October 24, 2019 Reference No. 18113464-004-L-Rev1-3000-TBD

Red Dog Tailings and Water Department
Teck Alaska Incorporated
Red Dog Operations
3105 Lakeshore Drive
Building A, Suite 101
Anchorage, AK 99517

2019 ANNUAL PERFORMANCE REPORT FOR TAILINGS BACK DAM, RED DOG MINE, ALASKA

Tailings and Water Team:

Golder Associates Inc. (Golder) is pleased to submit to Teck Alaska Incorporated (Teck) the 2019 Annual Performance Report (APR) for the Tailings Back Dam (TBD) at Red Dog Mine in northwest Alaska. The TBD has been assigned National Inventory of Dams (NID) identification number AK00303. The APR was supported by a site visit to inspect the dam on June 22, 2019 and a review of monitoring data provided by Teck. This work was performed in general accordance with our proposal dated February 6, 2019.

Based on the field inspection and review of available monitoring data the TBD and its appurtenant components appear to be maintained in a satisfactory condition and is performing as designed. Teck should continue to pay close attention to monitoring data and changing conditions in accordance to the O&M Manual.

1.0 INTRODUCTION AND BACKGROUND

The Red Dog Mine, a lead-zinc production mine, and Tailings Storage Facility (TSF) are located approximately 90 miles north of Kotzebue, Alaska in the Northwest Arctic Borough. The TBD forms the southern barrier of the Tailings Impoundment (tailings pond) and is located adjacent to the northern side of the Overburden Stockpile, as depicted in Figures 1 and 2. The Overburden Stockpile lies across the divide between the South Fork of the Red Dog Creek and Bons Creek drainages and is composed of unconsolidated material stripped off from over the mine pit area. The purpose of the TBD, in conjunction with the seepage water collection system and the aggraded permafrost within the Overburden Stockpile, is to prevent mine water from the tailings pond from entering into the Bons Creek drainage.

The TBD is a 4,956-feet-long gravel fill and rockfill embankment dam utilizing a centralized plastic concrete cut-off wall (COW) as the primary seepage reduction feature. An insulated fill section is typically installed over the COW to protect it from freeze-thaw degradation. The central sector of the dam embankment was constructed with compacted, generally well-graded, sand and gravel fill materials (select fill) processed from un-mineralized crushed rock. This select fill section was constructed over native soil and bedrock following the removal of native ice-rich and organic materials to reduce thaw settlement potential. The outside sectors of the dam embankment

Golder Associates Inc.
2121 Abbott Road, Suite 100, Anchorage, Alaska, USA 99507 T: +1 907 344-6001 F: +1 907 344-6011

are compacted rockfill. The native ice-rich and organic materials were not removed below the rockfill shell materials, so the rockfill was anticipated to deform as the frozen subgrade soils thaw and consolidate. This deformation has been observed during previous inspections, manifested as cracking parallel to the crest between the rockfill shell and select fill core.

The TBD has been constructed according to the following timeline:

- Stage I – Crest elevation 970 feet: Constructed 2007 through 2010
- Stage II – Crest elevation 976 feet: Constructed 2013
- Stage III – Crest elevation 986 feet: Constructed 2014 through 2016
- Stage IV – Crest elevation 996 feet: In progress, construction started in 2018 and slated to finish in 2021
- Stage V – Crest elevation 1,006 feet: This final raise is slated to commence in about 2025

Note that the crest elevation shown above is related to the design elevation of the plastic concrete COW. The dam embankment materials are constructed 0.5 feet higher to allow for settlement of the COW following placement and curing.

The performance of the TBD is monitored through the instruments shown in Figures 2 through 4. These instruments include 3 ShapeAccelArray movement monitoring arrays (SAAs), 12 vibrating wire piezometers (VWPs), 9 ground temperature monitoring arrays, 11 survey monuments, and a flowmeter at the sump pump. As part of the Stage IV construction the 9 ground temperature monitoring arrays within the TBD embankment are being decommissioned and ground temperature monitoring is being focused along the Overburden Stockpile, which acts as a secondary seepage barrier. The 11 survey monuments have also been decommissioned during the Stage IV construction but will be reestablished once construction is complete.

Stage IV construction activities began in 2018 and generally consisted of foundation preparation and buildout of the upstream and downstream rockfill sectors of the dam to the Stage V TBD footprint and a surface elevation of 986.5 feet. A brief summary of scheduled/ongoing 2019 construction activities includes the following:

- Subgrade and foundation preparation and verification at the East Abutment
- Removal of the existing insulation layer
- Modifications to monitoring instrumentation
- Embankment raise to an elevation of 996.5 feet
- Re-installation of insulation layer after embankment raise

The current *Certificate of Approval to Operate a Dam* (Certificate No. FY2018-14-AK00303) issued by the Alaska Department of Natural Resources Dam Safety and Construction Unit (ADNR Dam Safety) on February 12, 2018 stipulates that the holder of the certificate shall submit an APR by an engineer qualified in accordance with 11 AAC 93.193(b) by October 31 of each year during active mine operations. This submittal meets the above requirement.

2.0 FIELD INSPECTION

The field inspection for the TBD was performed by Golder employees Steven L. Anderson, PE, the designated Engineer of Record of the TBD, and Matthew Gillaspy, EIT. The field inspection was conducted on June 22, 2019 during the ongoing Stage IV raise construction. Prior to the inspection the insulation layer materials had been removed between Station 3+75 to Station 42+00, and the embankment fill had been raised to about elevation 989.5 feet. The weather during the inspection was partly cloudy with no precipitation. Select photographs taken during the site visit are included in Appendix A.

Highlights from the field inspection are summarized below.

- The tailings impoundment elevation during the site visit was approximately 976 feet.
- Except for the anticipated longitudinal cracking that is not a stability concern (see bullets below), the downstream and upstream dam embankment crest and slopes appeared in satisfactory condition with no indications of instability, such as slumping, depressions, etc.
- During past inspections, longitudinal surface cracking was observed on the downstream and upstream side of the dam typically along the interface between the select fill and rockfill. Such cracking was not observed during this inspection because it had been obscured by fill placed during the ongoing Stage IV construction. However, upstream longitudinal cracking was observed and noted along the edge of the board insulation during the Stage IV construction from about Stations 23+75 to 37+00 by Golder construction quality assurance (CQA) monitoring staff and during a weekly inspection by Teck, as shown in Photos 34, 36, and 37. A summary of historic lateral cracking that has been surveyed is shown in Figure 5. Although the cracking observed by Golder CQA staff and Teck during the inspections was not surveyed, the approximate location of the cracking is noted in Figure 5. Per design, this cracking is understood to be related to deformations from thaw consolidation of the previously frozen foundation materials below the rockfill and is not a stability concern.
- Similar to previous inspections, longitudinal cracking was observed along the downstream crest of the east abutment near Station 49+00 (Photo 24) and within the downstream rockfill about 8 feet from the crest near Station 45+00 (Photo 22). This cracking was observed during previous inspections and initially observed during the 2014 periodic safety inspection (PSI). The length and width of the cracking appeared to be similar to what has been previously observed. As described in previous reports, this cracking is not a stability concern and poses no risk to the COW.
- Water was observed in a topographic low spot downstream of the TBD, near Station 10+00, and closer to the southwest corner of the Overburden Stockpile (Photo 6). This ponded water is likely associated with watering for dust control. No other ponded water was observed at the ground surface near the downstream toe of the dam embankment during the inspection.
- Except for the survey monuments that have been decommissioned and will be reinstalled after the Stage IV dam construction is completed, dam monitoring instrumentation was observed along the embankment crest. Piezometers had been modified according to the Stage IV design so that their cables are protected in the pipe and run out perpendicular to the dam crest (Photo 30). SAA casings were being extended vertically as the embankment was raised (Photo 29). Most piezometers were connected to Navstar data loggers, but the remaining piezometers and the SAAs were disconnected and are being read manually.

- Erosion of the upstream embankment face was observed in areas where seepage pumpback was discharged onto the slope near Station 26+50 (Photo 14) and Station 34+00 (Photo 17).
- Undocumented fill was placed on the crest of the east abutment to form an access road (Photo 21).

2.1 Observations During Construction

As mention in Section 2.0 above, Golder personnel on-site for CQA monitoring of the Stage IV construction documented observations that are pertinent to this reporting effort. While these observations were not directly part of the field inspection of the dam their inclusion here provides additional valuable detail.

At the TBD crest, after removal of the insulation layer, Golder CQA monitoring staff observed and reported numerous instances of cracking, voids, and surficial ice in the select fill surface (Photos 31 to 33 and 35 to 37, Appendix A). A summary of the documented irregularities follows below:

- A small surficial void of approximately 1.5 inch diameter (Photo 32) was observed on the select fill near Station 28+75 following removal of the board insulation. After further investigation, Golder personnel measured an approximately 7-inch by 5-inch void to a depth of 3.5 inches (Photo 33) underneath the smaller surface opening. Snow and freezing temperatures were occurring onsite in 2015 when the insulation fill placement took place; therefore, the void was likely caused by snow or ice trapped between the select fill and insulation board and does not pose a concern to the performance of the TBD.
- Minor cracking near the select fill centerline (Photo 35) was observed at multiple locations under the insulation board layer at approximately 1/8-inches wide and up to 4.5-inches deep, although typically to a shallower depth. This cracking occurred underneath and at the interface between two insulation boards. These cracks are likely attributable to surficial thermal contractions of the select fill and do not impact the performance of the TBD.
- Golder observed longitudinal cracking of both the upstream and downstream select fill/rockfill interface (Photos 36 and 37) of up to 1-foot deep. The upstream cracks occurred intermittently from approximately Station 23+75 to 37+00. Per design, this cracking is understood to be related to deformations from thaw consolidation of the previously frozen foundation materials below the rockfill and is not a stability concern.
- Sporadic ice and ice veining (Photo 31) was found at a few locations (Station 6+50, 10+50, and 12+00) on the select fill surface after removal of the insulation boards. The ice did not penetrate the fill material and appeared to follow the bottom surface irregularities of the insulation board or underneath the interface between two boards that may have had a gap between them.

3.0 REVIEW OF MONITORING INSTRUMENTATION DATA

Monitoring instrumentation data related to the TBD and reviewed by Golder included data from the ShapeAccelArray (SAA) inclinometers, survey monuments, the Bons weather station, the sump pump flowmeter, VWPs, a tailings impoundment lake level survey, and temperature monitoring arrays. Monitoring data collected during the last year is summarized in the following subsections.

3.1 SAA Inclinometers

Three SAAs were installed in the existing Slope Indicator inclinometer casings in 2015 located at approximate - Stations 14+00 (Photo 4), 25+00, and 35+00 about 5 feet upstream of the COW. These instruments monitor the horizontal movement of the dam embankment, rate, and direction of horizontal movement, and temperature. While data is currently read weekly, Teck is in the process of integrating the SAAs into their NavStar data collection system (Geoexplorer) for real-time access to instrument readings. The SAAs record horizontal displacement of each vertical instrument segment with respect to the baseline survey taken immediately after installation of the instrument in the Fall of 2015. As specified in the Operations and Maintenance Manual (O&M Manual), Revision 3 (Golder 2016), the SAA data review does not incorporate the historical movements associated with the 10 to 11 preceding conventional inclinometer readings collected between October 2012 and July 2015 prior to the installation of the SAAs. Movement trigger levels for the SAA instruments include 1 inch of cumulative horizontal displacement since the initial baseline measurements and 0.2 inches per month of horizontal displacement rate. The accuracy of the SAA inclinometers is approximately 0.06 inches.

SAA data is presented in Figures 6 through 8 for instrument locations at 14+00, 25+00, and 35+00, respectively. These summary figures present data developed from raw SAA readings according to the procedure described in the O&M Manual. They include the cumulative magnitude of displacement with depth, the cumulative magnitude of displacement over time presented at the elevation in which the greatest displacement has occurred, and the direction of movement with respect to the COW centerline. A summary of the SAA data presented in the figures follows:

- **Station 14+00:** As shown in Figure 6, the SAA at Station 14+00 has recorded a maximum of approximately 0.25 inches of total displacement at an elevation of 971.5 feet since its initial survey in November 2015. Since 2015, the average annual incremental movement rate recorded has been less than 0.1 inches per year. Both the total displacement and incremental movement rates are within the acceptable limits prescribed by the O&M Manual. The cumulative direction of movement is to the northeast, in an upstream direction. Beginning in December 2018, the inclinometer began recording inconsistent readings with respect to historical data by showing an abrupt change in direction of movement. However, the magnitude of these readings is well within the accuracy of the instrument (0.06 inch) and thus does not pose a concern to the stability of the TBD embankment.
- **Station 25+00:** As shown in Figure 7, the SAA at Station 25+00 has recorded a maximum of approximately 0.7 inches of total displacement at an elevation of 985.0 feet since its initial survey in November 2015. Since 2015, the annual incremental movement rate recorded has been approximately 0.2 inches per year. Both the total displacement and incremental movement rates are within the acceptable limits prescribed by the O&M Manual. The cumulative direction of movement is to the south, in a downstream direction.
- **Station 35+00:** As shown in Figure 8, the SAA at Station 35+00 has recorded a maximum of approximately 0.55 inches of total displacement at an elevation of 985.4 feet since its initial survey in November 2015. Since 2015, the annual incremental movement rate recorded has been approximately 0.2 inches per year. Both the total displacement and incremental movement rates are within the acceptable limits prescribed by the O&M Manual. The cumulative direction of movement is to the southwest, in a downstream direction.

3.2 Survey Monuments

Eleven survey monuments are established along the crest of the TBD and are surveyed using Global Positioning System (GPS) and Real-Time Kinematic (RTK) survey techniques. The survey monuments are founded within the select fill prism of the TBD and are utilized to monitor vertical strain and horizontal movement of the dam embankment. The 11 survey monuments have been surveyed a total of 24 times since the initial baseline survey taken on August 15, 2016. The survey readings and their associated trigger levels are shown in Figure 9 and a summary follows below:

- Except for Mon-15-05, the cumulative horizontal movements of the survey monuments have remained below the trigger level of 3.0 inches, and generally less than 1.0 inch except for Mon-15-07 and Mon-15-09. Mon-15-05 has recorded relatively continuous movement since the baseline reading, crossing the trigger threshold of 3.0 inches on April 1, 2018, and continuing to increase up to over 4 inches of horizontal movement. The movement coincides with the nearby cracking observed at the select fill/rockfill interface during previous inspections and is understood to be an effect of consolidation of soft and thawed materials underneath the downstream rockfill sector of the embankment. Mon-15-07 and Mon-15-09 have recorded an increasing horizontal movement trend since the beginning of 2018 but have not exceeded the trigger level. Both monuments remain below 2.5 inches of horizontal movement.
- During late 2017 and beginning of 2018, the maximum cumulative vertical movements ranged from about 1.8 inches downward to 2.6 inches upward. However, due to each monument displaying the same significant variation in movement over just 4 consecutive surveys (November 13, 2017 to April 1, 2018), Golder infers that much of the variability in these readings is related to inconsistent equipment or lack of survey vertical control, resulting in data that cannot be related back to the baseline reading. Since Teck took measures to improve the reliability of their surveys, vertical movement has ranged from 1.2 inches downward to 1 inch upward, with most monuments well within the 1-inch vertical trigger level.

  Monuments showing the highest vertical settlements are coincident with those showing the highest horizontal movement. Mon-15-07 exceeded the vertical movement trigger level during the survey conducted on March 20, 2019, but has since returned to recording movements within the acceptable limits. Mon-15-09 also recorded vertical movements exceeding the trigger level by up to 0.2 inches on surveys conducted during April 27 and May 14, 2019, but is trending toward movements within the threshold. Snow may affect survey measurements during winter.

3.3 Air Temperature, Precipitation, Tailings Pond Elevation, and Sump Pump Data

Teck monitors the daily sump pump flow volumes at a flowmeter located near the TBD sump (Figures 2 and 4). The data is connected to Teck's "PI" system and is accessible in real-time from the mine offices. Flow rates from the sump on the downstream side of the TBD are considered as part of the evaluation of COW and TBD performance. However, the sump pump flow rate is not a direct representation of seepage across the COW, and other influences such as air temperature and precipitation that impact groundwater recharge from downstream catchments need to be considered. Golder understands that the sump pump was typically operated on a water level indicator, with pumping initiated at elevation 935.4 feet. However, over the 2017/2018 winter, ice formed on the water level indicator that prevented the sump pump from operating. To prevent this, the sump pump was reset to cycle on a timer. Teck has since repaired the system and has planned improvements to the sump pumphouse

to prevent the water level indicator from freezing again. In January 2019, Teck adjusted sump pump operation parameters to turn on and off at 20-minutes intervals rather than every 15 minutes as previously done during low flow conditions (under 775 gpm).

There are gaps in the sump flow data associated with times when the pump was frozen or down for maintenance. Spikes in the sump pump data (particularly following a data gap) are typically observed following a period of inactivity or a significant precipitation event that often quickly return to rates prior to the spike. Based on discussions with TAK personnel, sump pump rates lower than about 25 gpm (90,000 gallons per day) may not reflect a full day of operation.

Figure 10 shows the daily precipitation, sump pump volume, air temperatures, and tailings pond elevation over time since 2016. Figure 11 compares the sump pump rates and tailings pond elevation over the Julian year since 2016 and includes a chart comparing the cumulative sump pump volume and precipitation over the Julian year since 2016. Cumulative precipitation in 2018 was less than in 2017 and 2016. Cumulative sump pumping volume during the summer of 2018 was greater than the same time during 2016 and 2017, even though 2017 had a greater cumulative sump pumping volume compared to 2016 and 2018 by the end of the year. The 2019 cumulative sump pumping volume follows a similar trend as 2018 but is slightly greater. Prior to the spring freshet, 2019 daily sump pumping rates, typically under 100 gpm, are consistent with rates observed during the same period of previous years. The tailings pond level continues to rise with about a two-foot increase in elevation per year, reaching over 976 feet by the end of May 2019. Cumulative precipitation in 2019 through the end of May is approximately 5 inches greater than the same time during previous years. Average winter air temperatures during the 2018/2019 season were similar to that of the 2017/2018 season and warmer than the 2015/2016 and 2016/2017 winter seasons.

As shown in both charts in Figure 11, sump pumping rates decrease during the winter season when average air temperatures fall below freezing and groundwater recharge from precipitation declines. The lowest sump pumping rates generally occur during January through May, and pumping rates increase during the spring freshet when average air temperatures rise above 32 degrees Fahrenheit. Once the snowpack and frozen water accumulated during the winter months melts and the sump pump rates decrease from the spike, sump pump rates correlate well with rainfall events, indicating that much of the water that reaches the sump is related to precipitation within the catchment area downstream of the COW.

3.4 Vibrating Wire Piezometers

There are ten monitored VWPs installed within the TBD embankment between Stations 7+00 and 42+00. Two more VWPs were installed in 2018 on the West and East Abutments at approximate Stations 0+00 and 52+00, respectively. These instruments are connected to Teck's Navstar system and data can be viewed in real-time from the mine offices. There is another VWP installed in the Overburden Stockpile (P-12-109). Data from P-12-109 is collected in a battery-operated data logger and is downloaded annually by Teck personnel. VWP locations at the TBD and Overburden Stockpile are presented in Figure 2.

The groundwater monitoring data collected from the 12 VWPs along the TBD, the tailings pond elevation, trigger elevations identified in the O&M Manual, and the data collected from P-12-109 in the Overburden Stockpile are presented on Figure 12 and summarized below:

- Piezometers P-18-157 and P-18-158 installed on the west and east abutments, respectively, have been equalizing since initial readings in October 2018. However, the logger battery for both piezometers died around February 2019 and only P-15-158 has since been replaced and started recording again in May 2019 with elevations of around 993 feet.
- Temporarily shutting off the sump pump to accommodate construction or due to freezing conditions results in a clear response of piezometers P-15-138, -139, and -140 and to a lesser extent P-15-136 and -141 with an increase in groundwater elevation, illustrating the importance of the pump with respect to control of downstream water and gradients. Once the sump pump turns back on the piezometers tend to steadily decrease back to levels prior to the sump pump shutting off.
- Data from the two piezometers located upstream of the COW (P-15-137 and -142) correlates very well to the tailings pond elevation and have recorded water elevations over 976 feet in May 2019, indicating high permeability and free flow of water through the rockfill and select fill materials.
- The downstream TBD piezometers are influenced by the sump pump flow rate, seasonal variations in precipitation, tailings pond elevation, and air temperature. Of the downstream piezometers, the two consistently highest piezometric surfaces are at Station 7+00 and 42+00 near the abutments and furthest away from the sump. The lowest piezometric surfaces occur near the sump (Station 26+50) with the piezometer at Station 27+00 maintaining the lowest groundwater elevations, reflecting groundwater flow toward the sump. Data gaps exist where the communication system went down resulting in no information being recorded.
- The O&M Manual identifies two trigger levels related to the VWP monitoring array: exceedance of a groundwater elevation of 945 feet by P-15-138 or -139, and exceedance of a groundwater elevation of 981 feet (permitted freeboard) by P-15-137 or -142.
    - P-15-138 exceeded the trigger level elevation for two days during September and October of 2018. However, both brief spikes in water elevation occurred after the sump pump was off for 6 or more consecutive days due to power interruptions. Once the sump pump was restarted or manually operated, water elevations quickly returned to below the trigger level elevation.
    - Neither P-15-137 or -142 has exceeded the permitted freeboard elevation of 981 feet.
- Data available for P-12-109, which is located in the Overburden Stockpile, has consistently recorded water elevations above 945 feet. P-12-109 does not seem to respond to the spring freshet or pump shut down events; therefore, there may not be hydraulic conductivity between P-12-109 and the piezometers along the downstream side of the COW. The temperature reading from the instrument, which is located at an elevation of about 936 feet, indicates it is frozen. No data is recorded for P-12-109 after the end of 2018.
- Figure 13 also presents the downstream piezometric surface within the TBD superimposed on the COW profile. Data indicates that the groundwater flow gradient is towards the TBD sump.

3.5 Ground Temperature Monitoring

Subsurface temperatures on the TBD are collected at 11 ground temperature monitoring arrays (manufactured by Beaded Stream [7], Geokon [1], and Measurand [3]). Locations of the ground temperature monitoring arrays are presented in Figure 2. Appendix C presents select ground temperature monitoring data since 2017 at each of the arrays located along the TBD alignment and includes select data from 7 additional ground temperature monitoring arrays located in the Overburden Stockpile. For reference, the bottom elevation of the COW is shown on the array data along the TBD alignment when it is within the elevation range presented.

3.5.1 Ground Temperatures Data Along Dam Alignment

Figure 12 shows the interpolated permafrost table at each of the ground temperature monitoring arrays within the TBD along the COW profile. This profile view shows that the highest permafrost table elevation occurs downstream near Station 37+00 and is within the native overburden materials. The permafrost surface is below the ground temperature array at Station 17+00 and appears to be near the bottom of the ground temperature array at Station 12+00 where the bottom two nodes are slightly above 32 degrees Fahrenheit. Considering the accuracy of the Beaded Stream digital temperature cables are about plus or minus 0.2 degrees Fahrenheit, the permafrost elevation at Station 12+00 may be about 845 feet. The recent ground temperature monitoring data at Station 17+00 shown in Figure C-4, Appendix C indicates warming near the bottom of the COW, which may be indicative of higher seepage at that location.

On the upstream side of the COW, only one of the three SAAs (Station 35+00) indicates permafrost within the monitoring depth. Permafrost at this location lies above the bedrock surface and into native materials. Below the depth of seasonal frost penetration, the SAAs at Station 14+00 and 25+00 have not recorded any temperatures below 32 degrees Fahrenheit. The seasonal frost penetration at SAAs 14+00, 25+00, and 35+00 were noted to reach elevations of approximately 6 to 7 feet below the top of the COW (elevation 986 feet). However, the temperatures recorded in the SAAs are not representative of temperatures within the COW, since they are subject to thermal disturbance through the SAA casing, which is uninsulated and penetrates the insulation layer.

3.5.2 Ground Temperature Data at Overburden Stockpile

The approximate permafrost elevation within the Overburden Stockpile is shown on Figure 2 based on a review of the available ground temperature monitoring data summarized in Appendix C. Permafrost appears to be lower than the depth of the temperature acquisition casing at G17-03, which is located near a historic drainage and may represent a thaw bulb in the area. It should be noted that standpipe piezometers exist at both G17-03 and G17-04 but groundwater levels have not been recently recorded. On the east side of the Overburden Stockpile at G17-04, the permafrost elevation is about 942 feet. For the majority of the ground temperature monitoring instruments, which are near the low area of the original ground topography, the permafrost elevation ranges from about 948 feet to 983 feet. Comparing this permafrost surface to the groundwater levels and gradients along the downstream of the COW, the permafrost surface within the Overburden Stockpile continues to provide a secondary seepage barrier upstream of the original topographic divide.

The irregular data with depth (higher temperature spikes) from the three 96 series ground temperature arrays (T-96-21 to T-96-23) shown in Appendix C are indicative of failing nodes, and these three instruments were recommended to be replaced in 2015 (SRK 2015). Recent readings collected in June 2019 at the 12 series

ground temperature arrays (T-12-106 to T-12-108) suggest warming of the permafrost; however, this hypothesis should be confirmed through additional readings. Only two ground temperature readings have been collected at G17-03, OS-18-11, and G17-04.

4.0 REVIEW OF INSPECTIONS AND INSTRUMENTATION ASSESSMENTS

As required by the O&M Manual, Teck completes daily, weekly, and quarterly field inspections and monthly monitoring data reviews of the TBD. Teck additionally provides monthly reports to Golder that include the weekly and quarterly field inspections as well as the monthly data reviews. Golder reviewed these inspection forms and monitoring reports as part of the 2019 APR of the TBD.

