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TECHNICAL EVALUATION OF A HEAT EXTRACTION BARRIER

BRIDGETON LANDFILL

BRIDGETON, ST. LOUIS COUNTY, MISSOURI

November 2015

Prepared For:

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Technical Evaluation of a Heat Extraction Barrier

Bridgeton Landfill, LLC

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1 INTRODUCTION

Bridgeton Landfill, LLC ("Bridgeton Landfill") received a letter from the Missouri Department of Natural Resources (MDNR) on August 10, 2015 that included a request for a "...*workplan and schedule identifying a technology or technologies that may be used to halt any potential movement of the South Quarry smoldering fire*...". Bridgeton Landfill submitted a response letter dated August 25, 2015 proposing a technical evaluation of a heat extraction line to control temperature within the Neck Area. In a letter dated September 24, 2015, the MDNR required that the submittal also include *"…contingent corrective measures plan and installation/construction schedules for review and approval by the SWMP"* and *"…evaluation of those additional technologies recommended in the experts' report…"*

The following report titled "Technical Evaluation of a Heat Extraction Barrier" addresses the MDNR's requests in the following manner:

- This submittal comprises a work plan and schedule for implementation as requested,
- This work plan does not address technology to halt movement of a "smoldering fire", as a smoldering fire is not occurring,
- Instead, this work plan provides a technical evaluation and design focused on limiting movement of a potential subsurface heat front. The premise of the design is that a heat front can be neutralized if conditions facilitate extraction of more energy from the surroundings than is required to advance the heat front.

An evaluation of the additional technologies recommended in the experts' report is being addressed in a separate submittal (expert report by SCS Engineers to be submitted October 30, 2015).

This technical evaluation report is comprised of the following sections:

<u>Section 2 – Current Site Conditions</u> The report will include a brief presentation of the current conditions at the Bridgeton Landfill based on in situ waste temperatures and settlement analysis.

<u>Section 3 – Heat Removal Pilot Study Status</u> Bridgeton Landfill has demonstrated the efficacy of extracting heat from the waste mass through a significant heat removal pilot study. This report will include an update of the Heat Removal System Pilot Study which is still ongoing at the facility.

<u>Section 4 – Modeling</u> Thermal modeling software was utilized to determine a location and configuration for a heat extraction barrier (HEB), the goal of which is to maintain a conservative target maximum in situ waste temperature in the neck area, north of the

HEB. Modeling approach, input assumptions, and results are presented in this section of the report.

Section 5 - Heat Extraction Barrier Design Based on the results of the thermal modeling, a detailed design of a HEB will be presented. This section will present hardware details, specific locations of new features, and describe the operational details of the HEB.

Section 6 - System Performance Monitoring The design of the HEB will include a performance monitoring component. Extensive monitoring of the system performance (e.g. total heat extracted for each point) as well as system impact on the environs (e.g. in situ waste temperature north and south of the HEB) will be key performance indicators as described in this section.

Section 7 - Schedule of Installation An implementation schedule is included in this section. The schedule will include time required to complete the various components of the HEB. The components will be evaluated to determine critical path items and produce an estimated completion time from the time that a decision is made to install the HEB.

2 CURRENT SITE CONDITIONS

On August 13, 2013, Bridgeton Landfill submitted a report titled "North Quarry Contingency Plan" that was required by the First Agreed Order. Appendix E of that report, "Correlations of Site Metrics with Reaction Predictions," contained a thorough analysis of site data to assess how to determine the presence, location, and movement of the subsurface reaction. Among the conclusions are that the best parameters to identify the leading edge of reaction activity were: surface settlement rates greater than 1.35 feet per month (30 days) and in situ waste temperatures greater than 220° F as measured by thermocouples installed in the waste. Settlement rate and in situ temperatures have been observed to be up to 3.4 feet per month and approximately 300° F in the most active portions of the reaction but the edge of the reaction can be identified by the lower values previously stated. The analysis further concludes that when reaction activity abates in an area, settlement rates decrease but residual heat will remain causing temperatures to stay elevated.

Using these parameters, we have assessed the current conditions at Bridgeton Landfill which include:

1. An active subsurface reaction is still occurring in the South Quarry; however, the area of high activity is focused in the extreme southeast portion of the South Quarry.

2. The overall magnitude of subsurface reaction in the South Quarry has been steadily declining since at latest October 2013, as determined by monthly settlement volume analysis.
3. The subsurface reaction advanced northward until about October 2013 after which the reaction activity abated. Elevated temperatures remain south of the neck most likely as residual heat from the previous reaction activity in this area (October 2013). Conditions in the neck area have stabilized.
4. There is no evidence of subsurface reaction in the Neck Line or the North Quarry.

These items are further described in the following sections.

Location of Highly Active Subsurface Reaction

Appendix A presents a figure that shows the portion of the South Quarry that is experiencing settlement rates greater than 1.35 feet per 30 day period. This elevated settlement zone is limited to a small area within the light green shade in the southeastern portion of the South Quarry. Elevated temperatures remain outside of this high-settlement area, but as explained previously, this is due to residual heat left by a highly-active subsurface reaction previously experienced in the respective area.

Magnitude of Subsurface Reaction Activity

Since at least October 2013, the overall activity level of the subsurface reaction has been decreasing. Quantity of measured settlement (e.g. cubic yards per day) is indicative of the overall level of activity because the reaction results in an expedited reduction of waste mass. Overall settlement volume in the South Quarry has shown a significant decreasing trend since December 2013. As can be seen in **Appendix B**, the overall settlement volume has decreased consistently from approximately 1,500 cubic yards per day in December 2013 to below 600 cubic yards per day at present.

Conditions in the Neck Area

Until about mid-2013, subsurface reaction activity was shown to be moving toward the neck at a rate of approximately 0.5 feet per day based on advancement of the high-settlement zone. The northernmost advance of this "settlement front" occurred in October of 2013 (shown in **Appendix C**), reaching just beyond GIW-5 and -6 in the southern line of GIWs. The northward movement of the settlement front ceased in October 2013 and the rate of settlement south of the neck has been steadily declining throughout 2014 and 2015. Settlement within the neck has been consistent with normal landfill rates.

Using maximum in situ waste temperature measurements from TMPs, the northernmost extent of in situ waste temperature greater than 220° F is approximated on the figure in **Appendix C**. Construction details for the TMPs are provided in **Appendix D** and temperature graphs for the TMPs are included in **Appendix E**. The 220° F line is farther north than the settlement front line likely due to conduction and convection of the residual heat that was left in the area after the high subsurface reaction activity in this area abated (around October 2013). The TMP graphs generally indicate a moderate rise in temperature in the neck area in 2013, very slight rise in 2014, and steady or declining temperatures in 2015 (see trend graphs in the front portion of **Appendix E**). This data suggest that the northward conduction of heat has ceased.

So, while elevated temperatures remain from previous activity in the area, and have conducted north somewhat, the settlement front has abated and is now only present in a small area in the southeast portion of the South Quarry. In situ waste temperatures in the neck area have stabilized. It appears that this residual heat in the neck area is no longer being conducted northward because it is being mitigated by the natural conditions (e.g. heat absorption into quarry walls and ambient atmosphere) and by induced conditions (e.g. heat removed by the pilot study and other gas and leachate removal measures).

No Evidence of Subsurface Reaction in the Neck Line or North Quarry

Maximum in situ waste temperature are typically 20^{o} – 40^{o} higher than gas wellhead temperatures due to thermal averaging and cooling of gas as it travels to the wellhead. Using 120^{o} F – 140^{o} F as typical wellhead temperature in unaffected areas of Bridgeton Landfill, under normal methanogenic conditions, the respective maximum in situ waste temperatures would be expected to be approximately 140^{o} to 180^{o} F, dependent on waste thickness.

A neck line of TMPs has been monitored since November of 2012. The original locations were designated TMP-1, -2, -3 and -4. In February of 2015 TMP-3R and -4R were installed to provide continued temperature profiles at the respective locations. These TMP temperature profiles have indicated normal and consistent methanogenic biological temperatures since installation (**Appendix E**).

Data collected from TMPs in the North Quarry (TMP-16, -17, -18, -21, -22, -23, -24, -25, -26, -27, -28 and -29) have shown normal methanogenic biological temperature profiles at the respective locations. Temperature profiles for each of the North Quarry TMPs are included in **Appendix E.**

3 HEAT REMOVAL PILOT STUDY STATUS

Bridgeton Landfill developed the concept of enhancing Gas Interceptor Wells (GIWs) at the landfill into dual-purpose features that added heat removal by closed-loop water circulation. In July 2013, a closed loop was inserted into GIW-4 and water was circulated through the loop. It was immediately clear that significant heat could be removed and the heat removal sustained. This original testing successfully demonstrated the ability to remove over 15 kW from the single point.

Based on the success in GIW-4, Bridgeton Landfill proposed expanding the pilot study to include the enhancement additional GIWs. In September 2014, MDNR approved an Expanded Heat Removal Pilot Study. This expansion included enhancement of existing GIW-2, -3, -4, -5, -6, -7 and -10. The enhancement included installation of closed loop heat removal piping within the original steel casing. Also included in this phase of the study was installation of eleven (11) additional TMPs.

In July 2015, in an effort to increase heat removal and increase knowledge of heat removal related properties, Bridgeton Landfill enhanced five (5) additional GIWs (-8, -9, -11, -12 and -13) with heat removal technology. The enhanced heat removal points are currently operating as part of the Heat Removal Pilot Study System are shown in **Appendix F**. Heat extraction data from each of the pilot study points is included in **Appendix G**.

Pursuant to operation of the expanded system, a significant data collection effort was employed. This included weekly measurement of the TMPs and approximately bi-weekly reading of heat removal points. Data collected and subsequent analysis of data has been chronicled in the following pilot study reports:

-Expanded Heat Removal Pilot Study Quarterly Report (January 2015)
-Expanded Heat Removal Pilot Study Quarterly Report (April 2015)
-Expanded Heat Removal Pilot Study Quarterly Report (August 2015)
-Expanded Heat Removal Pilot Study Initial Report (August 2015)
-Expanded Heat Removal Pilot Study Quarterly Report (October 2015)

The current heat removal pilot study system continues to operate twenty-four hours per day and seven days per week. The system is currently removing over 7 million BTUs per day. The pilot study has conclusively demonstrated the ability to continuously and steadily remove heat from the waste mass.

Discussion of the data obtained and conclusions derived from the pilot study are presented below.

TMP Data within the Pilot Study Area

As part of the Expanded Heat Removal Pilot Study, the following eight (8) TMPs were installed adjacent to heat removal points GIW-5 and -10:

TMP 10-9N	TMP 5-9N
TMP 10-5N	TMP 5-5N
TMP 10-9S	TMP 5-9S
TMP 10-5S	TMP 5-5S

The naming convention is utilized to define the location of the TMP. Specifically, the first number designates the GIW that the TMP is adjacent to (TMP 10-5N is located next to GIW 10). The second number designates the offset distance from the GIW at the ground surface (TMP 10-5N is located five (5) feet away from the respective GIW). The last letter designates the general direction the TMP is offset from the local heat removal point or GIW (TMP-5N is approximately five (5) feet to the north of the GIW). The TMP installations were drilled at the specified offset distance at the ground surface. At depth, these offsets may vary due to differential settlement. All eight TMPs were installed to a depth of one hundred feet below the ground surface.

Generally, the thermocouples showed significant temperature reduction on TMPs drilled on the north side of the heat extraction element and moderate temperature reduction on the south side. This comparison of temperatures on the north side of the heat extraction to those on the south side suggest a heat flux from south to north which may be residual heat from a reaction which was previously highly active south of the neck area. The historic temperature profiles have been included in **Appendix E**.

The following tables represent the average of heat removal measured comparing temperature prior to heat removal system operation to recent measurements. The temperature reduction average is based on all thermocouple depths at each respective location.

GIW 10 Heat Removal Point

Location	Average Temp Reduction ^{o}F
TMP 10-9N	58
TMP 10-5N	98
TMP 10-9S	16
TMP 10-5S	29

GIW 5 Heat Removal Point

Location	Average Temp. Reduction ^{o}F
TMP 5-9N	43
TMP 5-5N	50
TMP 5-9S	11
TMP 5-5S	14

<u>TMP Data North of Original Expanded Heat Removal Pilot Study Line</u>

TMP-19 and -20 were installed in the South Quarry between the two lines of GIWs as part of the Expanded Heat Removal Pilot Study. TMP-19 is located approximately twenty-five (25) feet away from the closest heat removal point. TMP-20 is located approximately thirty (30) feet away from the closest heat removal point. These TMPs were installed to determine the effect of the heat removal pilot study in GIW-2, -3, -4, -5, -6, -7 and -10 on in situ waste temperatures a distance from the removal points. These TMPs showed temperature reduction of 20 to 30^{o} F; as the same time frame as the heat extraction was performed in the vicinity, thus demonstrating an ability to remove heat from a distance of at least thirty (30) feet under the conditions present in this area. The temperature profiles for TMP-19 and -20 are included in **Appendix E**.

Several TMPs have been utilized to continually assess the heat conditions in the neck area. These include TMP-6, -14R, -10 and -11. The maximum temperatures in these probes have been stable for the last several months. The maximum temperature graphs for all TMPs have been included in **Appendix E**.

4 MODELING

Thermal modeling using finite element analyses has been conducted to support the design of the heat extraction barrier (HEB). The modeling effort has been contracted to P.J. Carey & Associates, P.C. (Carey). A detailed report describing the modeling software, input parameters, boundary conditions, and results is included in **Appendix H** of this report.

> *It is important to recognize that the model is a <u>simulation</u> that requires the virtual placement and addition of an elevated heat-*

generating zone where one does not now exist. As discussed in Section 2, temperatures in the neck area are stable and it appears that a subsurface reaction is not highly-active in the neck area and that heat is not migrating north. However, for purposes of design of a heat extraction barrier, a heat flux must be simulated to assess the capability of the barrier to withstand a subsurface reaction should one ever exist in the neck area.

Details regarding the derivation of input assumptions, the model function, and results are presented in Appendix H and summarized below:

- Waste thermal properties have been calculated using results from the heat removal pilot studies. The model employs a waste thermal conductivity value of 1.4 watts per meter-degree Kelvin, and a waste heat capacity of 2.4 mega joules per cubic meter.
- Boundary conditions around the HEB have been determined based on actual temperature data.
- The model does not account for heat loss into the quarry walls, which is a significant conservative assumption.
- The modeling and design of the HEB assumes that heat removal conducted in the pilot study is continued in the future and becomes part of the overall long-term heat removal effort.
- The modeled heat generating zone (simulated subsurface reaction) is positioned approximately 80 feet north of the northern GIW line and at a depth range of 40-160 feet below ground surface. The heat flux assigned to the heat-generating zone is 0.7 watts per cubic meter (w/m^3). Normal methanogenic heat generation in the North Quarry is assigned as 0.25 w/m^3.
- Modeling results indicate that heat extraction points at a 15 foot center-to-center spacing with a maximum depth of 180 feet achieve the HEB goals.
- The model has been run for five-year duration and near steady-state results are observed at the end of the modeled period.
- A target maximum long-term in situ waste temperature north of the HEB and south of the neck was arbitrarily selected as 180° F. This target temperature was picked to be conservatively below the 200° F proposed by the MDNR in its July 24, 2013 letter (Table 1) for a "sentry criteria," and the 220° F level that Bridgeton Landfill believes may represent the leading edge of an approaching subsurface reaction. The model and design achieves this target.

The modeling effort is considered to be conservative in many respects, and is based on the premise that a significant heat-generating zone appears further north in the neck area further north than has ever been observed and even though data (see Section 2 of this report) suggests that there is no net positive heat flux in the HEB area at this time.

As described in Section 6 of this report, the HEB system will include performance monitoring. Due to the sensitivity of model results to input values, it is recommended that modeling be performed again within one year of system startup. This re-run would incorporate actual performance results to allow for calibration of model input. If a recalibrated model suggests that more heat is being generated than modeled, or less heat is being removed than modeled, or suggests that temperature targets are not being achieved, the HEB can be augmented with additional heat removal points.

5 HEAT EXTRACTION BARRIER DESIGN

Based on the findings compiled from the Expanded Heat Removal Pilot Study and the modeling performed and described in Section 4 of this report, Bridgeton Landfill has completed a full scale HEB design for the neck area. The purpose of the design is to maintain in situ waste temperatures in the neck area, north of the HEB, well below the 220° F value that could indicate presence of subsurface reaction.

The design of the HEB incorporates many of the existing features from the pilot study systems currently underway. In addition to existing components, the design includes a new line of heat removal points on fifteen (15) foot centers located north of the GIWs and south of the neck as shown on the drawings in **Appendix I.** The heat removal points will be advanced to within 15 feet of the estimated quarry bottom or to a maximum depth of 180 feet, whichever is greater.

Other major components of the system include:

- A 20,000 gallon equalization tank,
- A 23 horsepower Flygt Submersible pump with a variable frequency drive. Based on the performance curve for the pump and the maximum head calculation, the system pump would be able to supply over 6 gallons per minute (gpm) to 40 heat removal points, and
- The current closed loop cooling tower which has a capacity of 250 gpm and is able to temperature treat from 108° F to 85° F at 78° F wet-bulb temperature.

The heat extraction points are to be installed in a borehole or casing created by mud-rotary drill rig or a sonic drill rig. Both methods will include drilling to the desired depth, setting the heat removal point with a crane, and then backfilling with a cement grout mixture that exhibits high thermal conductivity. The influent and effluent piping at the top of the point is shown in **Appendix I**.

6 SYSTEM PERFORMANCE MONITORING

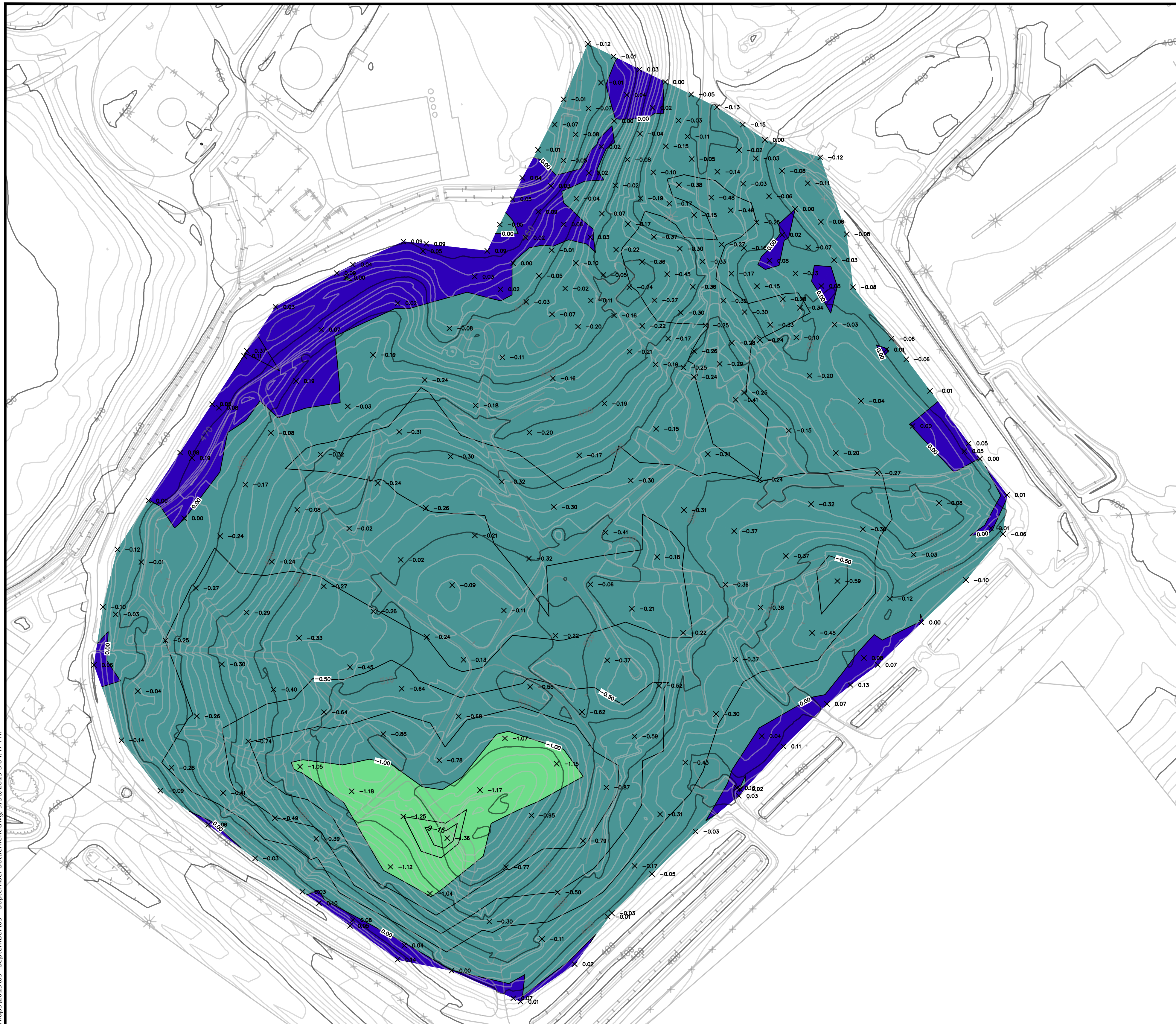
System performance monitoring is intended to verify that the heat removal system is achieving a target temperature in the neck area north of the HEB and to assess the presence and trend of heat input from south of the HEB. This will be verified by routine measurements of eight TMPs shown in **Appendix J**. Three of the TMPs are existing (TMP-1, -3R and -4R) and five are anticipated to be installed in conjunction with the HEB (TMP-2R, TMP-SPM1, -SPM2, -SPM3, and -SPM4). Bridgeton Landfill will perform regular operation, maintenance and data observation to ensure the system is functioning as designed. The facility Operation, Maintenance, and Monitoring Plan will be revised to include these procedures.

Monitoring of conditions south of the HEB will also allow determination of when heat extraction may be slowed, terminated, or even—if necessary—supplemented with additional points to achieve performance goals.

7 SCHEDULE OF INSTALLATION

Installation could be completed as quickly as (4) months from the time that a decision is made to proceed. The schedule is comprised of necessary time for materials procurement, contract completion for third party contractors, site preparation work, drilling and heat removal point installation, above ground piping and final connections. A detailed schedule of these construction components has been included as **Appendix K.** This schedule is contingent on inclement weather and unforeseen material sourcing delays.

Appendix A – Settlement Map



0 200'

GRAPHIC SCALE

NOTES

1. EXISTING CONTOURS DEVELOPED FROM SITE AERIAL TOPOGRAPHIC SURVEY BY COOPER AERIAL SURVEYS, CO. ON FEBRUARY 10, 2015.
2. FOR CLARITY, NOT ALL SITE FEATURES MAY BE SHOWN.
3. ELEVATION DIFFERENCE DETERMINED BY SUBTRACTING SPOT ELEVATIONS SURVEYED ON 8-17-15 FROM SPOT ELEVATIONS SURVEYED ON 9-15-15.
4. SURVEY POINTS WERE PERFORMED USING GPS METHODS.
5. SETTLEMENT RANGE SURFACE WAS GENERATED FROM THE SPOT ELEVATION DIFFERENCES.
6. ELEVATION DIFFERENCES THAT ARE SHOWN AS NEGATIVE INDICATE SPOTS OF SETTLEMENT.
7. ANY POINTS THAT ARE NOT A GROUND-TO-GROUND COMPARISON TO THE PREVIOUS MONTH'S POINTS, OR THAT WERE NOT SURVEYED IN THE SAME LOCATION AS THE PREVIOUS MONTH ARE NOT INCLUDED AND WERE NOT USED IN ANY SURFACE GENERATION.

LEGEND

× −0.42 SPOT ELEVATION DIFFERENCE (9-15-15 TO 8-17-15)

MINOR ELEVATION CHANGE CONTOUR (0.25 FEET)

−0.50 MAJOR ELEVATION CHANGE CONTOUR (0.50 FEET)

9−15 SETTLEMENT FRONT CONTOUR FOR AREA WITH 1.35' PER 30 DAYS FOR CURRENT PERIOD OF DAYS (AREA REPRESENTS 1.305' OVER 29 DAYS BASED ON CONVERSION)

ELEVATION CHANGE (FEET)				
Number	Minimum Elev. Change	Maximum Elev. Change	Area (sq.ft.)	Color
1	−5.00	−4.00	0.00	
2	−4.00	−3.00	0.00	
3	−3.00	−2.00	0.00	
4	−2.00	−1.00	62082.61	
5	−1.00	0.00	1335876.76	
6	0.00	1.00	142918.54	

REV. NO.	DATE	DESCRIPTION

BRIDGETON LANDFILL

CB&I Environmental & Infrastructure, Inc.

STATE OF ILLINOIS LICENSED DESIGN FIRM #184004093

BRIDGETON LANDFILL
BRIDGETON, MO

SETTLEMENT MAP
AUGUST 17, 2015 THROUGH SEPTEMBER 15, 2015

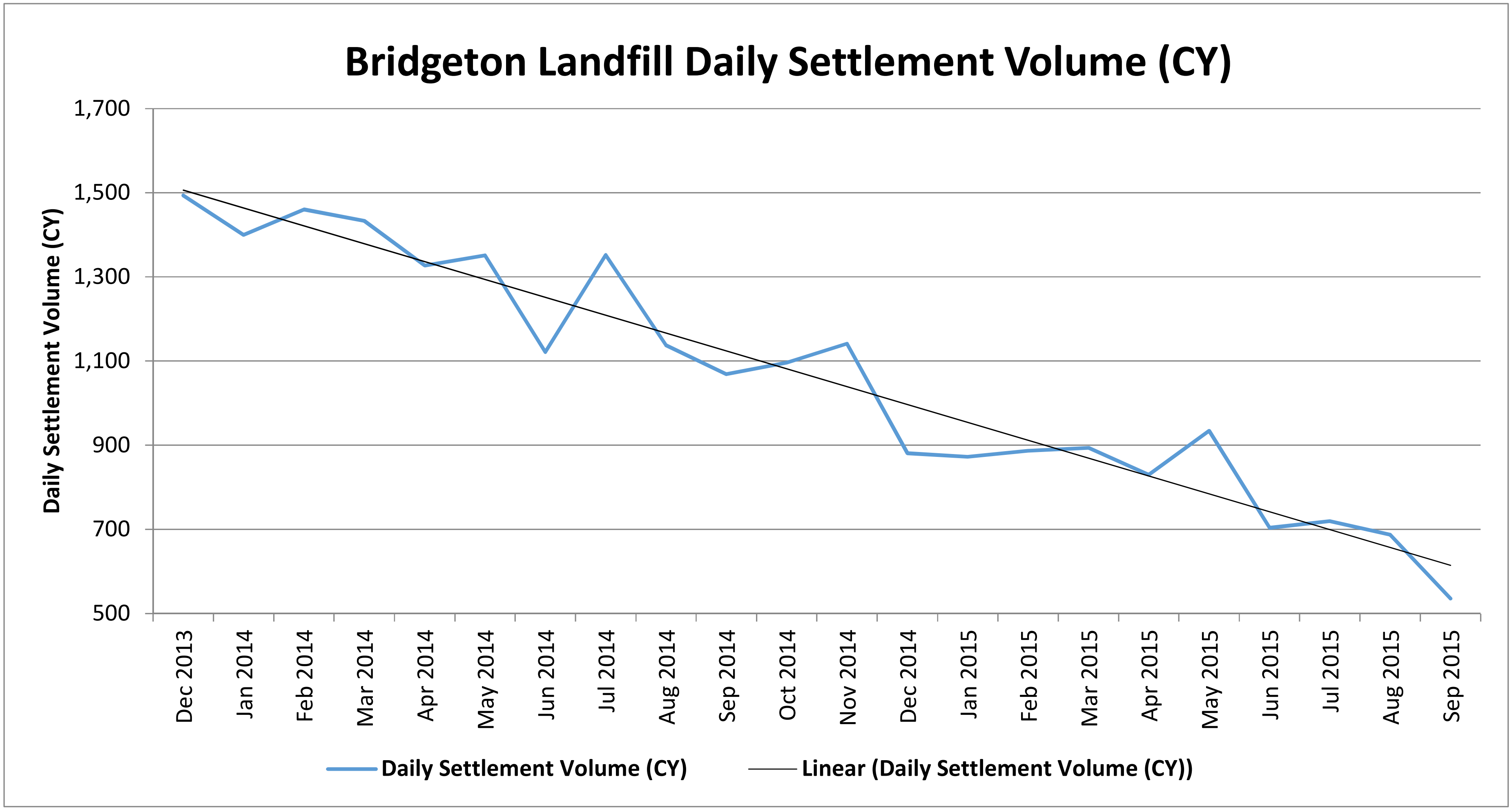
DRAWN BY: ORC | APPROVED BY: JPV | PROJ. NO.: 155162 | DATE: OCTOBER 2015

T:\AutoCAD\Projects\Bridgeton LF\Settlement Maps\2015\09 - September\09 - September Settlement.dwg, 9/30/2015 3:04:47 PM

Appendix B - Settlement Volume Analysis

BRIDGETON LANDFILL
SOUTH QUARRY SETTLEMENT VOLUME

	DAYS BETWEEN	SETTLEMENT VOLUME	AREA OF SETTLEMENT	AVG. SETTLEMENT
DATES	SURVEYS	(CY)	(SF)	CY/DAY
11-16-13 TO 12-19-13	33	49,297	1,484,401	1,494
12-19-13 TO 1-16-14	28	39,202	1,310,212	1,400
1-16-14 TO 2-18-14	33	48,183	1,420,729	1,460
2-18-14 TO 3-15-14	25	35,837	1,510,980	1,433
3-15-14 TO 4-15-14	31	41,153	1,454,183	1,328
4-15-14 TO 5-15-14	30	40,547	1,487,918	1,352
5-15-14 TO 6-15-14	31	34,772	1,423,179	1,122
6-15-14 TO 7-15-14	30	40,566	1,508,545	1,352
7-15-14 TO 8-15-14	31	35,278	1,488,288	1,138
8-15-14 TO 9-15-14	31	33,147	1,507,655	1,069
9-15-14 TO 10-15-14	30	32,912	1,486,440	1,097
10-15-14 TO 11-15-14	31	35,385	1,456,589	1,141
11-15-14 TO 12-18-14	33	29,073	1,450,136	881
12-18-14 TO 1-15-15	28	24,440	1,468,954	873
1-15-15 TO 2-13-15	29	25,721	1,382,888	887
2-13-15 TO 3-14-15	29	25,933	1,526,126	894
3-14-15 TO 4-17-15	34	28,222	1,401,940	830
4-17-15 TO 5-13-15	26	24,299	1,511,893	935
5-13-15 TO 6-16-15	34	23,923	1,381,817	704
6-16-15 TO 7-15-15	29	20,874	1,484,387	720
7-15-15 TO 8-17-15	33	22,681	1,540,907	687
8-17-15 TO 9-15-15	29	15,534	1,538,385	536



Bridgeton Landfill Daily Settlement Volume (CY)
Daily Settlement Volume (CY)
1,700
1,500
1,300
1,100
900
700
500
Dec 2013
Jan 2014
Feb 2014
Mar 2014
Apr 2014
May 2014
Jun 2014
Jul 2014
Aug 2014
Sep 2014
Oct 2014
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Sep 2015
Daily Settlement Volume (CY)
Linear (Daily Settlement Volume (CY))

Appendix C - Neck Area Conditions

NOTE: THE TEMPERATURE CONTOUR DISPLAYED WAS DEVELOPED BY INTERPOLATING BETWEEN THE MAXIMUM TEMPERATURE MEASURED AT THE FOLLOWING POINTS: TMP-5, -6, -9, 10-9N, -13, -14R, -19 AND -20. THE MAXIMUM TEMPERATURES WERE MEASURED AT DIFFERENT DATES THEREFORE THIS CONTOUR DOES NOT REPRESENT A SINGLE POINT IN TIME. TMP-12 WAS NOT INCLUDED DUE TO UNSTABLE READINGS DATING BACK TO JANUARY OF 2014.

NOTES:
1.) AERIAL TOPOGRAPHY WAS PROVIDED BY COOPER AERIAL SURVEYS CO. AND IS DATED MARCH 20, 2014.

BRIDGETON LANDFILL, LLC
13570 ST. CHARLES ROCK ROAD
BRIDGETON, MISSOURI 63044

BRIDGETON LANDFILL

NECK AREA CONDITIONS

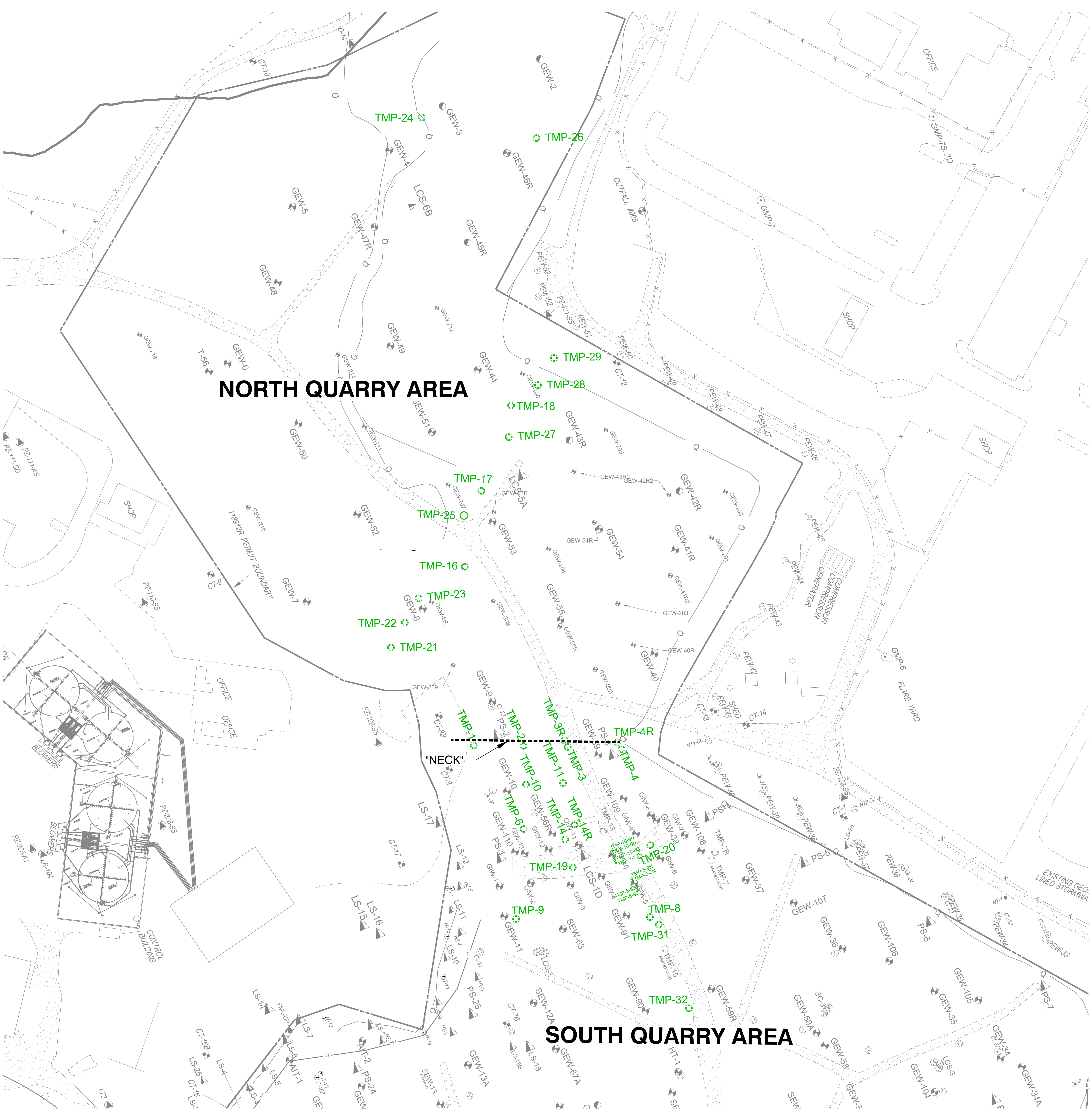
FEEZOR ENGINEERING, INC.
Engineering for a Better World

NOVEMBER 2015
DESIGNED BY: DMK
APPROVED BY: ALK

APPENDIX: C

PROJECT NUMBER: BT-062 | FILE PATH:
REVISION | DATE

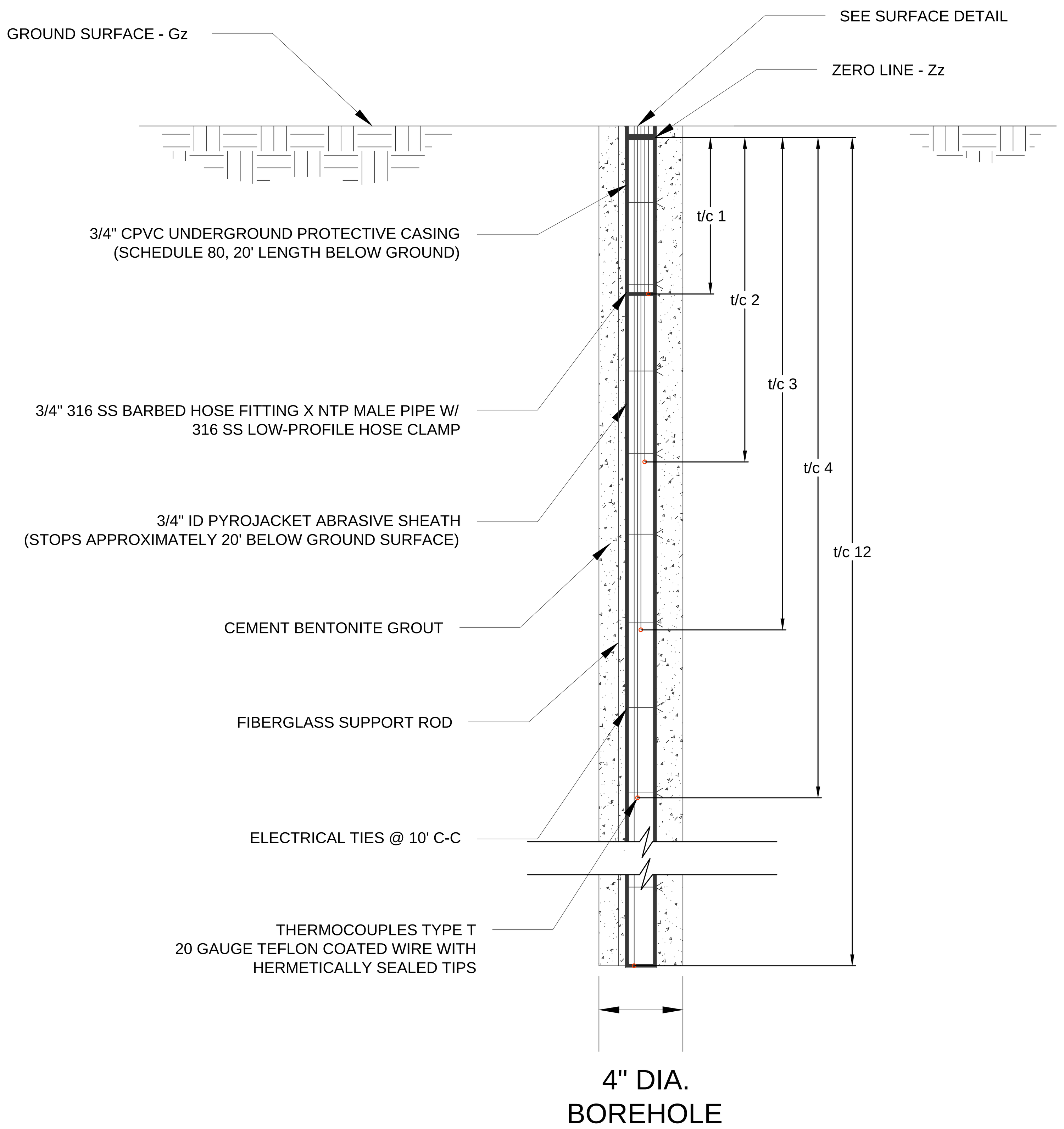
Appendix D - Temperature Monitor Probe Layout and Typical Detail



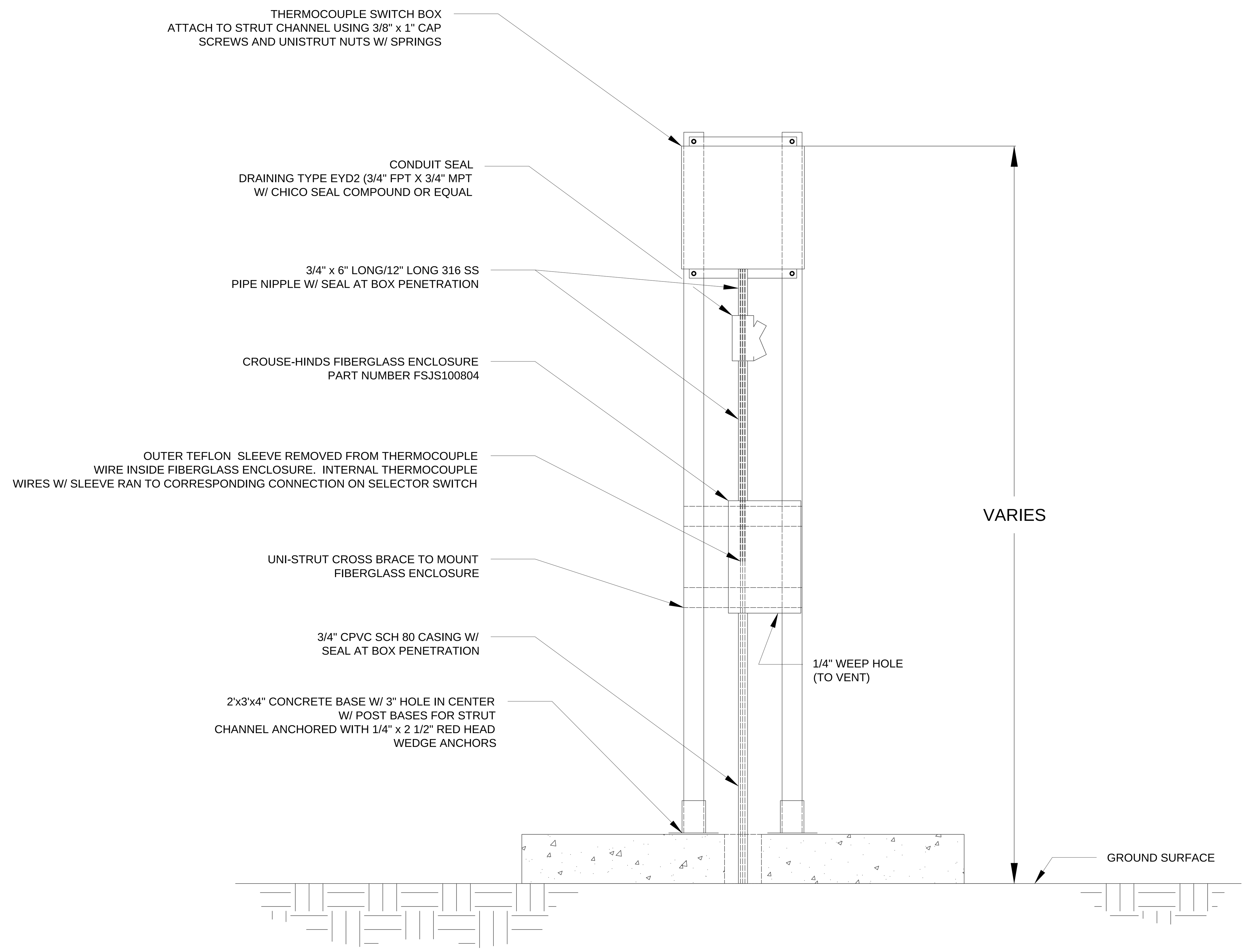
LEGEND

TMP-24 TEMPERATURE MONITORING PROBE

BRIDGETON LANDFILL, LLC 13570 ST. CHARLES ROCK ROAD BRIDGETON, MISSOURI 63044	BRIDGETON LANDFILL	FEEZOR ENGINEERING, INC. Engineering for a Better World	NOVEMBER 2015 DESIGNED BY: DMK APPROVED BY: ALK
TEMERATURE MONITORING PROBE LAYOUT			APPENDIX: D-1
PROJECT NUMBER: BT-062 FILE PATH:			REVISION DATE



SUBSURFACE DETAIL



SURFACE DETAIL

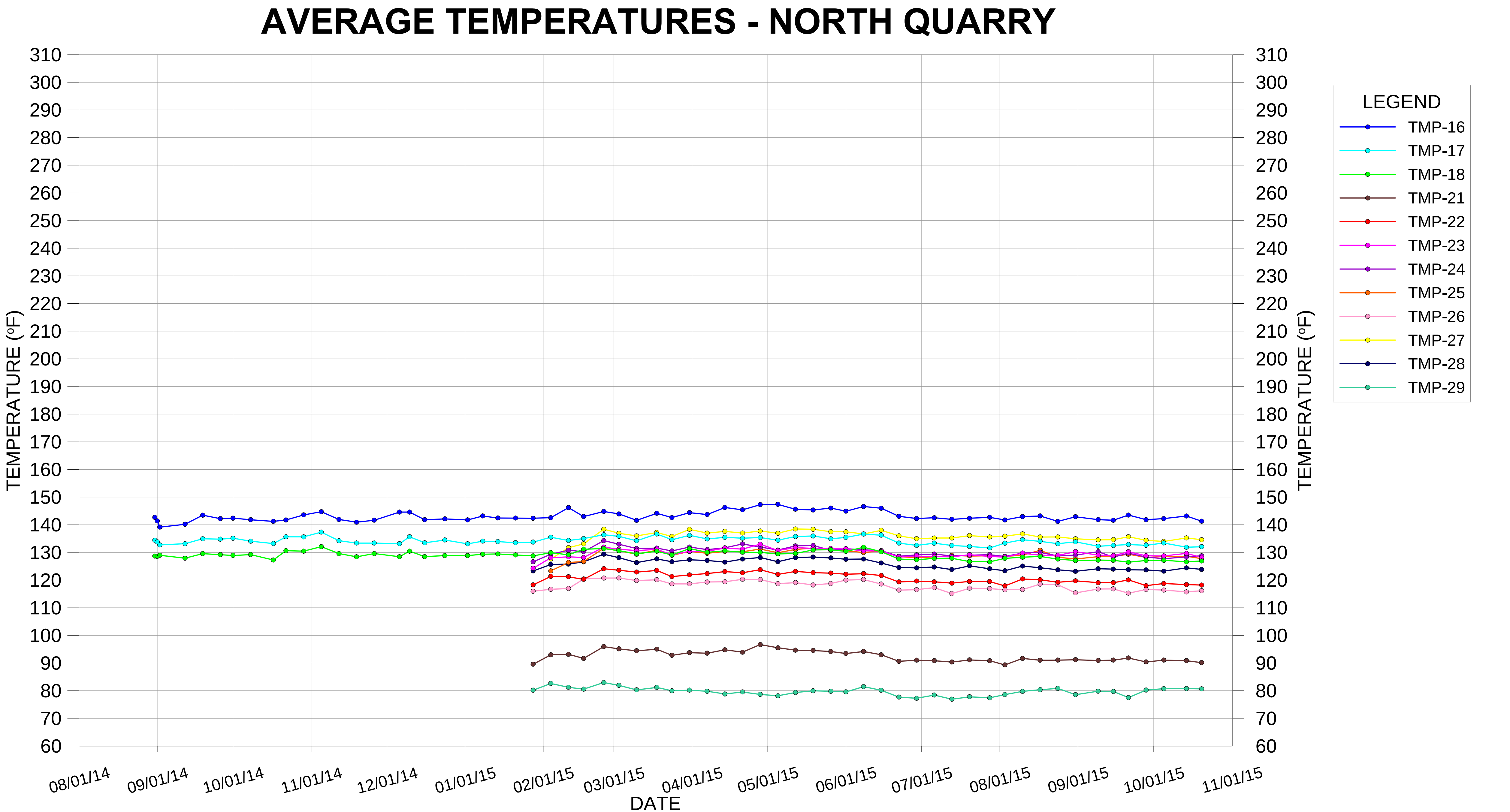
1 / D-2 TEMPERATURE MONITORING PROBE (TMP)

NTS

NOTES:
1:) SWITCH BOX IS SAGINAW CONTROL & ENGINEERING ENCLOSURE 1210ELJ - PANEL IS SCE-12P10J WITH JIC SWING OUT PANEL KIT - MOUNTED WITH HINGE ON RIGHT.
2.) HOLE FOR ROTARY SWITCH ACCOMODATES SW142G-12-B
3.) ALL PERFORATIONS AND CLAMPS NEMA 4 RATED

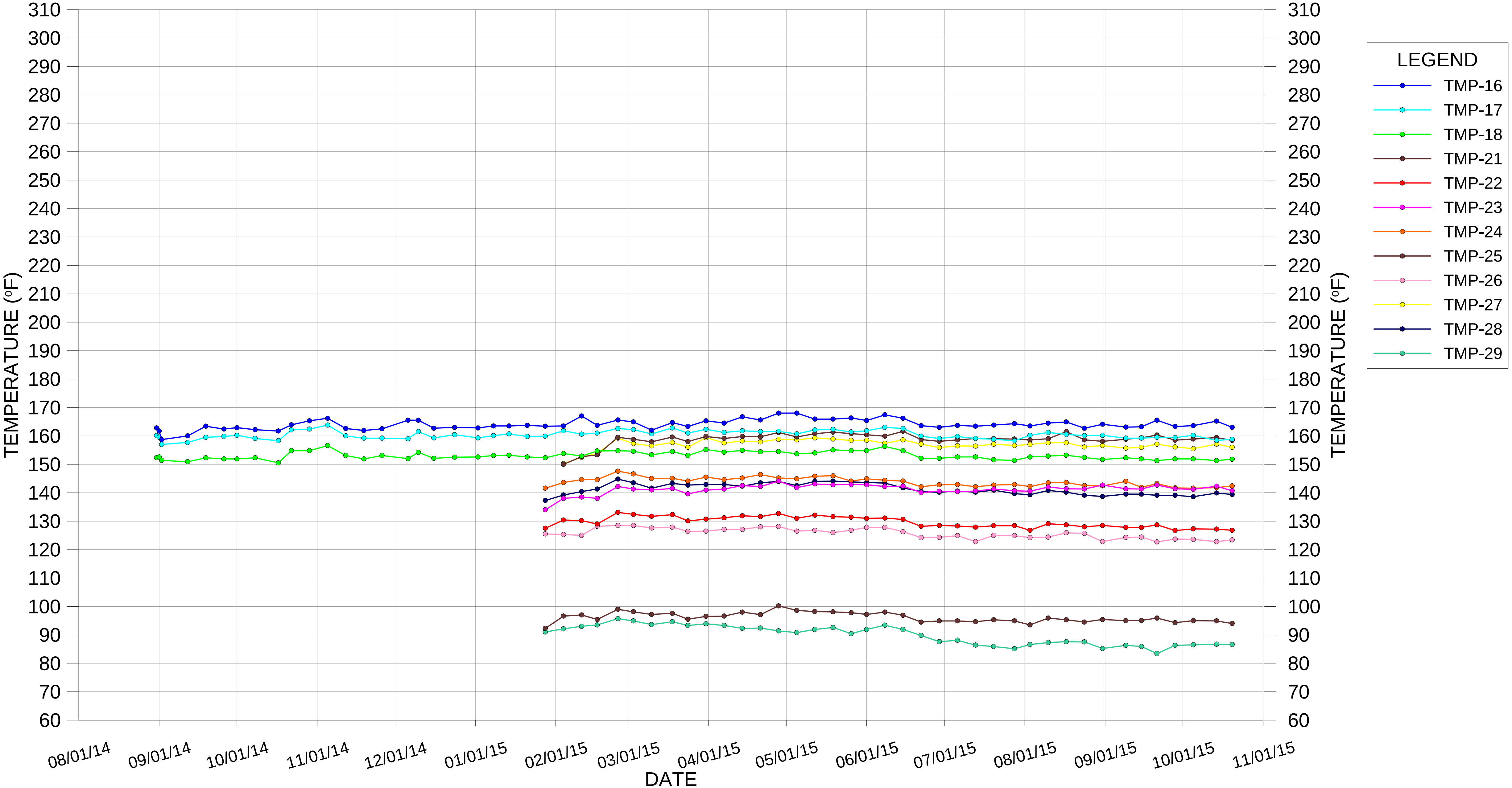
BRIDGETON LANDFILL, LLC 13570 ST. CHARLES ROCK ROAD BRIDGETON, MISSOURI 63044	BRIDGETON LANDFILL	Engineering for a Better World FEEZOR ENGINEERING, INC.	NOVEMBER 2015 DESIGNED BY: DMK APPROVED BY: ALK	APPENDIX: D-2
TEMPERATURE MONITORING PROBE TYPICAL DETAIL			REVISION / DATE	
PROJECT NUMBER: BT-062 / FILE PATH				

Appendix E - Temperature Monitoring Probe Graphs

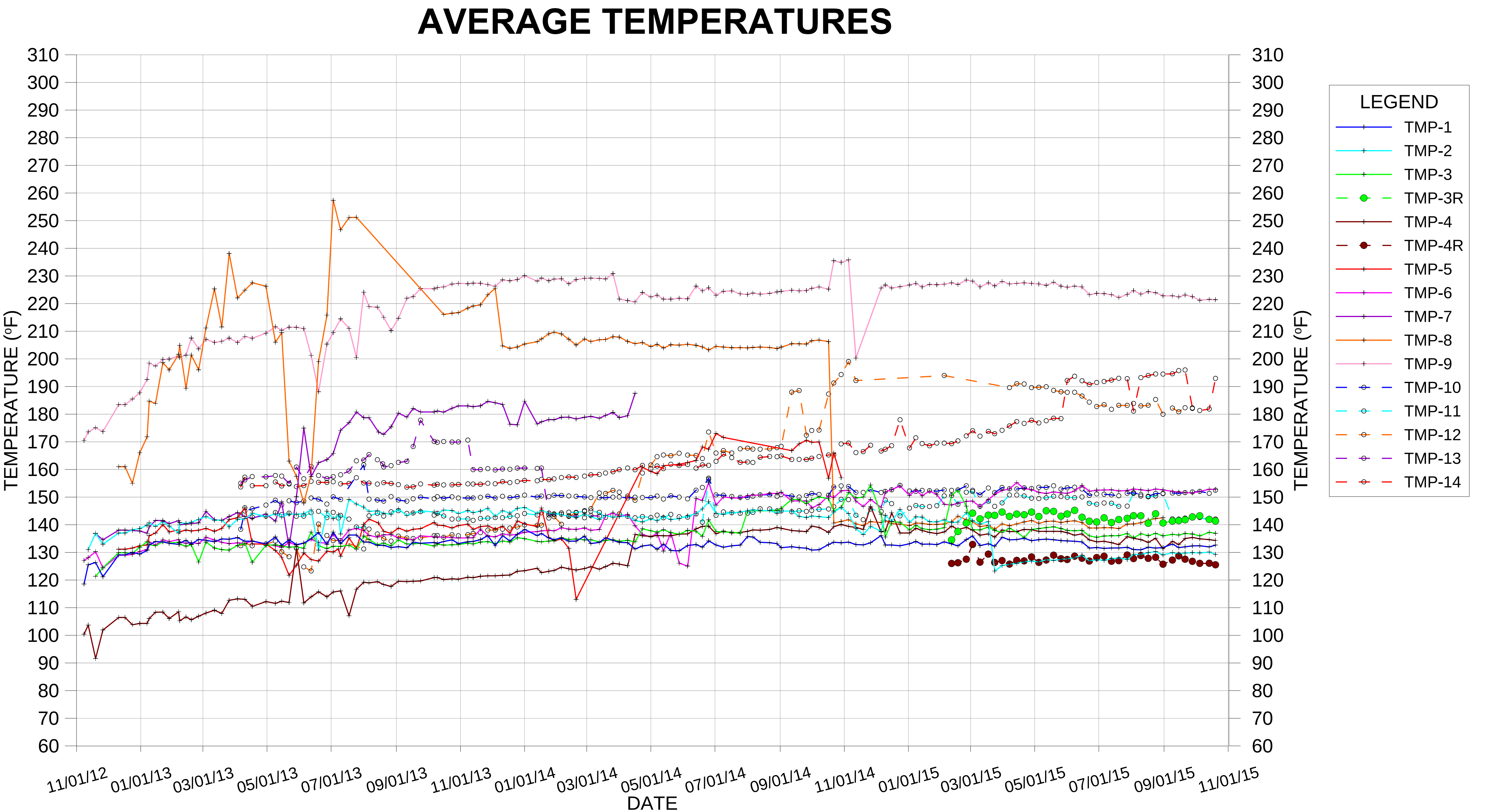


TEMPERATURE VS TIME
BRIDGETON LANDFILL

MAXIMUM TEMPERATURES - NORTH QUARRY

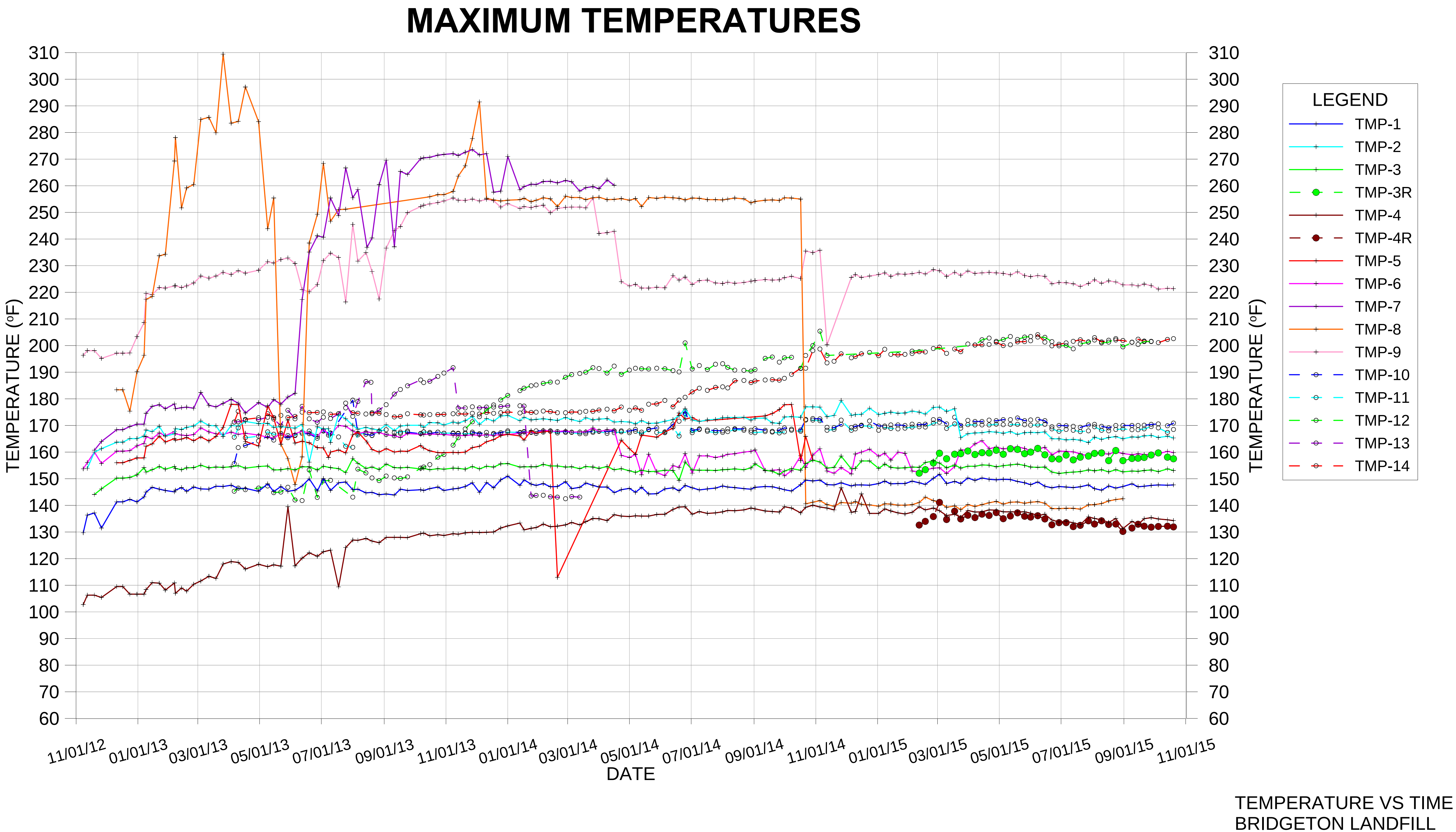


TEMPERATURE VS TIME
BRIDGETON LANDFILL

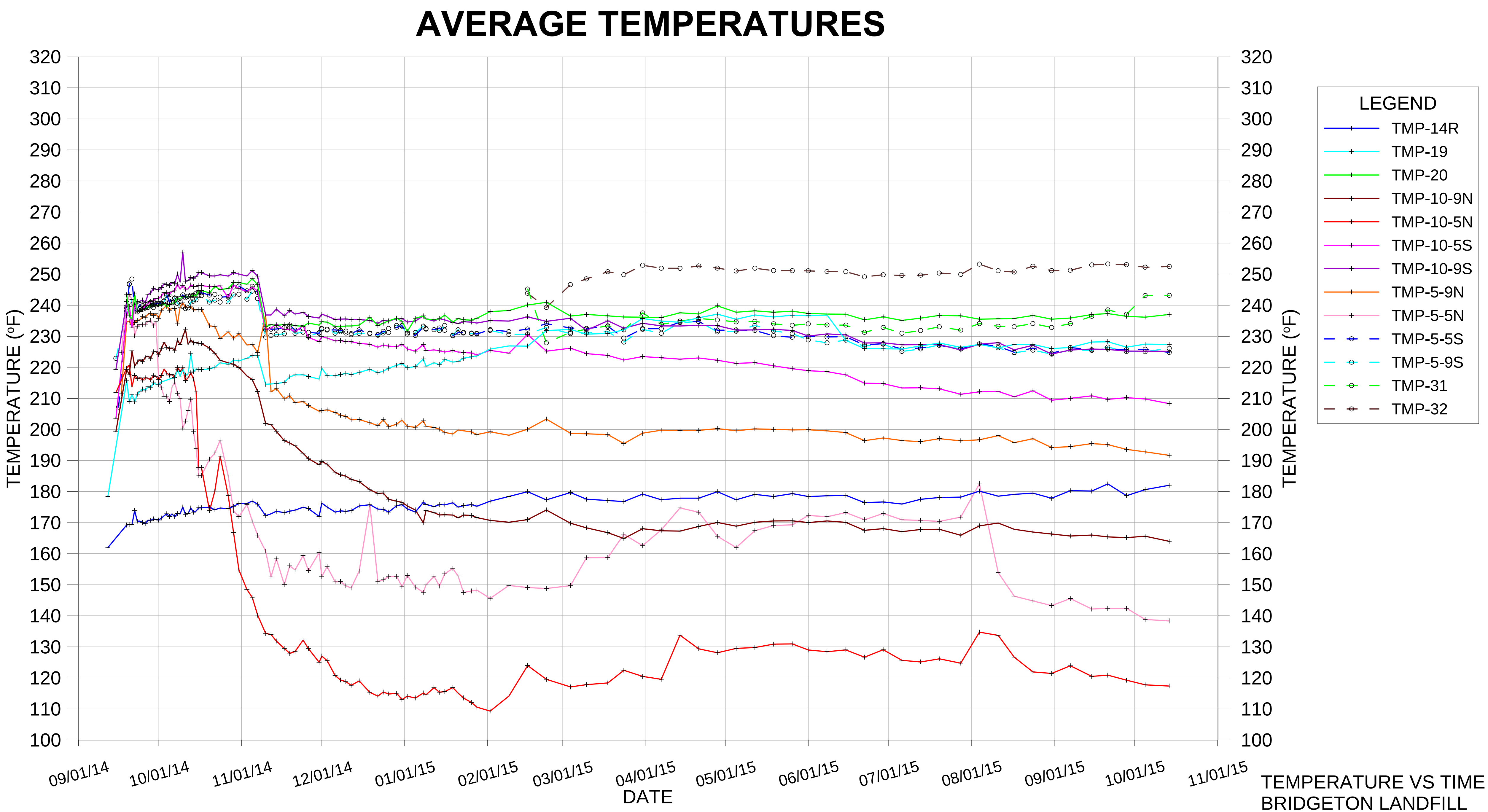


TEMPERATURE VS TIME
.ANDFILL

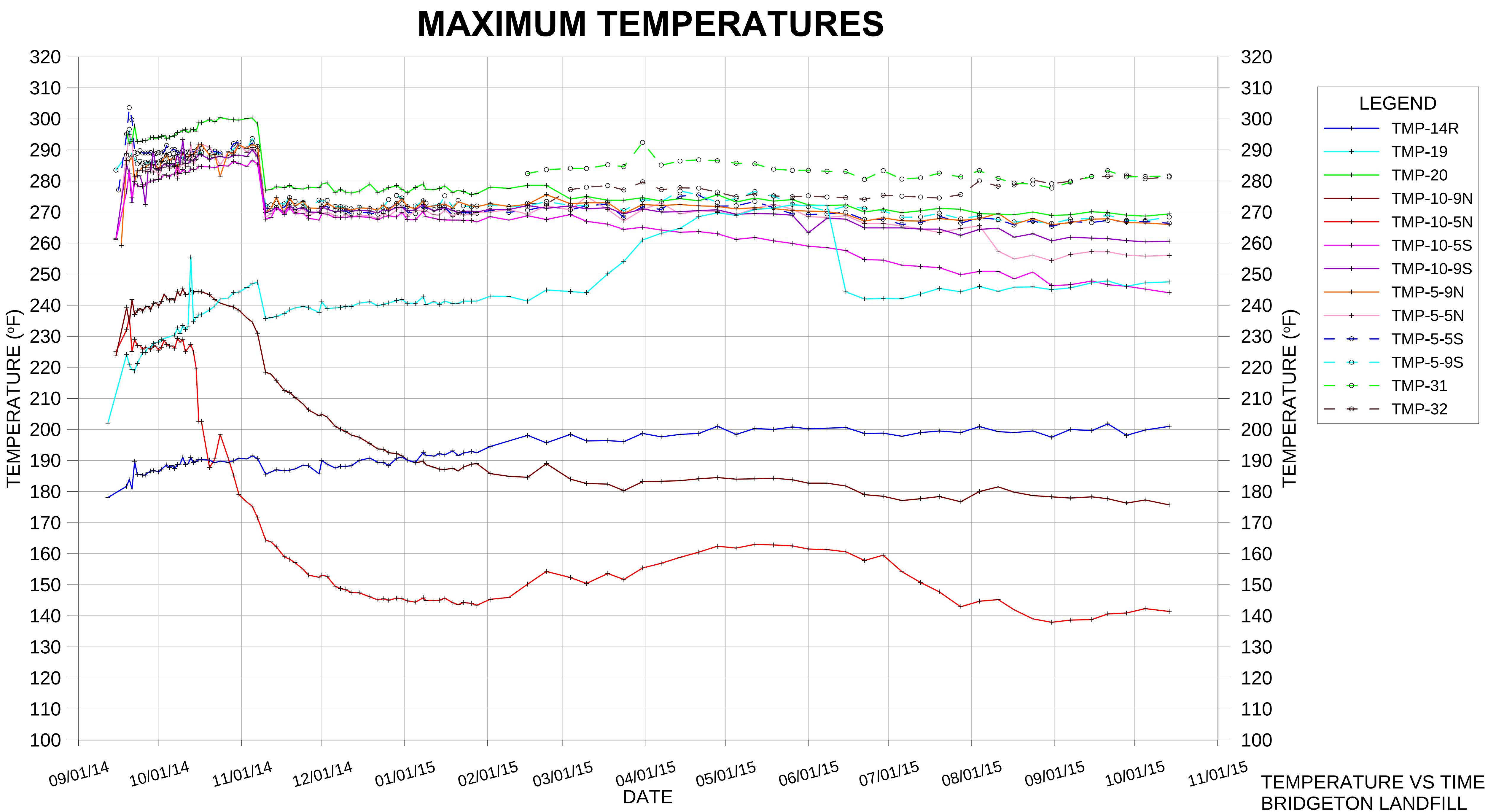
TMP-12 Has experienced fluctuating resistance and unstable readings since early 2014.



