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May 21, 2020

Mr. Jacob Hassan
U.S. Environmental Protection Agency
Region 5
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Chicago, Illinois – 60604-3507

Send Via E-mail
(hassan.jacob@epa.gov)

Dear Mr. Hassan:

Re: **Focused Feasibility Study (FSS) Report**
EPA Docket No. RCRA-05-2017-0009
Cline Avenue Oil Spill Site - Gary, Indiana

The enclosed Focused Feasibility Study (FFS) Report was prepared in accordance with Item E in Section III of Attachment 1 of the Administrative Order on Consent RCRA-05-2017-0009 (AOC) for the Cline Avenue Oil Spill Site in Gary, Indiana for your review and approval.

The following Statement/Certification statement is provided pursuant to Section XIII, Paragraph 52 of the AOC.

Certification

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Please call me at 713-215-7622 if you have any questions regarding this FFS Report.

Respectfully submitted,

GLENN SPRINGS HOLDINGS, INC.

Rick Passmore, OXY Project Coordinator

JEP/kf/5

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Focused Feasibility Study Report

Cline Avenue Oil Spill Site
Gary, Indiana

Glenn Springs Holdings (GSH)

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1. Introduction and Purpose

On behalf of Glenn Springs Holdings (GSH), a subsidiary of Occidental Petroleum Corporation, GHD Services Inc. (GHD) has prepared this Focused Feasibility Study (Report) to summarize the Design Investigation Results, including supplemental investigation, and analyses of alternatives to mitigate petroleum sheens from entering the ditch at the Cline Avenue Oil Spill Site, in Gary, Indiana. The Report has been prepared in accordance with the Administrative Order on Consent (AOC) dated March 3, 2017 between Oxy USA, Inc. and United States Environmental Protection Agency (USEPA) Region V (RCRA-05-2017-0009).

As detailed in the AOC and further agreed upon by USEPA and GSH, the purpose of this Report is to assess potential remedial alternatives designed to mitigate petroleum sheens from continuing to impact the ditch.

This report has been prepared in accordance with Section III – E of the Scope of Work (SOW) provided in the AOC. The outline is as follows:

Section 1 Introduction and Purpose

Section 2 Background

Section 3 Design Investigation Results

Section 4 Response Action Objectives and Goals

Section 5 Identification of Remedial Alternatives

Section 6 Description of Alternatives

Section 7 Evaluation of Alternatives

Section 8 Description and Rationale of the Proposed Action

2. Background

The investigation area or "Site" is located northeast of the intersection of Gary Avenue and Cline Avenue (Indiana Route 912) in Gary, Lake County, Indiana. The investigation area is bordered by a rail line and Gary International Airport property to the north and east, Gary Avenue to the south, and Cline Avenue to the west. The investigation area lies within the larger, heavily industrialized area to the west of the airport, which has for decades contained numerous manufacturing and industrial operations. The investigation area location associated with the current AOC is presented on Figure 1.1. The investigation area plan is presented on Figure 1.2.

The ditch is located along the western edge of the investigation area and was constructed in the 1960s to collect and carry surface water run-off from Cline Avenue and surrounding industrial areas. The ditch ultimately discharges into the Grand Calumet River. The ditch drains from north to south where it discharges into a culvert just south of the investigation area. The culvert conveys the water to the Grand Calumet River, located approximately 2,200 feet to the south of the investigation area.

As summarized in four USEPA Pollution Reports, dated June 16, 2004, July 22, 2004, August 6, 2004, and November 22, 2004; USEPA responded to a reported release of oil to the Grand Calumet River in June 2004. During the initial investigations, oil was identified as coming from a portion of the ditch along Cline Avenue. Containment and sorbent booms were placed to contain oil entering the ditch. In July 2004, contractors were remobilized to begin cleaning the impacted area. At that time an investigation was also completed in the area of two adjacent pipelines. A 6-inch gasoline pipeline (Marathon) and an 18-inch crude oil pipeline (British Petroleum [BP]) are located adjacent and parallel to the Cline Avenue ditch. Following the removal of impacted soil between the pipelines and the ditch, the area was backfilled and rip-rap was placed along the slope of the ditch to prevent erosion.

As stated in Weston's Site Assessment Report (Revision 1) dated July 20, 2011, the National Response Center received a call in January 2011 regarding the presence of an oil sheen within the Cline Avenue ditch, north of the intersection of Cline and Gary Avenues. BP initially responded to investigate whether one of its pipelines was leaking. BP installed absorbent booms to prevent floating product from migrating to the Grand Calumet River. The report also stated that in March 2011, USEPA and its contractor (Weston Solutions, Inc.) mobilized to place absorbent booms in the ditch and were maintaining the absorbent boom materials to control downstream flow of petroleum sheen originating at the Site. The absorbent materials were placed in the vicinity of seeps on the east bank of the ditch. Figures in Weston's Site Assessment Report (Revision 1) Addendum 1 dated October 21, 2011 identified three separate seep locations, whereas in 2004, five seeps were identified. As of 2017, boom maintenance is being conducted by GSH at two seep areas. The remainder of this report is focused on the petroleum sheen impacts to the ditch that originate, in part, from these two seep areas.

On March 3, 2017, Oxy USA, Inc., entered into an AOC with USEPA, to continue maintaining the absorbent boom materials controlling the sheen impacts in the ditch and to conduct investigations necessary to support the development of a feasibility assessment of potential remedial actions designed to mitigate ongoing sheen impacts to the ditch and determine if solid or hazardous wastes are migrating or will migrate off-Site via groundwater at levels that present unacceptable risks. On April 20, 2017, USEPA transitioned the control of the oil accumulation in the ditch to GSH in accordance with the AOC.

3. Design Investigation Results

The following sections summarize the activities conducted by GSH associated with assessing the extent and mobility of the remaining petroleum LNAPL impacts in the vicinity of the Cline Avenue ditch in order to establish the mechanisms of sheen formation, in support of the development of a feasibility assessment for potential remedial actions in accordance with AOC.

The Design Investigation/Focused Feasibility Study (DI/FFS) Work Plan was prepared and submitted to USEPA in accordance with the AOC. The purpose of the Design Investigation (DI) was to investigate petroleum seeps to the Cline Avenue ditch and to collect additional information to support a feasibility assessment of potential remedial alternatives designed to mitigate petroleum sheens from continuing to impact the ditch. The initial DI was conducted by GSH between May and

July 2017. The results of the initial DI are summarized in the DI Report which was submitted to USEPA on September 21, 2017, herein attached as Appendix A. A supplemental phase of investigation was conducted between September and October 2017 to fill in data gaps identified in the initial DI. The results of the supplemental investigation were provided in the November monthly report dated November 24, 2017. The following activities were conducted as part of the DI:

- Investigation Area Mapping
- Groundwater/LNAPL gauging
- LNAPL Fingerprint analysis
- Laser-Induced Fluorescence (LIF) Investigation
- Dart Investigation

The results of the DI are summarized in the following sections.

3.1.1 Investigation Area Mapping

Investigation area mapping activities were completed to generate accurate figures depicting critical features including seep locations, ditch sediment thicknesses, piezometer/well locations, buried pipelines/utilities, topography, etc. Investigation area mapping activities included both topographic and geophysical surveys. Figure 3.1 presents the base map of the investigation area (including topography) and Figure 3.2 presents the plan and profile of the ditch.

The following utilities were located in the investigation area:

- Buckeye Petroleum Pipeline (6-inch diameter at a depth between 4-feet, 5-inches and 7-feet, 4-inches below ground surface (bgs), not active)
- BP Petroleum Pipeline (18-inch diameter at a depth between 5-feet, 5-inches to 6-feet, 9-inches bgs, active)
- NIPSCO Gas Pipeline (30-inch diameter at a depth between 5-feet to 7-feet, 9-inches bgs, active)
- Unidentified Pipeline (4-inches diameter at a depth between 3-feet, 5-inches to 4-feet, 5-inches bgs, inactive)
- Two underground electrical lines
- Overhead electrical lines

3.1.2 Groundwater Conditions

Water level/LNAPL measurements were collected quarterly (May, August, and November) from the twelve piezometers (PZ-1 to PZ-12) and from two monitoring wells (MW-2 and MW-3) to monitor gauged LNAPL thickness and groundwater elevations. Measurements were taken with an oil/water interface probe with an accuracy of ±0.01 feet, to determine the depth to water, LNAPL (where present), and oil/-water interface. The date, depth to product, and depth to water were recorded, and used to calculate the LNAPL thickness (as applicable) and corrected groundwater elevation (where LNAPL was present). These results are summarized in Table 3.1. Groundwater flow at the

Site appears to be to the west towards the ditch, however, it is important to note that there is currently only one monitoring well interior to the Site.

3.1.3 LNAPL Fingerprint Analysis

In order to better understand the type and distribution of LNAPL, six samples of LNAPL were collected from existing piezometers with LNAPL during the initial gauging activities and submitted for hydrocarbon "fingerprint" analyses. The chromatograms and physical property analysis (results provided in Appendix C of the DI Report) indicate that all the samples contain a consistent mixture of hydrocarbon product types in terms of age/degree of weathering and composition. The LNAPL mixture consists of weathered gasoline hydrocarbons, weathered diesel hydrocarbons, and another hydrocarbon material that is slightly heavier than diesel but still within the diesel hydrocarbon range. The LNAPL fingerprinting results are consistent with the LNAPL fingerprinting results of samples previously collected by USEPA and its consultant Weston from the Site in 2011.

3.1.4 LIF Investigation

A LIF investigation was conducted to assist in determining the horizontal and vertical extent of residual hydrocarbons in soil. The Tar Green Optical Screening Tool (TarGOST) LIF system was utilized based on a sample of LNAPL provided to Dakota Technologies (Dakota) (LIF boring contractor) prior to mobilization. A total of 29 LIF borings (results presented in Appendix D of the DI Report herein attached as Appendix A) were completed by Dakota Technologies (Dakota) in July 2017 during the first round of LIF investigation. A total of 32 additional LIF borings (results presented in Appendix B) were completed by Dakota in October 2017 to fill in data gaps from the first round of LIF investigation. Figures 3.3, 3.4, and 3.5 present the horizontal distribution of hydrocarbon response at various elevations based on the LIF results. A 3D model of the LIF results is provided as an interactive PDF in Appendix B.

The LIF investigation reported results in units of percentage of the reference emitter (%RE)[1] ranging from 6.6 to 778 which indicates that there are highly variable hydrocarbon saturation levels. The maximum %RE for LIF borings on the west side of the ditch were at background/insignificant response levels (13.2 and 21.1 %RE), therefore no evidence of a petroleum source from the west side of the ditch was observed. High LIF intensities were observed east of the ditch and in an interior area concentrated approximately 250-500 feet to the east. Based on the gradient in LIF response along with an examination of the elevations/thicknesses of the petroleum-impacted intervals identified during the LIF events, the interior area represents a potential historical source zone. Impacts were noted both above and below the water table as shown in the LIF readings and extend under the ditch as inferred from DART results and observed ebullition[2].

The intensity of the LIF responses broadly correlate with hydrocarbon saturation levels. Most of the LIF responses, including some of the highest responses, are below the water table, which typically

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1 % reference emitter (%RE) indicates the fluorescence intensity in comparison to the fluorescence of the standard hydrocarbon mixture used to calibrate the equipment. Results are therefore semi-quantitative and most relevant in a comparative sense.

2 Ebullition refers to the sheen formation mechanism whereby petroleum impacts in sediment are mobilized by the upward movement of soil gas bubbles. This is observed at the ditch water surface by bubbling followed by the formation of radial sheens occurring away from the ditch banks (i.e., not due to lateral petroleum seepage).

signifies that the remaining petroleum impacts are largely immobile residual. This suggests that much of the impact to the ditch is resulting from residual petroleum impacts in the vicinity of the ditch, as opposed to being the result of the bulk movement of LNAPL from the interior of the Site towards the ditch currently.

3.1.5 PAH Dart Investigation

A PAH Dart[3] investigation was conducted in the ditch sediments to assist in determining the horizontal and vertical extent of residual hydrocarbons in the ditch sediment.

The Darts are designed to quickly screen for the presence of hydrocarbons in sediments and soft soils, where LIF, traditional soil boring, and other mechanized sampling are difficult to implement. The Dart sampler is comprised of a continuous rod coated with solid-phase extraction (SPE) media. The Dart sampler is deployed into the sediments (direct push, vibracore technology, slide hammer, etc.) where hydrocarbon molecules attach to sediment/soil particles, dissolved in sediment pore water, or exist as a component in non-aqueous phase liquids in sediments migrate onto the Dart sampler. This migration onto the surface of the Dart sampler is due to hydrocarbon's (specifically PAHs) high affinity for the SPE material versus its relatively low affinity for water or sediments. Dart samplers were left in place for 24 hours before being collected and shipped offsite for analysis. The Dart samples were then scanned with the UVOST laser. The response from the UVOST laser correlates to the relative concentration of hydrocarbons in the media sampled. This result is similar to what was obtained during the LIF push probe field work. Additional literature on the Dart technology is presented in Appendix C.

In September 2017, nine Darts were installed on the east side of the ditch and six Darts were installed on the west side of the ditch, as presented on Figure 3.6. Dart installation along the centerline of the ditch was attempted but proved infeasible due to the ditch lining materials being impenetrable to the Darts. Appendix C presents the results of the Dart analysis. The maximum %RE readings on the west side ranged from 17.4 to 94.1 and the maximum %RE on the east side of the ditch ranged from 9.8 to 711. The Dart results provide a complimentary line of evidence to the LIF results in indicating the bulk of the petroleum impacts and the potential historical source zone exist on the east side of the ditch.

3.1.6 Groundwater Investigation

A groundwater investigation was conducted at the request of the Indiana Department of Environmental Management (IDEM) to investigate the potential groundwater impacts at the Site prior to and subsequent to forthcoming re-engineering of the Cline Avenue ditch. The groundwater investigation was completed in accordance with the groundwater investigation work plan which was submitted to IDEM on February 13, 2019. The scope of work included the installation of 10 groundwater monitoring wells, gauging of new wells (10); existing wells (2); existing piezometers (12); and existing staff gauges (3); and groundwater sampling of the 10 new monitoring wells and 2 existing monitoring wells, as a baseline evaluation of potential groundwater impacts at the Site.

In August 2019 10 monitoring wells were installed (MW-07-19, MW-08-19, MW-09-19, MW-10-19, MW-11-19, MW-12-19, MW-13-19, MW-14-19, MW-15-19, and MW-16-19. One soil sample was

3 Darts manufactured/supplied by Dakota Technologies. See http://www.dakotatechnologies.com/products/darts.

collected per boring and analyzed for volatile organic compound (VOC), polychlorinated biphenyls (PCBs), semi-volatile organic compounds (SVOCs), and metals, except where hydrovacing was utilized to clear utilities beyond the saturated zone. A round of gauging was conducted between September 4 and 6, 2019 with a dual phase probe to evaluate water table conditions. Groundwater samples were collected using low flow procedures and analyzed for VOCs, PCBs, SVOCs, and metals from all the monitoring wells, except MW-03-07 which could not be located.

The potentiometric surface characterized by the established well network confirms groundwater flows towards the Cline Avenue ditch from both the west and east sides of the ditch. The soil sample results were compared against the IDEM Remediation Closure Guide (RCG) Migration to Groundwater Screening Levels, Residential Direct Contact Screening Levels, Commercial/Industrial Direct Contact Screening Levels, and Excavation Worker Soil Direct Contact Screening Levels. The soil results identified limited on-Site soil impacts and confirmed no soil exceedances off-Site. The groundwater sample results were compared against the IDEM RCG Residential Groundwater Tap Screening Level (RGWTSL). The groundwater results identified petroleum-related groundwater impacts are limited to on-Site monitoring wells, with no detectable VOCs or SVOCs in wells off-Site to the west and southwest.