4.1 Daily, Weekly, and Quarterly Inspections

The inspection reports provided for review included a total of 489 Daily Dam Inspection reports from January 1, 2018 through June 24, 2019 (540 day period) and 74 Visual Tailings Back Dam Inspection reports (weekly and quarterly inspections) from January 4, 2018 through June 17, 2019 (76 week period). The visual inspection reports provide a means to monitor and record the weather conditions, snow cover, wave action, ponded water condition, and apparent stability of the embankment, including signs of cracks, slumps, and seepage.

Our review initially focused on the weekly and quarterly reports, with review of the daily reports occurring when significant observations were noted in the weekly and quarterly reports. Based on our review the daily, weekly, and quarterly visual inspections have generally been performed as required by the O&M Manual for the TBD.

Notable occurrences found in the weekly and quarterly visual inspections are summarized below but they were not identified in the daily reports. This discrepancy is due to a cursory daily inspection compared to the more detailed weekly and quarterly inspection.

- The weekly inspection of May 21, 2018 described cracks along the shoulder of the crest.
- During the quarterly inspection on June 8-10, 2018, cracks between the seepage pump house and piezometer P-15-140 were noted as increasing. The quarterly inspection also recorded wave action eroding the east end of the causeway slope.
- On July 11, 2018 during a weekly inspection cracking near the sump pump was observed. This was noticed during the 2018 annual inspection conducted on June 25 and 26, 2018.
- The quarterly inspection on September 26, 2018 described a new slight longitudinal crack at approximately station 36+00 and noted the previously observed significant longitudinal cracking along the downstream crest of the embankment from the seepage pumphouse towards DD2.
- During the weekly inspection on October 26, 2018 the inspector surveyed a crack around Station 16+00.
- Weekly inspections conducted on May 19, May 26, June 3, and June 9 2019 noted varying cracking along the TBD including the reopening of cracks in areas west of the seepage pumphouse (identified as normal), cracks from the previous year, and new cracks at Station 24+00 and 28+00 upstream at approximately 1 foot deep and up to 3 inches wide.

Most of the cracks observed in 2018 were surveyed at the locations shown in Figure 5; however, those observed in September 2018 and those in 2019 were not.

4.2 Instrumentation Assessments

Starting in February 2018, Teck has implemented a Periodic Instrumentation Assessment program where monitoring data is reviewed according to the procedures prescribed in the O&M Manual. The reviews occur monthly, with data given in line with the monitoring frequencies in the O&M Manual and include weekly and quarterly inspection sheet scans. Teck submits these reports to Golder soon after they are compiled, usually within two weeks after the month end. These reports have been useful in initiating conversation between Teck and Golder related to monitoring data in exceedance of trigger levels and unusual observations made by Teck. The following bullets present each Periodic Instrumentation Assessment provided to Golder and their respective dates since July 2018. Noted observations by Golder from these monthly reviews have been incorporated within this 2019 APR.

- July 2018 Periodic Instrumentation Assessment – Dated August 2, 2018
- August 2018 Periodic Instrumentation Assessment – Dated September 12, 2018
- September 2018 Periodic Instrumentation Assessment – Dated October 6, 2018
- October 2018 Periodic Instrumentation Assessment – Dated November 1, 2018
- November 2018 Periodic Instrumentation Assessment – Dated December 7, 2018
- December 2018 Periodic Instrumentation Assessment – Dated December 31, 2018
- January 2019 Periodic Instrumentation Assessment – Dated January 31, 2019
- February 2019 Periodic Instrumentation Assessment – Dated March 1, 2019
- March 2019 Periodic Instrumentation Assessment – Dated April 1, 2019
- April 2019 Periodic Instrumentation Assessment – Dated May 2, 2019
- May 2019 Periodic Instrumentation Assessment – Dated June 7, 2019

5.0 CONCLUSIONS

Based on the field inspection and review of available monitoring data the TBD and its appurtenant components appear to be maintained in a satisfactory condition and is performing as designed. A summary of conclusions regarding the safety of the dam and its performance:

- During the field inspection, the TBD and its appurtenant components appeared to be in satisfactory condition with no indications of unanticipated instability. Teck should continue to pay close attention to monitoring data and changing conditions in accordance to the O&M Manual.

- Historic longitudinal cracking between Stations 20+00 and 27+00 near the interface of the select fill and rockfill materials was not visible during inspection due to the Stage IV embankment raise construction. However, Teck and Golder CQA personnel observed and documented longitudinal cracking at the select fill and mineralized rockfill interface from Station 23+75 to 37+00, which is within the area where ice-rich materials were encountered during historic investigations (see Figure 2). Per design, this cracking is understood to be related to consolidation of thawed foundation materials below the rockfill and is not considered to be a concern for the performance of the COW or the stability of the embankment. Movement monitoring data in this area via SAA inclinometers and survey monuments also reflect these observed deformations, but the movements are within the design tolerance and have not hindered the performance of the COW.
- Erosion was observed on the upstream embankment slope face at two seepage pumpback discharge locations near Station 26+50 and Station 34+00 that require repair. Undocumented fill was also observed at the east abutment that will need to be removed prior to additional fill placement.
- Recent SAA readings indicate a maximum resultant magnitude of movement ranging from 0.2 to 0.7 inches. None of the three SAAs have shown an increased rate of movement since their installation in 2015 and all have an annual incremental movement rate of 0.2 inches or less, indicating the dam is performing as designed with respect to movement of the select fill core and COW.
- The survey monument at Station 21+10 downstream of the COW (Mon-15-05) continues to record significantly more horizontal displacement than the other monuments, recently reaching a maximum of 4.1 inches. This is in excess of the trigger level threshold of 3.0 inches set in the O&M Manual. Although these survey monuments are founded in the select fill prism, they do cross the select fill/rockfill boundary, so they register movement that is occurring at this interface. None of the other survey monuments have exceeded the horizontal movement threshold. Downstream Mon-15-07 and Mon-15-09 at Station 27+90 and 34+70, respectively, have displayed continuously increasing horizontal movement trends since Fall 2017 that are likely related to thaw consolidation of the foundation soils below the rockfill. From the November 13, 2017 survey to April 1, 2018, vertical movement varied from 2.6 inches to -1.8 inches. It is suspected that the survey equipment or survey rod height varied for these surveys, resulting in inconsistent data. No dominant direction of movement appears for any monument with respect to the vertical direction after the April 1, 2018 survey, with movement varying from -1.2 inches up to 1.0 inches.
- Golder recently completed a numerical modeling effort (Golder 2018) evaluating the response of the TBD, including the COW, to the thawing of massive ice underneath the rockfill and adjacent to the select fill core. The modeling effort predicted a maximum of about 1.0 feet of displacement at the COW (modeled at Station 35+00). Similar to what has been observed in the field, the thawing ice and subsequent settlement within the model primarily affected the downstream rockfill zone of the embankment, with less movement translating to the select fill core. The modeling effort was based on simplifying assumptions related to the thickness of the thawing ice layer at the sections analyzed, and should not be viewed as a precise estimate of how much settlement can occur, or will translate to the COW. However, the modeling results do provide confirmation of how we understand the TBD will respond to thaw settlements, and an approximation of the magnitude of deformations that could occur.

  Comparison of the numerical modeling results with the field and monitoring observations, the TBD is responding as anticipated to thaw settlements occurring downstream of the embankment between

approximately Stations 20+00 and 27+00 and near Station 35+00. The SAA at Station 25+00 is recording deformations but remains below the trigger level of 1.0 inches set in the O&M Manual. Exceedance of the trigger level could potentially occur without critically damaging the COW or TBD, as up to 1.0 feet of deformation was predicted in the numerical modeling effort.

- The minimum sump pump flow rate before the spring freshet was observed to be similar to that of 2016 and greater than that during 2018, but still under 80 gpm. The minimum flow rate is typically used to evaluate the performance of the COW and TBD system, although groundwater recharge and precipitation also influence the sump pump flow rates. In 2018 Teck set the sump pump on a 15-minute interval timer to turn on and off during low flow conditions and subsequently switched the timer interval to 20 minutes in January 2019, likely contributing to an increase in daily sump pump rate because it allowed more time for groundwater recharge near the sump. The cross-wall gradient through the pre-spring freshet time period was similar to previous years and the minimum sump pump rate was about 71 gpm, indicating the COW and TBD are performing as designed and limiting seepage from the tailings pond.
- Groundwater monitoring data from the array of VWPs show that the two upstream piezometers at Station 12+00 and 32+00 follow the tailings pond elevation very closely. The downstream piezometers are hydrologically disconnected from the tailings pond by the COW, but show some similar behaviors, including a rapid water level rise during the spring freshet. Groundwater levels are highest near the abutments and lowest at Station 27+00 closest to the sump pump. The lowest head drop across the COW between January 1, 2018 and May 31, 2019 was 1.5 feet at Station 7+00 near the right abutment, while the highest is 40.7 feet at Station 27+00. The gradient across the embankment piezometers shows flow toward the sump pump over the entire data range. The higher piezometer rise during the 2019 spring freshet as compared to the 2018 spring freshet is likely related to the increase in precipitation in 2019 (see Figure 11). Piezometer P-12-109, located downstream of the TBD in the Overburden Stockpile, appears to be frozen and the data is unreliable for evaluation.
- Based on the temperature monitoring data collected at the TBD, there is no clear permafrost degradation or subsurface thermal disturbance occurring along the COW alignment. An increase in ground temperatures near the bottom of the COW at Station 17+00 could be indicative of higher seepage at that location. Except for the seasonal active layer, the TBD embankment fill materials remain unfrozen. Ground temperatures recorded in the SAAs indicated seasonal frost that extends 6 to 7 feet below the top of the COW (elevation 986 feet) but these are not representative of temperatures within the COW, since they are subject to thermal disturbance through the SAA casing, which is uninsulated and penetrates the insulation layer.
- Temperature monitoring at the Overburden Stockpile suggests the permafrost continues to act as a secondary seepage barrier upstream of the original topographic divide. Recent readings collected in June 2019 at the 12 series ground temperature arrays (T-12-106 to T-12-108) suggest warming of the permafrost; however, this hypothesis should be confirmed through additional readings. The irregular readings at the three 96 series ground temperature arrays (T-96-21 to T-96-23) suggest their data is questionable. The permafrost elevation at G17-03 is lower than the temperature acquisition casing, which may be related to a thaw bulb surrounding the historic drainage. Groundwater levels have not been recently collected from the standpipe piezometers at G17-03 and G17-04.
- Based on review of the daily, weekly, and quarterly inspection reports, and monthly monitoring data assessments, Teck is generally performing inspections in accordance with the O&M Manual. Some notable

observations concerning cracking in the weekly and quarterly reports were not captured in the daily reports that is related to the cursory daily inspections compared to the more detailed weekly and quarterly inspections.

6.0 RECOMMENDATIONS

The following recommendations were developed during preparation of this APR including the field inspection and our review of monitoring data. Recommendations that were also provided by Klohn Crippen Berger (KCB 2018) are designated with the appropriate KCB number (PSI-R-XX).

- Continue to conduct timely monitoring data review in accordance with the monitoring frequencies prescribed in the O&M Manual. The Periodic Monitoring Assessments provide useful dialog between Teck and Golder and ensure that any potential issues or data collection errors are quickly addressed.
- Continue to monitor for cracking along the dam crest and watch for correlations with monitoring data collected in nearby SAAs and survey monuments. Consider revision of daily inspection forms in regard to observed cracking during the next O&M Manual revision to reduce possible discrepancies between the daily and weekly/quarterly reporting. Collect a survey of any new cracking observed.
- Reconnect the cables for the SAAs and VWPs to the data loggers once Stage IV construction is completed or as soon as is practical.
- Insulate the cap and outside of the SAA casings that extend above the board insulation and use expansive foam to provide an insulative seal and connection to the board insulation. This will help prevent the possible intrusion of seasonal frost through the casing and into the ground. Insulation of the SAA casings can be performed once the COW has been raised to an elevation of 996 feet.
- Make the following improvements to the instrumentation in and near the Overburden Stockpile to monitor its performance as a secondary seepage barrier for the system:
  - Replace the three 96 series ground temperature arrays (T-96-21 to T-96-23), which range in length from 105 to 115 feet, with three of the Beaded Stream temperature monitoring arrays that were used along the TBD alignment.
  - Install VWPs within the standpipe piezometers at G17-03 and G17-04 to monitor groundwater levels.
  - Install two of the Beaded Stream temperature monitoring arrays that were used along the TBD alignment at OS-18-11 and at G17-04.
  - Replace the frozen VWP at P-12-109 with another that is installed with the instrument above the permafrost surface.
  - Drill and install a new ground temperature array between OS-18-11 and G17-03.
  - Connect the VWPs and if possible the temperature monitoring arrays into the NavStar data collection system, and incorporate them into the O&M Manual scheduled to be updated in 2019.

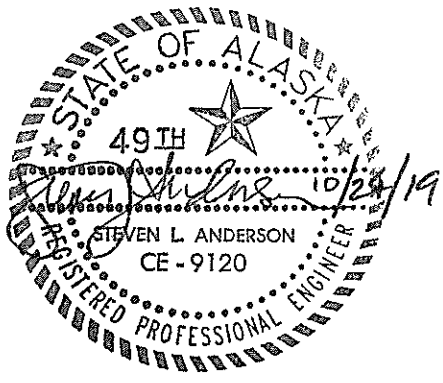
- Repair the erosion observed at the two discharge locations near Station 26+50 and Station 34+00 and extend the discharge pipes into the impoundment or provide rip rap to prevent erosion from occurring in the future.
- Remove the undocumented fill at the east abutment prior to fill placement associated with the Stage IV raise construction.
- Upgrade the sump pumphouse to prevent freezing of the sump pump / pumpback system.
- Install two additional SAA inclinometers, one upstream and one downstream of the COW, where cracks have been observed in the TBD crest (such as near survey monument Mon-15-05) to better characterize movements and compare with the numerical model (PSI-R-04, -10). Installation of these two additional SAA inclinometers is currently planned likely in the vicinity of Station 22+00 following completion of Stage VI raise construction.
- Evaluate the permeability of COW materials following degradation due to freeze-thaw cycling. This testing will guide the design of the insulation layer at closure (PSI-R-17). This testing is currently planned and may be completed during 2020.

8.0 CLOSING

The work program followed the standard of care expected of professionals undertaking similar work in the State of Alaska under similar conditions. No warranty expressed or implied is made. Please contact us if you have any questions or comments regarding this report.

Sincerely,

Golder Associates Inc.



Matthew S. Gillaspy, EIT
Project Engineer

Steven L. Anderson, PE
Associate and Senior Consultant

MSG/SLA/TGK/msg

Attachments: Figure 1 – Project Location
Figure 2 – Plan View of Tailings Back Dam
Figure 3 – Cut-off Wall Profile – Station 0+00 to 26+00
Figure 4 – Cut-off Wall Profile – Station 26+00 to 49+52
Figure 5 – Historic Cracking Along Dam Alignment
Figure 6 – SAA Inclinometer Sta 14+00
Figure 7 – SAA Inclinometer Sta 25+00
Figure 8 – SAA Inclinometer Sta 35+00
Figure 9 – Survey Monument Movement Monitoring
Figure 10 – Air Temperature, Precipitation, Tailings Pond Elevation, and Sump Pump Data with Time (2016-2019)
Figure 11 – Sump Pump and Tailings Pond Elevation Data
Figure 12 – Groundwater Monitoring
Figure 13 – Ground Temperature Monitoring

Appendix A – 2019 Site Inspection Photographs
Appendix B – ADNR Inspection Form
Appendix C – Ground Temperature Monitoring Data

https://golderassociates.sharepoint.com/sites/101201/deliverables/3.0 issued/18113464-004-l-tbd apr/rev 1/18113464-004-l-rev1-3000-tbd-20191024.docx

9.0 REFERENCES

Golder (Golder Associates Inc.). 2016. Operations and Maintenance Manual Revision 3, Tailings Back Dam, Red Dog Mine, Alaska, report prepared for Teck Alaska Incorporated, dated October 16. (Project Number 1545935). Anchorage, AK: Golder.

Golder. 2018. Static and Seismic Deformation Analysis of the Tailings Back Dam, report prepared for Teck Alaska Incorporated, dated March 28. (Project Number 1664603). Anchorage, AK: Golder.

KCB (Klohn Crippen Berger, Ltd.). 2018. Red Dog 2017 Inspections, Tailings Back Dam Facility, Periodic Safety Inspection Report, Red Dog Tailings Back Dam, prepared for Teck Alaska Incorporated, dated January 24. (Project Number M09811A05.730). Vancouver, BC, CA: KCB.

SRK (SRK Consulting (US), Inc.). 2015. Red Dog Mine Overburden Dump-Data Review and Instrument Function, technical memorandum prepared for WHPacific, dated August 4. (Project Number 400300.020). Anchorage, AK: SRK.

Figures

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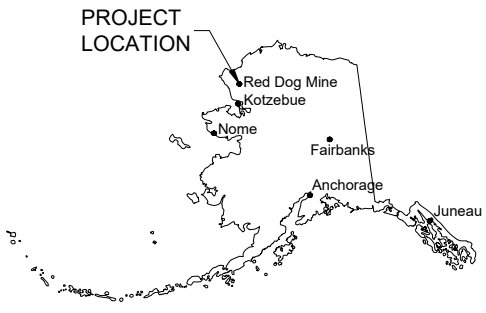

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CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	SLA

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS BACK DAM
RED DOG MINE, ALASKA

TITLE
PROJECT LOCATION

PROJECT No.	PHASE	Rev.	FIGURE
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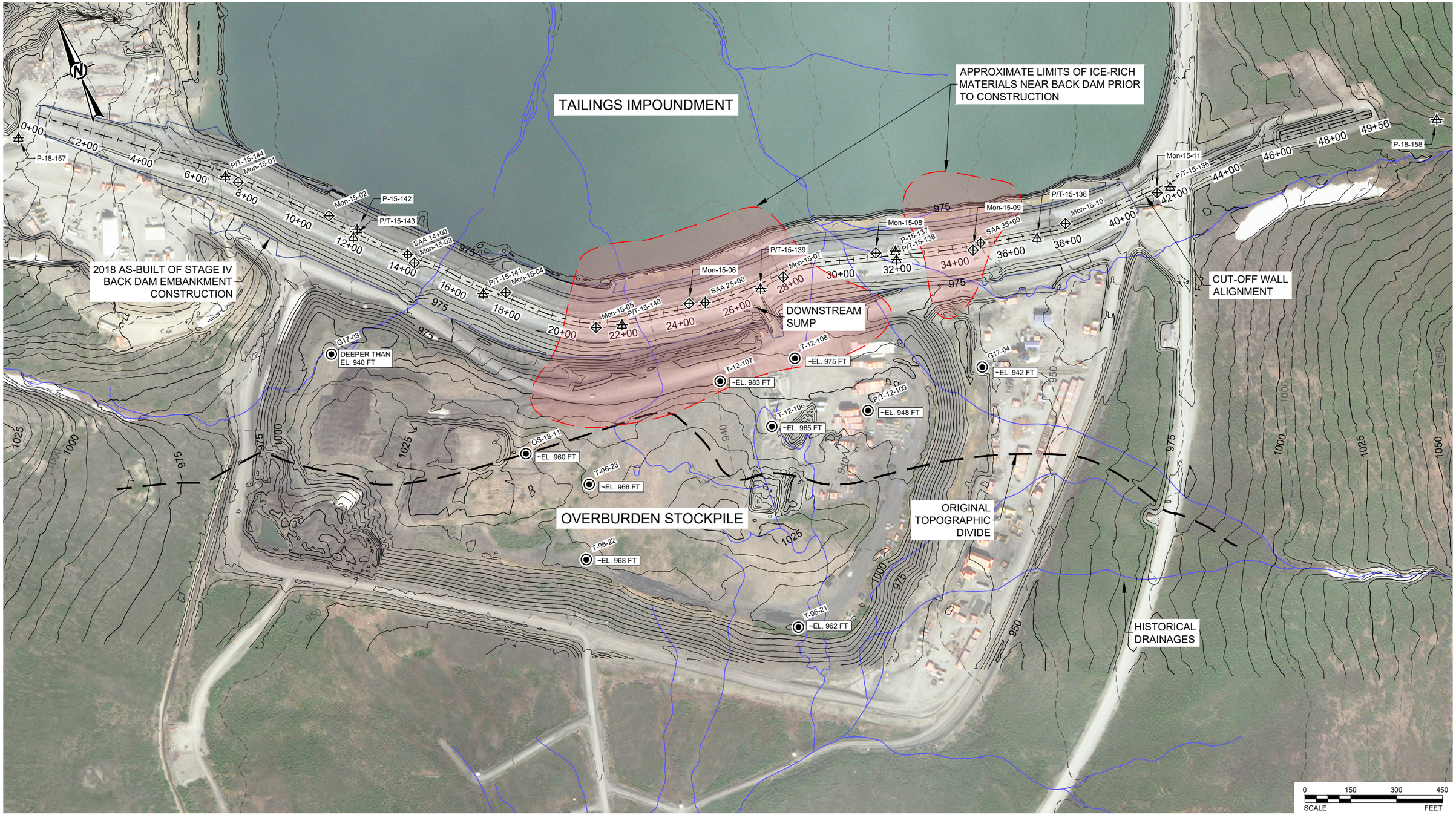

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1000	ORIGINAL TOPOGRAPHY (10 AND 50 F00T CONTOURS)
Mon-15-01	SETTLEMENT MONUMENT
T-96-22 ~EL. 968 FT	TAC AND/OR PIEZOMETER LOCATION AT OVERBURDEN STOCKPILE AND ESTIMATED PERMAFROST ELEVATION
SAA 14+00	SAA INCLINOMETER
P/T-15-135	PIEZOMETER (P) AND/OR TEMPERATURE ACQUISITION CABLE [TAC] (T) AT TAILINGS BACK DAM

REFERENCES

1. EXISTING TOPOGRAPHY PROVIDED BY TAK, FILENAME: 2018 As-built Topo Surface-EG.dwg
2. ORIGINAL TOPOGRAPHY AND HISTORICAL DRAINAGES SHOWN FROM 1984 TOPOGRAPHIC CONTOURS PROVIDED BY TAK.
3. AERIAL IMAGERY ACQUIRED BY PHOTOSAT INFORMATION LTD ON JUNE 13, 2019; FILENAMES: red_dog_wo4032a_wv2_2019jun13_mine_grid_east.tif AND red_dog_wo4032a_wv2_2019jun13_mine_grid_west.tif

CLIENT
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CONSULTANT
GOLDER

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DESIGNED	N/A
PREPARED	BAH
REVIEWED	SLA
APPROVED	SLA

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS BACK DAM
RED DOG MINE, ALASKA

TITLE
PLAN VIEW OF TAILINGS BACK DAM

PROJECT NO.	PHASE	REV.	FIGURE
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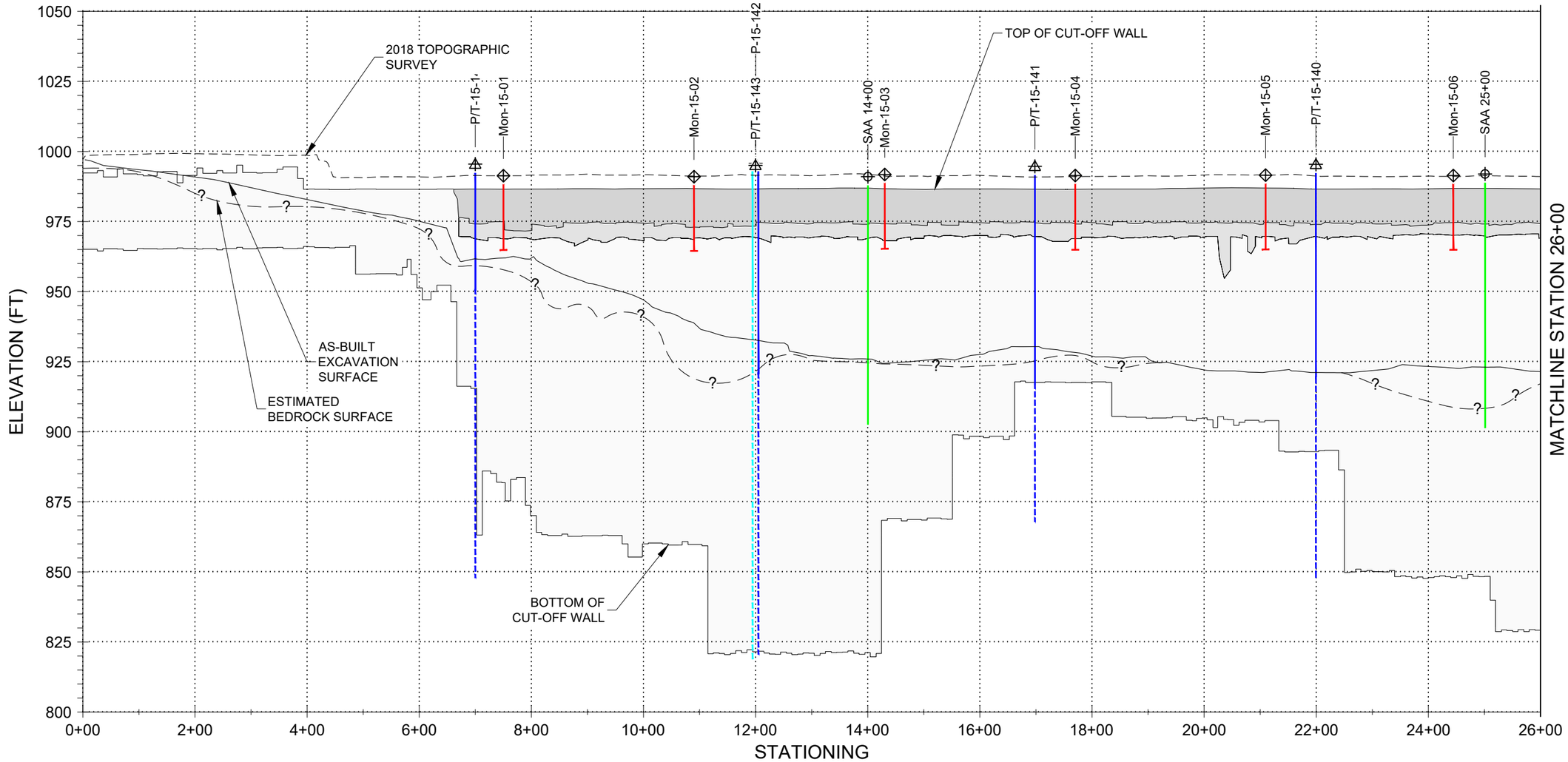