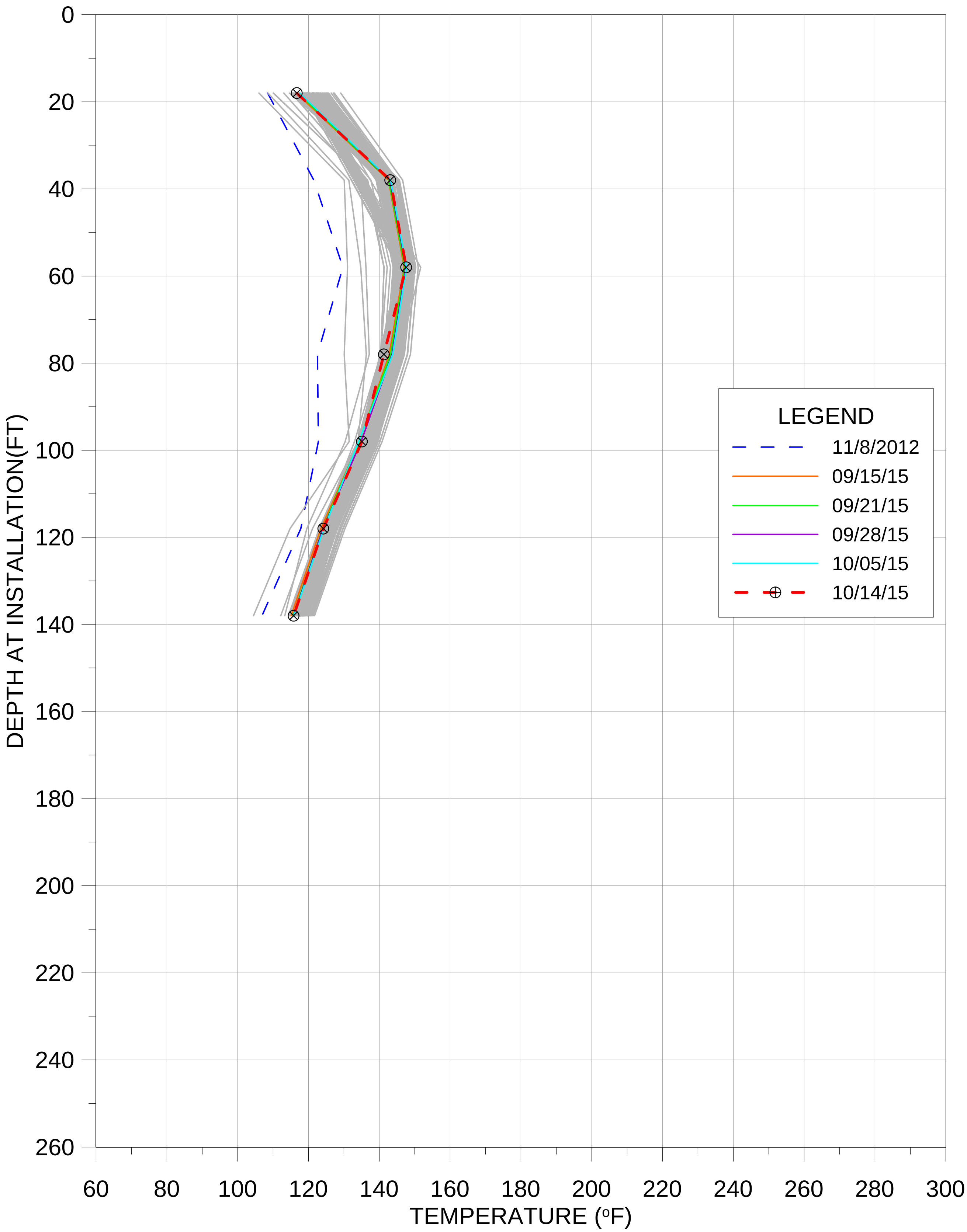
TMP-12 Has experienced fluctuating resistance and unstable readings since early 2014



TEMPERATURE VS TIME
BRIDGETON LANDFILL

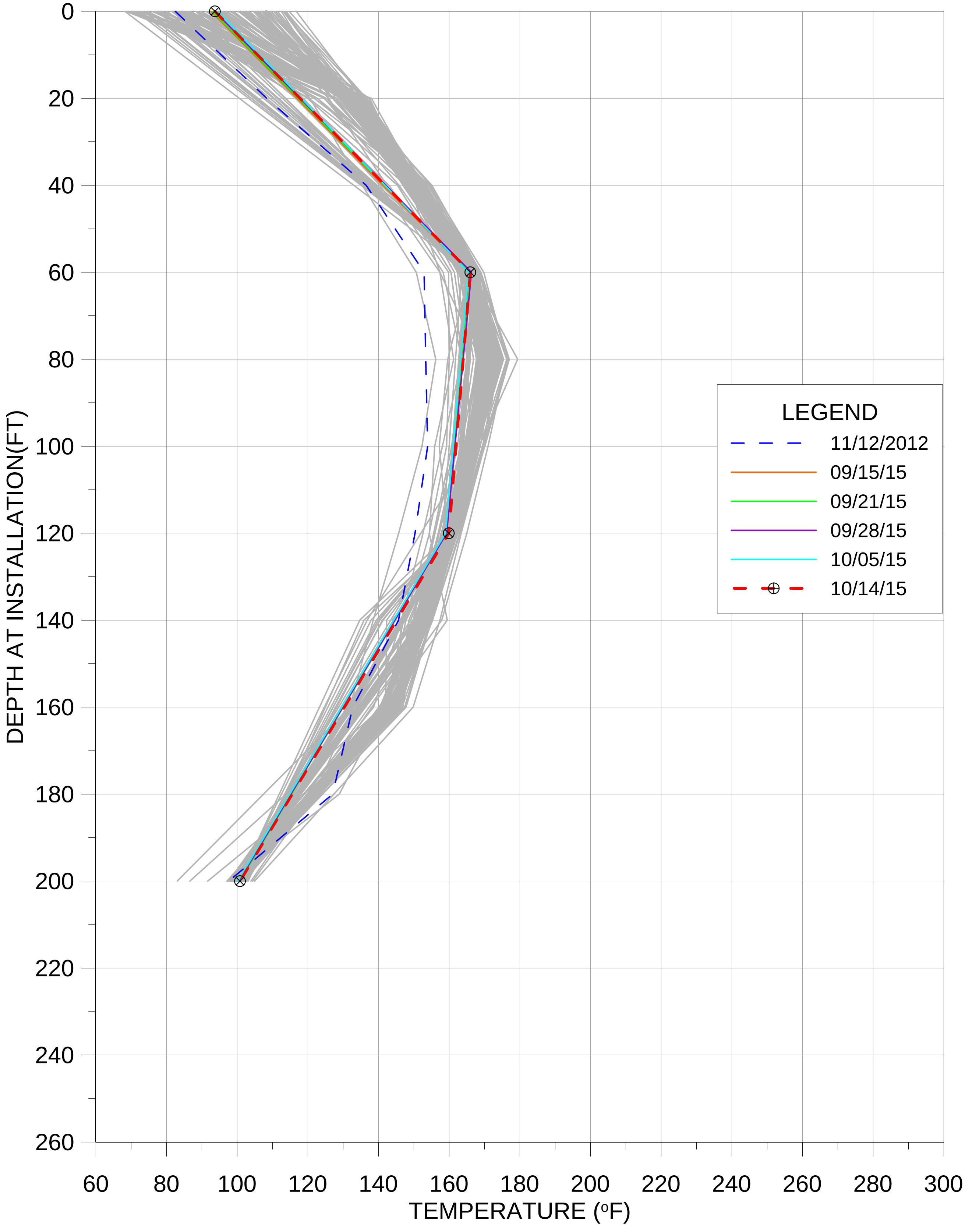

MAXIMUM TEMPERATURES
TEMPERATURE (ºF)
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
09/01/14
10/01/14
11/01/14
12/01/14
01/01/15
02/01/15
03/01/15
04/01/15
05/01/15
06/01/15
07/01/15
08/01/15
09/01/15
10/01/15
11/01/15
DATE
LEGEND
TMP-14R
TMP-19
TMP-20
TMP-10-9N
TMP-10-5N
TMP-10-5S
TMP-10-9S
TMP-5-9N
TMP-5-5N
TMP-5-5S
TMP-5-9S
TMP-31
TMP-32
TEMPERATURE VS TIME
BRIDGETON LANDFILL

TMP-1



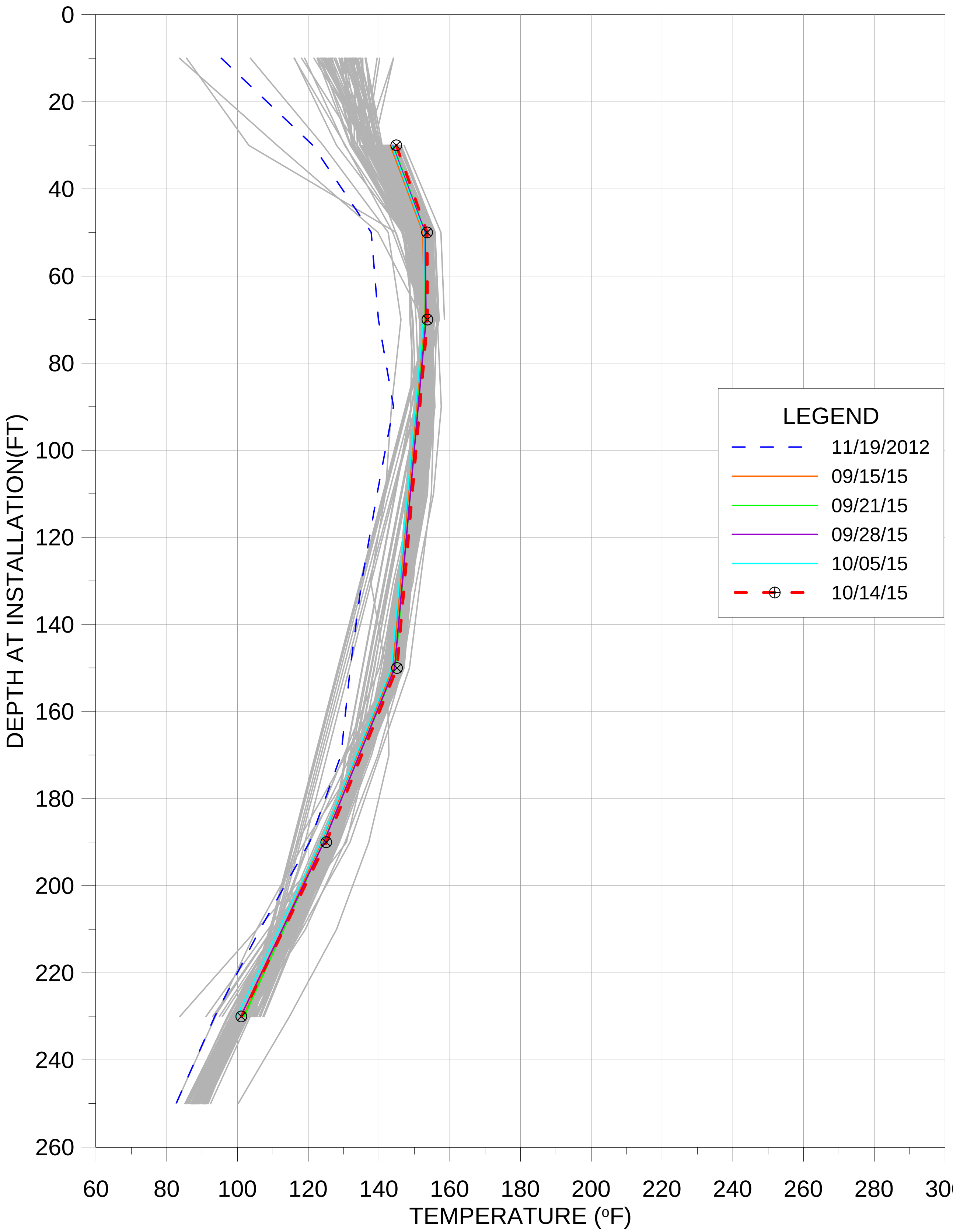
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-2



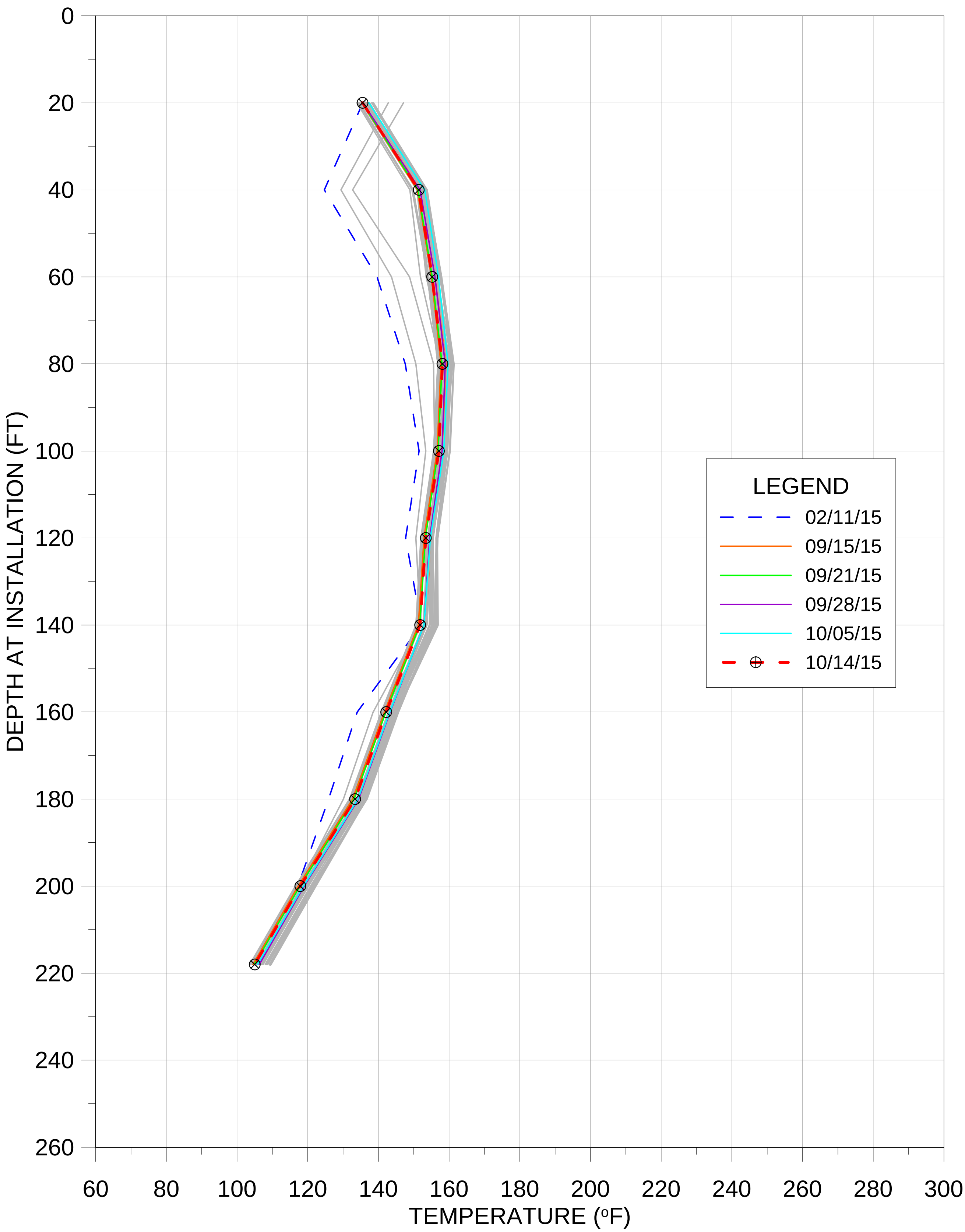
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-3



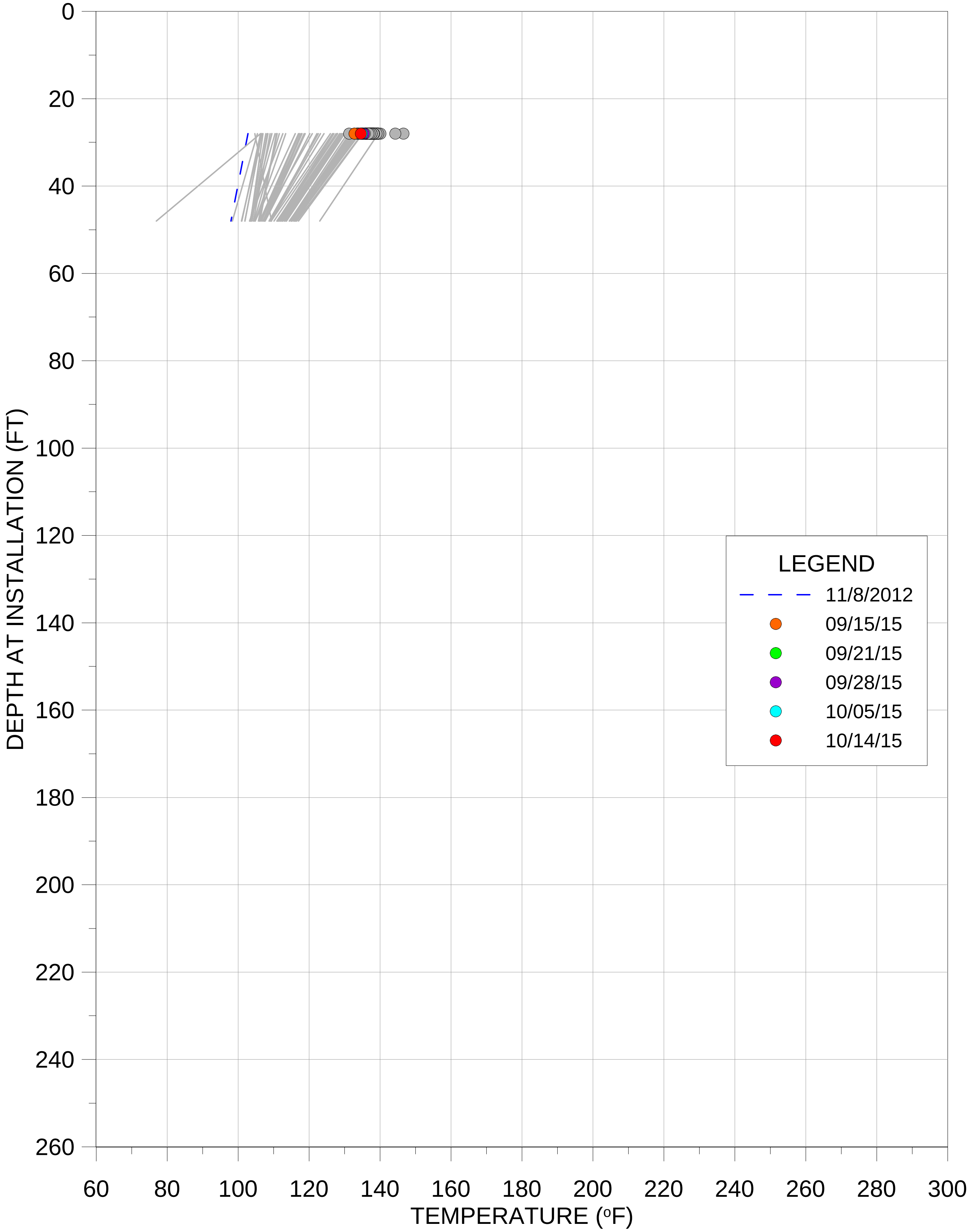
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-3R



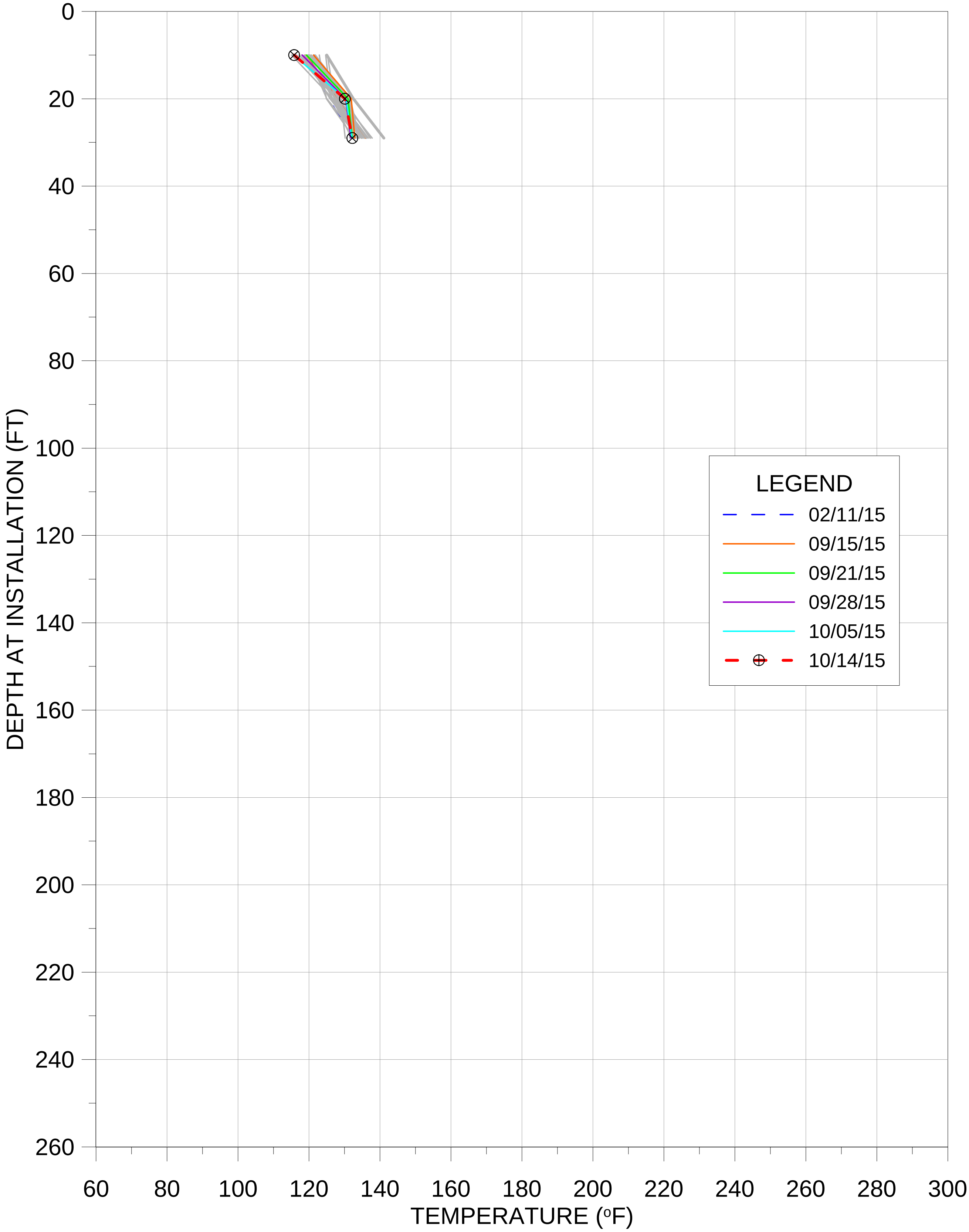
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-4



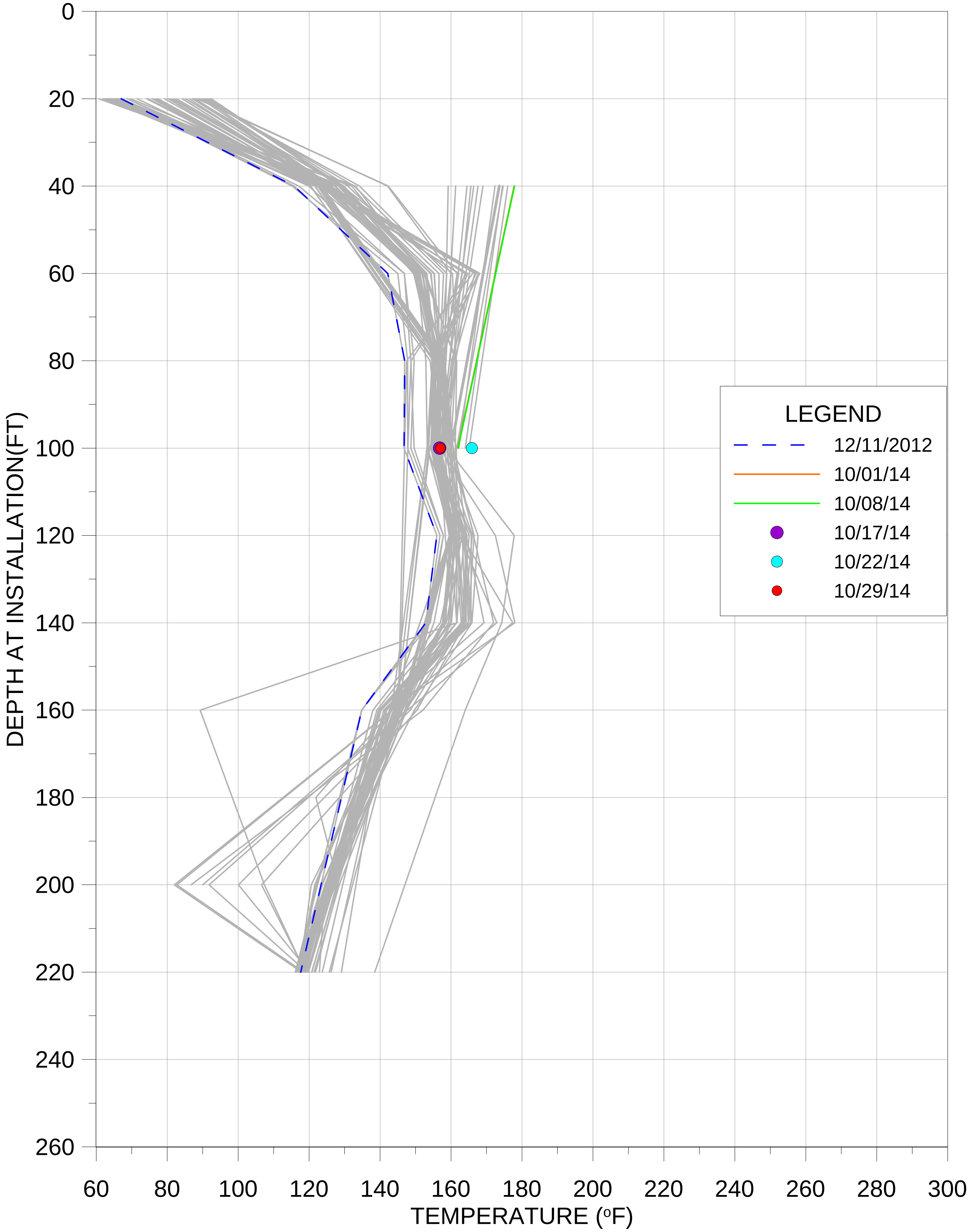
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-4R



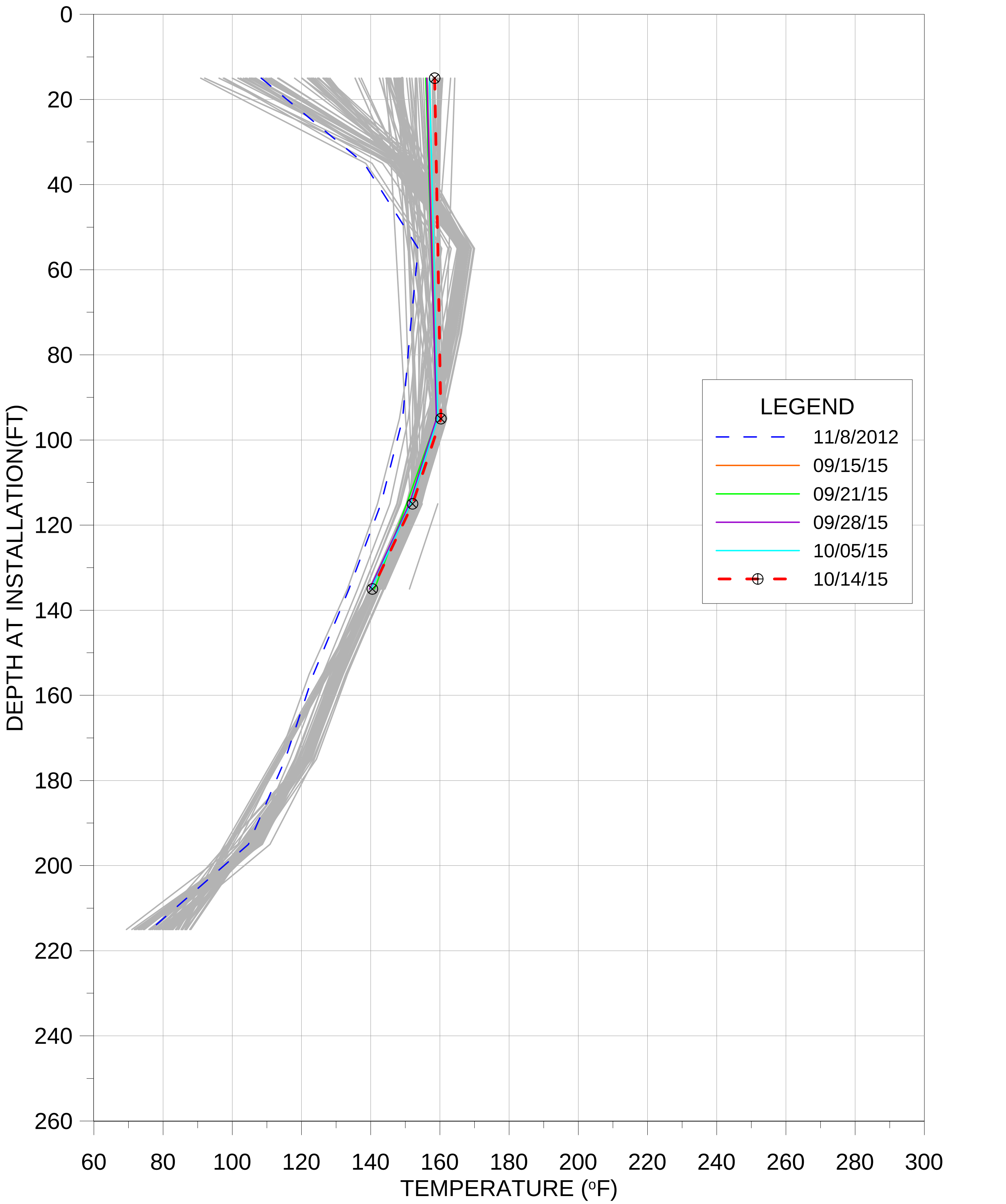
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-5



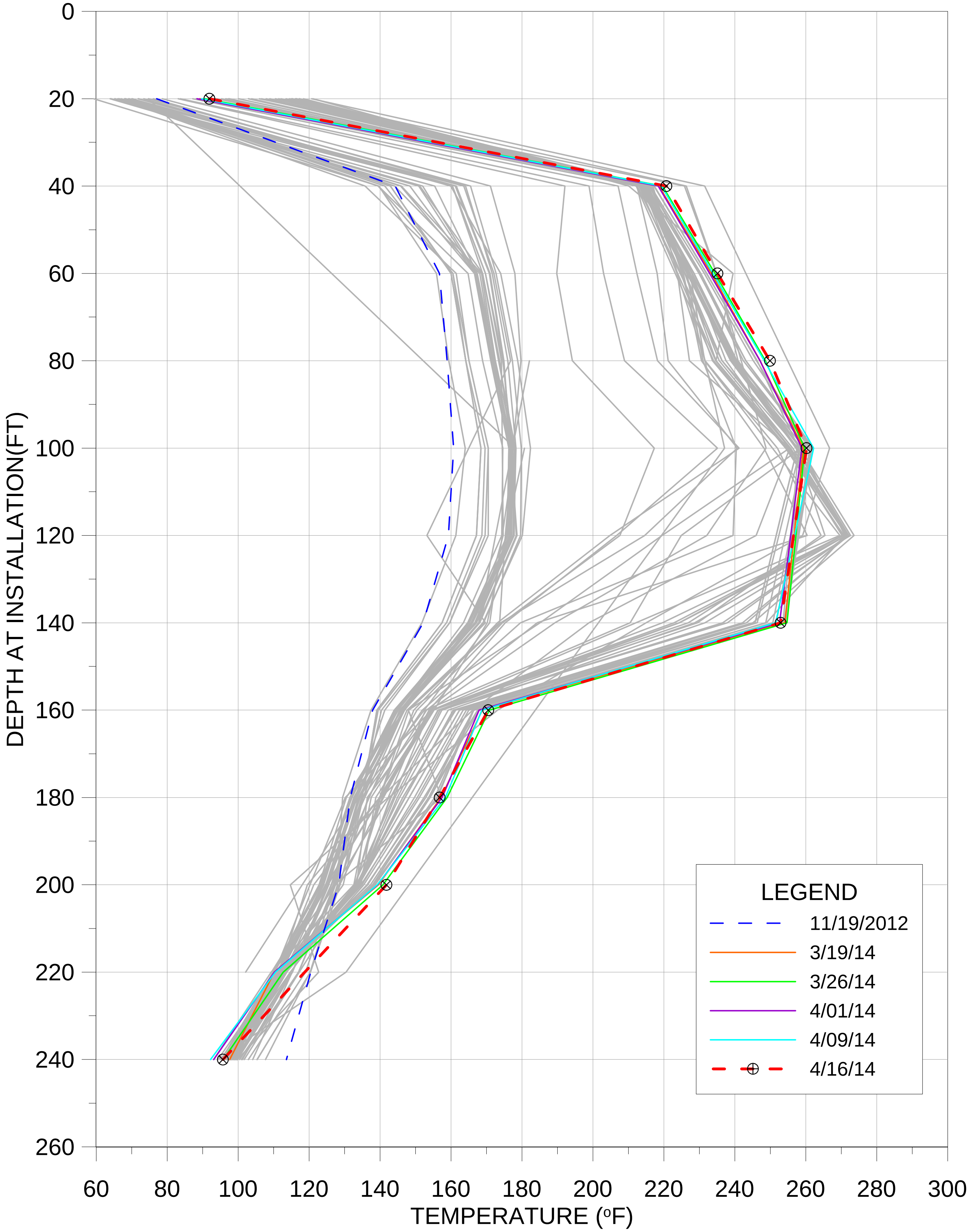
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-6



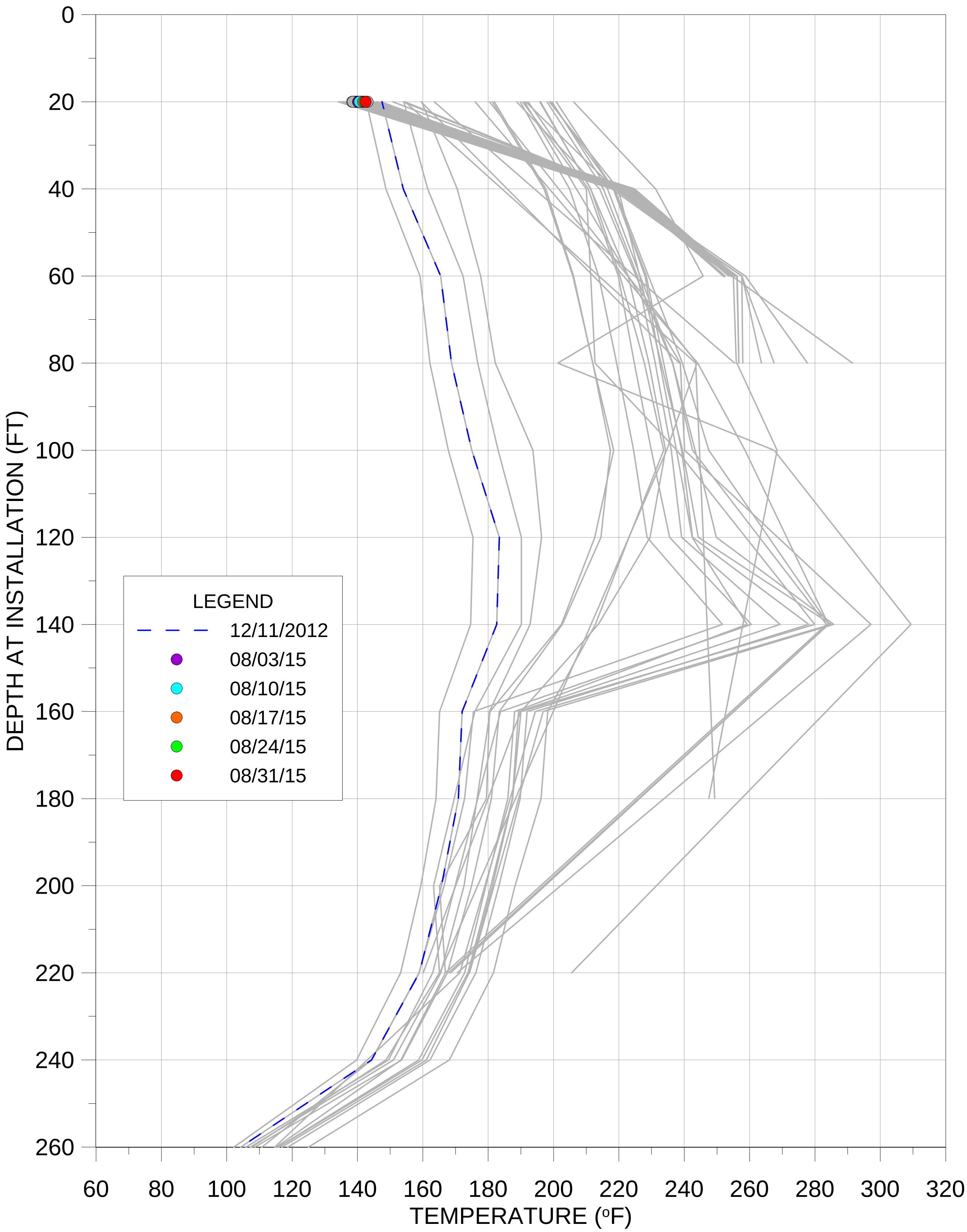
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-7R



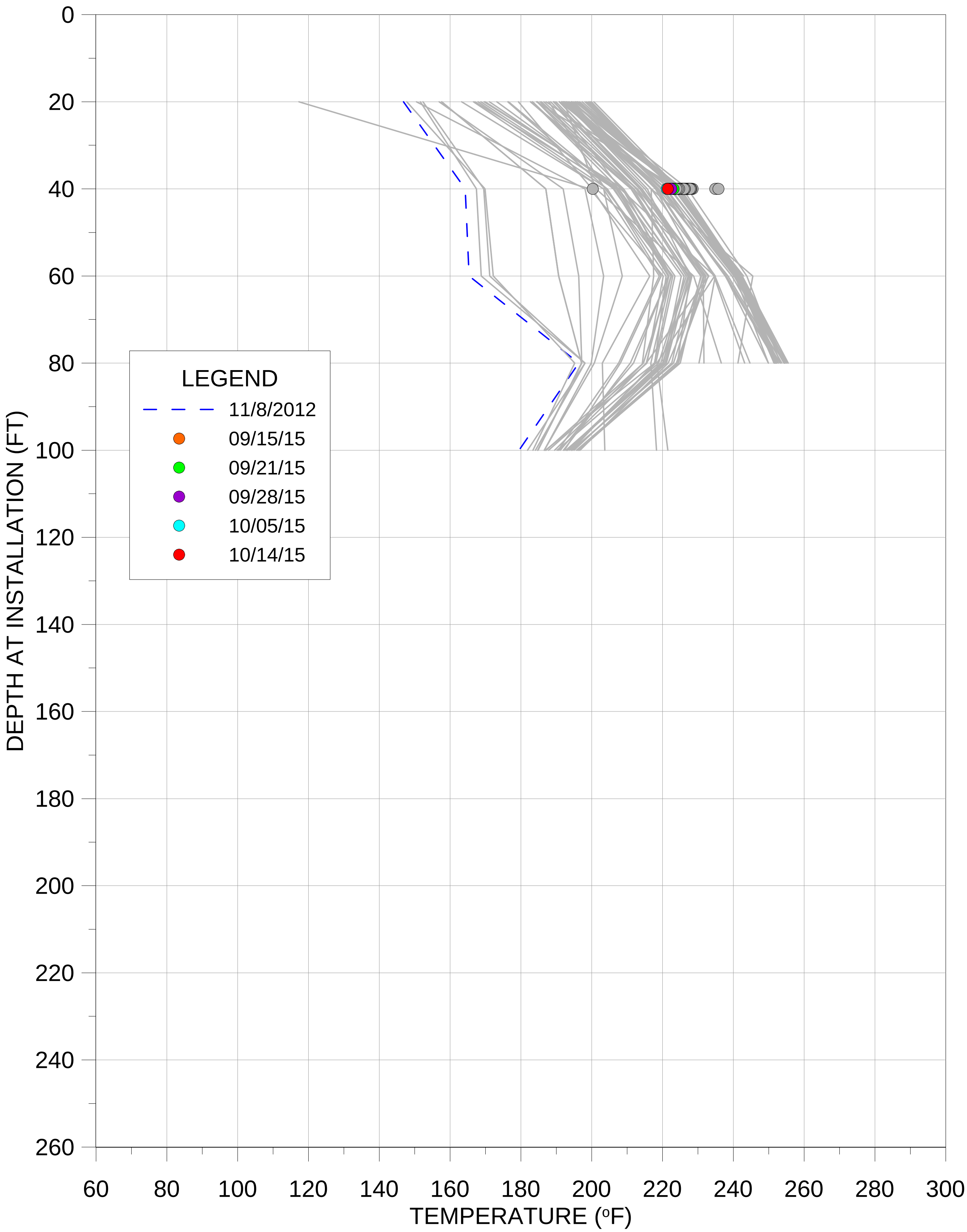
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-8



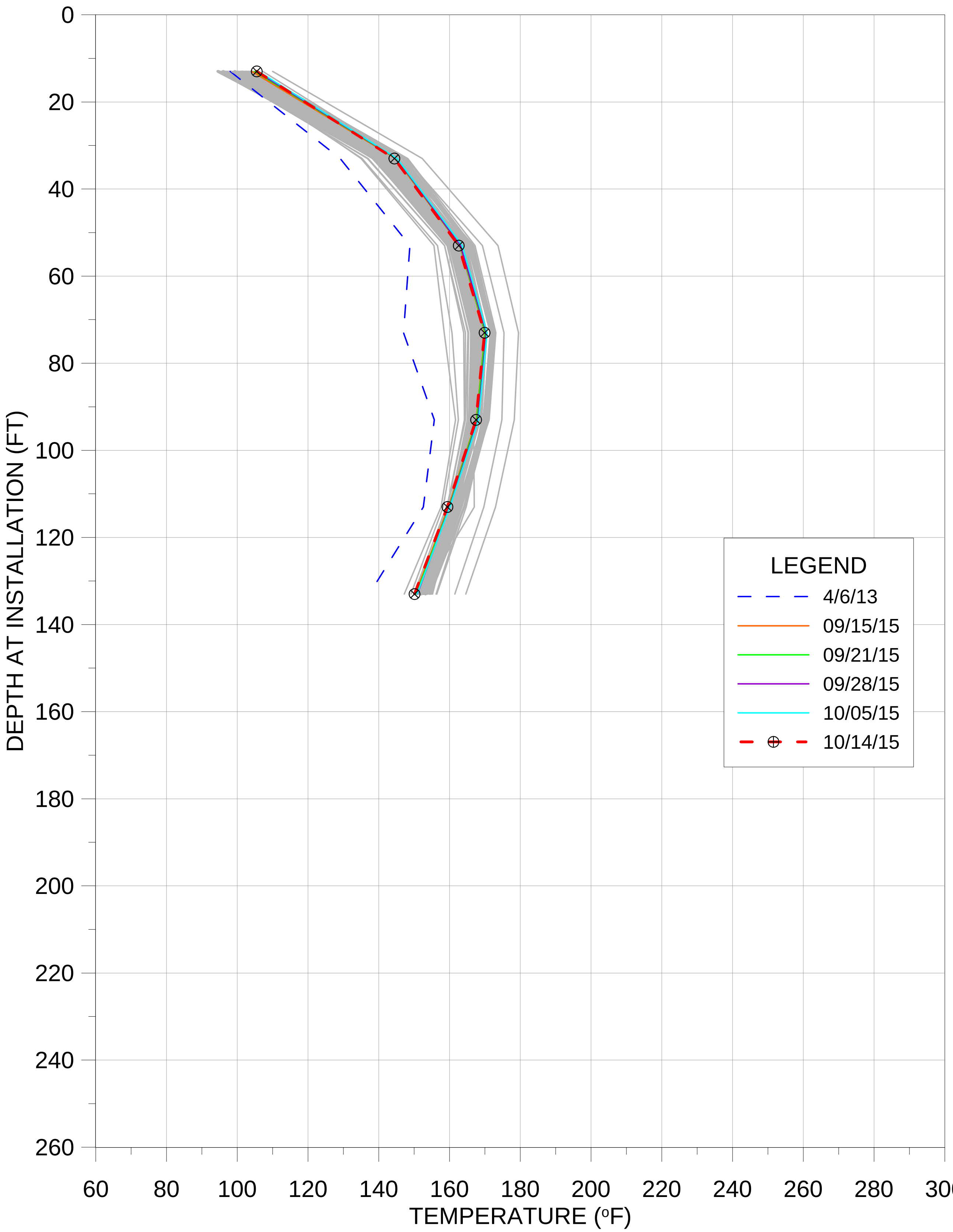
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-9



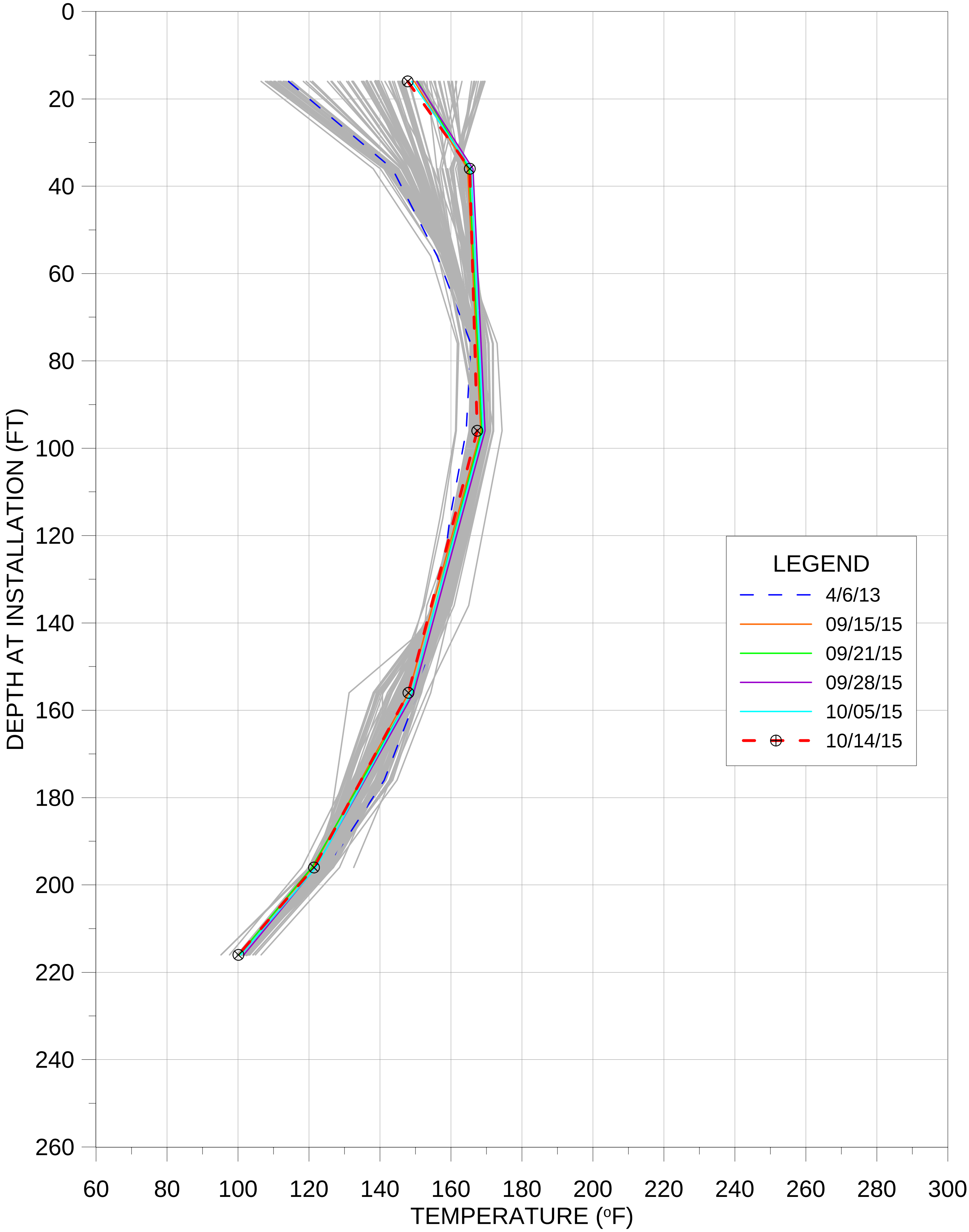
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-10



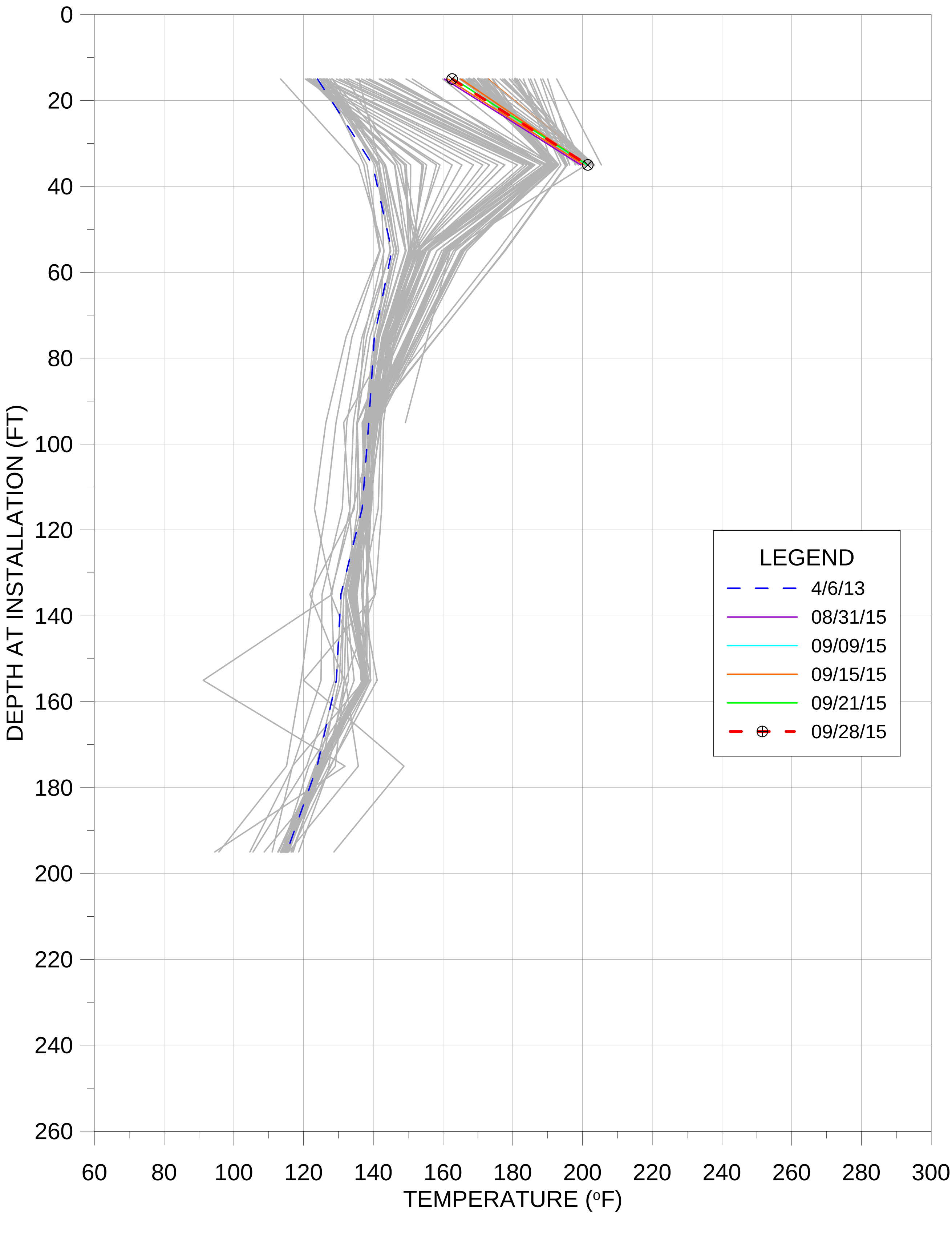
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-11