3.1.7 Conceptual Site Model

Historical data as well as the data collected as part of the DI have been analyzed to develop a Conceptual Site Model (CSM). These data indicate that the petroleum sheens are entering the ditch through two transport models:

1. Laterally from sidewalls – immediate vicinity of ditch and not as bulk movement internal to the Site (due to the lack of resistance at the ditch bank surface that allows residual LNAPL movement, whereas similarly saturated soil would not allow LNAPL movement in the interior of the Site).
2. Ebullition – pressure and/or soil gas bubbles periodically dislodge otherwise immobile residual hydrocarbons from beneath the ditch.

The LNAPL is old and primarily located below the water table; therefore, the bulk of the Site LNAPL is likely to be present as hydraulically immobile residual. Where LNAPL is present at residual levels, it will largely exist as discontinuous globules of LNAPL trapped in the pore space. Under this condition, groundwater moves through the pore space around the LNAPL globules without having any effect on the mobility of the LNAPL itself. As such, LNAPL mass recovery efforts will not affect a significant fraction of what is there nor would a significant LNAPL recovery radius of influence be achievable (i.e., recovery efforts are likely to only affect LNAPL in the immediate vicinity of a given extraction point). Observations made during ditch booming activities over several years have identified generally stable conditions of oil entering the ditch, with some fluctuations during precipitation events in dry periods (i.e., sheen impacts are more severe during and following heavy rain events).

3.1.8 Conclusions

Empirical Site data, including the LNAPL chromatograms, LNAPL physical property analysis, and the LIF and Dart results, indicate similar types/mixtures of hydrocarbons present across the investigated area. The LIF results identified the presence of hydrocarbons across the study area that is expected to exist primarily as residual LNAPL, which is largely immobile under typical Site conditions and would be relatively unaffected by LNAPL mass recovery efforts. Based on the distribution of LIF responses, along with the elevations/thicknesses of the petroleum-impacted intervals identified during the LIF events, an interior area of the Site 250-500 feet east of the ditch appears to be a potential historical source zone. From this area, hydrocarbons underwent some degree of radial spreading with a historical preference for migration towards the ditch. There is no known source of LNAPL on the west side of the ditch.

Visual observation of sheen formation in the ditch identified that sheen formation is due to both lateral seepage from the eastern bank of the ditch and vertically from the bottom of the ditch through ebullition.

4. Response Action Objectives and Goals

In accordance with Section III – E of the Statement of Work (SOW) – Attachment 1 provided in the AOC the response action objectives and goals include the following:

- Provide protection of human health and the environment
- Comply with applicable local, State, and Federal regulations
- Mitigate or eliminate oil from entering the ditch
- Provide practical, cost-effective actions
- Utilize actions that may be implemented and completed in an expeditious timeframe, where applicable
- Determine if solid or hazardous wastes are migrating or will migrate off-Site via groundwater at levels that present unacceptable risks

5. Identification of Remedial Alternatives

The remedial alternatives presented in this section were developed to identify viable remedial alternatives to address the purpose of the AOC, to prevent oil from entering the ditch (AOC Section I.1 and SOW-Section I).

The list of alternatives evaluated in this Report are as follows:

Alternative No.	Description
Alternative 1	Continue Current Approach • Perform Boom Maintenance activities in the ditch weekly to remove petroleum impacts and contain sheens to mitigate downstream migration • Aquatic Vegetation Control within the ditch • Maintain Bird Deterrent across ditch • Routine Inspection and Reporting
Alternative 2	Line Ditch with HDPE Liner

Alternative No.	Description
	• Install HDPE liner in ditch • Routine monitoring and reporting
Alternative 3	Storm Sewer Pipe Installation within Ditch • Install Storm Sewer pipe to replace ditch • Backfill ditch • Routine monitoring and reporting
Alternative 4	Barrier Wall and Continue Current Approach • Install barrier wall (slurry wall) • Include same activities as Alternative 1
Alternative 5	Underflow or Weir Dam

In accordance with Attachment 1, Section I of the AOC, Alternatives 4 and 5 were included, however, the underflow or weir damn proposed in Alternative 5 only provides a modified approach to collecting petroleum that accumulates in the ditch and does not prevent the formation of sheen in the ditch. Therefore, Alternative 5 is not carried through in the more detailed evaluation as it does not meet the objective of the remedial action, to mitigate petroleum sheens from continuing to impact the ditch.

None of the alternatives carried forward include an LNAPL recovery component since it would not add value to any of the remedies due to the largely residual LNAPL conditions. As previously noted, LNAPL mass recovery efforts will not affect a significant fraction of the residual LNAPL, will not be able to achieve a significant LNAPL recovery radius of influence (i.e., recovery efforts are likely to only affect a small fraction of the LNAPL in the immediate vicinity of a given extraction point), and will not mitigate the ebullition mechanism of sheen formation.

For each of the remaining alternatives (Alternatives 1, 2, 3, and 4), present costs have been calculated. Under each alternative, costs have been developed in 2020 dollars for major capital tasks and annual operation and maintenance tasks. For calculating present costs, capital costs were assumed to be incurred within the first year and the annual operation and maintenance costs were assumed to occur for a period of 30 years. Current activity costs included under Alternatives 1 and 4 were estimated from effort expended in 2019 and therefore no contingency was included for the activities. All capital costs developed for Alternatives 2, 3, and 4 include a 20% contingency and the annual operation and maintenance costs developed for Alternatives 2 and 3 also include a 20% contingency. The present estimate was calculated by summing the capital costs (which is to be incurred in the first year) and the present costs of the annual operation and maintenance tasks which was calculated using the Real Discount Rate (0.4% for 30-years) identified on the Whitehouse website (https://www.whitehouse.gov/wp-content/uploads/2019/12/M-20-07.pdf) over the applicable period of 30 years. The discount rate was selected to allow the calculation of a realistic present estimate of the remedial alternatives.

6. Descriptions of Remedial Alternatives

Detailed descriptions of the remedial alternatives are provided in the following sections.

6.1 Alternative 1 – Continue Current Approach

Alternative 1 is the "Continue Current Approach" Alternative. This alternative includes the current ongoing field activities: performing absorbent boom maintenance activities in the ditch weekly, aquatic vegetation control, maintaining bird deterrents over the ditch, and routine monitoring and reporting. The components of Alternative 1 are presented on Figure 6.1.

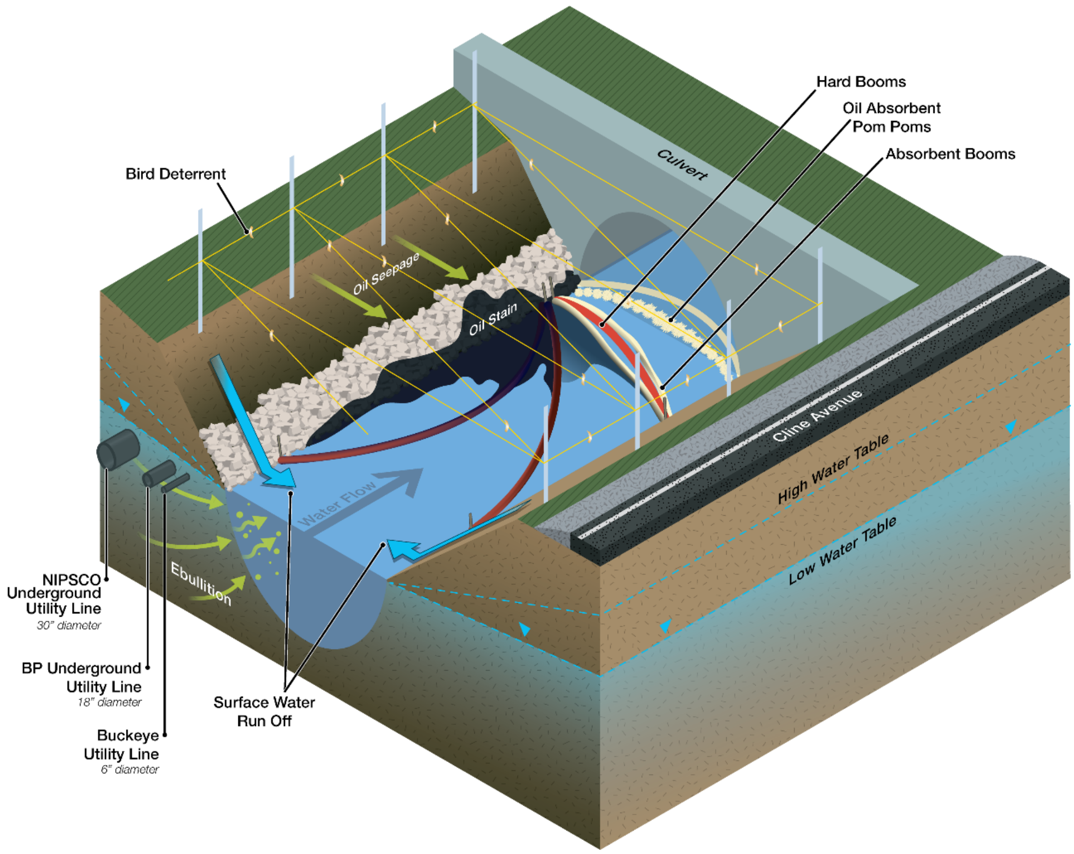


Figure 6.1 Alternative 1 – Continue Current Approach – Conceptual Sketch

The conceptual configuration of the booms at the two seep areas (North and South) and the Grand Calumet River is presented in Figure 6.1 and includes a combination of hard booms and absorbent booms. The boom maintenance and inspection activities (generally once a week) involve inspecting conditions of booms, removing/replacing "spent" absorbent booms, soaking up any oil present on the water surface with absorbent booms/pads, placing spent absorbent material in plastic bags and placing in the on-Site roll-off box for disposal off-Site when full.

Aquatic vegetation control involves the application of herbicide within the ditch as needed, typically between spring and fall to limit the amount of vegetation growth within the ditch, thereby limiting the presence of habitat that may attract birds.

Bird deterrent is an additional measure put in place to deter birds from landing in the ditch. The first type of bird deterrent is generally installed once a year in the spring and involves tying reflective tape on rope that is strung back and forth across the ditch. In addition to the reflective tape, predator replicas have been installed along the ditch to discourage birds and other animals from entering the ditch area. The replicas are relocated periodically to provide continued effectiveness.

Currently, inspections of the boom maintenance activities and bird deterrent measures are generally completed weekly at the same time the boom maintenance is completed. Reporting is completed monthly and quarterly in accordance with the AOC and is expected to be completed for 30 years.

A detailed cost breakdown for Alternative 1 is presented in Table 6.1. The total capital cost is estimated to be $0 and the estimated annual operation and maintenance cost is $235,000. The total present cost of this alternative is estimated at $6,639,000.

6.2 Alternative 2 – Line Ditch with HDPE Liner

Alternative 2 includes the installation of a high density polyethylene (HDPE) liner along the impacted length of ditch, along with routine inspections to evaluate the integrity of the HDPE liner and monitoring the ditch for the presence of LNAPL. The expected service life of the HDPE liner is assumed to be 20 years, after which it would require replacement. Figure 6.2 presents a conceptual sketch and Figure 6.3 presents a plan and profile of the Alternative 2 components.

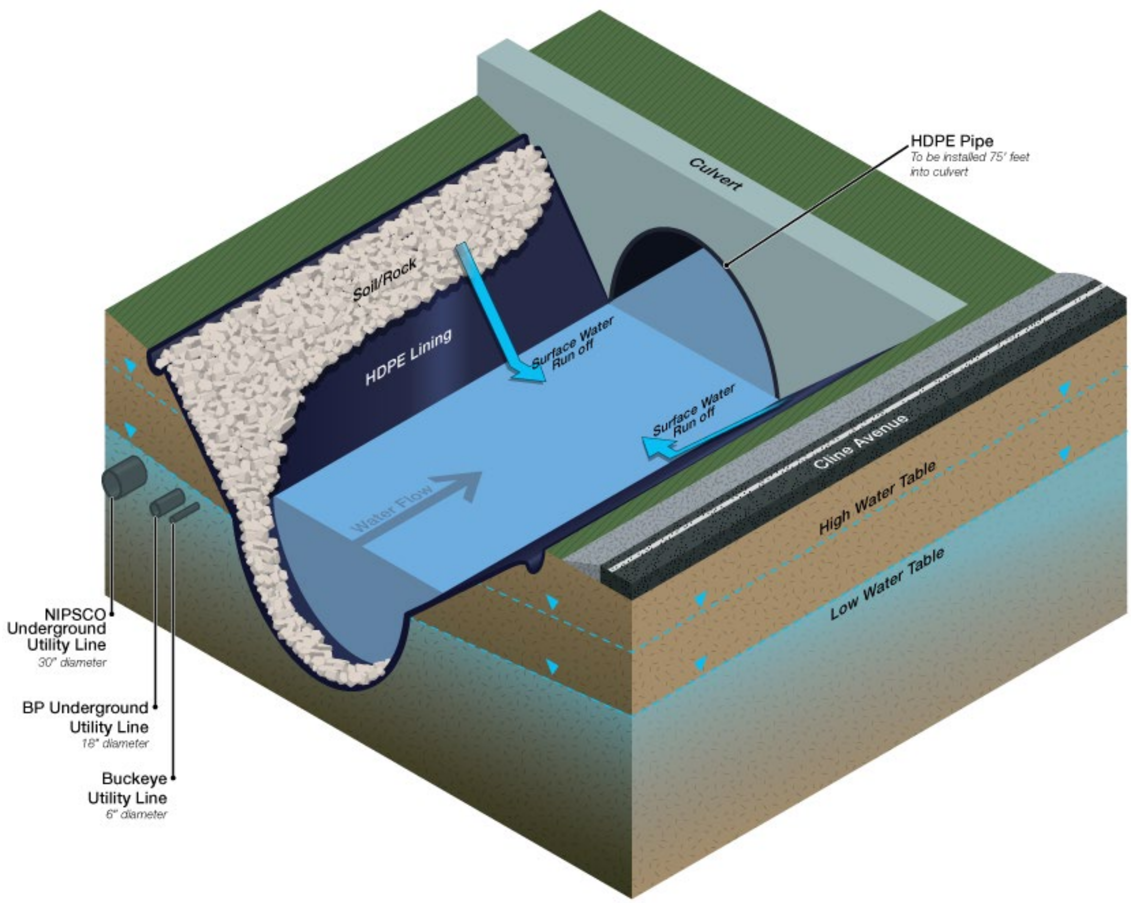


Figure 6.2 Alternative 2 – Line Ditch with HDPE Liner – Conceptual Sketch

Installation of the HDPE liner will require preparation of the ditch area, including removal of the existing bird deterrent, vegetation clearing, and limited grading to promote positive drainage. The work zone portion of the ditch will need to be isolated and temporary diversion of the stormwater flow in the ditch will be required to facilitate installation of HDPE liner under dry conditions. Due to the proximity of the ditch to nearby gas pipelines, the work will need to be coordinated with the various utility companies. Additionally, associated permitting for the work may be required by the INDOT, City of Gary and/or other agencies.

The isolated work zone portion of the ditch will require dewatering to maintain dry conditions for the installation. The water will be collected, treated, and disposed of. Prior to placement of the HDPE liner, oily/soft sediments in the ditch may require removal. Additional material placement will be required within the ditch to provide a smooth base for the HDPE liner installation. The liner will be keyed into a shallow trench at the top the bank on either side of the ditch and connections made around the terminations (e.g., culverts). The seams of the liner will be tested for integrity and water tightness as construction proceeds. A geotextile will be placed over the liner followed by a cover material (e.g., Fabric-Form concrete or river rock or similar) to protect the liner and to minimize deterioration. In addition, a storm sewer sleeve or in-situ form piping will be extended into the downstream culvert from the termination of the liner to eliminate the potential for LNAPL entering the culverts through cracks in the culvert walls.