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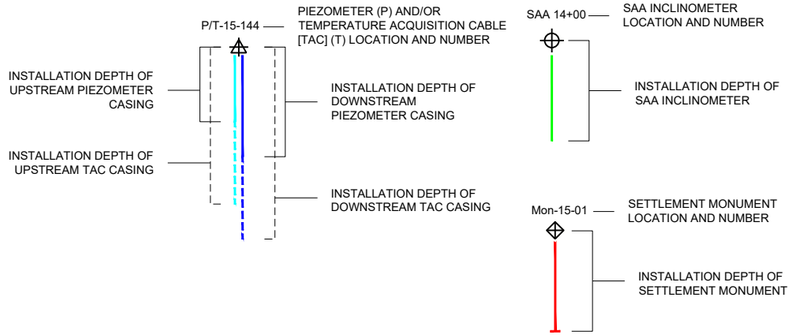
- STAGE II CUT-OFF WALL RAISE (CONSTRUCTED 2013)
- STAGE III CUT-OFF WALL RAISE (CONSTRUCTED 2015)
- AS-BUILT EXCAVATION SURFACE
- ESTIMATED BEDROCK SURFACE
- 2018 TOPOGRAPHIC SURVEY



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HORIZONTAL SCALE FEET

0 20 40 60
VERTICAL SCALE FEET

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
DESIGNED	N/A
PREPARED	BAH
REVIEWED	SLA
APPROVED	SLA

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS BACK DAM
RED DOG MINE, ALASKA

TITLE
CUT-OFF WALL PROFILE
STATION 0+00 TO 26+00

PROJECT NO.	PHASE	REV.	FIGURE
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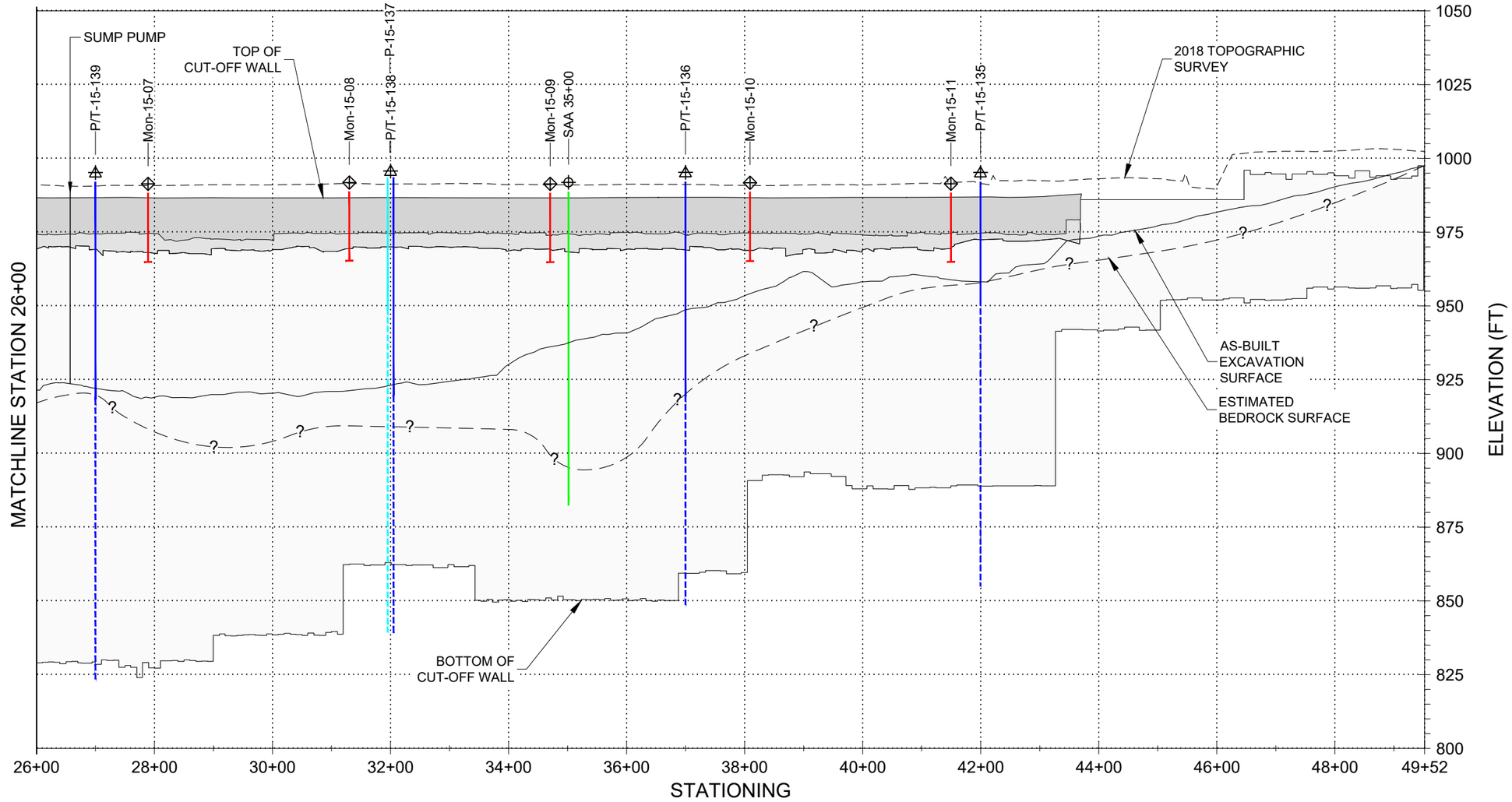

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- STAGE I CUT-OFF WALL (CONSTRUCTED 2007-2010)
- STAGE II CUT-OFF WALL RAISE (CONSTRUCTED 2013)
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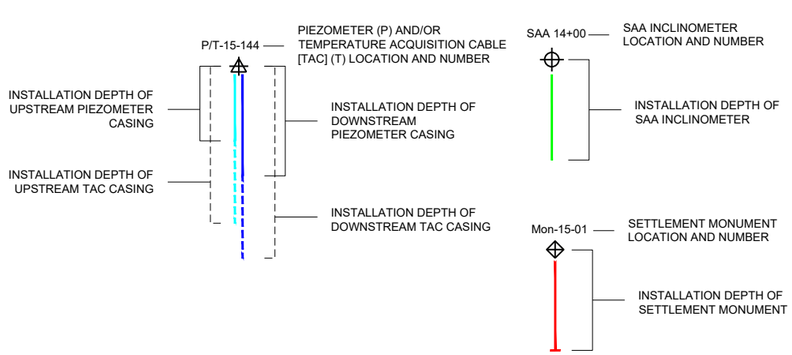
- AS-BUILT EXCAVATION SURFACE
- ESTIMATED BEDROCK SURFACE
- 2018 TOPOGRAPHIC SURVEY



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CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
DESIGNED	N/A
PREPARED	BAH
REVIEWED	SLA
APPROVED	SLA

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS BACK DAM
RED DOG MINE, ALASKA

TITLE
CUT-OFF WALL PROFILE
STATION 26+00 TO 49+52

PROJECT NO.	PHASE	REV.	FIGURE
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LEGEND

- CRACK OBSERVED IN 2019 BUT NOT SURVEYED (SEE NOTE 2)
- CRACK SURVEYED IN 2018
- CRACK SURVEYED IN 2015
- CRACK SURVEYED IN 2013

REFERENCES

1. AERIAL IMAGERY BY PHOTOSAT INFORMATION LTD. DATED 06-13-2019.
2. OBSERVED 2019 CRACKING LOCATIONS AND LENGTH BASED ON REVIEW OF ASSOCIATED PHOTOS AND WRITTEN RECORDS DATED JUNE 9 AND 10, 2019 THAT NOTED CRACKING WAS INTERMITTENT AND NOT CONTINUOUS BETWEEN THE STATIONING INDICATED.
3. SURVEY MONUMENTS HAVE BEEN DEMOLISHED AS PART OF THE STAGE IV RAISE CONSTRUCTION AND WILL BE REESTABLISHED AFTER CONSTRUCTION IS COMPLETED .

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
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CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
DESIGNED	N/A
PREPARED	BAH
REVIEWED	SLA
APPROVED	SLA

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS BACK DAM
RED DOG MINE, ALASKA

TITLE
HISTORIC CRACKING ALONG DAM ALIGNMENT

PROJECT NO.	PHASE	REV.	FIGURE
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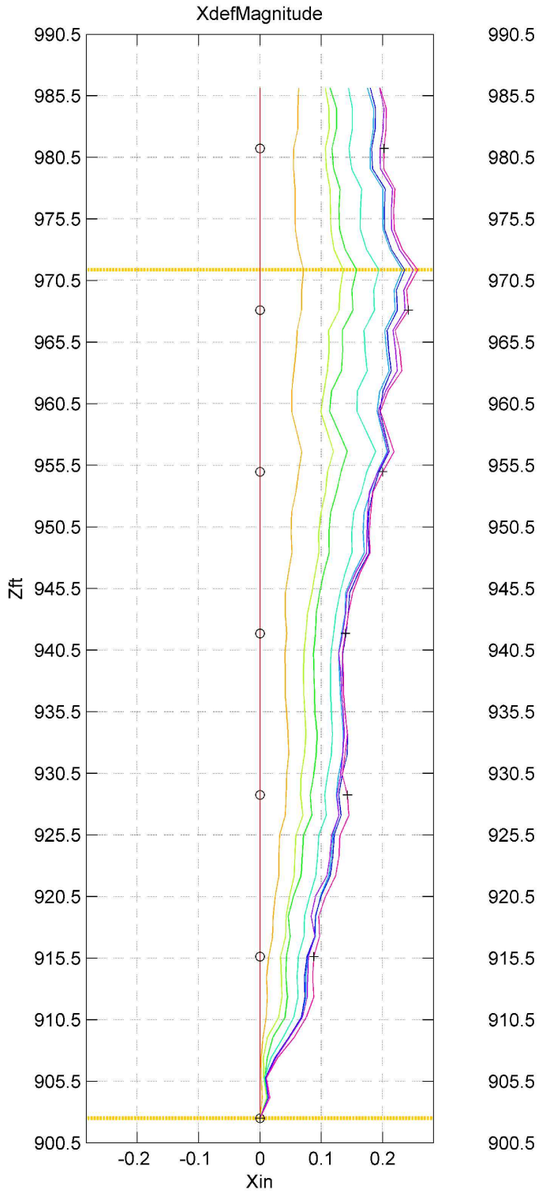

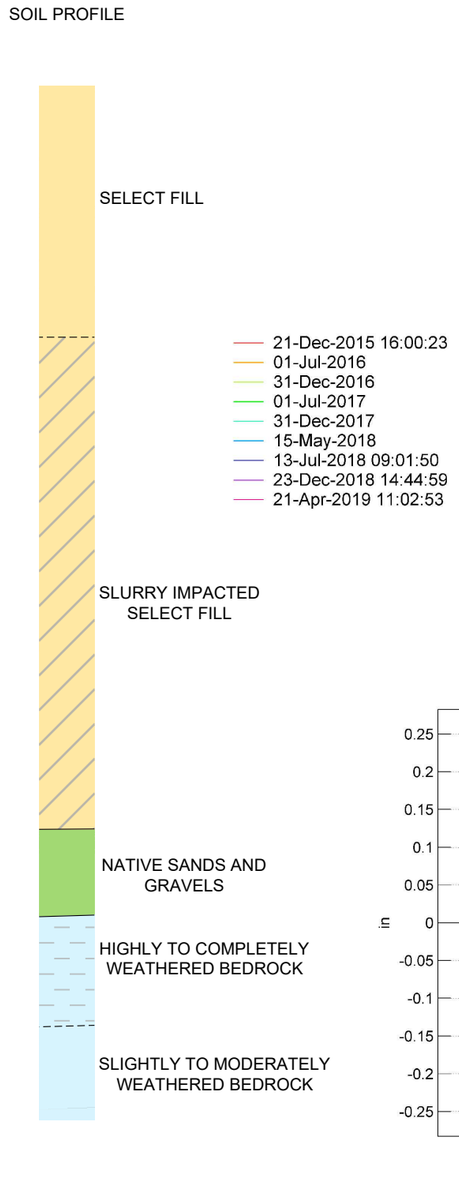

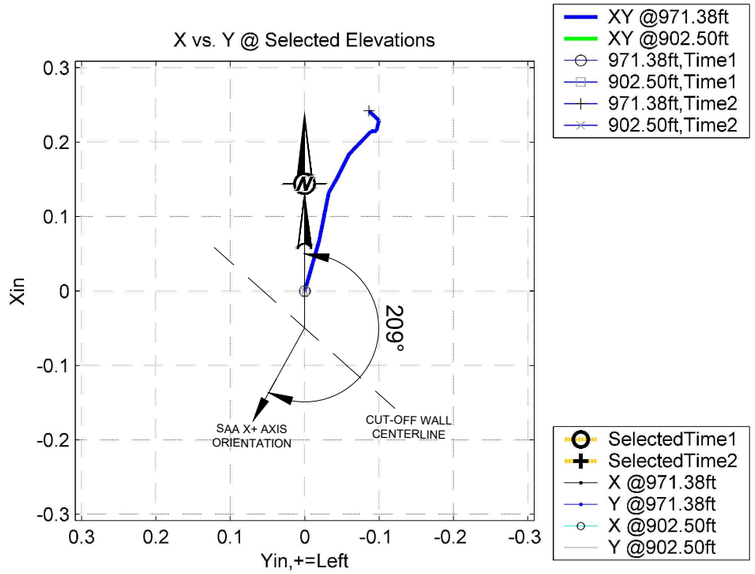

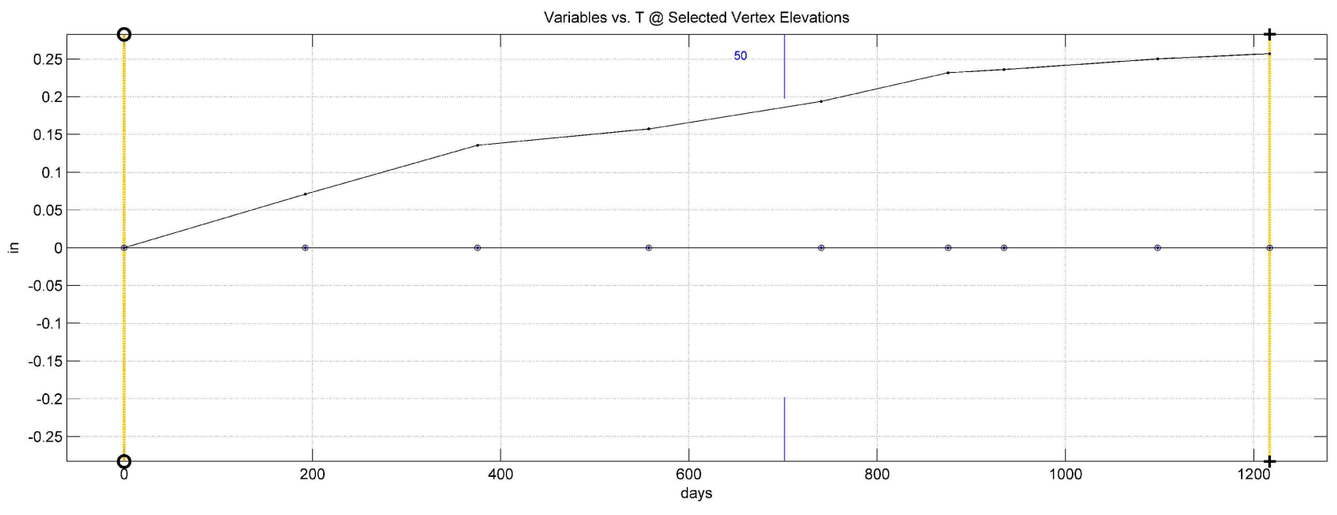

CUMULATIVE SAA INCLINOMETER DATA COLLECTED FROM NOVEMBER 2015 BASELINE

NOTE(S)

1. DISPLACEMENT PLOTTED VERSUS TIME AT LOCATION OF MAXIMUM DISPLACEMENT WITHIN VERTICAL ARRAY.

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	SLA

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS BACK DAM
RED DOG MINE, ALASKA

TITLE
SAA INCLINOMETER STA 14+00

PROJECT No.	PHASE	Rev.	FIGURE
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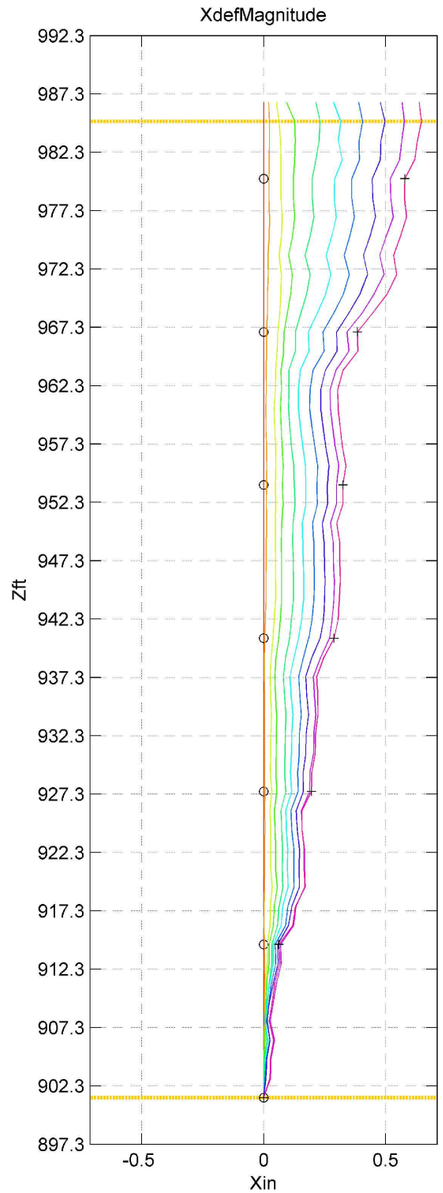

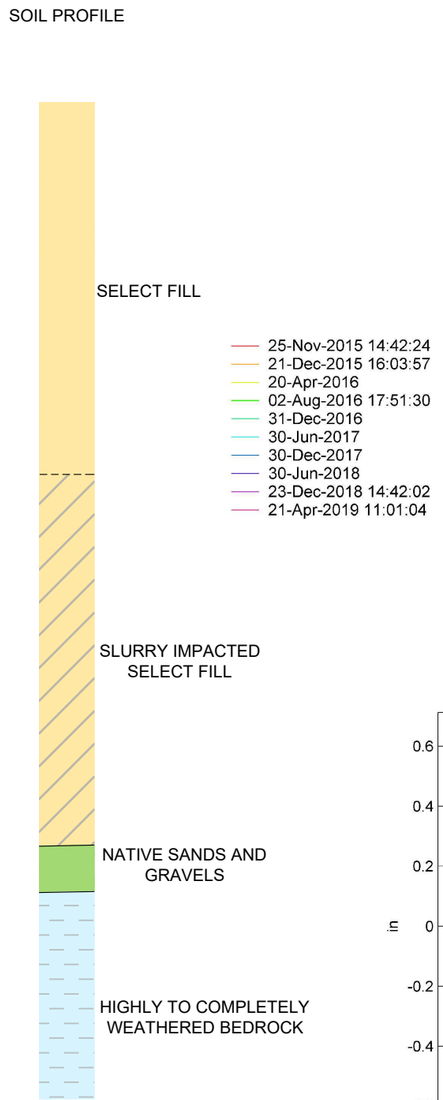

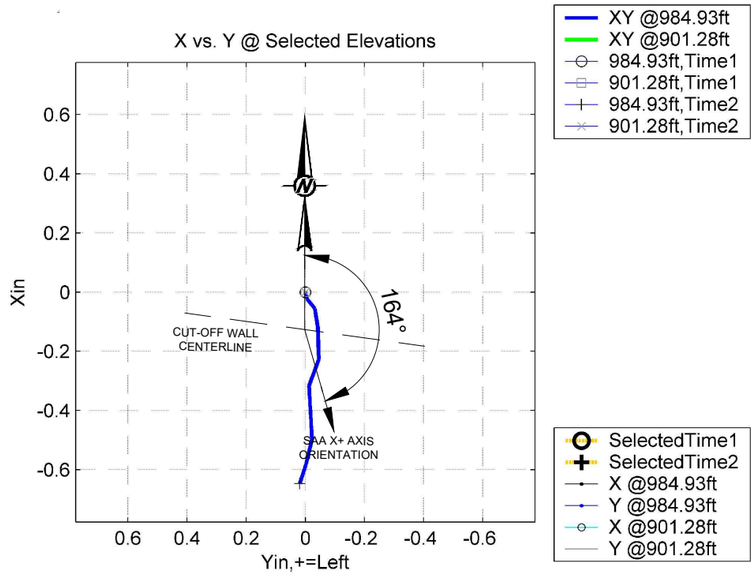

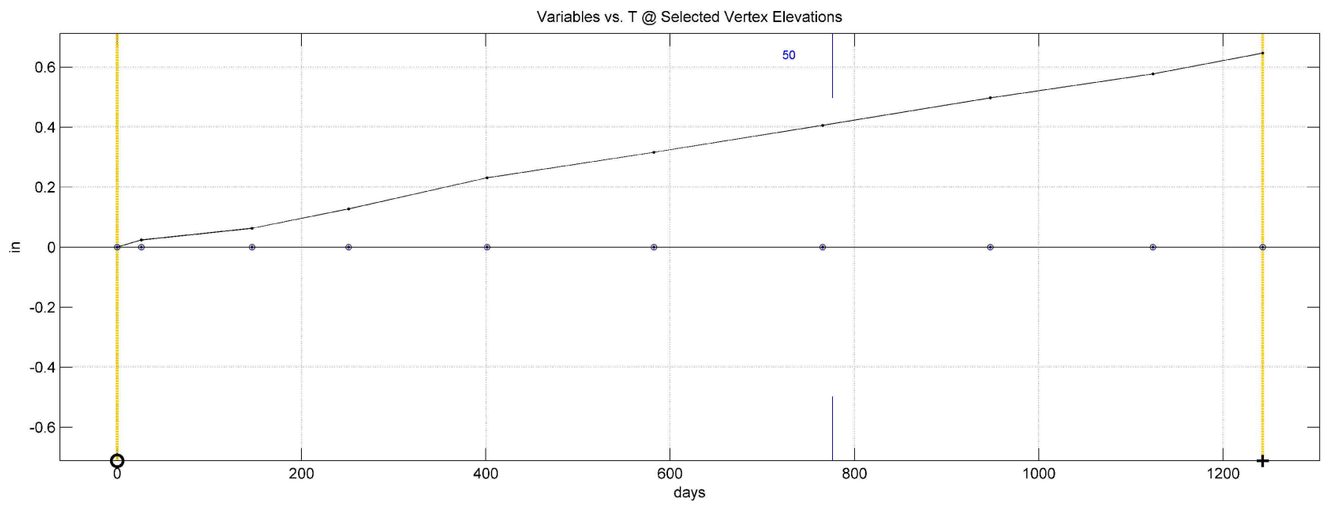

CUMULATIVE SAA INCLINOMETER DATA COLLECTED FROM NOVEMBER 2015 BASELINE

NOTE(S)

1. DISPLACEMENT PLOTTED VERSUS TIME AT LOCATION OF MAXIMUM DISPLACEMENT WITHIN VERTICAL ARRAY.

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	SLA

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS BACK DAM
RED DOG MINE, ALASKA