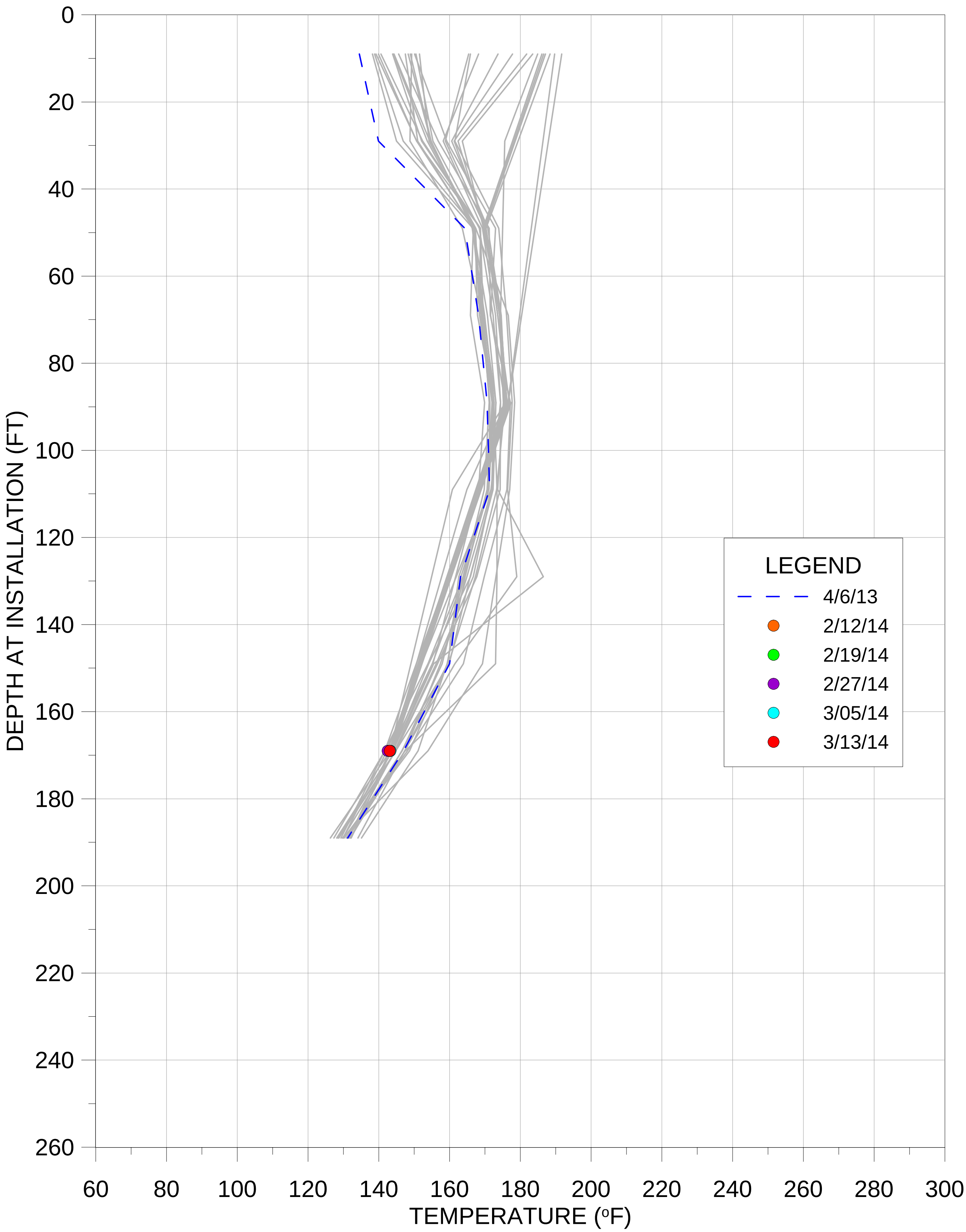
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-12



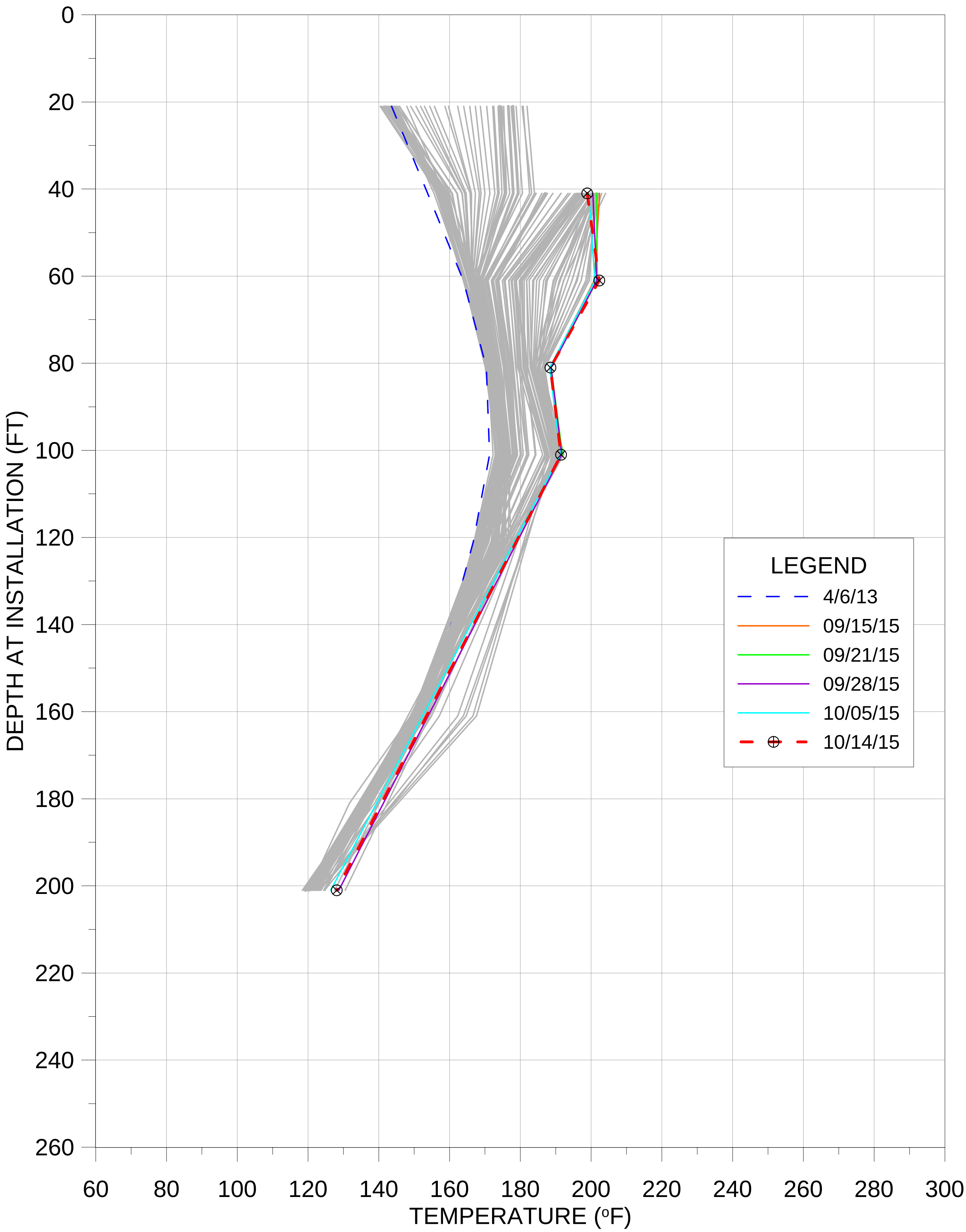
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-13



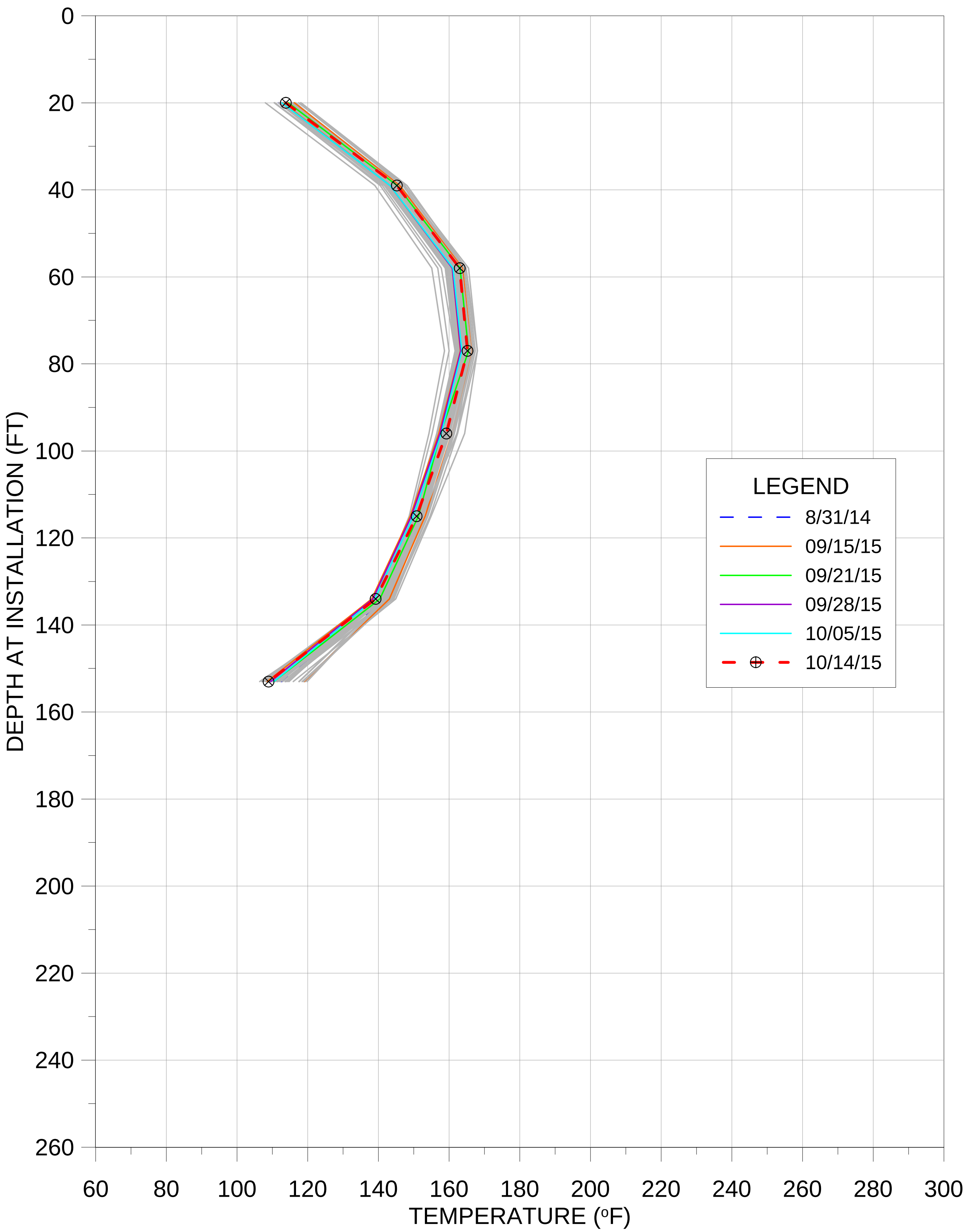
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-14



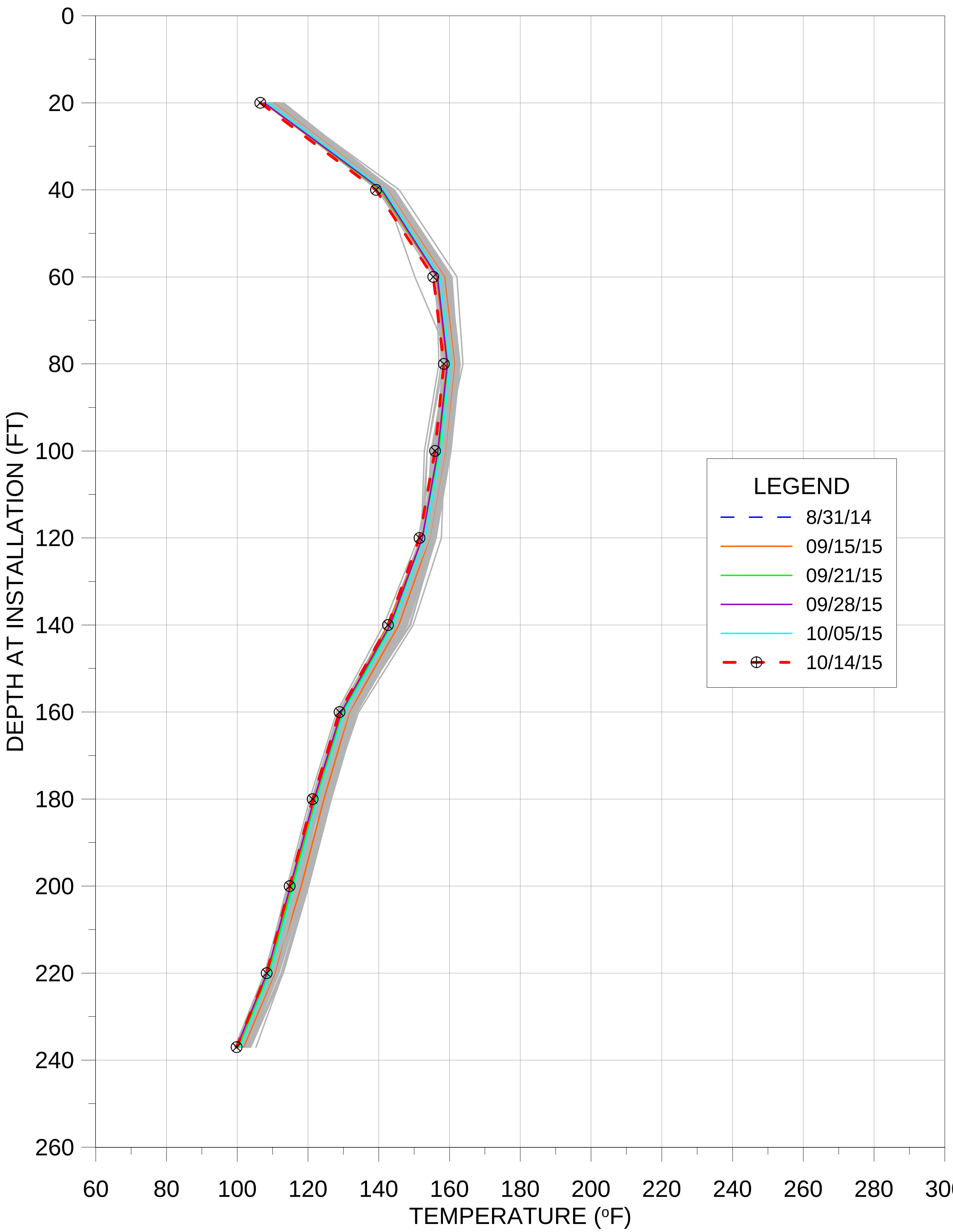
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-16



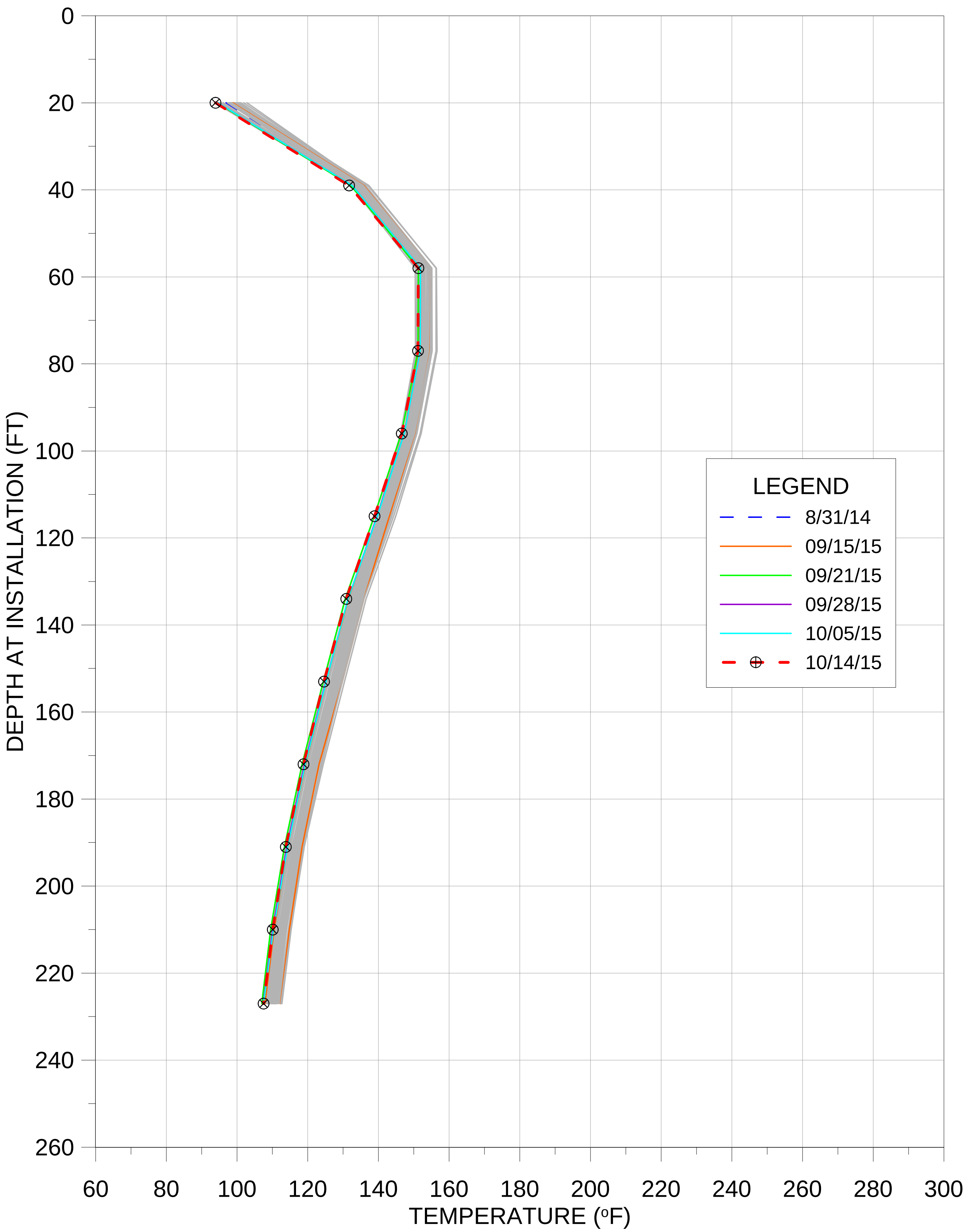
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-17



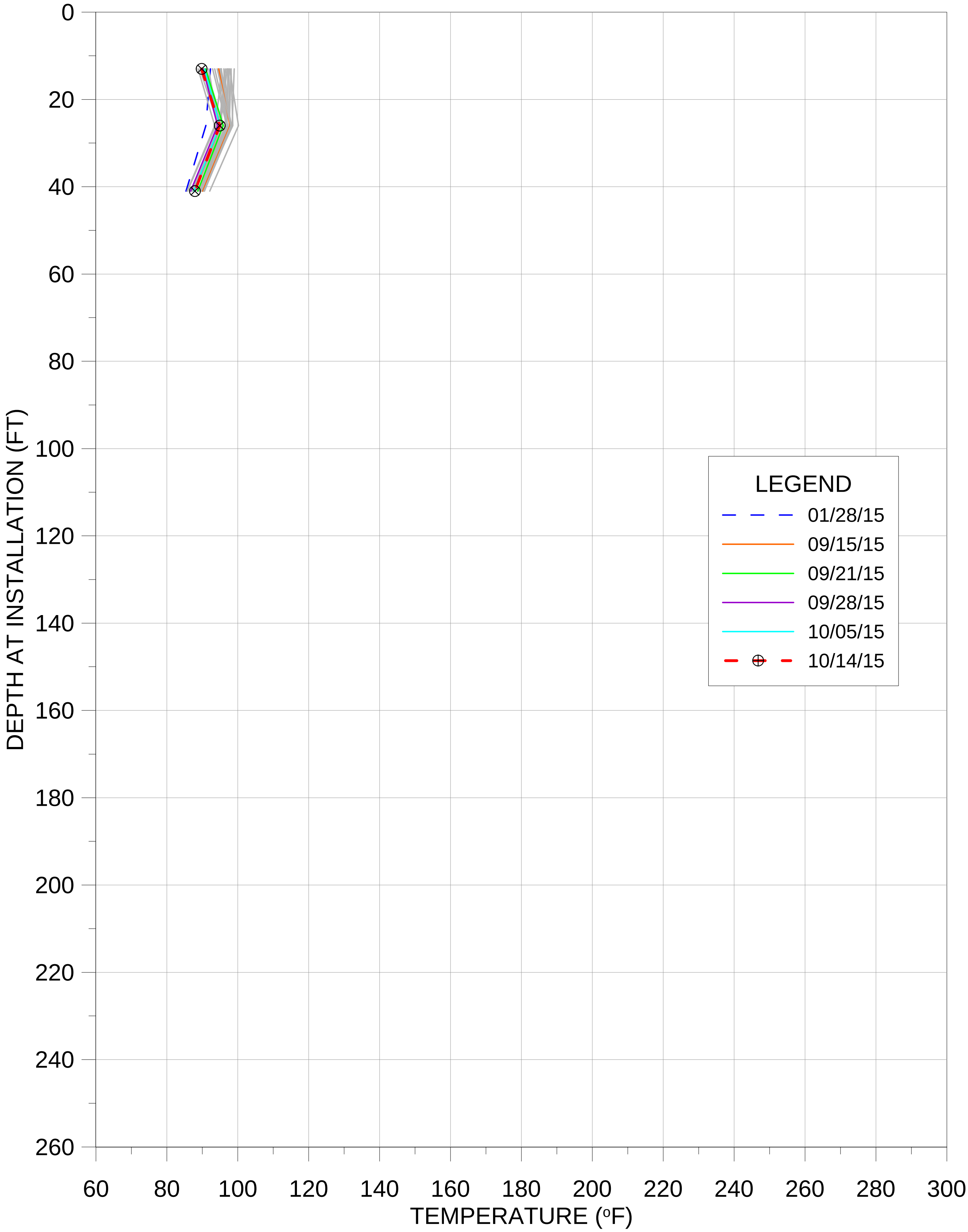
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-18



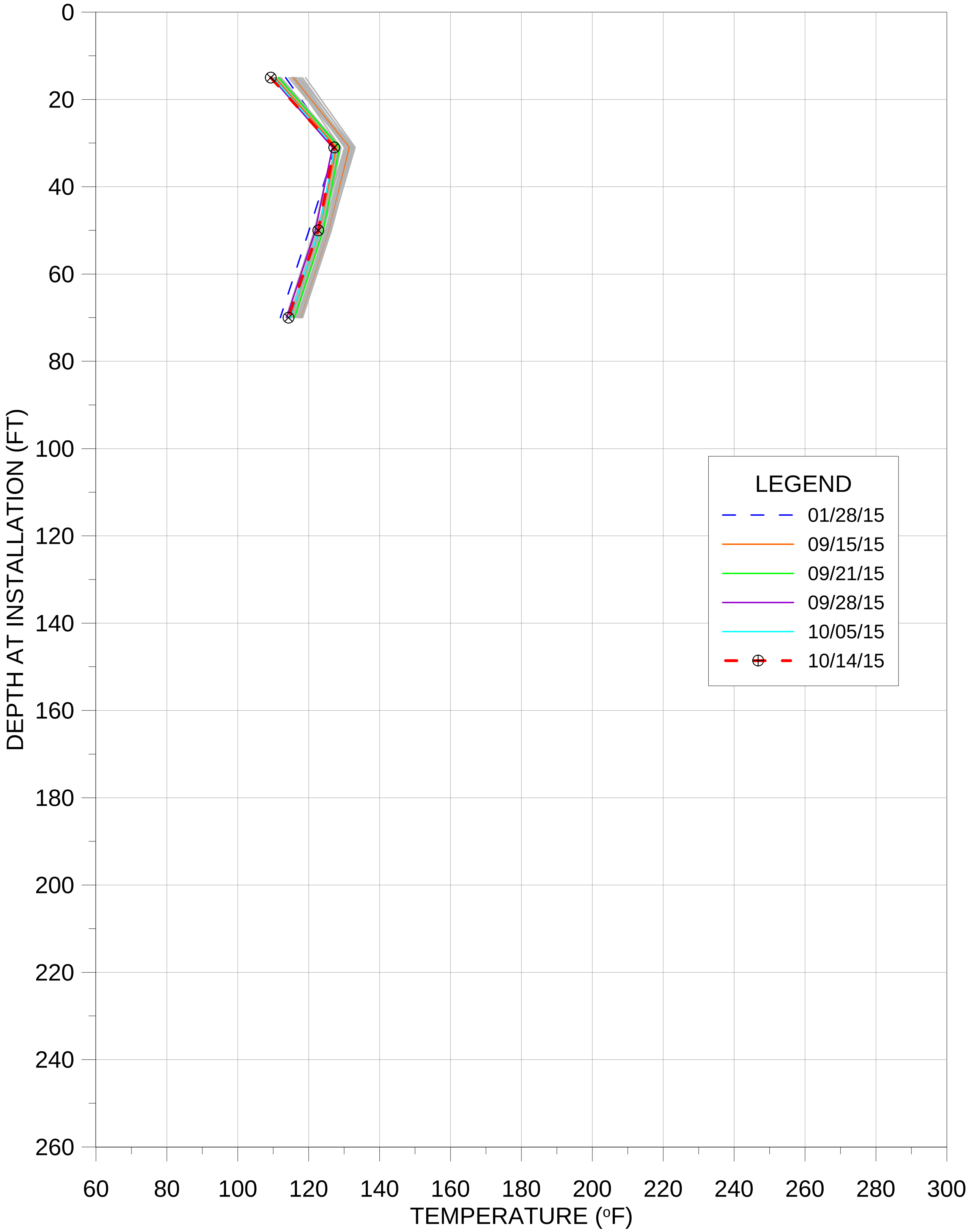
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-21



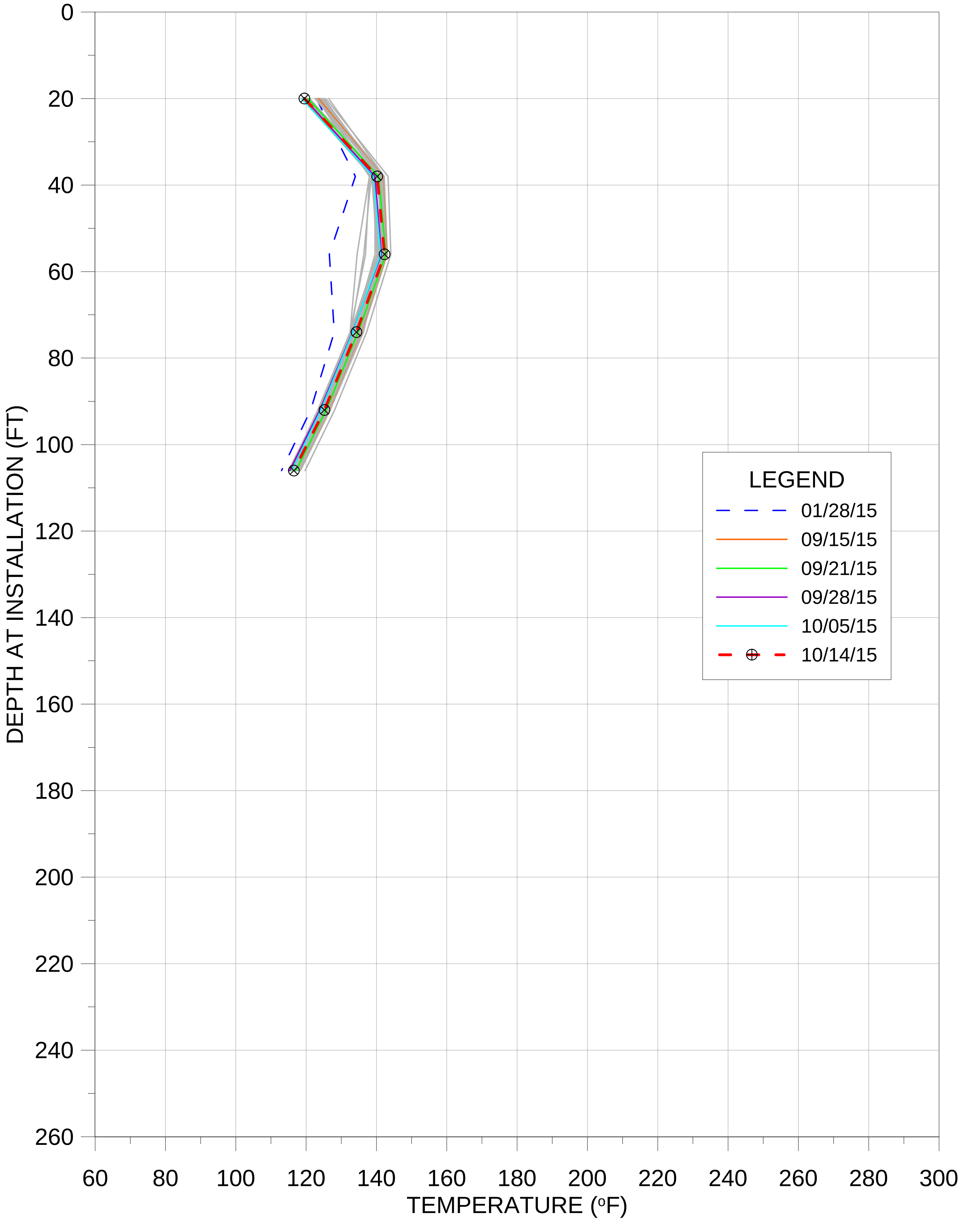
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-22



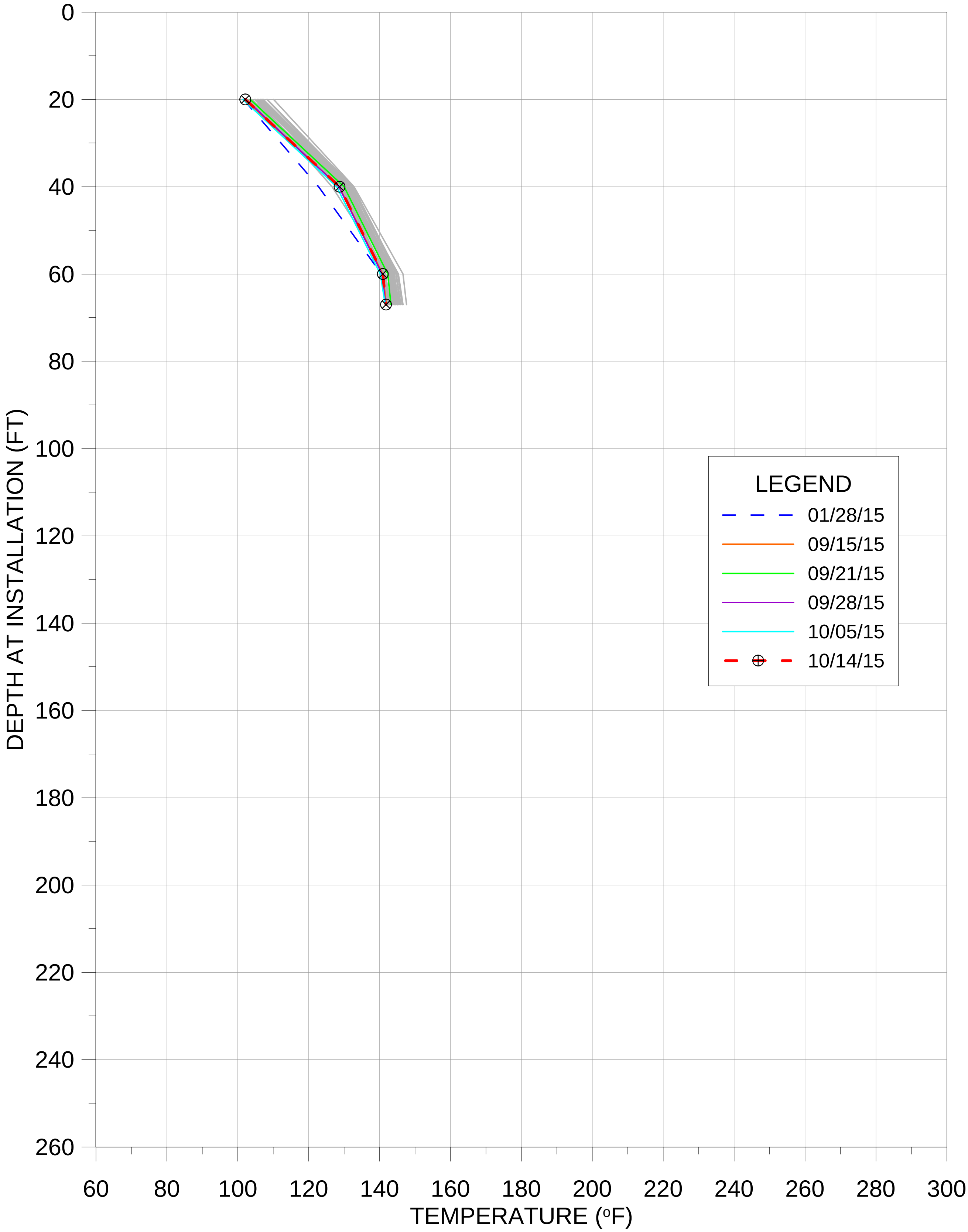
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-23



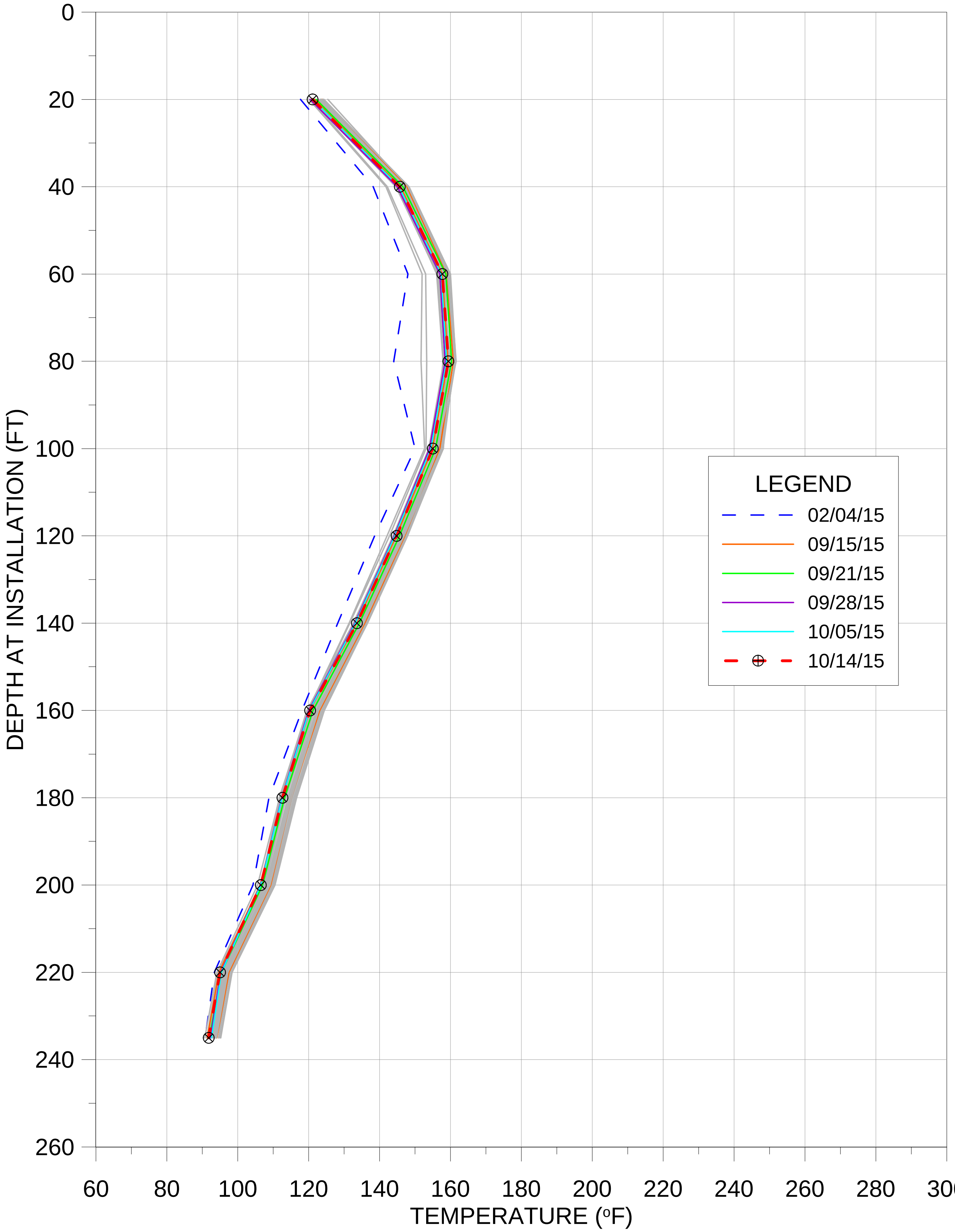
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-24



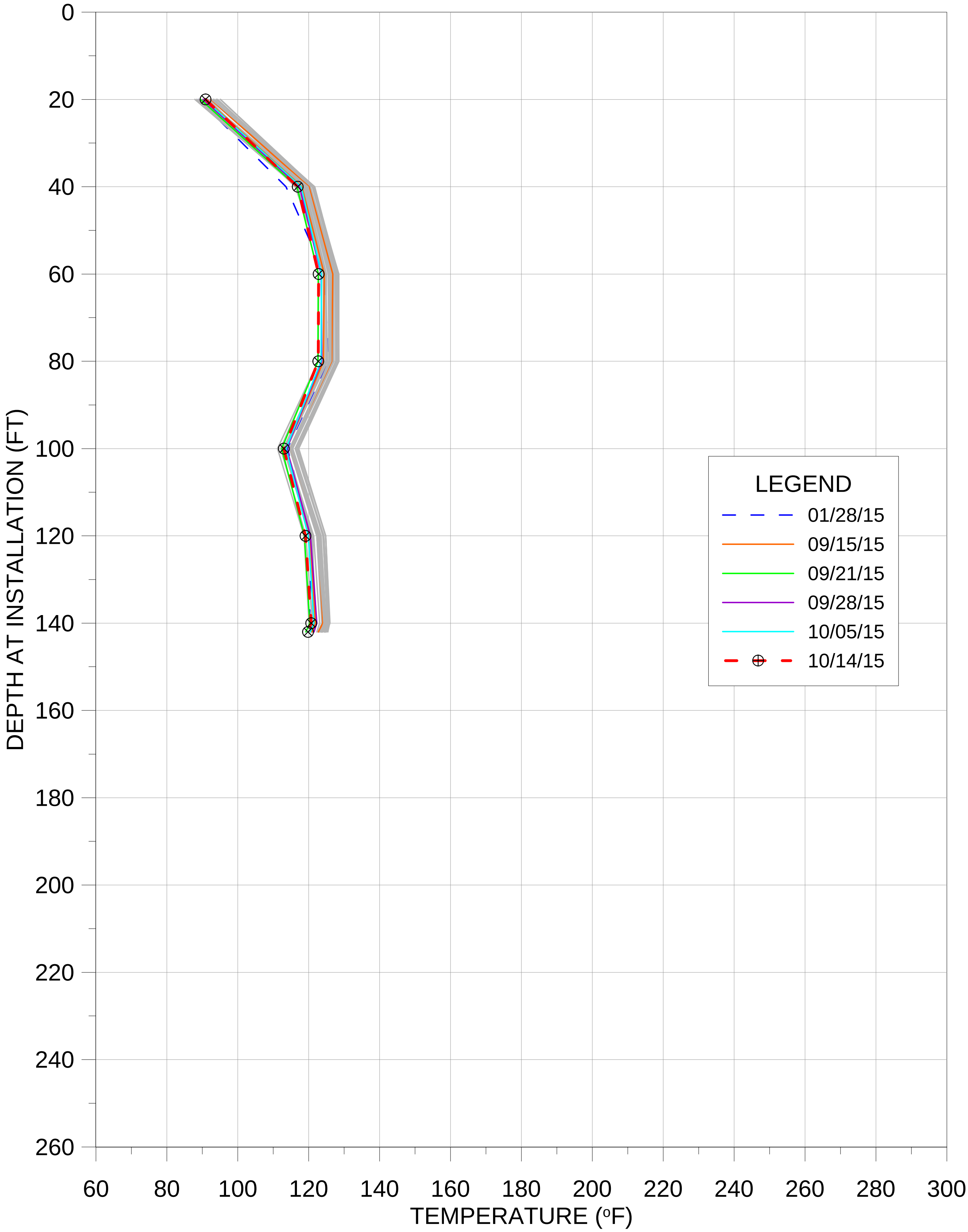
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-25



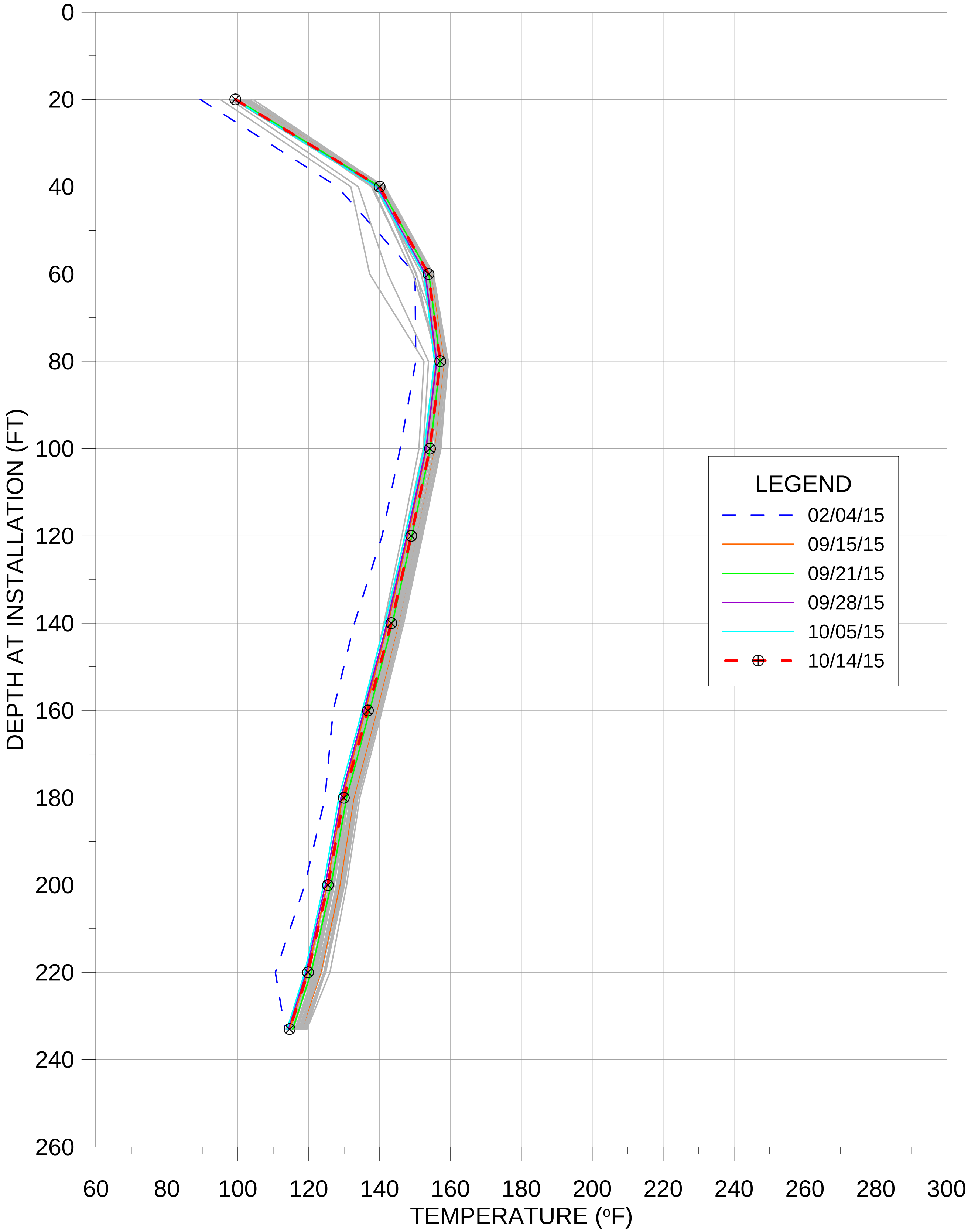
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-26



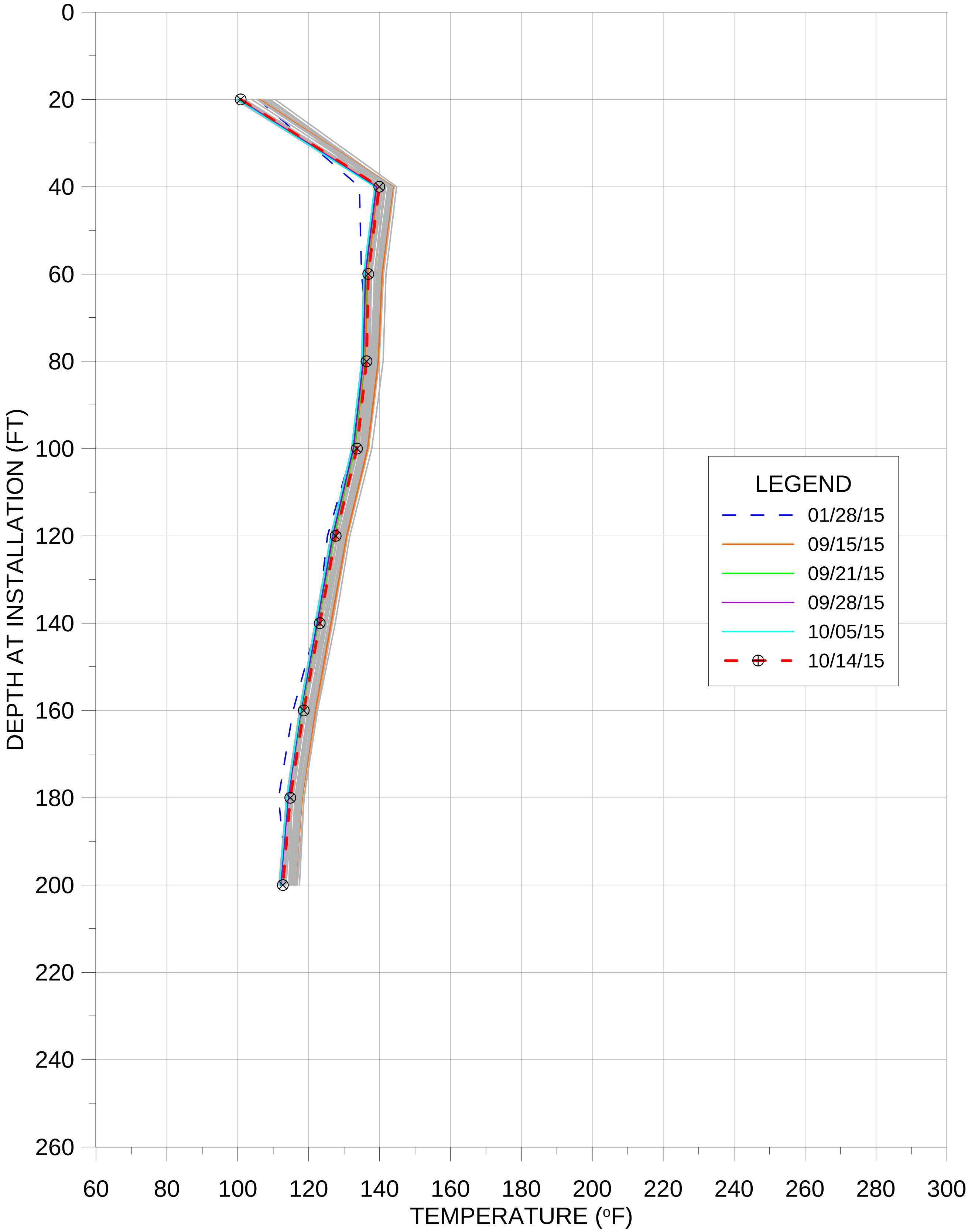
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-27



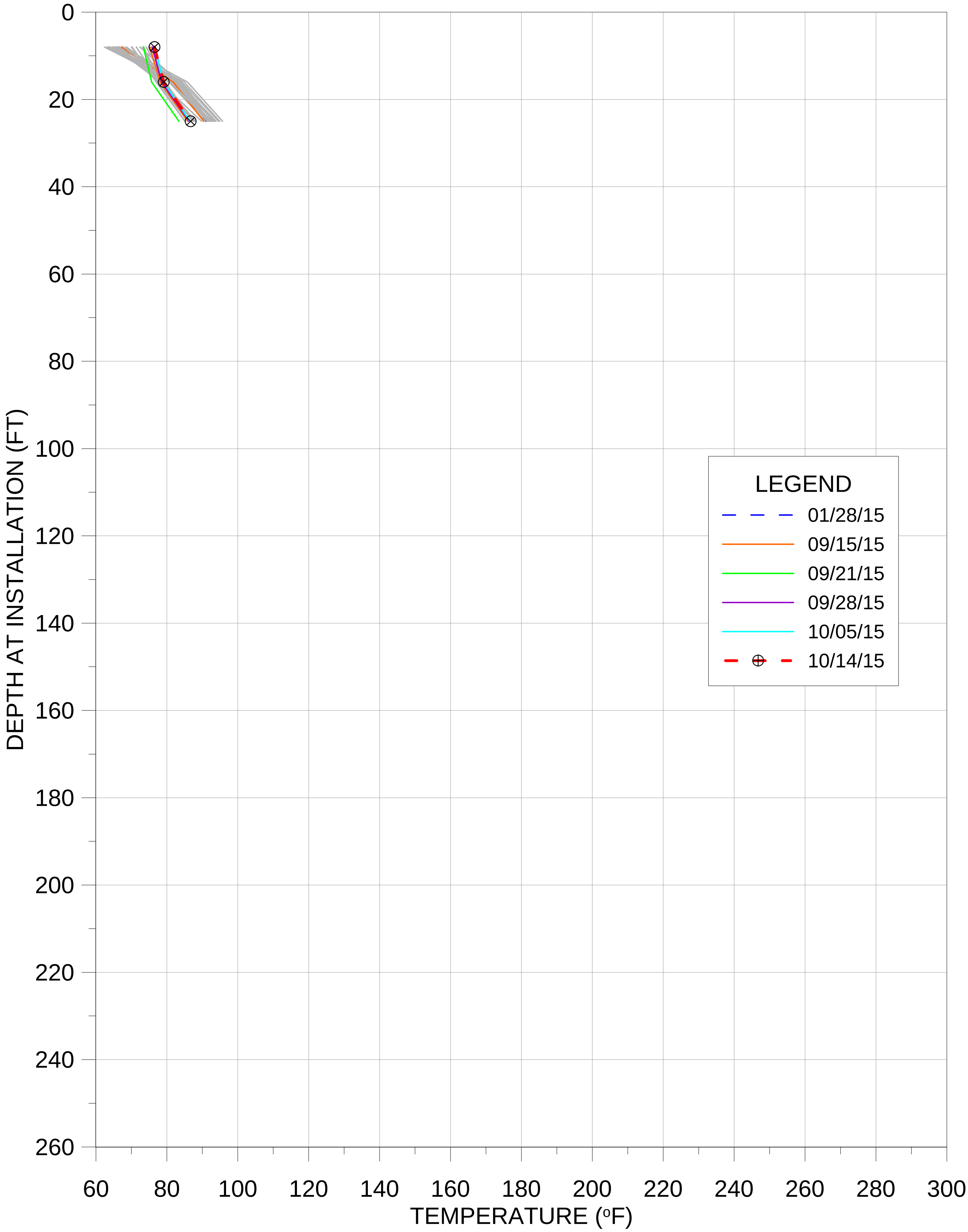
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-28



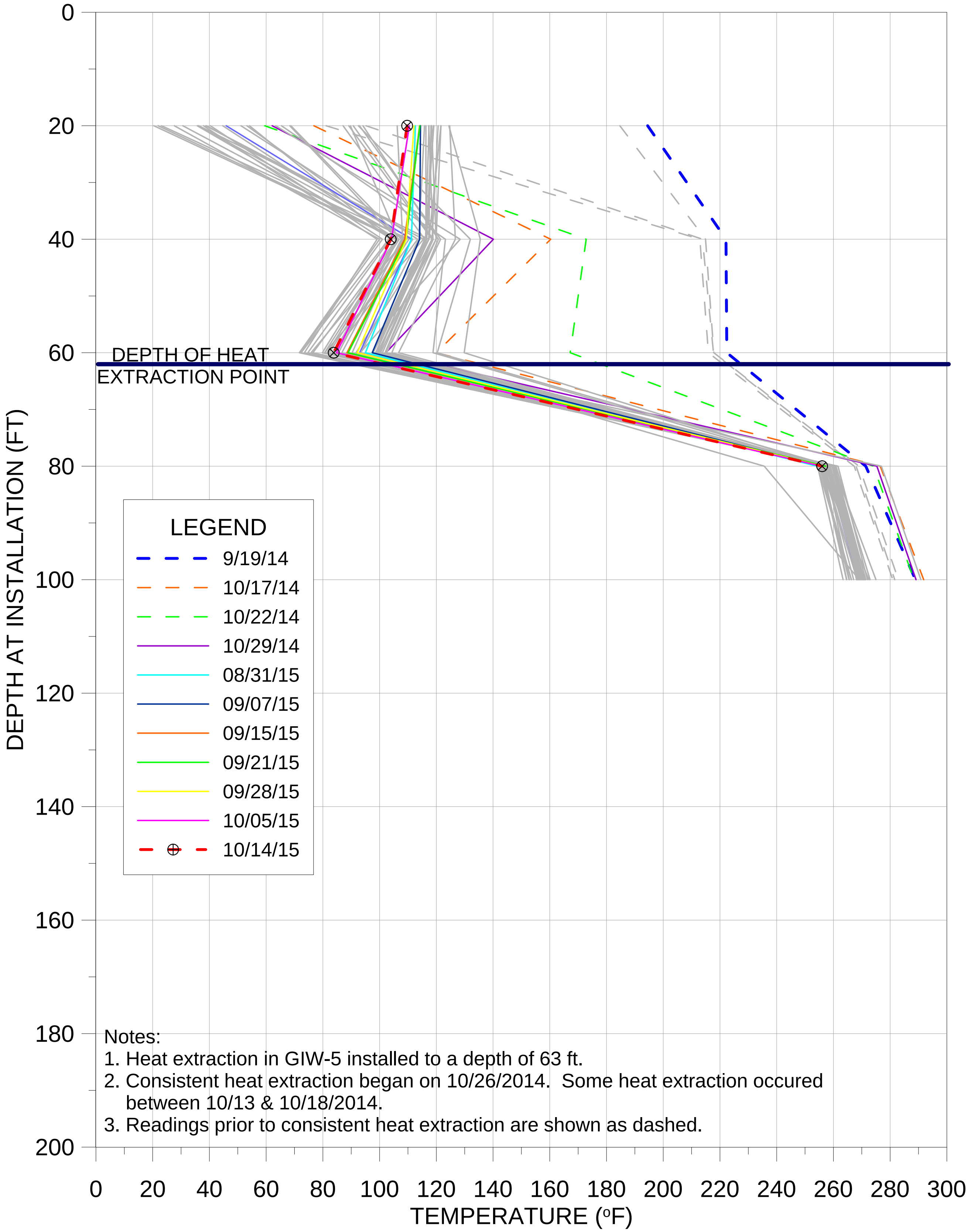
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-29



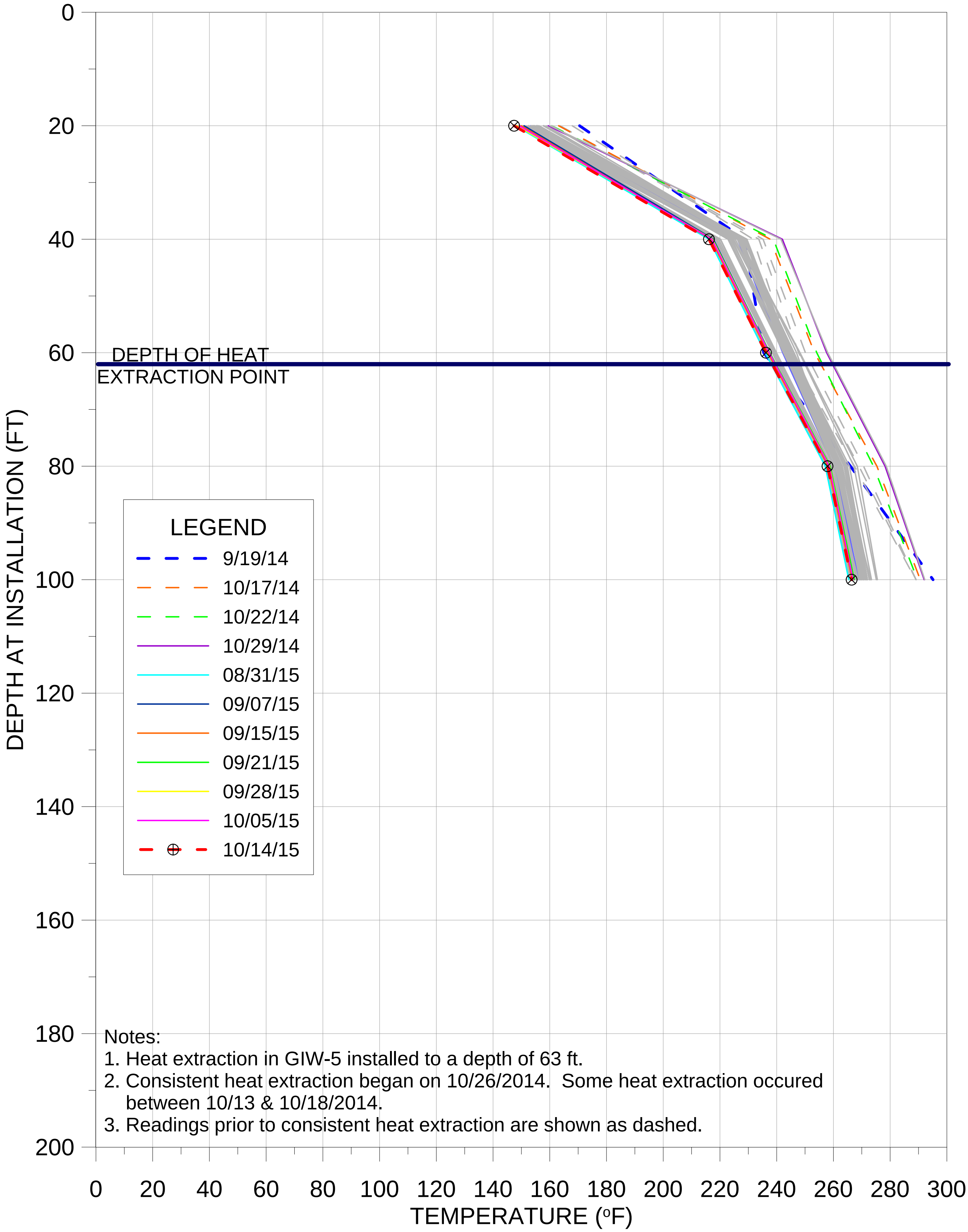
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-5-5N



