloudy, turning to 10 C light rain and fog
Project Activities completed today:	CAM-E Visual inspection of NHWL – completed. Wildlife Monitor Interview – completed. No Staining Observed. RTK GPS Survey and RPA aerial imagery acquisition – completed. RPA video of site – completed. The groundwater monitoring program was completed. - All sites were frozen no samples obtained. Thermistors were not downloaded due to missing cable from inventory. CAM-D Visual inspection of NHWL – completed. Wildlife Monitor Interview – completed. No Staining Observed. The groundwater monitoring program was completed. - All sites taken with a duplicate on MW-02
Health and Safety:	Daily tailgate meeting theme was “See something, say something”. No incidents or near misses to report.
Visitors and Third Party Enquiries:	n/a
Wildlife Sightings	Two polar bear sightings at CAM-E. Recon flight getting to site had 5 bear sightings near site at CAM-E. No sightings at CAM-D
Project activities planned for tomorrow:	Download Thermistors data at CAM-E if cable is found. Mobilize to Cambridge Bay

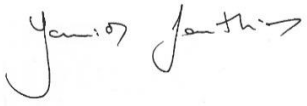
Labour Hour Tracking

Name	Position	From	To	Hours	Notes
Fred Qavvik	Wildlife Monitor	10:00	19:30	9.5	

Equipment Tracking					
Name	Model	From	To	Hours	Notes

Sample Summary

Samples Collected	Total # Samples	Analysis								
		Metals	PHCs	VOCs	PAHs	PFAS	PCBs	Lead Paint	Asbestos	Other
Soil										
Sediment										
Surface Water										
Groundwater	4+ dup	4	4	4	4		4			
Vegetation										
Grain Size										
Building Material										
Other										

Other Notes/Comments	
Prepared by (print):	Matt Kitchen
Reviewed by (print):	Yannick Lanthier
Signature:	

NATURAL ENVIRONMENT CHECKLIST

Date:		28/Aug/20	
Site:		CAM-E	
Note	**Response**	**Extent**	**Description**
	Y/N	Provide information as applicable (i.e. length/width/depth/type)	Features of note, photographic reference with scale, point of view and direction.
Wildlife Sightings	Y	- Polar Bears (3 seen from the plane, 2 onsite) - Snow geese	Photos 129, 128 and 125.
Evidence of Wildlife	Y	- Caribou droppings	Photo 126
Wildlife Activity	Y	- Geese flying over - Wildlife passing through - Polar bears browsing or hunting	
Relative Number	Y	- 5 Polar bears - ~50 Snow geese - <5 Caribou	
Evidence of Revegetation	N	- Very Limited vegetation on site	Photo 100

Wildlife Monitor Notes

- Potential Wildlife:
    - Polar Bear, caribou, arctic fox, geese, and rarely wolverines.
- Region used for hunting, fishing (Lake Trout), and berry picking.

VISUAL MONITORING CHECKLIST

Date:		28/Aug/20	
Landfill Location:		CAM-E	
Note	**Response**	**Extent**	**Description**
	Y/N	Provide information as applicable (i.e. length/width/depth/type)	Features of note, photographic reference with scale, point of view and direction.
Evidence of Settlement	Y	See Notes below on Frost Action	
Evidence of Erosion	Y	None on landfills, multiple erosion areas around site	101-103, 105-108.
Evidence of Frost Action	Y	None on landfill, multiple frost cracks around site.	Photos 1, 2, 11, 12-16, 26, 27, 47-51, 58-61, 64, 66, 67, 93.
Animal Burrows	Y	Attempted burrows (shallow 4' in diameter)	Photos 72 and 73.
Vegetation Present	Y	None present/observed	
Vegetation Stresses	N/A		
Staining Present	N	None observed	
Seepage Points	N	None observed	
Exposed Debris	Y	None observed	
Condition of Instruments		In good condition	
Other Features			

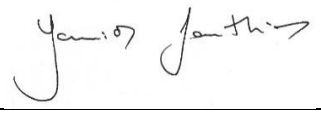
Daily Activities

Date:	Tuesday September 8, 2020
Project Name:	2020 Long Term Monitoring
BluMetric Project #	200537
Client:	CIRNAC
BluMetric Personnel on site:	Kim Carlton
Client personnel on site:	-
Site Visited:	CAM-E
Start time (on site):	1:55 PM EST
End time (off site):	3:48 PM EST
Weather conditions:	N/A
Project Activities completed today:	CAM-E 5 Thermistors data downloaded **Summary** Key supplied by Lakewood did not work in the lock**s** on the wells (they were silver on the inside covered in yellow and black plastic). We broke the locks off each of the wells. We left the broken locks on the wells so the lids wouldn't come off (see picture below). **All** logger battery inside said it was good until Aug 2021. Cable worked great and data will be uploaded to the server this evening. We will coordinate with Trek Geotechnical Inc. for analysis and reporting. Cable, key and software (usb stick) will be delivered to client in Iqaluit this week.
Health and Safety:	Daily tailgate meeting theme was "See something, say something". No incidents or near misses to report.
Visitors and Third Party Enquiries:	n/a
Wildlife Sightings	5 polar bear sightings at CAM-E. While scoping out our landing we noted 5 bears in the area. After landing we waited onsite for about 30 minutes for a mother and her cubs to be further from the landfill area before heading up to take data readings. No bear incidents onsite as they kept their distance.
Project activities planned for tomorrow:	N/A

Labour Hour Tracking

Name	Position	From	To	Hours	Notes
Simon Curley	Wildlife Monitor	10:00	16:30	6.5	Paid/Receipt From Hall Beach

Photos

Other Notes/Comments	
Prepared by (print):	Yannick Lanthier
Signature:	

APPENDIX B

Site Photographs

Photo 1: Erosion around the landfill.

Photo 2: Crack adjacent to Tier II Landfill.

Photo 3: Crack Northwest of Tier II Landfill

Photo 4: Small Depression West of Tier II Landfill

Photo 5: Small Depression Southwest of Tier II Landfill

Photo 6: Crack adjacent to Non-Hazardous Waste Landfill.

Photo 7: Small Crack West of Non-Hazardous Waste Landfill

Photo 8: Large Crack West of Non-Hazardous Waste Landfill

Photo 9: Washboard South of Non-Hazardous Waste Landfill.

Photo 10: Attempted Animal Burrow.

Photo 11: A polar bear seen from the plane.

Photo 12: Snow geese flying overhead.

Photo 13: Caribou droppings.

Photo 14: Limited vegetation observed on site.

Photo 15: Thermistor lock.

Photo 16: Cut thermistor lock.