TITLE
SAA INCLINOMETER STA 25+00

PROJECT No.	PHASE	Rev.	FIGURE
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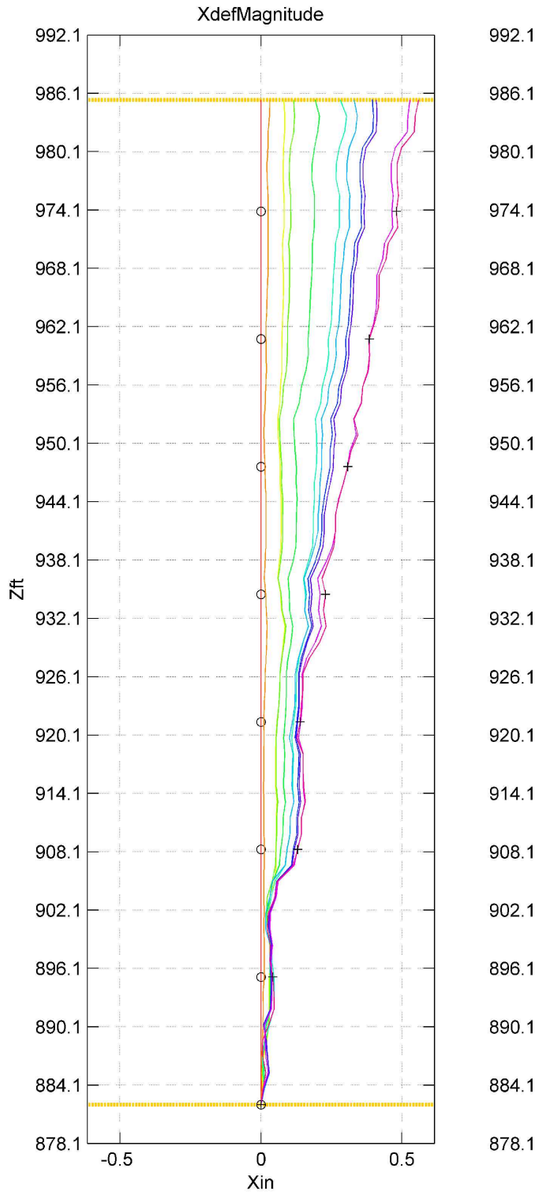
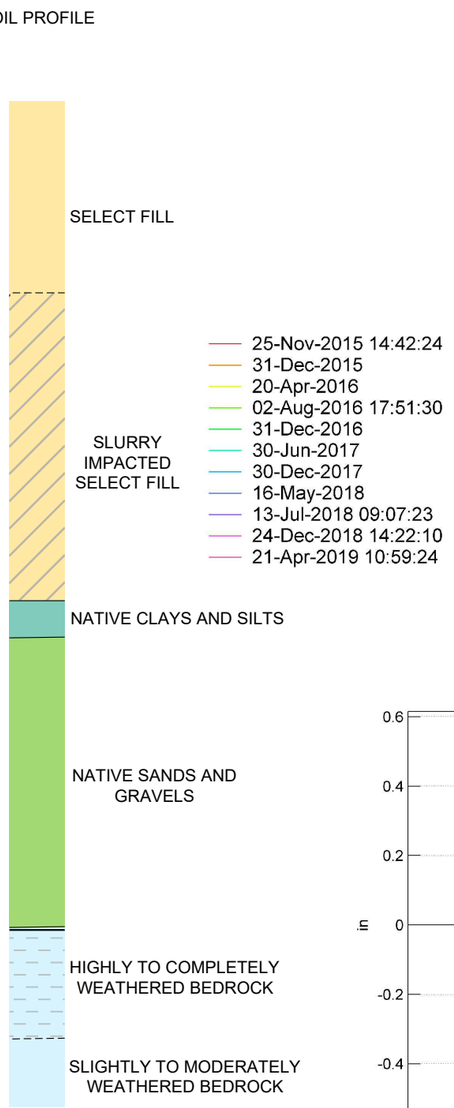
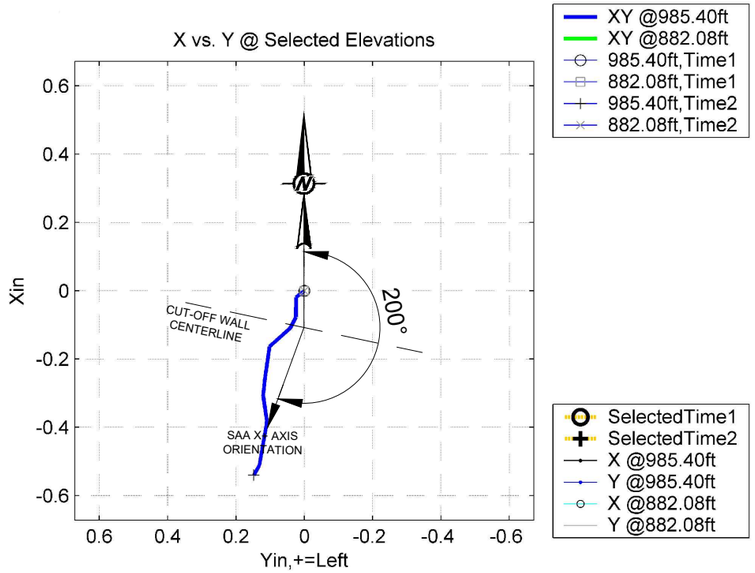
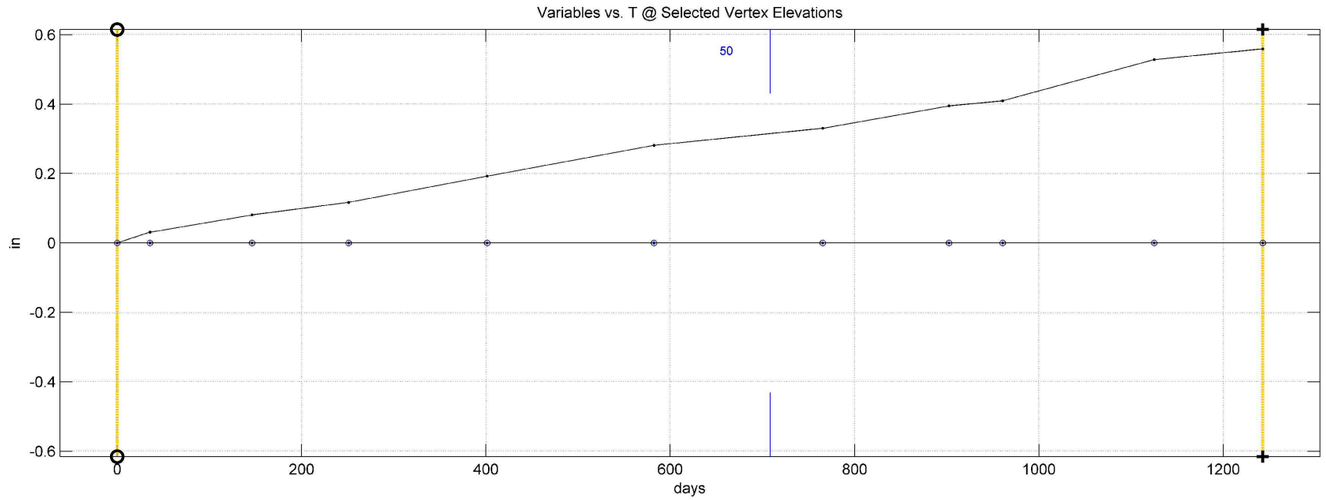








CUMULATIVE SAA INCLINOMETER DATA COLLECTED FROM NOVEMBER 2015 BASELINE

NOTE(S)

1. DISPLACEMENT PLOTTED VERSUS TIME AT LOCATION OF MAXIMUM DISPLACEMENT WITHIN VERTICAL ARRAY.

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

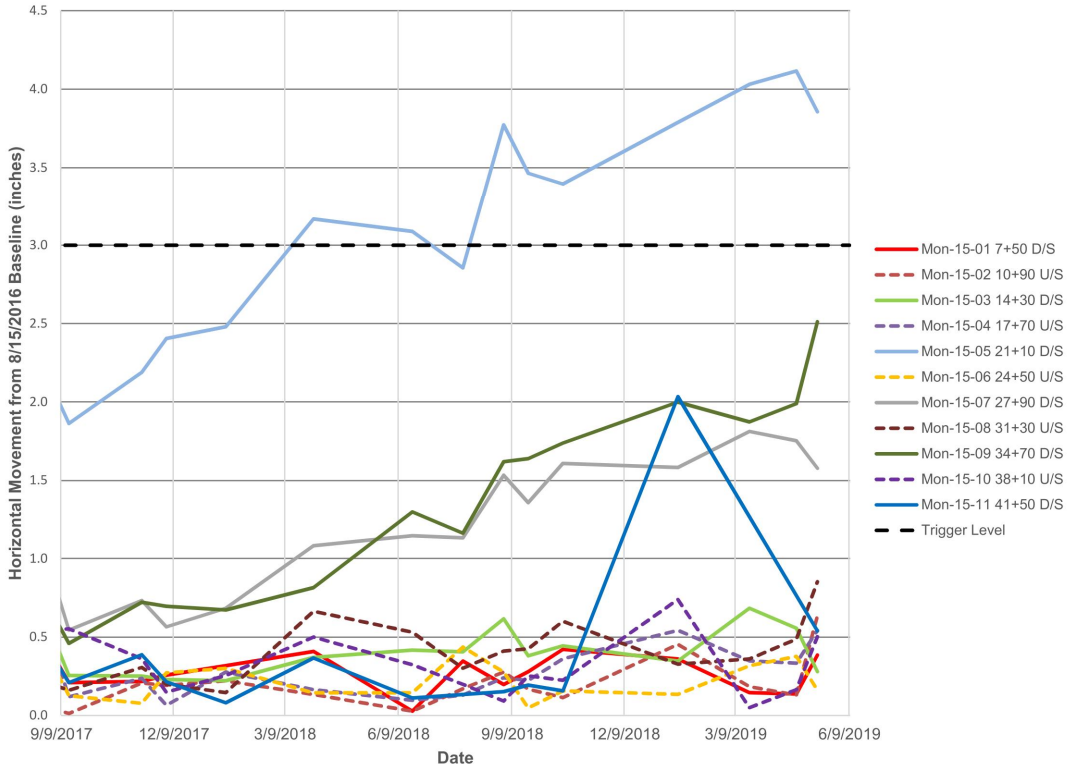
CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	SLA

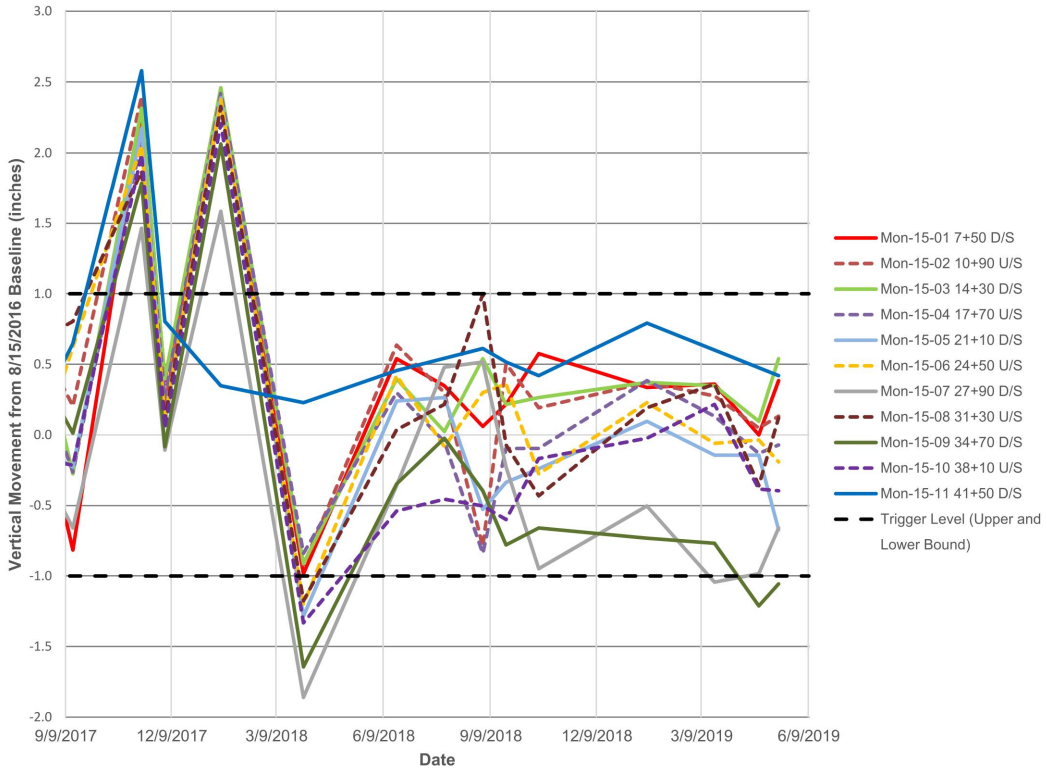
PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS BACK DAM
RED DOG MINE, ALASKA

TITLE
SAA INCLINOMETER STA 35+00

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	1	8



SUMMARY OF HORIZONTAL MOVEMENTS



SUMMARY OF VERTICAL MOVEMENTS

NOTES

1. BASELINE SURVEY READINGS TAKEN ON AUGUST 15, 2016.

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

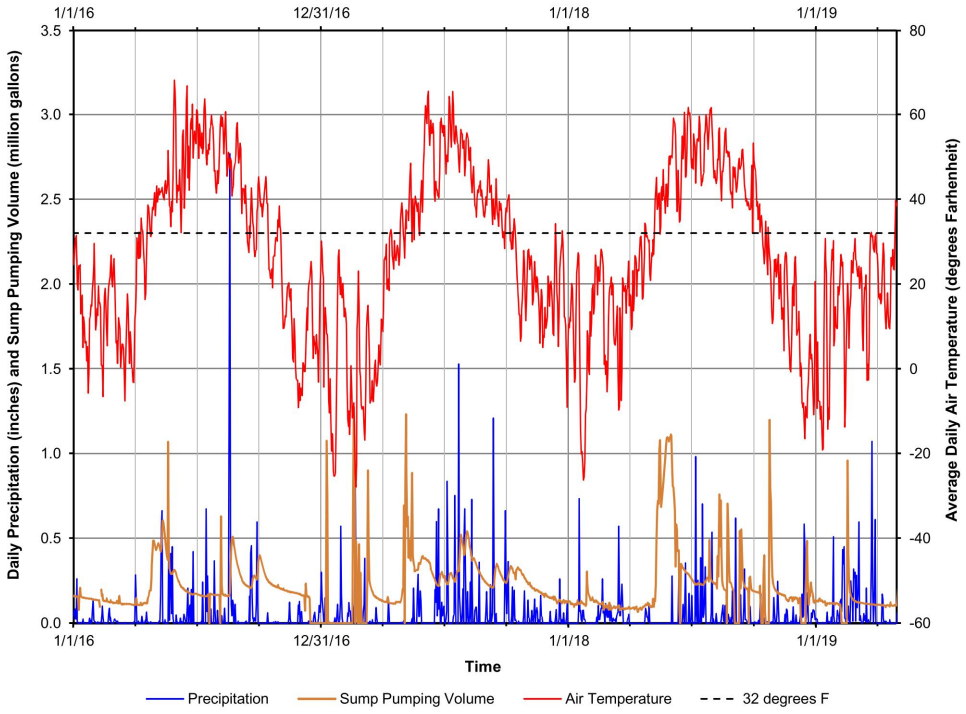
CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	SLA

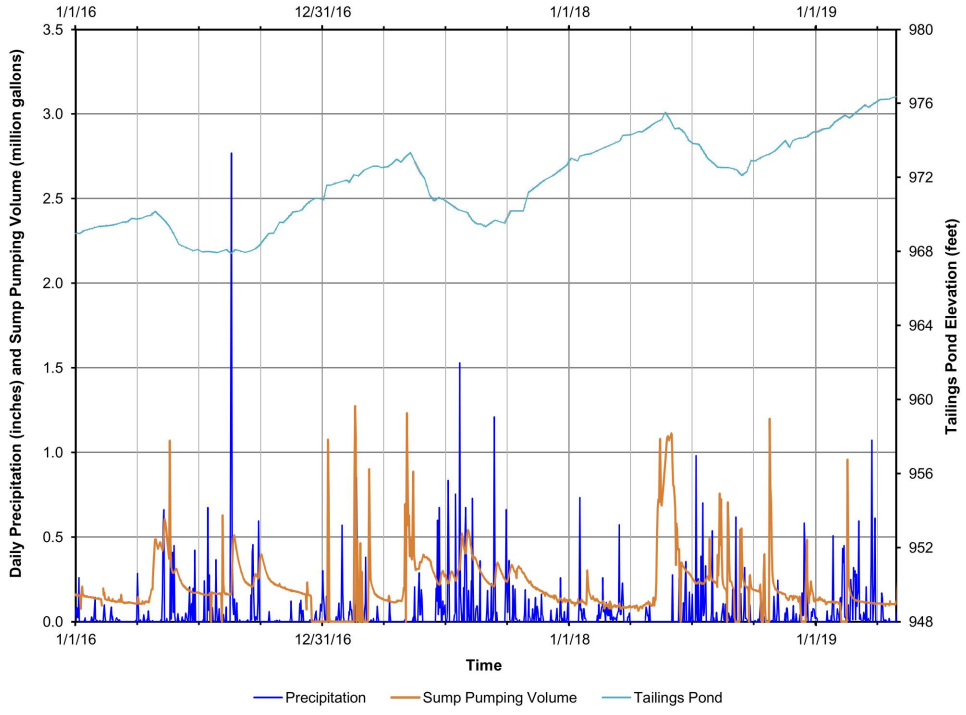
PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS BACK DAM
RED DOG MINE, ALASKA

TITLE
SURVEY MONUMENT MOVEMENT MONITORING

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	1	9



PRECIPITATION, SUMP PUMP, AND AIR TEMPERATURE DATA



PRECIPITATION, SUMP PUMP, AND TAILINGS POND ELEVATION DATA

NOTES

1. SUMP PUMP DATA THAT IS MISSING IS LIKELY RELATED TO PERIODS WHEN SUMP PUMP WAS FROZEN OR DOWN FOR MAINTENANCE.

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

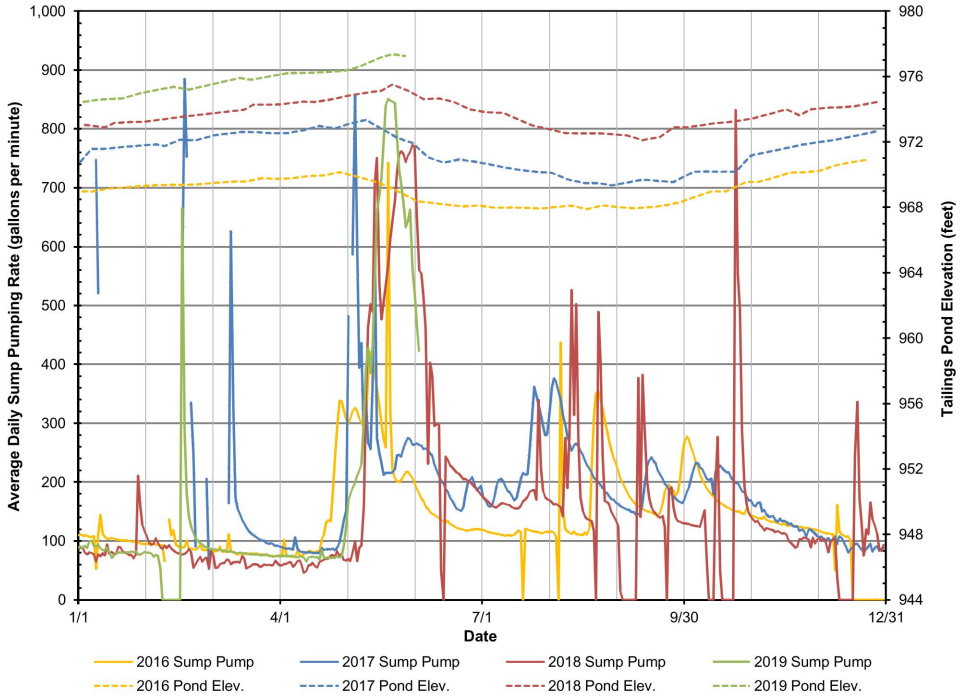
CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	SLA

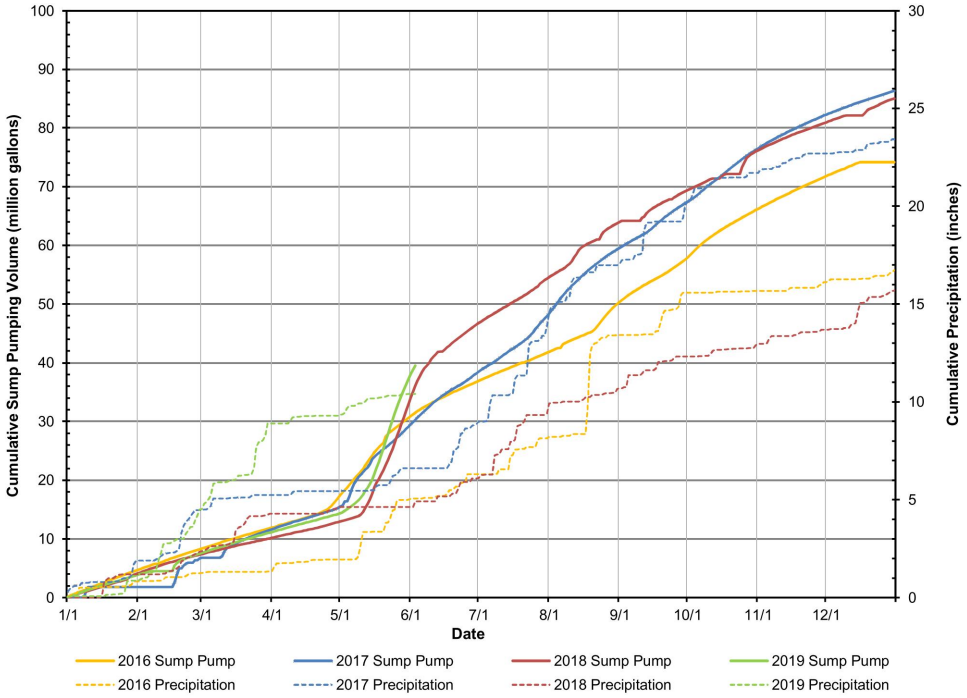
PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS BACK DAM
RED DOG MINE, ALASKA

TITLE
AIR TEMPERATURE, PRECIPITATION, TAILING POND ELEVATION, AND SUMP PUMP DATA WITH TIME (2016-2019)

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	1	10



DAILY SUMP PUMPING RATES AND TAILINGS POND ELEVATION



CUMULATIVE SUMP PUMPING VOLUMES AND PRECIPITATION

NOTES

1. SUMP PUMP DATA THAT IS MISSING IS LIKELY RELATED TO PERIODS WHEN SUMP PUMP WAS FROZEN OR DOWN FOR MAINTENANCE.

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

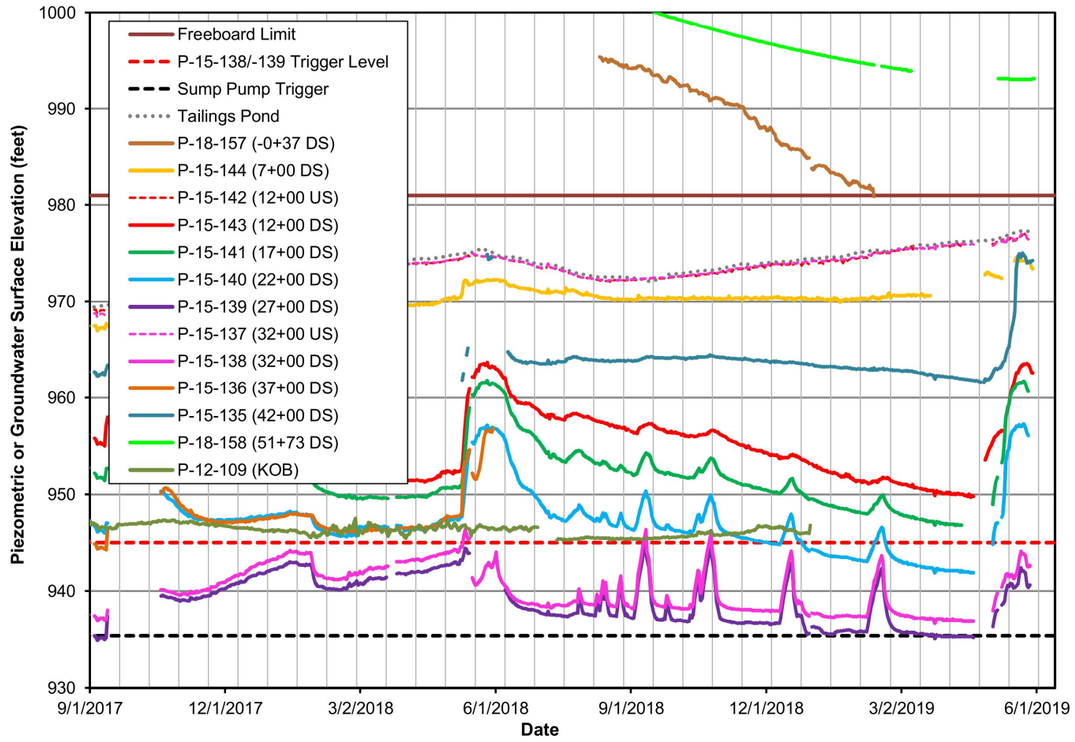
CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	SLA

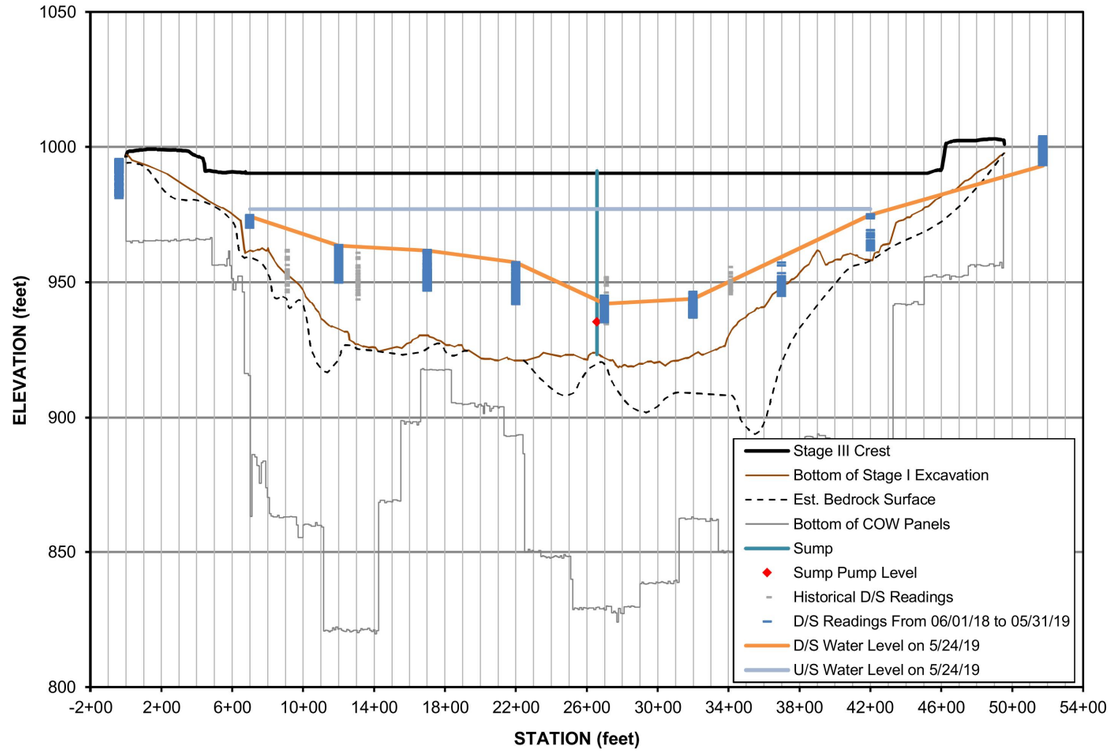
PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS BACK DAM
RED DOG MINE, ALASKA

TITLE
SUMP PUMP AND TAILINGS POND ELEVATION DATA

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	1	11



RECENT PIEZOMETRIC DATA - NOTE 1



PROFILE VIEW - PEIZOMETRIC SURFACE (HISTORICAL AND RECENT DATA)

NOTES

1. P-12-109 IS LOCATED AT THE OVERBURDEN STOCKPILE (KOB), AS SHOWN IN FIGURE 2. WATER LEVEL DATA IS CALIBRATED BASED ON A WATER TAPE READING FROM OCTOBER 29, 2017. NOTE THAT THE WATER LEVEL DATA FOR P-12-109 IS SUSPECT BECAUSE THE INSTRUMENT IS FROZEN.
2. MONITORING PERIOD IS FROM JUNE 1, 2018 UNTIL MAY 31, 2019.