Inspections of the liner and ditch will be performed monthly, to evaluate the integrity of the liner and to monitor for the presence of LNAPL. After one year of monthly inspections, the frequency will reduce to semi-annually. Possible maintenance may include repairs to the liner and removal of vegetation. Periodic routine reporting costs are also included.

A detailed cost breakdown for Alternative 2 is presented in Table 6.2. The total capital cost is estimated to be $2,375,000 and the estimated annual operation and maintenance cost is $13,600. The total present cost of this alternative is estimated to be $4,950,000.

6.3 Alternative 3 – Storm Sewer Installation within Ditch

Alternative 3 includes the installation a storm sewer pipe along the general alignment/invert of the impacted section of the ditch, backfilling the ditch adjacent to and overlying the storm sewer pipe, and regular inspections to evaluate the integrity of the pipe and to monitor for the presence of LNAPL. The expected service life of the storm sewer pipe is approximately 50 years. Figure 6.4 presents a conceptual sketch and Figure 6.5 presents a plan and profile of the Alternative 3 components.

Installation of the storm sewer pipe will require preparation of the Site including removal of the existing bird deterrent, vegetation clearing, surveying, and limited grading to promote positive drainage. In addition, the work zone portion of the ditch will need to be isolated and temporary diversion of stormwater flow in the ditch will be required, to facilitate installation of the storm sewer pipe under dry conditions (typically during the third quarter of the year). Due to the proximity of the ditch to nearby gas pipelines, the work will need to be coordinated with the various utility companies. Additionally, associated permitting for the work may be required by the INDOT, City of Gary and/or other agencies.

The isolated work zone portion of the ditch will require dewatering to maintain dry conditions for the installation. The water will be collected, treated, and disposed of. Excavation activities will maximize the amount of hydrocarbon stained soil removed within reason. It is estimated that approximately 1,000 cubic yards of material will be removed from within the ditch as well as approximately 800 cubic yards from bank areas and disposed of off-site. Material removed from the bank areas will be limited as the brick lining the ditch is to remain in place to provide support for the new storm sewer pipe, as well as, complexities involved with excavating in close proximity to the existing underground utility lines.

Pipe connections will be sealed to prevent infiltration. Low permeability collars (or engineered equivalents) will be installed around the pipe to prevent preferential migration pathways. Bedding material will be placed above the paver stones currently in the ditch to provide a competent base for the storm sewer pipe installation. The design and construction of the storm sewer pipe joints and connections at terminations (e.g., at culverts, etc.) will be watertight to prevent potential leakage.

For the purposes of this Report it is contemplated that the storm sewer pipe with be constructed of HDPE or another impermeable material. However, the actual pipe material will be selected based on the Final Design. A soil/bentonite cut off wall will be installed east of the transition chamber on the downstream culvert to reduce the potential for LNAPL entering the culverts through cracks in the culvert walls.

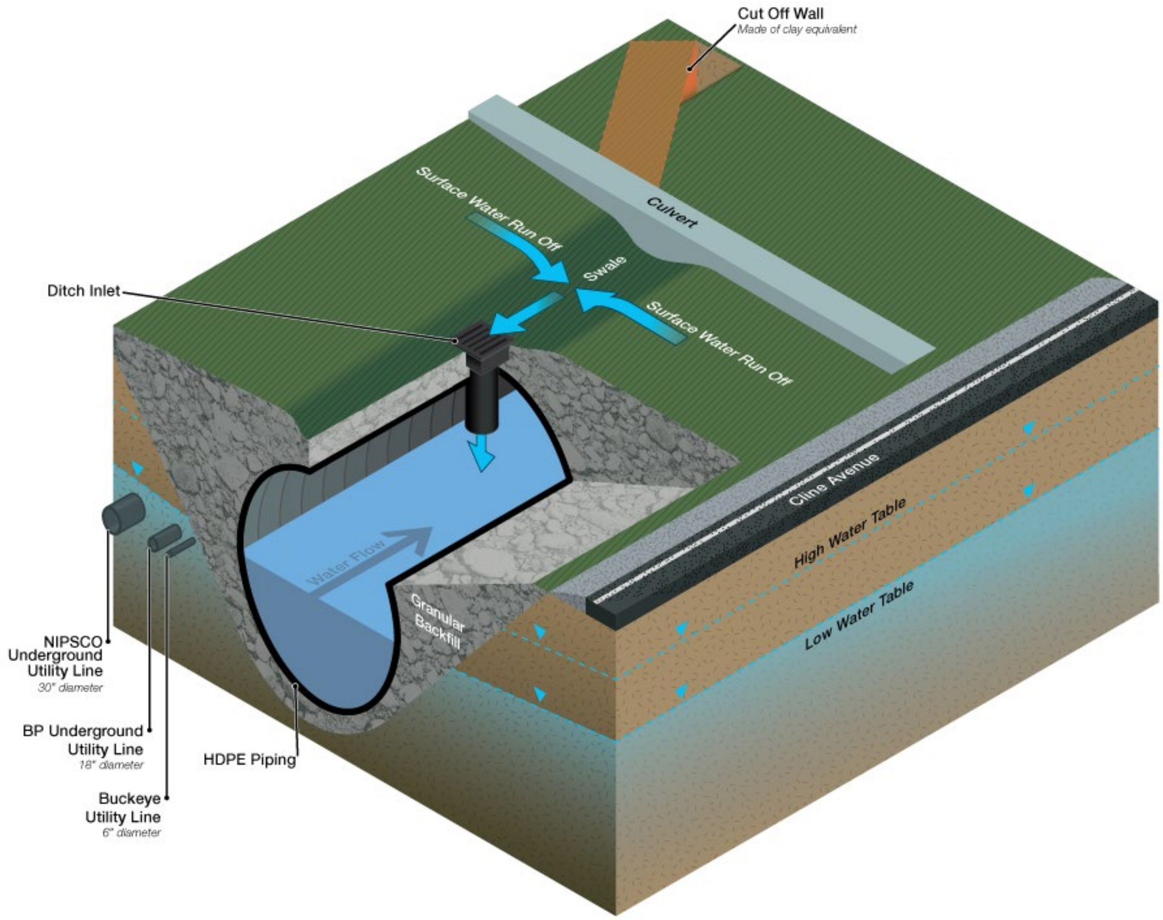


Figure 6.4 Alternative 3 – Storm Sewer Installation within Ditch – Conceptual Sketch

Monitoring of the pipe and groundwater monitoring will be included as part of the ongoing operation and maintenance of the ditch and culvert. Visual inspections will initially be performed monthly to evaluate remedy performance. This may include evaluating the integrity of the pipe, monitoring for the presence of LNAPL, and observations of oil upwelling to the ground surface. The monitoring program and inspections will be documented in a separate Operation, Maintenance, and Monitoring (OM&M) Plan that will be submitted for review prior to initiation of construction.

A detailed cost breakdown for Alternative 3 is presented in Table 6.3. Periodic routine reporting costs are included. The total capital cost is estimated to be $2,362,000 and the estimated annual operation and maintenance cost is $13,600. The total present cost of this alternative is estimated to be $2,745,000.

6.4 Alternative 4 – Barrier Wall Installation East of Ditch

Alternative 4 includes the installation of a low permeability barrier wall to the east of the impacted section of the ditch; ongoing maintenance of absorbent booms in the ditch, aquatic vegetation control, bird deterrents over the ditch, and inspections to evaluate the integrity of the barrier wall and to confirm the effectiveness of the booming, bird deterrents, and vegetation control. The expected service life of the barrier wall is approximately 50 years. Figure 6.6 presents a conceptual sketch and Figure 6.7 presents a plan and profile of the Alternative 4 components.

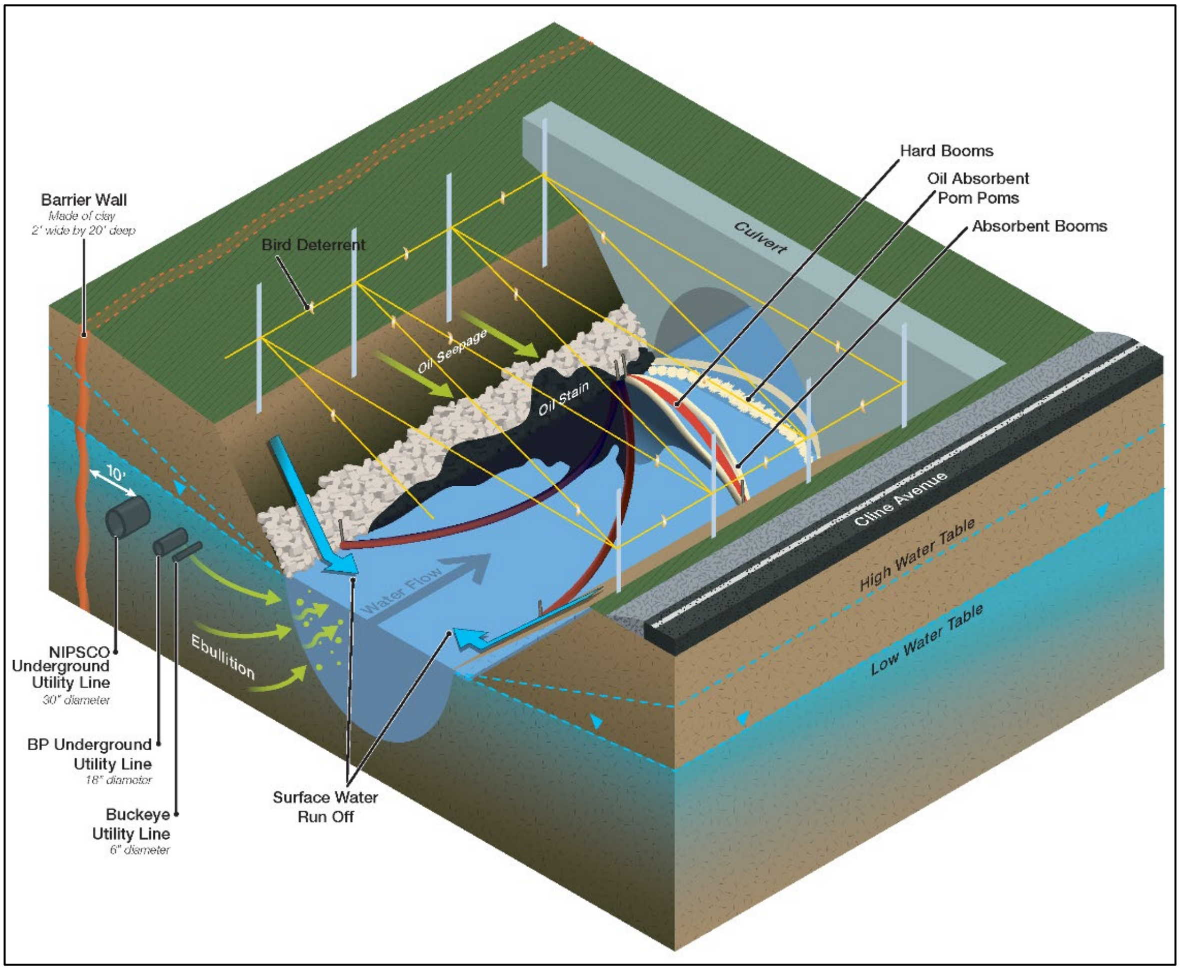


Figure 6.6 Alternative 4 – Barrier Wall with Continuing Current Approach – Conceptual Sketch

The amount of Site preparation required for installation of a low permeability barrier wall would be dependent upon the type of barrier wall selected during detailed design. For example, installation of a slurry barrier wall would require a moderate amount of ground surface area along the alignment of the wall due to the need to manage excavated soils, whereas a sheet pile barrier wall would require comparatively less area and disturbance of the ground surface. As remedial construction work would not be conducted in the ditch area itself, the existing bird deterrent features and oil absorbent materials would remain in place during and after barrier wall construction. The barrier wall will be constructed as close as reasonably practical, but not interfere with, the pipelines and utilities east of the ditch, therefore the work would need to be coordinated with the various pipeline and utility companies. The anticipated location of a barrier wall is east of the ditch and the pipelines and utilities. Due to the location of the barrier wall, ongoing boom maintenance (Alternative 1 plus barrier wall) is included.

If it is determined that a slurry barrier wall (e.g., soil-bentonite) is the preferred type of barrier wall, then any excess excavated soil that could not be returned to the barrier wall excavation would require off-Site for disposal.

Since the barrier wall is primarily underground, there are only limited surface features that can be monitored. Inspections of the barrier wall at the ground surface would be conducted concurrently with, but less frequently than, the inspection of the other components of this alternative (i.e., boom maintenance activities and bird deterrent measures) that would be conducted at a frequency consistent with Alternative 1. Inspection of the barrier wall at the ground surface would initially be completed quarterly for the first year to monitor potential settlement. After one year of quarterly inspections, the frequency will reduce to semi-annually. Reporting would be monthly and quarterly in accordance with the AOC and is expected to be completed for 30 years.

A detailed cost breakdown for Alternative 4 is presented in Table 6.4. Periodic routine reporting costs are included. The total capital cost is estimated to be $575,000 and the estimated annual operation and maintenance cost is $235,000. The total present cost of this alternative is estimated to be $7,214,000.

7. Evaluation of Alternatives

7.1 Evaluation Criteria

The evaluation of alternatives herein is consistent with the criteria identified in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), which is also provided in the AOC. The evaluation criteria include:

1. **Effectiveness** - Alternatives shall be assessed for short-term effectiveness and long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will prove successful. Factors that shall be considered, as appropriate, include the following:

    a. Short-term risks that might be posed to the community during implementation of an alternative.

    b. Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures.

    c. Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation.

    d. Time until protection is achieved.

    e. Magnitude of residual risk remaining from untreated waste or treatment residuals remaining at the conclusion of the remedial activities. The characteristics of the residuals should be considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bioaccumulate.

    f. Adequacy and reliability of controls such as containment systems and institutional controls that are necessary to manage treatment residuals and untreated waste. This factor addresses in particular the uncertainties associated with land disposal for providing long-term protection from residuals; the assessment of the potential need to replace technical components of the alternative, such as a cap, a slurry wall, or a treatment system; and the potential exposure pathways and risks posed should the remedial action need replacement.

2. **Implementability** - The ease or difficulty of implementing the alternatives shall be assessed by considering the following types of factors as appropriate:

   a. Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, the reliability of the technology, ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy.

   b. Administrative feasibility, including activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for off-site actions).

   c. Availability of services and materials, including the availability of adequate off-site treatment, storage capacity, and disposal capacity and services; the availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources; the availability of services and materials; and availability of prospective technologies.

3. **Cost** - The types of costs that shall be assessed include the following:

   a. Capital costs, including both direct and indirect costs.

   b. Annual operation and maintenance costs.

   c. Net present value of capital and O&M costs.

4. **Risks** - Alternatives shall be assessed to determine whether they can adequately protect human health and the environment, in both the short- and long-term, from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the site by eliminating, reducing, or controlling exposures to levels established during development of remediation.

7.2 Evaluation of Alternatives with NCP Criteria

7.2.1 Effectiveness

Effectiveness is evaluated in two parts, the effect of the alternatives on the local community during implementation and the ability of the alternatives to remain protective over time. The alternatives included involve technologies that have been demonstrated to be effective in a wide range of other projects (e.g., liners and pipe installation).