Photo 17: Condition of thermistor at end of site visit.

APPENDIX C

Groundwater Sampling Logs

Water Sampling Log

Project Number: 200537 **Date:** 2020-Aug-28 **Samplers Names:** Jeff Rosanowski

Location: CAM-E **Start** 11:30 **End** 13:00 **Sample Type: GW**

Well ID	Depth to Bottom	Water Level Depth	Well Volume	Comments	DO	ORP	Temp	pH	Cond	Turbidity	TDS
eg. MW-19-01	mbtp	mbtp	Litres=H(m)x2.03	Colour, sheen, odour, etc	g/L		C		s/cm	NTU	g/L
MW17-07	N/A	Frozen @ 1.24	N/A	Not sampled, frozen.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MW17-06	N/A	Frozen @ 1.24	N/A	Not sampled, frozen.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MW17-05	N/A	Frozen @ 1.17	N/A	Not sampled, frozen.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MW17-04	N/A	Frozen @ 1.25	N/A	Not sampled, frozen.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MW17-03	N/A	Frozen @ 1.27	N/A	Not sampled, frozen.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MW17-02	N/A	Frozen @ 1.19	N/A	Not sampled, frozen.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MW17-01	N/A	Frozen @ 1.38	N/A	Not sampled, frozen.	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Notes: N/A = Not applicable

APPENDIX D

CIRNAC Long Term Monitoring Program – Trek Geotechnical Thermistor Report

December 7, 2020 Our File No. 0154 015 00

Andrea Jenney, P.Eng.
Senior Engineer - Government Sector Market Lead
Blumetric Environmental Inc.
57 Cambrian Heights Dr Unit 102,
Sudbury, ON
P3C 5S5

RE: CIRNAC Long Term Monitoring Program 2020 – Thermistor Data (Revised)

The letter presents thermistor data that has been reduced and plotted as requested. The thermistor data was provided by Blumetric and originates from data obtained from the intermediate DEW Line Site Cam-E at Keith Bay. Four thermistors at the Tier 2 landfill facility were installed shortly after construction of the facility and logged for a two year period, twice daily using a Lakewood Data Acquisition system (Model RX16ML Data Logger) attached to each thermistor. The thermistors include 11 to 13 beads spaced about 0.6 m apart for a general length of 5 to 7 m.

The attached plots show the temperature profiles over time (Figures 01 to 05), but also by depth selecting the same days throughout the year in the following months; Feb, May, Jul, Sep, and Dec for all thermistors (Figures 06 to 10). The maximum thaw measured in the data set is also plotted following the first (2019) and second winter (2020).

Overall, the data set is of good quality with temperature profiles and trends as expected with changes in seasons and by depth (e.g. shallower beads exhibiting larger variations in temperature by season). The data set for Bead 12 on thermistor VT-A-3 did include some unrealistic readings (560 of 1451 data points) noting very high temperatures. These unrealistic readings have been removed from the plots. The table presents the maximum thaw measured over the two-year period for each thermistor.

Table 1 – Maximum Thaw Depth By Year

Thermistor	Year 2019 (m below ground surface)	Year 2020 (m below ground surface)
VT-A-1	1.9	1.7
VT-A-2	2.2	2.0
VT-A-3	2.3	2.0
VT-B-1	2.8	1.9
VT-B-2	3.0	1.9

The measured maximum thaw over the two years of monitoring is between 1.9 to 3.0 m below ground in 2019 and 1.7 to 2.0 m below ground in 2020 indicating the core of the Tier 2 facility has started to freeze over. The loggers were downloaded in the beginning of September 2020 and in this regard, may have not captured the maximum thaw that occurred in 2020. This statement is supported based on the maximum thaw of 2018 which was measured in early October. The reduced data and plots will be sent to you electronically by e-mail for your records.

Closure

The geotechnical information provided in this report is in accordance with current engineering principles and practices (Standard of Practice). The findings of this report were based on information provided (monitoring data).

All information provided in this report is subject to our standard terms and conditions for engineering services, a copy of which is provided to each of our clients with the original scope of work or standard engineering services agreement. If these conditions are not attached, and you are not already in possession of such terms and conditions, contact our office and you will be promptly provided with a copy.

This report has been prepared by TREK Geotechnical Inc. (the Consultant) for the exclusive use of the Blumetric Environmental Inc. (the Client) for the work product presented in the report. Any findings or recommendations provided in this report are not to be used or relied upon by any third parties, except as agreed to in writing by the Client and Consultant prior to use.

We thank you for the opportunity to provide engineering services on this assignment. If you have any questions regarding the findings or recommendations presented, please contact the undersigned at your earliest convenience.

Kind Regards,

TREK Geotechnical Inc.

Per:

Beta Taryana P.Eng. (MB)
Geotechnical Engineer
Attach.