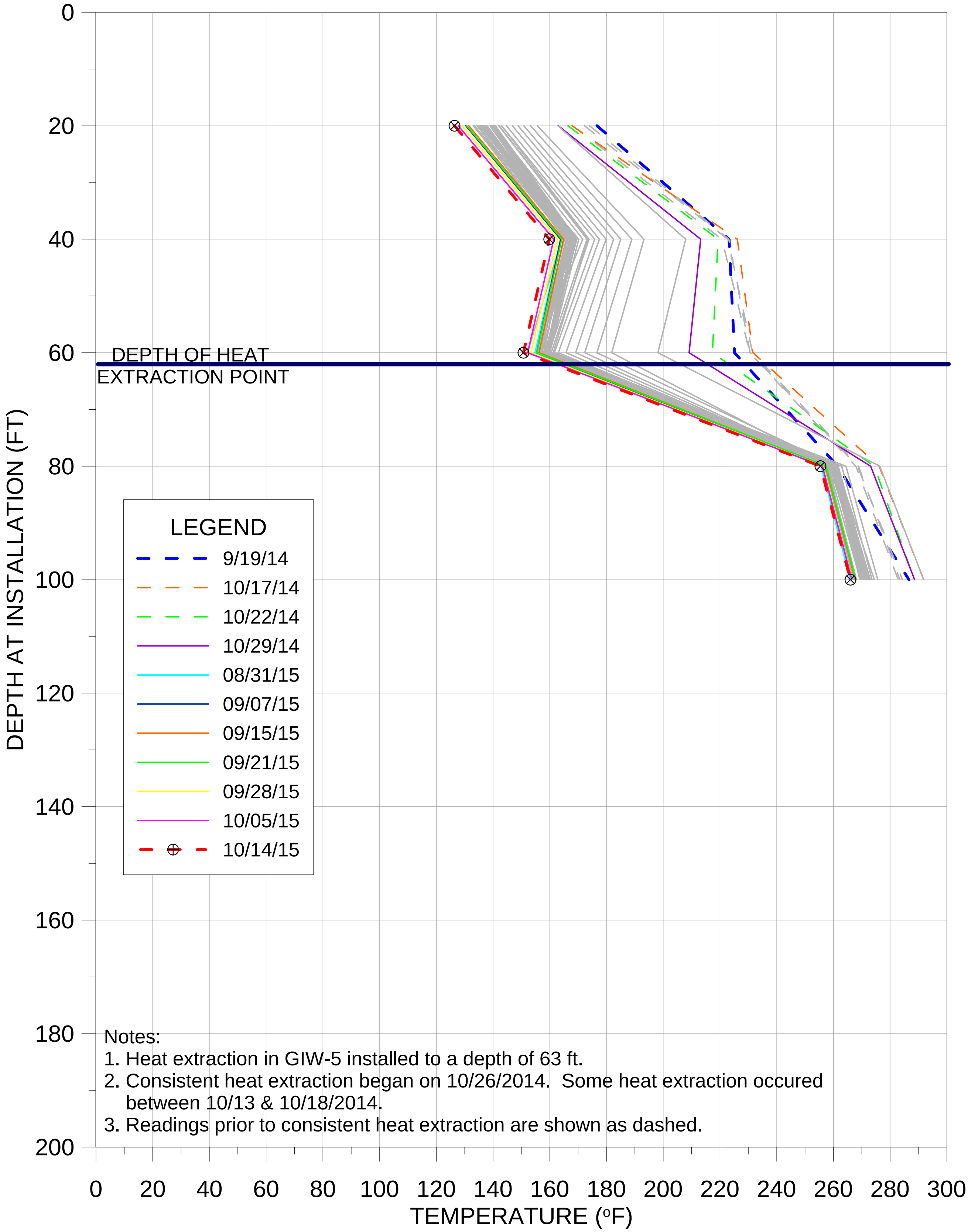
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-5-5S



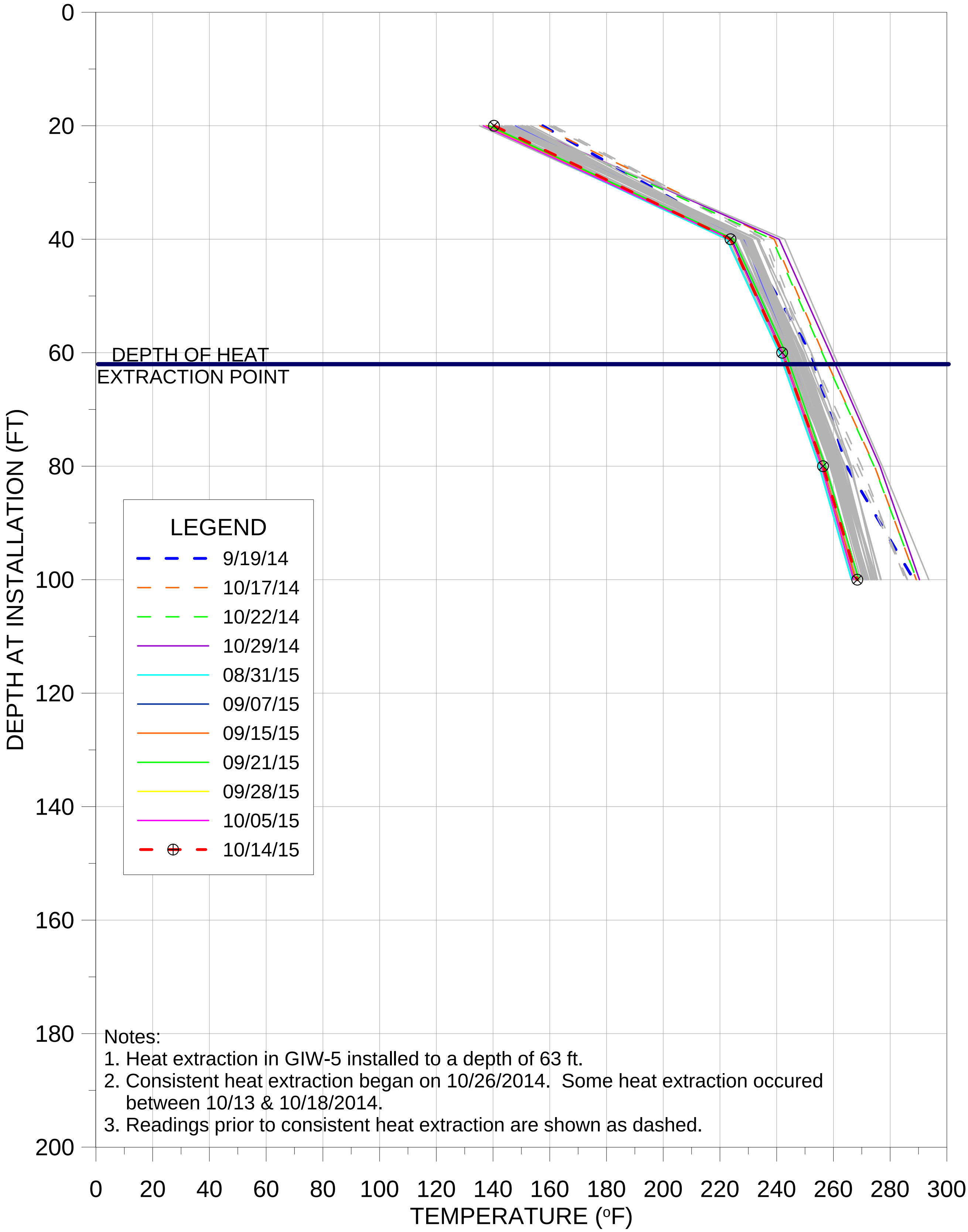
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-5-9N



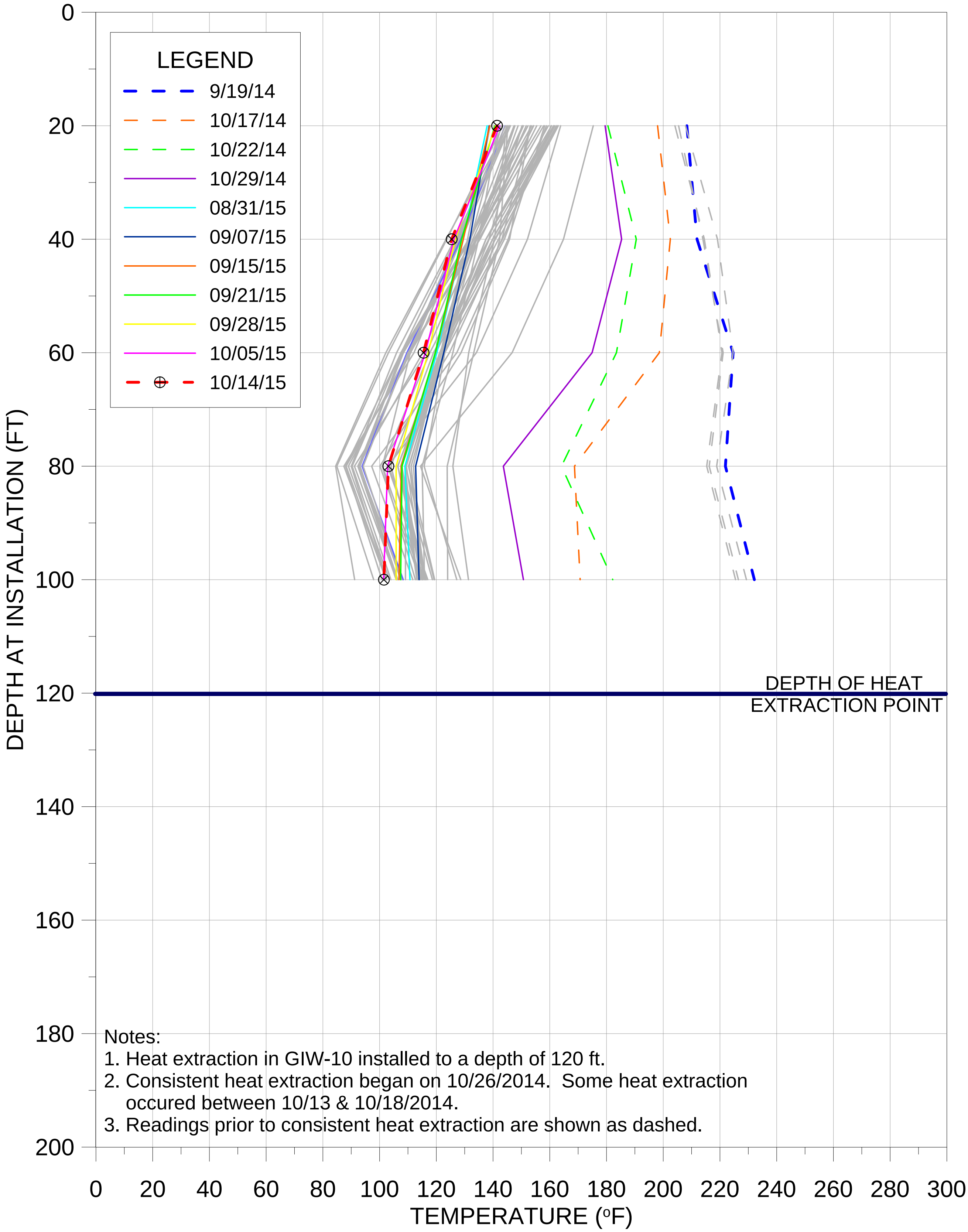
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-5-9S



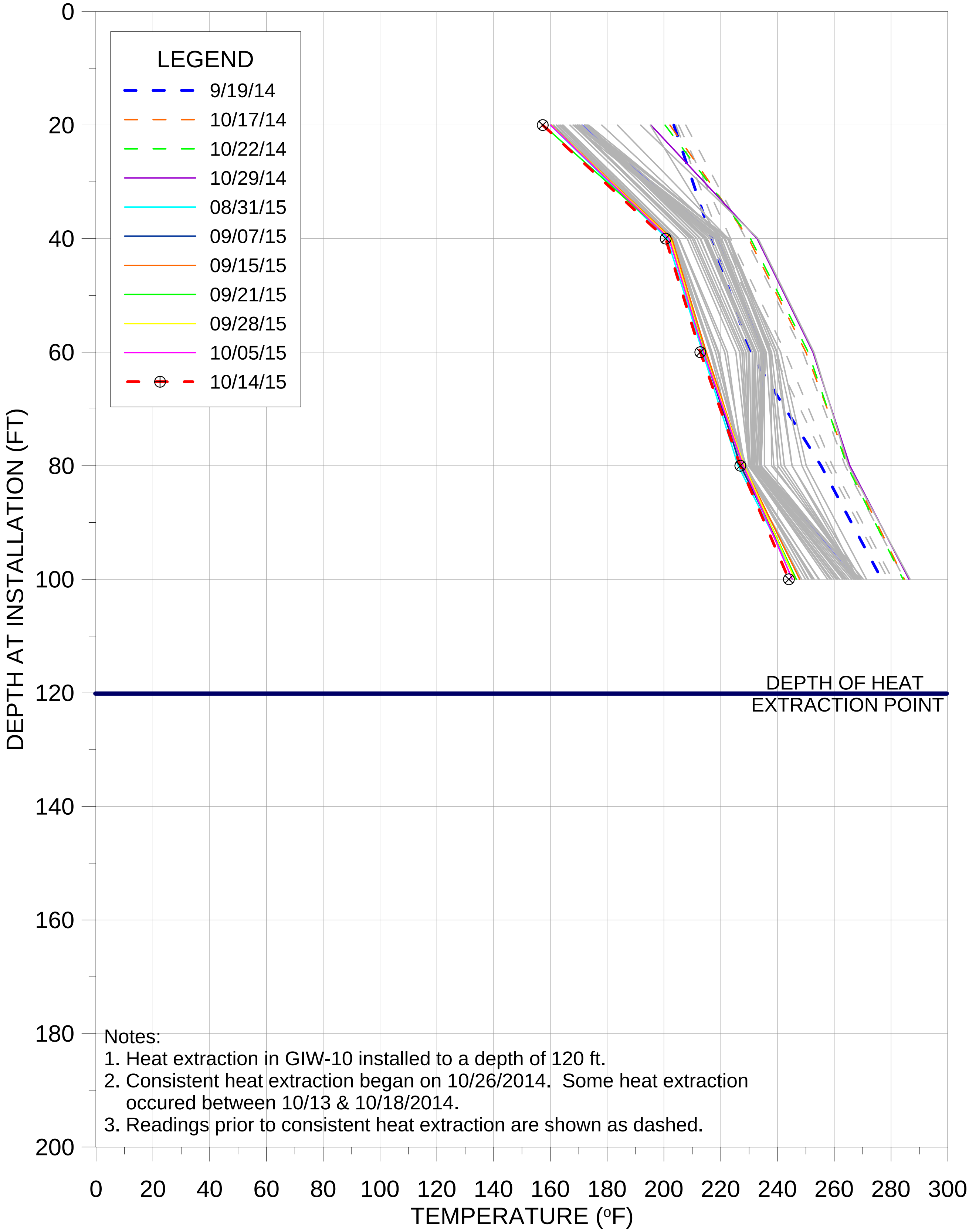
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-10-5N



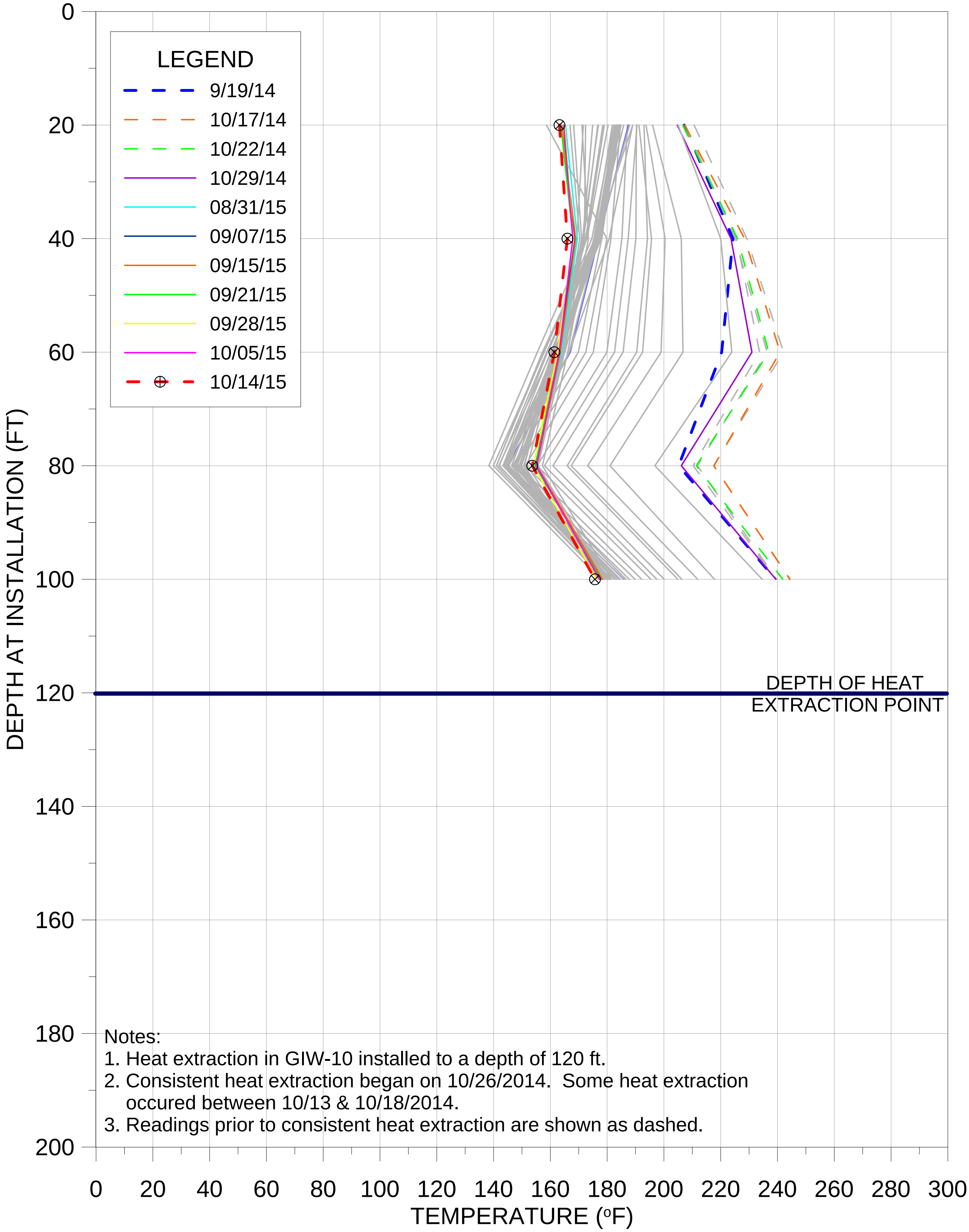
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-10-5S



TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

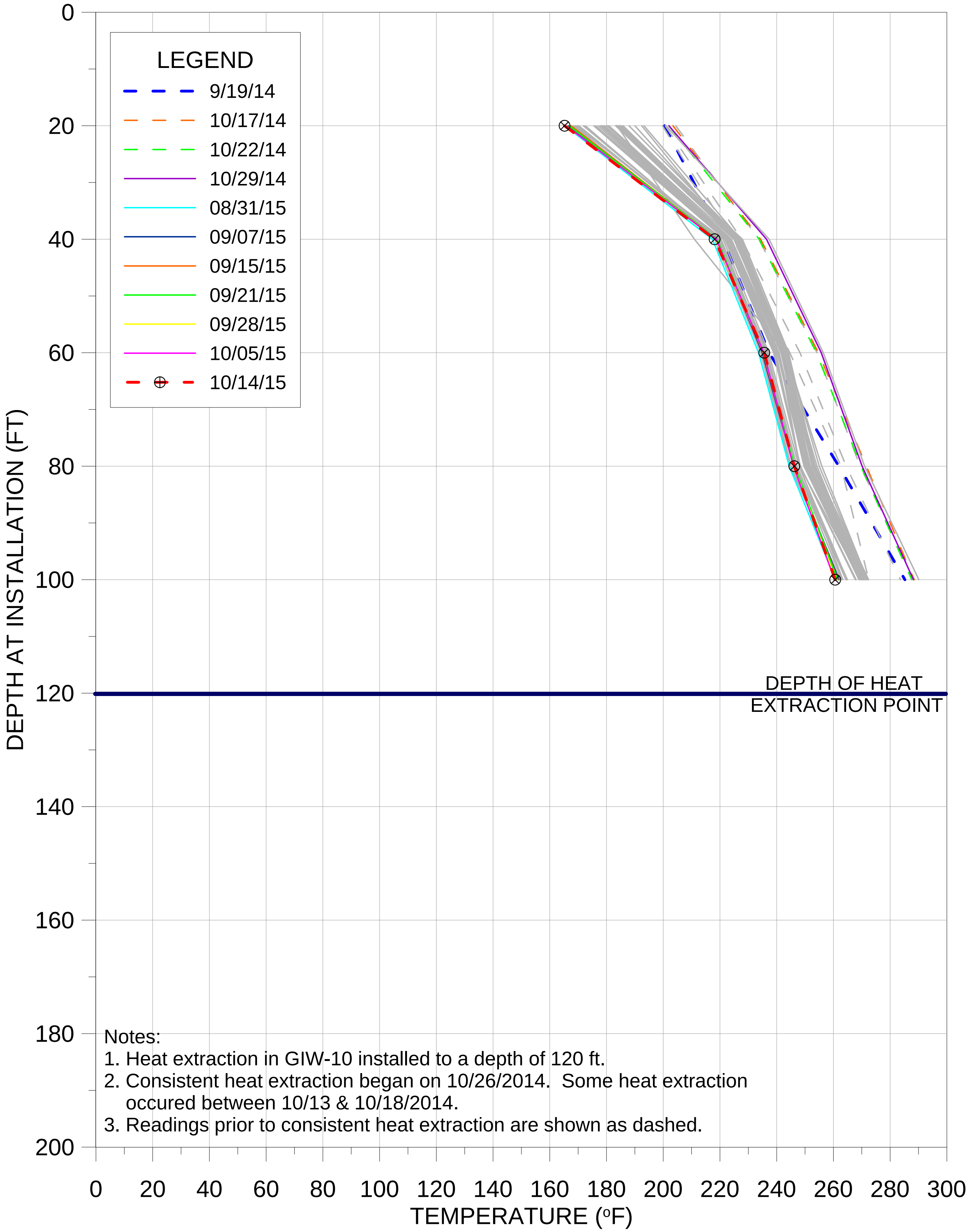
TMP-10-9N



Notes:
1. Heat extraction in GIW-10 installed to a depth of 120 ft.
2. Consistent heat extraction began on 10/26/2014. Some heat extraction occured between 10/13 & 10/18/2014.
3. Readings prior to consistent heat extraction are shown as dashed.

TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

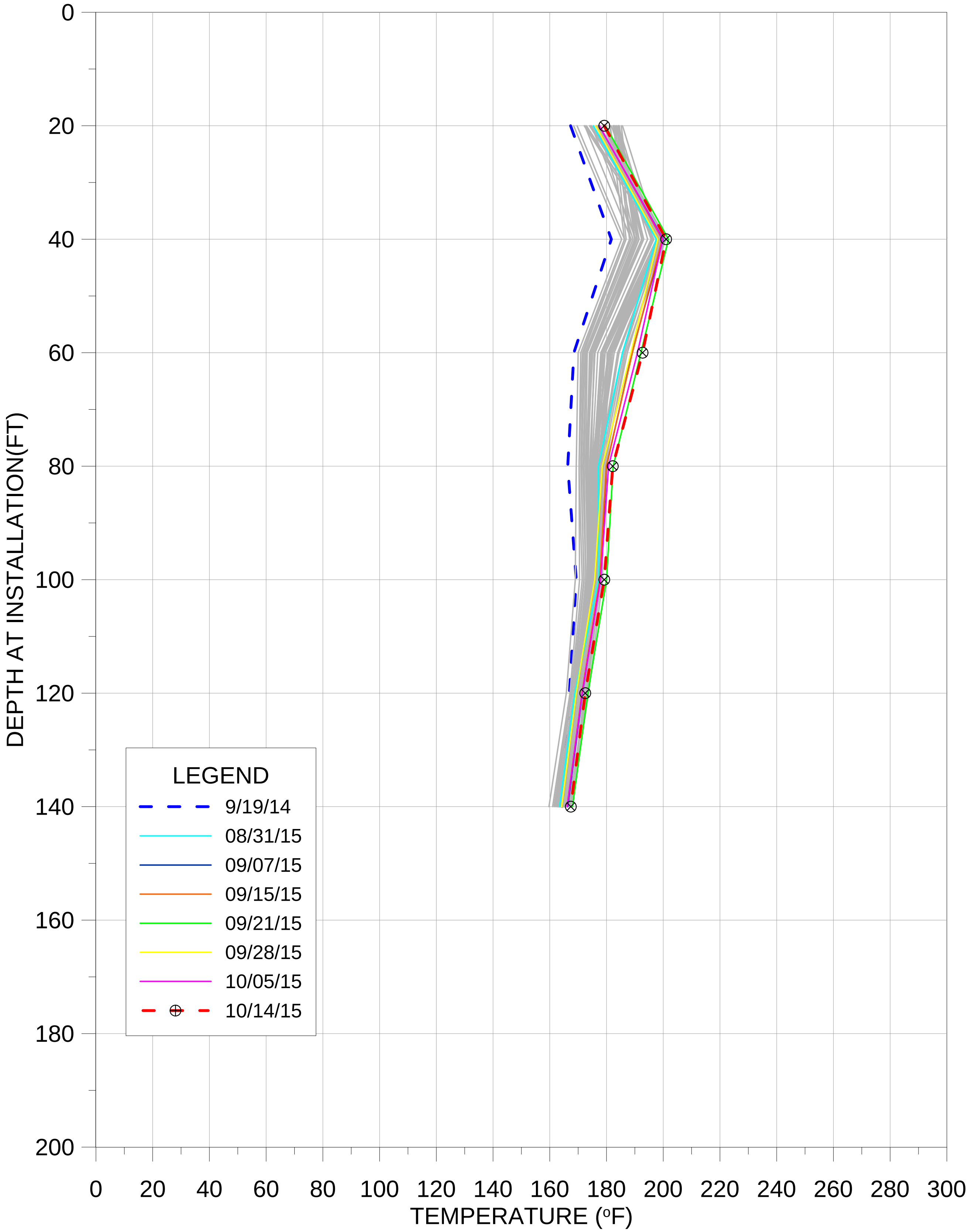
TMP-10-9S



Notes:
1. Heat extraction in GIW-10 installed to a depth of 120 ft.
2. Consistent heat extraction began on 10/26/2014. Some heat extraction occured between 10/13 & 10/18/2014.
3. Readings prior to consistent heat extraction are shown as dashed.

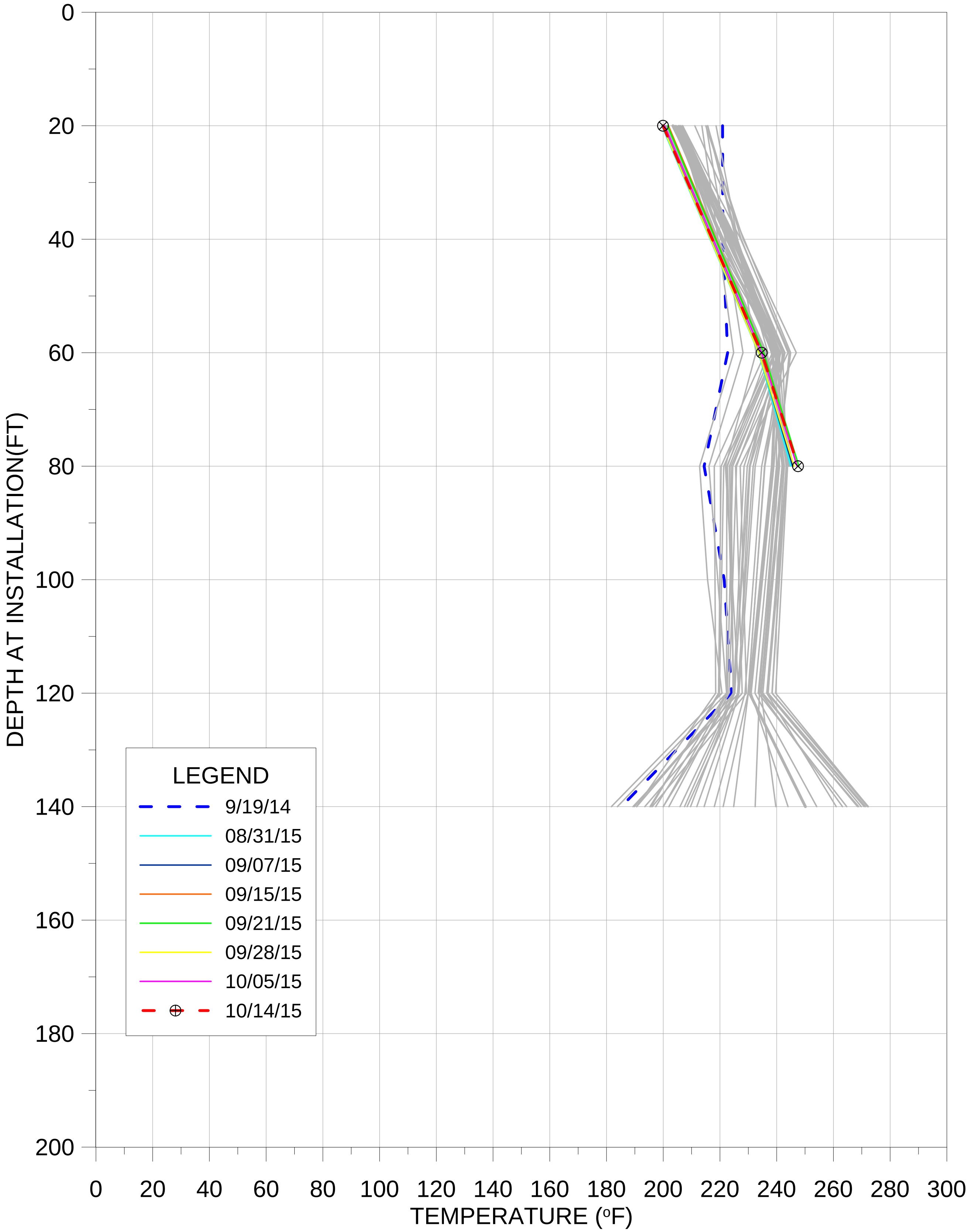
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-14R



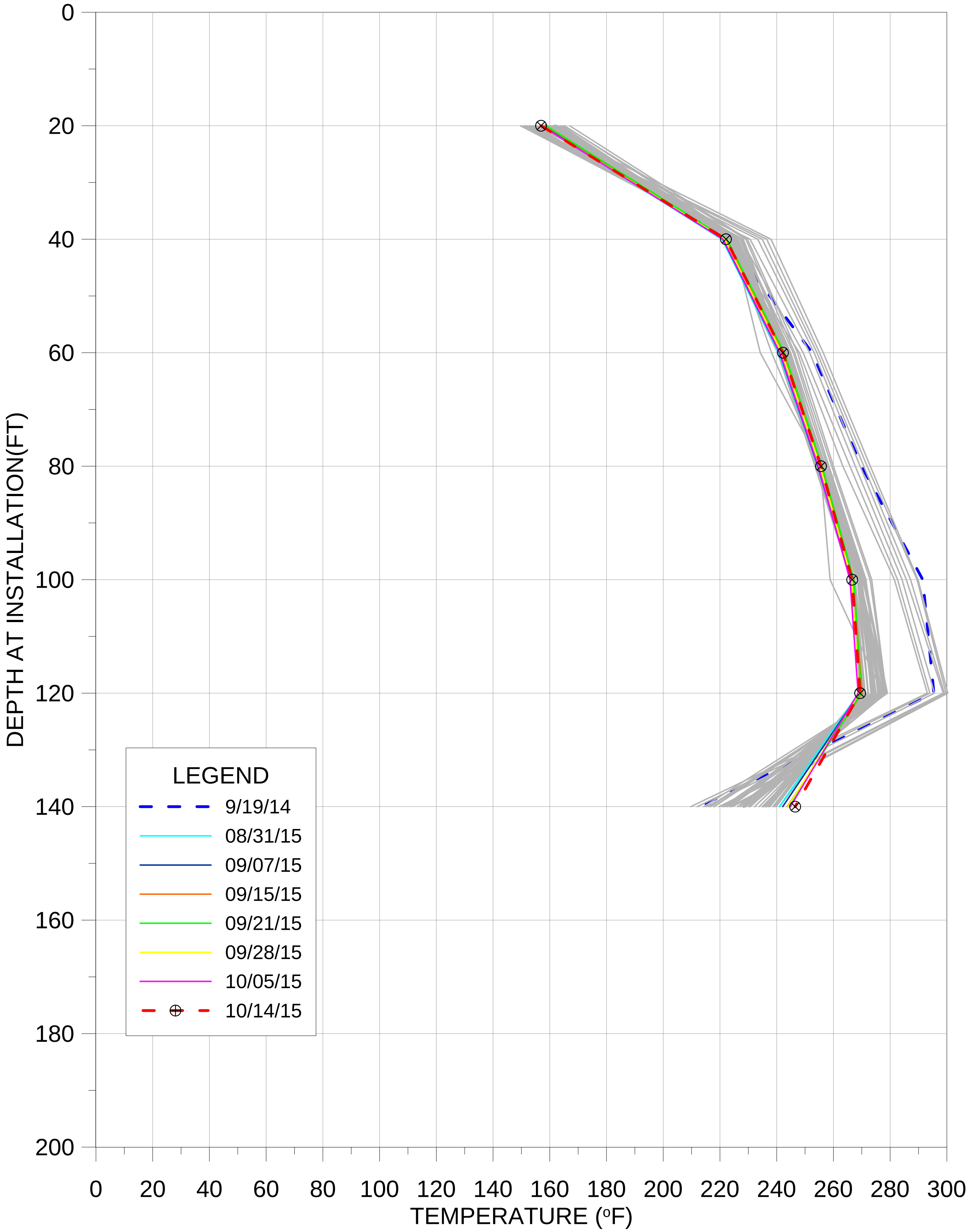
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-19



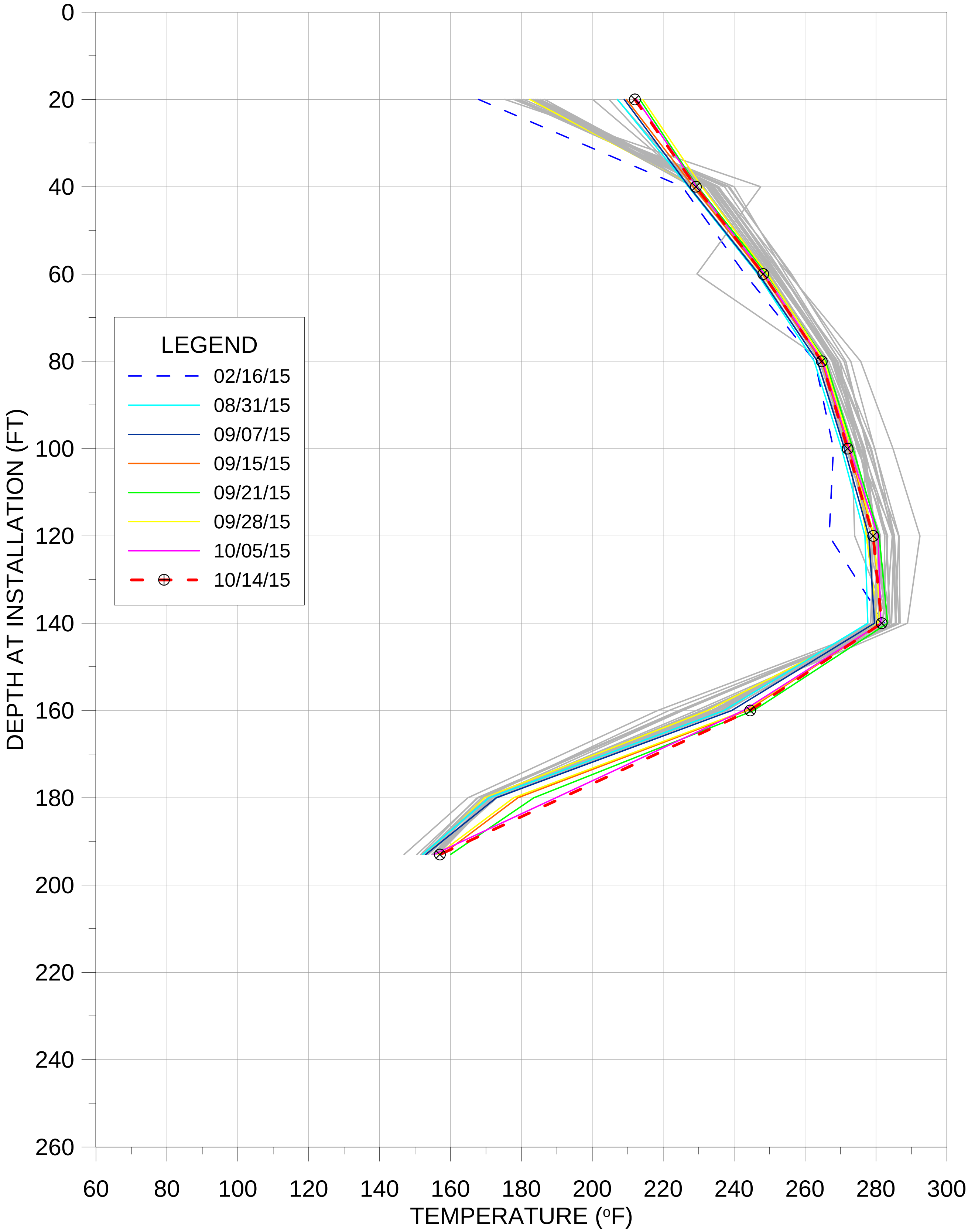
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-20



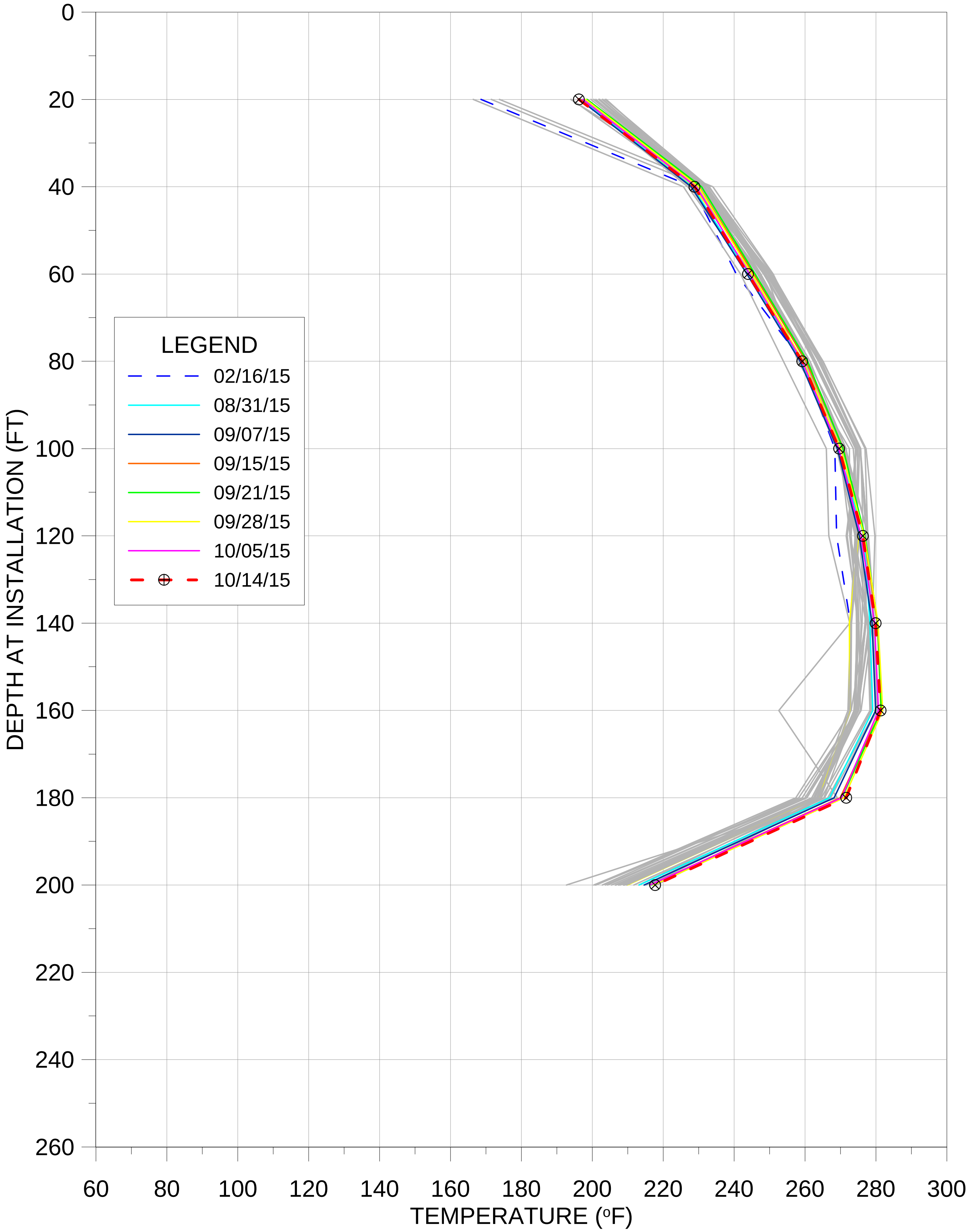
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-31



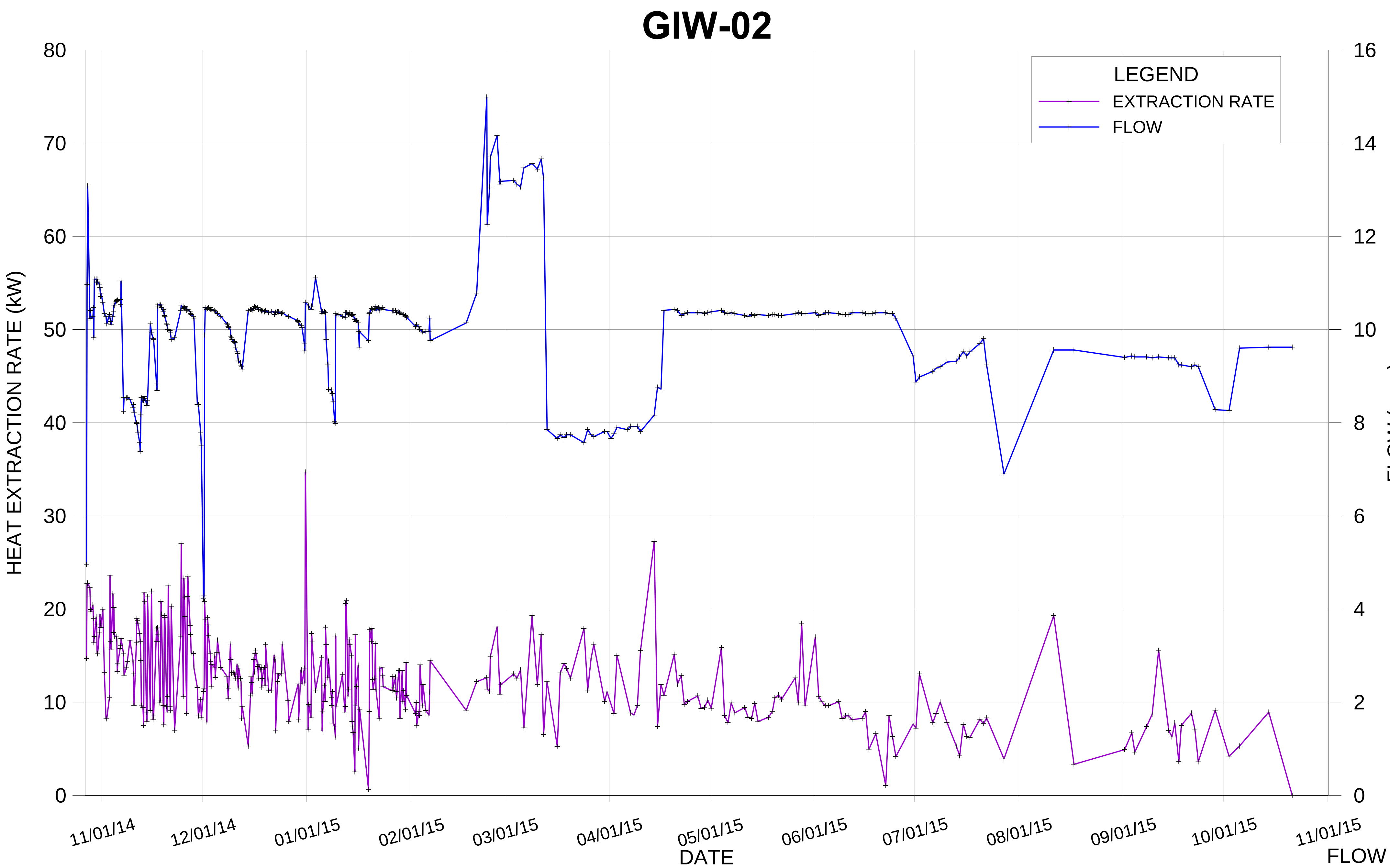
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-32