Alternative 1 is effective at limiting the extent of impacts to within the ditch in the short term. However, Alternative 1 is not protective in the long term since there will continue to be a footprint where the environment will be exposed to LNAPL. In addition, maintenance staff would potentially be exposed to the LNAPL as long as LNAPL continues to seep into the ditch.

Alternatives 2 and 3 are both effective at mitigating the migration of LNAPL impacts to the ditch and therefore limiting the potential for migration of impacts. Both Alternatives 2 and 3, flatten the groundwater table by backfilling the ditch with soil or creating a barrier to groundwater flow (HDPE liner). Slowing the groundwater flow will increase the residence time for degradation. The HDPE liner has a shorter expected service life and would therefore, require replacement sooner than the storm sewer pipe. In addition, the HDPE liner, even when protected by the concrete or other materials, will likely require more maintenance than the storm sewer pipe due to potential breaches (e.g., potential damage from contents flowing down the ditch, refuse). Therefore, Alternative 3 provides a more permanent mitigation of petroleum sheen migration to the ditch and is therefore preferred based on effectiveness. Exposure of construction workers to LNAPL can be effectively managed by a site-specific Health and Safety Plan. Following construction, there would be little to no exposures of the environment to LNAPL.

As identified through the design investigation, the petroleum sheen is forming in the ditch through two processes: laterally through the sidewalls and vertically through ebullition from beneath the ditch. The proposed barrier wall included in Alternative 4 would reduce sheen formation in the ditch through lateral seepage, however continuing current booming activities would still be required to collect the petroleum sheen forming from the ditch from the residual LNAPL between the barrier wall and the ditch through lateral seepage and through ebullition from beneath the ditch. Alternative 4 is effective at preventing the migration of LNAPL impacts interior to the Site to the ditch, however, residual LNAPL impacts between the barrier wall and the ditch will continue to impact the ditch. Performing absorbent boom maintenance activities in the ditch weekly will limit the extent of impacts to within the ditch in the short term. However, Alternative 4 is not protective in the long term since there will continue to be a footprint where the environment will be exposed to LNAPL. In addition, maintenance staff would potentially be exposed to the LNAPL as long as LNAPL continues to seep into the ditch.

7.2.2 Implementability

Implementability refers to the ease or difficulty of implementing the alternatives, considering as appropriate the technical feasibility of constructing, operating, and monitoring the remedy, the administrative feasibility of coordinating with and obtaining necessary approvals and permits from other agencies, and the availability of services and materials, including capacity and location of needed treatment, storage, and disposal services. Implementability issues include the working in close proximity to the underground utility lines (petroleum, electrical and gas) and working within an operating ditch.

Alternative 1 can be implemented safely with minimal engineering and administrative procedures as is currently evidenced by the on-going work.

Alternatives 2 and 3 will be more difficult to implement, however, these alternatives use standard construction approaches (including water bypass systems, working in close proximity to buried utilities, working in close proximity to traffic) and the construction activities would be of comparatively short duration. Alternative 2, will be slightly more difficult to implement as a result of groundwater below the liner tending to float the liner, as well as, the proximity of the tie-ins on the bank to the buried utility lines.

Alternative 4 is also slightly more difficult to implement than Alternative 1, however, it is less difficult than Alternative 2 and 3, since this alternative uses standard construction approaches, does not require construction within the ditch (thereby avoiding dealing with LNAPL impacted water and sediment), and the work will be completed a safe distance from the underground utilities. However, due to the long-term nature of the ditch maintenance activities, the potential for an incident (e.g., petroleum sheen breach of absorbent boom; safety, slip/trip/fall incident to workers) to occur is high.

A site-specific health and safety plan would be required for implementation of all alternatives, to ensure that construction workers are aware of the hazards associated with implementation of the selected remedy and to establish safe work procedures.

7.2.3 Cost

Estimated costs for the alternatives were developed and presented in Section 6, and are discussed briefly below. The costs to implement Alternative 3 are the lowest and, therefore, is the preferred alternative based on cost. Alternative 2, would have a similar cost, however the service life of the HDPE liner is much shorter than the service life of the storm sewer pipe. Implementation of Alternatives 1 and 4 involve a significant cost increase compared with the other alternatives due to the ongoing nature of the work.

7.2.4 Risk

Alternatives 1 and 4 are protective of human health and the environment through continued maintenance of the ditch to maintain engineering controls (i.e., absorbent boom replacement, aquatic vegetation control, bird deterrents). Alternatives 2 and 3 have the benefit of eliminating exposures of humans and the environment to LNAPL entering the ditch and allowing the ditch area to revert back to a more natural state, without the need for engineering controls.

7.2.5 Evaluation Summary

The following presents a summary of the alternative evaluations by relative ranking of alternatives. A rank of 1 indicates the best alternative when compared to the other alternatives.

Table 7.1 Selection Matrix

	Technical Effectiveness	Implementability	Cost Effectiveness (Ranking)	Protection of Human Health and the Environment	Total
Alternative 1 Continue Current Approach	4	1	3	4	12
Alternative 2 Line Ditch with HDPE Liner	2	3	2	2	9
Alternative 3 Storm Sewer Installation Within Ditch	**1**	**2**	**1**	**1**	**5**
Alternative 4 Barrier Wall and Continue Current Approach	3	4	4	3	14

Based on summing the rankings, Alternative 3 is the preferred option.

8. Description and Rationale of the Proposed Action

To mitigate petroleum sheens from continuing to impact the ditch, Alternative 3 is selected as the proposed remedial alternative for the Site. The current remedial design includes:

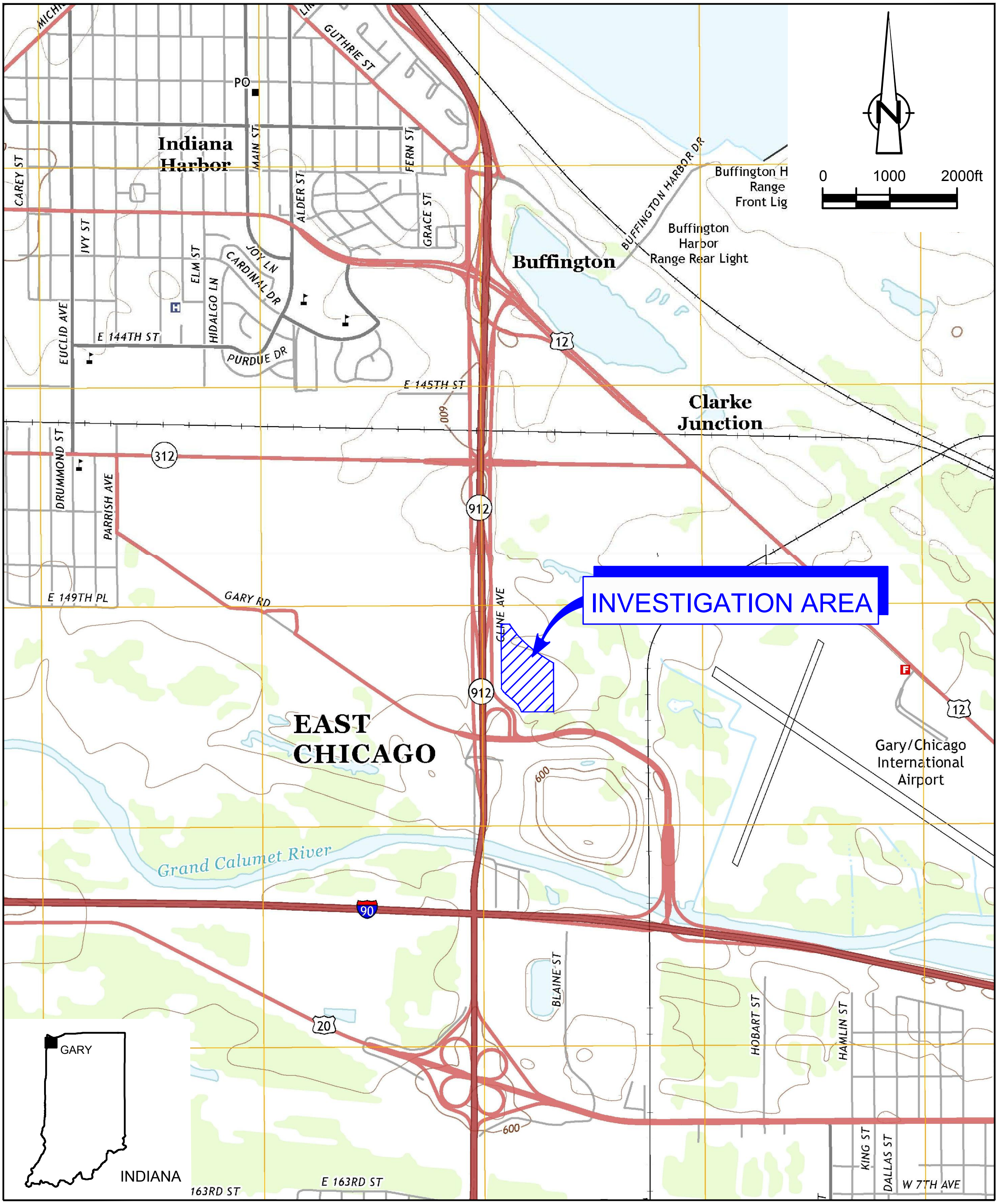
- Installation of a storm sewer pipe to replace the open channel ditch
- Removal of hydrocarbon impacted material above the paver stones within the ditch and in construction areas where impacted soils are disturbed
- Installation of low permeability collars (or engineered equivalents)
- Sealed pipe joints
- Installation of soil/bentonite cut off wall
- Long-term monitoring and reporting

The basis for selecting Alternative 3, as identified in Section 7, is that this alternative is the most effective alternative, is similar to Alternative 2 with regards to implementability and is the most cost effective alternative. Remedial construction costs for this alternative are detailed in various units and quantities in Table 6.3. This alternative also includes removal and off-site disposal of approximately 1,800 cubic yards of impacted material from within the ditch (above the existing paver stones) and from select areas. A Draft 90% design-drawing package for this alternative is included in Appendix D. These documents have been provided in order to provide greater engineering and construction information specific to this alternative.

Alternative 1 – Continue Current Approach, does not address the purpose of the remedial alternatives, "to mitigate petroleum sheens from continuing to impact the ditch" and the cost is significantly higher than the other alternatives, therefore Alternative 1 is not a viable option.

Alternative 2 – Line Ditch with HDPE Liner, is a viable option. However, it is less effective than Alternative 3 since it has a shorter design life and will also require more maintenance. In addition, Alternative 2 is less cost effective than Alternative 3.

Alternative 4 – Barrier Wall and Continue Current Approach does not address the purpose of the remedial alternatives, "to mitigate petroleum sheens from continuing to impact the ditch" and the cost is significantly higher than the other alternatives, therefore Alternative 4 is not a viable option.



Source: USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE; HIGHLAND AND WHITING, INDIANA 2013

CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

85886-D21105

Nov 24, 2017

INVESTIGATION AREA LOCATION

FIGURE 1.1

CAD File: P:\drawings\85000s\85886\85886-REPORT\85886-D21105(004)\85886-D21105(004)GN\85886-D21105(004)GN-WA002.DWG

LEGEND

- LIMITS OF CLINE DITCH
- NORTH → SEEP LOCATION (2017)
- E — SURVEYED UNDERGROUND ELECTRICAL LINE
- O/H — SURVEYED OVERHEAD WIRE
- G — SURVEYED NIPSCO UNDERGROUND UTILITY LINE
- G — SURVEYED BP UNDERGROUND UTILITY LINE
- G — SURVEYED BUCKEYE UTILITY LINE

Source: AERIAL IMAGE BY TERRASERVER, 0.5m RESOLUTION, 2016-10-23.

0 200 400ft

Coordinate System:
INDIANA WEST STATE
PLANE NAD83

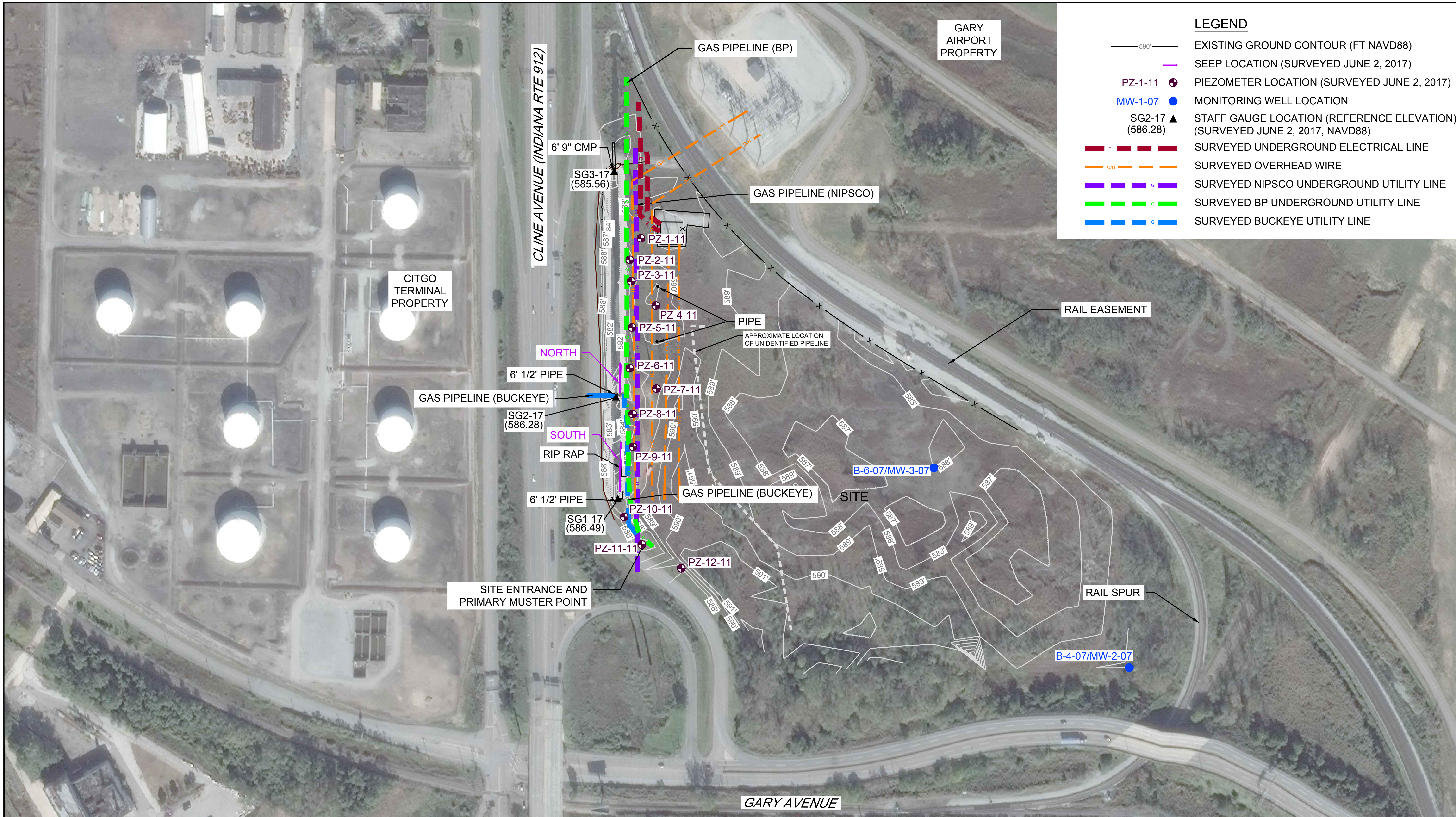
CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

INVESTIGATION AREA PLAN

85886-D21105
Nov 24, 2017

FIGURE 1.2

CAD File: P:\drawings\85000s\85886\85886-REPORT\85886-D21105(004)\85886-D21105(004)GN\85886-D21105(004)GN-WA003.DWG



Source: CM LAVOIE & ASSOCIATES, INC., SURVEY DATED JUNE 2, 2017, UPDATED JULY 27, 2017 (INDIANA WEST NAD83, NAVD88). AERIAL IMAGE BY TERRASERVER, 0.5m RESOLUTION, 2016-10-23.