Reviewed by

Nelson John Ferreira, Ph. D., P.Eng. (NWT-NU)
Senior Geotechnical Engineer

RATE PLOT
VT-A-1

Northing: 7571335.722 m
Easting: 452305.47 m
Gnd Elev.: 57.852 mamsl

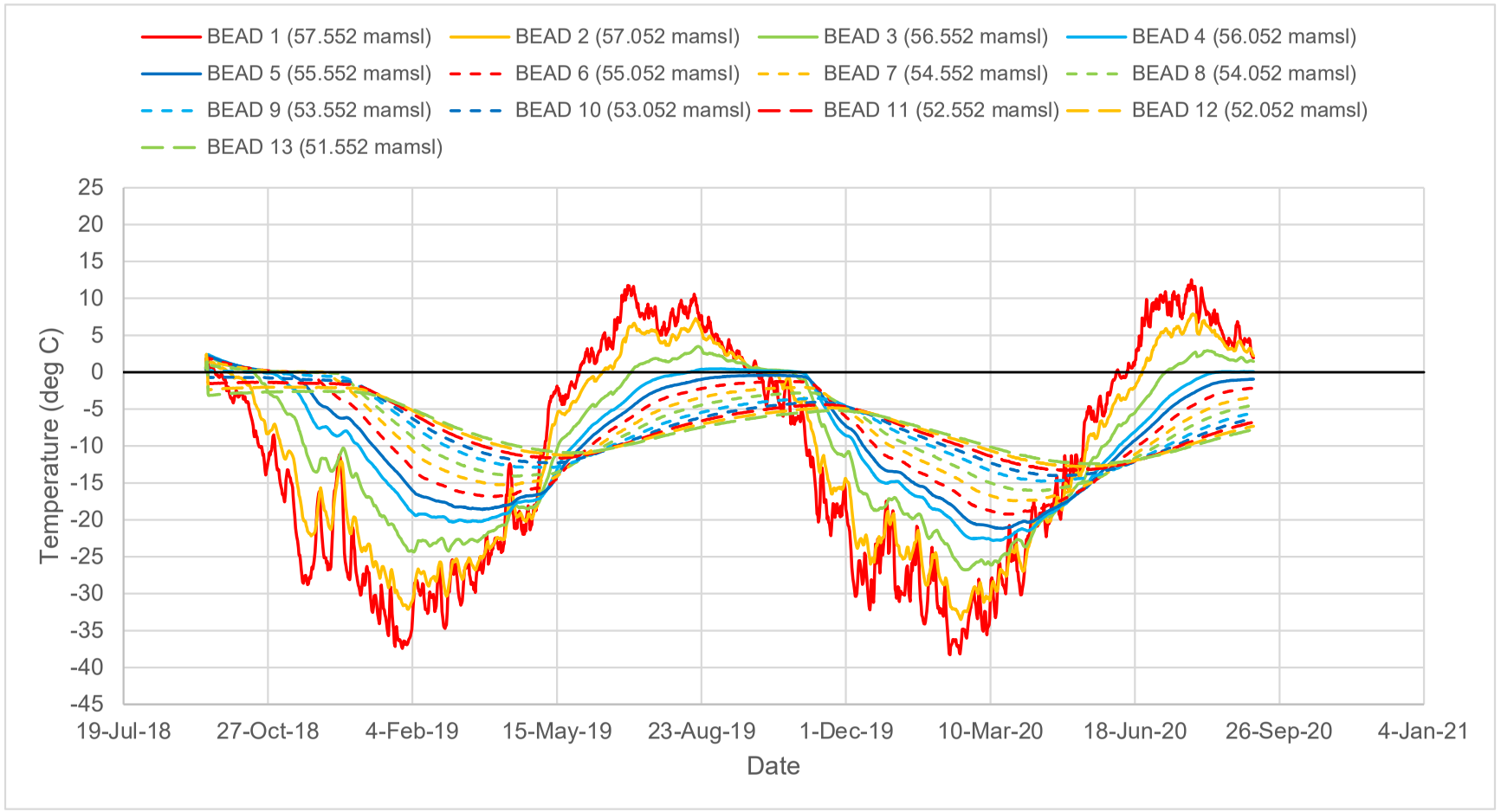


Figure 01
VT-A-1
Rate Plot

RATE PLOT
VT-A-2

Northing: 7571274.026 m
Easting: 452325.173 m