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	SLA

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS BACK DAM
RED DOG MINE, ALASKA

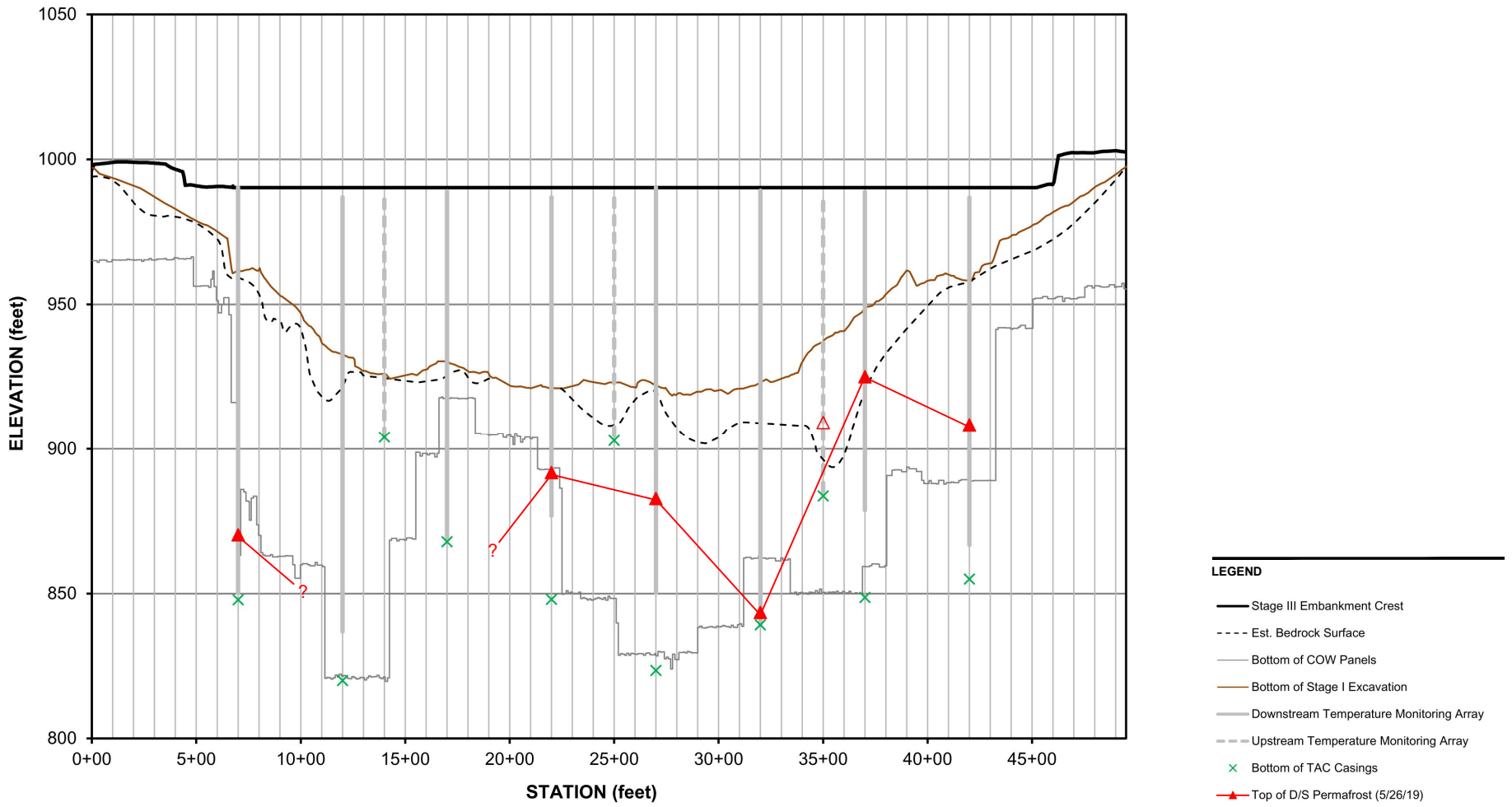
TITLE
GROUNDWATER MONITORING

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	1	12

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

1 in
0

Path: \\Anchorage\Public\Geomatics\Teck\Red Dog\99_PROJECTS\18113464 TAK 2019 Red Dog Dam Inspections\02_PRODUCTION\DWG\Back Dam\ | File Name: RD BD 2019 Piezos and TACs.dwg



PROFILE VIEW - PERMAFROST SURFACE (HISTORICAL AND RECENT DATA)

NOTES

1. ESTIMATED PERMAFROST ELEVATION (32 DEGREES FAHRENHEIT) DETERMINED THROUGH REVIEW OF THERMISTOR DATA AND INTERPOLATION BETWEEN READINGS.

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	SLA

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS BACK DAM
RED DOG MINE, ALASKA

TITLE
GROUND TEMPERATURE MONITORING

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	1	13

APPENDIX A

2019 Site Inspection Photographs

Appendix A: Photographs

PHOTO 1

WEST (RIGHT) ABUTMENT NEAR STATION 0+00, LOOKING EAST

June 22, 2019

PHOTO 2

DOWNSTREAM EMBANKMENT NEAR STATION 5+00, LOOKING EAST

June 22, 2019

Appendix A: Photographs	
PHOTO 3 UPSTREAM EMBANKMENT AND TAILINGS POND NEAR STATION 7+00, LOOKING EAST June 22, 2019	
PHOTO 4 DOWNSTREAM EMBANKMENT SLOPE NEAR STATION 8+00, LOOKING EAST June 22, 2019	

Appendix A: Photographs	
PHOTO 5 PIPE CROSSING ON UPSTREAM CREST NEAR STATION 10+00, LOOKING WEST June 22, 2019	
PHOTO 6 PONDED WATER IN LOW SPOT ON DOWNSTREAM SIDE NEAR STATION 10+00, LOOKING SOUTHWEST June 22, 2019	

Appendix A: Photographs

PHOTO 7

DOWNSTREAM EMBANKMENT SLOPE AND OVERBURDEN STOCKPILE NEAR STATION 19+00, LOOKING EAST

June 22, 2019

PHOTO 8

COFFERDAM ROAD AND UPSTREAM EMBANKMENT SLOPE NEAR STATION 20+00, LOOKING EAST

June 22, 2019

Appendix A: Photographs	
PHOTO 9 UPSTREAM CREST AND SLOPE NEAR STATION 23+00, LOOKING EAST June 22, 2019	
PHOTO 10 DOWNSTREAM CREST NEAR STATION 24+00, LOOKING WEST June 22, 2019	

Appendix A: Photographs

PHOTO 11

DOWNSTREAM EMBANKMENT SLOPE NEAR STATION 25+00, LOOKING EAST

June 22, 2019

PHOTO 12

DOWNSTREAM CREST NEAR STATION 26+50, LOOKING WEST

June 22, 2019

Appendix A: Photographs

PHOTO 13

SUMP PUMPHOUSE AND DISCHARGE PIPE NEAR STATION 26+50, LOOKING SOUTH

June 22, 2019

PHOTO 14

SUMP PUMPHOUSE DISCHARGE EROSION ON UPSTREAM FACE NEAR STATION 26+50, LOOKING WEST

June 22, 2019

Appendix A: Photographs	
PHOTO 15 COFFERDAM ROAD AND UPSTREAM EMBANKMENT SLOPE NEAR STATION 27+00, LOOKING EAST June 22, 2019	
PHOTO 16 DAM CREST AND SAA 35+00 NEAR STATION 33+00, LOOKING EAST JUNE 22, 2019	

Appendix A: Photographs

PHOTO 17

OVERBURDEN STOCKPILE PUMPBACK DISCHARGE EROSION ON UPSTREAM FACE NEAR STATION 34+00, LOOKING SOUTH

June 22, 2019

PHOTO 18

DOWNSTREAM EMBANKMENT SLOPE NEAR STATION 36+50, LOOKING WEST

June 22, 2019

Appendix A: Photographs

PHOTO 19

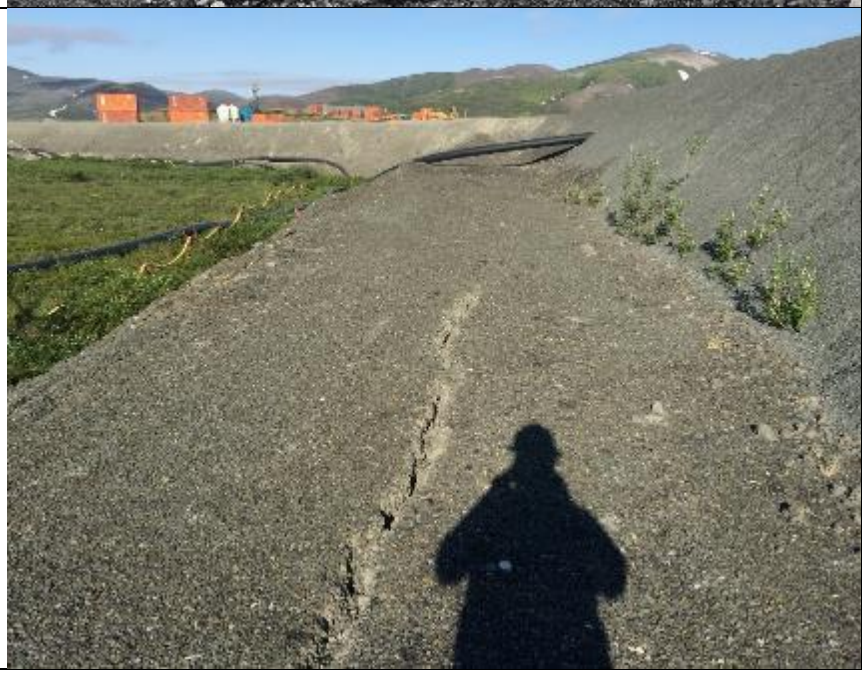
DOWNSTREAM EMBANKMENT SLOPE NEAR STATION 39+50, LOOKING WEST

June 22, 2019

PHOTO 20

UPSTREAM SLOPE AND COFFERDAM ROAD NEAR STATION 41+00, LOOKING WEST

June 22, 2019

Appendix A: Photographs	
PHOTO 21 PIPE CROSSING AND UPSTREAM SLOPE NEAR STATION 43+00, LOOKING EAST June 22, 2019	
PHOTO 22 HISTORIC CRACKING AT DOWNSTREAM CREST NEAR STATION 45+00, LOOKING WEST June 22, 2019	

Appendix A: Photographs	
PHOTO 23 DOWNSTREAM EMBANKMENT CREST NEAR STATION 47+00, LOOKING WEST June 22, 2019	
PHOTO 24 HISTORIC CRACKING AT DOWNSTREAM EMBANKMENT CREST NEAR STATION 49+00, LOOKING WEST June 22, 2019	

Appendix A: Photographs	
PHOTO 25 CREST AT EAST (LEFT) ABUTMENT, LOOKING WEST June 22, 2019	
PHOTO 26 SUMP PUMP HOUSE AND COMMUNICATIONS TOWER NEAR STATION 26+50, LOOKING SOUTHWEST June 22, 2019	

Appendix A: Photographs	
PHOTO 27 INTERIOR OF SUMP PUMPHOUSE June 22, 2019	
PHOTO 28 MONITORING BOX AT COMMUNICATION TOWER, LOOKING SOUTH June 22, 2019	

Appendix A: Photographs

PHOTO 29

RAISED CASING AT SAA 35+00, LOOKING NORTH

June 22, 2019

PHOTO 30

UPSTREAM PIEZOMETER P-15-137 CABLE EXTENSION NEAR STATION 32+00, LOOKING SOUTHWEST

June 22, 2019

Appendix A: Photographs

PHOTO 31

SURFICIAL ICE BENEATH BOARD INSULATION

OBSERVED DURING GOLDER STAGE IV CQA MONITORING, June 5, 2019

PHOTO 32

VOID IN SELECT FILL SURFACE AFTER INSULATION REMOVAL NEAR STATION 28+75

OBSERVED DURING GOLDER STAGE IV CQA MONITORING, June 9, 2019

Appendix A: Photographs

PHOTO 33

DUG UP VOID IN SELECT FILL NEAR STATION 28+75

OBSERVED DURING GOLDER STAGE IV CQA MONITORING, June 9, 2019

PHOTO 34

CRACKING NEAR THE UPSTREAM SELECT FILL/ROCKFILL INTERFACE FROM APPROX. STATION 24+00 TO 28+00, LOOKING EAST

OBSERVED DURING TECK INSPECTION, June 9, 2019

Appendix A: Photographs

PHOTO 35

CRACKING OBSERVED AT CENTERLINE OF SELECT FILL AFTER INSULATION REMOVAL NEAR STATION 35+75

OBSERVED DURING GOLDER STAGE IV CQA MONITORING, June 10, 2019

PHOTO 36

CRACKING NEAR THE UPSTREAM SELECT FILL/ROCKFILL INTERFACE NEAR STATION 32+00, LOOKING EAST

OBSERVED DURING GOLDER STAGE IV CQA MONITORING, June 10, 2019

Appendix A: Photographs	
PHOTO 37 CRACKING OF THE DOWNSTREAM SELECT FILL-ROCKFILL INTERFACE NEAR STATION 31+00 OBSERVED DURING GOLDER STAGE IV CQA MONITORING, June 10, 2019	

APPENDIX B

ADNR Inspection Form

ALASKA DAM SAFETY PROGRAM
VISUAL INSPECTION CHECKLIST

NID AK00303
ID# 1
SHEET 1 OF 3

GENERAL INFORMATION

NAME OF DAM: Tailings Back Dam	POOL ELEVATION: ~975 feet
NATIONAL INVENTORY OF DAMS ID#: AK00303	TAILWATER ELEVATION: N/A
OWNER: Teck Alaska Incorporated	CURRENT WEATHER: Partly Cloudy
HAZARD POTENTIAL CLASSIFICATION: Class II (Signific	PREVIOUS WEATHER: Partly Cloudy
SIZE CLASSIFICATION: N/A	INSPECTED BY: Steven L. Anderson, PE and Matthew S. Gillaspy, EIT
PURPOSE OF DAM: Tailings Storage Facility	INSPECTION FIRM: Golder Associates Inc.
O & M MANUAL REVIEWED: Yes	DATE OF INSPECTION: June 22, 2019
EMERGENCY ACTION PLAN REVIEWED: Yes	

ITEM	YES	NO	REMARKS
RESERVOIR			
1. Any upstream development?	☐	✔	
2. Any upstream impoundments?	☐	✔	
3. Shoreline slide potential?	☐	✔	
4. Significant sedimentation?	✔	☐	Stored tailings
5. Any trash boom?	☐	✔	
6. Any ice boom?	☐	✔	
7. Operating procedure changes?	✔	☐	Stage IV construction occuring
DOWNSTREAM CHANNEL			Overburden Stockpile
1. Channel			
a. Eroding or Backcutting	☐	✔	N/A
b. Sloughing?	☐	✔	N/A
c. Obstructions?	☐	✔	N/A
2. Downstream Floodplain			
a. Occupied housing?	✔	☐	Emulsion Plant
b. Roads or bridges?	✔	☐	
c. Businesses, mining, utilities?	✔	☐	Mine Water Supply
d. Recreation Area?	☐	✔	
e. Rural land?	✔	☐	
f. New development?	☐	✔	
EMERGENCY ACTION PLAN			
1. Class I or Class II Dam?	✔	☐	Class II Dam- will be Class I after Stage IV
2. Emergency Action Plan Available?	✔	☐	In O&M Manual
3. Emergency Action Plan current?	✔	☐	
4. Recent emergency action plan exercise?	✔	☐	**DATE:** Tabletop exercise 9/19/2018
INSTRUMENTATION			
1. Are there			
a. Piezometers?	✔	☐	
b. Weirs?	☐	✔	
c. Observation wells?	✔	☐	Seepage Pumpback Sump
d. Settlement Monuments?	✔	☐	removed during Stage IV raise construction
e. Horizontal Alignment Monuments?	✔	☐	SAA Inclinometers
f. Thermistors?	✔	☐	removed during Stage IV raise construction
2. Are readings			
a. Available?	✔	☐	
b. Plotted?	✔	☐	
c. Taken periodically?	✔	☐	In accordance with O&M Manual

ALASKA DAM SAFETY PROGRAM
VISUAL INSPECTION CHECKLIST

SAFETY

ITEM	YES	NO	REMARKS
SAFETY			
1. ACCESS			**TYPE:** Gravel Road
a. Road access?	✔		From Red Dog Port
b. Trail access?		✔	
c. Boat access?		✔	
d. Air access?	✔		Prominent mine access
e. Access safe?	✔		
f. Security gates and fences?		✔	Remote Secured Site
g. Restricted access signs?	✔		
2. PERSONNEL SAFETY			
a. Safe access to maintenance and operation areas?	✔		
b. Necessary handrails and ladders available?			N/A
c. All ladders and handrails in safe condition?			N/A
d. Life rings or poles available?	✔		Available at mine offices
e. Limited access and warning signs in place?	✔		
f. Safe walking surfaces?	✔		
3. DAM EMERGENCY WARNING DEVICES			
a. Emergency Action Plan required?	✔		
b. Emergency warning devices required by EAP?	✔		**TYPE(S):** Monitoring instrumentation
c. Emergency warning devices available?	✔		
d. Emergency warning devices operable?	✔		
e. Emergency warning devices tested?	✔		
f. Emergency warning devices tested by owner?	✔		**WHEN:** Monthly during instrumentation review
g. Emergency procedures available at dam?	✔		Mine offices
h. Dam operating staff familiar with EAP?	✔		
4. OPERATION AND MAINTENANCE MANUAL			
a. O & M Manual reviewed?	✔		
b. O & M Manual current?	✔		**DATE:** Rev 3, October 21, 2016
c. Contains routine inspection schedule?	✔		
c. Contains routine inspection checklist?	✔		

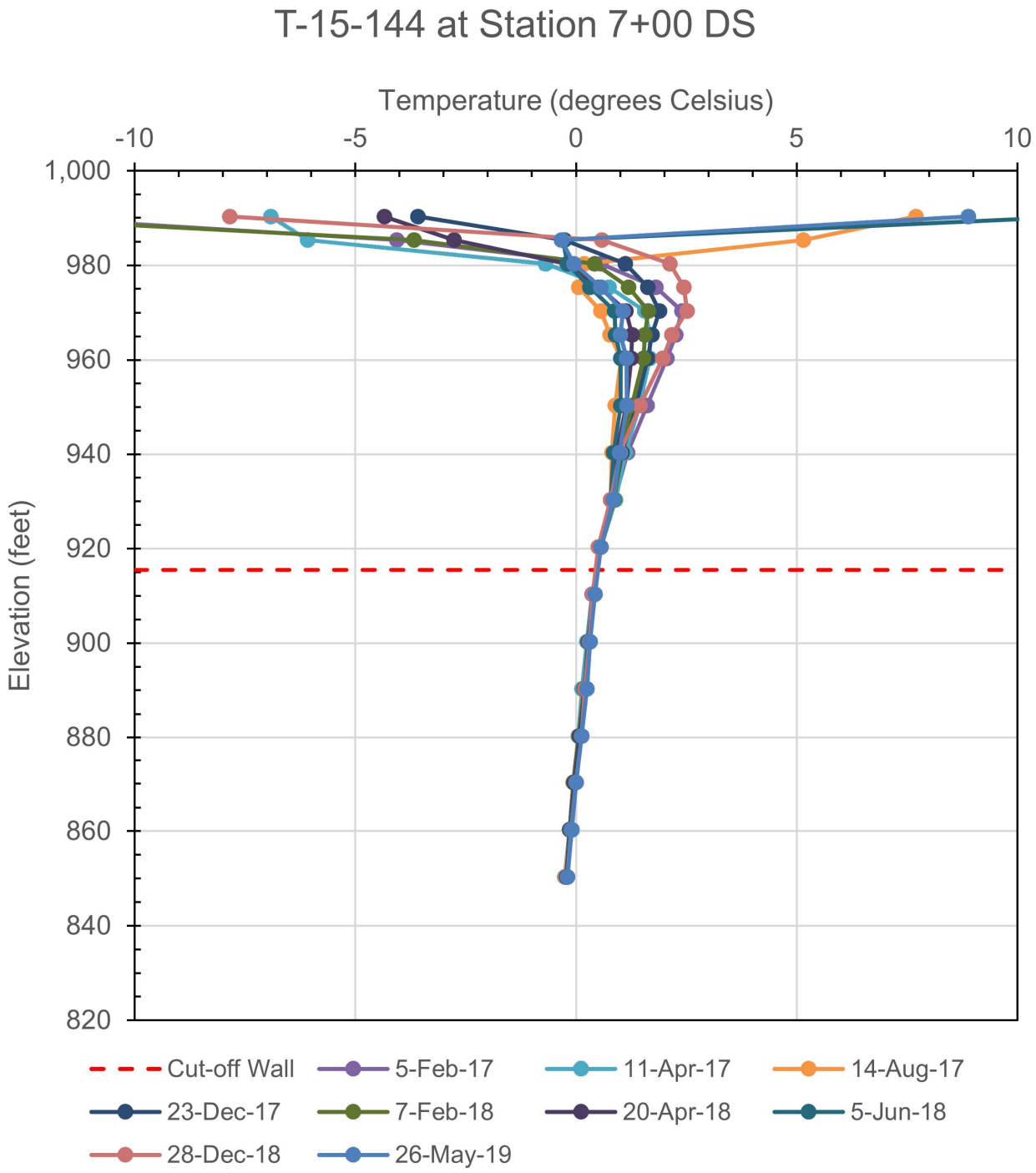
ALASKA DAM SAFETY PROGRAM
VISUAL INSPECTION CHECKLIST

EMBANKMENT DAMS

ITEM	YES	NO	REMARKS
EMBANKMENT DAMS			**TYPE:** Gravel and Rockfill centerline plastic concrete cut-off wall
1. CREST			
a. Any settlement?		✔	
b. Any misalignment?		✔	
c. Any cracking?	✔		Along select fill / rockfill interface
d. Adequate freeboard?	✔		
2. UPSTREAM SLOPE			
a. Adequate slope protection?	✔		
b. Any erosion or beaching?	✔		Erosion at pumping discharge locations
c. Trees or brush growing on slope?		✔	
d. Deteriorating slope protection?		✔	
e. Visual settlement?		✔	
f. Any sinkholes?		✔	
3. DOWNSTREAM SLOPE			**TYPE:** Rockfill
a. Adequate slope protection?	✔		
b. Any erosion?		✔	
c. Trees or brush growing on slope?		✔	
d. Animal burrows?		✔	
e. Sinkholes?		✔	
f. Visual settlement?		✔	
g. Surface seepage?		✔	
h. Toe drains dry?			N/A
i. Relief wells flowing?			N/A
j. Slides or slumps?		✔	
4. ABUTMENT CONTACTS			
a. Any erosion?		✔	
b. Seepage present?		✔	
c. Boils or springs downstream?		✔	
5. FOUNDATION			**TYPE:** Overburden, stripped of ice-rich materials during constructio
a. If dam is founded on permafrost			
(1) Is fill frozen?		✔	N/A
(2) Are internal temperatures monitored?	✔		
b. If dam is founded on bedrock			**TYPE:** Cherts and Shales
(1) Is bedrock adversely bedded?		✔	
(2) Does rock contain gypsum?		✔	
(3) Weak strength beds?		✔	
c. If dam founded on overburden			**TYPE:** Clays, silty clays, clayey sand and gravel
(1) Pipeable?		✔	
(2) Compressive?	✔		fine-grained soils could consolidate
(3) Low shear strength?		✔	