0 125 250ft

Coordinate System: INDIANA WEST STATE PLANE NAD83

GHD

CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

BASE MAP

85886-D21105
Apr 16, 2018

FIGURE 3.1

CAD File: P:\drawings\85000s\85886\85886-REPORT\85886-D21105(004)\85886-D21105(004)GN\85886-D21105(004)GN-WA004.DWG

LEGEND

(magenta line)	SEEP LOCATION (SURVEYED JUNE 2, 2017)
PZ-1-11	PIEZOMETER LOCATION (SURVEYED JUNE 2, 2017)
TG-7-17	LIF BORING LOCATION
SG2-17 (586.28)	STAFF GAUGE LOCATION (REFERENCE ELEVATION) (SURVEYED JUNE 2, 2017, NAVD88)
	SURVEYED UNDERGROUND ELECTRICAL LINE
	SURVEYED OVERHEAD WIRE
	SURVEYED NIPSCO UNDERGROUND UTILITY LINE
	SURVEYED BP UNDERGROUND UTILITY LINE
	SURVEYED BUCKEYE UTILITY LINE
	WATER ELEVATION (JULY 24, 2017)
+2.18	SEDIMENT THICKNESS (OCTOBER 2017 SURVEY)

CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

DITCH
PLAN AND PROFILE

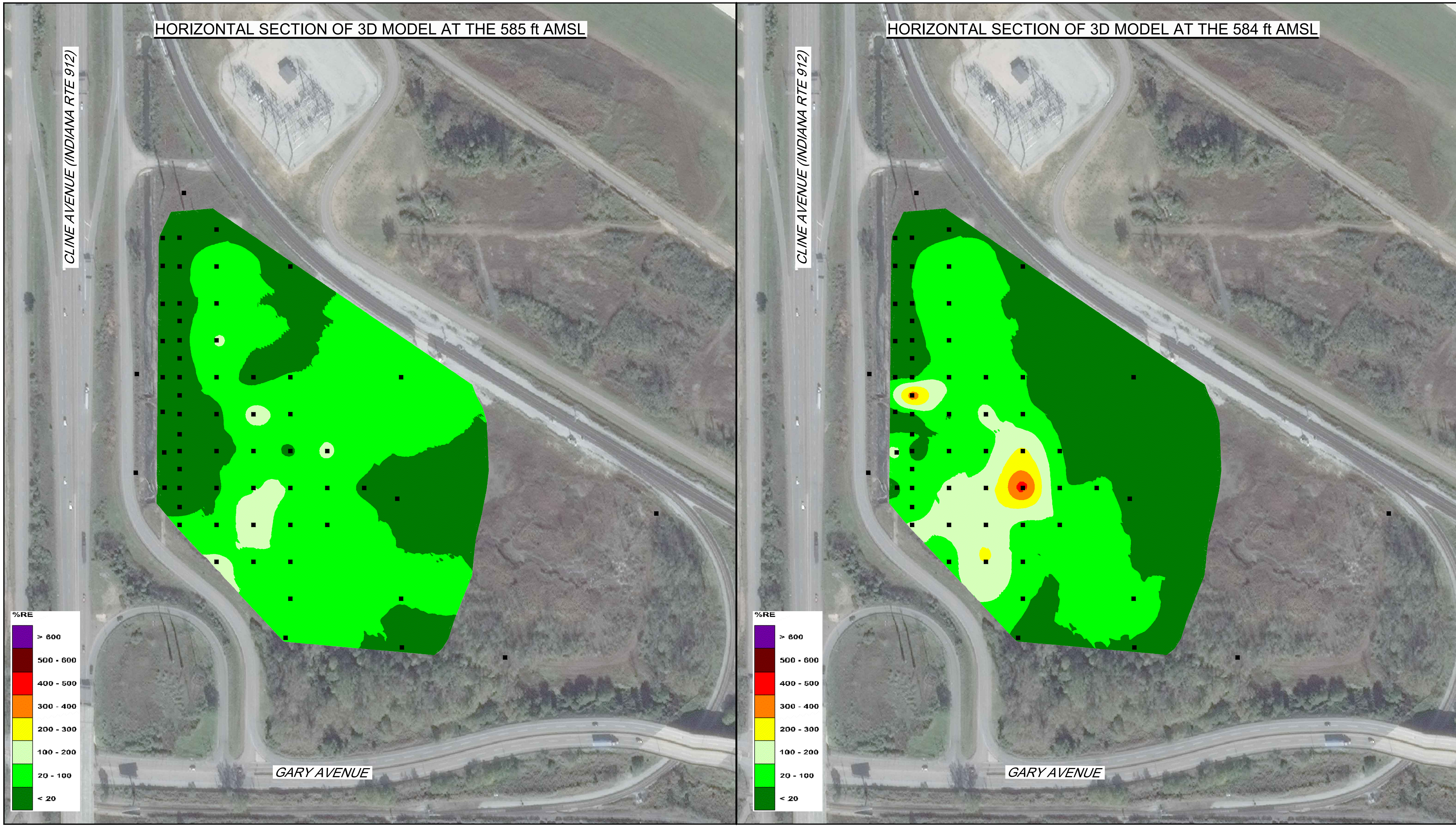
GHD

Source: CM LAVOIE & ASSOCIATES, INC., SURVEY DATED JUNE 2, 2017, UPDATED JULY 27, 2017 AND OCTOBER 5, 2017. (INDIANA WEST NAD83, NAVD88)

Project No. 85886-D21105 | Report No. 004

Date: November 27, 2017 | **FIGURE 3.2**

Plot Date: 13 April 2018 - 9:54 AM   Plotted By: Melissa Jerome   CAD File: P:\drawings\85000s\85886\85886-REPORT\85886-D21105(004)\85886-D21105(004)GN\85886-D21105(004)GN-WA005.DWG



Source: CM LAVOIE & ASSOCIATES, INC., SURVEY DATED JUNE 2, 2017, UPDATED JULY 27, 2017 (INDIANA WEST NAD83, NAVD88). AERIAL IMAGE BY TERRASERVER, 0.5m RESOLUTION, 2016-10-23.

0 125 250ft

Coordinate System:
INDIANA WEST STATE
PLANE NAD83

N

LEGEND

■ LIF BORING LOCATION

NOTE: THE HORIZONTAL DISTRIBUTION OF HYDROCARBON RESPONSE WAS DEVELOPED THROUGH THE CREATION OF A 3-D MODEL OF 62 LIF BORINGS THAT WERE COMPLETED AT THE SITE IN JULY AND OCTOBER 2017.

CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

HORIZONTAL DISTRIBUTION OF HYDROCARBON RESPONSE ABOVE WATER TABLE (585 AND 584)

85886-D21105
Nov 27, 2017

FIGURE 3.3

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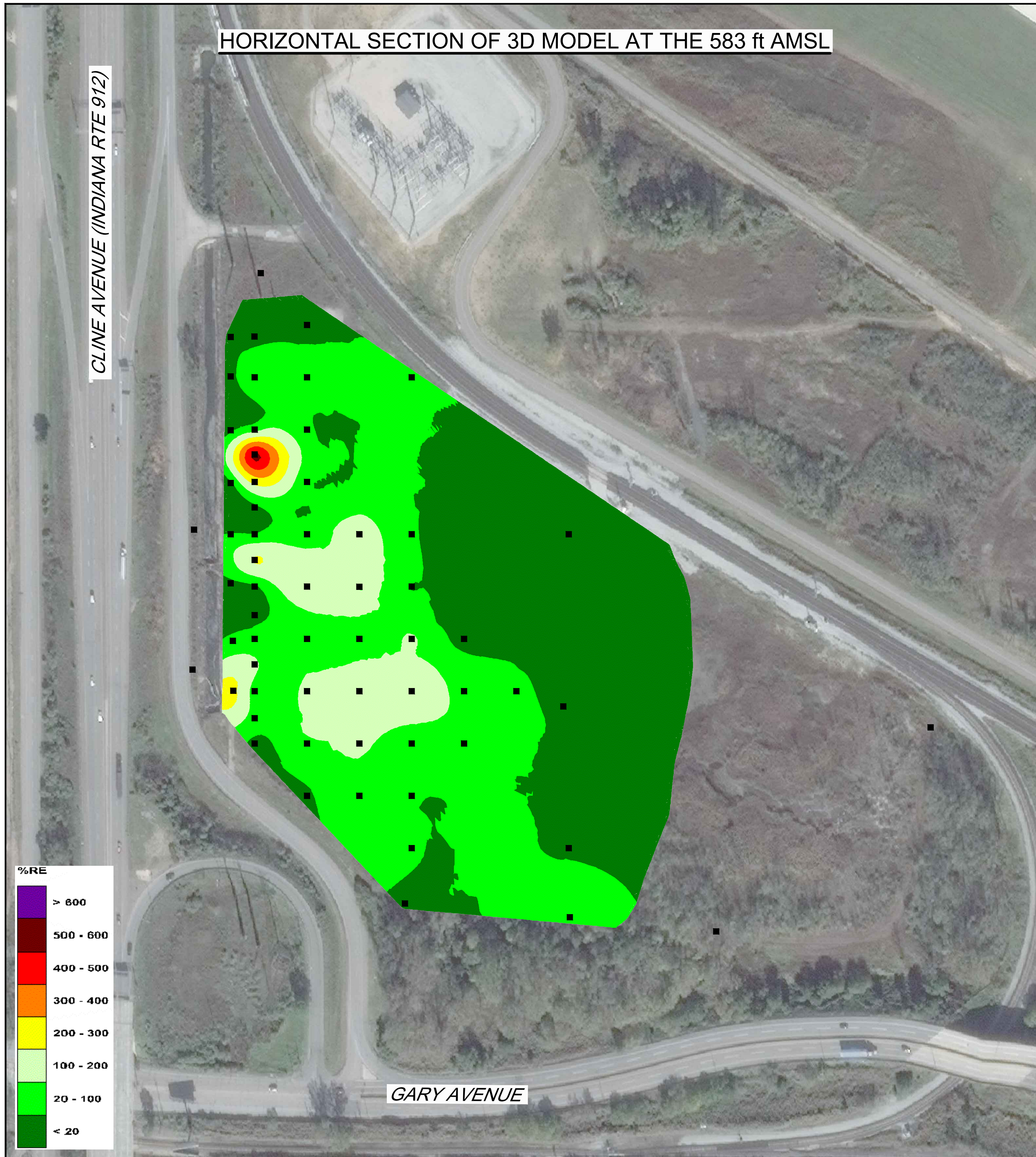

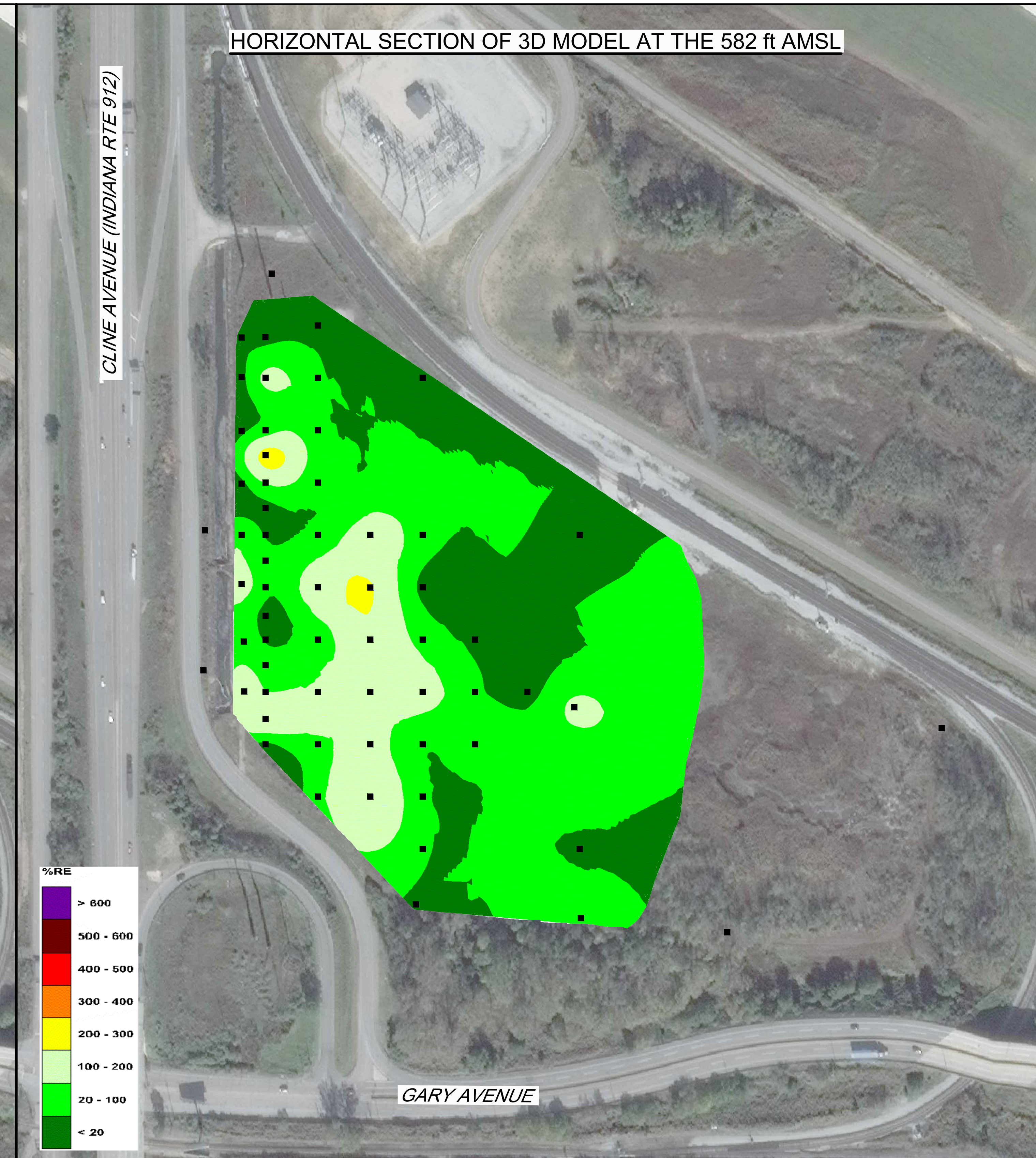

Source: CM LAVOIE & ASSOCIATES, INC., SURVEY DATED JUNE 2, 2017, UPDATED JULY 27, 2017 (INDIANA WEST NAD83, NAVD88). AERIAL IMAGE BY TERRASERVER, 0.5m RESOLUTION, 2016-10-23.

0 125 250ft

Coordinate System: INDIANA WEST STATE PLANE NAD83

LEGEND

■ LIF BORING LOCATION

NOTE: THE HORIZONTAL DISTRIBUTION OF HYDROCARBON RESPONSE WAS DEVELOPED THROUGH THE CREATION OF A 3-D MODEL OF 62 LIF BORINGS THAT WERE COMPLETED AT THE SITE IN JULY AND OCTOBER 2017.

CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

HORIZONTAL DISTRIBUTION OF HYDROCARBON RESPONSE AT WATER TABLE (583 AND 582)

85886-D21105

Nov 27, 2017

FIGURE 3.4

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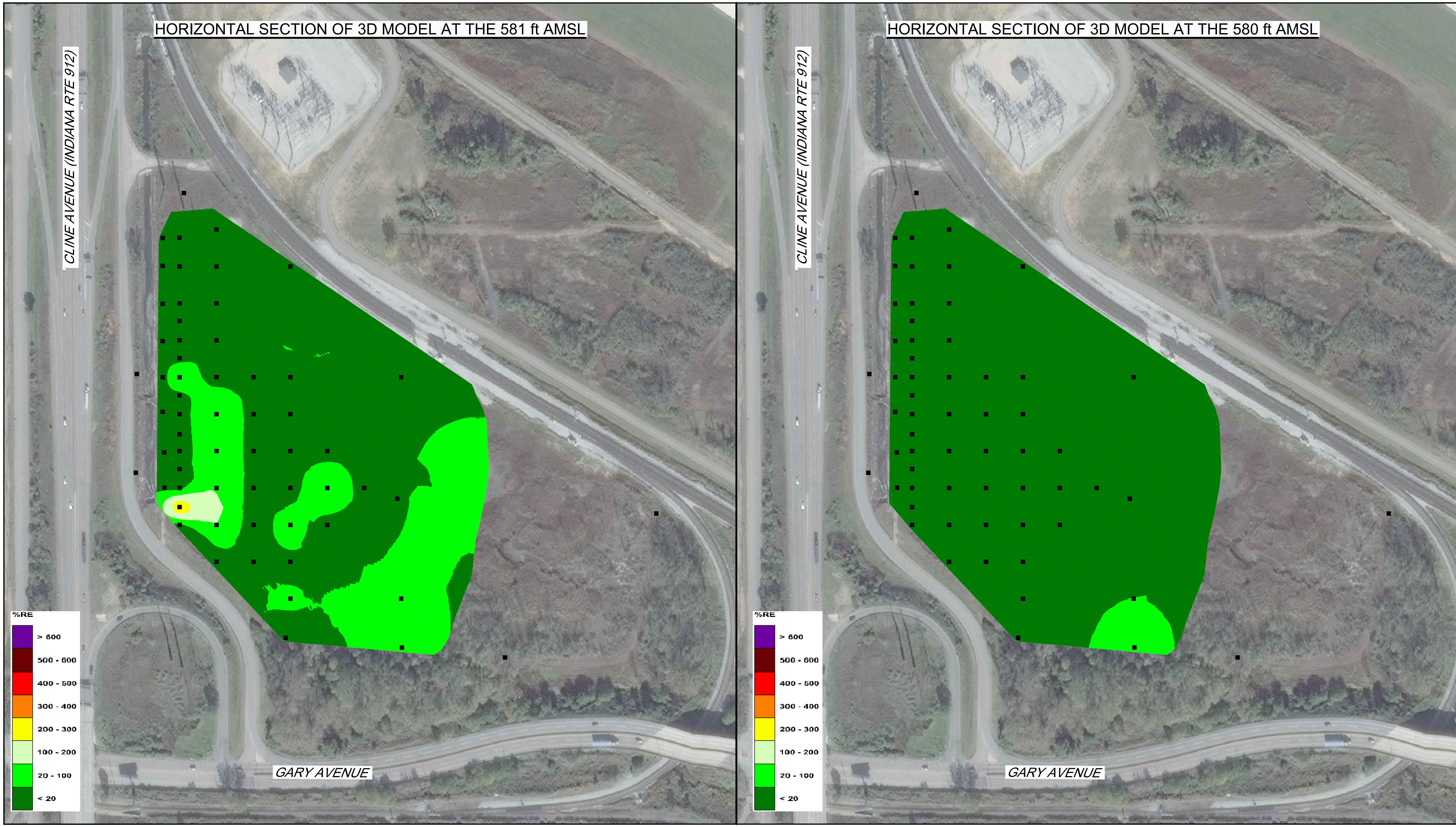

Source: CM LAVOIE & ASSOCIATES, INC., SURVEY DATED JUNE 2, 2017, UPDATED JULY 27, 2017 (INDIANA WEST NAD83, NAVD88). AERIAL IMAGE BY TERRASERVER, 0.5m RESOLUTION, 2016-10-23.

0 125 250ft

Coordinate System:
INDIANA WEST STATE
PLANE NAD83

N

LEGEND

■ LIF BORING LOCATION

NOTE: THE HORIZONTAL DISTRIBUTION OF HYDROCARBON RESPONSE WAS DEVELOPED THROUGH THE CREATION OF A 3-D MODEL OF 62 LIF BORINGS THAT WERE COMPLETED AT THE SITE IN JULY AND OCTOBER 2017.

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CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

HORIZONTAL DISTRIBUTION OF HYDROCARBON RESPONSE BELOW WATER TABLE (581 AND 580)

85886-D21105
Nov 27, 2017

FIGURE 3.5

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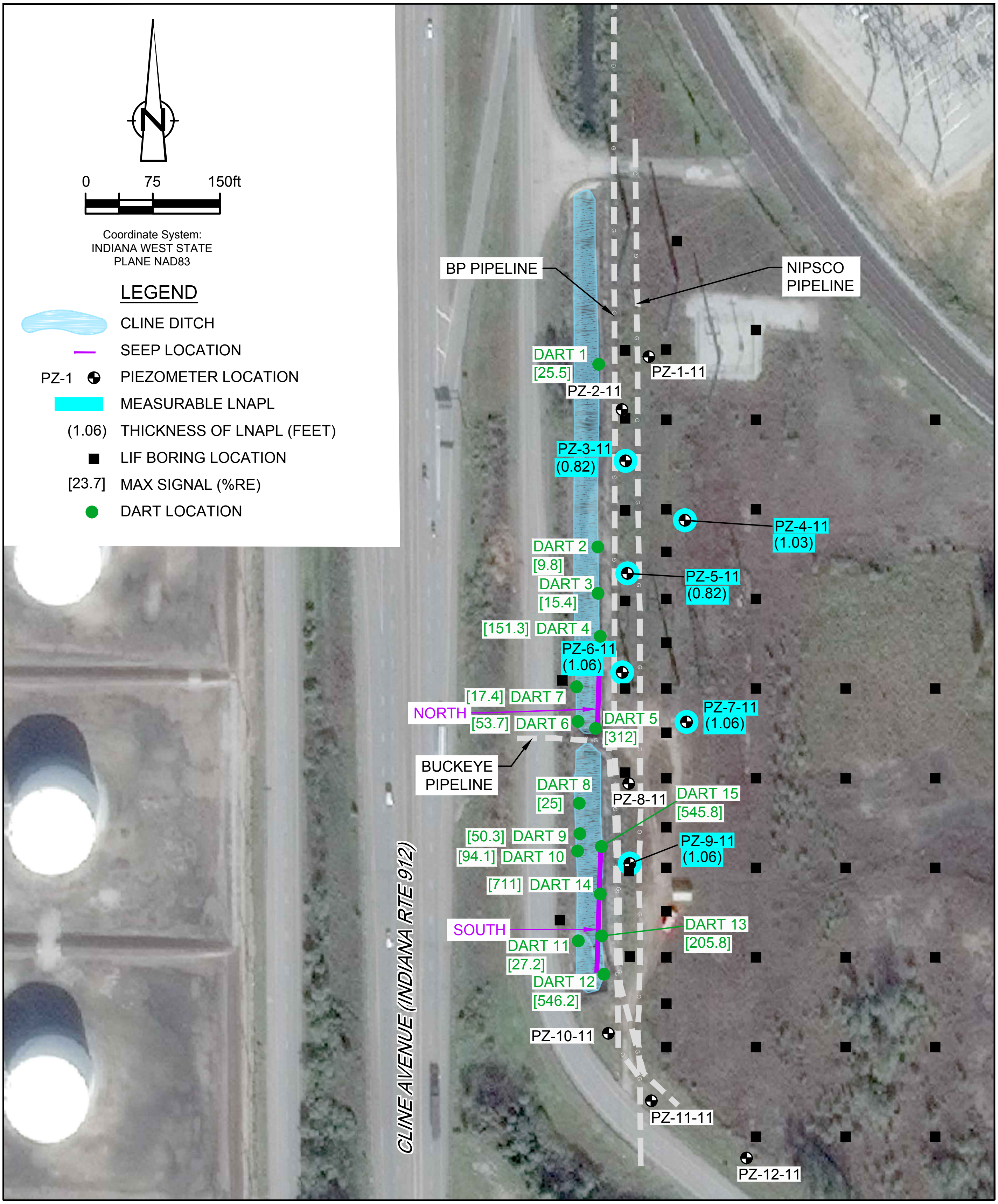

Source: CM LAVOIE & ASSOCIATES, INC., SURVEY DATED JULY 27, 2017 (INDIANA WEST NAD83, NAVD88). AERIAL IMAGE BY TERRASERVER, 0.5m RESOLUTION, 2016-10-23.

CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

85886-D21105

Nov 27, 2017

DART SAMPLE LOCATIONS

FIGURE 3.6

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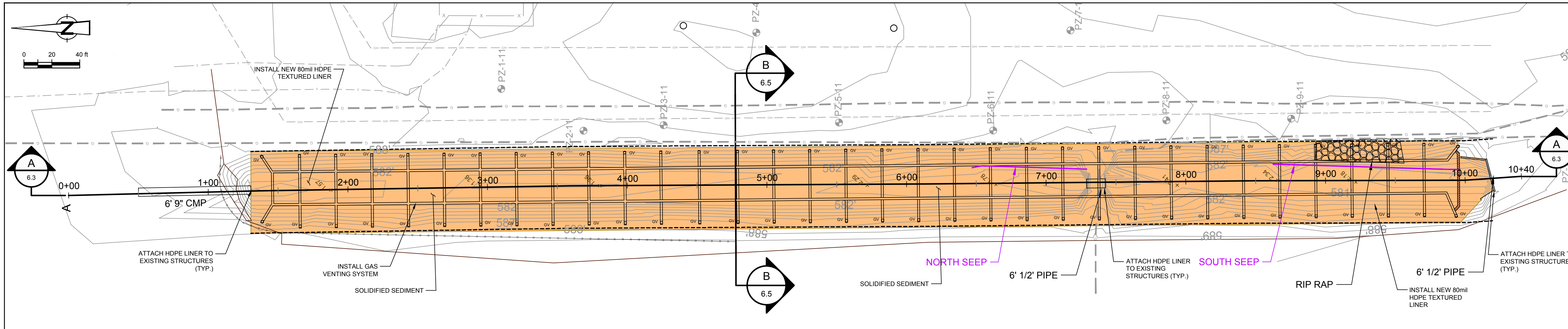

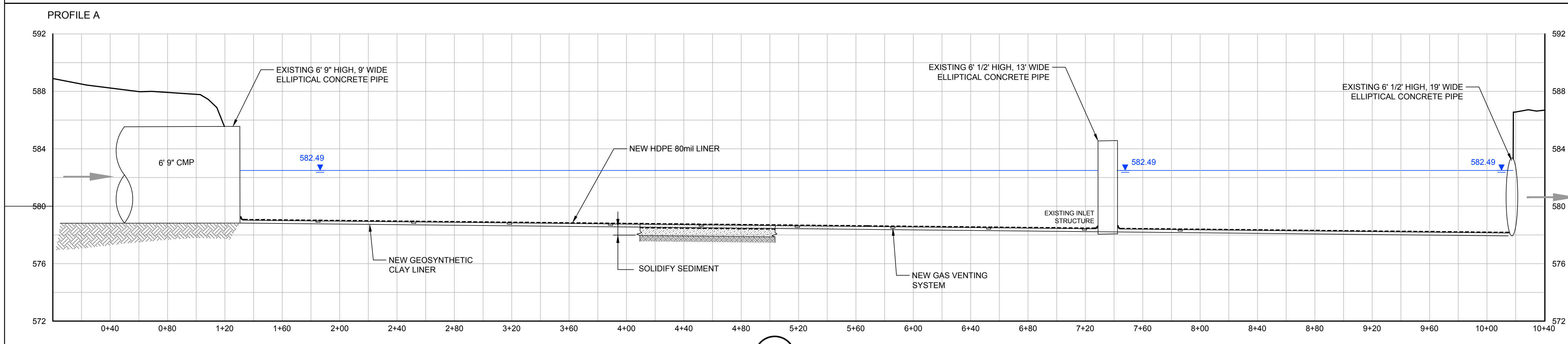

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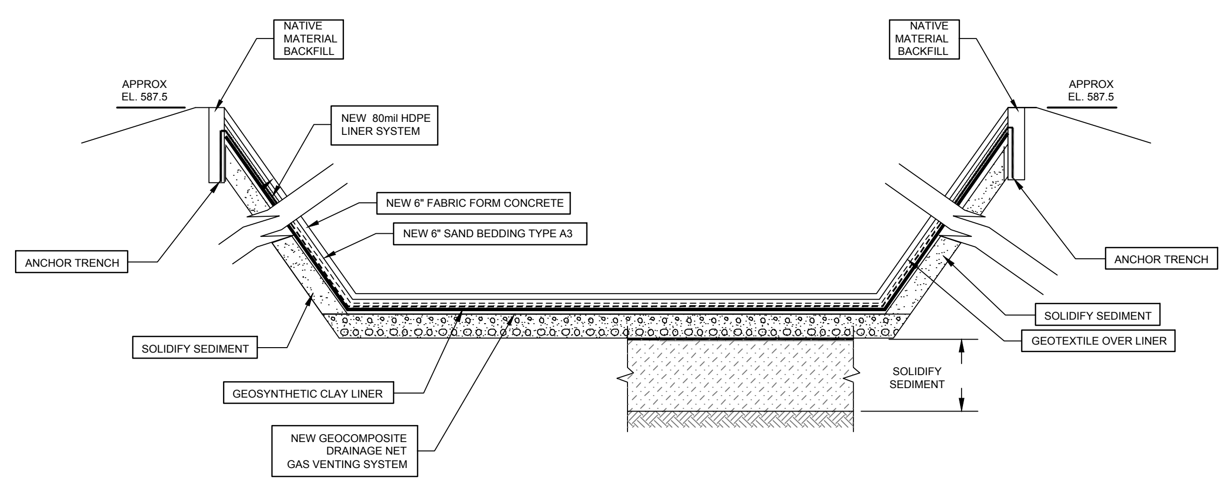

SECTION B 6.3
H 1"=10' V 1"=2'