Gnd Elev.: 58.707 mamsl

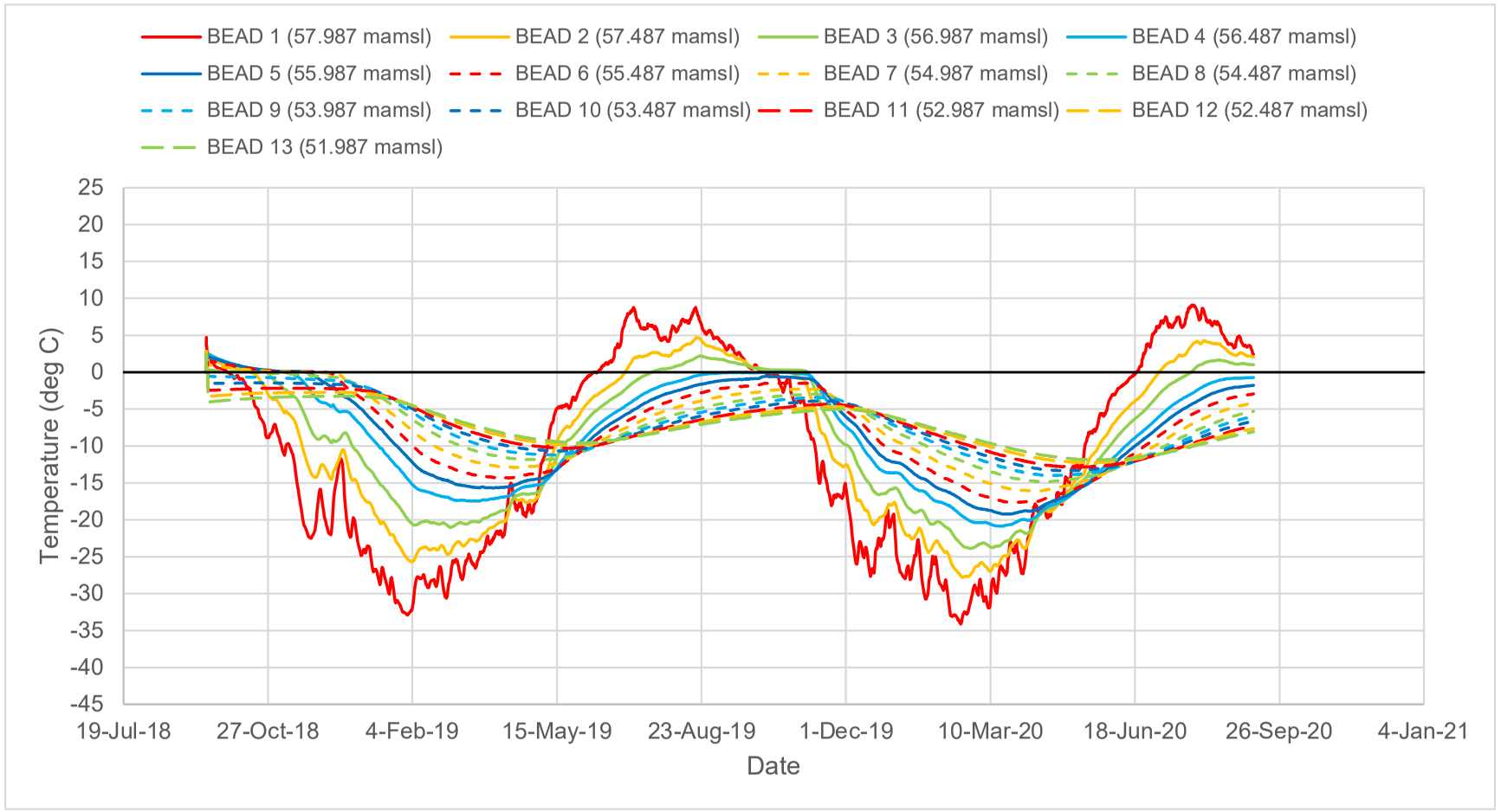


Figure 02
VT-A-2
Rate Plot

RATE PLOT
VT-A-3

Northing: 7571300.812 m
Easting: 452368.034 m
Gnd Elev.: 57.661 mamsl

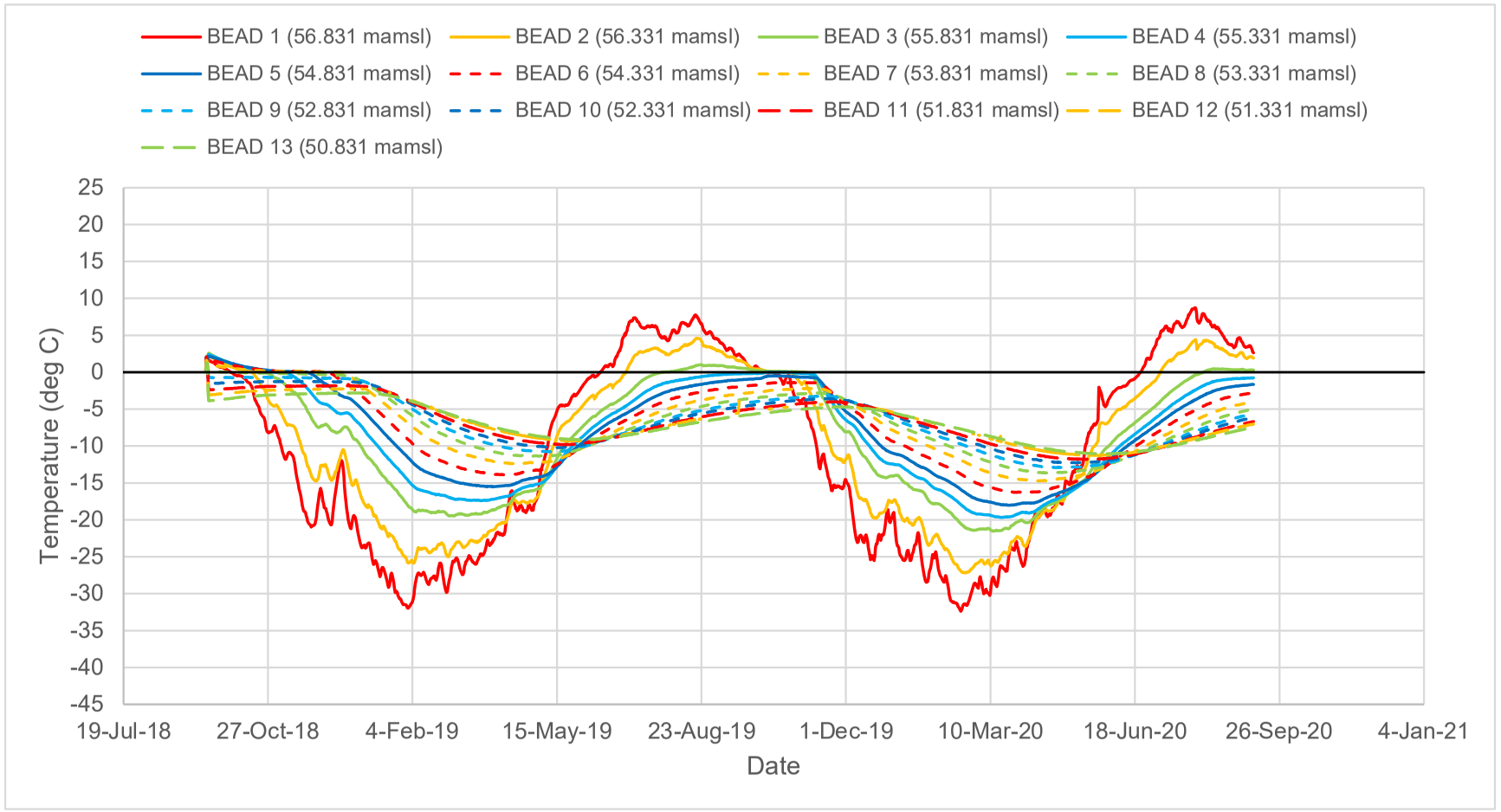


Figure 03
VT-A-3
Rate Plot

RATE PLOT
VT-B-1

Northing: 7571319.507 m
Easting: 452326.108 m