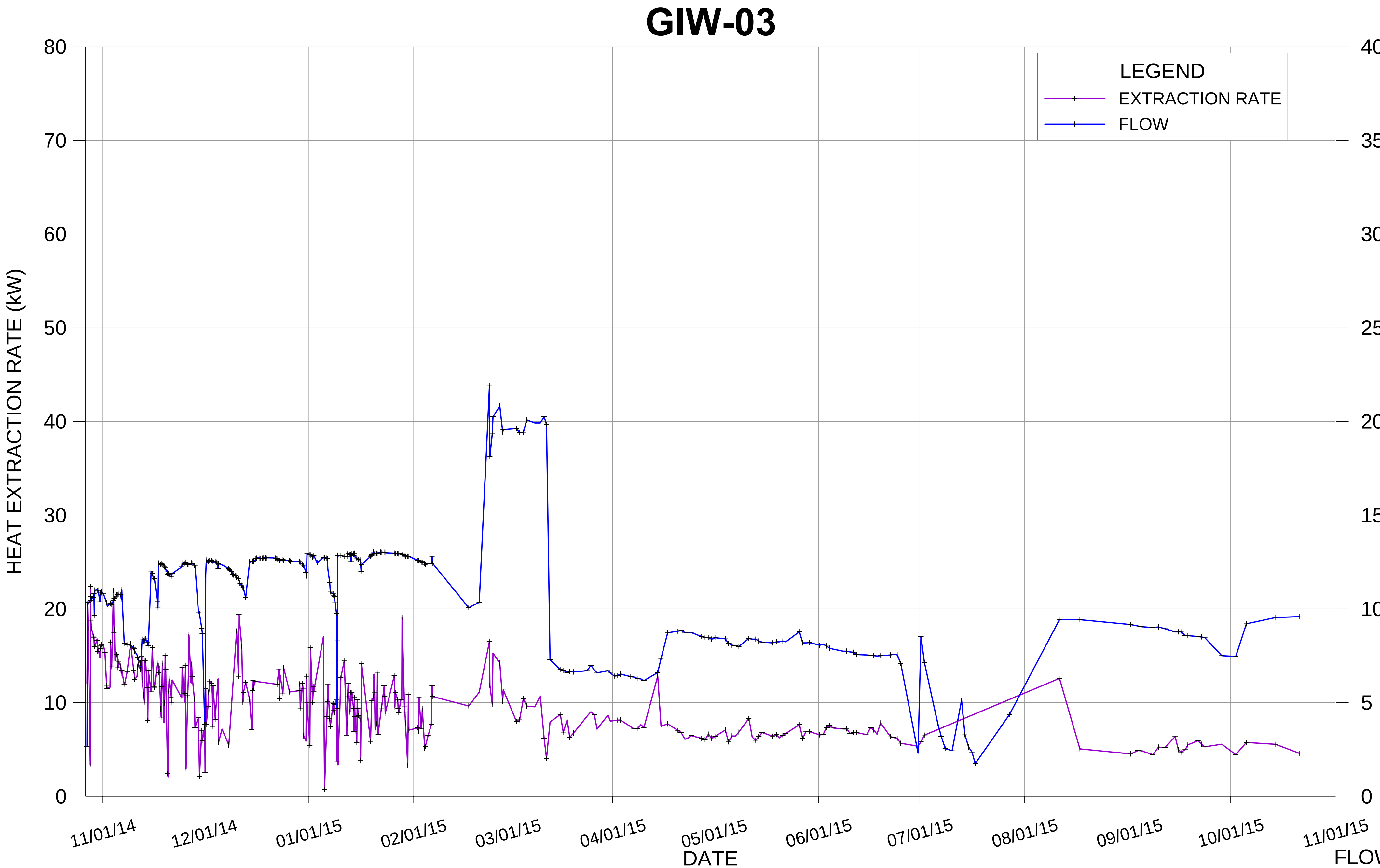


TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

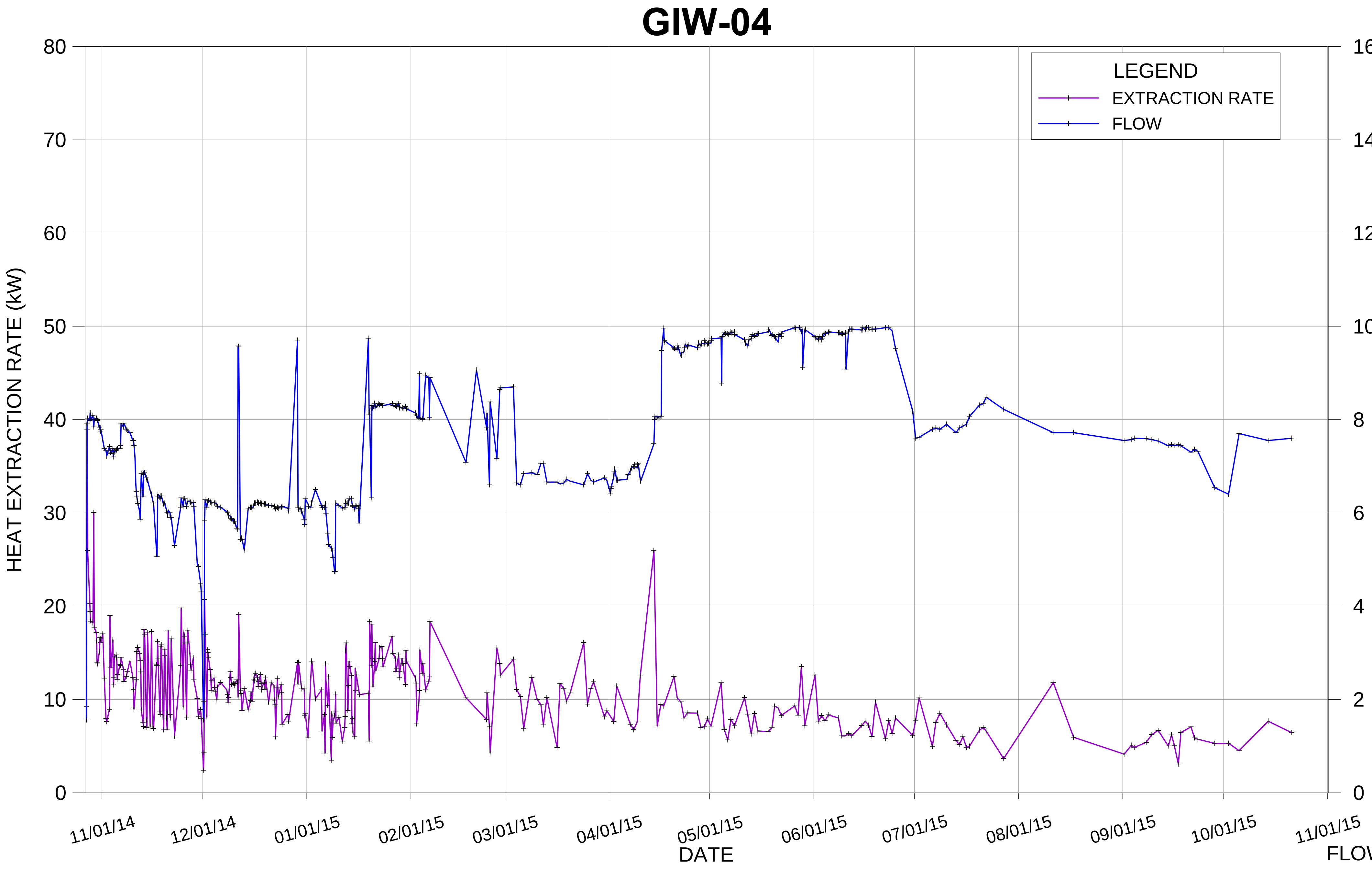
Appendix F - Heat Extraction Point Data



FLOW RATE AND HEAT
EXTRACTION VS TIME
BRIDGETON LANDFILL

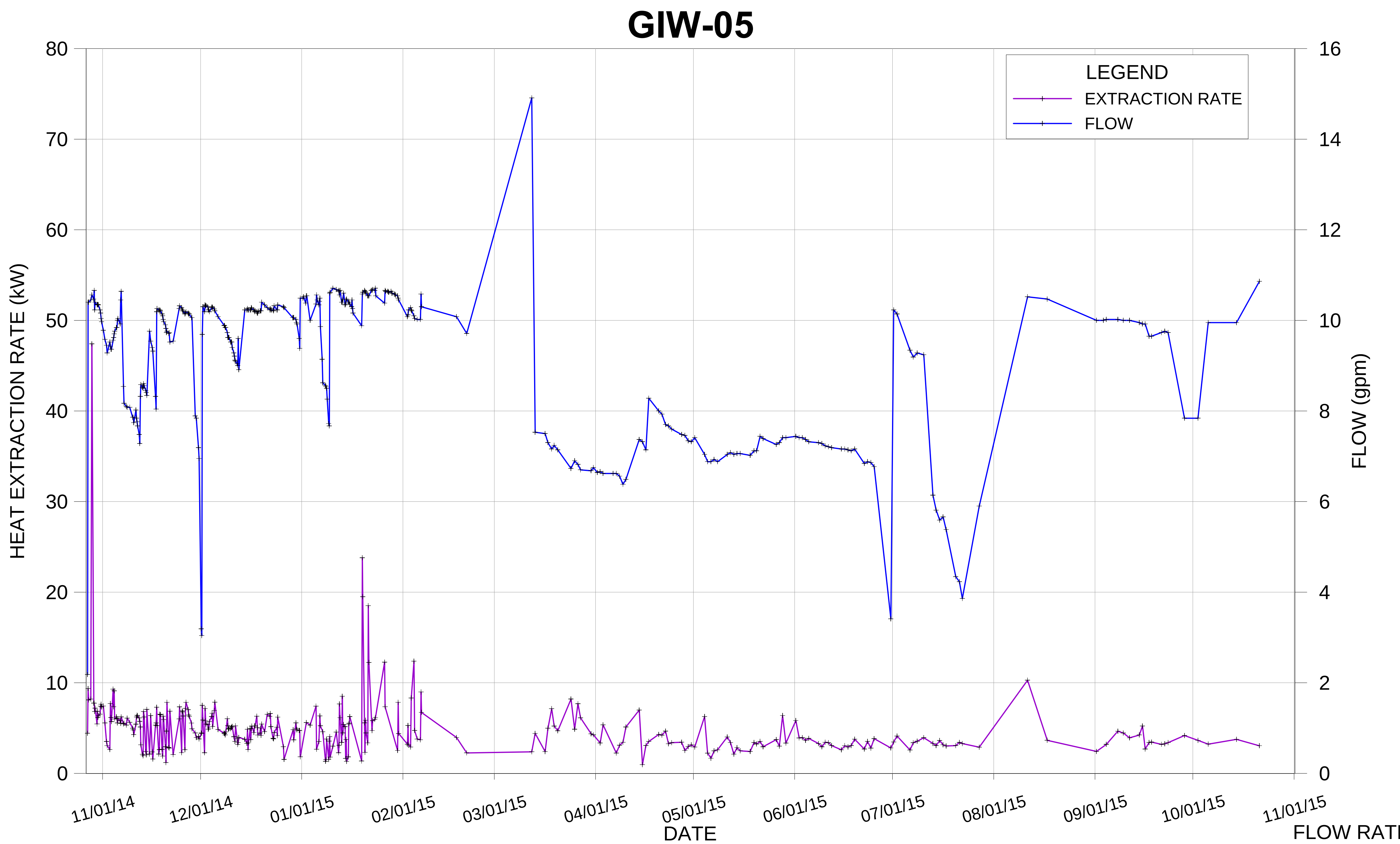


FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL



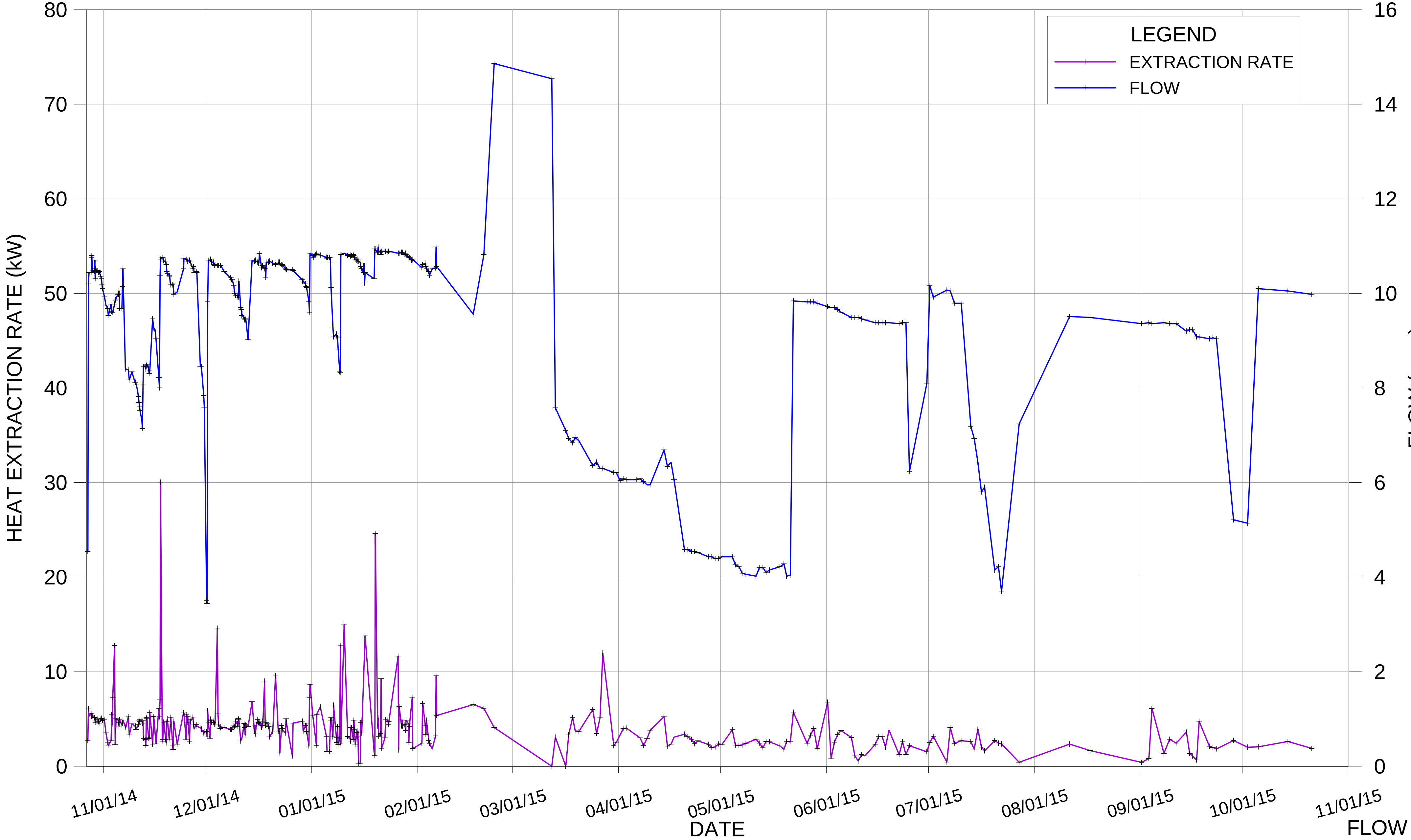
FLOW RATE AND HEAT
EXTRACTION VS TIME
BRIDGETON LANDFILL

GIW-05

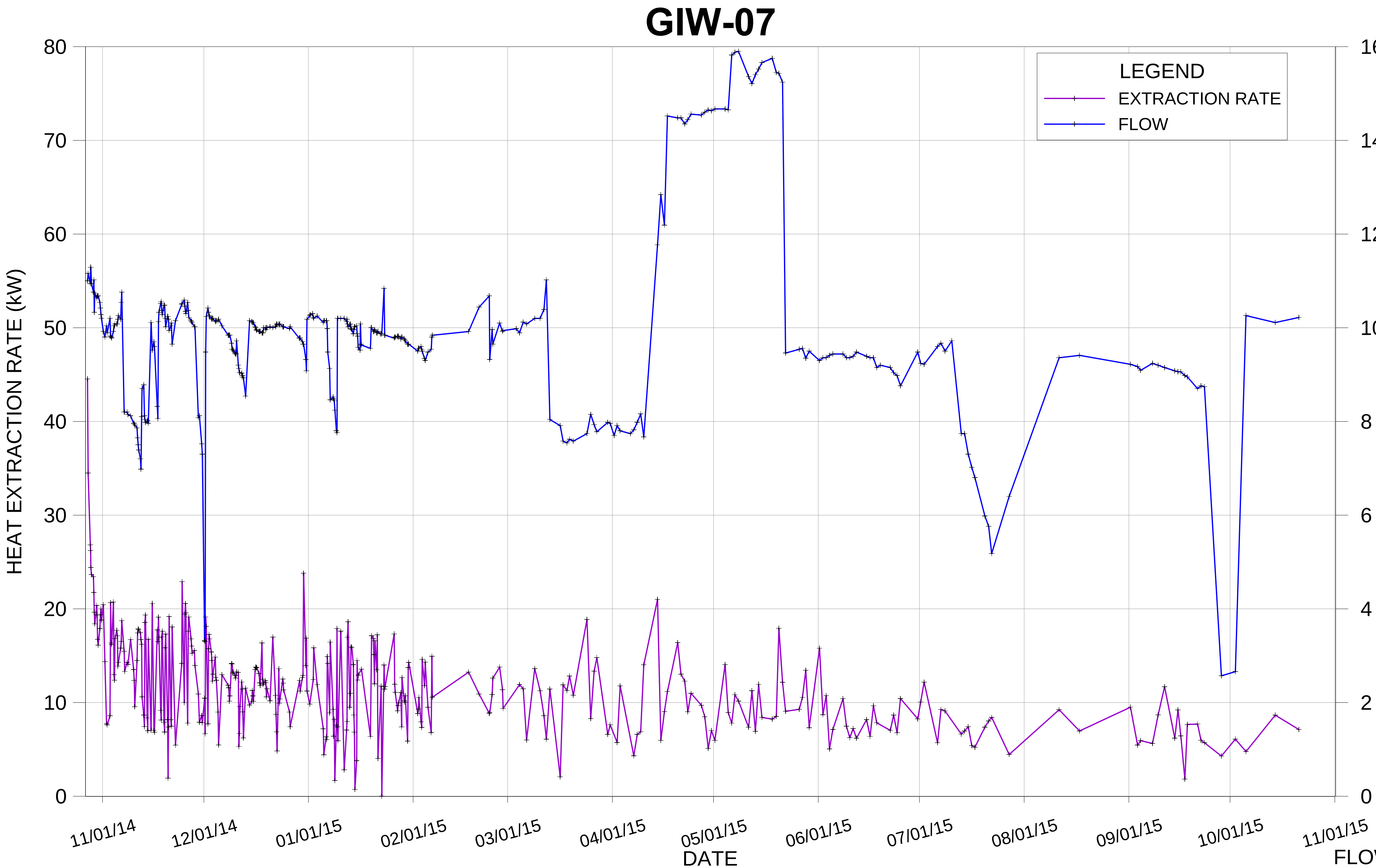


FLOW RATE AND HEAT
EXTRACTION VS TIME
BRIDGETON LANDFILL

GIW-06

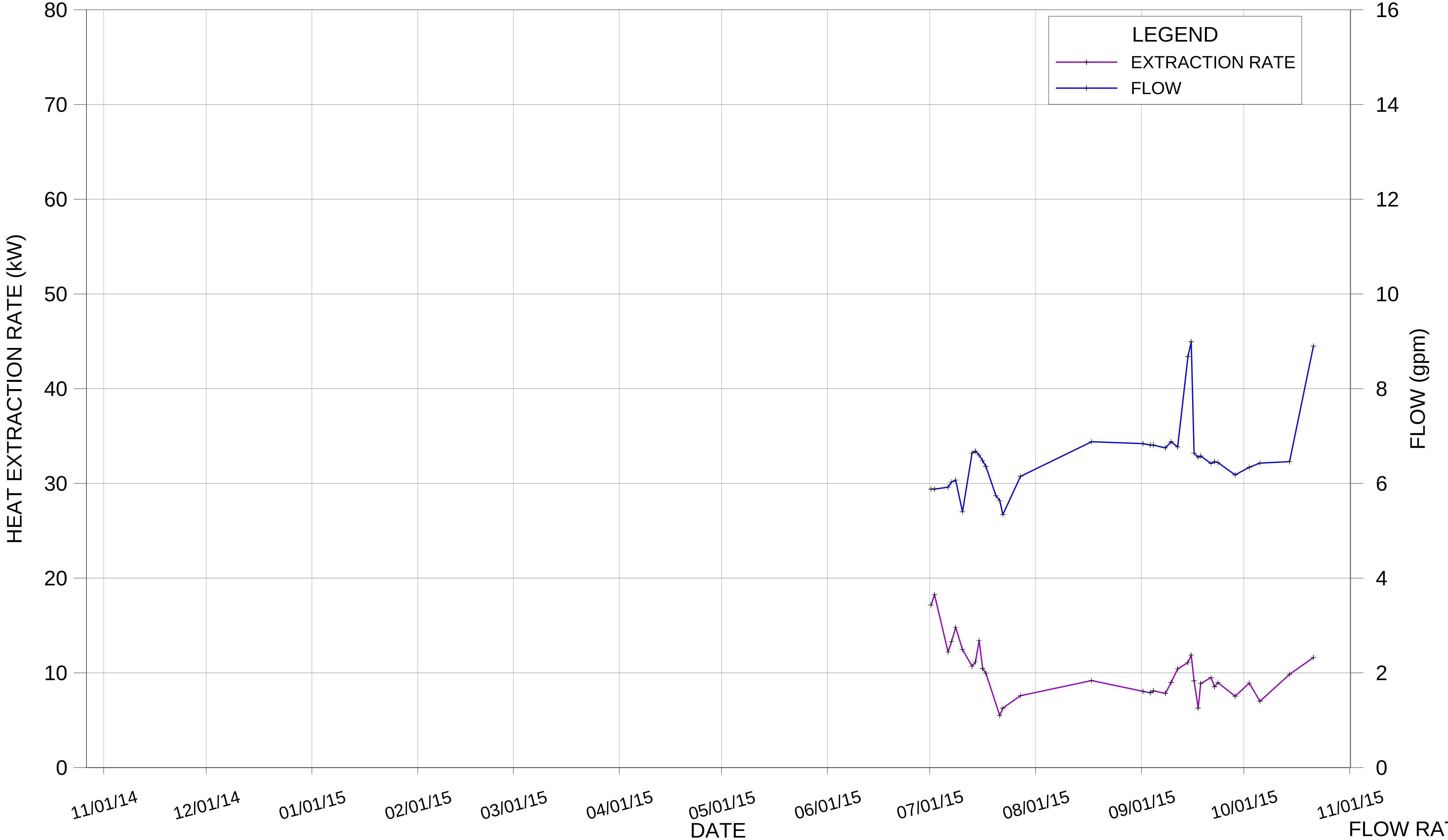


FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL



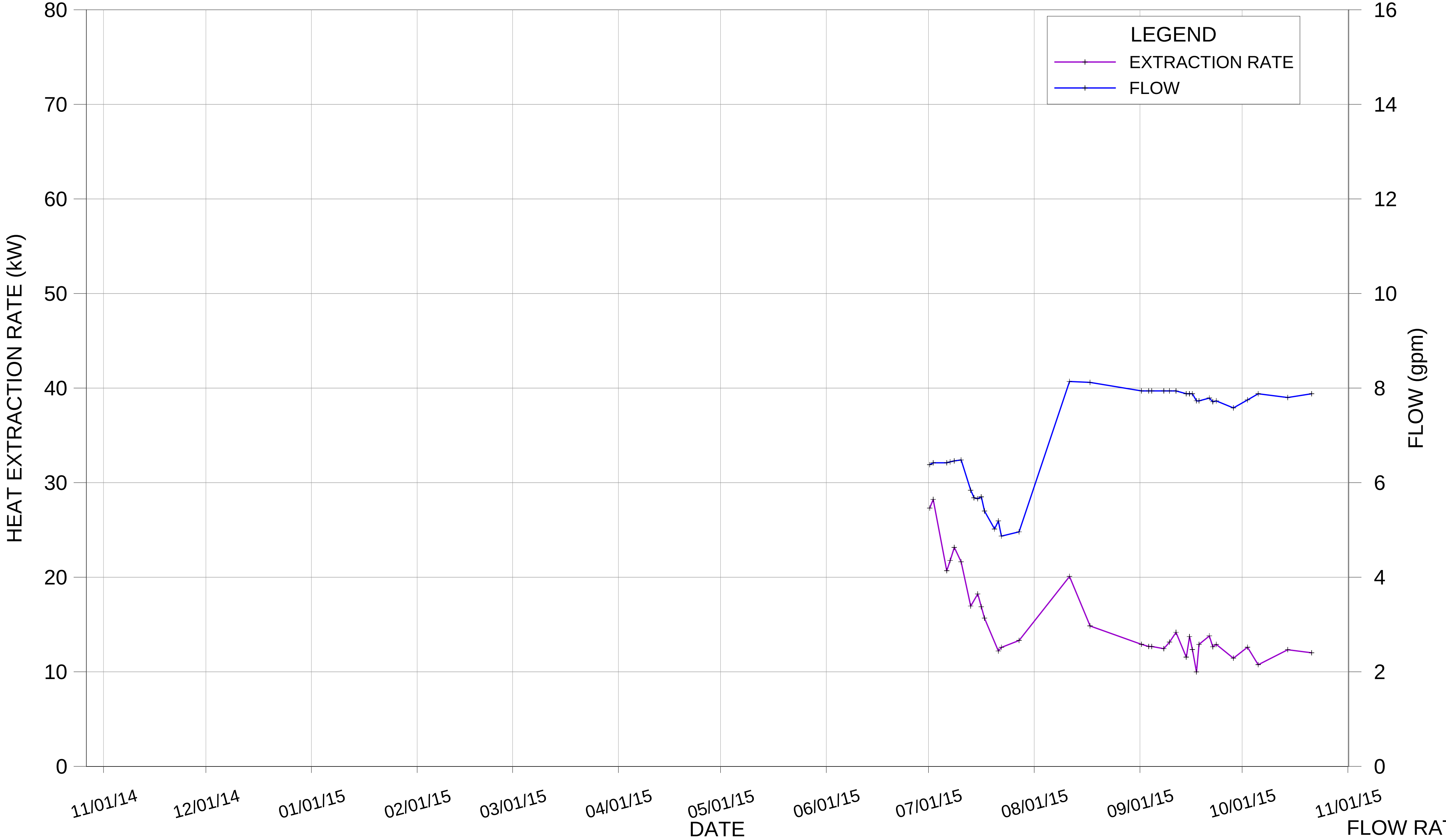
FLOW RATE AND HEAT
EXTRACTION VS TIME
BRIDGETON LANDFILL

GIW-8



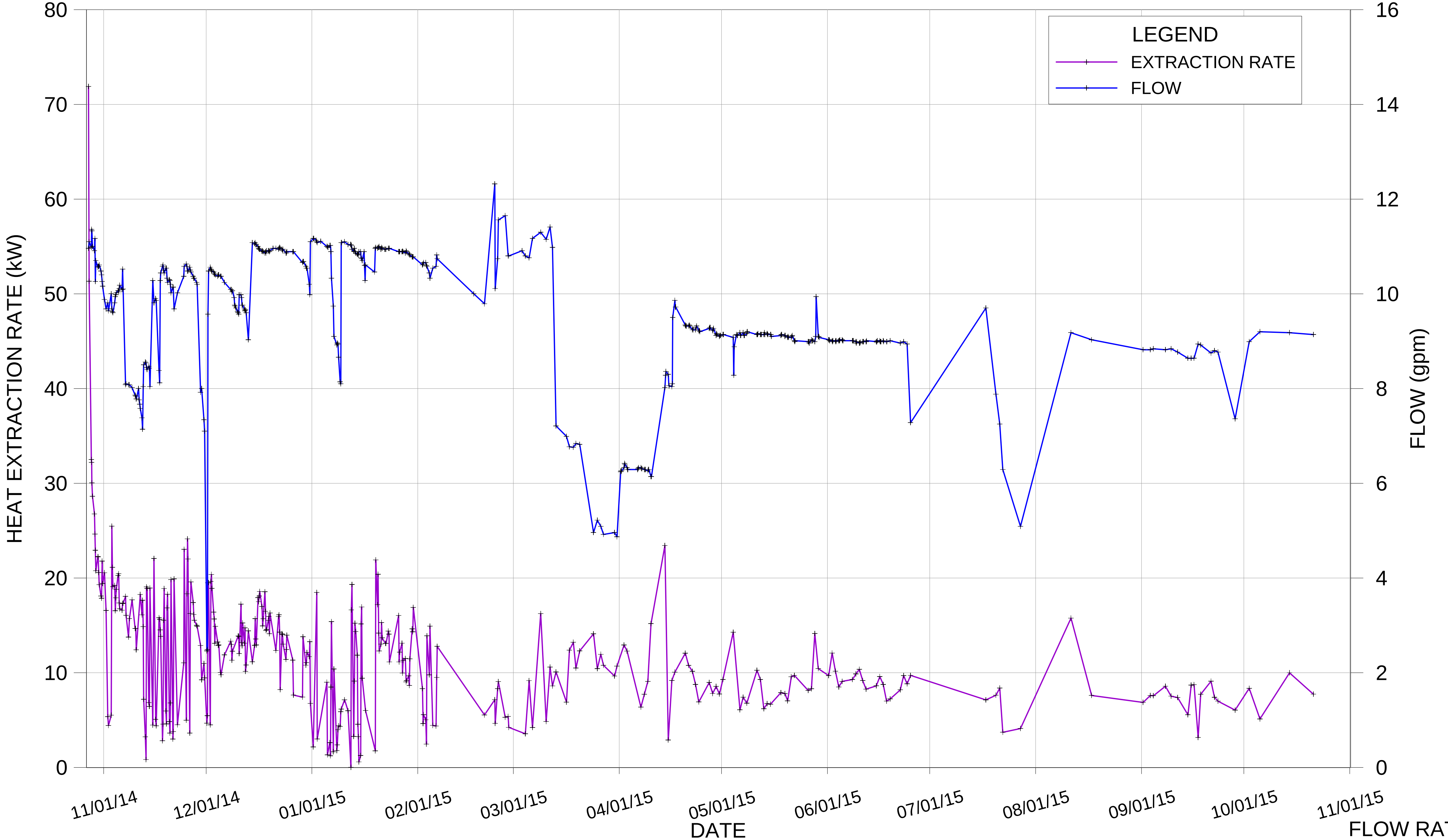
FLOW RATE AND HEAT
EXTRACTION VS TIME
BRIDGETON LANDFILL

GIW-9



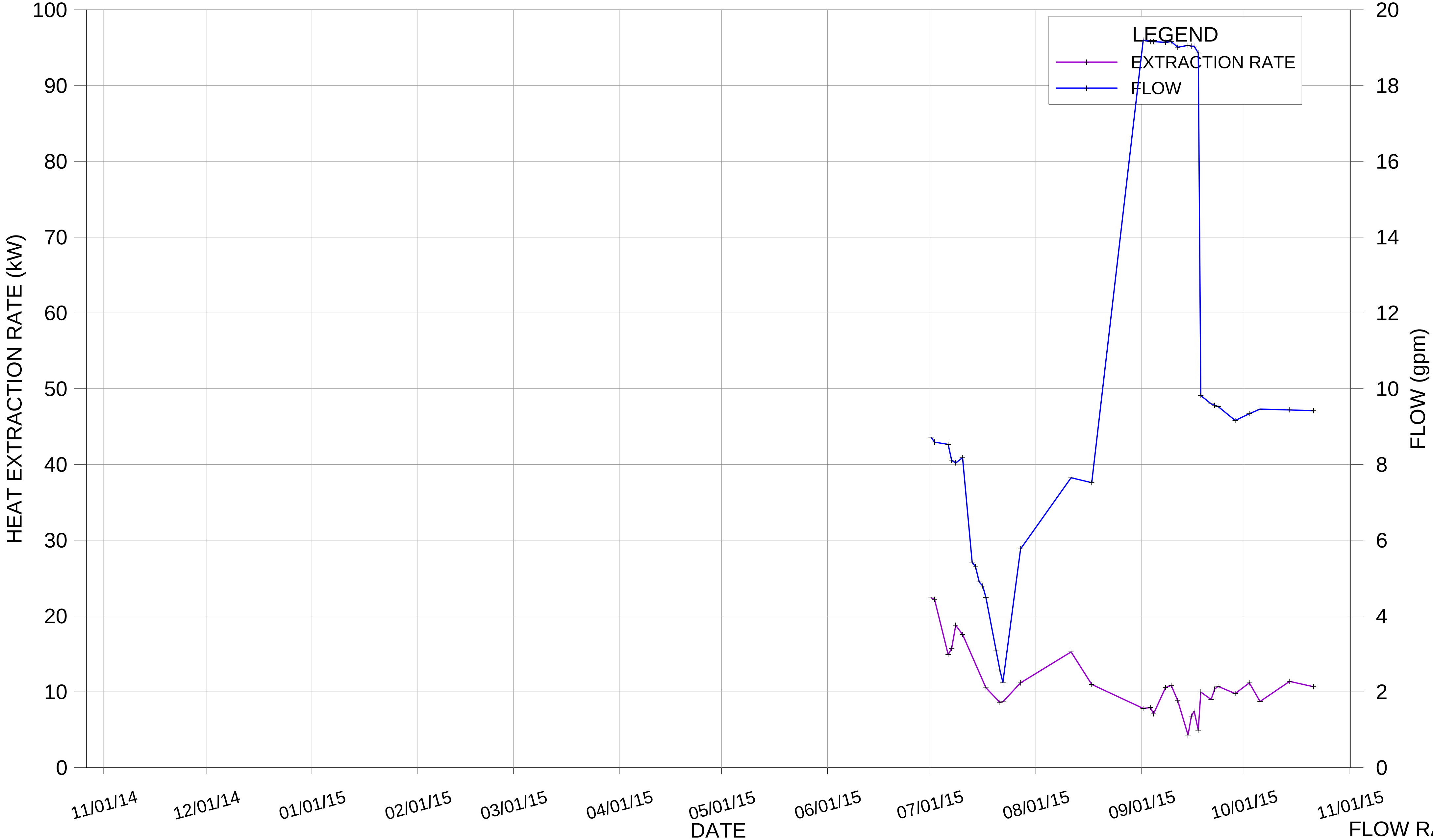
FLOW RATE AND HEAT
EXTRACTION VS TIME
BRIDGETON LANDFILL

GIW-10



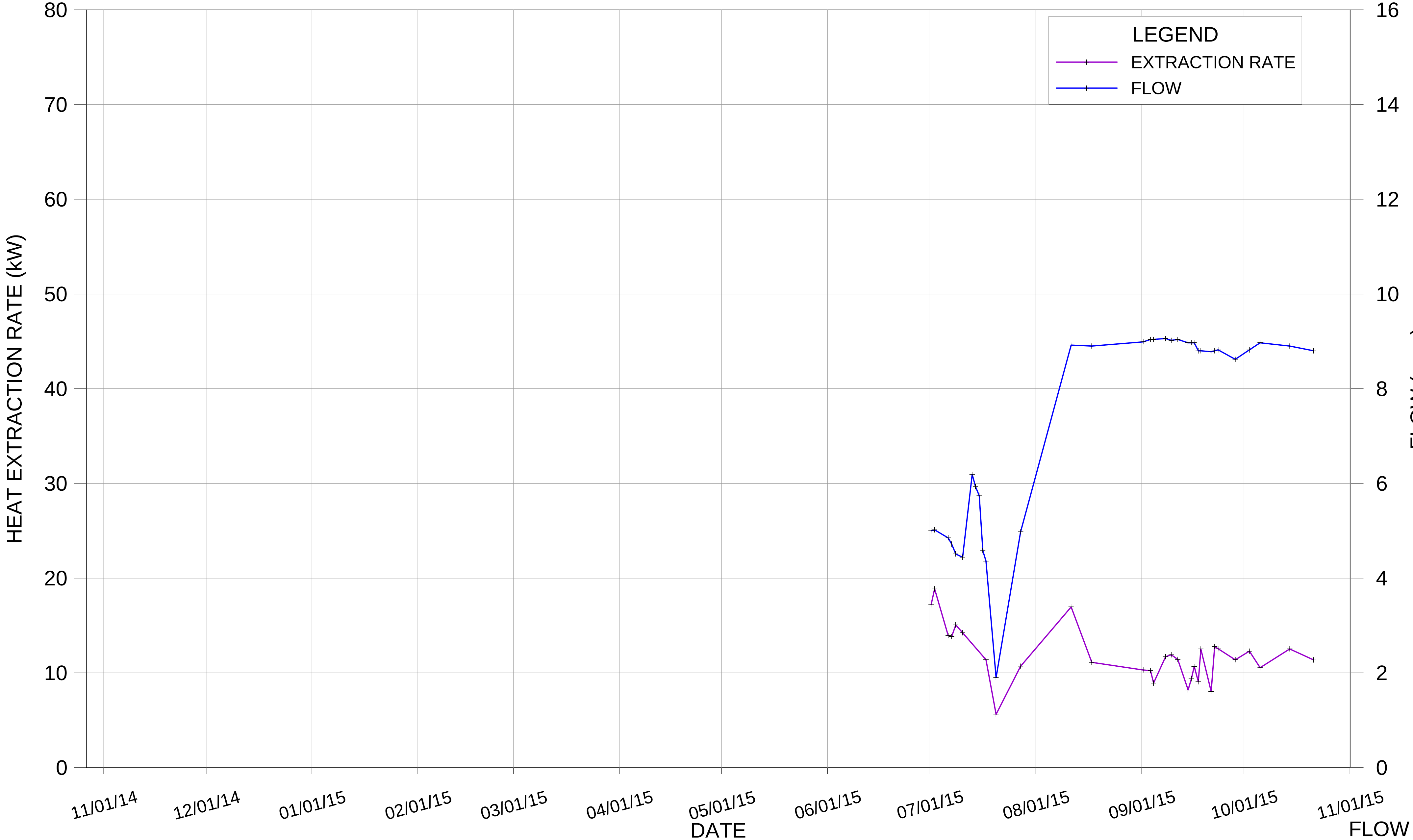
FLOW RATE AND HEAT
EXTRACTION VS TIME
BRIDGETON LANDFILL

GIW-11



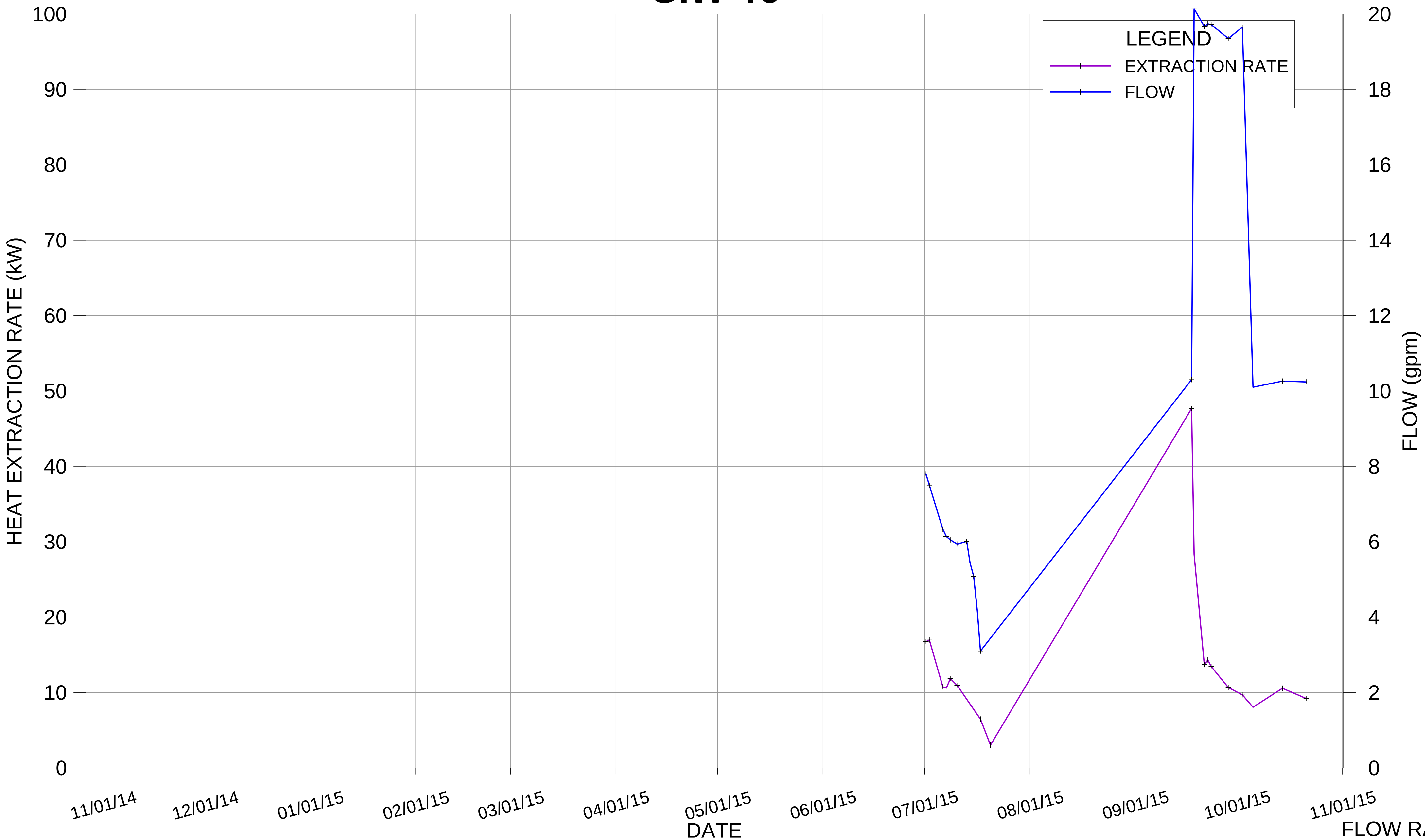
FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL

GIW-12



FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL

GIW-13



FLOW RATE AND HEAT
EXTRACTION VS TIME
BRIDGETON LANDFILL

Appendix G - Current Heat Removal System

LEGEND

- EXISTING GRADE (2' CONTOUR)
- 500 EXISTING GRADE (10' CONTOUR)
- EXISTING GAS EXTRACTION WELL
- EXISTING TEMPERATURE MONITOR PROBE
- EXISTING HEAT EXTRACTION POINT
- 4" COOLING LOOP INFLUENT PIPING (EXISTING)
- 2" COOLING LOOP INFLUENT PIPING (EXISTING)
- 4" COOLING LOOP EFFLUENT PIPING (EXISTING)
- 2" COOLING LOOP EFFLUENT PIPING (EXISTING)
- TEMPERATURE MONITORING LOCATION
- CHECK VALVE
- FLOW CONTROL VALVE
- FLOWMETERS
- SW EXISTING SOLID WASTE PERMIT BOUNDARY
- EXISTING QUARRY HIGHWALL

NOTES:
1.) AERIAL TOPOGRAPHY WAS PROVIDED BY COOPER AERIAL SURVEYS CO. AND IS DATED MARCH 20, 2014.

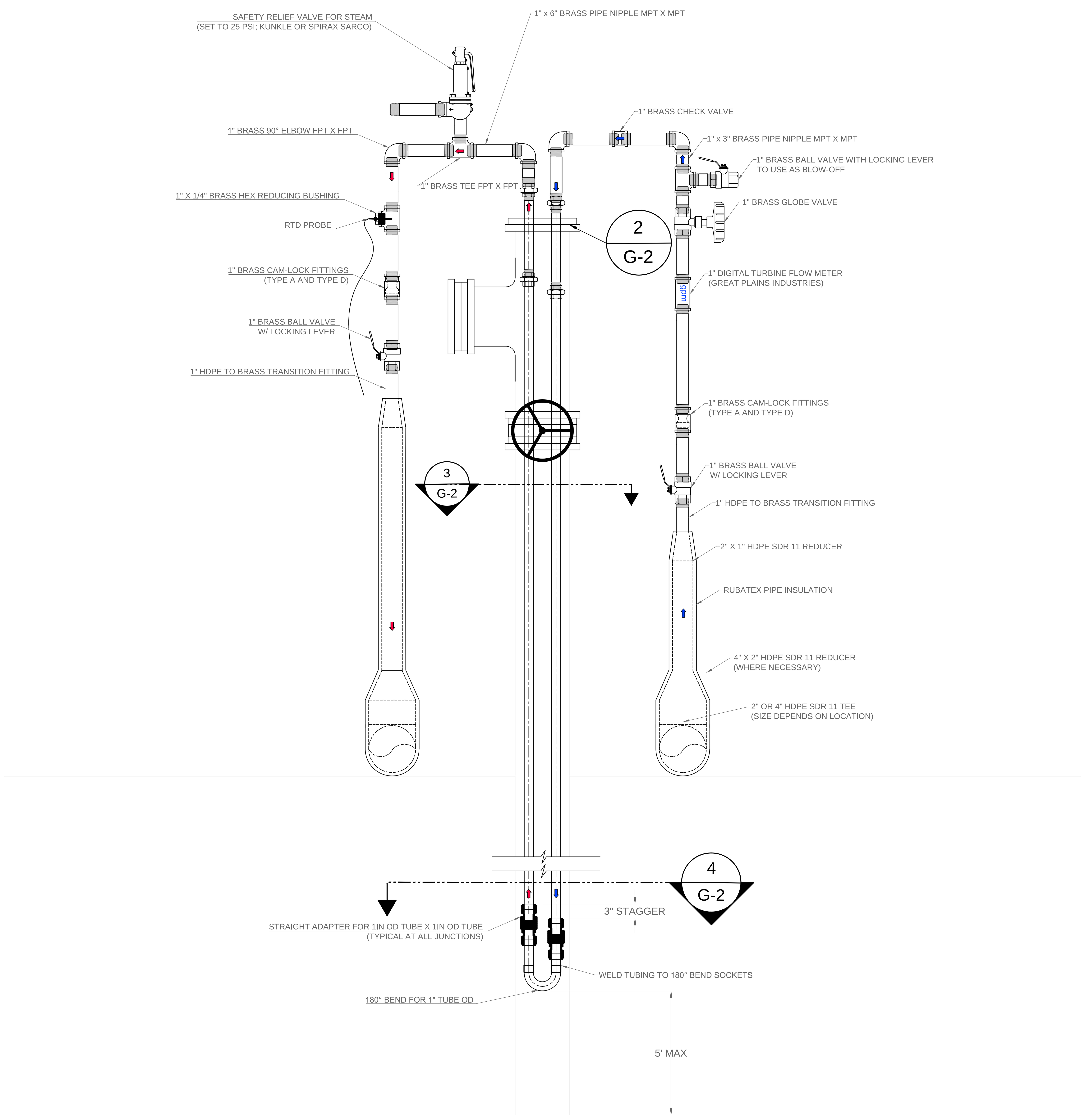
30 0 15 30 60

SCALE: 1" = 30'

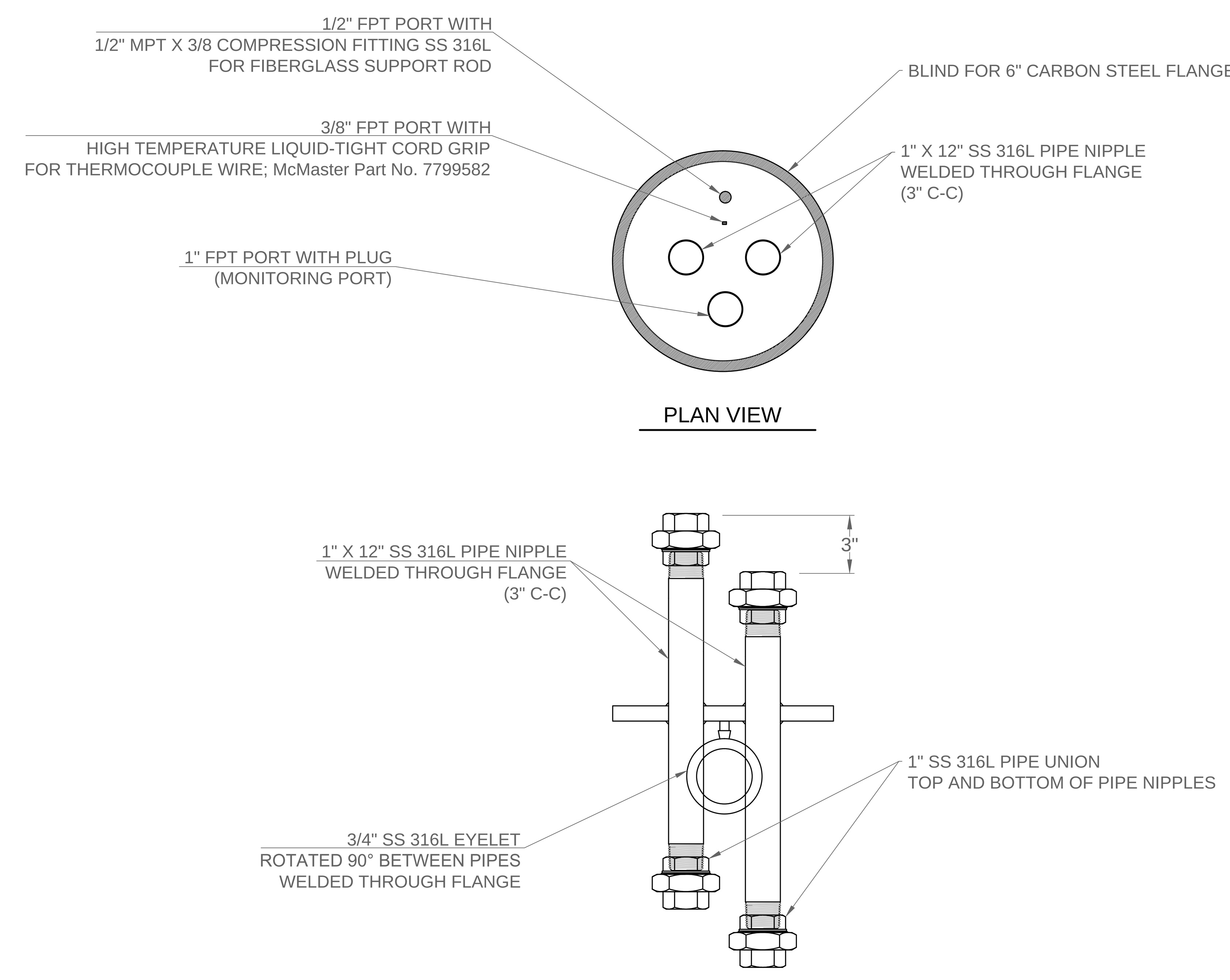
BRIDGETON LANDFILL, LLC 13570 ST. CHARLES ROCK ROAD BRIDGETON, MISSOURI 63044	BRIDGETON LANDFILL	FEEZOR ENGINEERING, INC. Engineering for a Better World	NOVEMBER 2015 DESIGNED BY: DMK APPROVED BY: ALK
CURRENT HEAT REMOVAL SYSTEM PLAN VIEW			REVISION / DATE
PROJECT NUMBER: BT-062	FILE PATH: C:\Users\Diane\Desktop\BT-062 Heat Extraction Services\drawings For Nov 1 2015 Report\APPENDIX G\BT-062-APPENDIX G1.dwg		

APPENDIX:

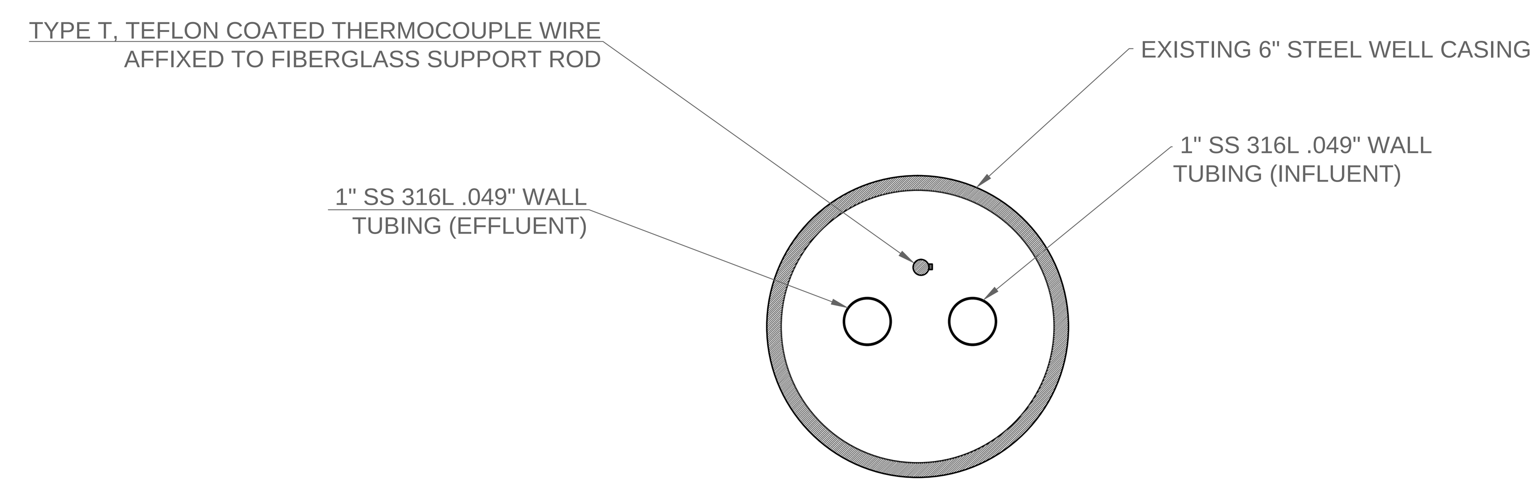
G-1



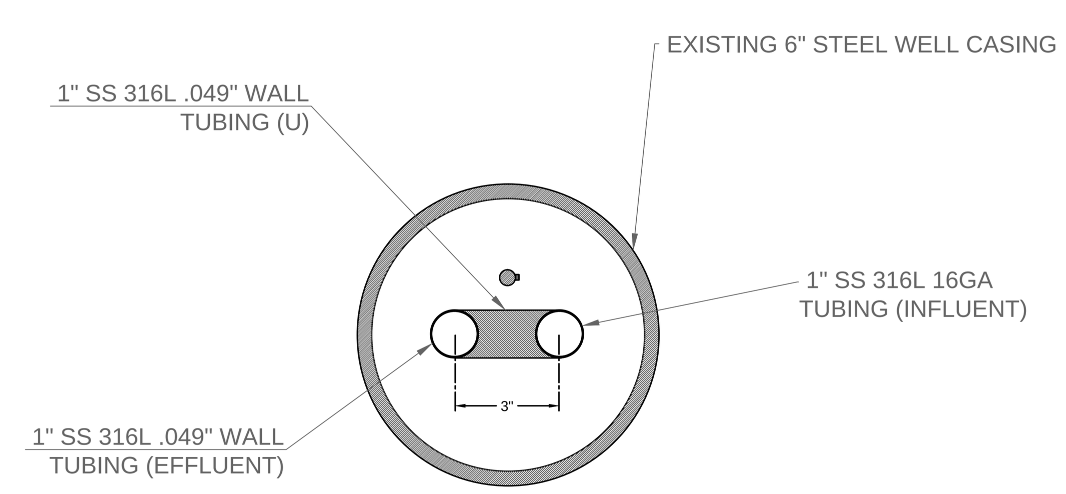
1 G-2 GIW WELL (RETROFIT FOR COOLING LOOP)
NTS



2 004 GIW WELL (RETROFIT FOR COOLING LOOP - TYPICAL) FLANGE COMPONENTS
NTS

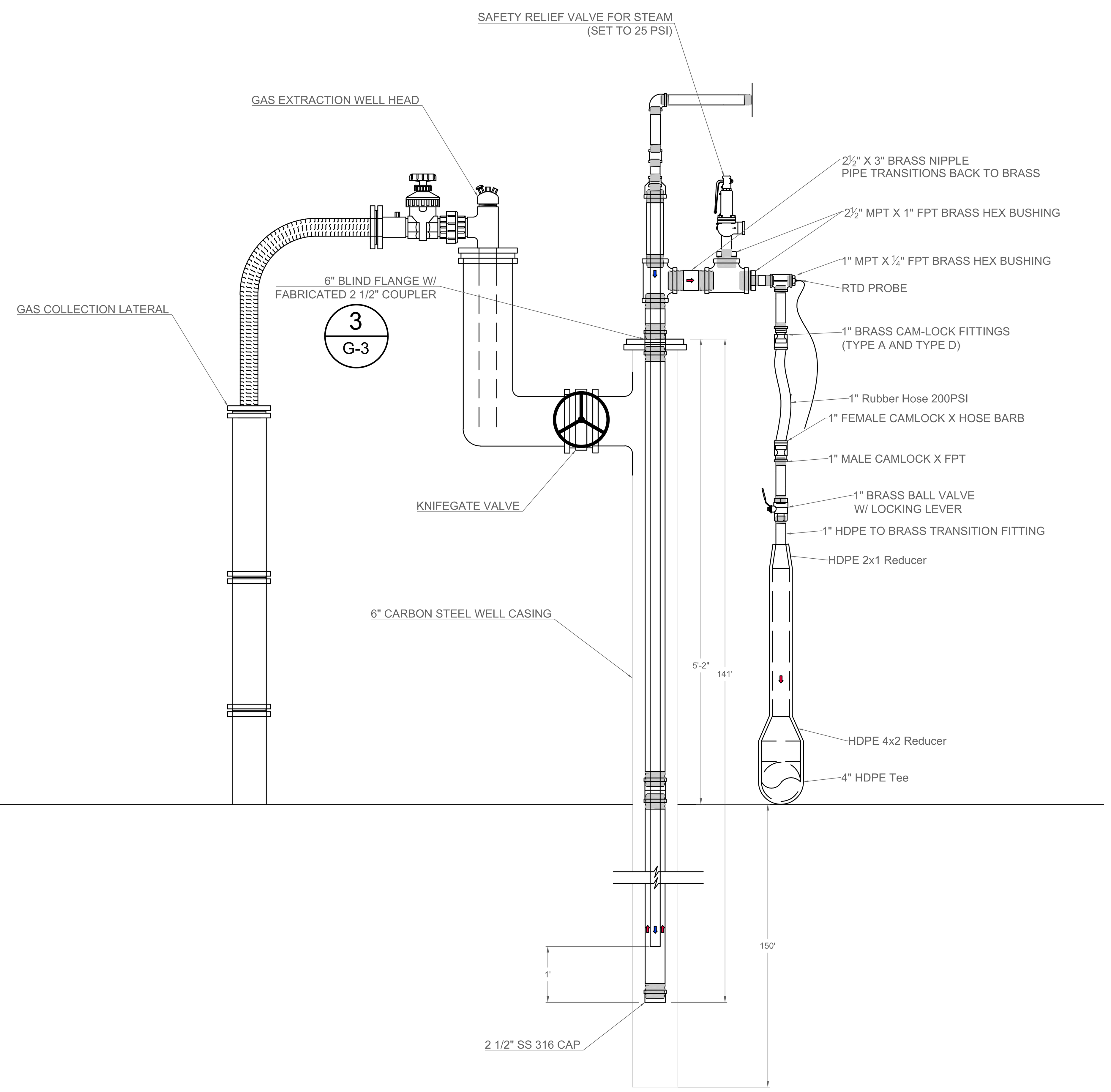


3 004 GIW WELL (RETROFIT FOR COOLING LOOP - TYPICAL) CROSS SECTION
NTS



4 004 GIW WELL (RETROFIT FOR COOLING LOOP - TYPICAL) CROSS SECTION
NTS

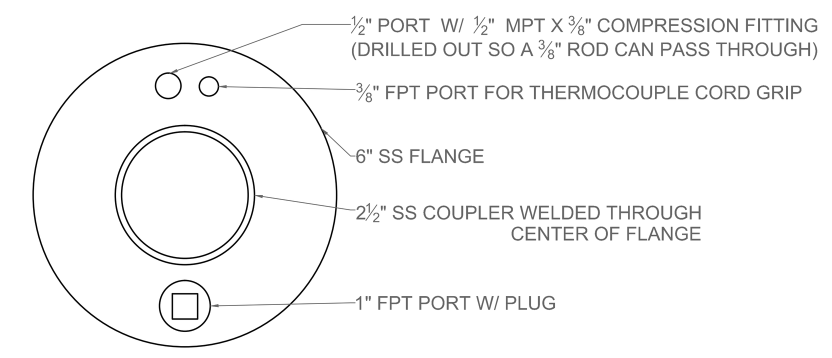
BRIDGETON LANDFILL, LLC 13570 ST. CHARLES ROCK ROAD BRIDGETON, MISSOURI 63044	BRIDGETON LANDFILL	Engineering for a Better World FEEZOR ENGINEERING, INC.	NOVEMBER 2015 DESIGNED BY: BJV APPROVED BY: ALK	APPENDIX: G-2
CURRENT HEAT REMOVAL SYSTEM DETAILS (GIW -2,3,4,5,6,7 AND 10)			REVISION / DATE	
PROJECT NUMBER: BT-062	FILE PATH:			



1 G-3 HEAT EXTRACTION POINT EFFLUENT LINE

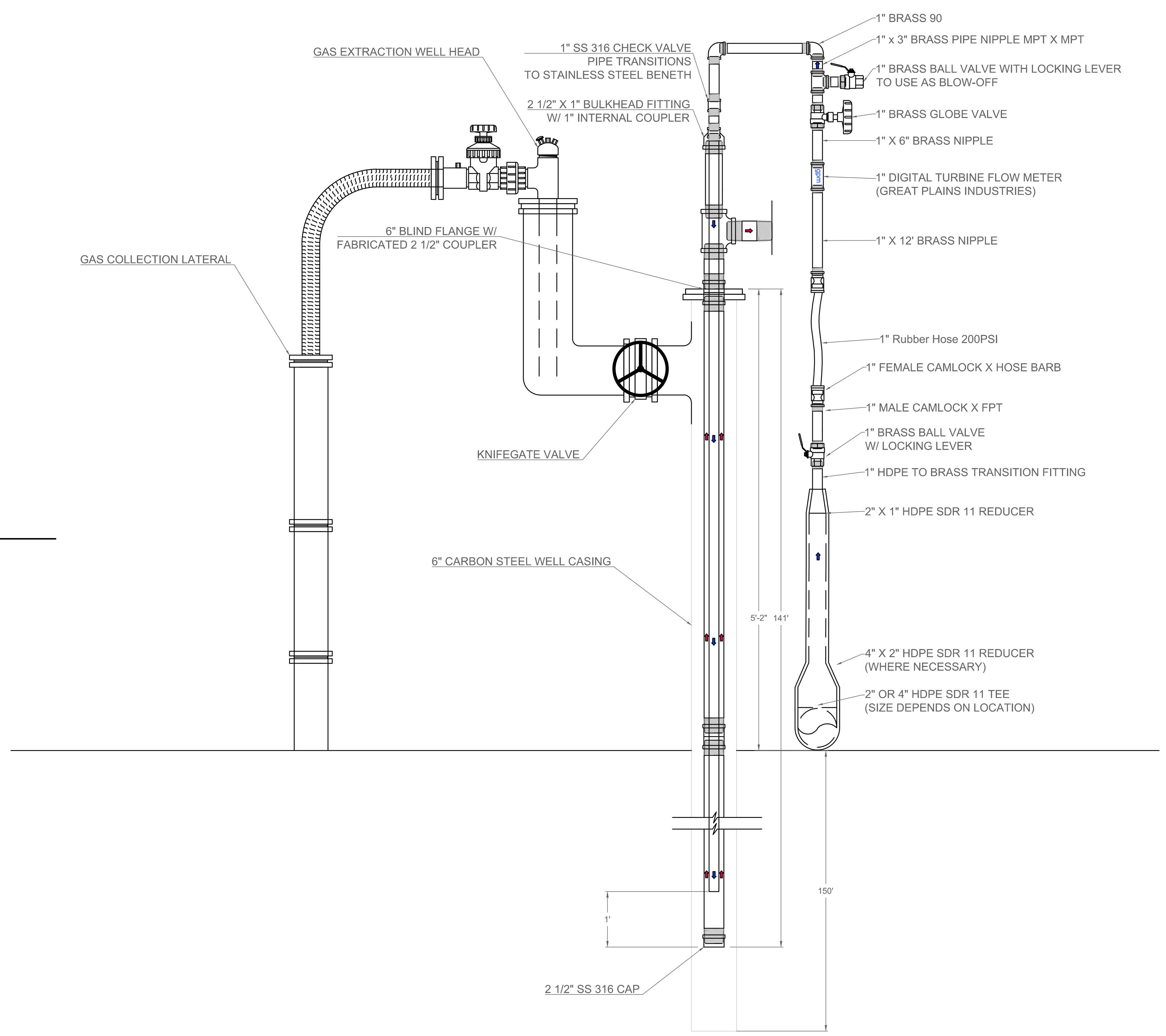
NTS

NOTE: DETAIL APPLICABLE TO GIW 8, 9, 11, 12 AND 13



3 G-3 6" SS FLANGE

NTS



2 G-3 HEAT EXTRACTION POINT INFFLUENT LINE

NTS

NOTE: DETAIL APPLICABLE TO GIW 8, 9, 11, 12 AND 13

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CURRENT HEAT REMOVAL SYSTEM DETAILS (GIW -8, 9, 11, 12, AND 13)			REVISION / DATE	
PROJECT NUMBER: BT-062 / FILE PATH:				

Appendix H - Thermal Modeling

EVALUATION OF HEAT EXTRACTION BARRIER

MODELING OF PILOT STUDY AND HEAT EXTACTION SYSTEM

PREPARED FOR:

BRIDGETON LANDFILL LLC

Prepared by

P.J. Carey & Associates, P.C.

Sugar Hill, Georgia

11/2/2015

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1 INTRODUCTION

1.1 PURPOSE

The purpose of this report is to design a heat removal barrier at the quarry neck area that will result in waste temperatures north of the system that would not sustain the reaction that has been observed in south quarry. The system design was primarily based on data collected from the heat removal pilot study and data collected from the observation of waste temperatures in the quarry neck area since the fall of 2012.

1.2 SCOPE OF WORK

The scope of work for this modeling effort consisted of back calculation of design parameters from the pilot study. Additionally, selecting an array of heat removal extractors, based on modeling, to be installed at a location north of the current heat front that would result in the maintaining temperatures below the desired levels north of the location of the array of extractors.

Model simulations were run to evaluate the heat energy extracted by the modified Gas Interceptor Wells (GIW) to obtain approximations of

- waste heat conductivity, and
- waste heat capacity.

The modeling activity was broken into two separate components. The initial component consisted of evaluating the results from GIW extractors used in the pilot study to determine empirical heat related material parameters the site. The second component focused on evaluating select designs for heat extraction barrier systems.

2 MODELING METHODS

2.1 SOFTWARE

The modeling of heat flow and removal was performed using the program FEFLOW, developed by DHI-Wasy GMB of Germany and commercially available in the US through MIKE Powered by DHI. FEFLOW is a finite element based software that allows modeling of groundwater, heat and mass transport in two and three dimensions. The modeling reported in this report utilized the latest release available, Version 6.2 (P11) issued late September 2015. The 64 bit version of the software was employed.

The software allows for steady state and transient modeling of saturated or partially saturated media in both a saturated only or saturated/unsaturated systems. Given the nature of the activity at the site, only transient saturated/ unsaturated analysis was performed. This allows for a fixed geometry independent of the groundwater surface to be utilized.

The software includes modules that allow for the input of borehole heat extractors (BHE). The BHE input can be utilized to simulate the removal or addition of heat from multiple geologic layers with varying properties at the respective layer..

2.2 MODEL CONSTRUCTION

2.2.1 GENERAL APPROACH

As noted in Section 1.2, the modeling effort was separated into two major components. The first section included evaluation of enhanced GIWs as operated pursuant to the on-going pilot study. The second component included a full scale Heat Removal Barrier (HEB), just south of the neck line, modeling evaluation. The same general modeling approach was used for both components, though the model dimension and time frames were different to reflect the look-back on the GIW operation and the look-forward on the HEB operation.

Three dimensional modeling was used for all the analyses presented in this report. The use of a three dimensional model allowed for the spacing and varied depths of BHE units to be evaluated.

2.2.2 SIMPLIFYING ASSUMPTIONS

2.2.2.1 Quarry Geometry

The shape of the neck area along with the varying elevation of the top of waste and depth to the quarry bottom, together with an incomplete record of temperatures along the edge of the waste made it convenient and conservative to ignore the variation in depth of waste and interaction with the quarry walls. Given that the quarry walls and floor represent non-reactive surfaces and heat sinks, this is a very conservative assumption. Using this assumption the

- model sides (nominally the east and west sides) were assumed to parallel and vertical,

- the bottom of the waste/floor of quarry was assumed to be at elevation 235 ft (approximately 5 feet lower than the lowest spot identified thus far in the neck area, and

- the top of the waste was assumed to be at a constant elevation of 495 ft .

The models were also constructed to be symmetrical about the north/south center axis with respect to any BHE insertions, allowing a nominal width of 150 ft to be utilized.

Boundary conditions were applied uniformly across the model in an east west direction. These simplifying assumptions for geometry resulted in quasi 2 dimensional model that allowed for discrete extraction features to be evaluated. These assumptions provided a conservative modeling approach, by discounting the heat loss to the irregular quarry wall configuration and including a waste column thicker than present based on historical data.

2.2.2.2 Boundary Conditions

Boundary conditions were applied to all exterior model faces. The east and west faces were assigned no flow conditions by default (no specific assignments in FEFLOW create a no flow interface to fluid, heat or mass). The north and south boundary of the model were assigned constant temperature values at each node. The temperature varied with depth only and was based on observed temperatures measured at the landfill. The top of the landfill was treated as a heat loss boundary by assigning a fixed reference temperature with addition heat transmission coefficient (3^{rd} kind/Cauchy boundary. This assignment allowed the transmission of heat at the surface to account for the solid /gas interface along with allowing adjustments to account for some heat losses associated with vapor removal under the cap due to near surface gas transmission. The bottom of the model was assigned a constant boundary temperature of 75°F, a conservative estimate of the ground temperature 40 feet (or more) below the bottom of waste.

2.2.2.3 Material Assignments

The materials in the model were divided into waste and bedrock. Each material was assigned a value for permeability, porosity with respect to flow, porosity with respect to heat, heat conductivity of the solid, heat capacity of the solid, internal heat generation (referred to in FEFLOW as Source/Sink) for the solid. All other assignments used by the model were left to the default settings as they did not impact the modeling were required to be assigned.

The internal heat generation value (energy per unit volume) was used to represent energy release in decomposition of the waste as well as any release of energy by the processes referred to as the “reaction” in the south quarry. It should be noted that the assignments were made as constants for various zones within the waste mass. This is a conservative assumption in that it presumes that the energy generation is a constant with time and does not diminish. Observations at the site strongly suggest that the energy released in the “reaction” diminishes after some time. In addition, the energy released via decomposition of the waste under normal conditions diminishes with time and becomes near zero when temperatures elevate above 165 °F. Therefore, energy assignments to non-reacting waste, especially in the neck area and north would reduce if the temperature increased. At the present time, a function that would account for either of these time or temperature related phenomena has not been included in the modeling effort.

Therefore, predicted temperatures resulting from modeling using this set of heat generation assumption should be viewed as conservatively high with time, as the excess energy per unit time is cumulative.

2.2.2.4 Groundwater Considerations

FEFLOW requires that groundwater levels and other hydraulic related properties need to be entered to perform heat flow analysis. To simplify matters, the porosity with respect to heat flow was assumed to be a nominal 0.01 for all model layers except the upper model layer. This layer was assigned a 0.15 porosity, thereby reducing its conductance and total heat capacity. Ground water level within the model was assigned a uniform elevation of 475. This uniform assignment resulted in the assumption of lack of saturation in the upper 20 ft and saturation below that level. No flow gradient results from this assignment, making the permeability of the material of no consequence. The assignment of a porosity value of 0.01 for the solid removes any dependence on the water level in the model, except at the upper layer within the model, for heat flow.

2.2.3 BOREHOLE EXTRACTION UNITS

BHE of the type used or proposed for use at the site are commonplace in type and were contained in the BHE data base contained in the FEFLOW software. Screen shots of the data input page for the units are provided in figures of this report. A detailed explanation as to how the model uses these heat exchange features are used in the model can be found in chapter 13.5 of the FEFLOW reference book [1]. The use of these elements allows the variables of

- boring diameter,
- grout or backfill conductivity,
- pipe or tubing size and conductivity,
- flow rate, and
- varying or constant temperature of fluid circulated

to be included in the analysis with ease.

[1] (Diersch, 2014)

3 GIW EXTRACTION EVALUATION

3.1 MODEL GEOMETRY

A simplified model 150 ft wide (east – west) and 190 feet long (north – south), depicted in Figure 1, was constructed to evaluate extraction rates from GIW that were converted into BHE. A total of 12 units had been converted over. However, the units are very similar and cover a range in depth from as little as 30 ft to a maximum of 120 ft. As can be seen in Figure 1, three BHE units were included, symmetrical about the centerline of the model in north south direction. Boundary conditions were applied as shown in Figure 2. As described in 2.2 of this report, the model overall depth is 300 feet, subdivided into 15 layers, each 20 feet thick. This is depicted in Figure 3. The property assignments were uniform with respect to width of the model. Only the property assignments for the modeling runs that were consistent with the extraction of energy with time are depicted in Figure 4, Figure 5, and Figure 6. All other property assignments were as discussed in 2.2.2.3 of this report.

Values assigned to the limestone are based on typical values presented in the literature choosing the lower end of the spectrum for solid material (Roberston).

The variation in internal heat energy generation within the waste are based on the observations of the TMPs at the site that have indicated a relatively limited zone where elevated heat energy appears to be generated vertically, and the observation that increased energy release appears to be correlated to a waste temperature in excess of 240 °F.

The upper boundary surface of the model was assigned an out transfer rate of 600 joules/m^2sec K and a reference temperature of 75 °F.

3.2 TEMPERATURE BOUNDARY CONDITION ASSIGNMENT

Boundary conditions on the north and south face of the model were as depicted in Figure 7. The north boundary condition was based on TMP-11. A 6^{th} order polynomial function was used to approximate the variation with depth. The function was modified to convert depth to elevation and temperature from F to C and used to assign the boundary conditions across the north model face. The south face boundary condition was computed similarly using current readings from TMP -31, TMP-32 and readings from TMP-8 and TMP-7R from earlier dates (prior to failure of the units).

3.3 STARTING TEMPERATURE ASSIGNMENT

The initial starting temperatures used for the Day 0 of the transient model were assigned by making a separate model run with a the south and north boundaries conditions as described above and the north boundary conditions assigned to all the model. The model was allowed to progress in time until the temperatures in the vicinity of the GIW BHE units were similar to those existing in late October 2014, when the pilot testing began with multiple BHE units. The initial starting temperatures are depicted in Figure 6 along the north – south section. The temperatures were uniform across the model width.