APPENDIX C

Ground Temperature Monitoring Data

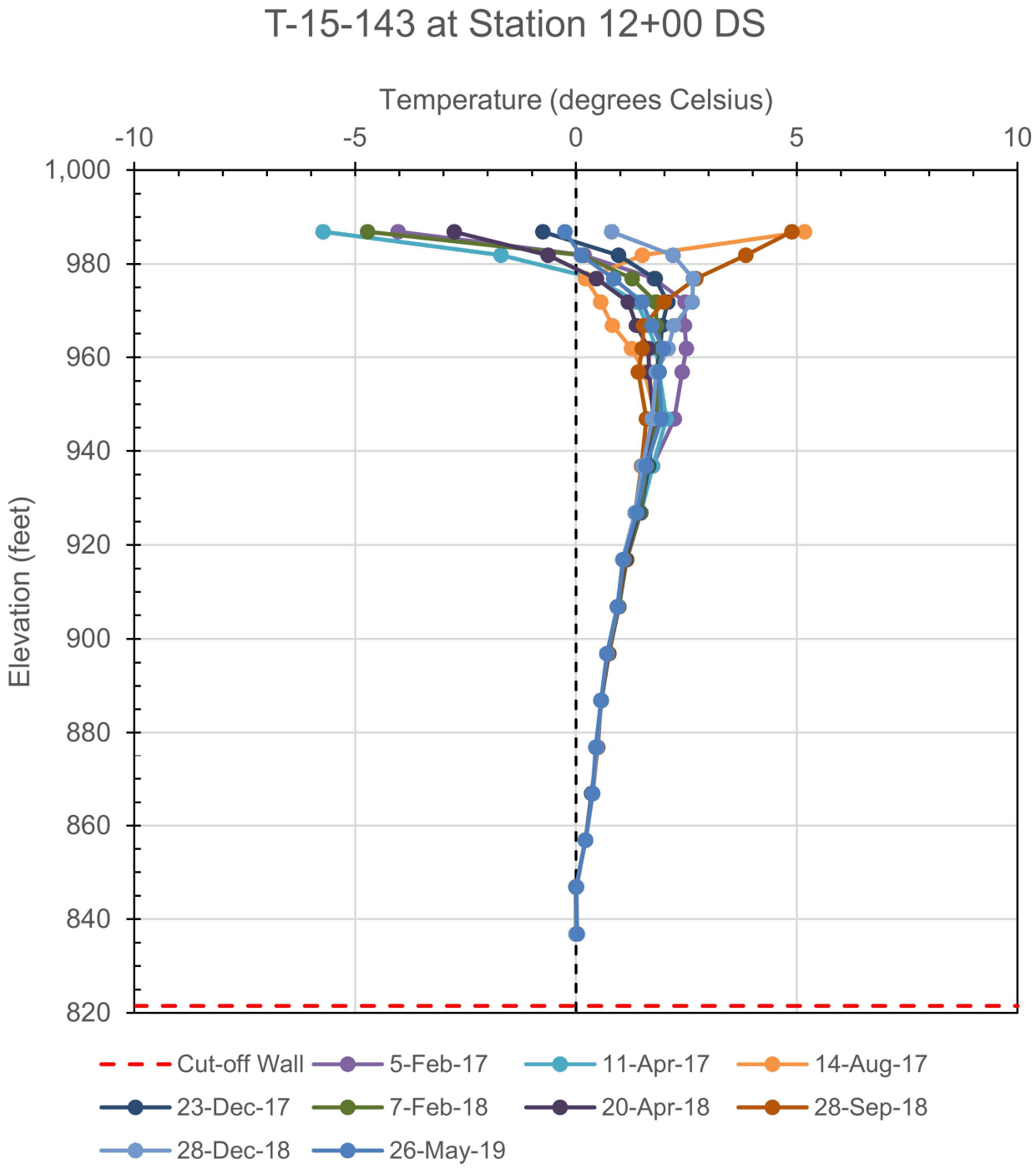


RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT STATION 7+00 DS

FIGURE C-1

GOLDER

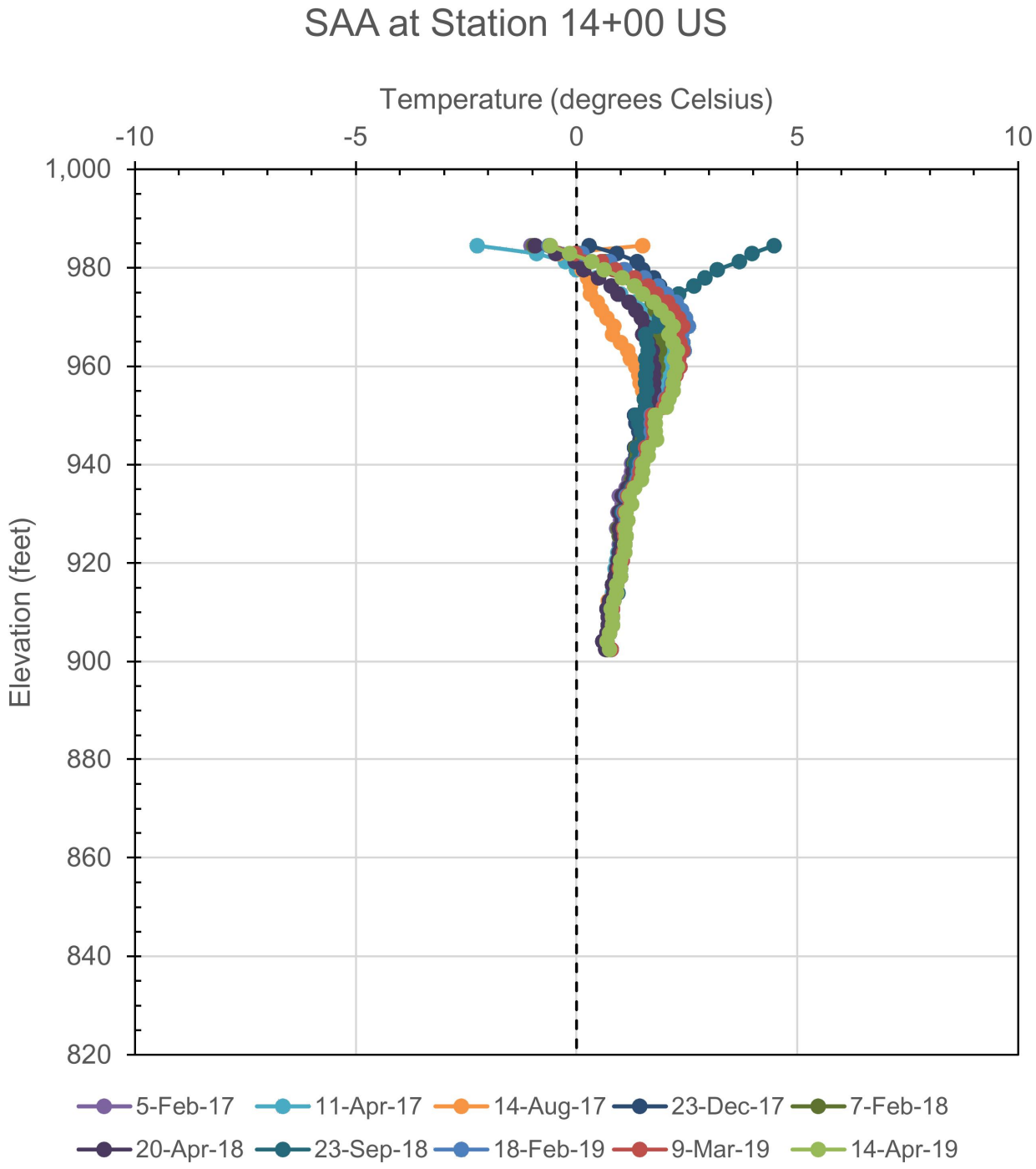


RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT STATION 12+00 DS

GOLDER

FIGURE C-2



NOTE(S)

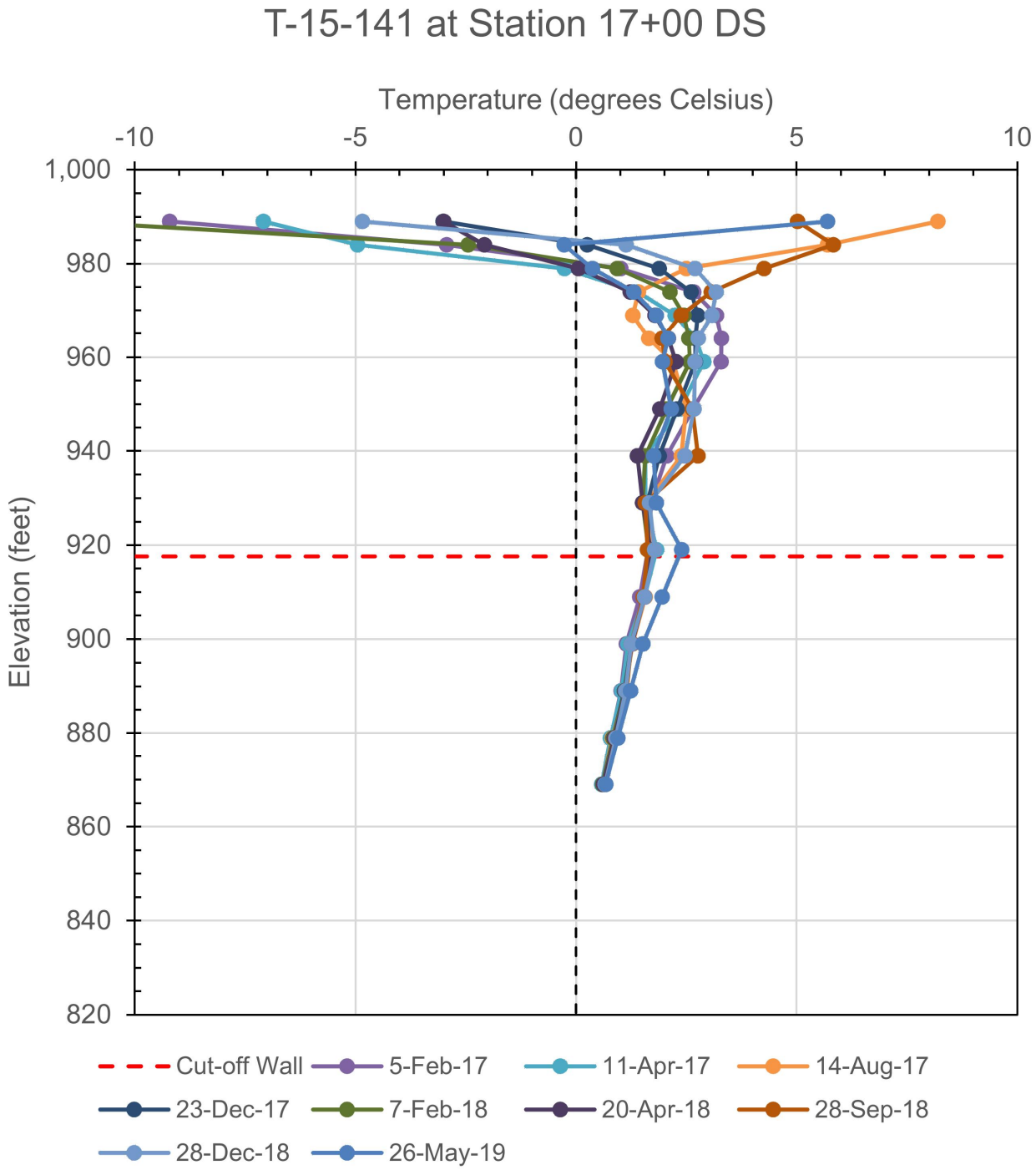
1. Bottom of Concrete Cut-off Wall elevation at 821.2 feet

GOLDER

RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT STATION 14+00 US

FIGURE C-3

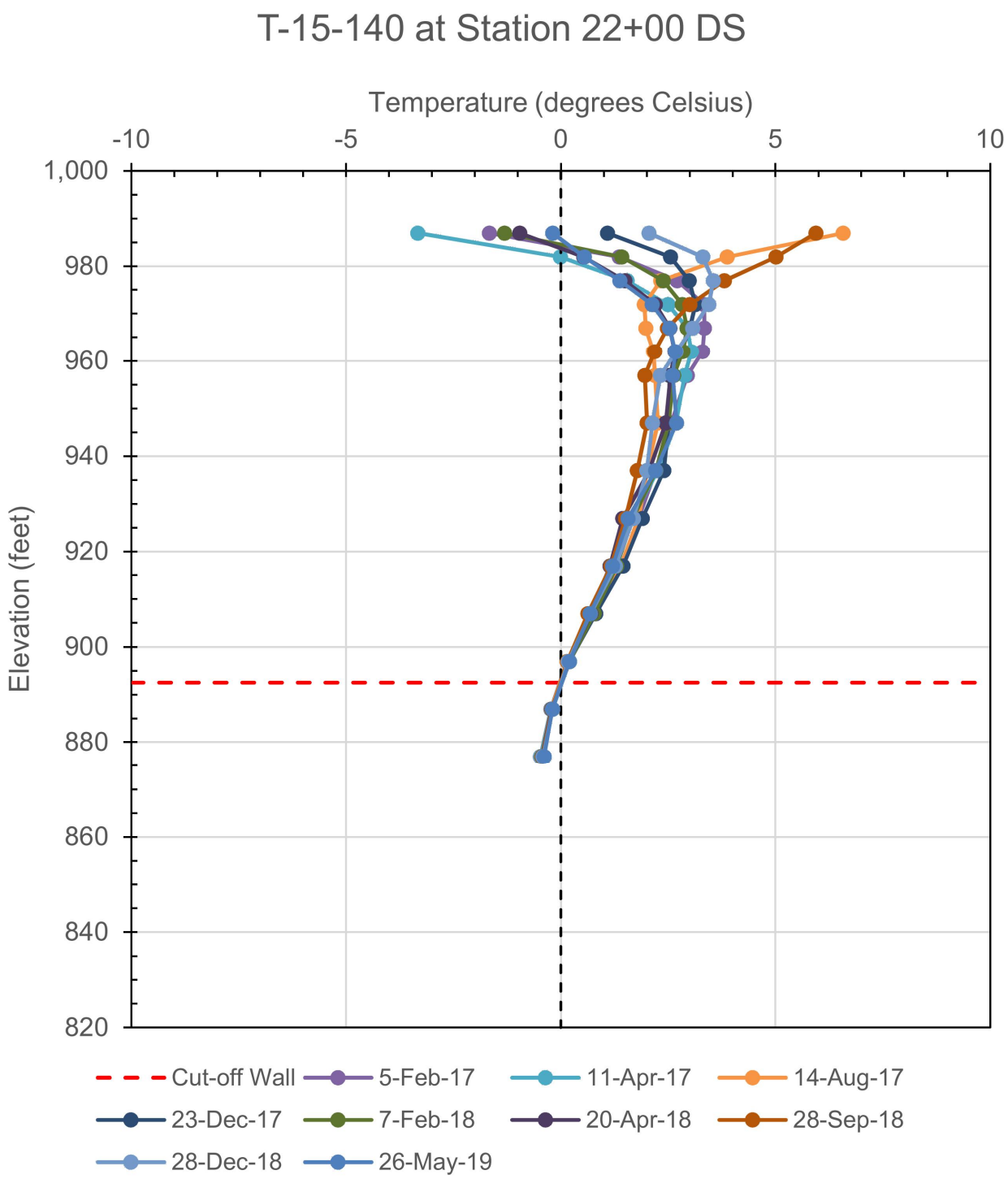


RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT STATION 17+00 DS

GOLDER

FIGURE C-4

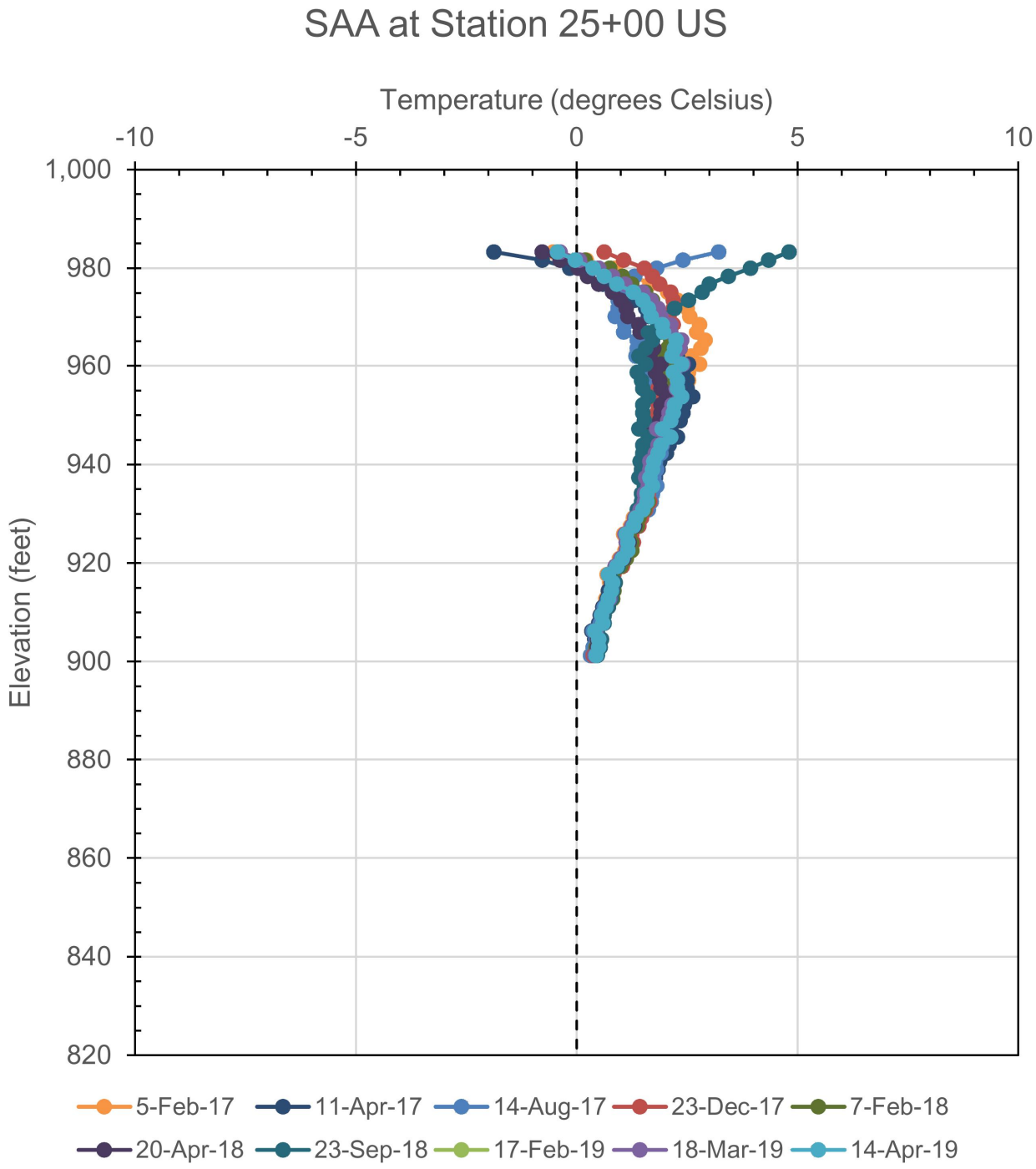


RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT STATION 22+00 DS

GOLDER

FIGURE C-5



NOTE(S)

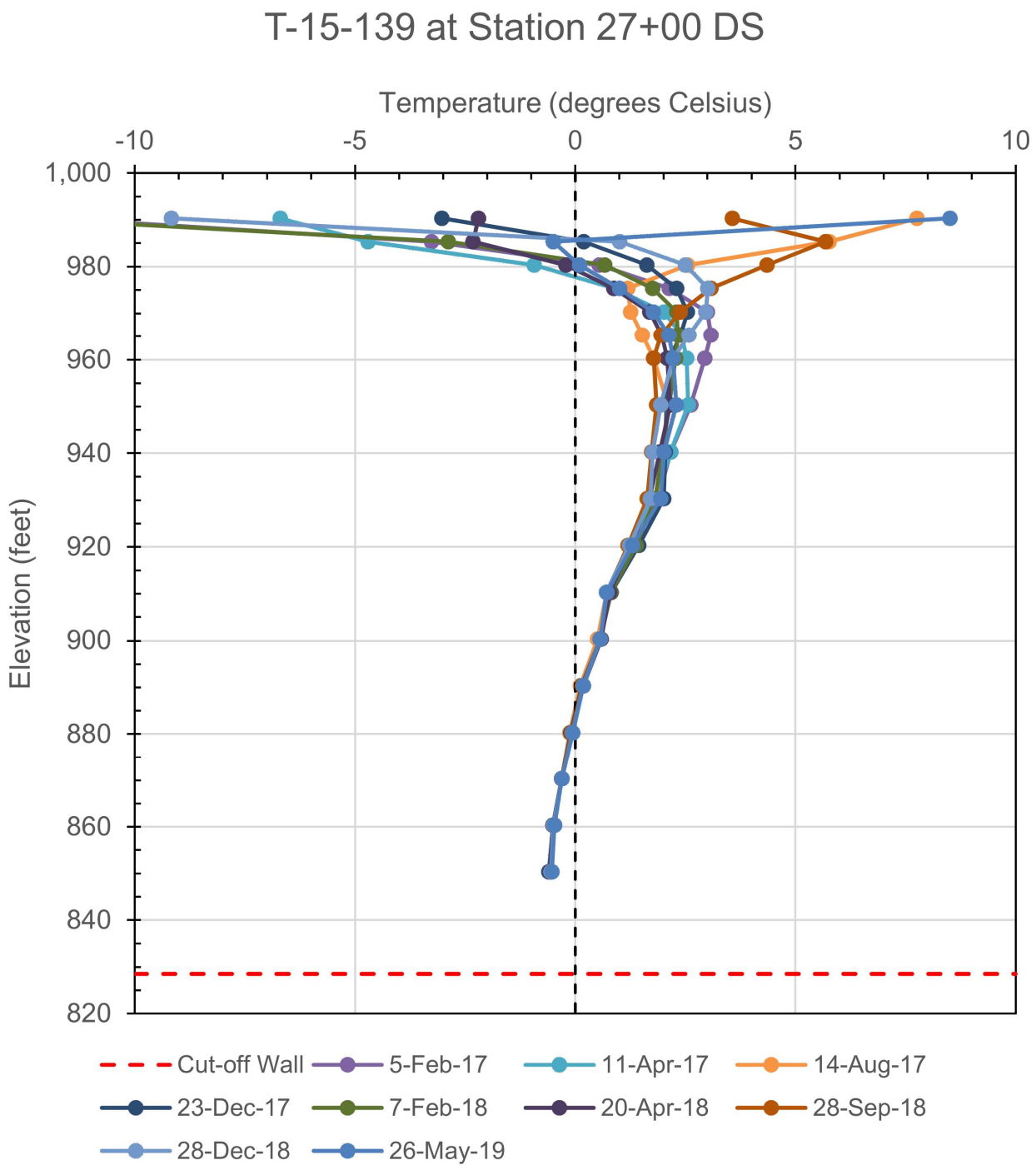
1. Bottom of Concrete Cut-off Wall elevation at 848.8 feet

RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT STATION 25+00 US

GOLDER

FIGURE C-6

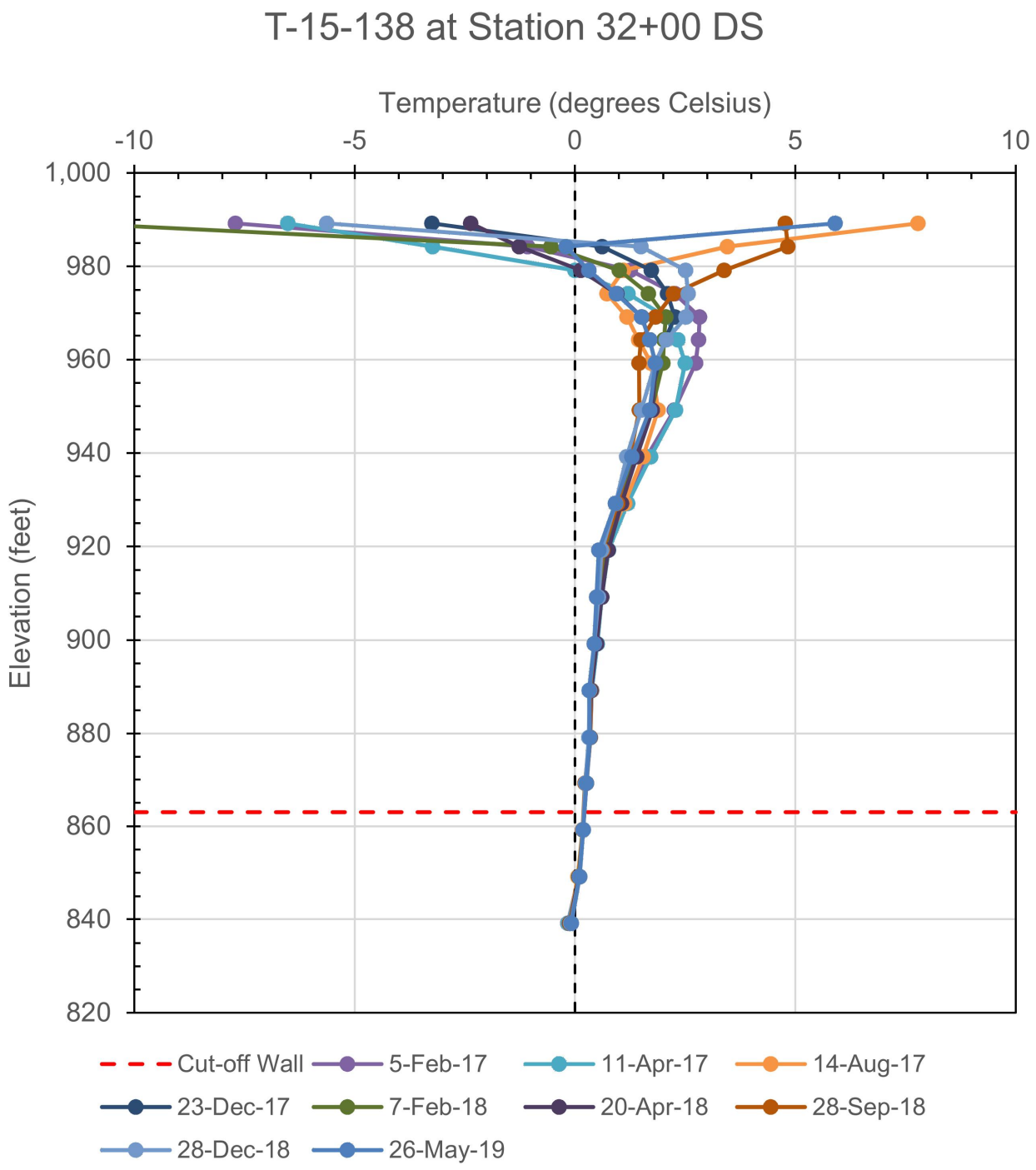


RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT STATION 27+00 DS

GOLDER

FIGURE C-7

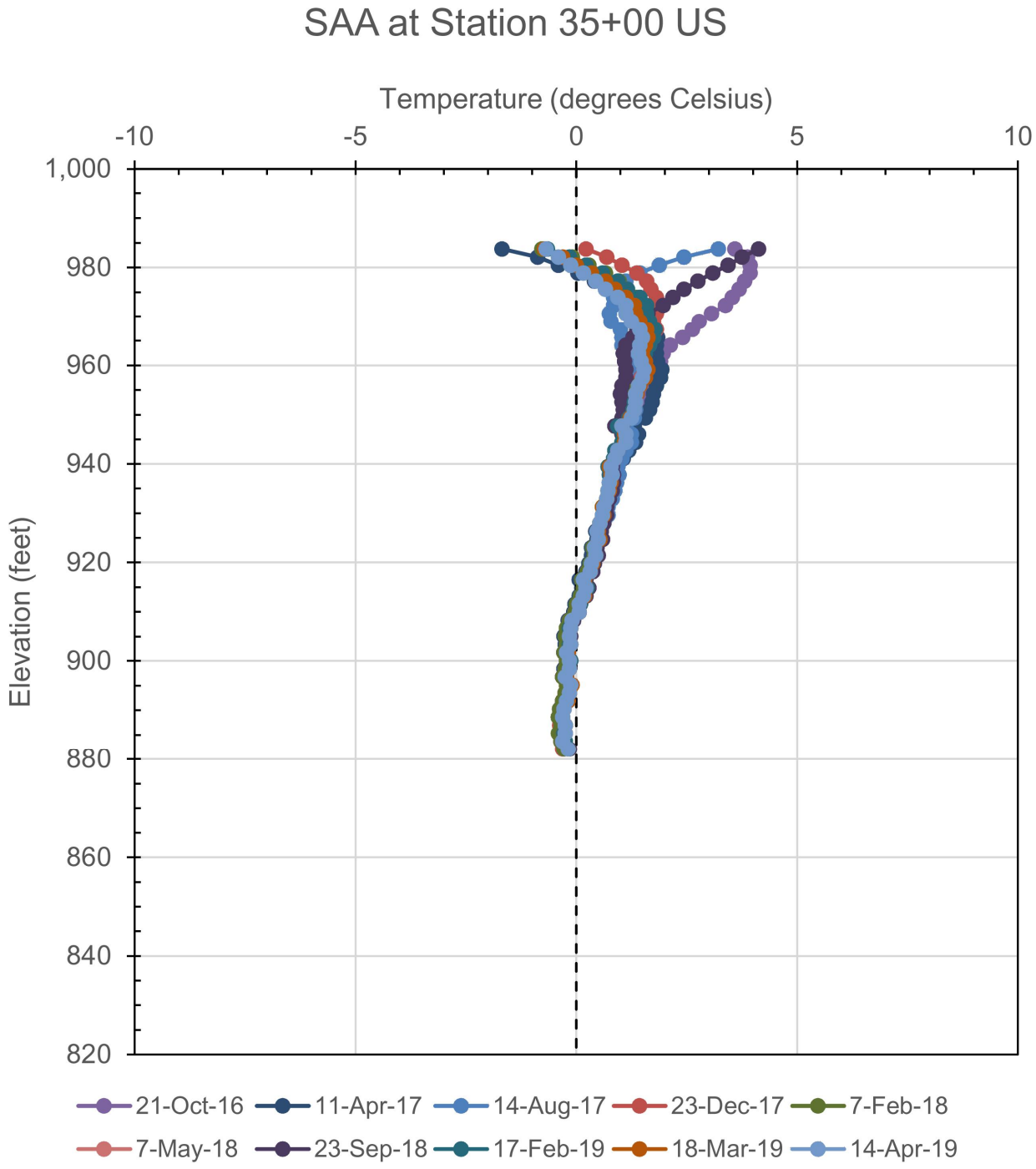


RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT STATION 32+00 DS

GOLDER

FIGURE C-8



NOTE(S)

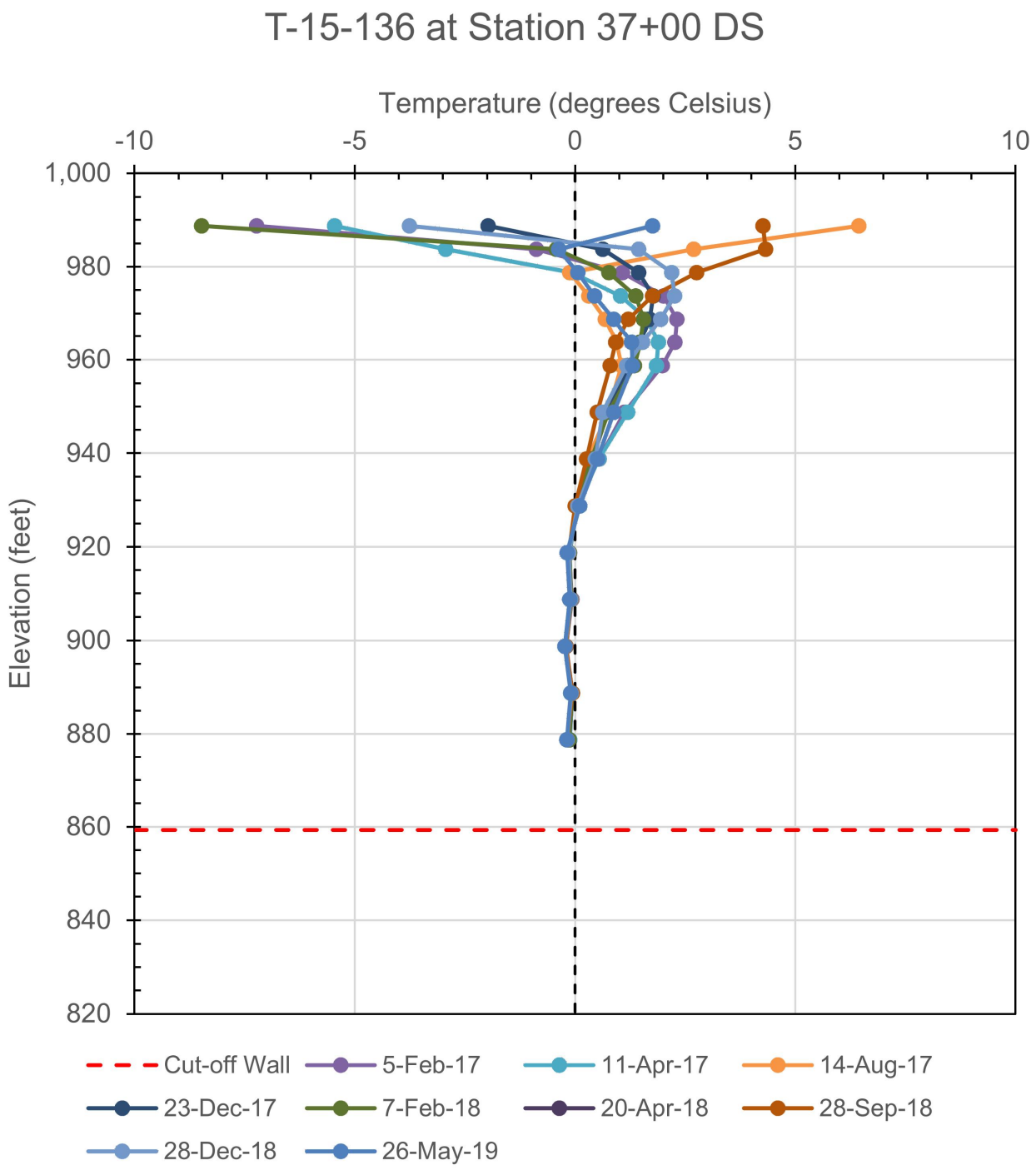
1. Bottom of Concrete Cut-off Wall elevation at 850.4 feet

RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT STATION 35+00 US

FIGURE C-9

GOLDER

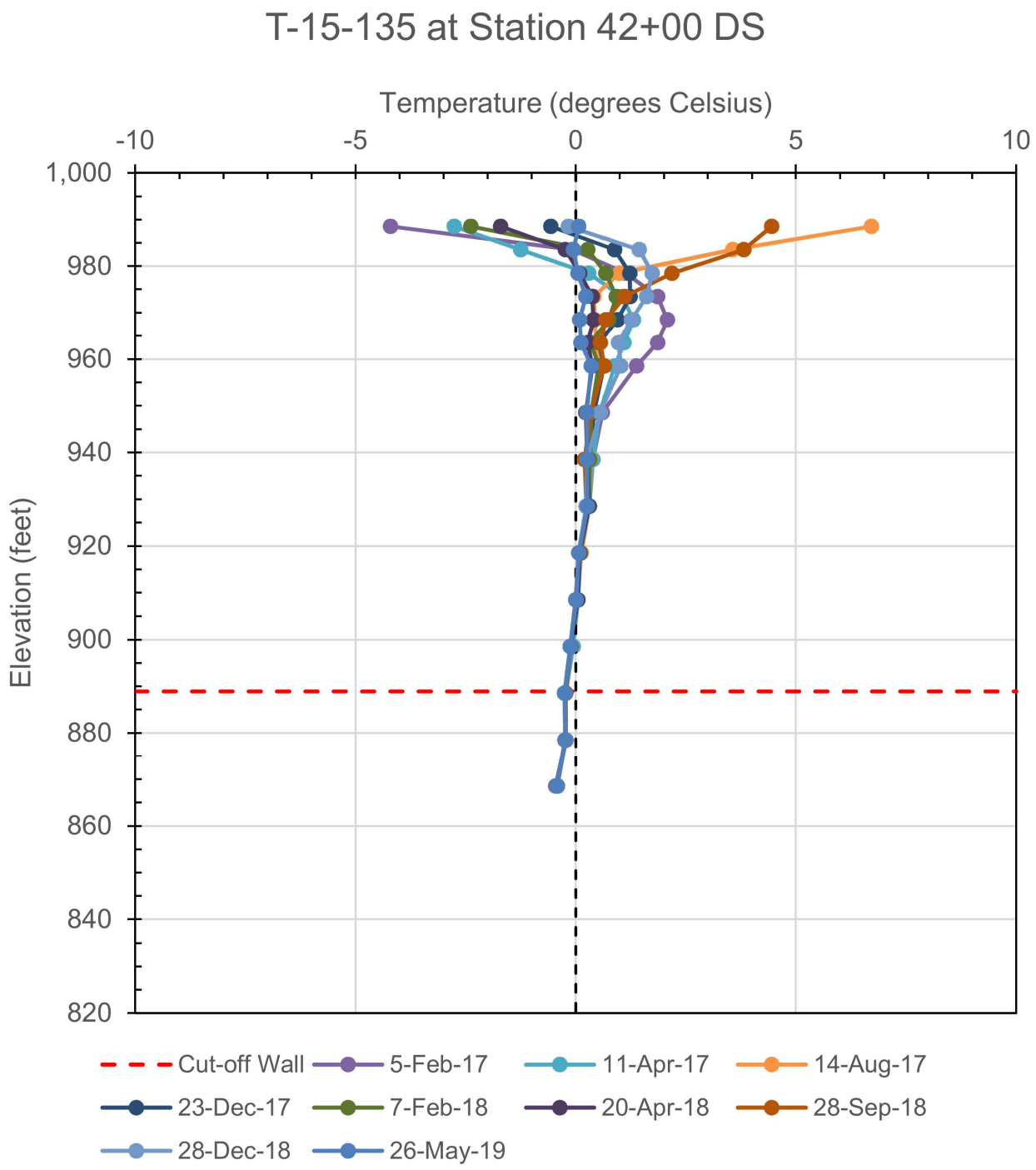


RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT STATION 37+00 DS

GOLDER

FIGURE C-10

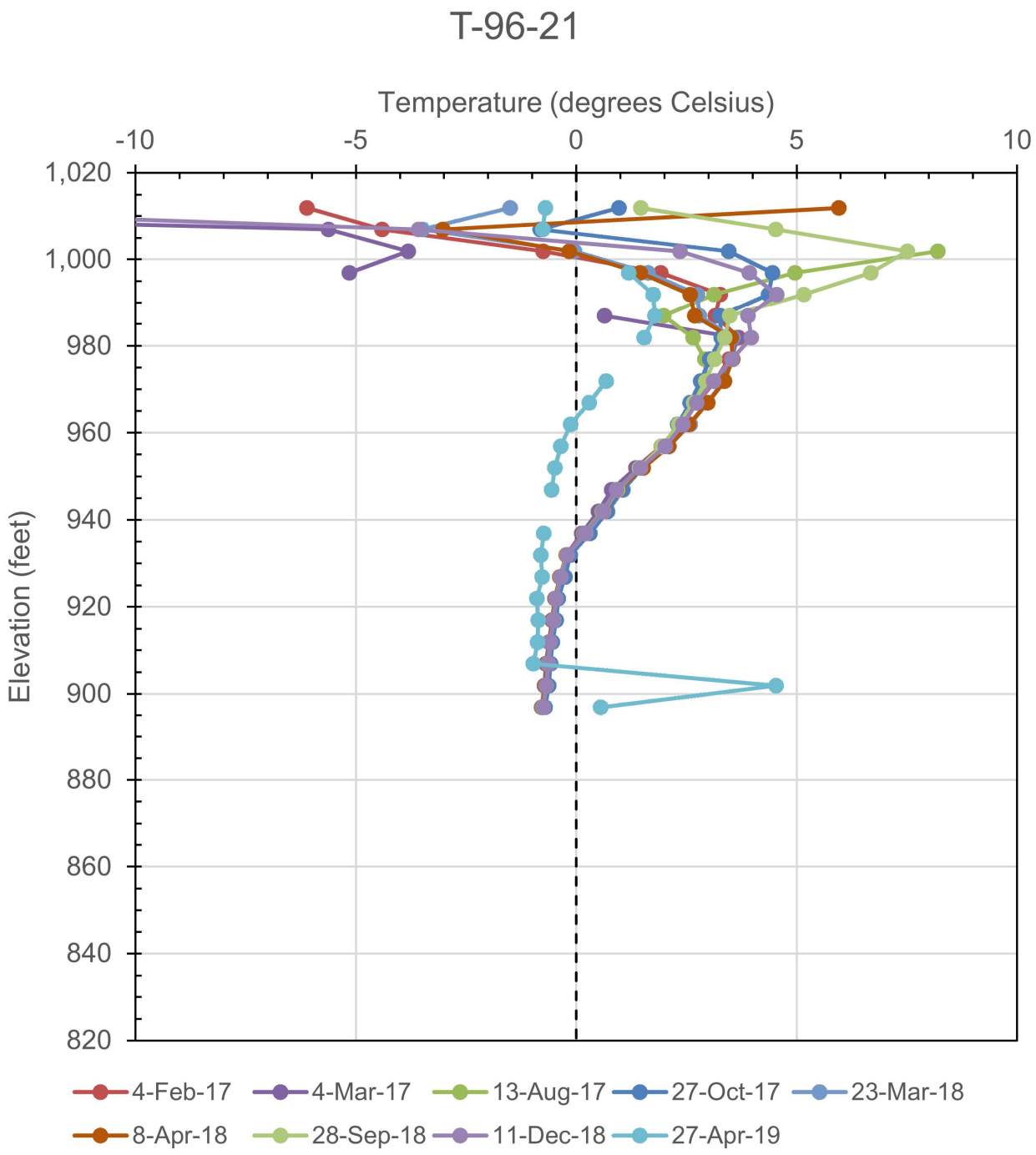


RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT STATION 42+00 DS

GOLDER

FIGURE C-11

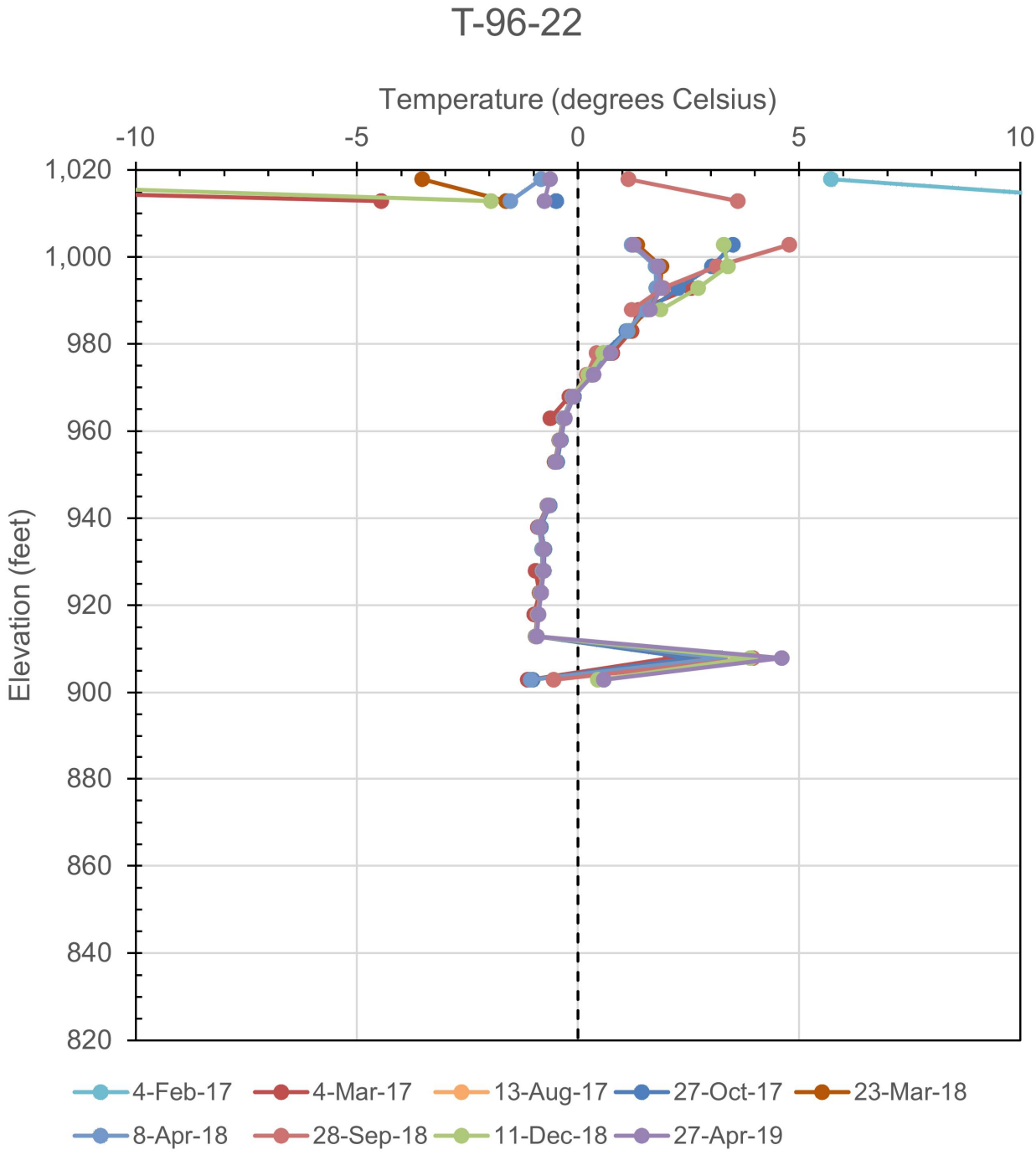


GOLDER

RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT OVERBURDEN STOCKPILE T-96-21

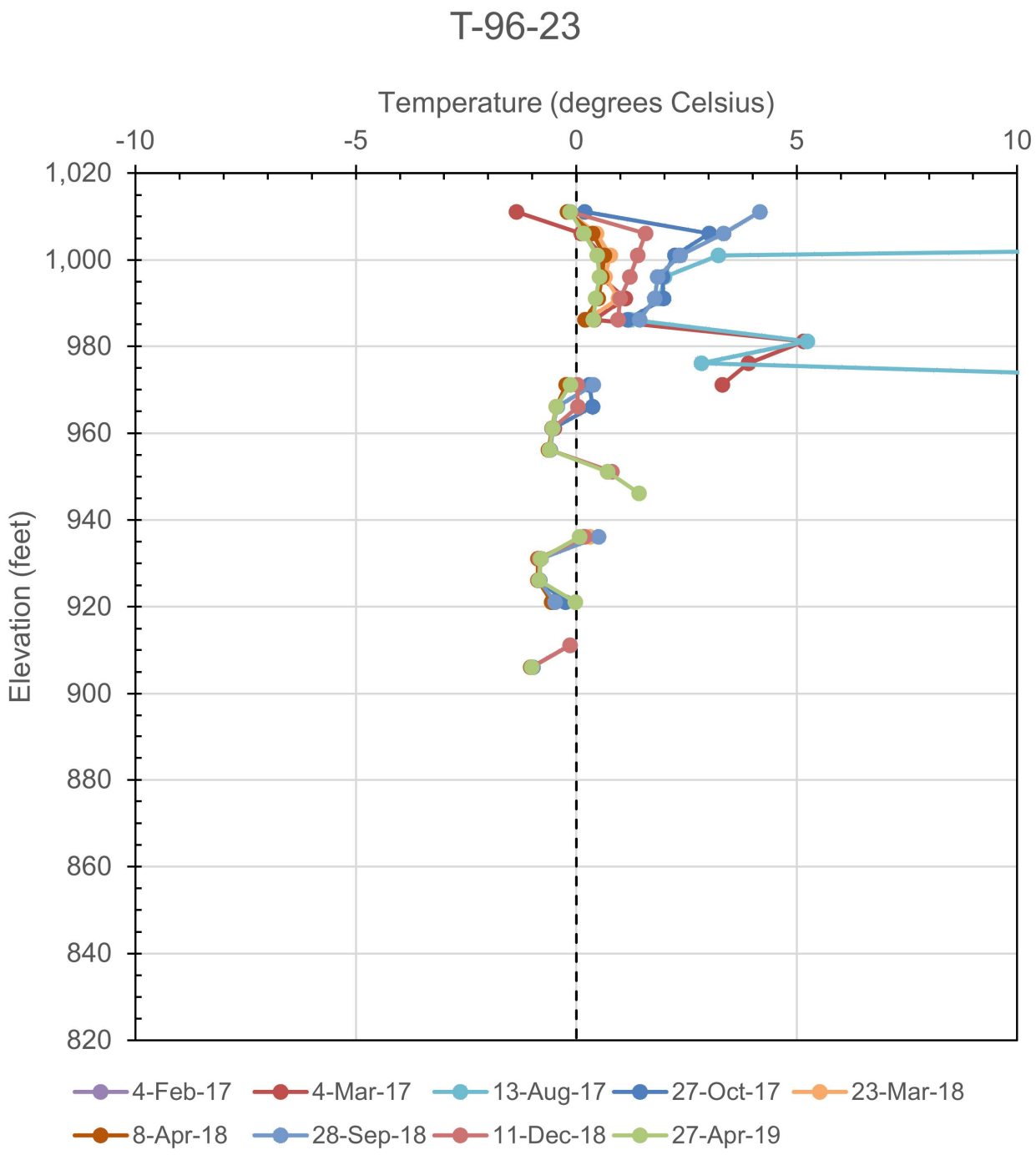
FIGURE C-12



RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT OVERBURDEN STOCKPILE T-96-22