Gnd Elev.: 57.929 mamsl

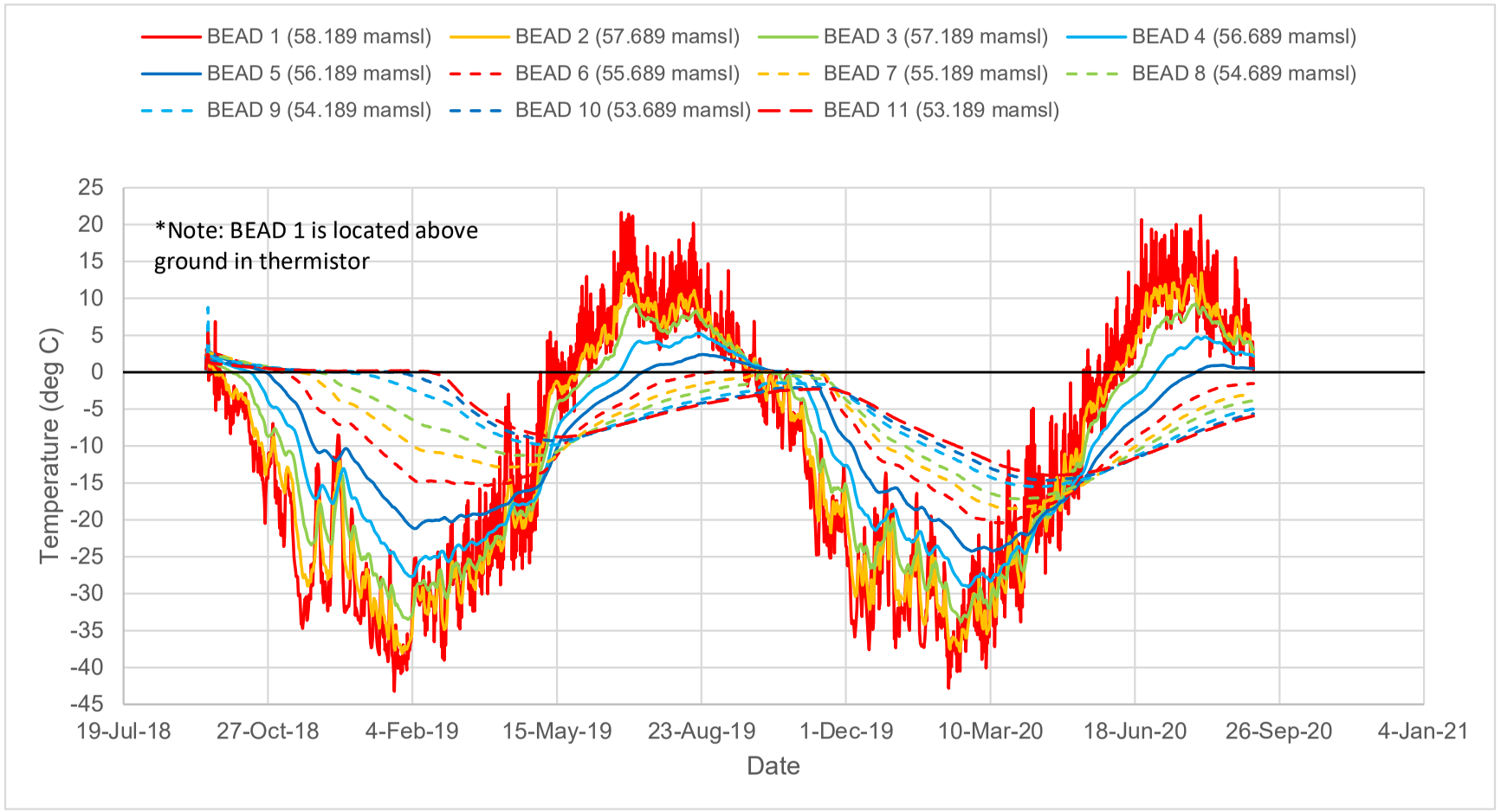


Figure 04
VT-B-1
Rate Plot

RATE PLOT
VT-B-2

Northing: 7571294.347 m
Easting: 452342.954 m
Gnd Elev.: 58.057 mamsl

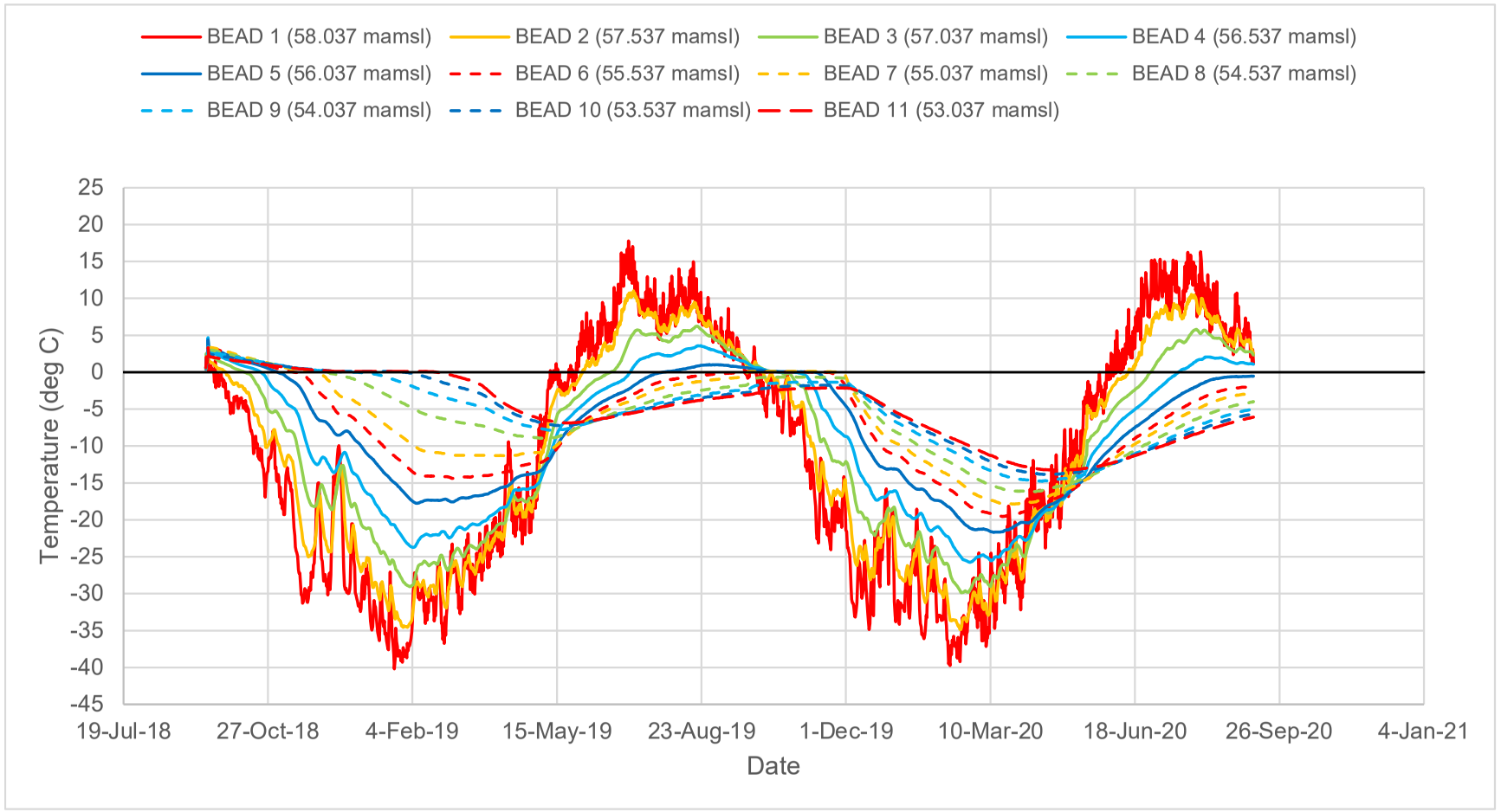


Figure 05
VT-B-2
Rate Plot

GROUND TERMPERATURE PLOT
VT-A-1

Northing: 7571335.722 m