3.4 EVALUATION OF ENERGY EXTRACTION

Records of the rate of energy extraction have been collected for the GIW units since late October 2014. In addition, TMP's were installed proximate to two of the GIW BHE units to allow some evaluation of rate of temperature impact with distance. After installation of the TMPs around GIW 5 and GIW 10 it was determined that the offset from the well casing was not constant with depth. This was caused by lateral movements of the GIW well casings between March 2013 and October 2014. Due to this, the distance from any thermocouple tip in the TMPs close to these wells is not known. Therefore, it was decided that the energy extraction rate would more useful to allow the determination of waste thermal properties as well as the effective radius of the GIW BHE units.

A series of model runs were made with varying waste conductivity, effective borehole diameter and grout conductivity (while there is not grout in the GIW BHE units the backfill around the wells is rich in stone gravel and the gravel has infilled with heat modified waste and it is saturated making it likely of a higher conductivity that waste). Simulations were conducted for a time period of 1 year. The two types of BHE units evaluated are depicted in Figure 8.

The results from the model run using the BHE properties in the shaded column below are presented in Figure 9, showing the maximum radius of influence and temperatures at the end of the year, 100 ft below ground surface.

Table 1 – Energy Extraction Rate from 120 ft BHE with Varying Properties

Property	units	u-tube	u-tube	u-tube	u-tube	Pipe in Pipe
Effective Diameter	(meter)	0.35	.6	0.8	0.8	0.35
Grout Conductivity	W/mK	2.0	1.8	1.8	1.8	2
Waste Conductivity	W/mK	1.5	1.7	1.7	1.4	1.4
Energy Extraction rate after 365 days	kW	6.4	6.8	9.7	8.9	6.1

The energy extraction rate was determined based on a constant inflow temperature of 59 °F which is approximately 10 °F higher than the dewpoint annual average for the St. Louis area. A typical inflow and outflow temperature for the three BHE units in the GIW Evaluation model are presented in Figure 10. Energy extraction rates for the shaded run are presented in Figure 11.

3.5 DISCUSSION OF WASTE MATERIAL AND BHE HEAT RELATED PROPERTIES

The extraction rate from the 120 long unit in the shaded column of Table 1 corresponds to the extraction rates that have been achieved in GIW – 10. The most recent readings for GIW 10 indicate it is still removing energy at the rate of nearly 9 kW and has varied from maximum of 70 kW at the onset of operations to under 10 kW on average since June of 2015. Higher extraction rates from GIW 10 were obtained during the cold months of the year, when cooled liquid temperatures of less than the assumed value were obtained in the pilot study. The assumptions of smaller effective radii than 0.8, or lower conductivity than 1.4, would produce significantly lower energy extraction rates than experienced at the site. Higher waste conductance values than 1.4 resulted in too high an extraction rate when the correct size radius is used.

The computed model derived Grout and Waste k_{heat} values are consistent with the literature value for moist waste with improvement related to high rock content from the stone backfill around the wells.

The values in the shaded column of Table 1 reasonably approximate the extraction rates from GIW 10 and are consistent with the behavior seen in the Pilot Study. They model runs in general show little difference between the Pipe in Pipe type BHE and U-tube loop type. The properties consistent with the GIW evaluation run presented were used as the starting point for the HEB evaluation.

3.6 SELECTION OF PARAMETERS FOR CONTINUATION REMOVAL LINE EVALUATION

In addition to those material properties discussed in 3.5 above, the heat generation and surface conduction rate constant were also evaluated. Use of the 0.8 W/m^3 energy generation rate, resulted in a maximum temperature of 297 °F higher than temperatures further south of the area modeled. This occurred despite the proximity of the BHE to the south boundary and is not supported by any measurements made at the facility. This suggests the 0.8 W/m^3 value may be somewhat higher than appropriate. As will be discussed in Section 4, when the simulations were extended for years into the future it is apparent that a either a lower value of permanent energy generation or a time decay function applied to the energy generation assignment is appropriate.

In addition to the parameters derived, the approximate radius of influence for the GIW HBE unit is 36 feet based on the model. This is consistent with impacts measured at TMP 20 which has dropped over 30°F since the onset of the pilot test and is more than 20 feet away from any GIW HBE unit. The approximate radius of influence is presented in Figure 9.

4 HEAT EXTRACTION BARRIER EVALUATION

4.1 MODEL GEOMETRY

The model geometry for the HEB evaluation was similar to that used for the GIW evaluation during the pilot study. The model for the HEB evaluation was extended northward an additional 160 feet beyond the limit of the GIW evaluation model. The same model width and depth was utilized. The model space was re-meshed to allow elements around the BHE units to approach or be larger than the ideal element size, avoiding computational issues around the BHE. The model space is depicted in Figure 12. Figure 12 also shows the location of the BHE units that were included in the HEB evaluation.

The model is an idealized representation of the neck area, with the TMP 1-4 line, on average, located at northing 275, approximately 65 feet north of the single line of BHE units that crosses the entire model space. The north end of the model is located at northing 350 is within the North Quarry. The existing northern line of GIW BHE is idealized at 50 ft center to center spacing located at a uniform northing of 125. Two GIW BHE are also included at northing of 75. The selection of two units was made to allow the units to be offset from the GIW N line and not be influenced by the side boundaries.

The general boundary conditions for the HEB evaluation model are depicted in Figure 13, and are of the same types used for the GIW evaluation model.

The specific BHE assignments for the presented HEB evaluation model are depicted in Figure 14. The inclusion of a shorter BHE in the GIW South extraction row was made to determine if the shorter unit had a measureable impact on the heat extraction outcomes at the northern end of the model, as the shorter units were shown to extract less energy (Figure 11). A section view of the HEB evaluation model is presented in Figure 15.

4.2 MATERIAL ASSIGNMENTS

The material assignments in the HEB model were nearly identical to those used for the presented GIW evaluation modeling. Some changes were made to only to the internal energy generation levels. The assignments were constant in the east - west direction and are most easily depicted in north-south section views. These are presented in Figure 16, Figure 17, and Figure 18.

Modifications to the internal heat generation rate can be seen in Figure 18, relative to assignments in the GIW evaluation model. These were as follows.

- Extension of the higher energy producing waste block to the north from northing 75 to northing 175±. This reflects a conservative assigned location of the temperatures elevated to 240 °F as of November 2016 relative to the GIW N extraction line. (see Figure 23 for section view of initial temperatures discussed in Section 4.5)
- Decrease in the rate of energy production from 0.8 W/m^3 to 0.7 W/m^3. This change was made to decrease the model generated maximum temperatures in the south portion of the model that resulted from the assignment of 0.8 W/m^3 with time. Maximum temperatures in the waste increased well above the temperatures measured in TMP-31 and TMP- 32 to above

350 °F in two years, approximately 60 degrees higher than measured to the south. The increase in temperature continued to accumulate with increasing time, suggesting the value was too high. Use of the lower 0.7 W/m^3 still produced temperatures higher than recorded to the south by approximately 30 degrees in two years and 44 degrees in 4 years, suggesting it still represents a conservative choice of heat energy generation.

- Heat generation rates in the northern region of the model were left a 0.25 W/m^3 for the primary modeling run. With slightly higher values used for the area to the south of the 15 ft c-c BHE elements line. A value of 0.28 W/m^3 was assigned for north of 15 ft c-c BHE line as a conservative choice. A final model run is presented where the internal heat generation value was decreased to 0.1 W/m^3 simulating the rise in temperature of this waste to approximately that which stops methanogenisis. This was done to identify the conservative nature of the heat generation assumptions in the northern section of the model.

4.3 TEMPERATURE BOUNDARY CONDITION ASSIGNMENT

The southern boundary of the model is at the same location, relative to the site geometry as it was for the GIW evaluation model. Therefore, it was assigned the same constant temperature boundary condition described in Section 2.2.2.2 . A review of temperatures measured at TMPs 31 and 32 and previous temperatures at TMP 8 and 7R indicate that temperatures within the fully heated zone have not changed significantly since early 2013 with the exception that conduction of heat with depth appears to have resulted in an increase in temperature depths below 160 ft. This is evident in a comparison between TMP 32 and TMP 31 current values and TMP 8 in June of 2013, reasonably assuming TMP 32 is in a location that has been warmer longer. Northern boundary condition temperature assignment was made utilizing TMP – 17 as a guide. A graphic depiction of the boundaries is presented in Figure 19.

4.4 BHE ASSIGNMENTS

The same BHE units were assigned to the GIW extraction rows in the HEB model. The added extractors along the 15 ft c-c line were assumed to be constructed in 12 inch diameter grouted holes, with a grout conductivity of 1.5 W/mK. The grout conductivity value is on the lower end of cementious grouts containing sand/stone material. (Allan, 1997)The assignments are depicted in Figure 22. The values are consistent with a standard weight 2.5 inch diameter stainless steel outer pipe with a thin walled stainless feed tube of 1 inch diameter.

4.5 STARTING TEMPERATURE ASSIGNMENT

The starting temperature, shown in section view in Figure 23, was generated by mapping importing the temperatures from previous GIW evaluation runs assuming not heat removal operations as starting temperatures of the southern portion of the boundary, and adding the boundary conditions at the north and south. The model was allowed to smooth the temperatures and allow advancement of the front until a date approximating May of 2015.

After this time all GIW extractors were activated and allowed to run using the cyclic temperature function for the cooled influent to the BHE based on the average monthly dew point plus 5 degrees, based on NOAH data for the St. Louis Airport weather station. This assumption of inflow temperature is consistent with the operational properties of the cooling system now being used for the pilot study. The starting date of operations for the full HEB elements of Nov 1 2016 was selected for the simulations. The initial temperatures at 100 feet BGS are depicted in plan view for this date in Figure 24.

4.6 HEAT EXTRACTION BARRIER EVALUATION

Potential configurations for BHE to the existing GIW extraction system were investigated. A row of extraction devices as depicted in plan view in Figure 21 was eventually selected as sufficient for the intended purpose. The efficacy of the HEB configurations was evaluated by performing transient model runs from the operational starting date of the 15 ft c-c elements, November 1, 2016 into the future. Variation in BHE depth along the added line of BHE along with the impact of assumption of internal heat generation explored to assess the predicted outcomes.

The model simulation using the conservative estimates of properties and boundary conditions are presented for a period of 4 years following the beginning of operations of the full HEB system. The results are presented graphically in Figure 25 through Figure 28, depicting predicted temperatures at 6 months, 1 year, 2 years, and 4 years following the beginning of the HEB operation. Inlet and outlet fluid temperatures of the BHE units are presented in Figure 29. The 3 traces in Figure 29 are identified in the legend as to the type of unit they represent along with a single trace of the inlet temperature. Energy extraction rates for the GIW North line of BHE and 15 ft c-c BHE are depicted in Figure 30.

Temperatures at two plan locations, depicted in Figure 24 as Point A and Point B, were extracted from the model results. These are presented in Figure 31 (A and B).

As discussed in Section 4.2, an additional model run was made to show the dependency of the temperatures north of the HEB on assumptions concerning the level of heat generation within the waste mass in this area. The modeling results, shown in section view for the 4 yrs following onset of operations of the HEB are presented in Figure 32

The results of the modeling are discussed below.

4.7 DISCUSSION OF RESULTS

The HEB modeling presented shows that a single added line of BHE units extending to within 80 feet of the bottom of waste create a zone of reduced temperature north of the current reaction zone.

The depressed zone of temperature, as seen in Figure 25, develops within 6 months after operations and continues to reduce in temperature for at least 2 years, as can be seen in Figure 26 and Figure 27. What is also apparent in the three aforementioned figures, is that the model predicted temperatures in the waste mass to the north of HEB continue to rise slightly with time, as a result of assumed energy generation in the waste in north quarry even when the temperature exceeds 165 °F, which should be the normal limiting temperature for biodegradation related heat. This suggests that the model assigned heat generation value in the primary runs is too high.

The zone of elevated internal heat generation in the waste mass to the south assigned to the model runs extends beyond the 240°F isotemp for the four years of the simulation, identifying it as a conservative assumption.

The model simulation shows the advancement of the heat front is controlled by the HEB and that no temperatures currently associated with elevated energy production occur beyond the HEB. As can be seen in Figure 31, the maximum temperatures found in the area to the north of HEB and south of the neck (TMP-1 to 4) line (Point A), notwithstanding the conservative nature of the internal energy generation of the waste are below 182°F for the simulation. As can be seen in Figure 32, the elevation of temperatures beyond 170°F in the same region of A and B does not occur with a reduction of internal energy assigned to this portion of the waste mass. It should be noted that Figure 32 has had a contour interval at 170 °F added just for this demonstration.

The simulations did not address the portions of the neck where waste is much less in thickness than modeled herein. It is reasonable to limit the depth of the BHE units to 180 feet or no closer than 15 feet to limit base of the waste.

Total flow and energy extraction rates can planned for by pro rating the values obtained for the installed BHE units these are summarized below.

- 15’ c-c , pipe in pipe units,
    - Flow rate 6 gpm
    - kW out 3.5 during winter, 2 during summer
- GIW units
    - Flow rate 10 gpm
    - kW out 9

The requirements for the BHE 15’ c-c units can be roughly pro-rated on a footage basis for shorter units

5 SUMMARY

The modeling of the heat extraction pilot testing using the BHE units converted from the GIW allowed the determination of thermal properties of the waste mass at Bridgeton. These properties are presented in Section 3.5 of this report. Using these values with minor modification, a conservative model, with respect to geometry, material properties, boundary conditions and heat generation assignment was constructed.

The proposed HEB was evaluated using observations at the site coupled with the GIW extraction evaluation obtained parameters. Transient models projected forward show the proposed HEB system, consisting of BHE spaced at 15 centers extending to a depth of 60 feet above the bottom of waste, result in separating the north quarry from temperatures that are associated with the onset of the reaction related heat release despite the several compounding conservative assumptions used in the modeling effort.

6 BIBLIOGRAPHY

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Diersch, H.-J. G. (2014). *FEFLOW - Finite Element Modeling of Flow, Mass and Heat Transport in Porous and Fractured Media.* Heidelberg: Springer.

Roberston, E. C. (n.d.). *Thermal Properties of Rock.* US Department of the Interior, US Geological Survey. Reston VA: US Department of the Interior.

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FIGURES

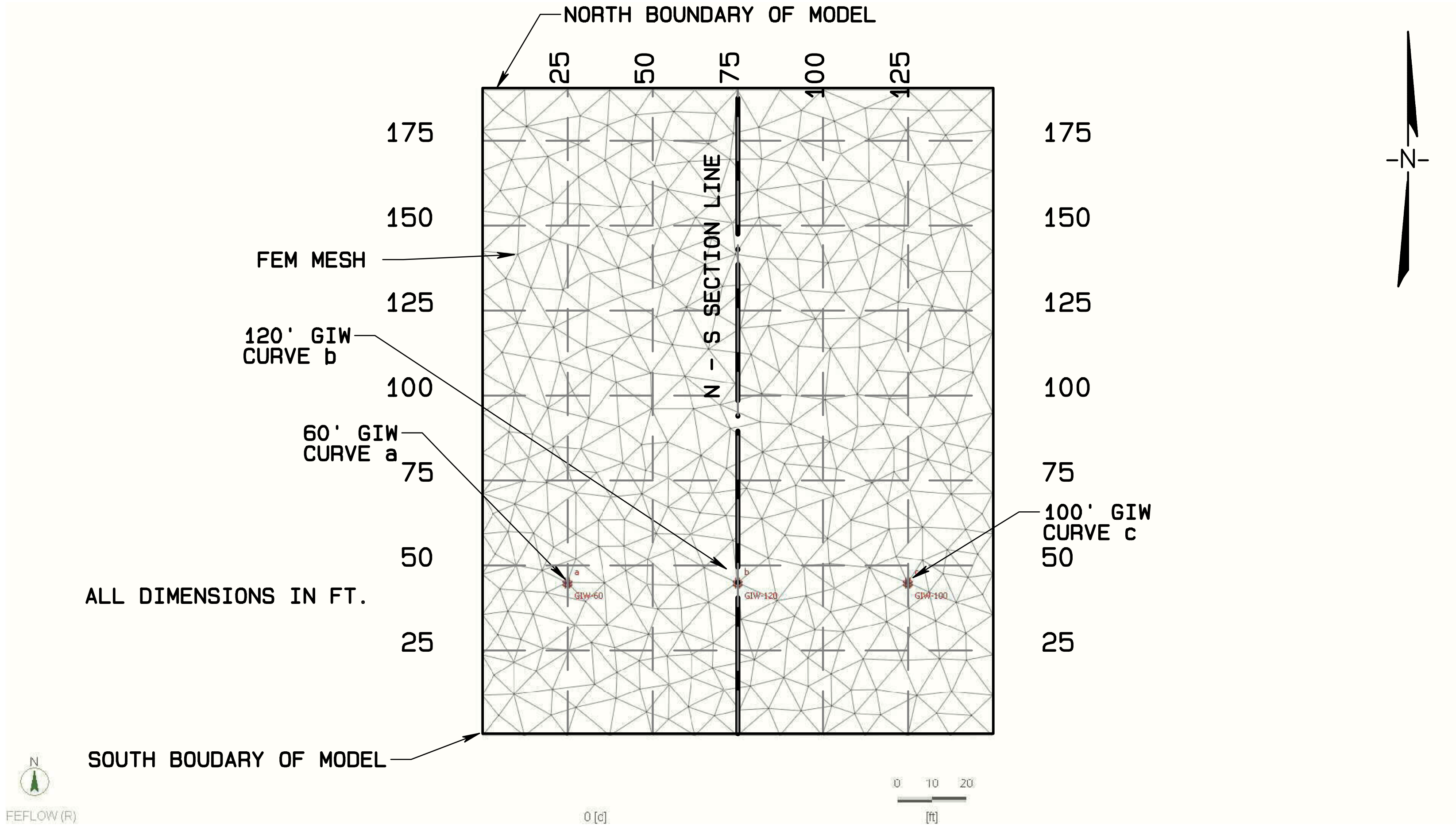


FIGURE –1 GIW EVALUATION MODEL PLAN VIEW

MODEL EXTENDS VERTICALL FROM ELEVATION
495 TO 195 FT.

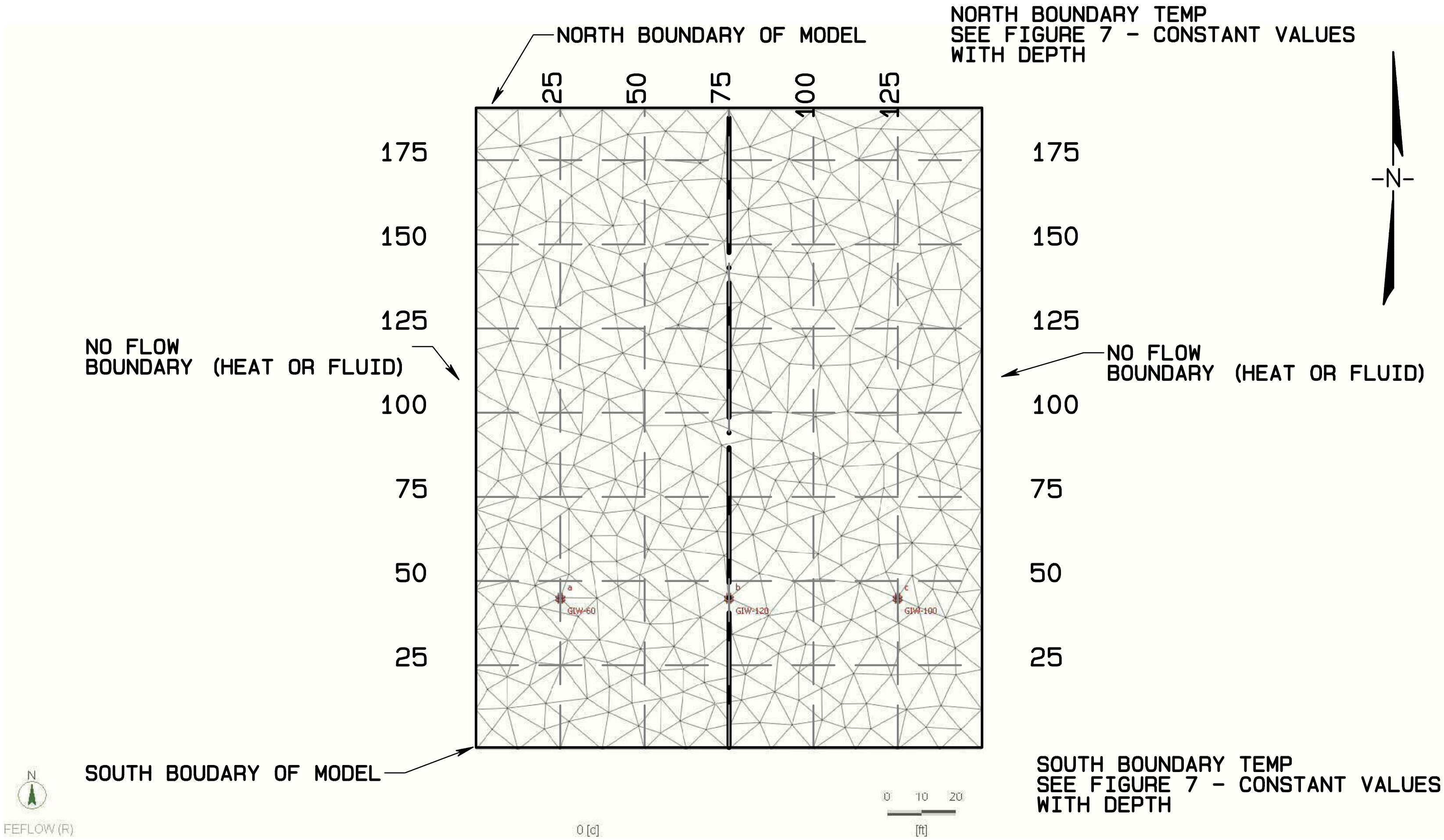


FIGURE -2 GIW EVALUATION GENERAL BOUNDARY CONDITION ASSIGNMENTS

**MODEL EXTENDS VERTICALL FROM ELEVATION
495 TO 195 FT.**

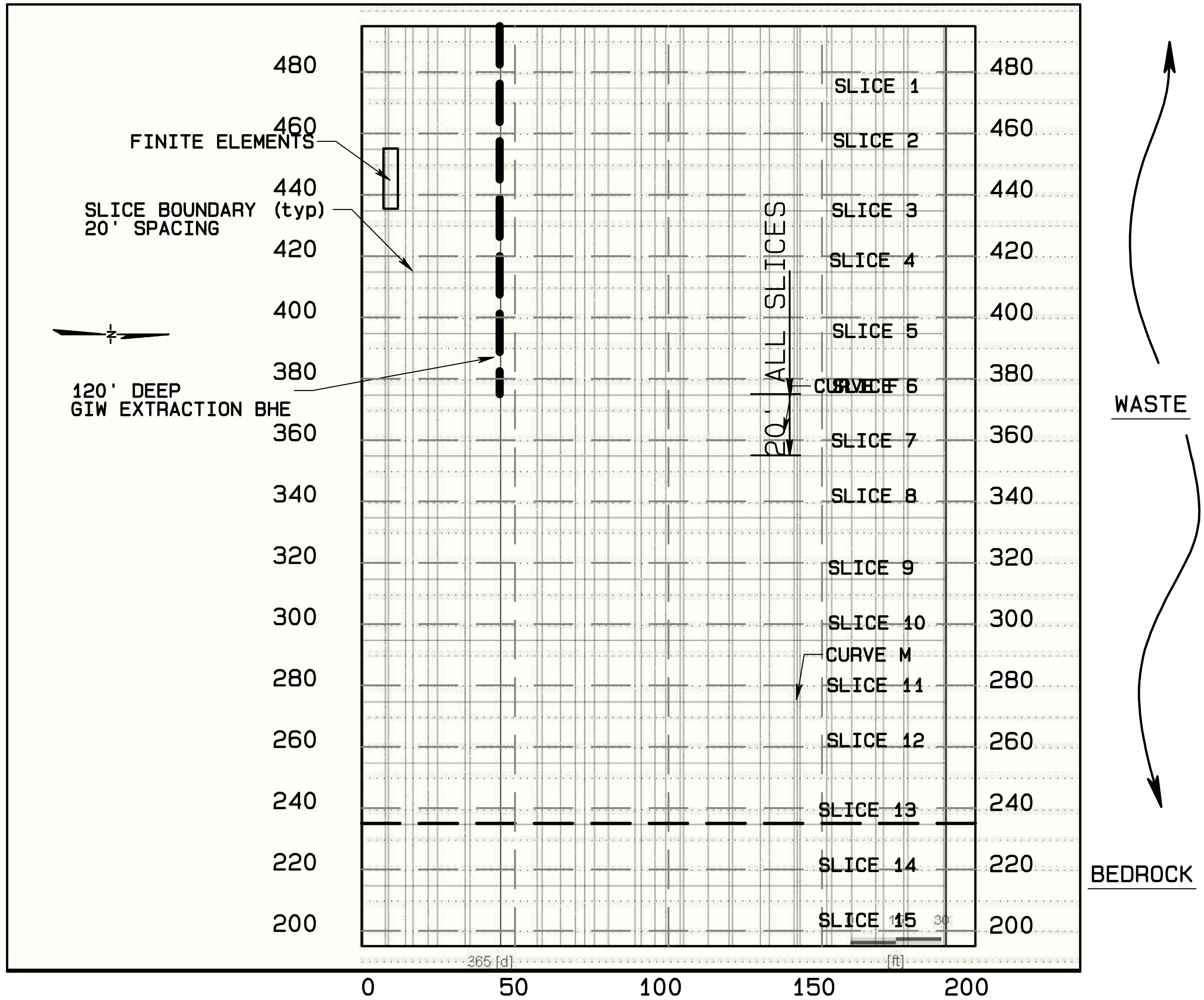


FIGURE -3 GIW EVALUATION MODEL
N-S SECTION

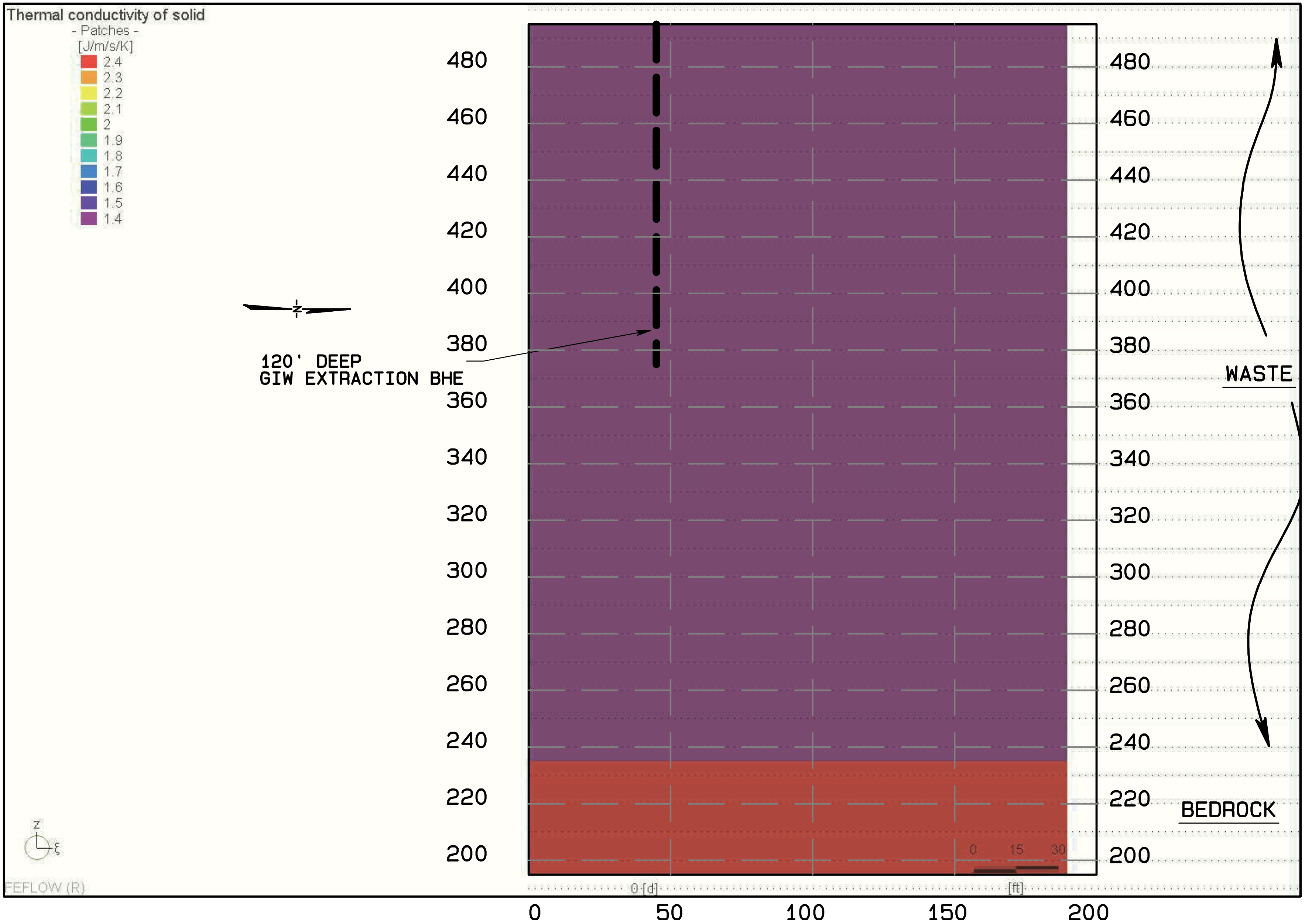


FIGURE –4 GIW EVALUATION MODEL

HEAT CONDUCTIVITY ASSIGNMENTS

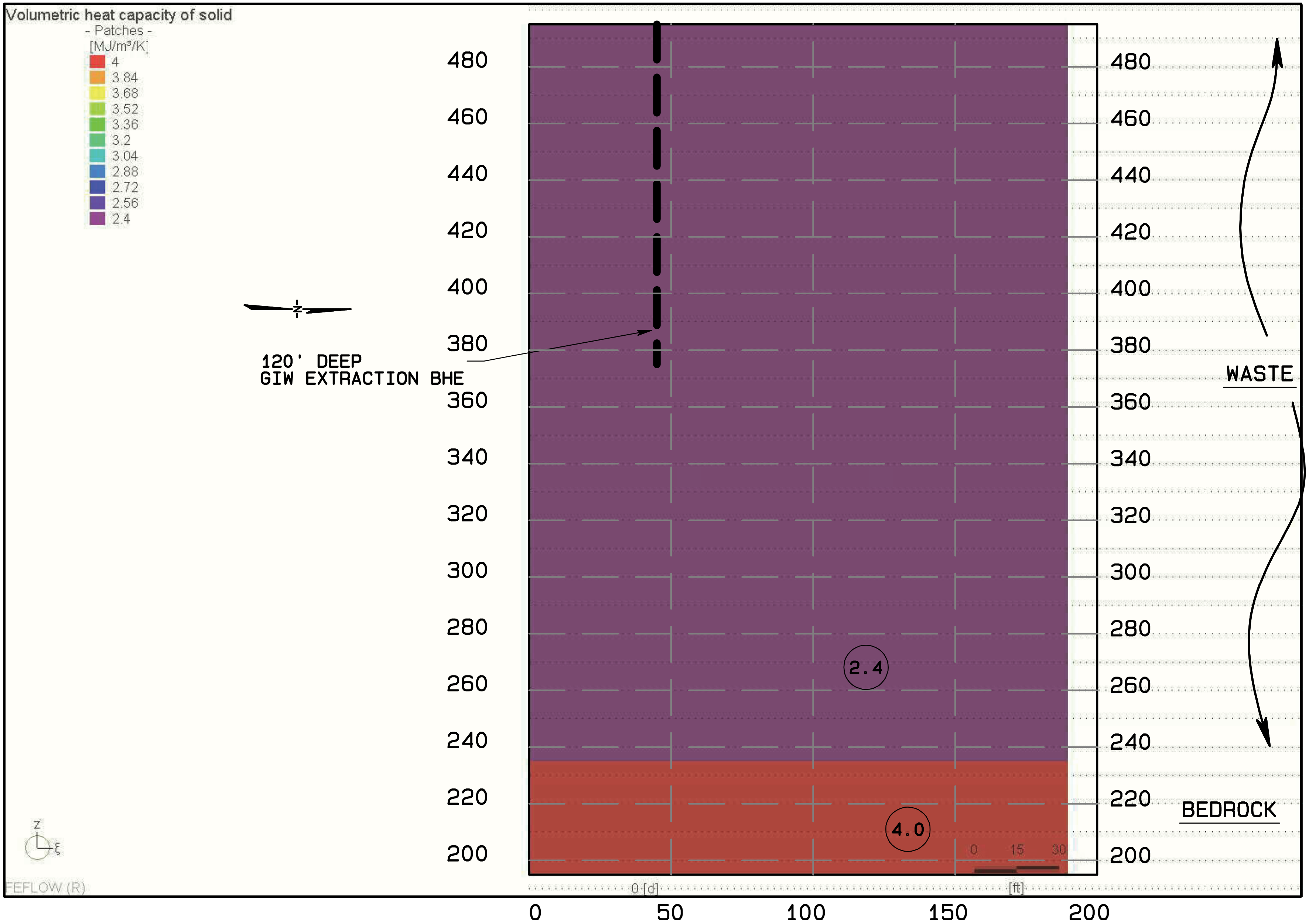


FIGURE –5 GIW EVALUATION MODEL

HEAT CAPACITY ASSIGNMENTS

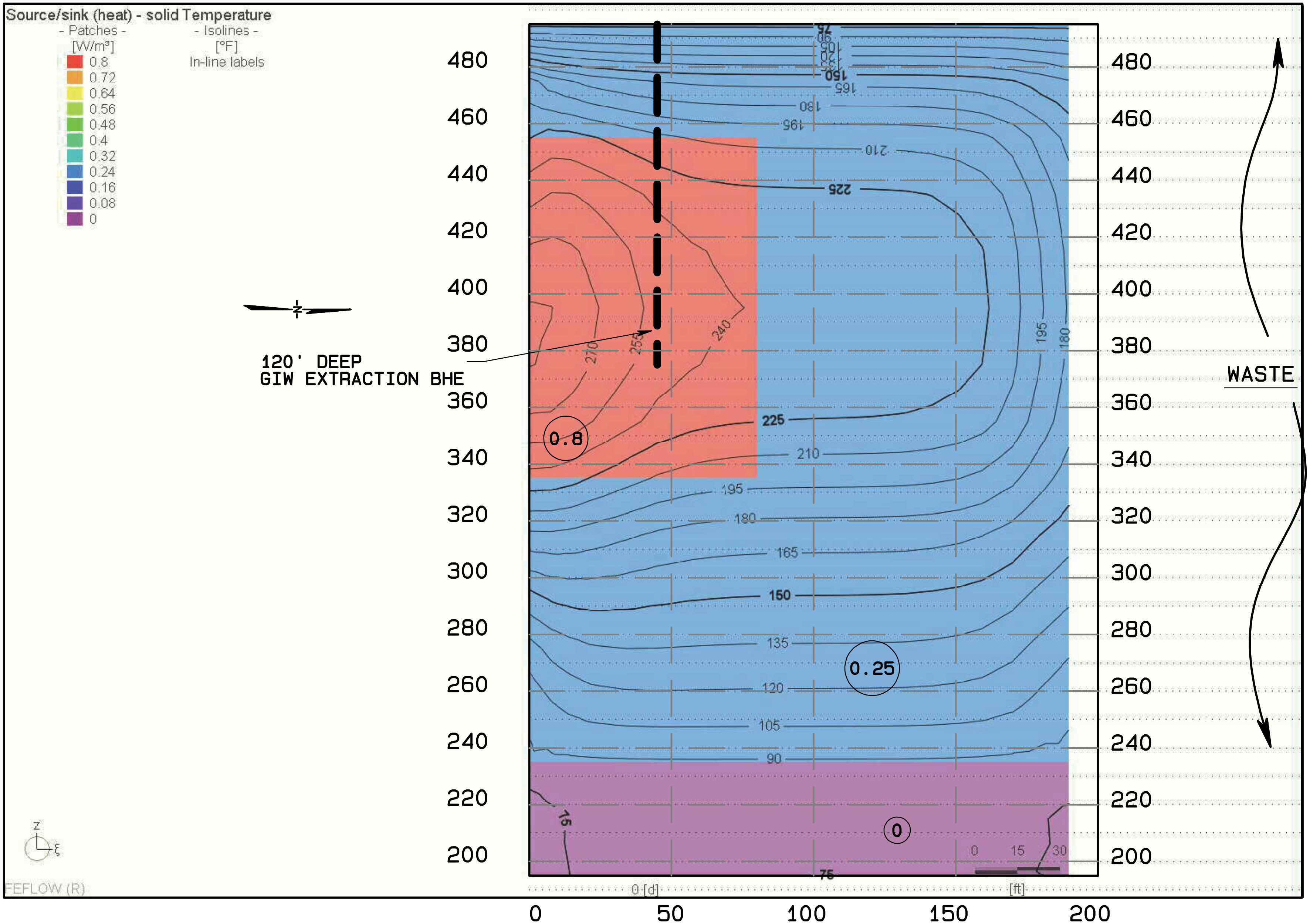
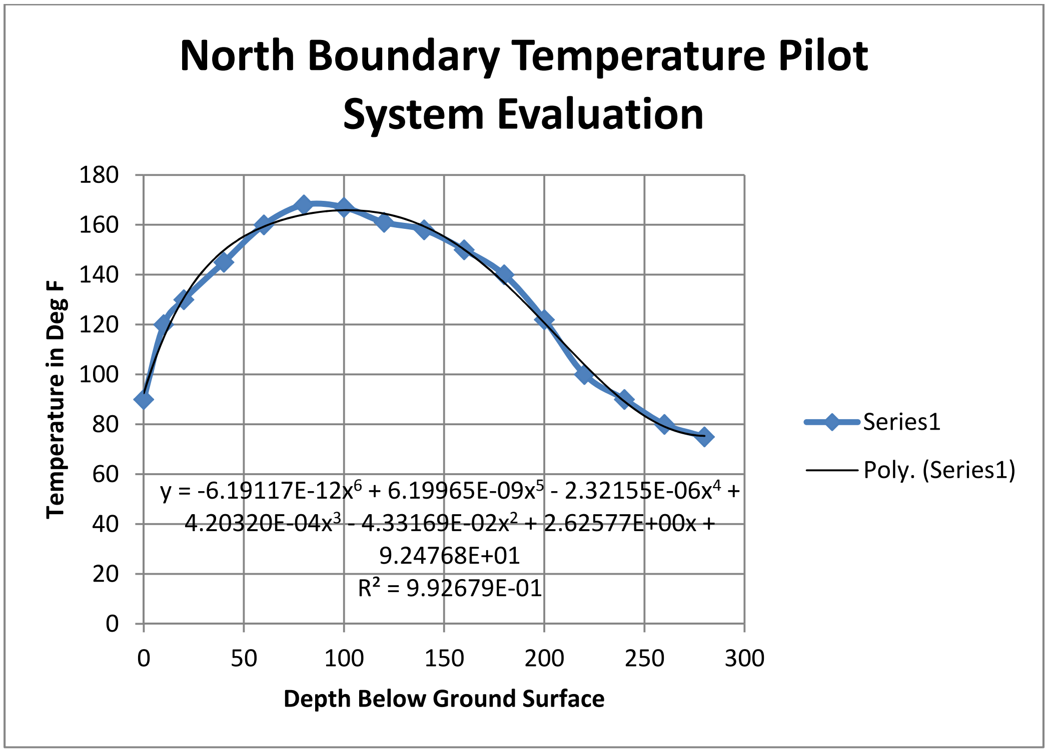


FIGURE -6 GIW EVALUATION MODEL

INTERNAL HEAT GENERATION ASSIGNMENTS WITH INITIAL TEMPERATURES

FIGURE 7 – GIW Evaluation

North and South Boundary Conditions



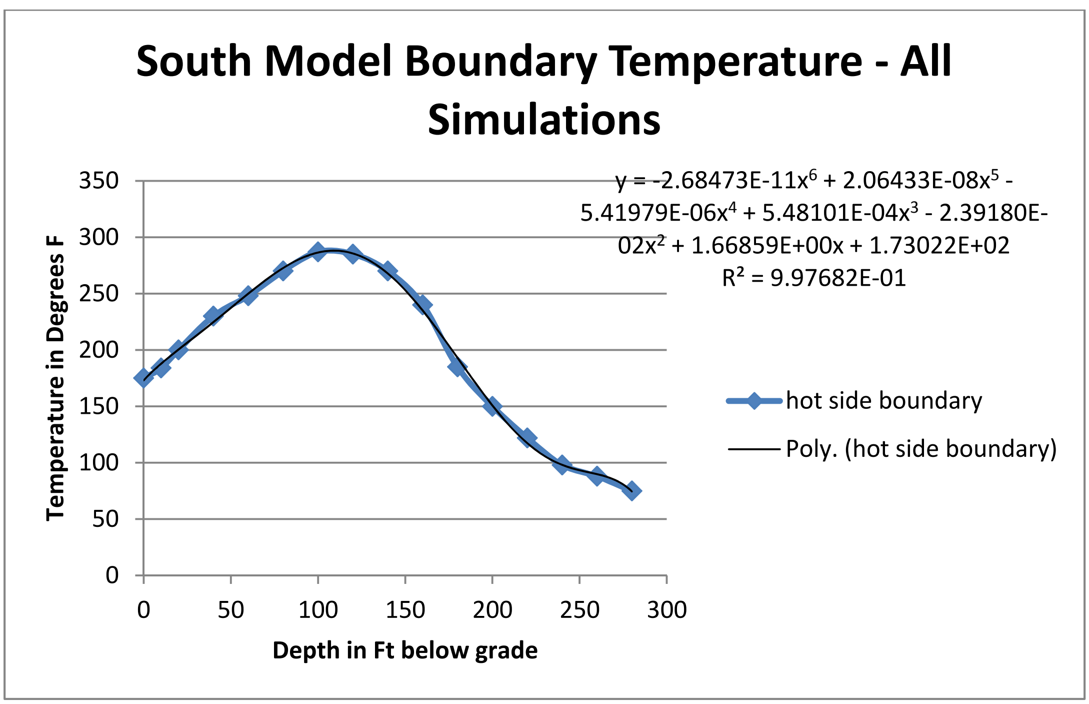
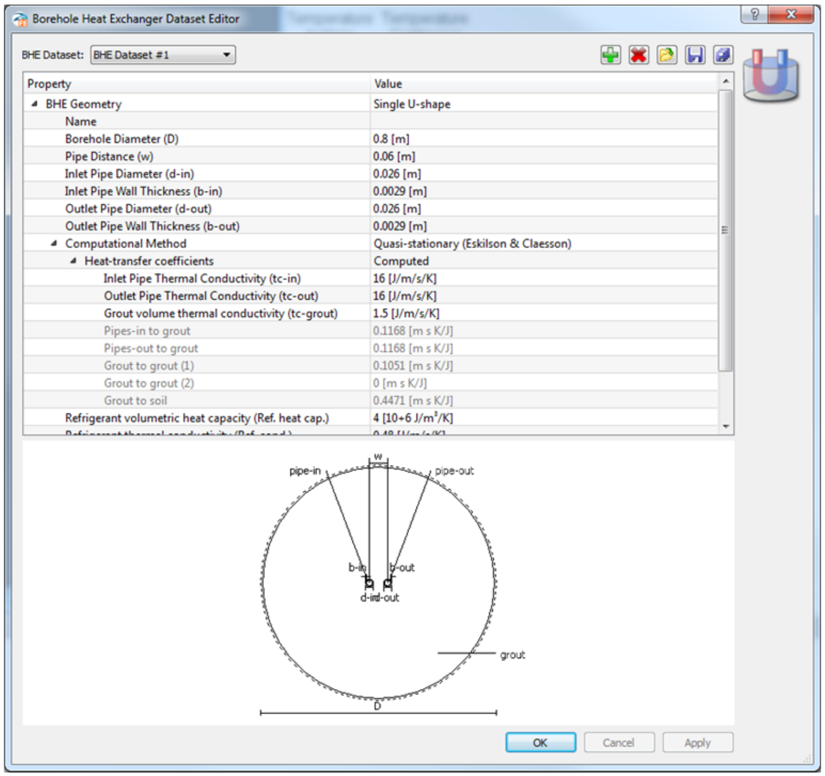
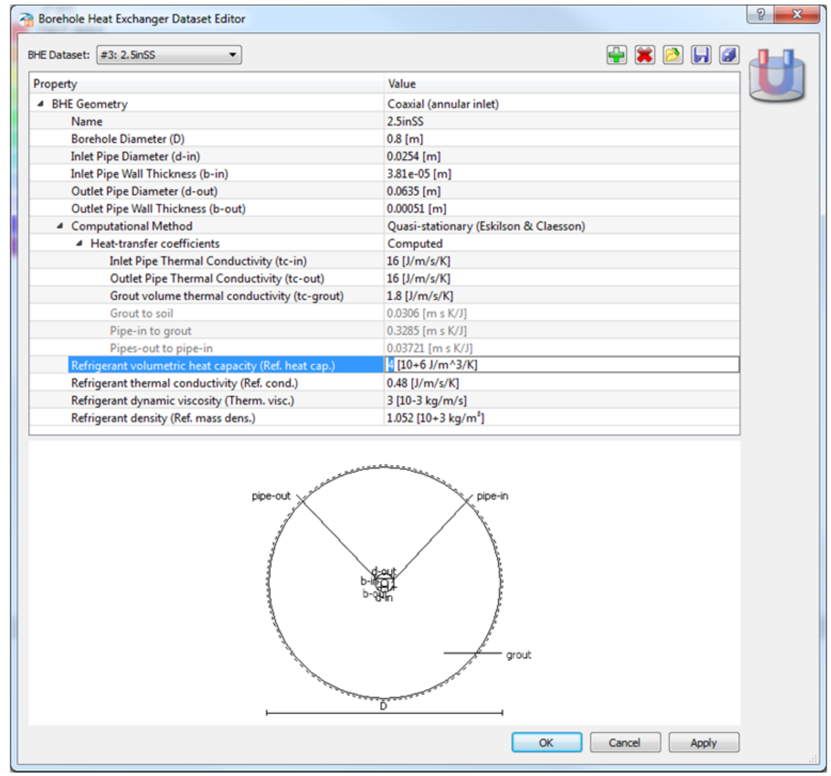


FIGURE 8 – GIW EVALUATION BHE DIAGRAMS

GIW – Single U- Tube BHE



GIW N PIPE IN PIPE BHE



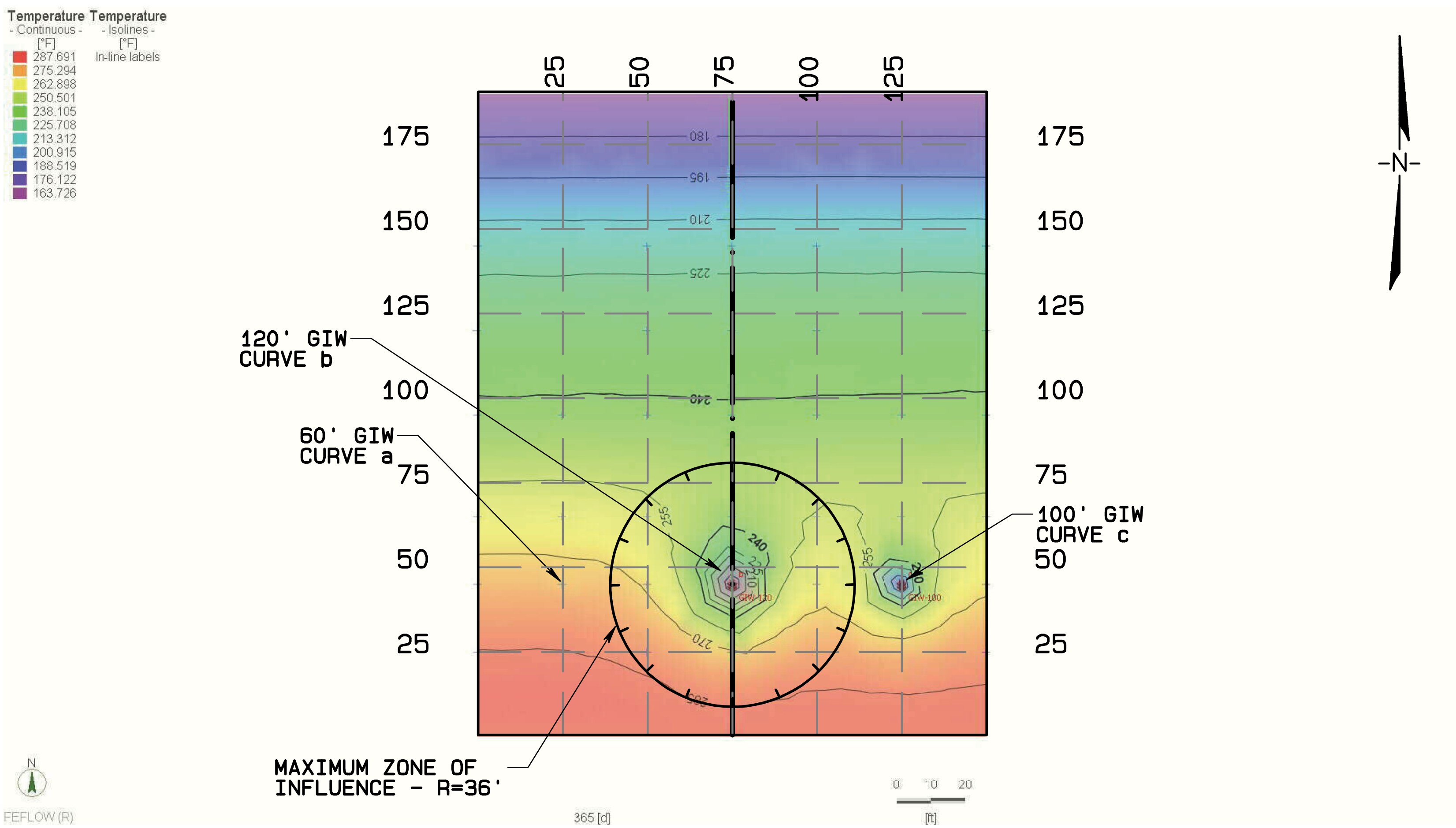
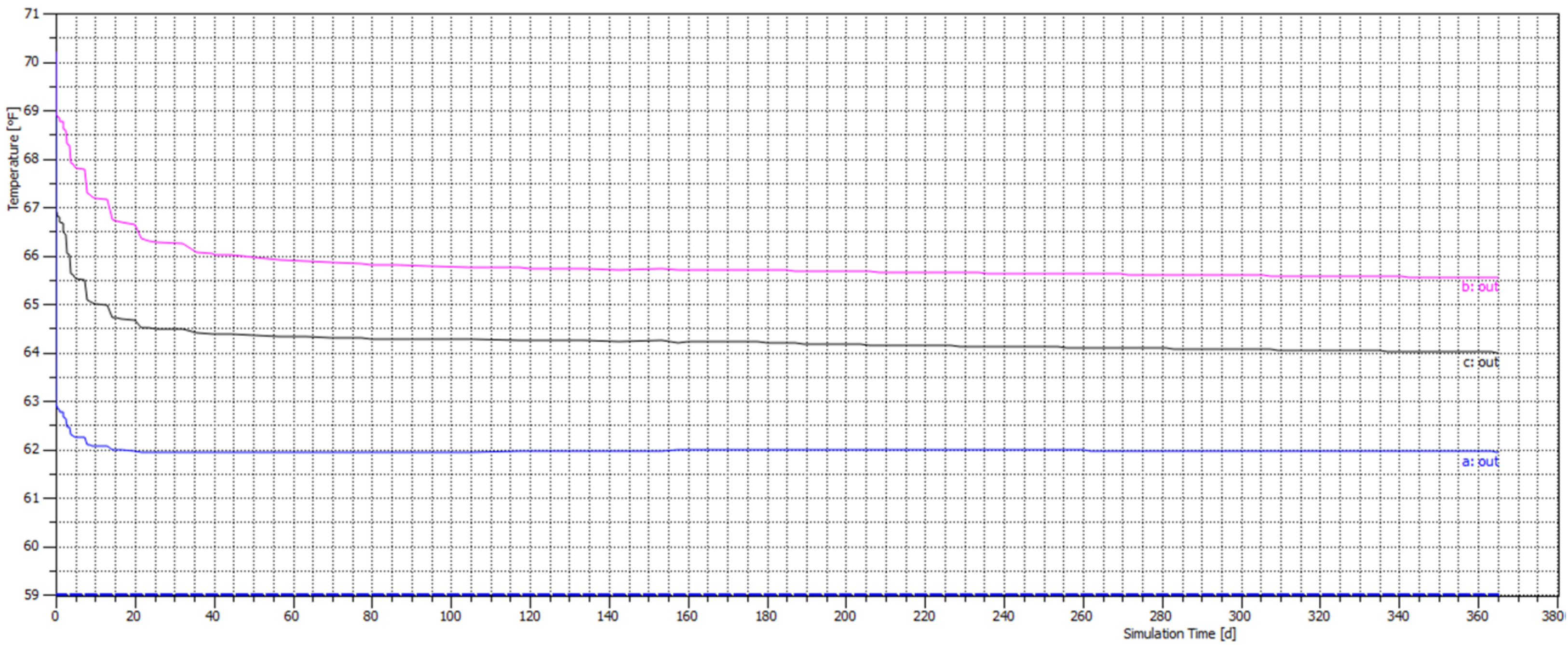


FIGURE -9 GIW EVALUATION

TEMPERATURE PLAN VIEW - DEPTH 100' BGS, 1YR

FIGURE 10 – GIW Evaluation

Extraction Liquid Temperature Variation with Time



Constant input temperature of 59 degrees assumed as average plus

Curve a:out is 60’ deep unit (blue solid)

Curve b:out is 120’ deep unit (black solid)

Curve c:out is 100’ deep unit (magenta)

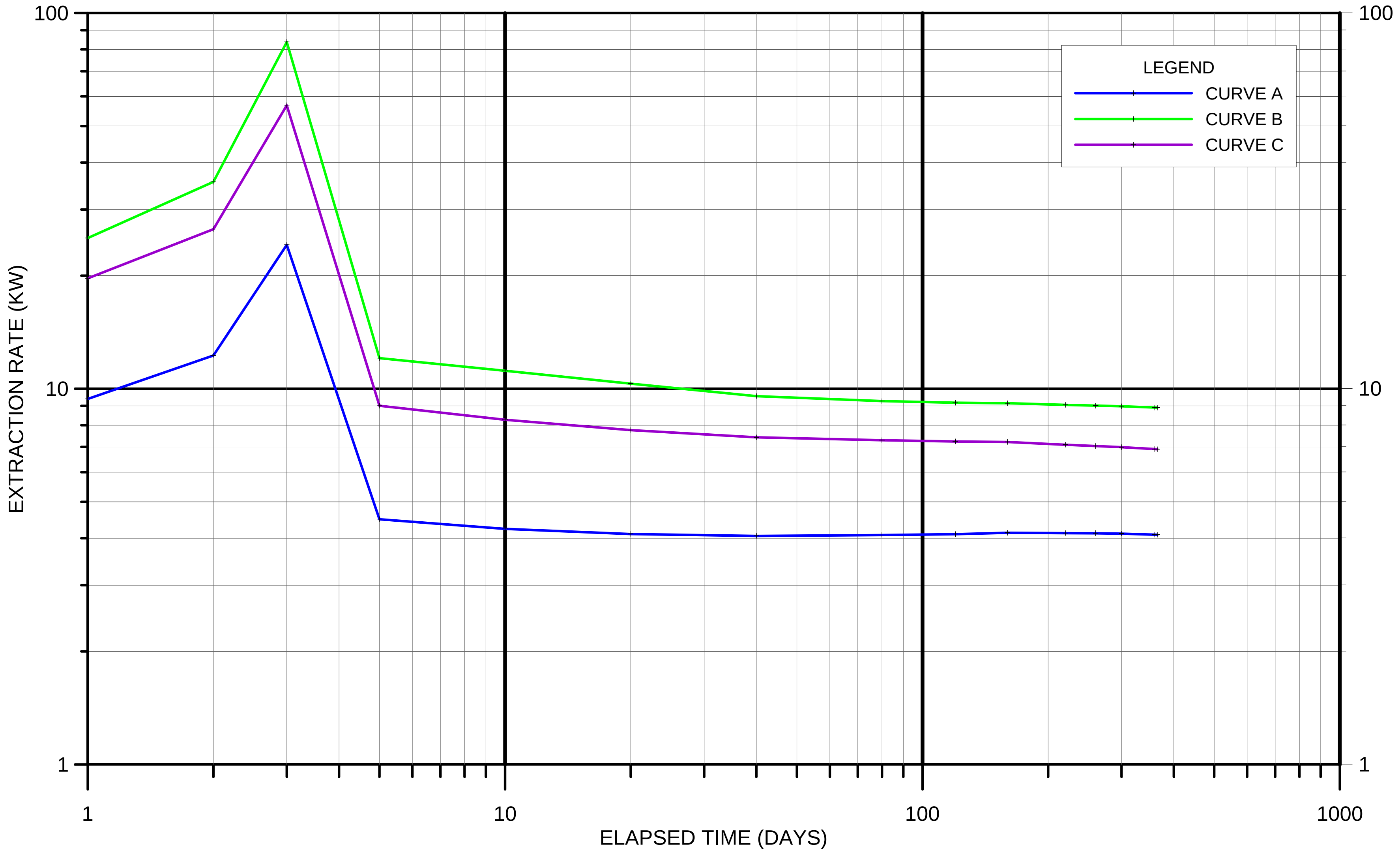


FIGURE 11 - GIW EVALUATION
HEAT EXTRACTION RATE VS TIME
(IN kW)

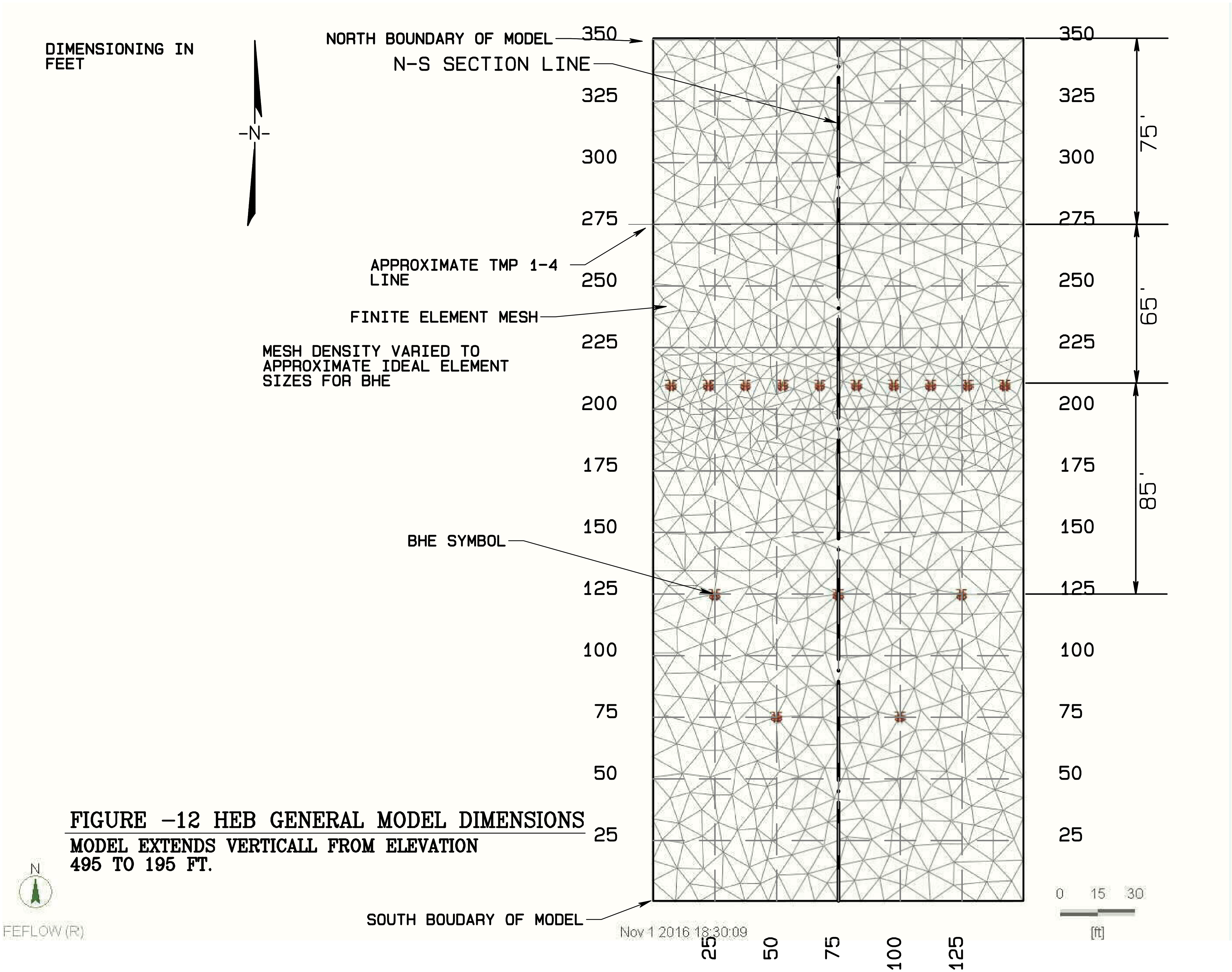


FIGURE -12 HEB GENERAL MODEL DIMENSIONS

MODEL EXTENDS VERTICALL FROM ELEVATION 495 TO 195 FT.