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No.	Issue	Drawn	Approved	Date
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Drawn	MJ	Designer	JP
Drafting Check	JP	Design Check	JP
Project Manager	MT	Date	Apr 20, 2018
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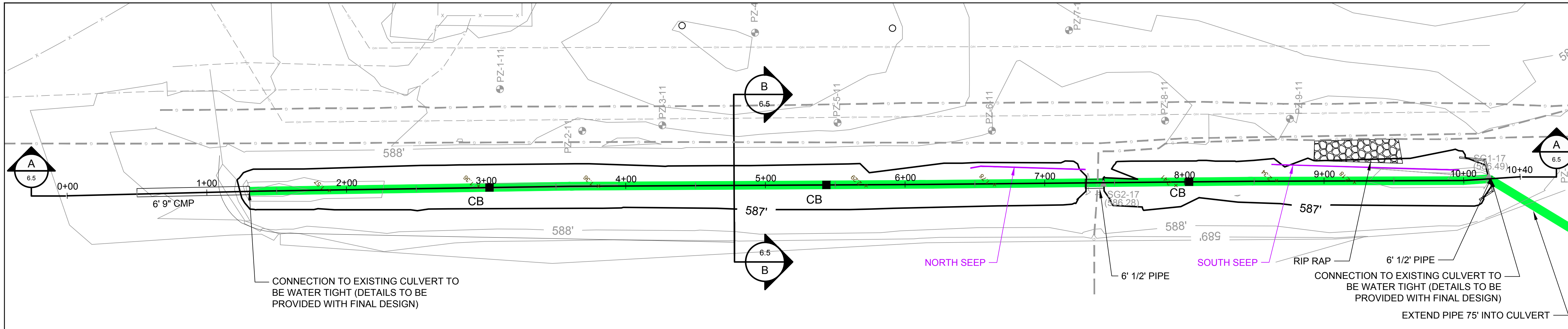
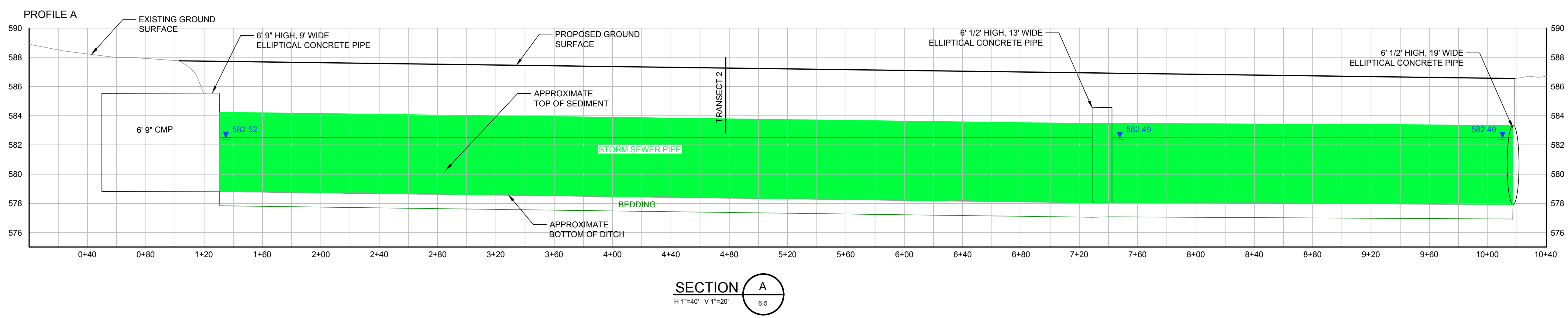
Title
ALTERNATIVE 2 LINE DITCH WITH HDPE LINER PLAN AND PROFILE

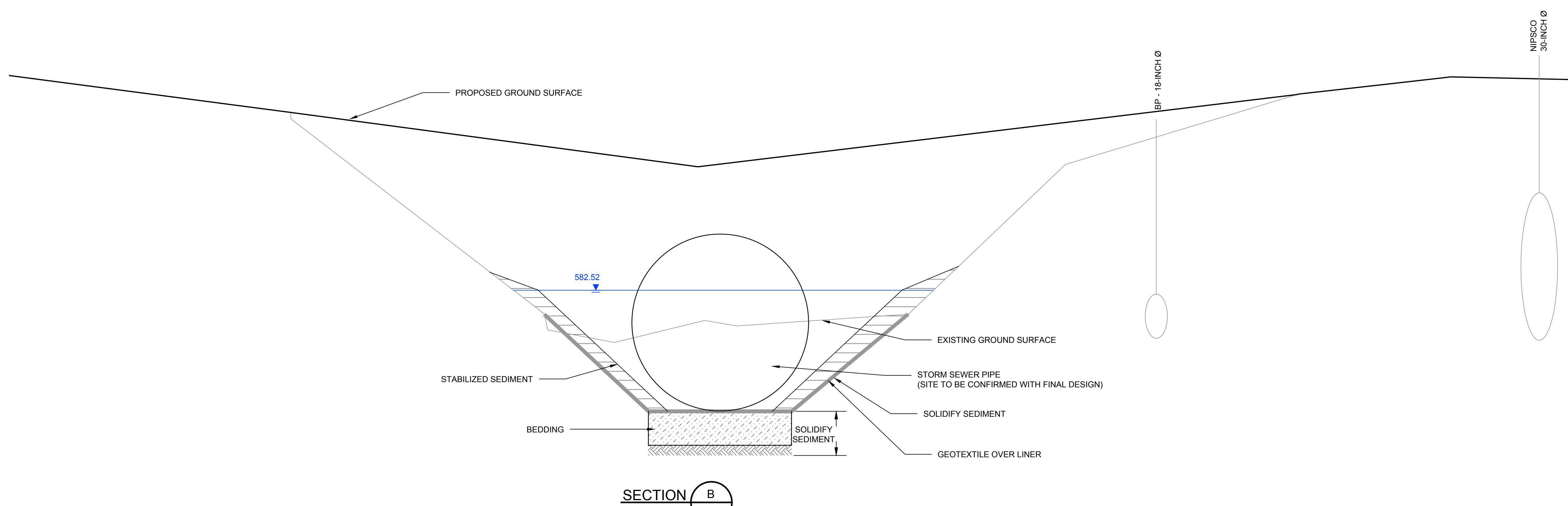
Sheet No.
FIGURE 6.3

Sheet of

Plot Date: 20 April 2018 - 9:57 AM Plotted By: Gerry Balzer CAD File: P:\drawings\85000s\85886\85886-REPORT\85886-D21105(004)\85886-D21105(004)GN\85886-D21105(004)GN-WA010.DWG







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Project Manager	MT	Date	Apr 16, 2018
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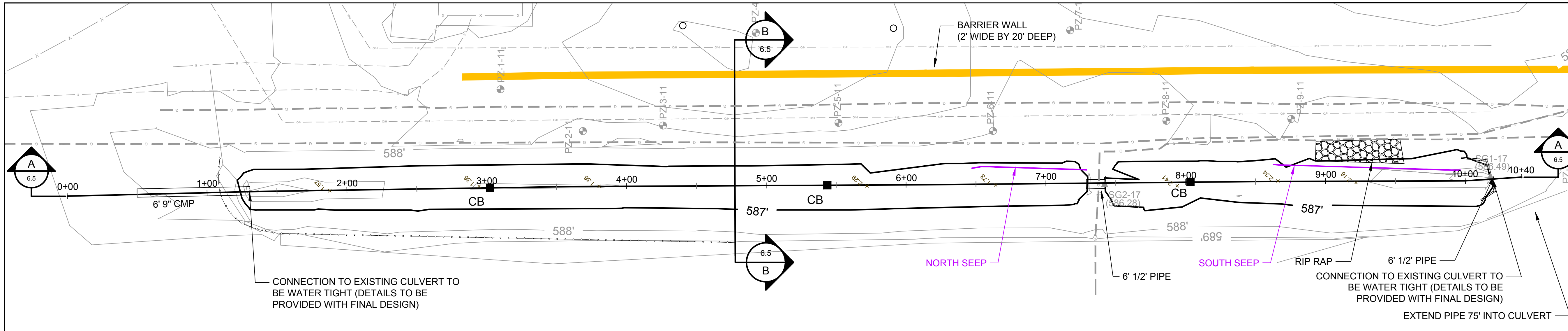
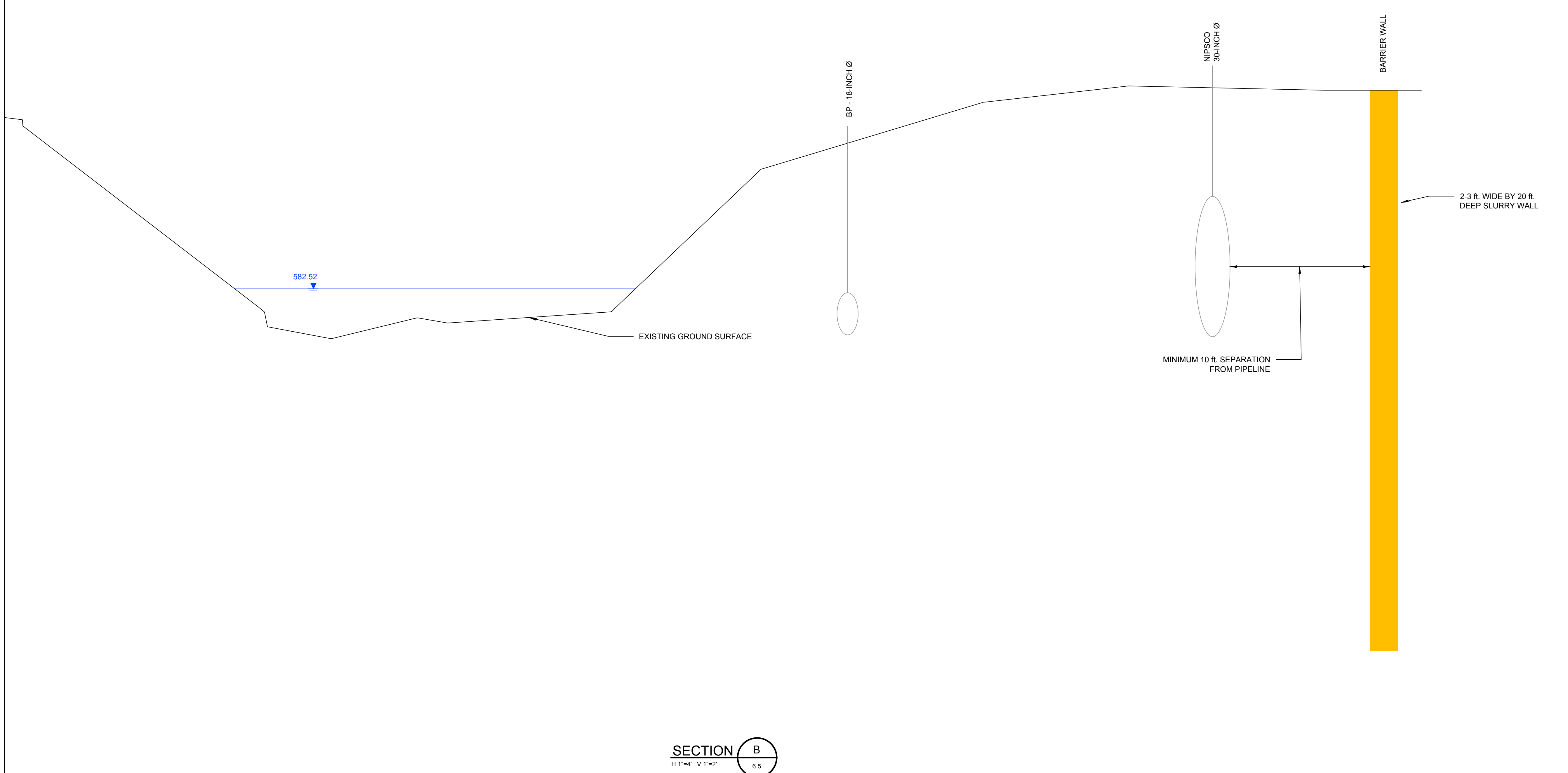
Title
ALTERNATIVE 3 STORM SEWER INSTALLATION WITHIN DITCH

Sheet No.
FIGURE 6.5

Sheet of

Plot Date: 16 April 2018 - 2:18 PM Plotted By: Gerry Balzer CAD File: P:\drawings\85000s\85886\85886-REPORT\85886-D21105(004)\85886-D21105(004)GN\85886-D21105(004)GN-WA011.DWG





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Drawn	MJ	Designer	JP
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Project Manager	MT	Date	Apr 19, 2018
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Project No. 85886-D21105

Title
ALTERNATIVE 4 BARRIER WALL PLAN AND PROFILE

Sheet No.
FIGURE 6.7

Sheet of

Table 3.1

Gauging Summary
Cline Avenue Oil Spill Site
Gary, Indiana

Location ID	Reference Elevation (ft AMSL)(1)	9/30/2011 Depth to LNAPL (feet)	9/30/2011 LNAPL Thickness (feet)	8/21/2014 Depth to LNAPL (feet)	8/21/2014 LNAPL Thickness (feet)	11/20/2014 Depth to LNAPL (feet)	11/20/2014 LNAPL Thickness (feet)	11/24/2014 Depth to LNAPL (feet)	11/24/2014 LNAPL Thickness (feet)	2/26/2015 Depth to LNAPL (feet)	2/26/2015 LNAPL Thickness (feet)	5/21/2015 Depth to LNAPL (feet)	5/21/2015 LNAPL Thickness (feet)	9/3/2015 Depth to LNAPL (feet)	9/3/2015 LNAPL Thickness (feet)
Monitoring Wells															
MW-2	592.34	--	--	--	--	--	--	--	--						
MW-3	591.42	--	--	--	--	--	--	--	--						
Piezometers															
PZ-1	589.12	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-2	588.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-3	588.97	--	--	6.57	1.65	6.72	1.93	6.60	1.84	6.85	2.13	6.63	1.05	6.59	1.37
PZ-4	590.86	8.23	3.09	7.92	0.31	8.05	2.02	7.84	1.76	8.28	2.37	6.82	0.79	NA	NA
PZ-5	589.24	7.20	1.01	6.96	1.32	7.15	2.53	6.98	2.77	7.25	3.19	6.98	1.69	6.94	1.62
PZ-6	587.98	5.99	0.23	5.79	0.49	6.09	1.49	5.89	0.91	6.19	2.37	5.85	1.99	5.81	0.44
PZ-7	588.43	6.31	0.83	5.40	2.29	5.64	3.31	5.50	2.89	5.86	3.98	5.31	2.15	5.43	2.74
PZ-8	587.51	7.12	1.23	--	--	--	--	--	--	--	--	--	--	--	--
PZ-9	587.90	6.72	2.39	5.45	2.18	5.71	3.30	5.48	3.22	5.88	3.54	5.54	2.28	5.44	2.03
PZ-10	587.14	7.11	1.46	--	--	--	--	--	--	--	--	--	--	--	--
PZ-11	586.42	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-12	587.94	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Staff Gauges															
SG-1-17 (south culvert)	586.49	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-2-17 (mid-culvert)	586.28	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-3-17 (North Culvert)	585.56	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Location ID	Reference Elevation (ft AMSL)(1)	9/30/2011 Depth to Water (feet)	9/30/2011 Water Elevation (ft AMSL)	8/21/2014 Depth to Water (feet)	8/21/2014 Water Elevation (ft AMSL)	11/20/2014 Depth to Water (feet)	11/20/2014 Water Elevation (ft AMSL)	11/24/2014 Depth to Water (feet)	11/24/2014 Water Elevation (ft AMSL)	2/26/2015 Depth to Water (feet)	2/26/2015 Water Elevation (ft AMSL)	5/21/2015 Depth to Water (feet)	5/21/2015 Water Elevation (ft AMSL)	9/3/2015 Depth to Water (feet)	9/3/2015 Water Elevation (ft AMSL)
Monitoring Wells															
MW-2	592.34	-	-	-	-	-	-	4.64	587.70	--	--	--	--	--	--
MW-3	591.42	-	-	-	-	-	-	4.15	587.27	--	--	--	--	--	--
Piezometers															
PZ-1	589.12	6.81	582.31	6.61	582.51	6.73	582.39	6.63	582.49	6.93	582.19	6.52	582.60	6.61	582.51
PZ-2	588.24	6.16	582.08	6.02	582.22	6.15	582.09	6.03	582.21	6.31	581.93	5.99	582.25	6.00	582.24
PZ-3	588.97	6.92	582.05	8.22	582.24 (2)	8.65	582.06 (2)	8.44	582.19 (2)	8.98	581.91 (2)	7.68	582.24 (2)	7.96	582.24 (2)
PZ-4	590.86	11.32	582.32 (2)	8.23	582.91 (2)	10.07	582.61 (2)	9.60	582.84 (2)	10.65	582.34 (2)	7.61	583.96 (2)	7.87	582.99 (2)
PZ-5	589.24	8.21	581.94 (2)	8.28	582.15 (2)	9.68	581.84 (2)	9.75	581.98 (2)	10.44	581.67 (2)	8.67	582.09 (2)	8.56	582.14 (2)
PZ-6	587.98	6.22	581.97 (2)	6.28	582.14 (2)	7.58	581.74 (2)	6.80	582.00 (2)	8.56	581.55 (2)	7.84	581.93 (2)	6.25	582.13 (2)
PZ-7	588.43	7.14	582.04 (2)	7.69	582.80 (2)	8.95	582.46 (2)	8.39	582.64 (2)	9.84	582.17 (2)	7.46	582.91 (2)	8.17	582.73 (2)
PZ-8	587.51	8.35	580.27 (2)	5.25	582.26	5.56	581.95	5.23	582.28	5.74	581.77	5.33	582.18	5.23	582.28
PZ-9	587.90	9.11	580.94 (2)	7.63	582.23 (2)	9.01	581.86 (2)	8.70	582.10 (2)	9.42	581.67 (2)	7.82	582.13 (2)	7.47	582.26 (2)
PZ-10	587.14	8.57	579.88 (2)	4.02	583.12	4.38	582.76	4.02	583.12	4.67	582.47	4.06	583.08	4.10	583.04
PZ-11	586.42	8.55	577.87	2.37	584.05	2.94	583.48	2.36	584.06	3.31	583.11	2.44	583.98	2.77	583.65
PZ-12	587.94	8.91	579.03	3.51	584.43	3.82	584.12	3.34	584.60	4.24	583.70	3.16	584.78	3.81	584.13
Staff Gauges															
SG-1-17 (south culvert)	586.49			--	--	--	--	--	--	--	--	--	--	--	--
SG-2-17 (mid-culvert)	586.28			--	--	--	--	--	--	--	--	--	--	--	--
SG-3-17 (North Culvert)	585.56			--	--	--	--	--	--	--	--	--	--	--	--