Easting: 452305.47 m
Gnd Elev.: 57.852 mamsl

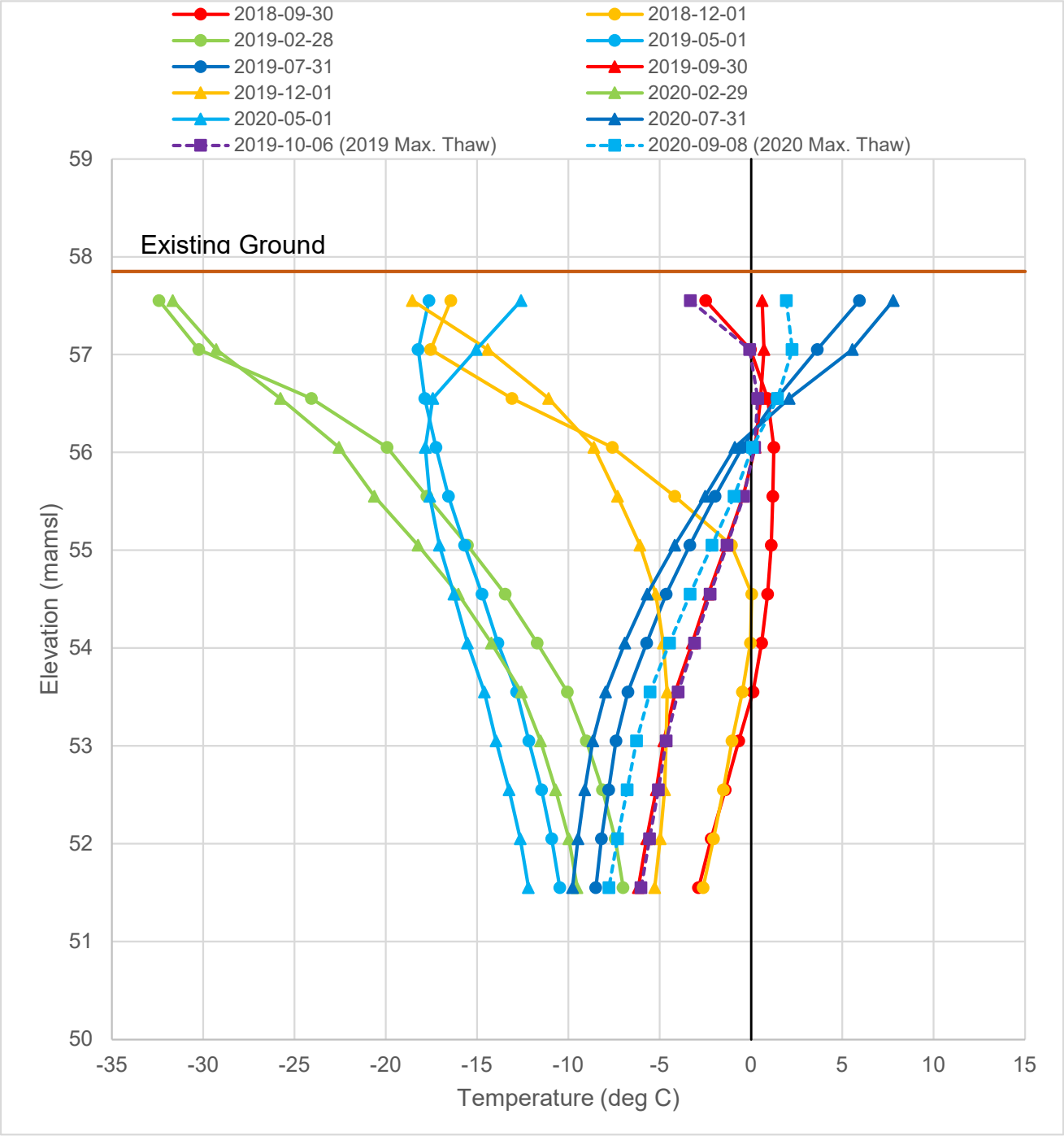


Figure 06
VT-A-1
Ground Temperature Plot

GROUND TERMPERATURE PLOT
VT-A-2

Northing: 7571274.026 m
Easting: 452325.173 m
Gnd Elev.: 58.707 mamsl

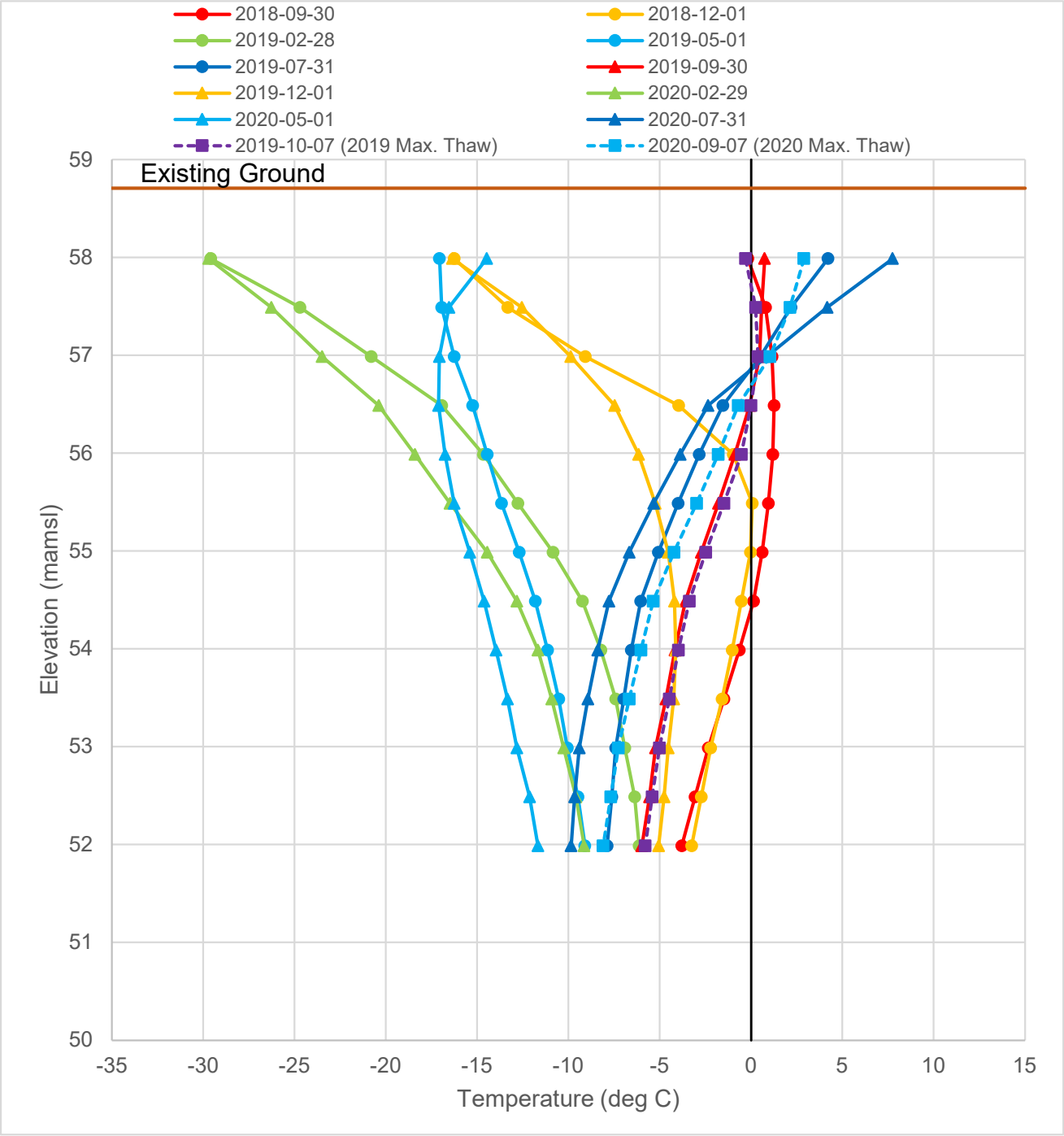


Figure 07
VT-A-2
Ground Temperature Plot