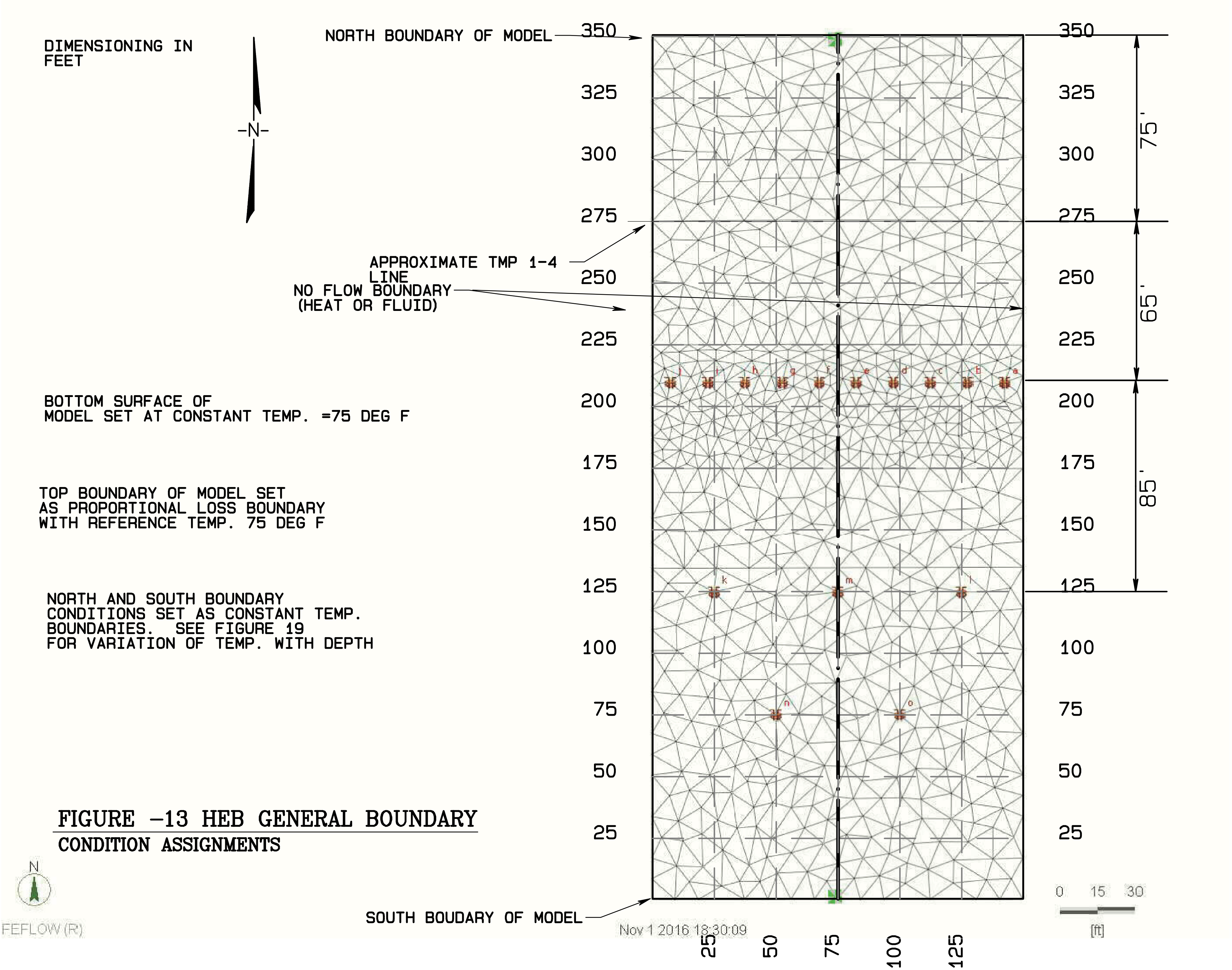
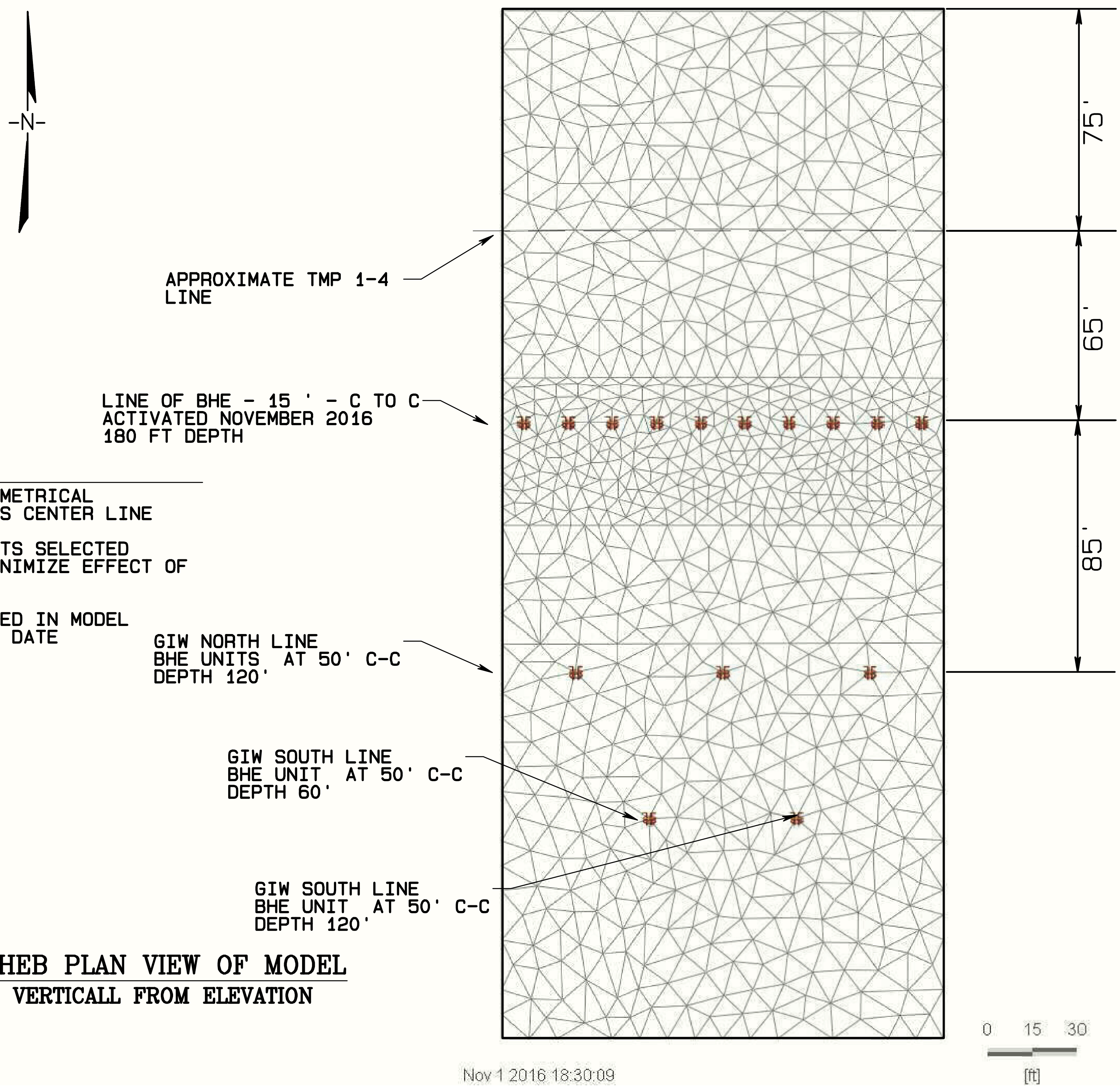


FIGURE -13 HEB GENERAL BOUNDARY CONDITION ASSIGNMENTS



NOTES:

LOCATION OF BHE SYMETRICAL WITH RESPECT TO N/S CENTER LINE

SOUTH LINE GIW UNITS SELECTED TO BE OFFSET, TO MINIMIZE EFFECT OF THIS ROW OF BHE

NO BHE WERE INSTALLED IN MODEL PRIOR TO ACTIVATION DATE

FIGURE -14 HEB PLAN VIEW OF MODEL

MODEL EXTENDS VERTICALL FROM ELEVATION 495 TO 195 FT.

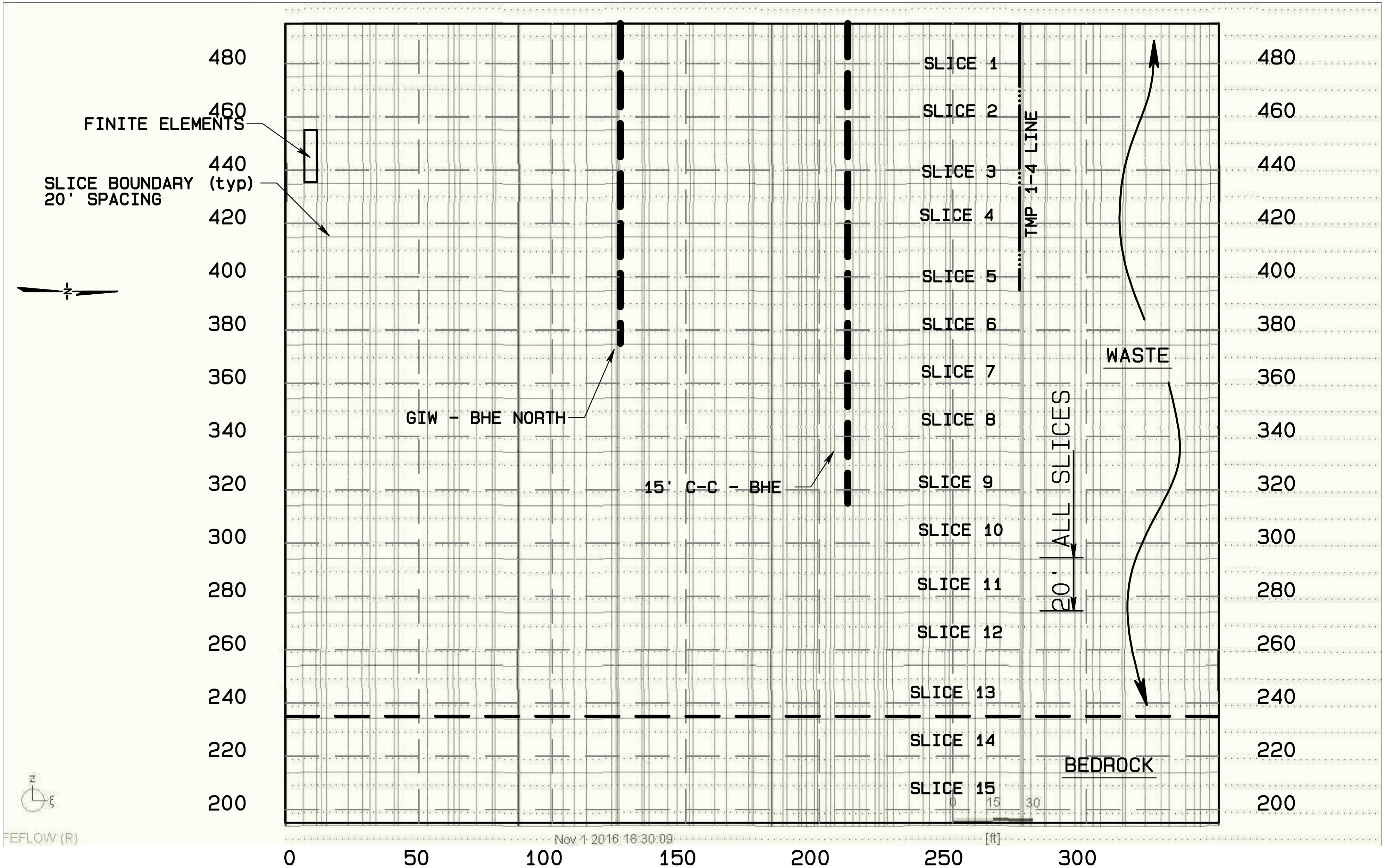


FIGURE –15 HEB SECTION VIEW OF MODEL

DEPICTS MESH, SLICES AND BHE LOCATIONS

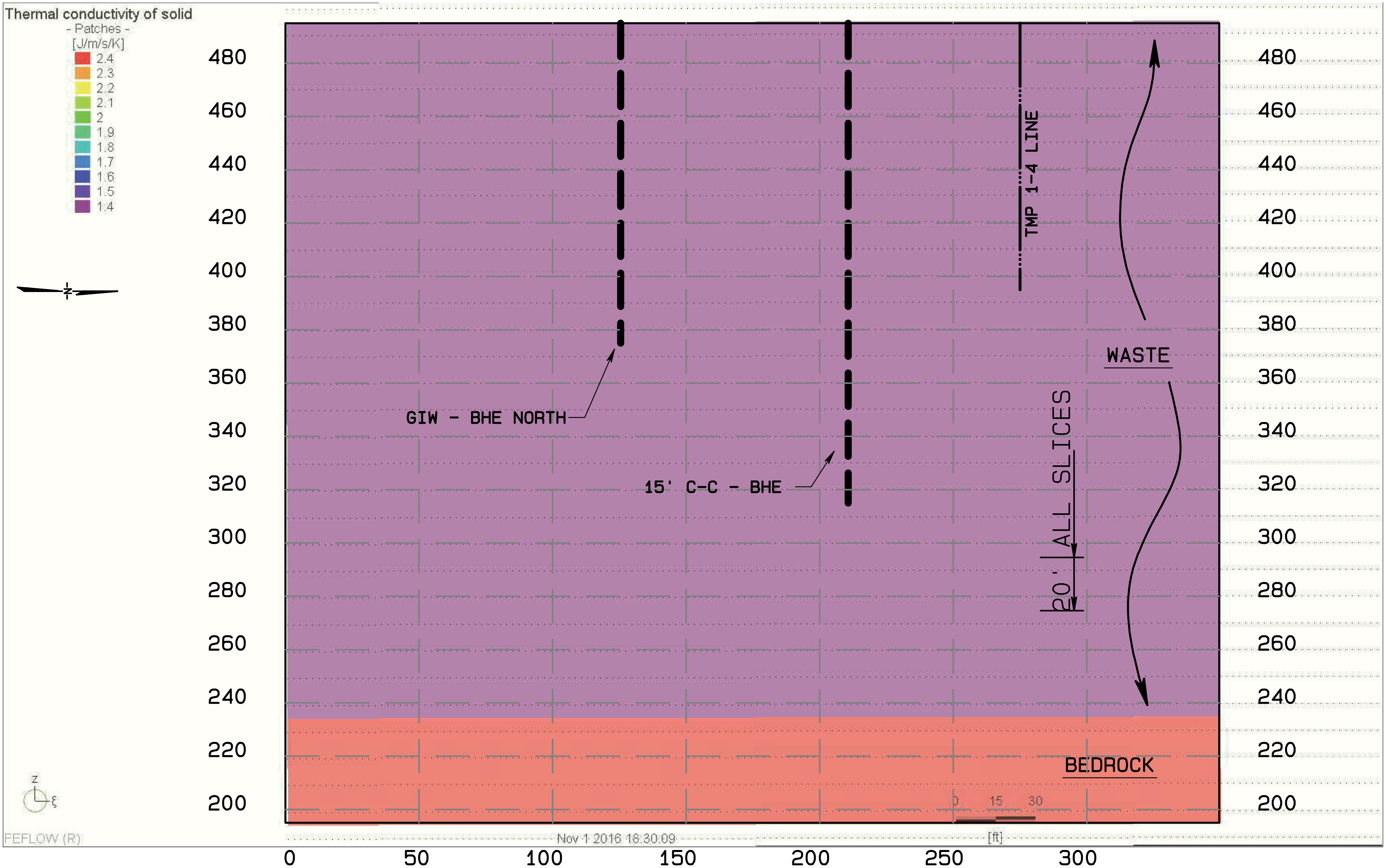


FIGURE –16 HEB ASSIGNMENT OF HEAT CONDUCTIVITY (k) IN W/m K

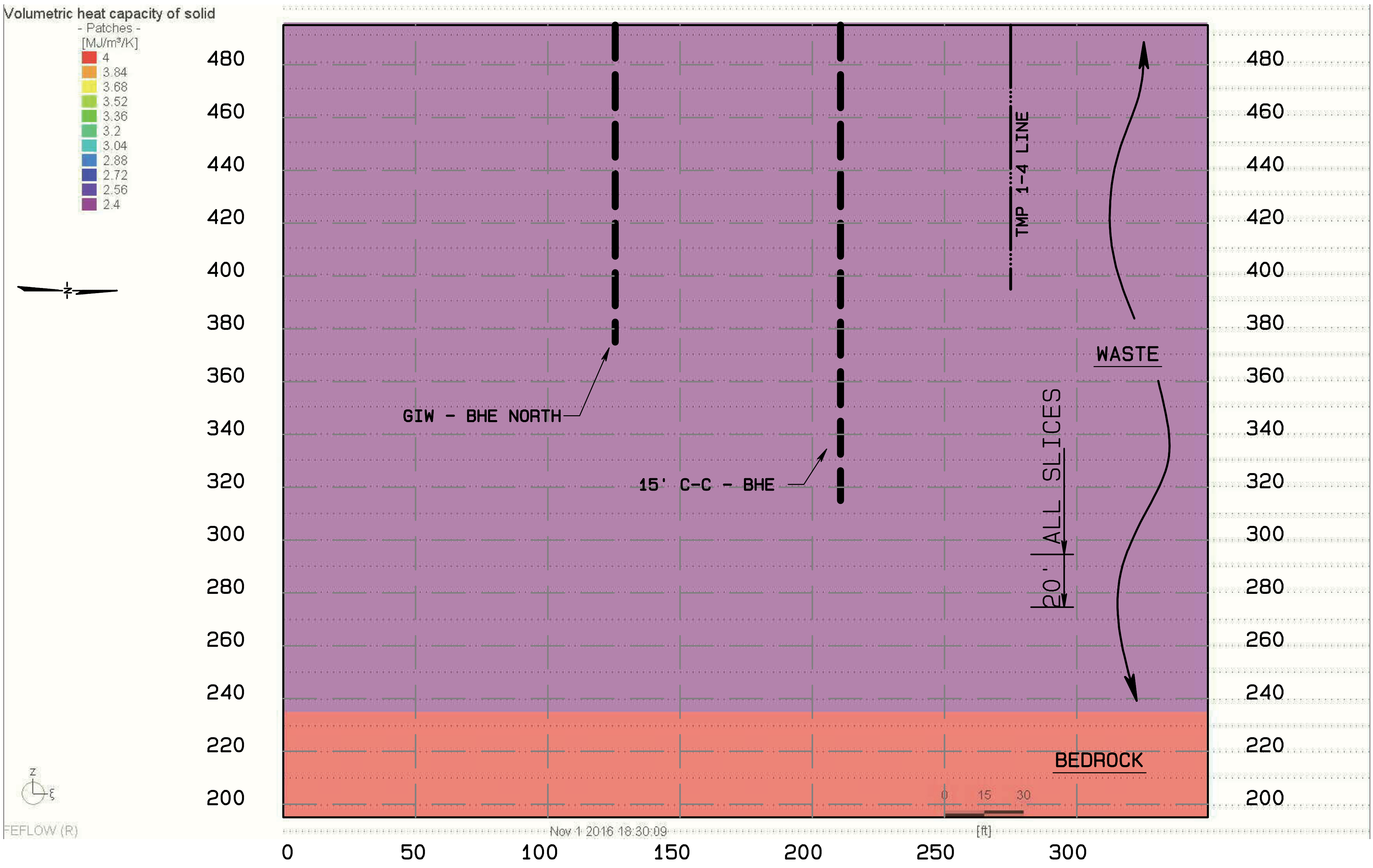


FIGURE –17 HEB ASSIGNMENT OF HEAT CAPACITY (Cv) IN MJ/m^3 K

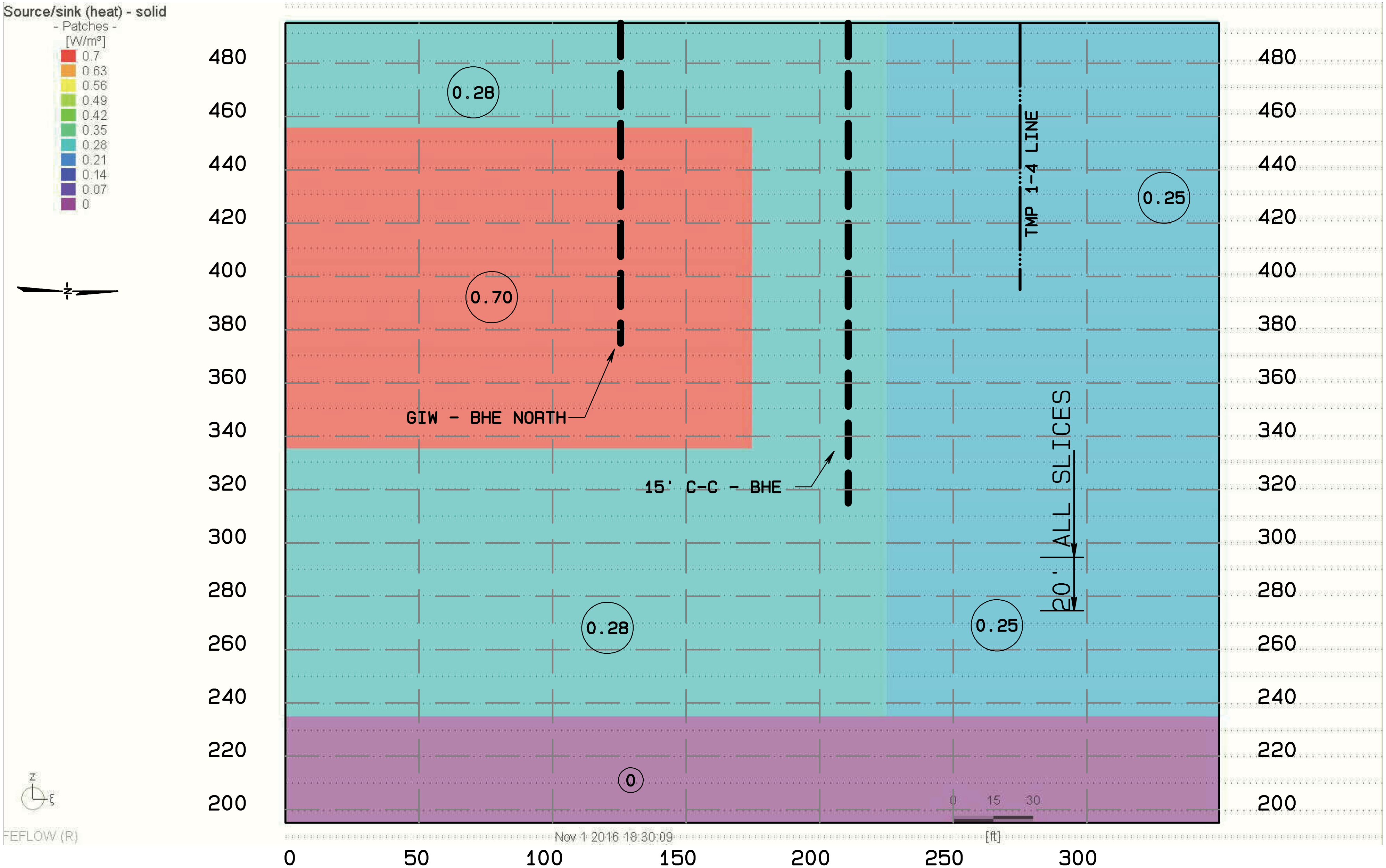
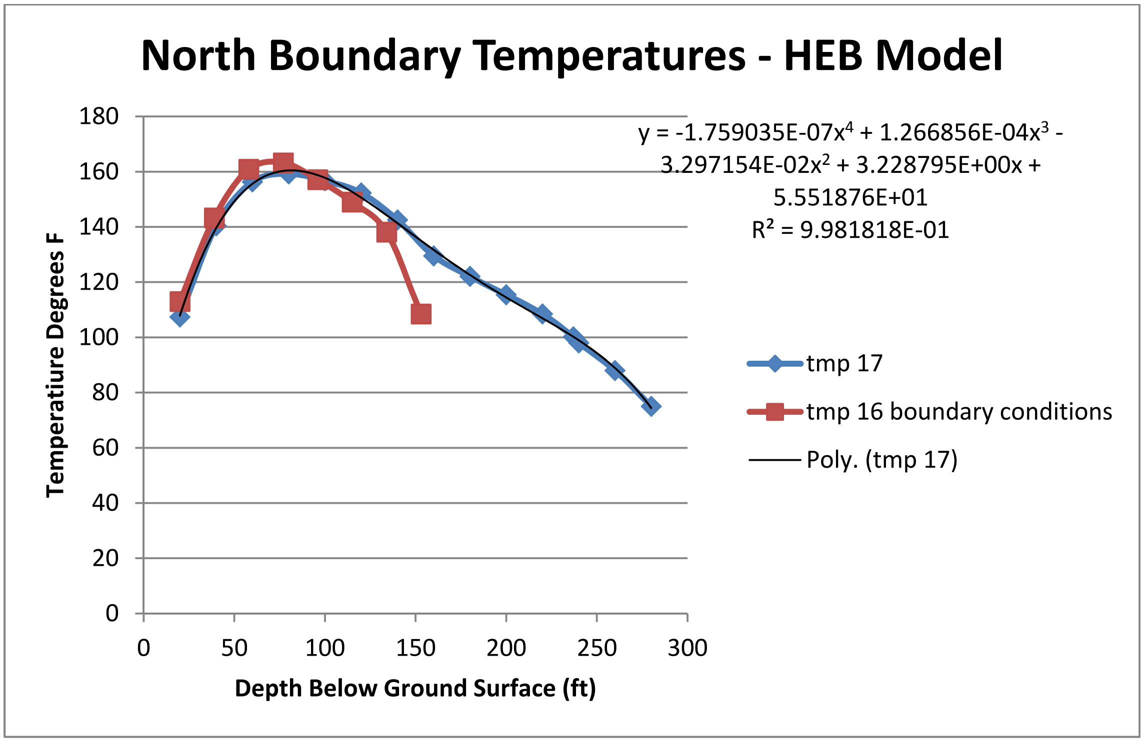
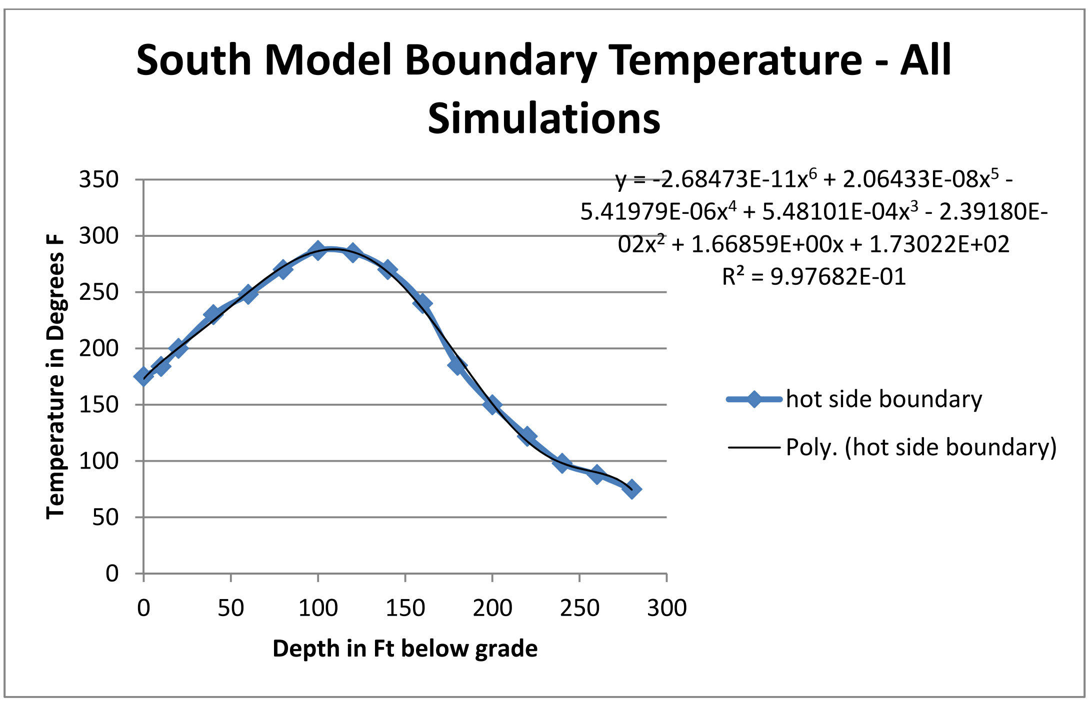


FIGURE –18 HEB INTERNAL ENERGY GENERATION ASSIGNMENTS – WATTS PER CU. M

FIGURE 19 – HEB NORTH AND SOUTH BOUNDARY CONDITIONS





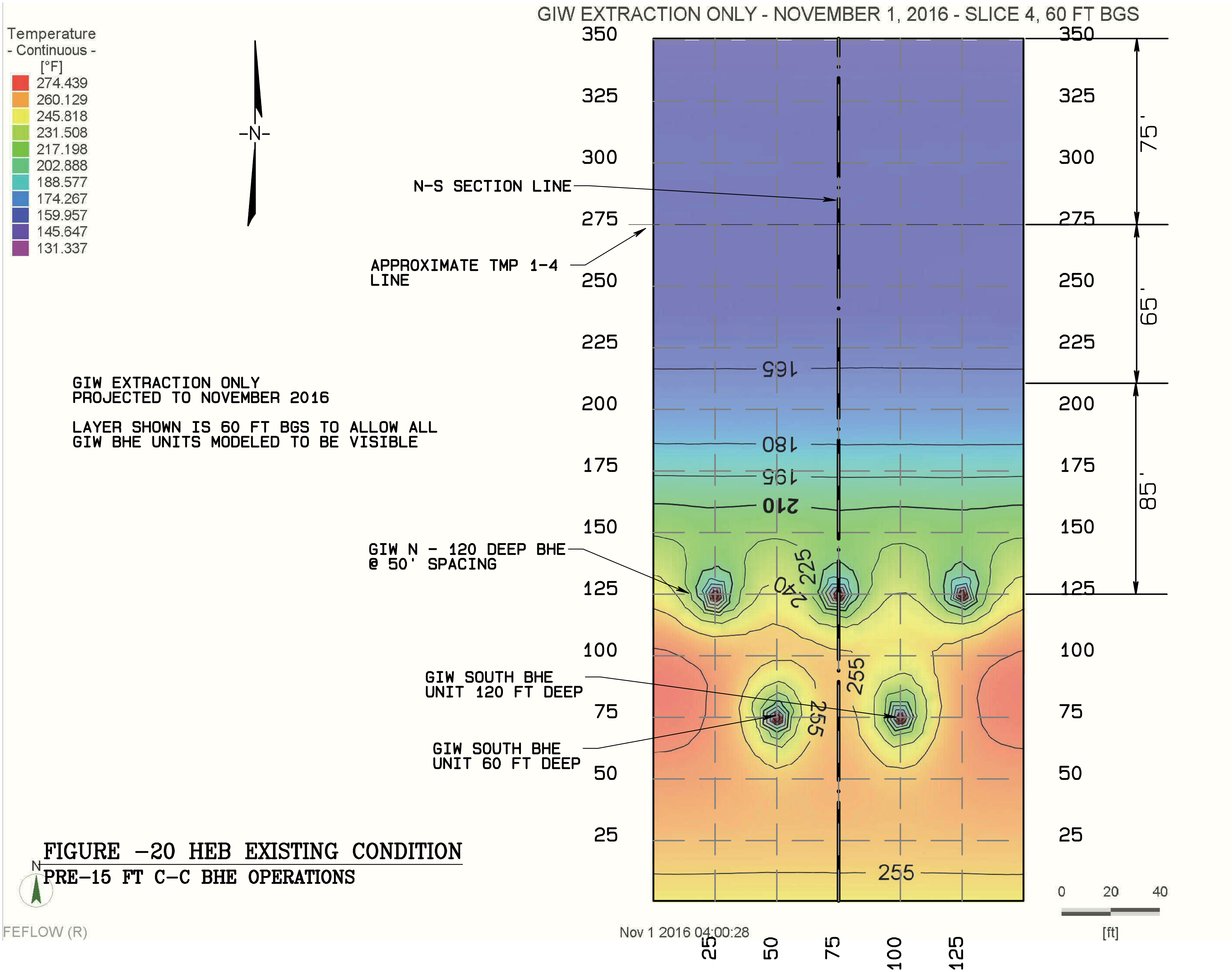


FIGURE -20 HEB EXISTING CONDITION
PRE-15 FT C-C BHE OPERATIONS

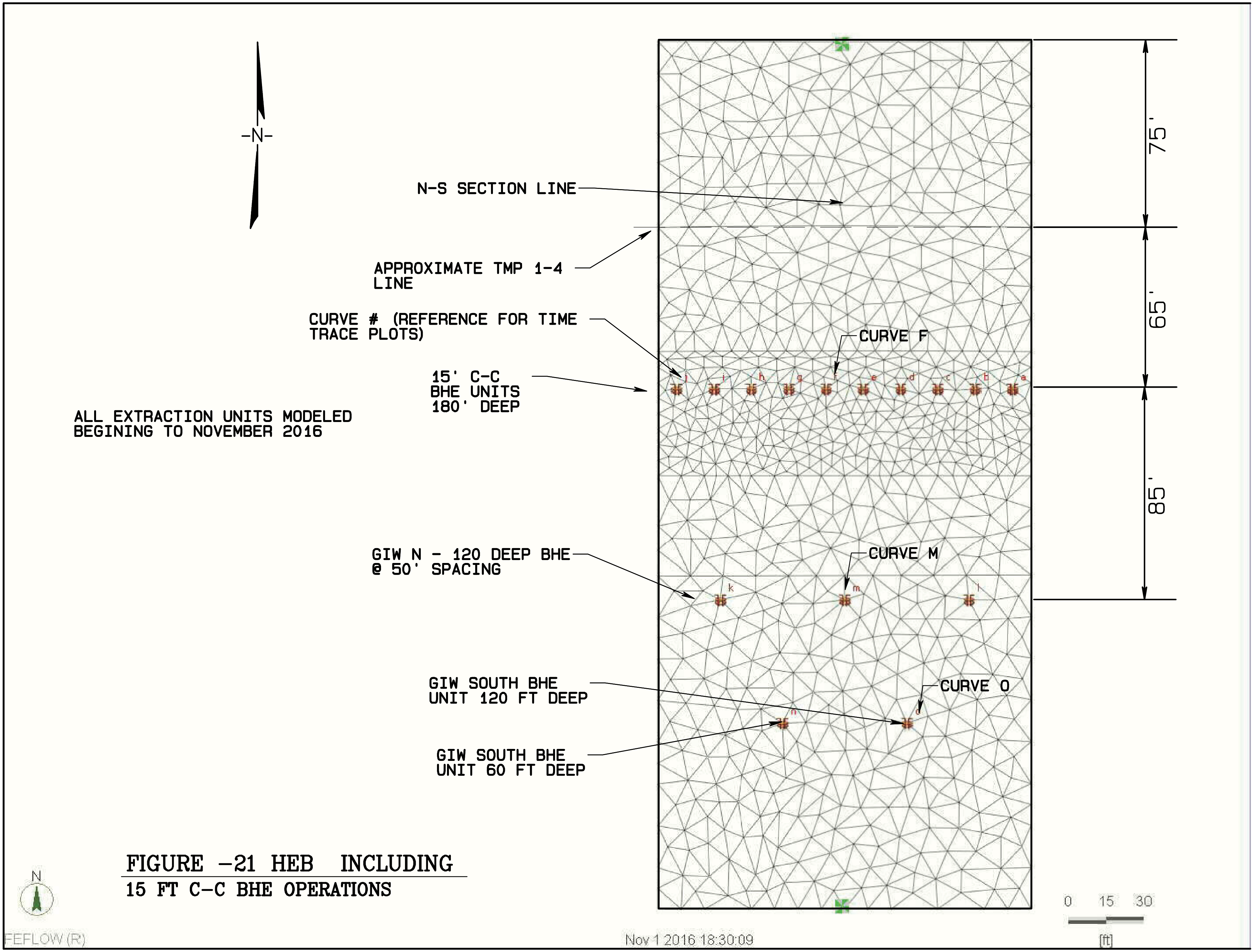


FIGURE -21 HEB INCLUDING
15 FT C-C BHE OPERATIONS

BHE for 15’ c-c Line (note may change)

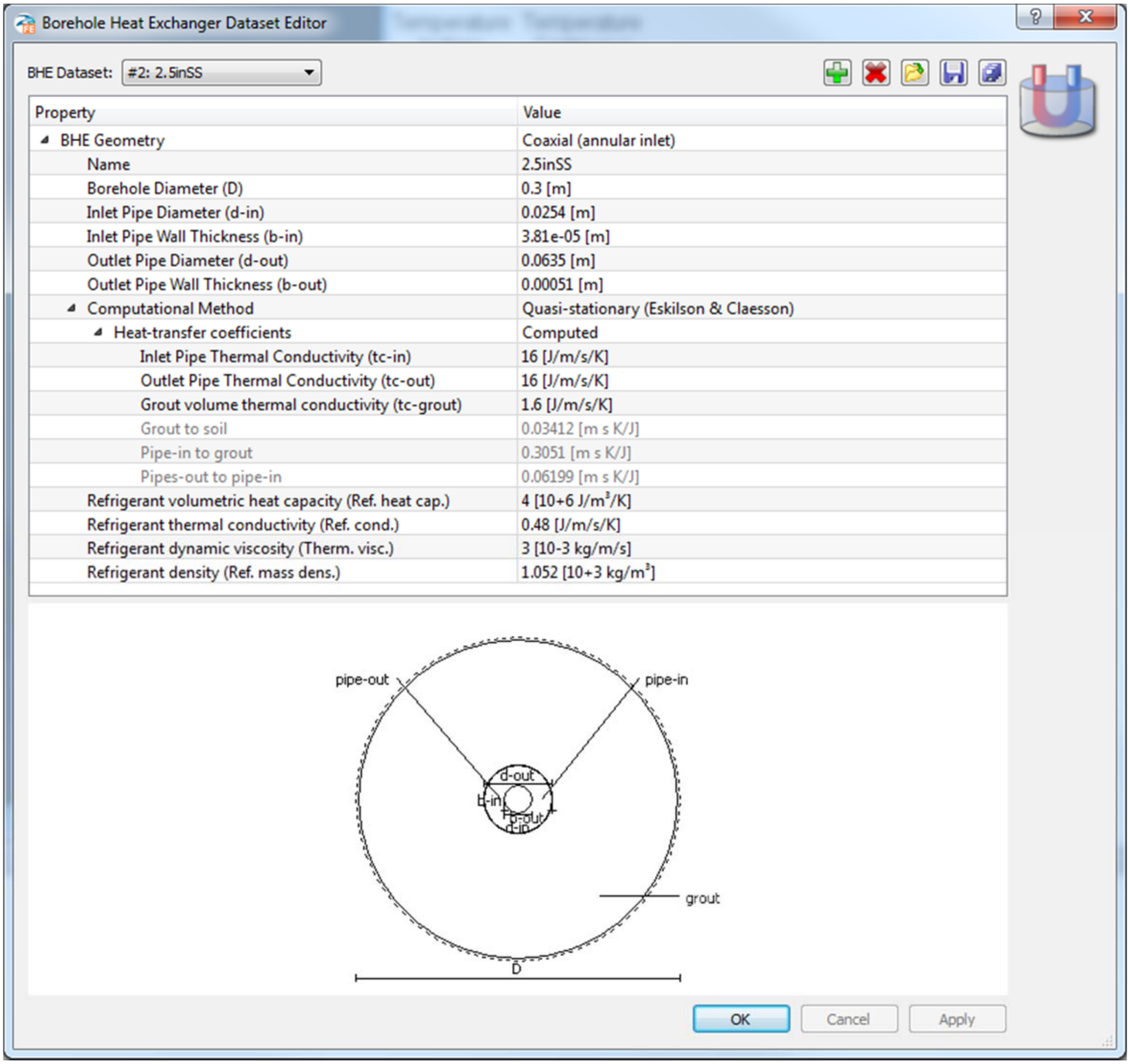


FIGURE 22 BHE DIAGRAM FOR 15’ C-C LINE (HEB EVALUATION

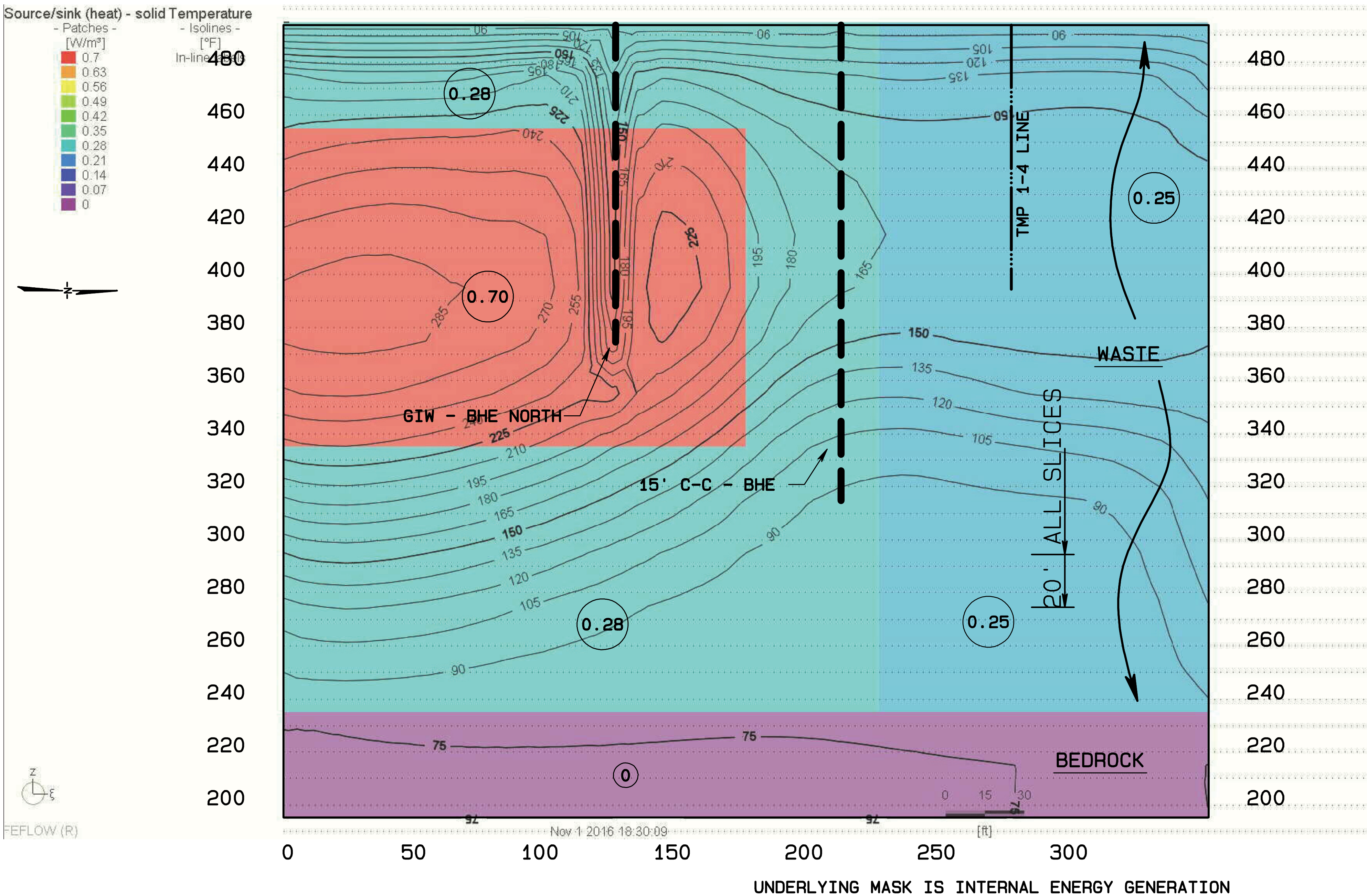


FIGURE –23 HEB INITIAL TEMPERATURE

SECTION VIEW – NOV 2016

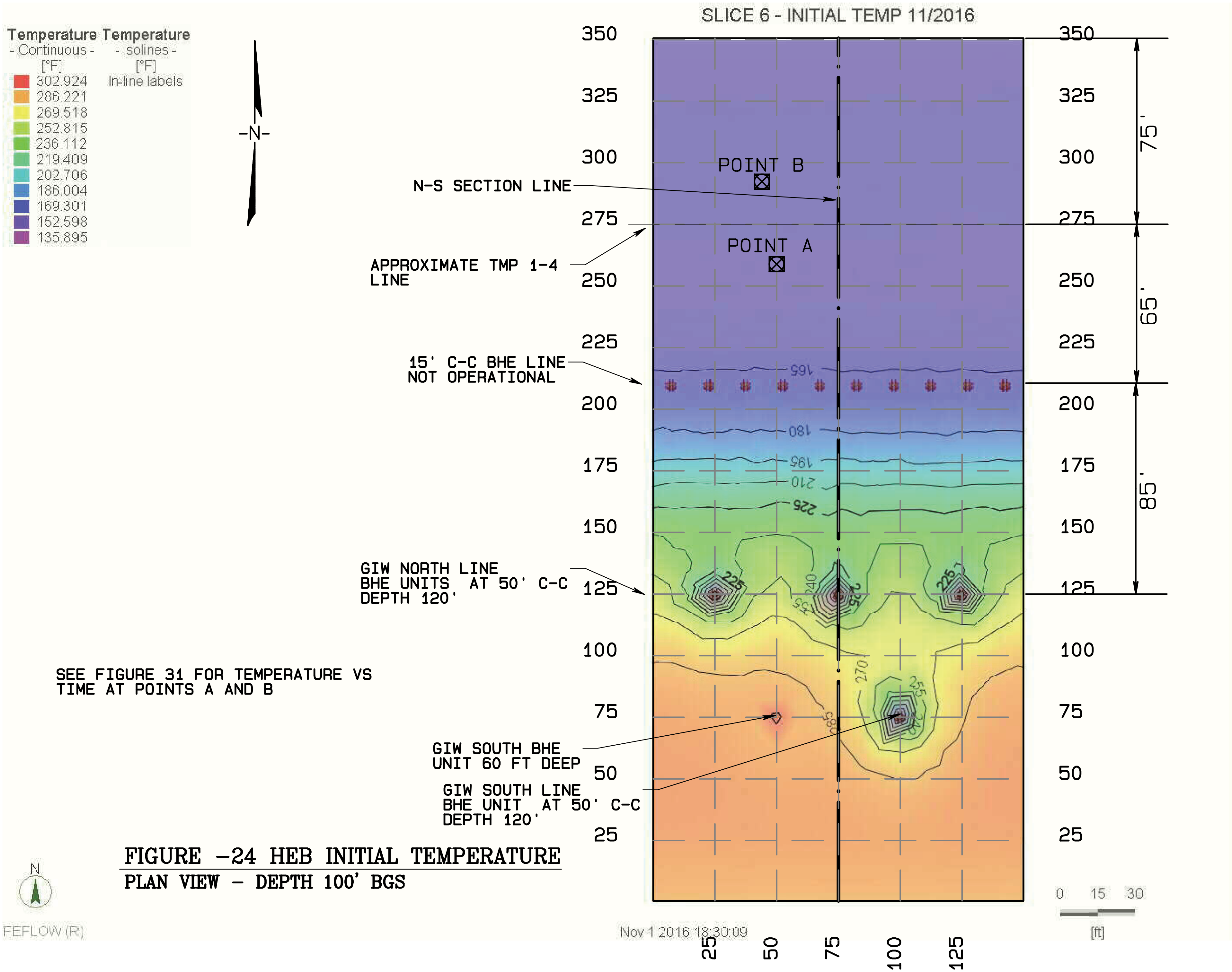


FIGURE -24 HEB INITIAL TEMPERATURE
PLAN VIEW - DEPTH 100' BGS

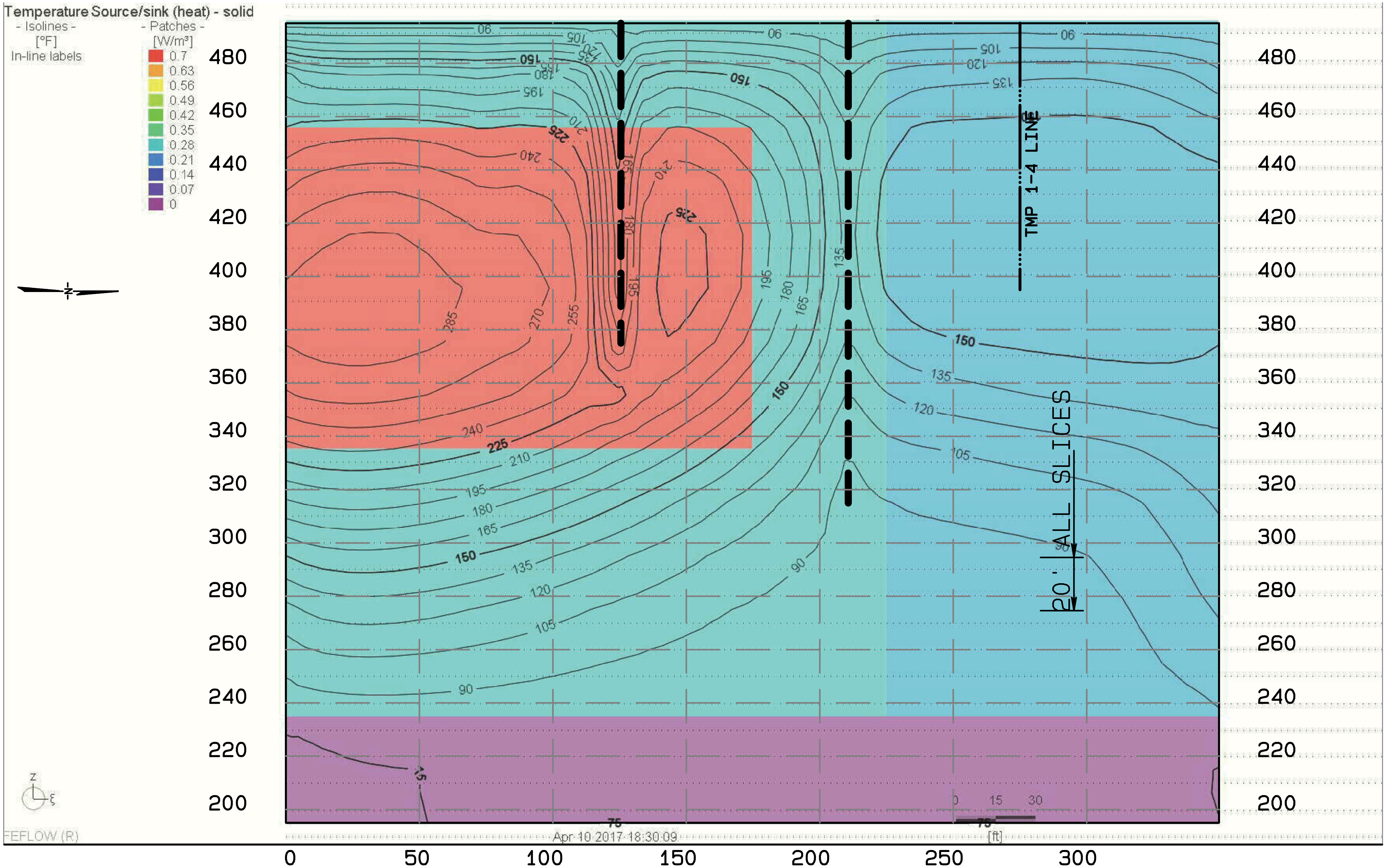


FIGURE -25 HEB TEMPERATURE @ 6 MONTHS

SECTION VIEW - APRIL 2017

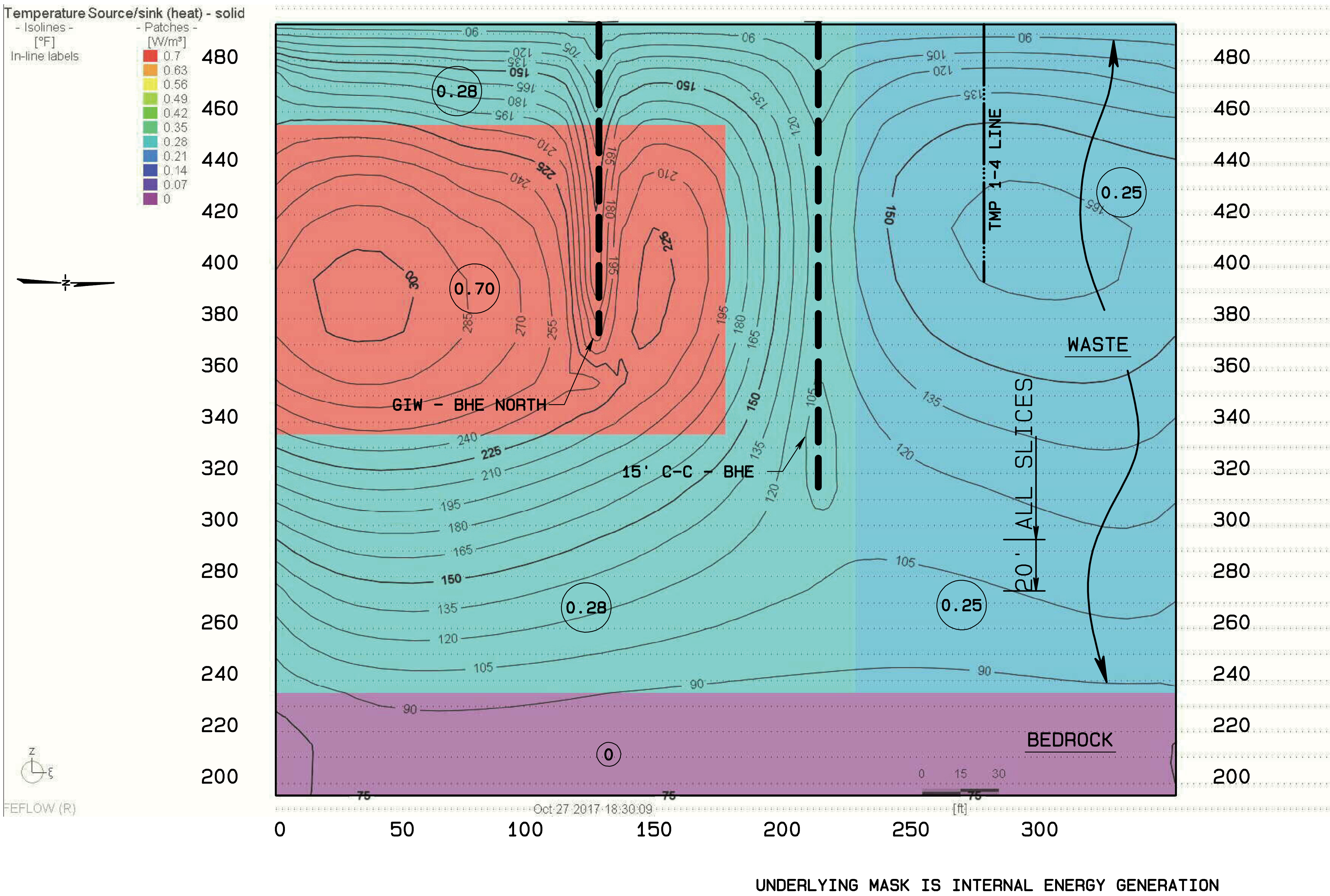
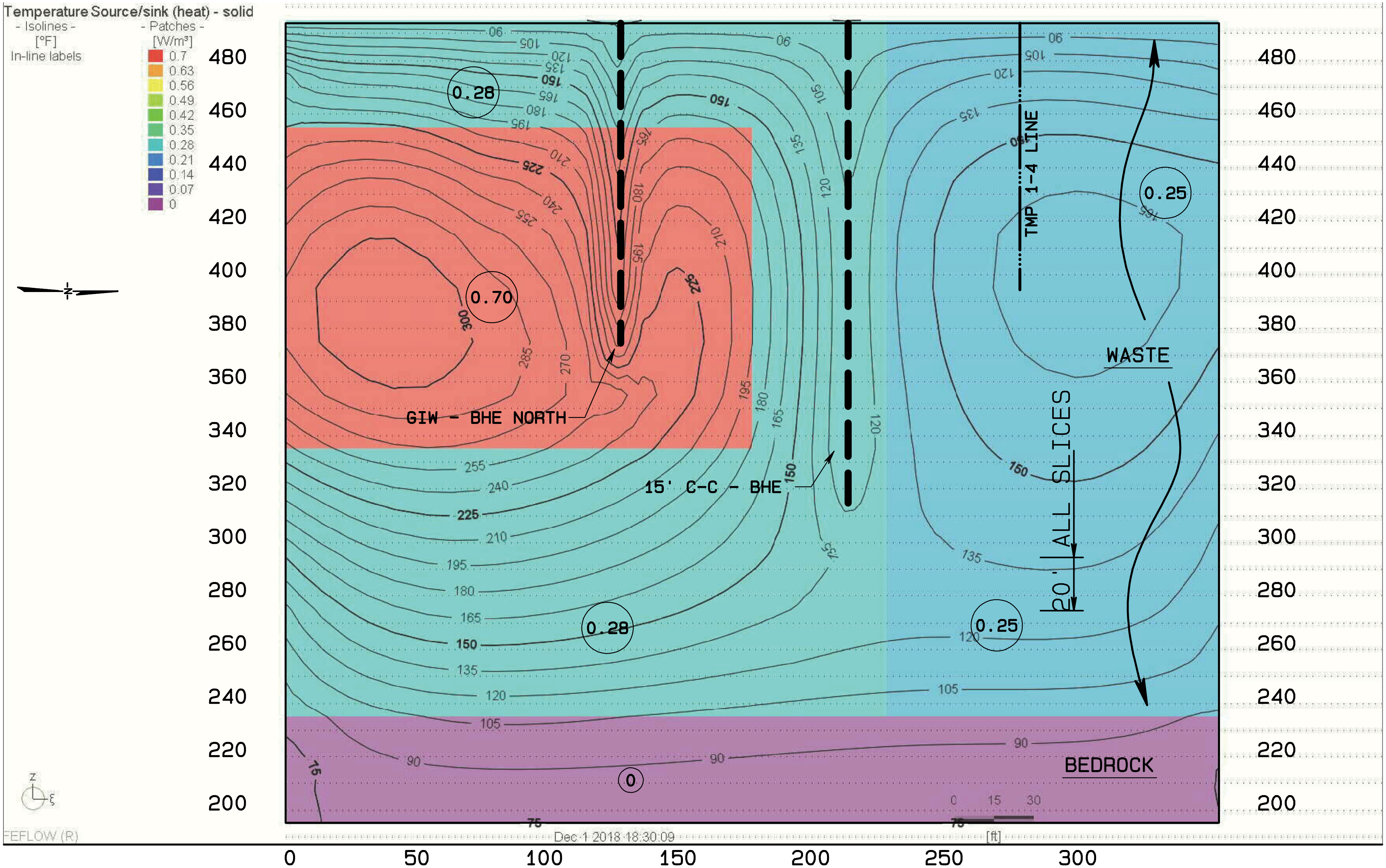