FIGURE C-13

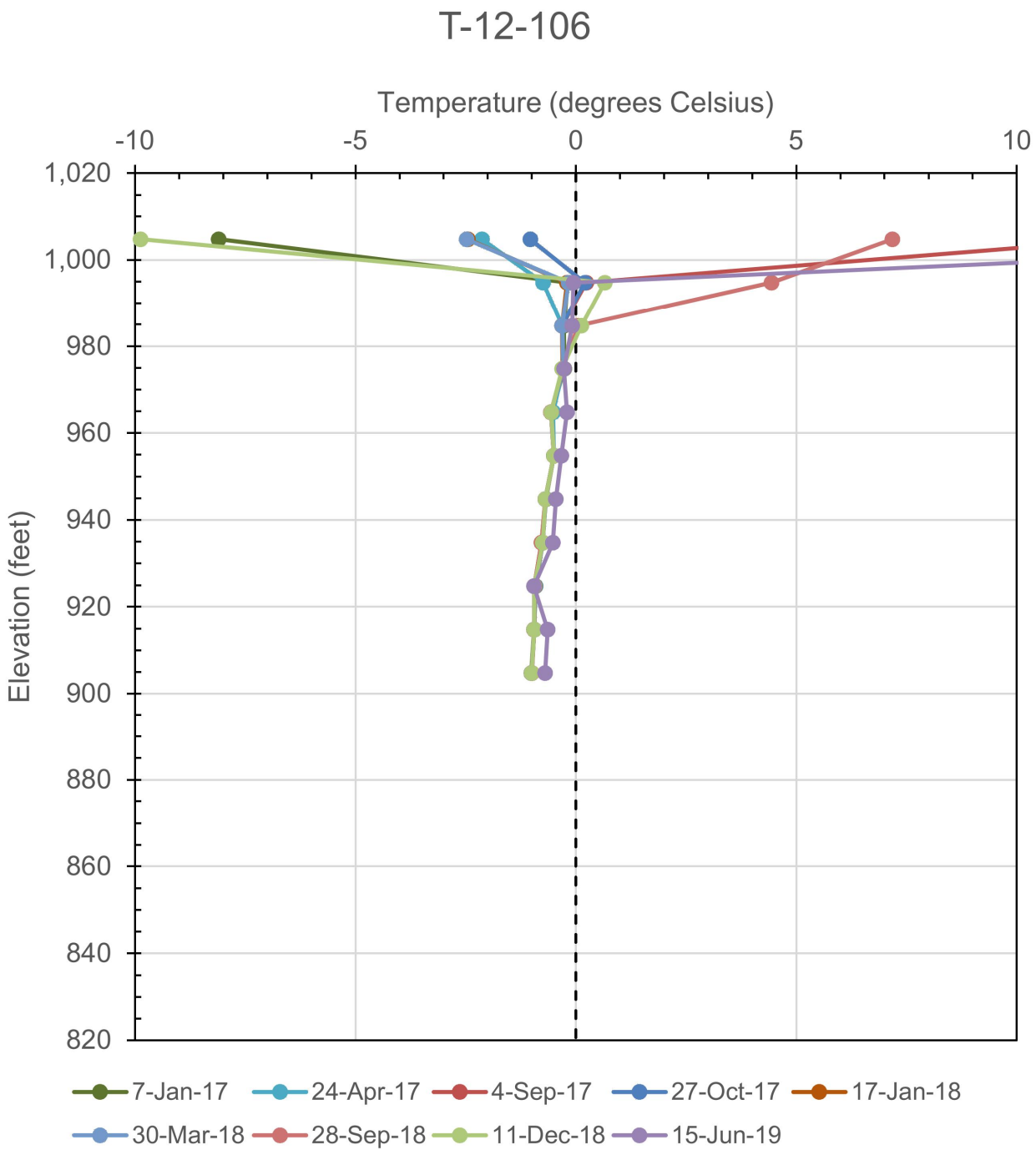


RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT OVERBURDEN STOCKPILE T-96-23

FIGURE C-14

GOLDER

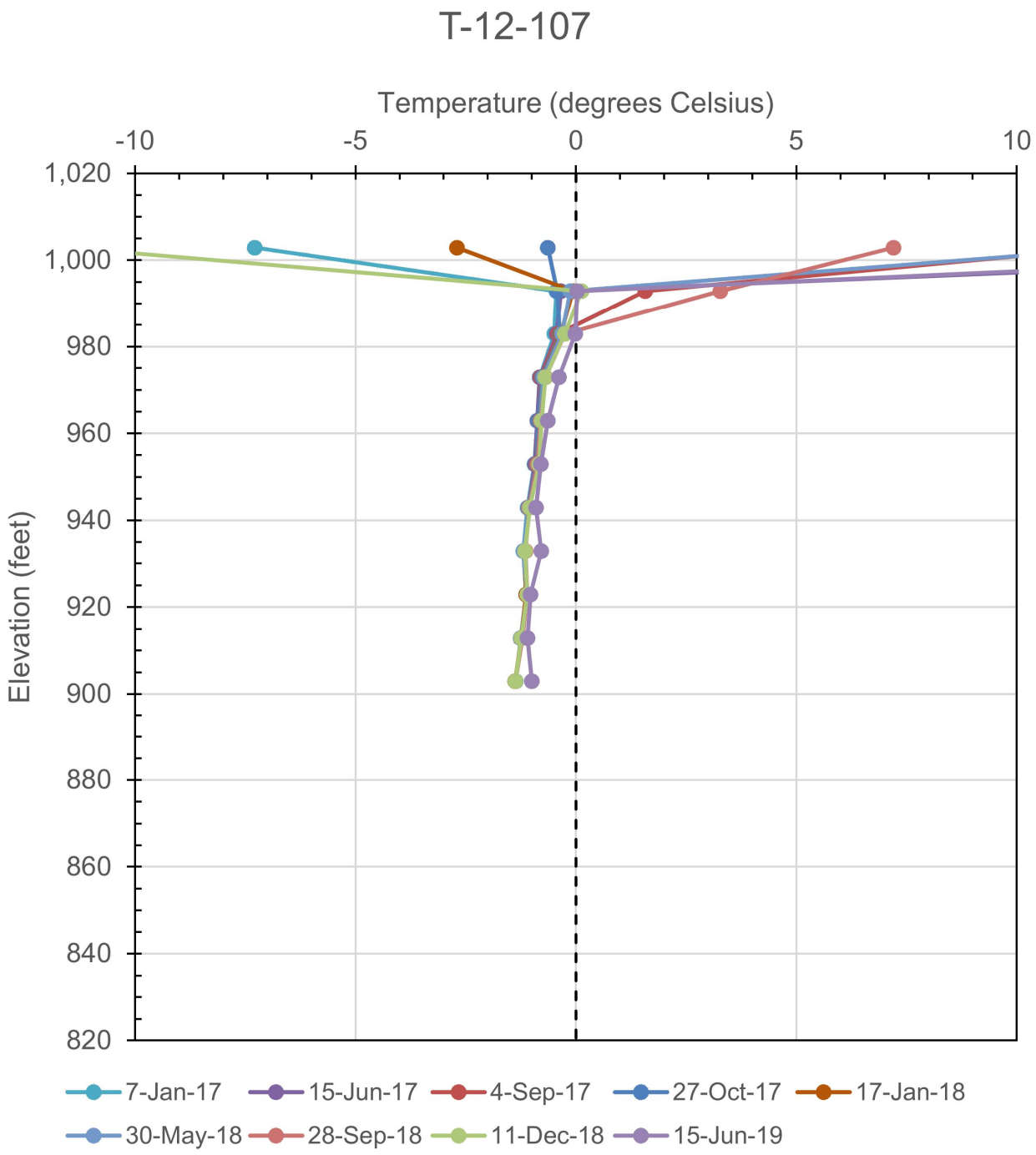


RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT OVERBURDEN STOCKPILE T-12-106

FIGURE C-15

GOLDER

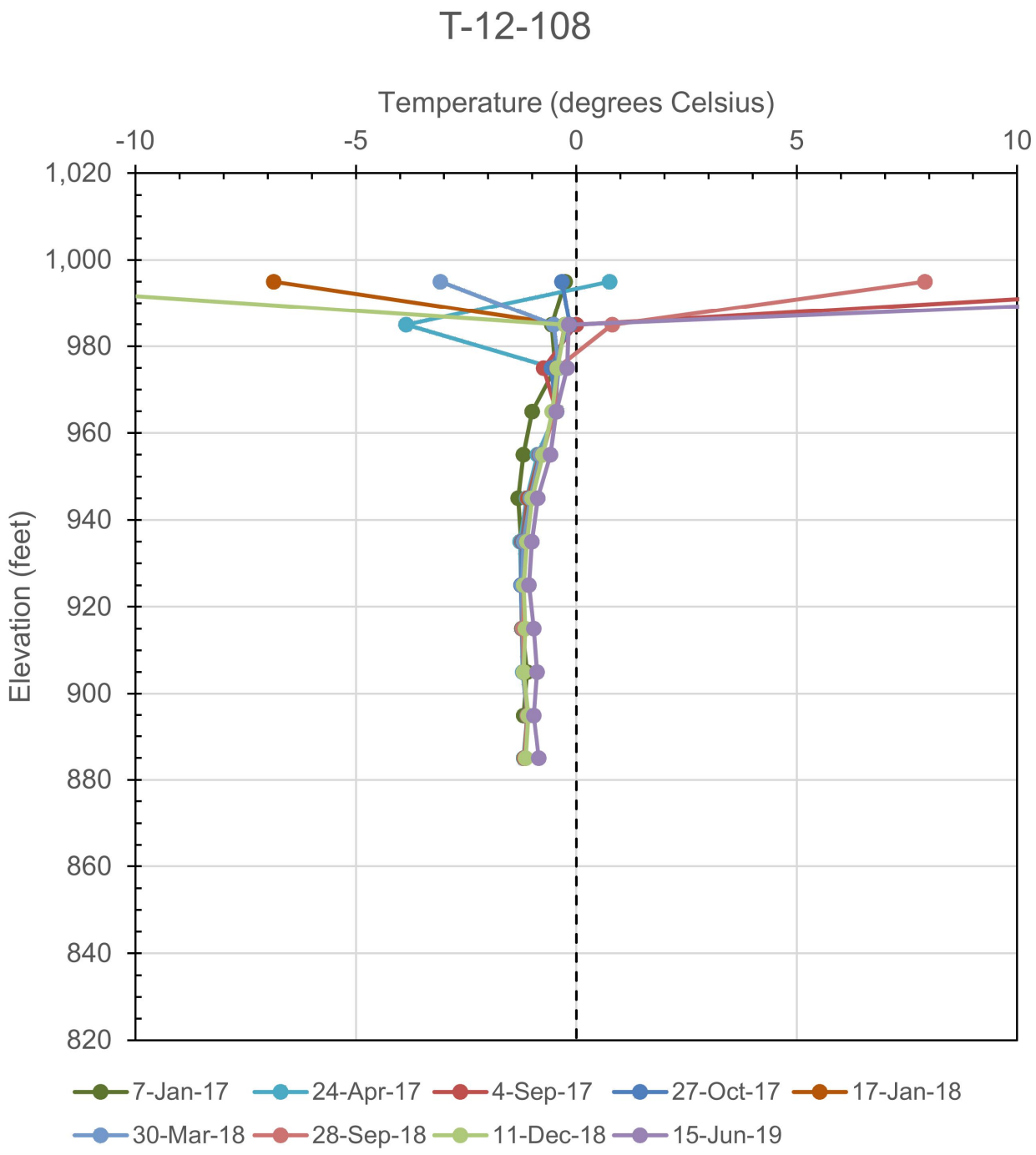


RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT OVERBURDEN STOCKPILE T-12-107

FIGURE C-16

GOLDER

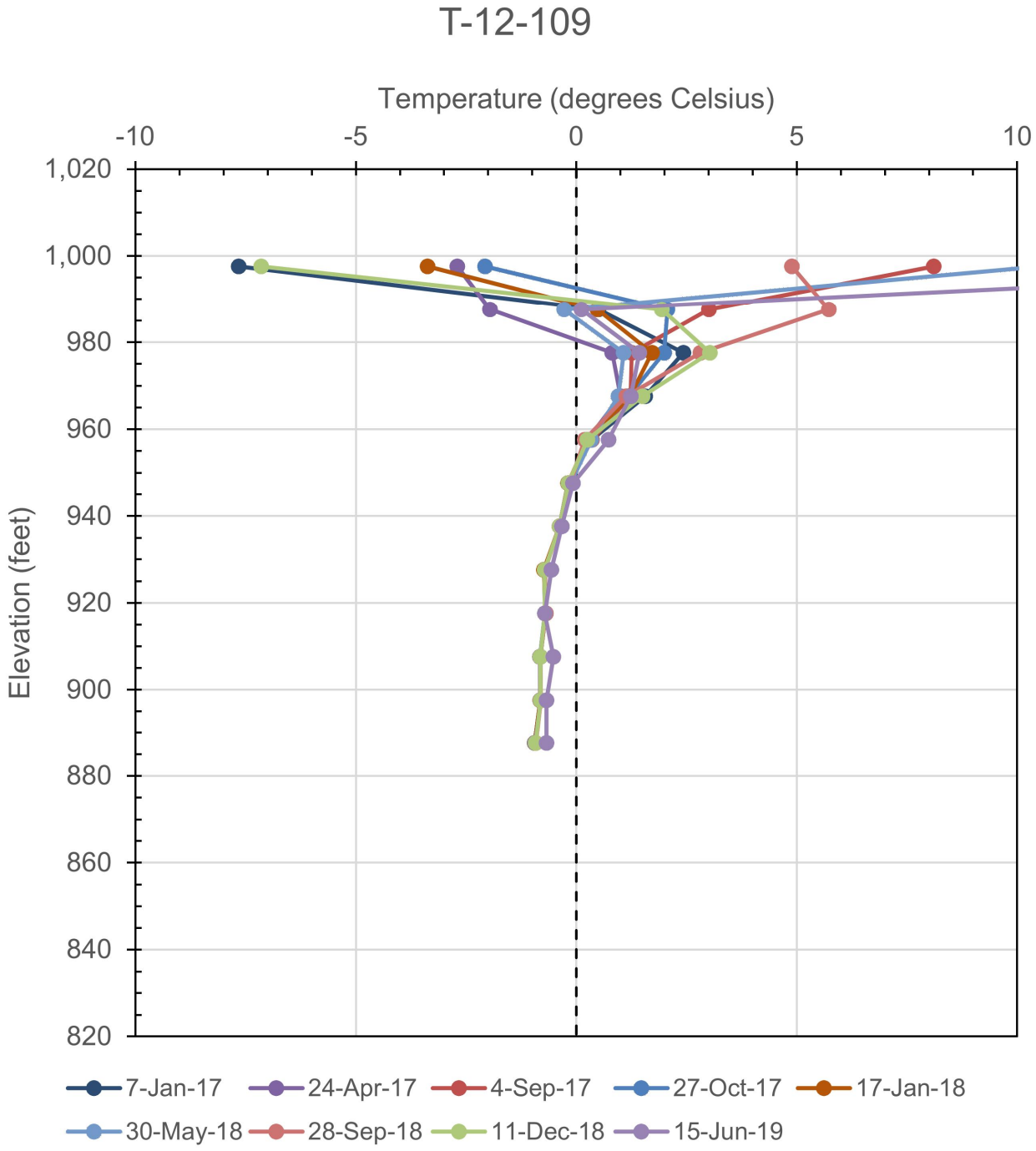


RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT OVERBURDEN STOCKPILE T-12-108

FIGURE C-17

GOLDER

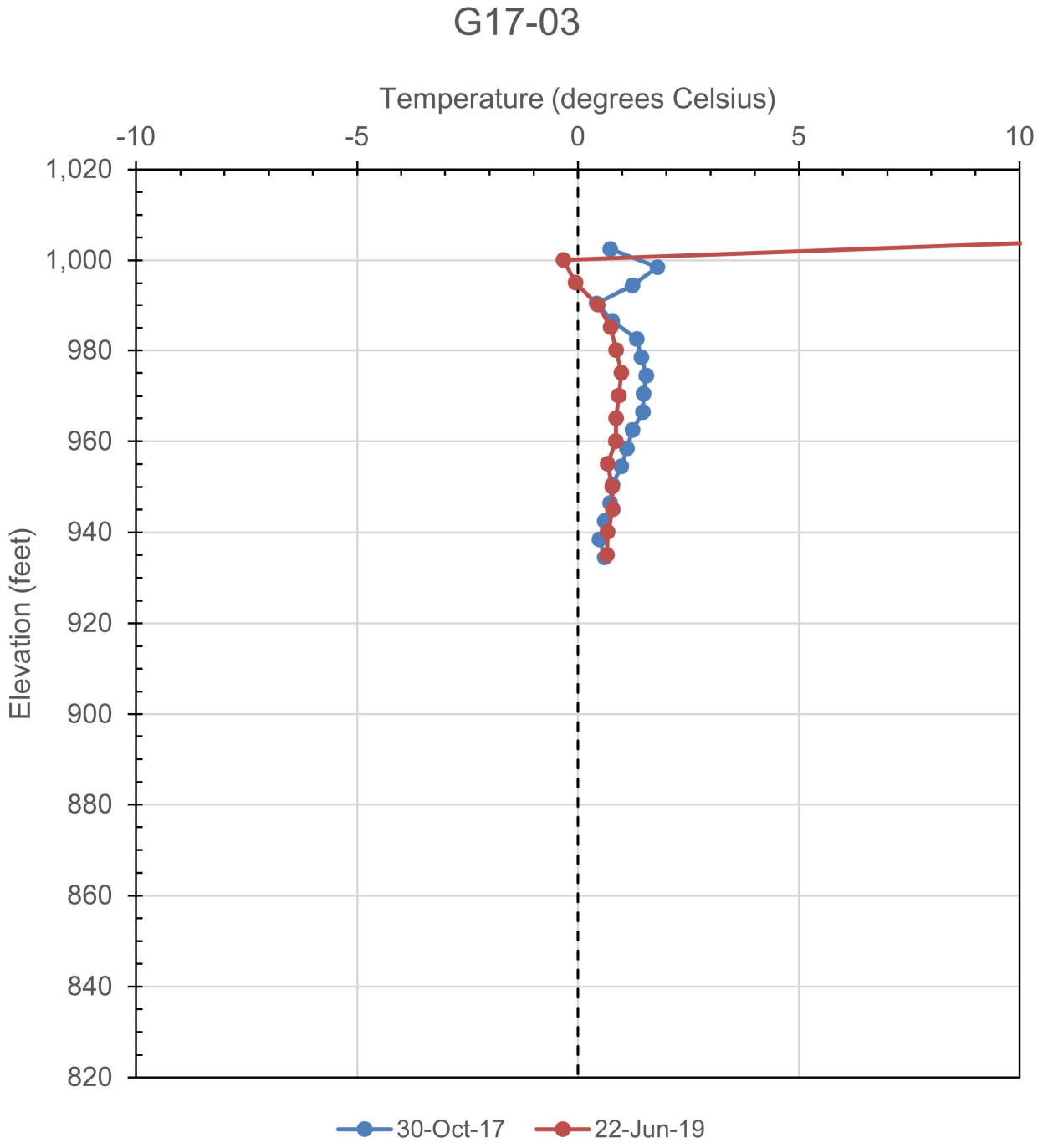


RED DOG 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT OVERBURDEN STOCKPILE T-12-109

FIGURE C-18

GOLDER

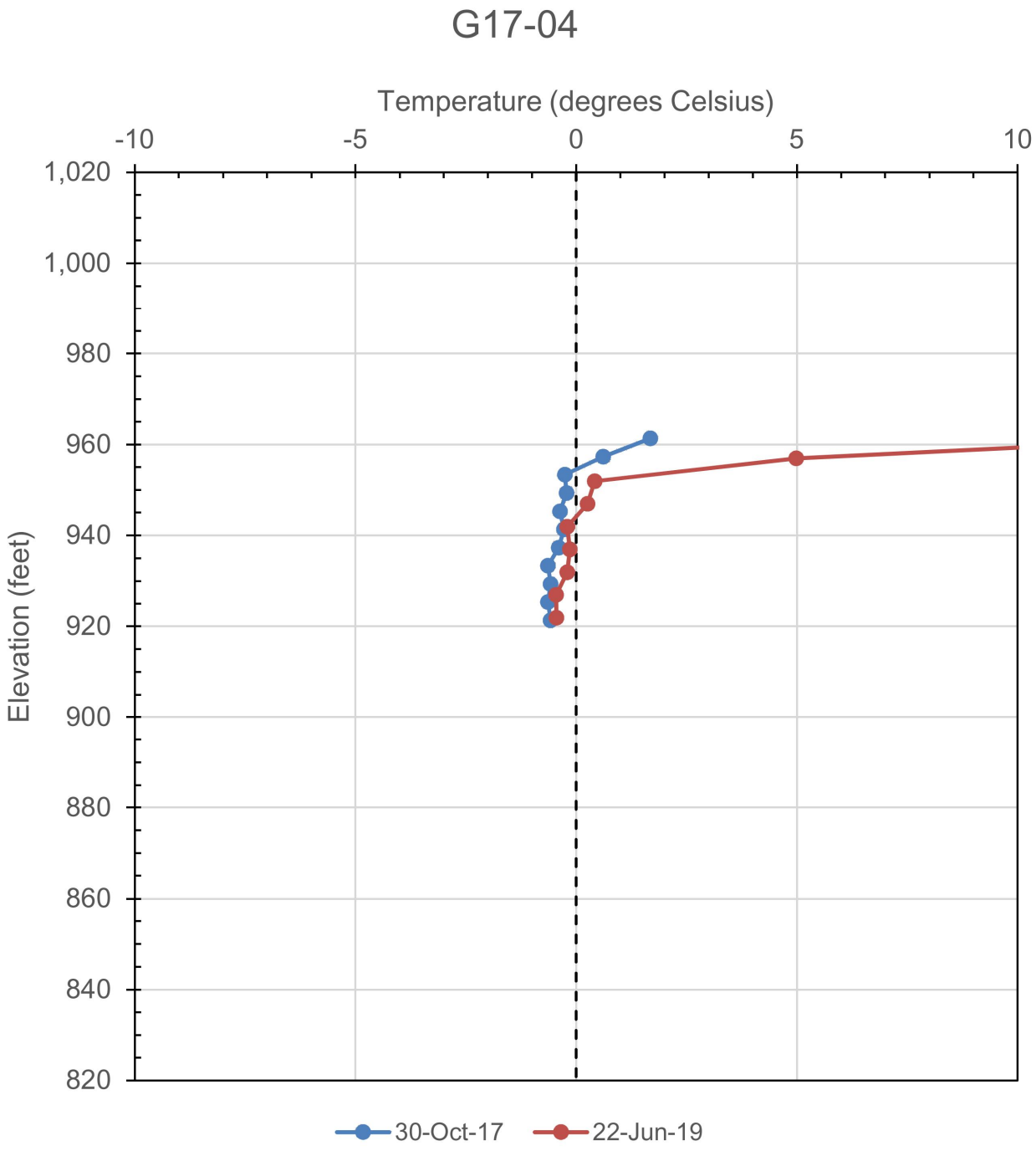


RED DOG MINE 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT OVERBURDEN STOCKPILE G17-03

FIGURE C-19

GOLDER

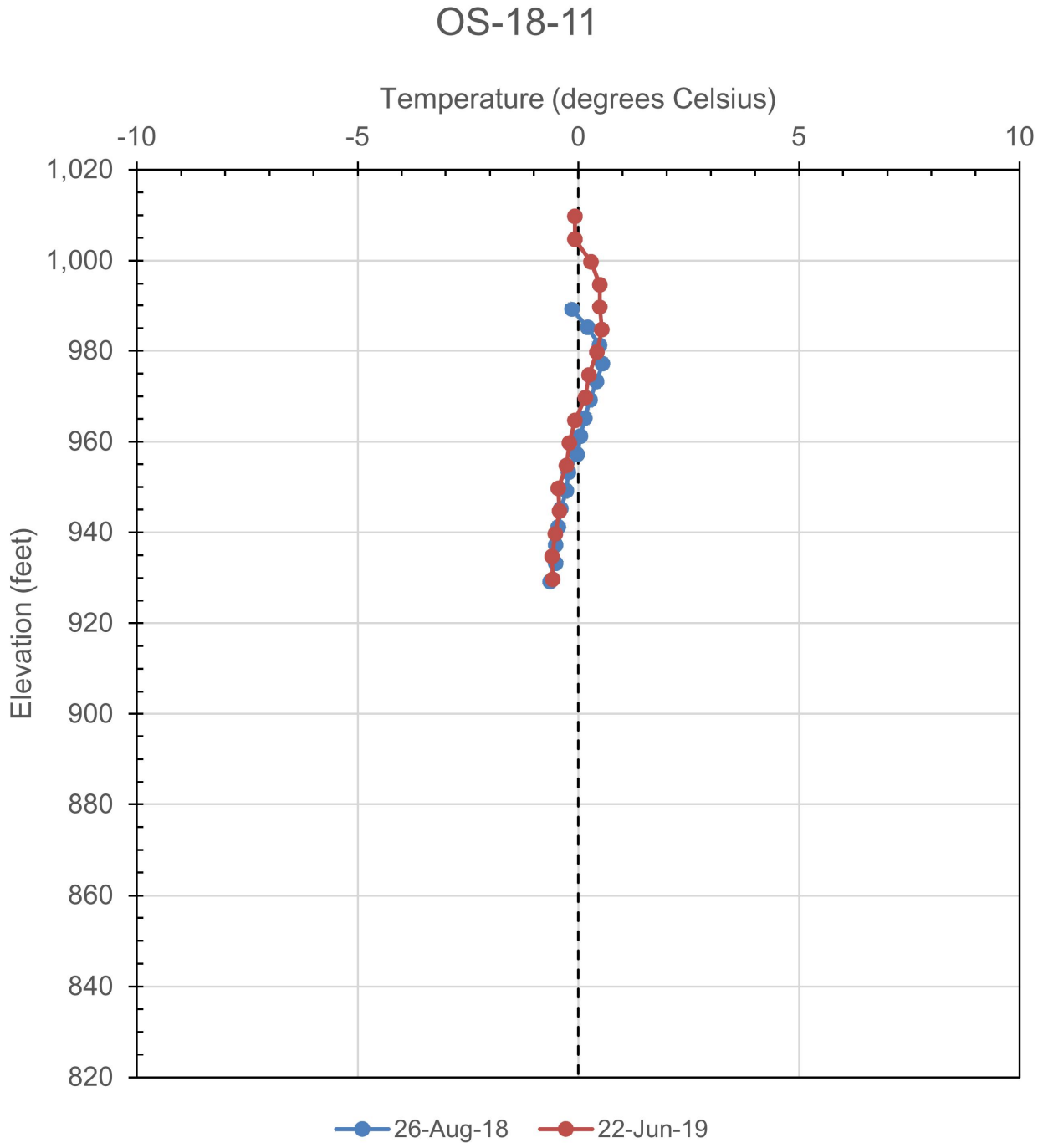


RED DOG MINE 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT OVERBURDEN STOCKPILE G17-04

FIGURE C-20

GOLDER



RED DOG MINE 2019 ANNUAL INSPECTION

GROUND TEMPERATURE DATA AT OVERBURDEN STOCKPILE OS-18-11

FIGURE C-21

GOLDER