GROUND TERMPERATURE PLOT
VT-A-3

Northing: 7571300.812 m
Easting: 452368.034 m
Gnd Elev.: 57.661 mamsl

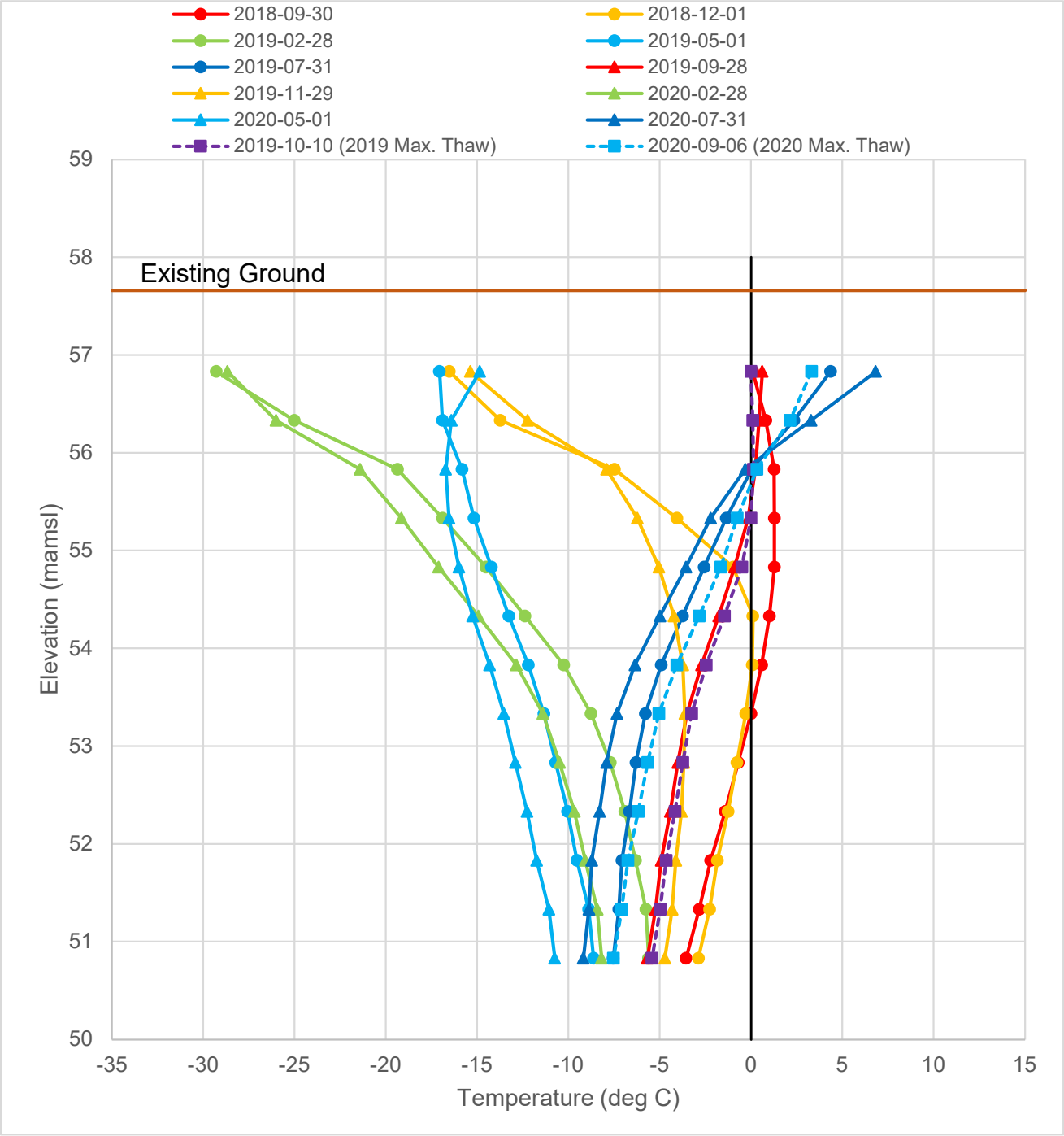


Figure 08
VT-A-3
Ground Temperature Plot

GROUND TERMPERATURE PLOT
VT-B-1

Northing: 7571319.507 m
Easting: 452326.108 m
Gnd Elev.: 57.929 mamsl