FIGURE -26 HEB TEMPERATURE @ 1 YR

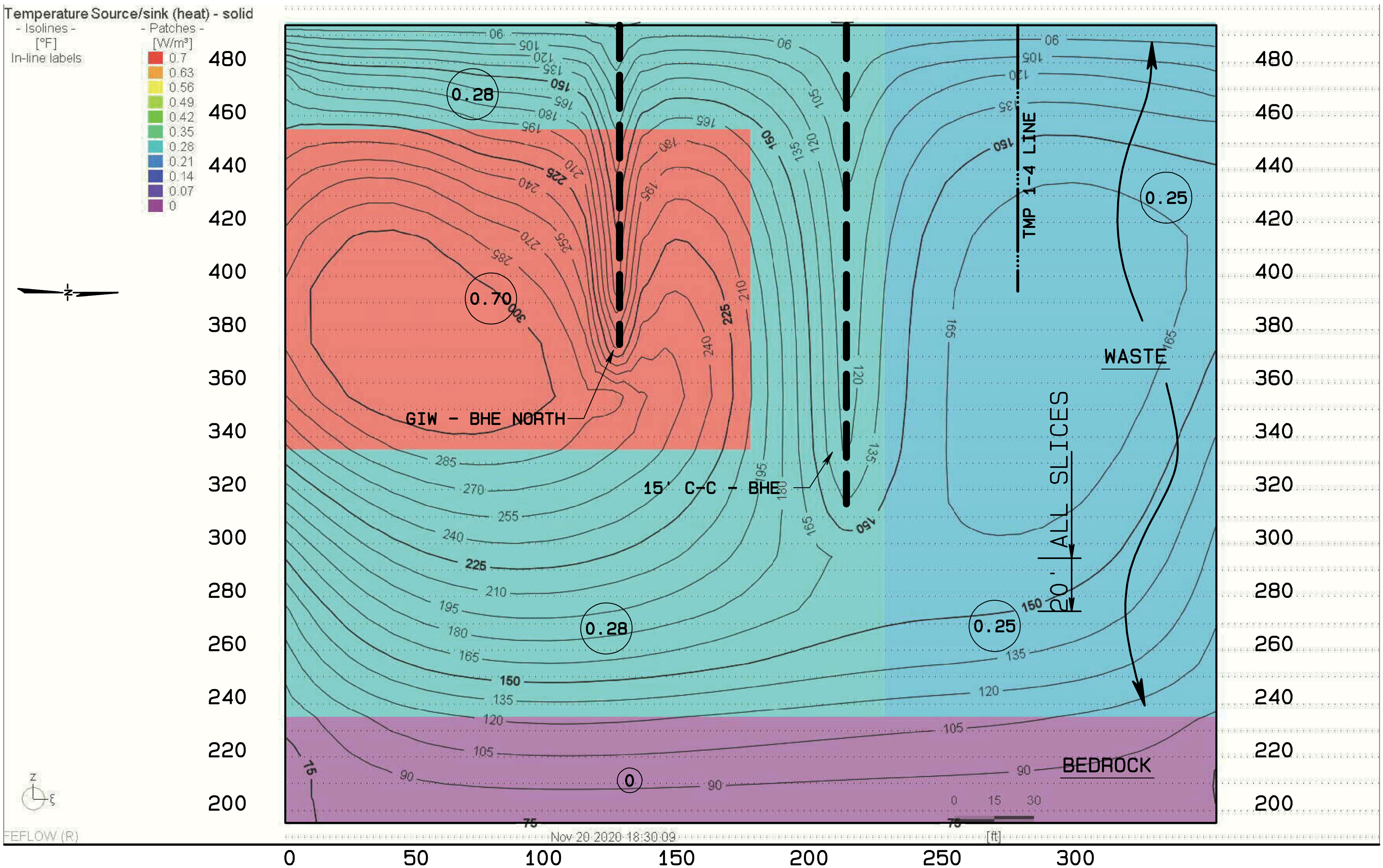
OCTOBER 27, 2017



UNDERLYING MASK IS INTERNAL ENERGY GENERATION

FIGURE -27 HEB TEMPERATURE @ 2 YR

DECEMBER 1,2018



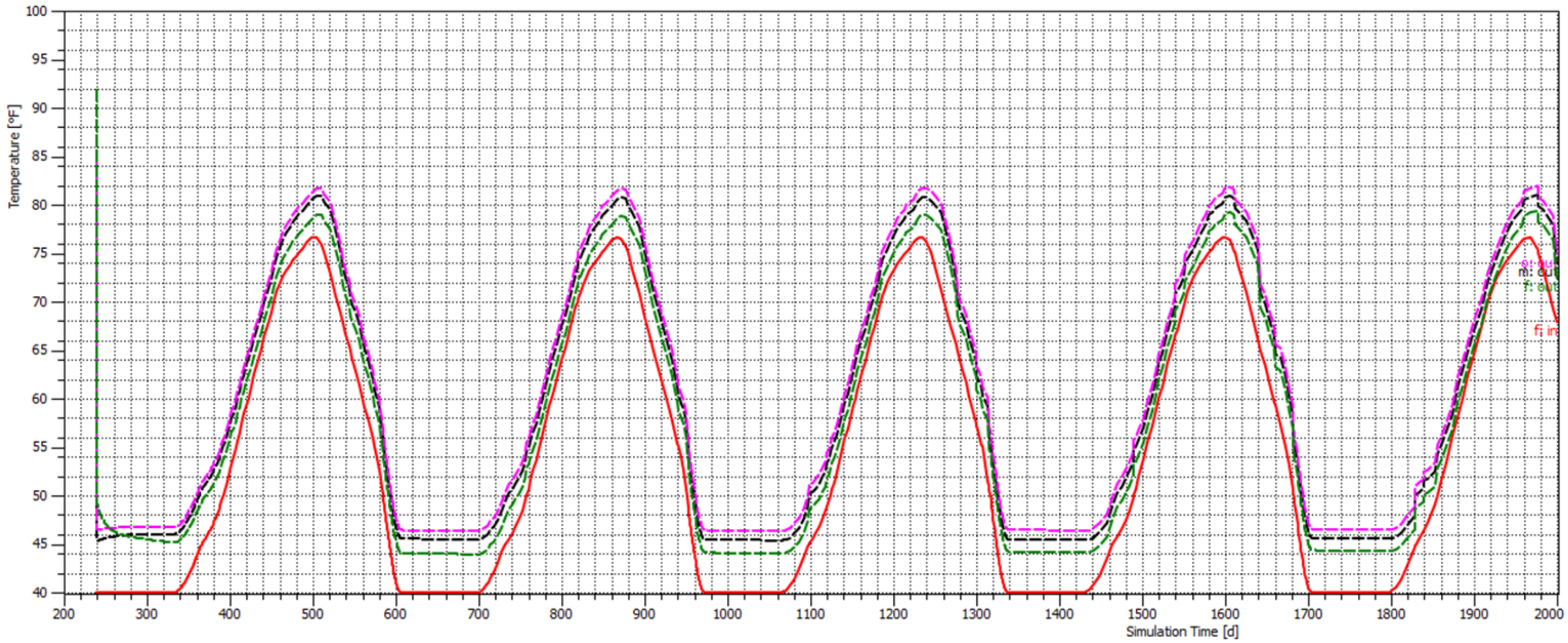
UNDERLYING MASK IS INTERNAL ENERGY GENERATION

FIGURE -28 HEB TEMPERATURE @ 4 YR

NOVEMBER 20, 2020

FIGURE – 29

HEB – PLOT OF INLET AND OUTLET TEMPERATURES



LEGEND

RED SOLID LINE – INFLET TEMP FROM COOLER

DASHED GREEN – OUTLET TEMP FROM 15’ C-C BHE (CURVE F DENOTED IN FIGURES)

DASHED MAGENTA – OUTLET TEMP FROM GIW SOUTH 120’ LONG BHE (CURVE O)

DASHED BLACK – OUTLET TEMP FROM GIW NORTH BHE (CURVE M)

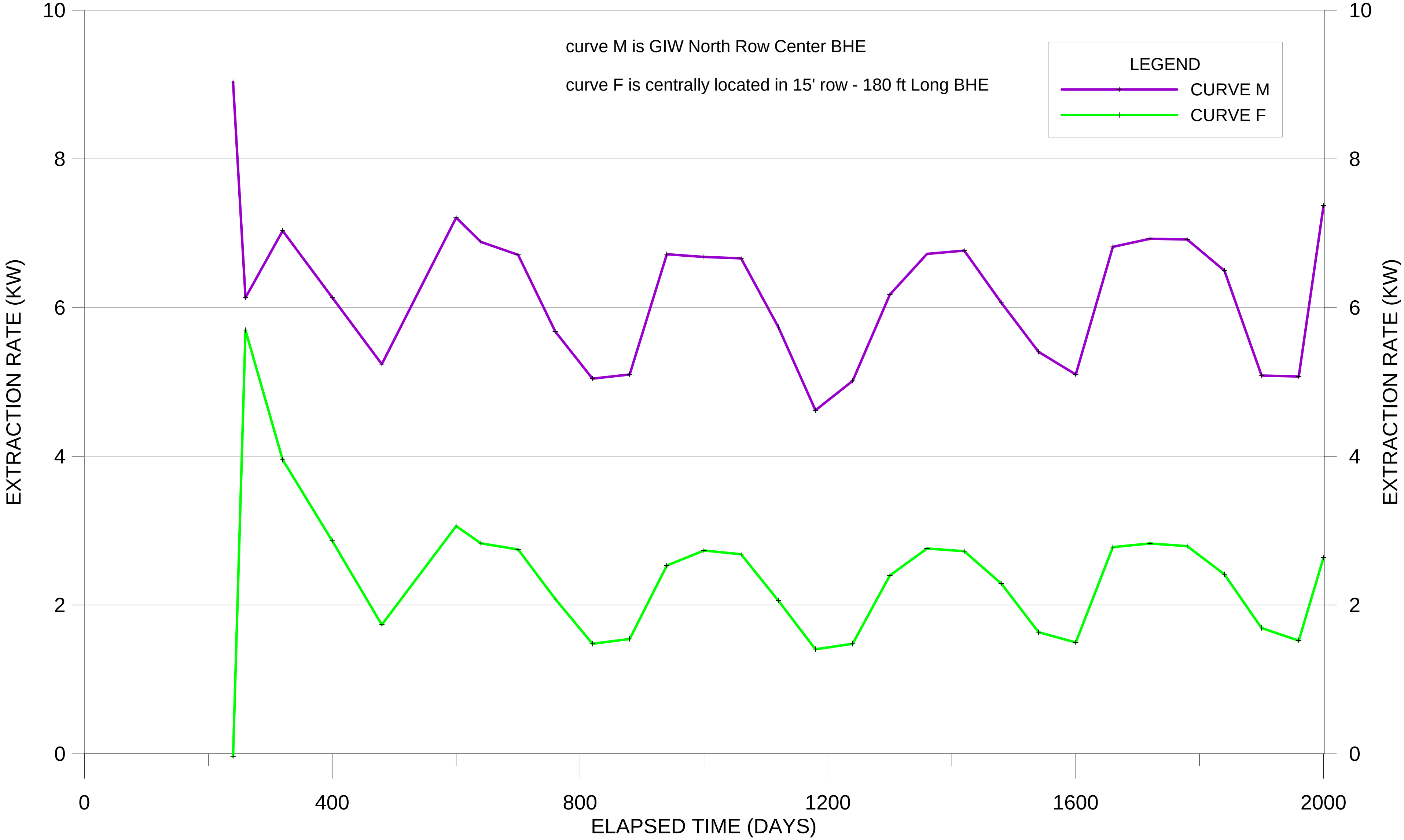


FIGURE 30 - HEB MODEL SIMULATION
ENERGY EXTRACTION VS. TIME PER BHE TYPE

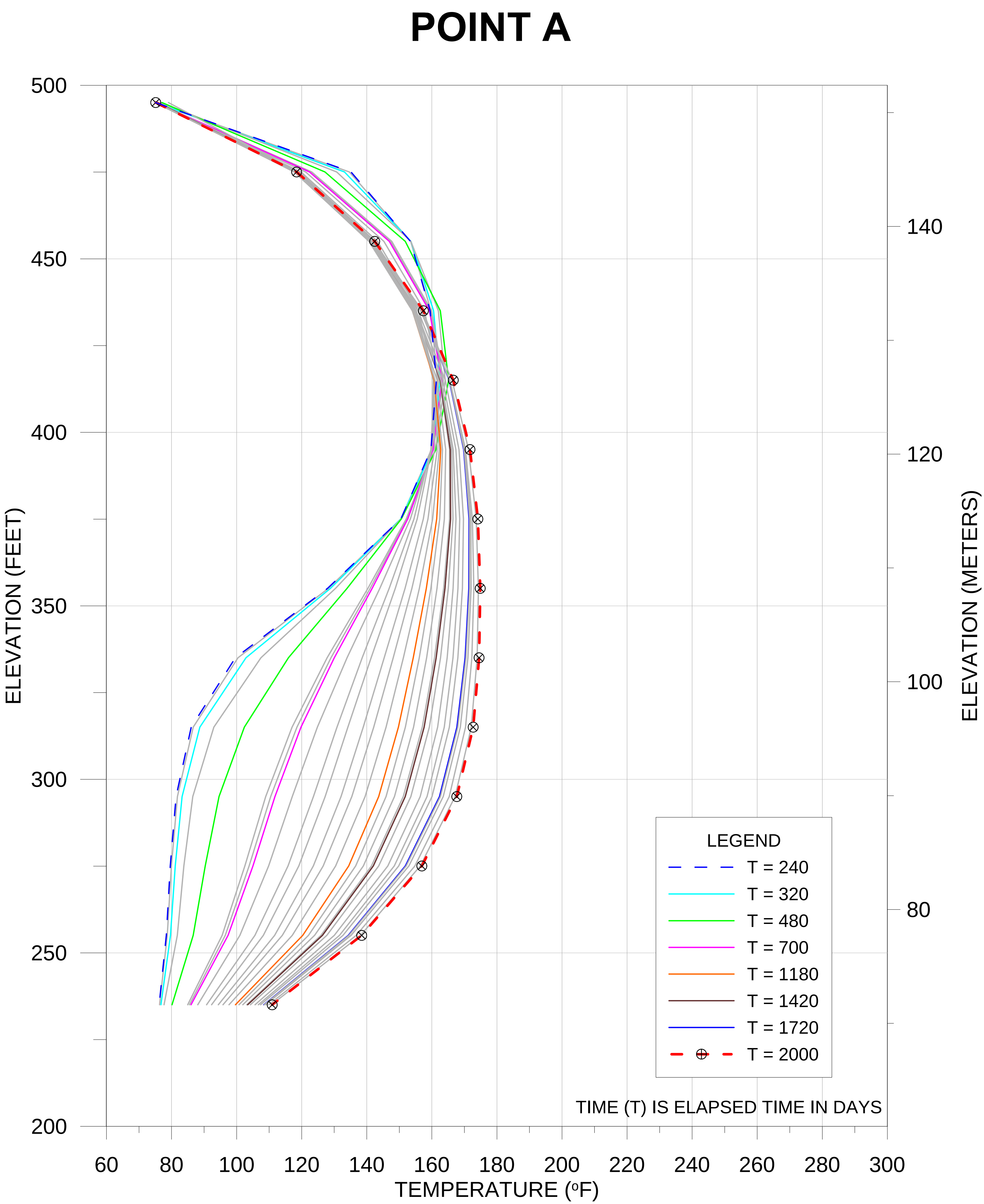


FIGURE 31 A -HEB
TEMPERATURE VS ELEVATION PT A
HEAT MODEL SIMULATION

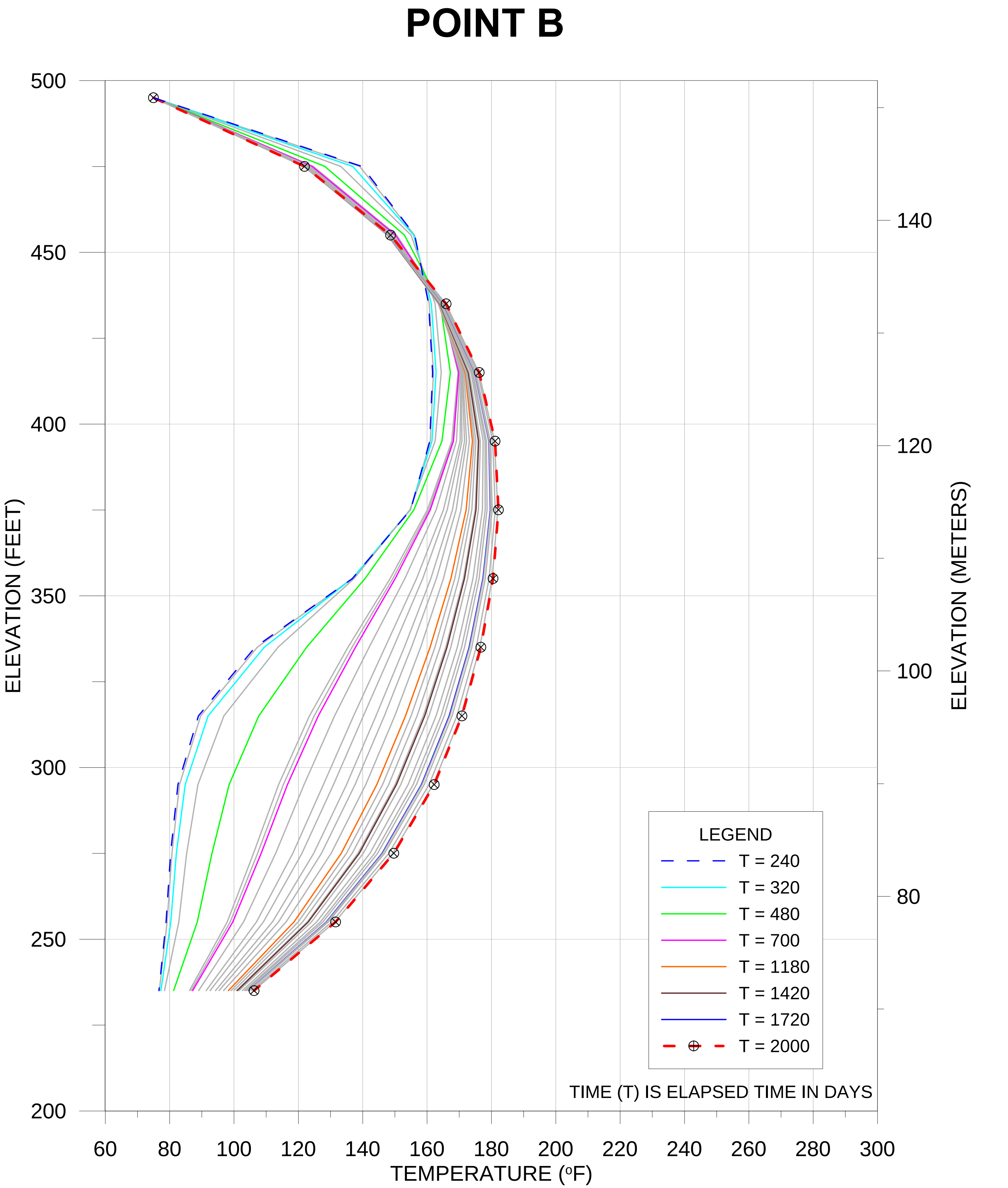


FIGURE 31 B - HEB
TEMPERATURE VS ELEVATION
HEAT MODEL SIMULATION

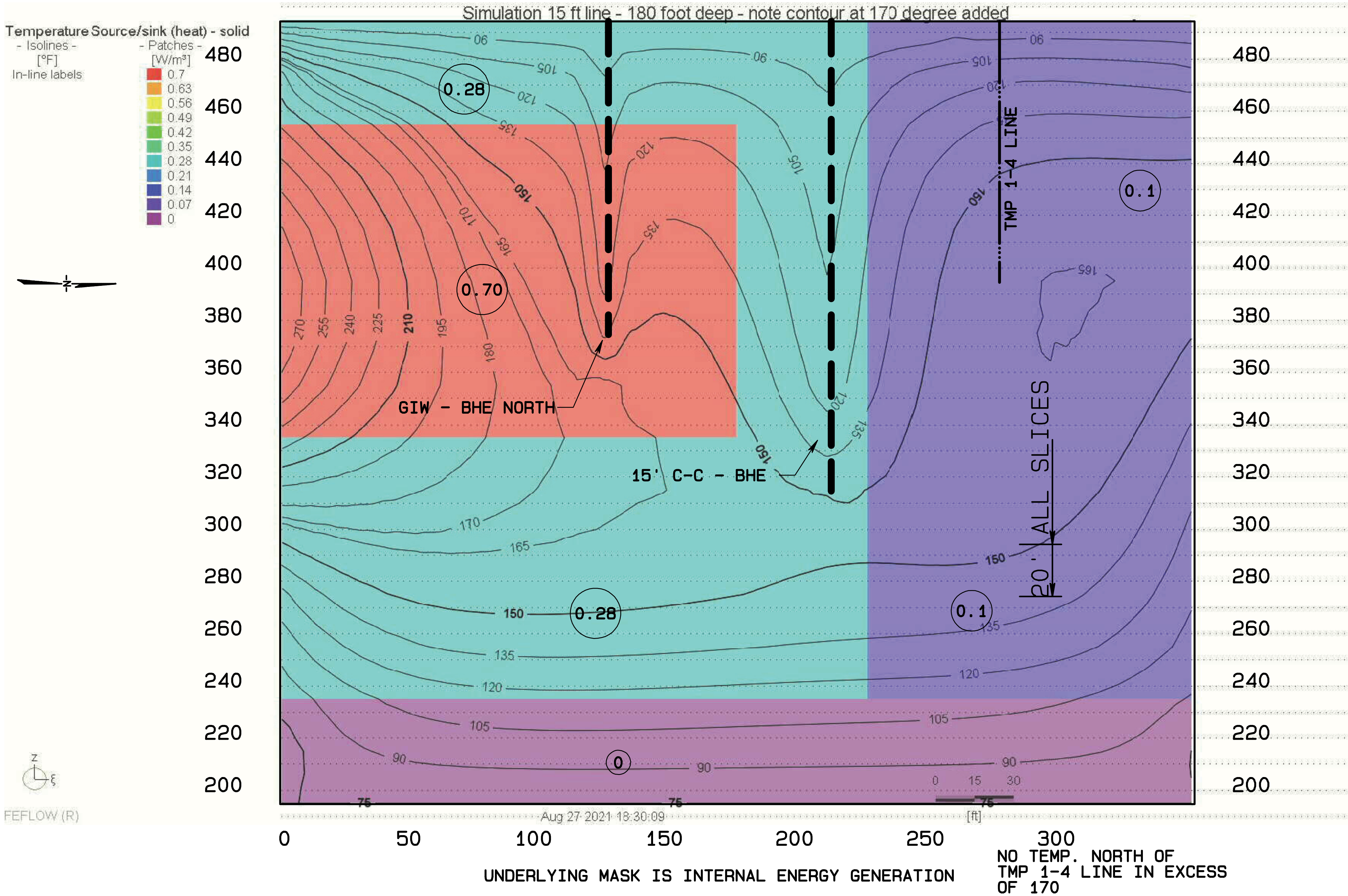


FIGURE –32 HEB TEMPERATURE @ 4.75 YR

AUGUST 27, 2021

Appendix I - Heat Extraction Barrier Design Plans

LEGEND

- EXISTING GRADE (2' CONTOUR)
- 500 — EXISTING GRADE (10' CONTOUR)
- EXISTING GAS EXTRACTION WELL
- EXISTING TEMPERATURE MONITOR PROBE
- EXISTING HEAT EXTRACTION POINT
- 4" COOLING LOOP INFLUENT PIPING
- 2" COOLING LOOP INFLUENT PIPING
- 4" COOLING LOOP EFFLUENT PIPING
- 2" COOLING LOOP EFFLUENT PIPING
- TEMPERATURE MONITORING LOCATION
- CHECK VALVE
- FLOW CONTROL VALVE
- FLOWMETERS
- PROPOSED HEAT EXTRACTION POINTS
- SW — EXISTING SOLID WASTE PERMIT BOUNDARY
- EXISTING QUARRY HIGHWALL

30 0 15 30 60

SCALE: 1" = 30'

NOTES:

1.) AERIAL TOPOGRAPHY WAS PROVIDED BY COOPER AERIAL SURVEYS CO. AND IS DATED MARCH 20, 2014.

BRIDGETON LANDFILL, LLC
13570 ST. CHARLES ROCK ROAD
BRIDGETON, MISSOURI 63044

BRIDGETON LANDFILL

HEAT EXTRACTION BARRIER PLAN VIEW

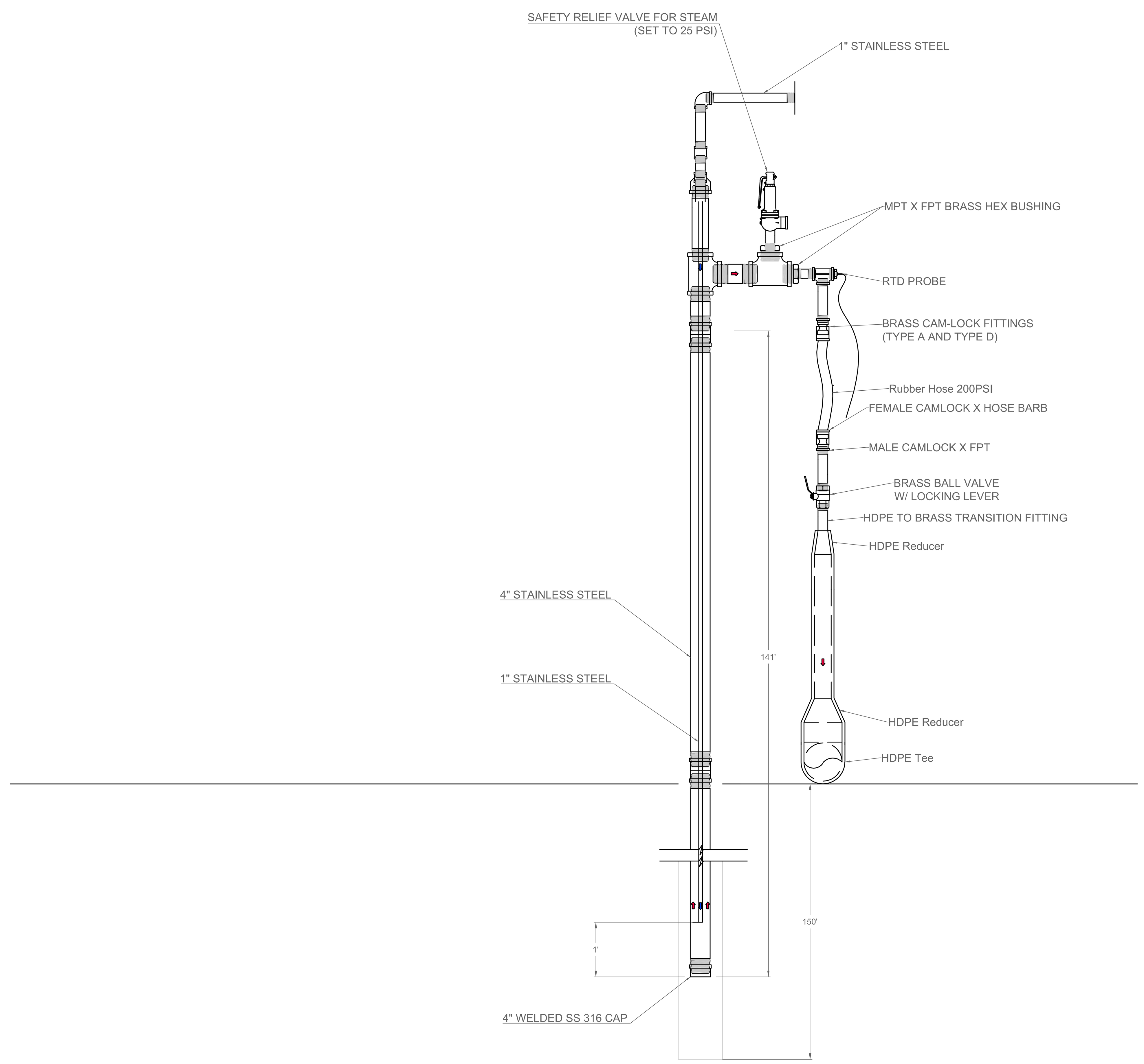
FEEZOR ENGINEERING, INC.
Engineering for a Better World

NOVEMBER 2015
DESIGNED BY: DMK
APPROVED BY: ALK

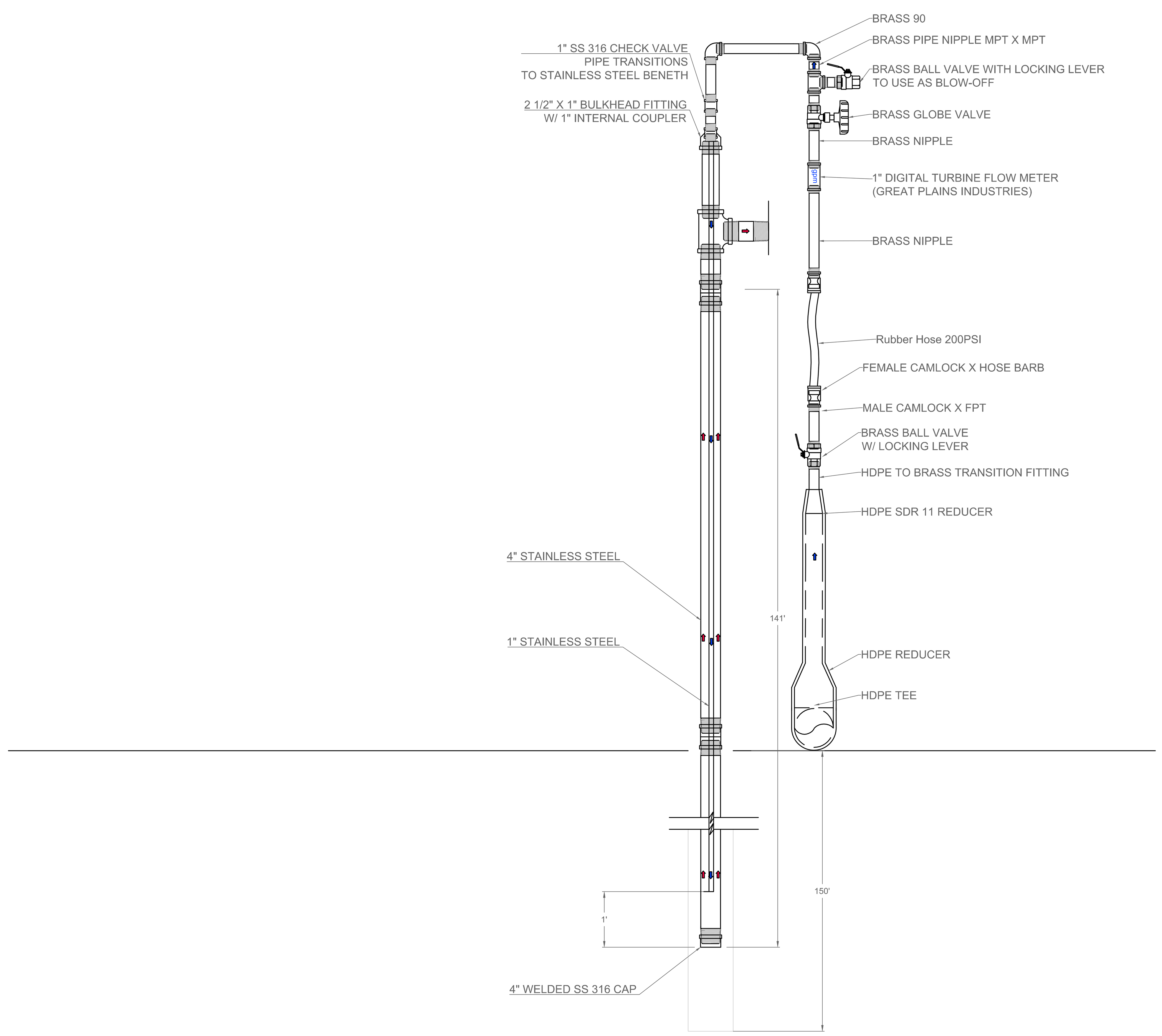
REVISION	DATE

APPENDIX: I-1

PROJECT NUMBER: BT-062 | FILE PATH:



1 I-2 HEAT EXTRACTION POINT EFFLUENT LINE
NTS



2 I-2 HEAT EXTRACTION POINT INFFLUENT LINE
NTS

BRIDGETON LANDFILL, LLC
13570 ST. CHARLES ROCK ROAD
BRIDGETON, MISSOURI 63044

BRIDGETON LANDFILL

PROPOSED HEAT EXTRACTION BARRIER DETAILS

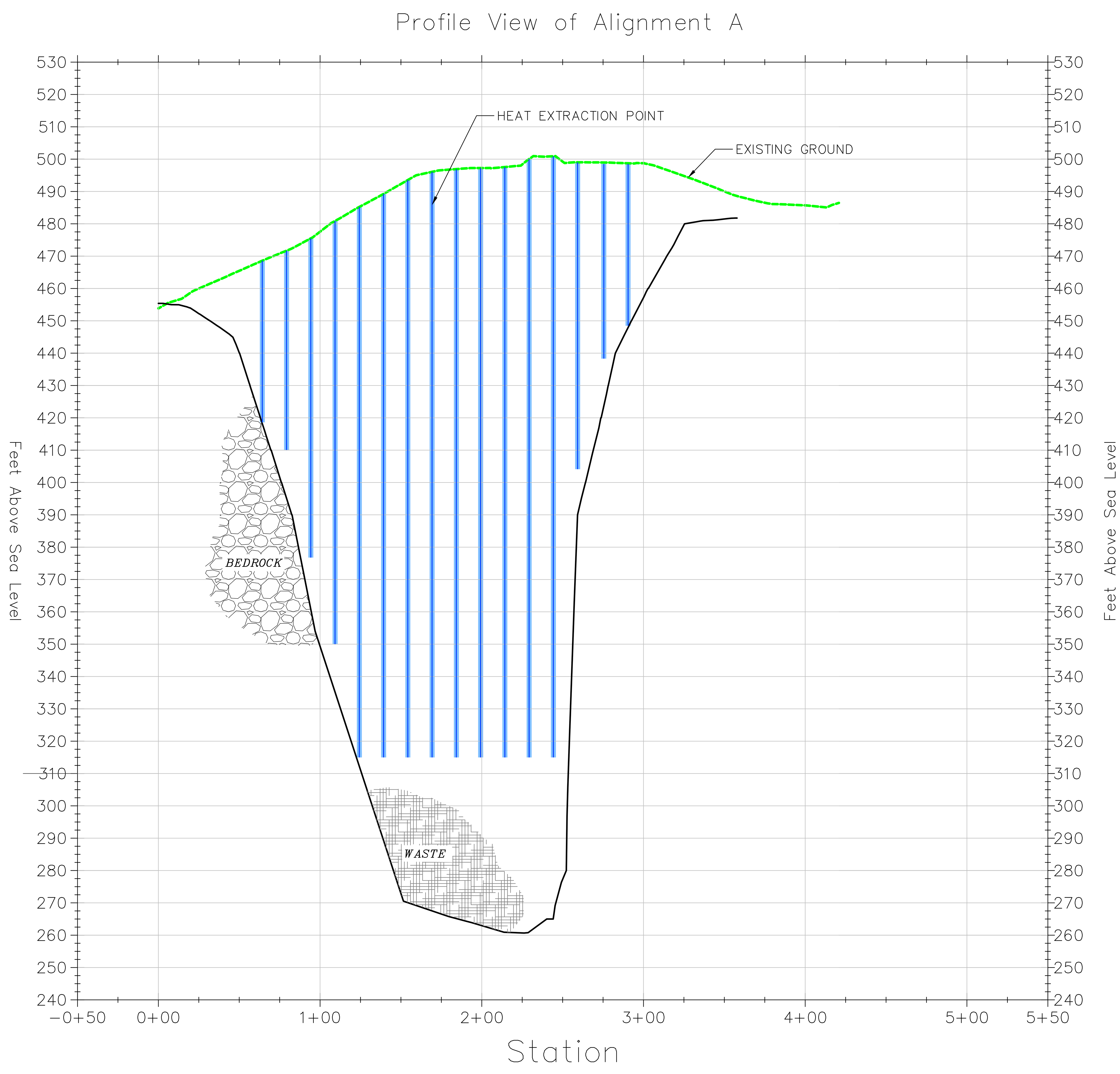
Engineering for a Better World
FEEZOR ENGINEERING, INC.

NOVEMBER 2015
DESIGNED BY: DMK
APPROVED BY: ALK

REVISION | DATE

APPENDIX:
I-2

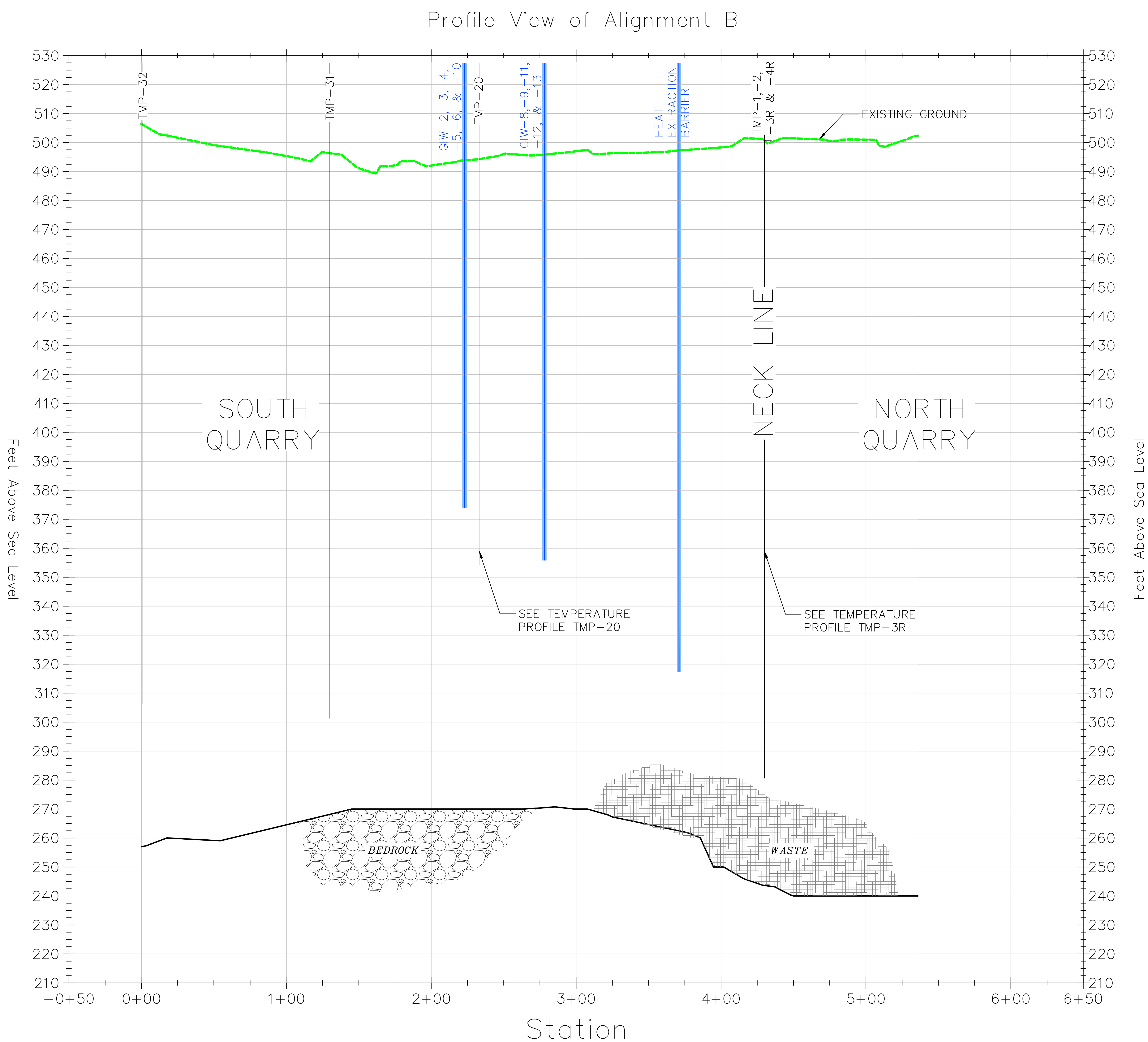
PROJECT NUMBER: BT-062 | FILE PATH:

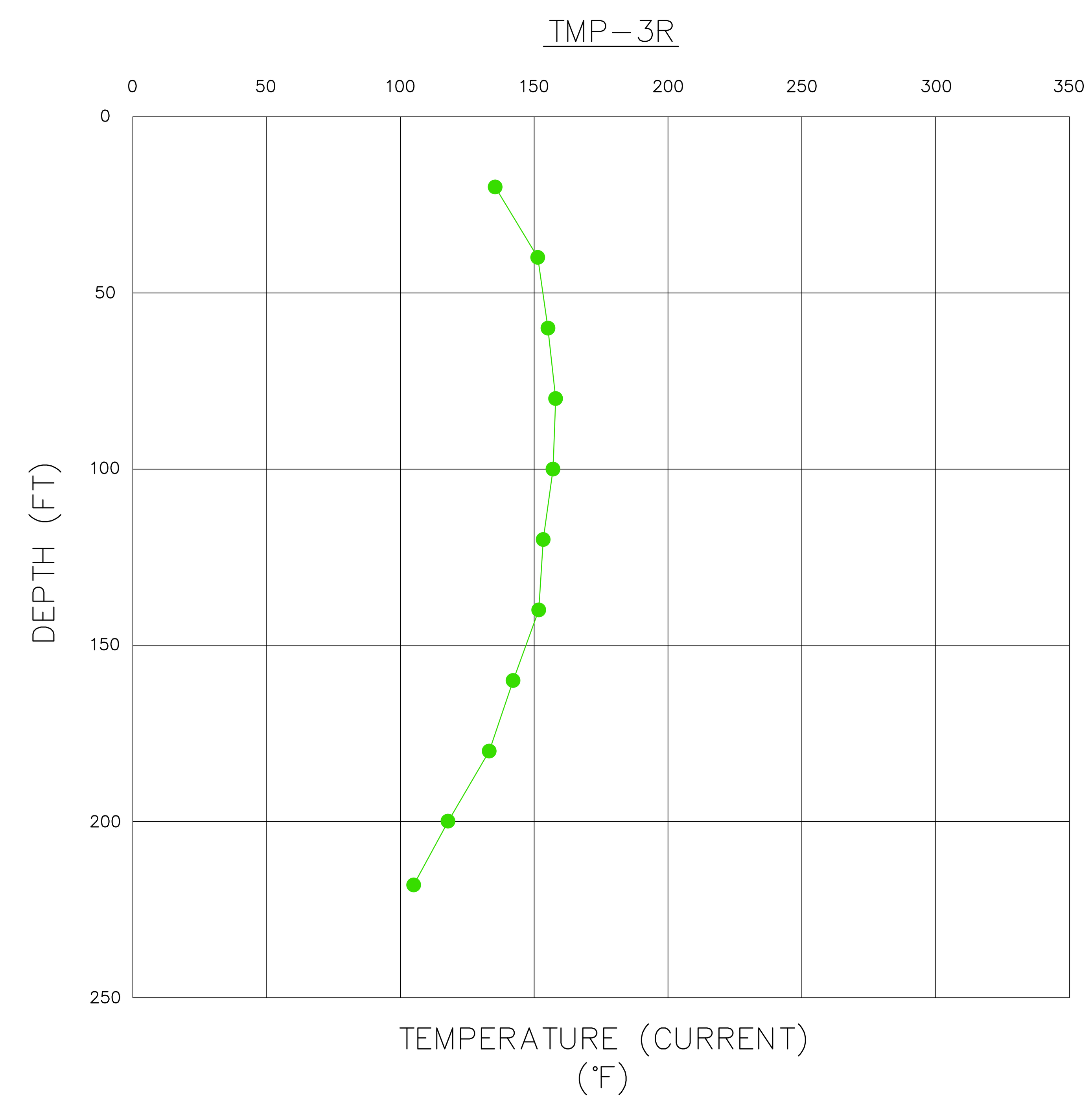


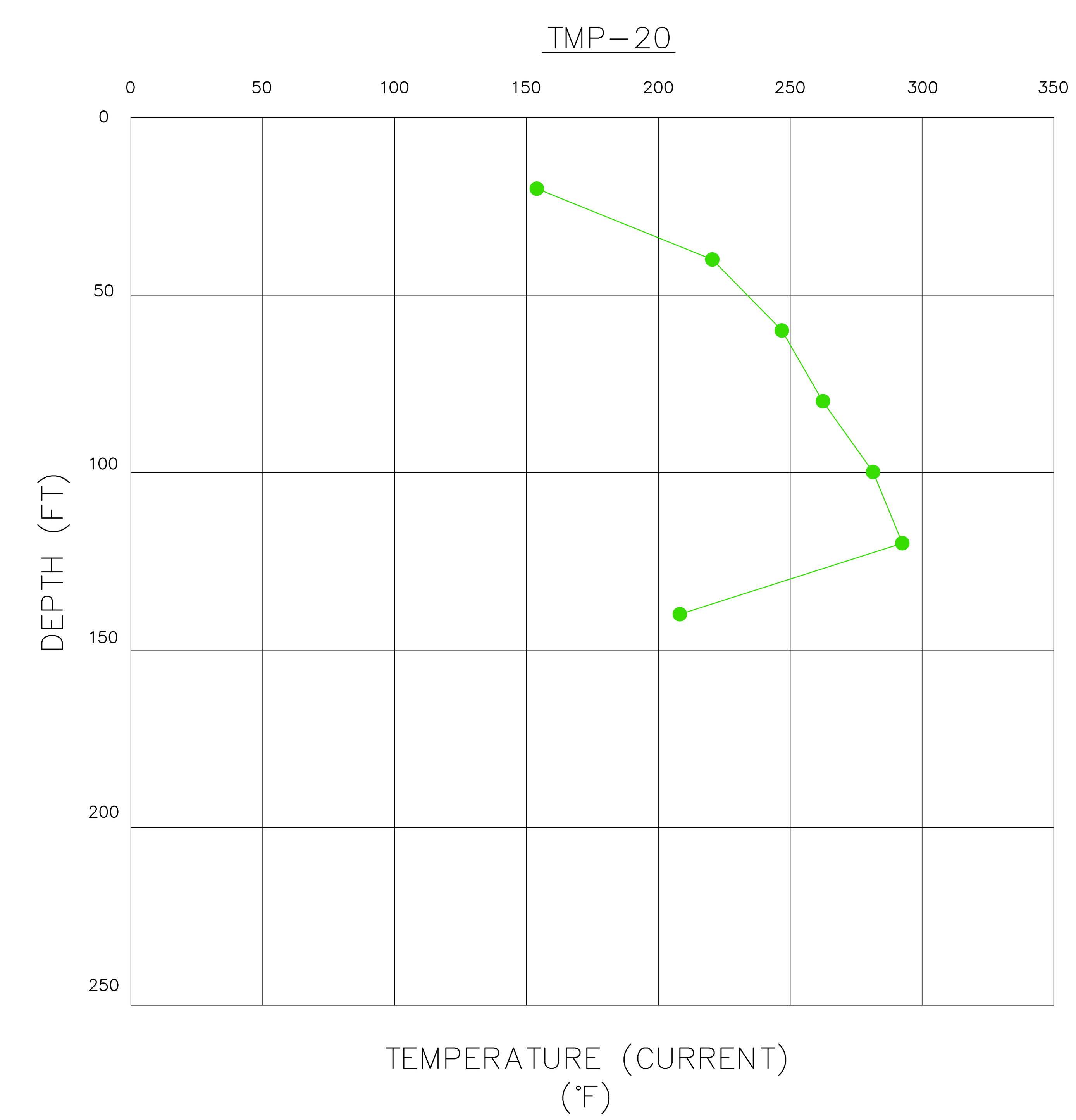
BRIDGETON LANDFILL, LLC 13570 ST. CHARLES ROCK ROAD BRIDGETON, MISSOURI 63044	BRIDGETON LANDFILL	Engineering for a Better World FEEZOR ENGINEERING, INC.	NOVEMBER 2015 DESIGNED BY: DMK APPROVED BY: ALK
HEAT EXTRACTION BARRIER PROFILE VIEW			REVISION / DATE
PROJECT NUMBER: BT-062	FILE PATH:		

APPENDIX:

I-3

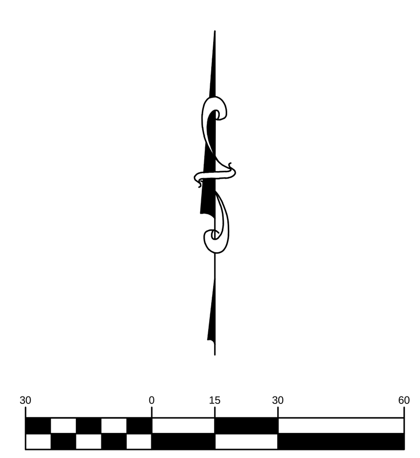






BRIDGETON LANDFILL, LLC 13570 ST. CHARLES ROCK ROAD BRIDGETON, MISSOURI 63044	BRIDGETON LANDFILL	Engineering for a Better World FEEZOR ENGINEERING, INC.	NOVEMBER 2015 DESIGNED BY: DMK APPROVED BY: ALK	APPENDIX: I-4
HEAT EXTRACTION BARRIER PROFILE VIEW			REVISION / DATE	
PROJECT NUMBER: BT-062	FILE PATH:			

Appendix J - Performance Monitoring Plan



SCALE: 1" = 30'

LEGEND

	EXISTING GRADE (2' CONTOUR)
500	EXISTING GRADE (10' CONTOUR)
	EXISTING GAS EXTRACTION WELL
	EXISTING TEMPERATURE MONITOR PROBE
	PROPOSED SYSTEM PERFORMANCE TEMPERATURE MONITORING PROBES (TMP 1, 3R AND 4R ARE EXISTING TMPs)
	EXISTING HEAT EXTRACTION POINT
	4" COOLING LOOP INFLUENT PIPING
	2" COOLING LOOP INFLUENT PIPING
	4" COOLING LOOP EFFLUENT PIPING
	2" COOLING LOOP EFFLUENT PIPING
	TEMPERATURE MONITORING LOCATION
	CHECK VALVE
	FLOW CONTROL VALVE
	FLOWMETERS
	PROPOSED HEAT EXTRACTION POINTS
SW	EXISTING SOLID WASTE PERMIT BOUNDARY
	EXISTING QUARRY HIGHWALL

NOTES:

1.) AERIAL TOPOGRAPHY WAS PROVIDED BY COOPER AERIAL SURVEYS CO. AND IS DATED MARCH 20, 2014.

2.) TMP 1, 3R AND 4R ARE EXISTING TMPs.

BRIDGETON LANDFILL, LLC
13570 ST. CHARLES ROCK ROAD
BRIDGETON, MISSOURI 63044

BRIDGETON LANDFILL

PERFORMANCE MONITORING PLAN

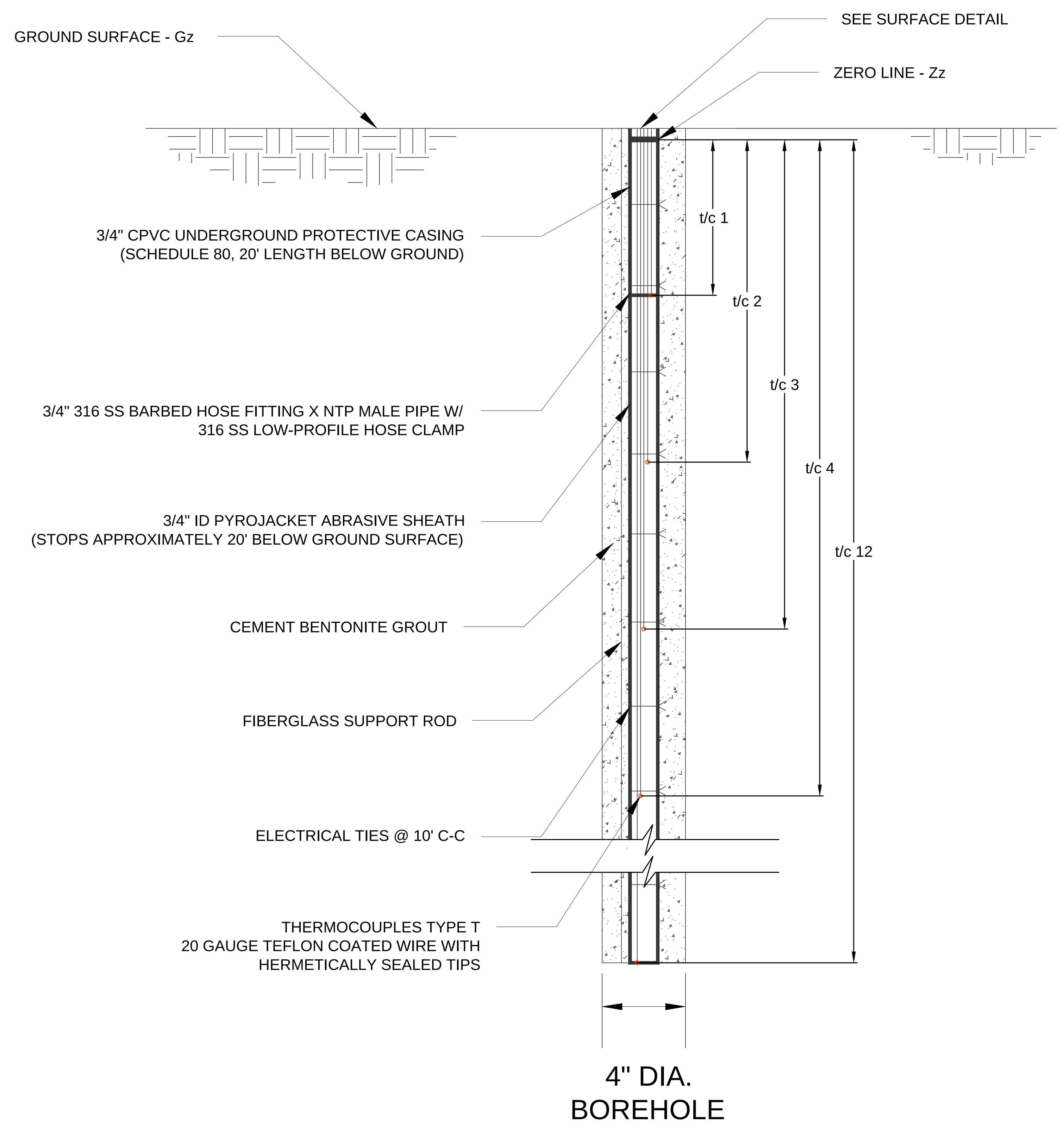
FEEZOR ENGINEERING, INC.
Engineering for a Better World

NOVEMBER 2015
DESIGNED BY: DMK
APPROVED BY: ALK

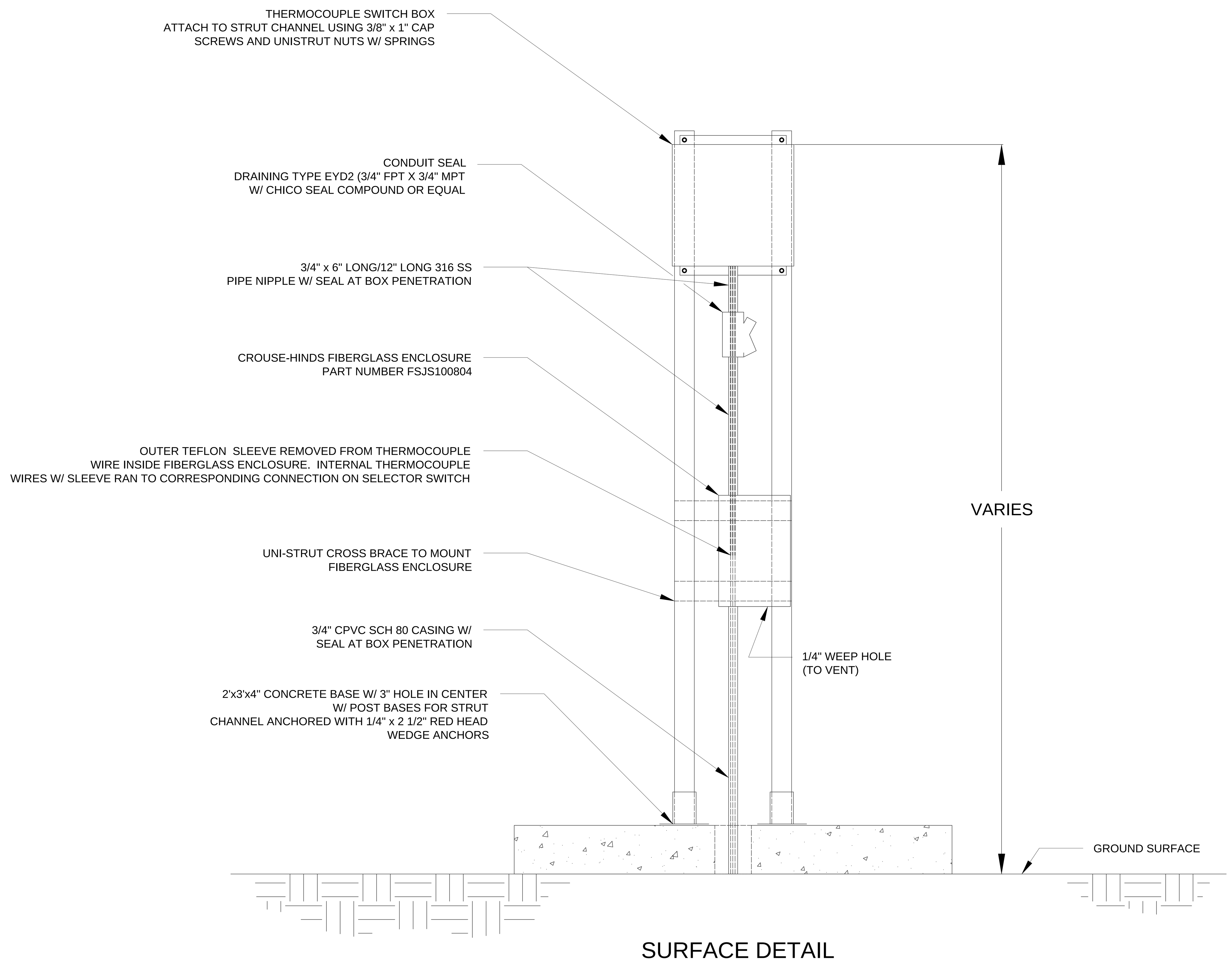
REVISION	DATE

APPENDIX: J-1

PROJECT NUMBER: BT-062 | FILE PATH:



SUBSURFACE DETAIL



SURFACE DETAIL

1 / J-2 TEMPERATURE MONITORING PROBE (TMP)

NTS

NOTES:

1:) SWITCH BOX IS SAGINAW CONTROL & ENGINEERING ENCLOSURE 1210ELJ - PANEL IS SCE-12P10J WITH JIC SWING OUT PANEL KIT - MOUNTED WITH HINGE ON RIGHT.
2.) HOLE FOR ROTARY SWITCH ACCOMODATES SW142G-12-B
3.) ALL PERFORATIONS AND CLAMPS NEMA 4 RATED

BRIDGETON LANDFILL, LLC 13570 ST. CHARLES ROCK ROAD BRIDGETON, MISSOURI 63044	BRIDGETON LANDFILL	Engineering for a Better World FEEZOR ENGINEERING, INC.	NOVEMBER 2015 DESIGNED BY: DMK APPROVED BY: ALK
TEMPERATURE MONITORING PROBE TYPICAL DETAIL			REVISION / DATE
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Appendix K -Heat Extraction Barrier Installation Schedule

Bridgeton Landfill L.L.C.

Heat Extraction Barrier Installation Schedule

ACTIVITY	TASK START	TASK DURATION (WEEKS)
Material Order and Procurement	1	6
Onsite Pipe Welding	7	2
Driling Contract	1	4
Site Work Contract	1	4
Site Work and Drill Pad Work	5	4
Drilling and Installation of Heat Removal Points	7	5
Above Ground HDPE Pipe Installation	5	1
Final Connections and System Startup	12	2
TMP Materials Procurement	1	5
TMP Installation	13	4