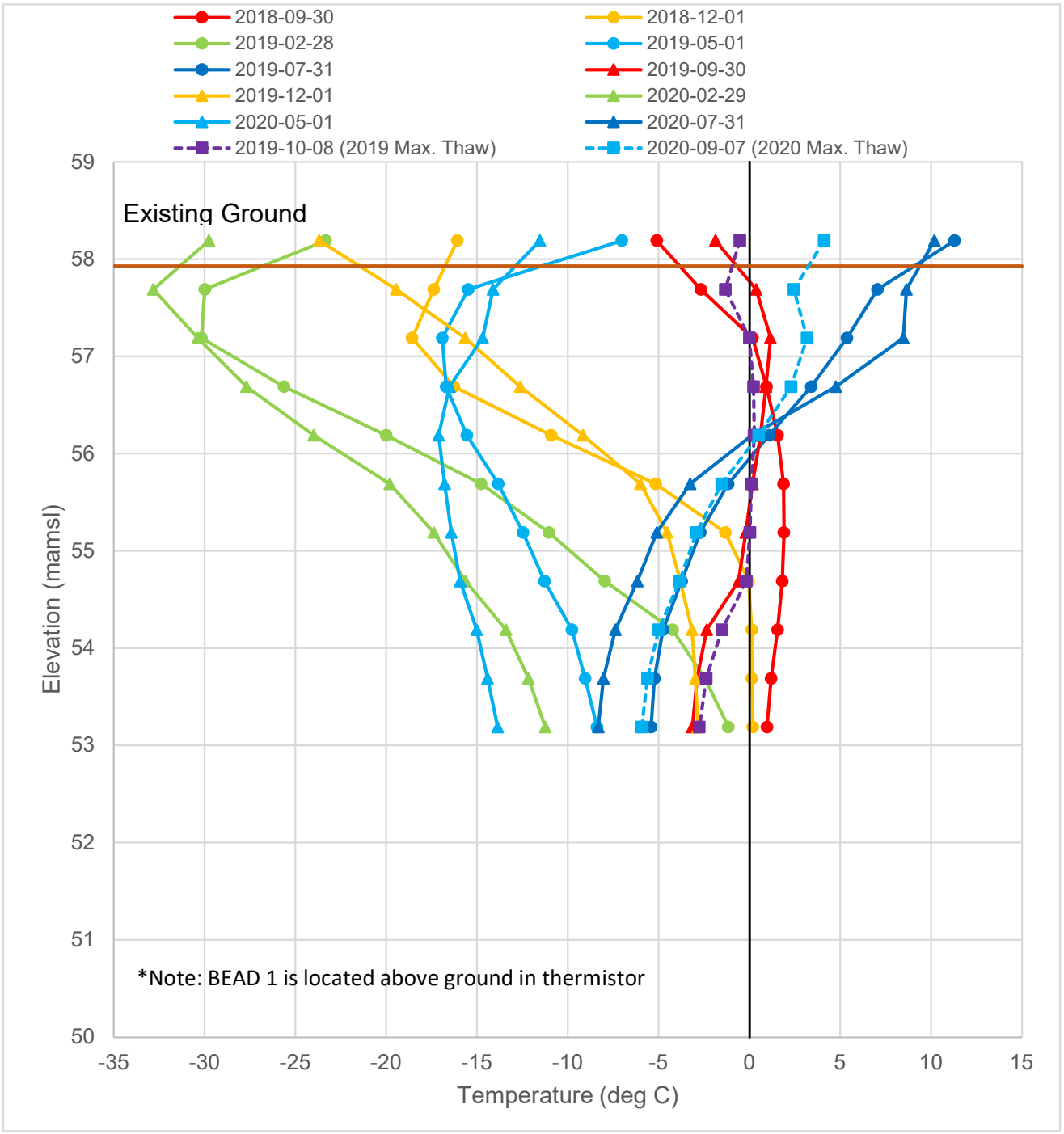


Figure 09
VT-B-1
Ground Temperature Plot

GROUND TERMPERATURE PLOT
VT-B-2

Northing: 7571294.347 m
Easting: 452342.954 m
Gnd Elev.: 58.057 mamsl

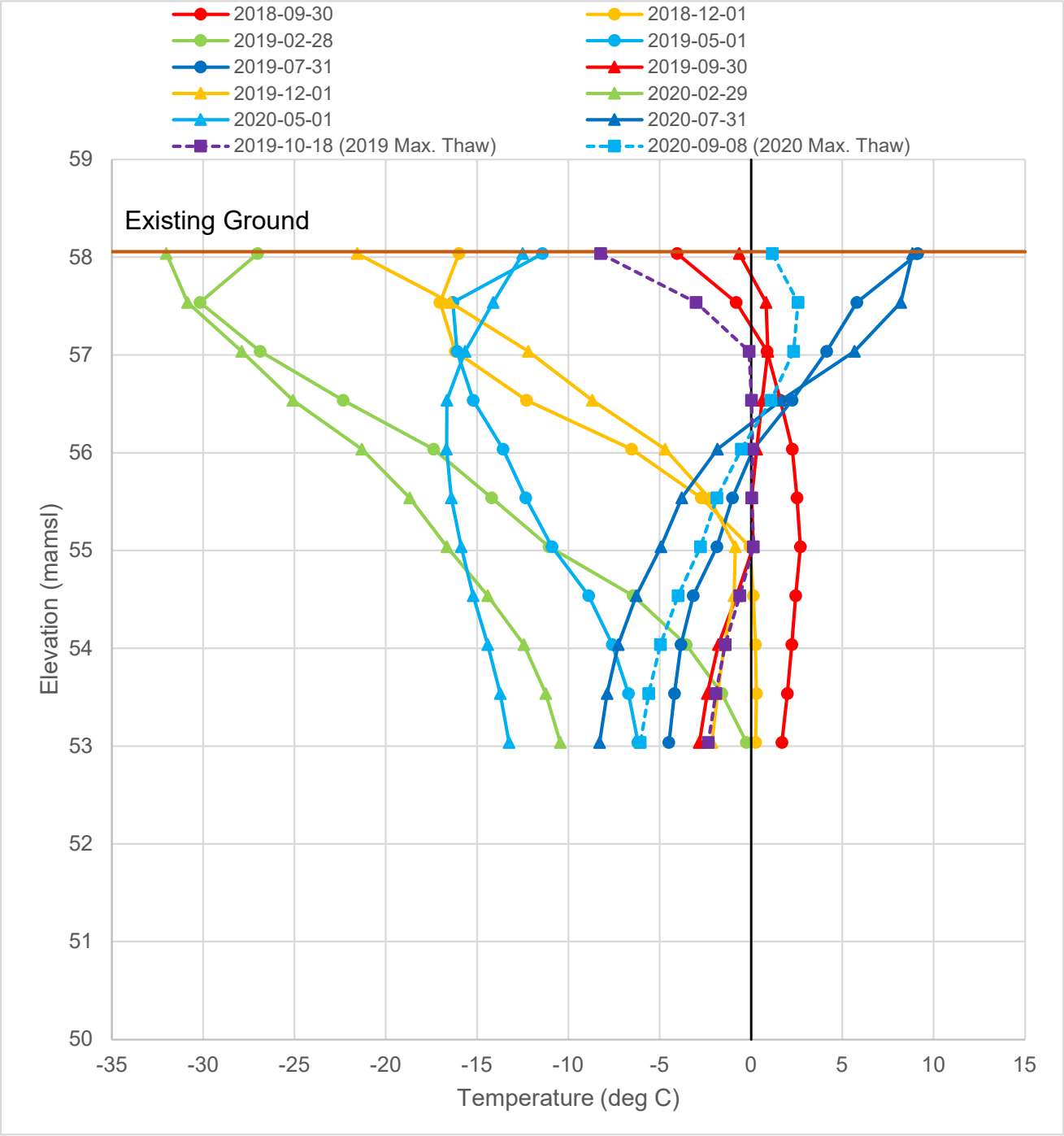


Figure 10
VT-B-2
Ground Temperature Plot

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