Notes:

(1) ft AMSL - feet above mean sea level
(2) Correct Water Elevation due to the presence of LNAPL
NAVD88 - Datum for Elevations
NA - not available
Reference elevations surveyed by C. M. Lavoie on June 2, 2017

Table 3.1

Gauging Summary
Cline Avenue Oil Spill Site
Gary, Indiana

Location ID	Reference Elevation (ft AMSL)(1)	12/3/2015 Depth to LNAPL (feet)	12/3/2015 LNAPL Thickness (feet)	3/3/2016 Depth to LNAPL (feet)	3/3/2016 LNAPL Thickness (feet)	6/16/2016 Depth to LNAPL (feet)	6/16/2016 LNAPL Thickness (feet)	9/29/2016 Depth to LNAPL (feet)	9/29/2016 LNAPL Thickness (feet)	12/22/2016 Depth to LNAPL (feet)	12/22/2016 LNAPL Thickness (feet)	5/18/2017 Depth to LNAPL (feet)	5/18/2017 LNAPL Thickness (feet)	6/27/2017 Depth to LNAPL (feet)	6/27/2017 LNAPL Thickness (feet)
Monitoring Wells															
MW-2	592.34											--	--	--	--
MW-3	591.42											--	--	--	--
Piezometers															
PZ-1	589.12	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-2	588.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-3	588.97	6.52	0.82	6.56	1.23	6.52	0.02	6.30	0.10	6.72	2.59	6.31	1.91	6.49	1.02
PZ-4	590.86	NA	NA	7.29	0.09		--	7.73	0.83	8.24	0.64	5.81	1.85	7.56	0.23
PZ-5	589.24	6.91	0.04	6.94	1.42	6.84	2.13	6.66	0.86	7.11	3.33	6.78	2.85	6.81	0.92
PZ-6	587.98	5.71	2.65	5.88	0.96	5.68	0.83	5.39	0.96	6.09	1.73	5.43	1.02	5.60	0.87
PZ-7	588.43	5.34	1.50	5.22	1.54	5.28	2.19	5.21	1.89	5.67	3.48	4.75	2.94	5.14	1.86
PZ-8	587.51	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-9	587.90	5.50	1.83	5.48	1.93	5.31	1.91	5.13	1.09	5.73	3.45	5.17	1.62	5.26	1.34
PZ-10	587.14	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-11	586.42	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-12	587.94	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Staff Gauges															
SG-1-17 (south culvert)	586.49	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-2-17 (mid-culvert)	586.28	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-3-17 (North Culvert)	585.56	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Location ID	Reference Elevation (ft AMSL)(1)	12/3/2015 Depth to Water (feet)	12/3/2015 Water Elevation (ft AMSL)	3/3/2016 Depth to Water (feet)	3/3/2016 Water Elevation (ft AMSL)	6/16/2016 Depth to Water (feet)	6/16/2016 Water Elevation (ft AMSL)	9/29/2016 Depth to Water (feet)	9/29/2016 Water Elevation (ft AMSL)	12/22/2016 Depth to Water (feet)	12/22/2016 Water Elevation (ft AMSL)	5/18/2017 Depth to Water (feet)	5/18/2017 Water Elevation (ft AMSL)	6/27/2017 Depth to Water (feet)	6/27/2017 Water Elevation (ft AMSL)
Monitoring Wells															
MW-2	592.34	--	--	--	--	--	--	--	--	--	--	4.16	588.18	--	--
MW-3	591.42	--	--	--	--	--	--	--	--	--	--	3.63	587.79	--	--
Piezometers															
PZ-1	589.12	6.34	582.78	6.43	582.69	6.58	582.54	6.36	582.76	6.78	582.34	6.12	583.00	--	--
PZ-2	588.24	5.87	582.37	5.97	582.27	5.97	582.27	5.71	582.53	6.21	582.03	5.80	582.44	--	--
PZ-3	588.97	7.34	582.37 (2)	7.79	582.29 (2)	6.54	582.45 (2)	6.40	582.66 (2)	9.31	581.99 (2)	8.22	582.47 (2)	7.51	582.38 (2)
PZ-4	590.86	7.44	583.42 (2)	7.38	583.56 (2)	7.66	583.20 (2)	8.56	583.05 (2)	8.88	582.56 (2)	7.66	584.87 (2)	7.79	583.28 (2)
PZ-5	589.24	6.95	582.33 (2)	8.36	582.16 (2)	8.97	582.19 (2)	7.52	582.49 (2)	10.44	581.80 (2)	9.63	582.18 (2)	7.73	582.34 (2)
PZ-6	587.98	8.36	582.01 (2)	6.84	582.00 (2)	6.51	582.22 (2)	6.35	582.49 (2)	7.82	581.72 (2)	6.45	582.45 (2)	6.47	582.29 (2)
PZ-7	588.43	6.84	582.94 (2)	6.76	583.06 (2)	7.47	582.93 (2)	7.10	583.03 (2)	9.15	582.41 (2)	7.69	583.39 (2)	7.00	583.10 (2)
PZ-8	587.51	5.26	582.25	5.25	582.26	5.12	582.39	4.82	582.69	5.61	581.90	4.85	582.66	--	--
PZ-9	587.90	7.33	582.22 (2)	7.41	582.23 (2)	7.22	582.40 (2)	6.22	582.66 (2)	9.18	581.83 (2)	6.79	582.57 (2)	6.60	582.51 (2)
PZ-10	587.14	3.89	583.25	3.98	583.16	4.03	583.11	3.74	583.40	4.43	582.71	3.36	583.78	--	--
PZ-11	586.42	2.28	584.14	2.33	584.09	2.64	583.78	2.37	584.05	3.01	583.41	1.57	584.85	--	--
PZ-12	587.94	3.04	584.90	2.99	584.95	3.55	584.39	3.50	584.44	3.87	584.07	2.15	585.79	--	--
Staff Gauges															
SG-1-17 (south culvert)	586.49	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-2-17 (mid-culvert)	586.28	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-3-17 (North Culvert)	585.56	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Notes:

(1) ft AMSL - feet above mean sea level
(2) Correct Water Elevation due to the presence of LNAPL
NAVD88 - Datum for Elevations
NA - not available
Reference elevations surveyed by C. M. Lavoie on June 2, 2017

Table 3.1

Gauging Summary
Cline Avenue Oil Spill Site
Gary, Indiana

Location ID	Reference Elevation (ft AMSL)[1]	6/29/2017 Depth to LNAPL (feet)	6/29/2017 LNAPL Thickness (feet)	7/6/2017 Depth to LNAPL (feet)	7/6/2017 LNAPL Thickness (feet)	7/13/2017 Depth to LNAPL (feet)	7/13/2017 LNAPL Thickness (feet)	7/17/2017 Depth to LNAPL (feet)	7/17/2017 LNAPL Thickness (feet)	7/24/2017 Depth to LNAPL (feet)	7/24/2017 LNAPL Thickness (feet)	7/27/2017 Depth to LNAPL (feet)	7/27/2017 LNAPL Thickness (feet)	8/10/2017 Depth to LNAPL (feet)	8/10/2017 LNAPL Thickness (feet)	8/14/2017 Depth to LNAPL (feet)	8/14/2017 LNAPL Thickness (feet)
Monitoring Wells																	
MW-2	592.34	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	591.42	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Piezometers																	
PZ-1	589.12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-2	588.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-3	588.97	6.51	1.10	6.43	0.88			6.29	0.69	5.99	0.82	--	--	--	--	6.30	0.62
PZ-4	590.86	7.76	0.26	7.71	0.60			7.66	1.25	7.37	1.03	--	--	--	--	7.68	1.43
PZ-5	589.24	6.81	0.87	6.65	0.77			6.58	0.79	6.30	0.82	--	--	--	--	6.61	0.71
PZ-6	587.98	5.60	0.54	5.51	0.70			5.39	0.89	5.01	1.06	--	--	--	--	5.33	0.97
PZ-7	588.43	5.17	1.66	5.14	1.65			5.10	1.71	4.86	1.06	--	--	--	--	5.14	2.13
PZ-8	587.51	--	--		--				--	--	--	--	--	--	--	--	--
PZ-9	587.90	5.26	1.53	5.21	1.46			5.16	1.54	4.75	1.06	--	--	--	--	5.05	1.40
PZ-10	587.14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-11	586.42	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-12	587.94	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Staff Gauges																	
SG-1-17 (south culvert)	586.49	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-2-17 (mid-culvert)	586.28	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-3-17 (North Culvert)	585.56	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Location ID	Reference Elevation (ft AMSL)[1]	6/29/2017 Depth to Water (feet)	6/29/2017 Water Elevation (ft AMSL)	7/6/2017 Depth to Water (feet)	7/6/2017 Water Elevation (ft AMSL)	7/13/2017 Depth to Water (feet)	7/13/2017 Water Elevation (ft AMSL)	7/17/2017 Depth to Water (feet)	7/17/2017 Water Elevation (ft AMSL)	7/24/2017 Depth to Water (feet)	7/24/2017 Water Elevation (ft AMSL)	7/27/2017 Depth to Water (feet)	7/27/2017 Water Elevation (ft AMSL)	8/10/2017 Depth to Water (feet)	8/10/2017 Water Elevation (ft AMSL)	8/14/2017 Depth to Water (feet)	8/14/2017 Water Elevation (ft AMSL)
Monitoring Wells																	
MW-2	592.34	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6.42	585.92
MW-3	591.42	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.84	585.58
Piezometers																	
PZ-1	589.12	--	--	--	--	--	--	--	--	--	--	6.05	583.07	--	--	6.32	582.80
PZ-2	588.24	--	--	--	--	--	--	--	--	--	--	5.48	582.76	--	--	5.65	582.59
PZ-3	588.97	7.61	582.35 (2)	7.31	582.45 (2)	--	--	6.98	582.61 (2)	6.81	582.90 (2)	--	--	--	--	6.92	582.61 (2)
PZ-4	590.86	8.02	583.07 (2)	8.31	583.09 (2)	--	--	8.91	583.08 (2)	8.40	583.39 (2)	--	--	--	--	9.11	583.04 (2)
PZ-5	589.24	7.68	582.34 (2)	7.42	582.51 (2)	--	--	7.37	582.58 (2)	7.12	582.86 (2)	--	--	--	--	7.32	582.56 (2)
PZ-6	587.98	6.14	582.33 (2)	6.21	582.40 (2)	--	--	6.28	582.50 (2)	6.07	582.86 (2)	--	--	--	--	6.30	582.55 (2)
PZ-7	588.43	6.83	583.09 (2)	6.79	583.13 (2)	--	--	6.81	583.16 (2)	5.92	583.46 (2)	--	--	--	--	7.27	583.08 (2)
PZ-8	587.51	--	--	--	--	--	--	--	--	--	--	4.61	582.90	--	--	4.78	582.73
PZ-9	587.90	6.79	582.49 (2)	6.67	582.54 (2)	--	--	6.70	582.59 (2)	5.81	583.04 (2)	--	--	--	--	6.45	582.71 (2)
PZ-10	587.14	--	--	--	--	--	--	--	--	--	--	3.54	583.60	--	--	3.86	583.28
PZ-11	586.42	--	--	--	--	--	--	--	--	--	--	2.21	584.21	--	--	2.68	583.74
PZ-12	587.94	--	--	--	--	--	--	--	--	--	--	3.19	584.75	--	--	3.78	584.16
Staff Gauges																	
SG-1-17 (south culvert)	586.49	--	--	4.41	582.08	4.32	582.17	4.27	582.22	4.00	582.49	--	--	4.34	582.15	4.25	582.24
SG-2-17 (mid-culvert)	586.28	--	--	4.17	582.11	4.09	582.19	4.06	582.22	3.79	582.49	--	--	4.10	582.18	4.06	582.22
SG-3-17 (North Culvert)	585.56	--	--	3.44	582.12	3.34	582.22	3.30	582.26	3.04	582.52	--	--	3.31	582.25	3.27	582.29

Notes:

(1) ft AMSL - feet above mean sea level
(2) Correct Water Elevation due to the presence of LNAPL
NAVD88 - Datum for Elevations
NA - not available
Reference elevations surveyed by C. M. Lavoie on June 2, 2017

Table 6.1

Alternative 1 - Continue Current Approach - Cost Estimate
Cline Avenue Oil Spill Site
Glenn Springs Holdings
Gary, Indiana

Item	Task	Quantity	Unit	Unit Cost	Cost
Annual Operation and Maintenance Costs					
1.	Boom Maintenance in Ditch (weekly maintenance for 8 months, twice a week maintenance for 4 months, and required reporting)	82	per visit	$ 2,500	$ 205,000
2.	Brush Clearing (for access to ditch)	1	L.S	$ 8,730	$ 8,730
3.	Bird Deterrents	1	L.S	$ 13,865	$ 13,865
4.	Aquatic Vegetation Control	1	L.S.	$ 7,703	$ 7,703
	Total Estimated Annual Operation and Maintenance Cost				$ 235,000
Total Present Costs					
	Boom Maintenance in Ditch (discount factor of 0.4% for 30 years)				$ 5,784,446
	Brush Clearing (for access to ditch) (discount factor of 0.4% for 30 years)				$ 246,319
	Bird Deterrents (discount factor of 0.4% for 30 years)				$ 391,212
	Aquatic Vegetation Control (discount factor of 0.4% for 30 years)				$ 217,340
	Total Present Costs (1)				$ 6,639,000

Notes:

(1) Total Costs have been rounded to three significant figures.
L.S. Lump Sum
Interest rates: https://www.whitehouse.gov/wp-content/uploads/2019/12/M-20-07.pdf

Table 6.2

Alternative 2 - Line Ditch with HDPE Liner - Cost Estimate
Cline Avenue Oil Spill Site
Glenn Springs Holdings
Gary, Indiana

Item	Task	Quantity	Unit	Unit Cost	Cost
Capital Costs - HDPE Liner (Design Life of 20 years)					
1.	Mobilization/Demobilization	1	L.S	$ 118,619	$ 118,619
2.	Site Setup (General Conditions, Erosion Controls, Staging Areas, surveying)	1	L.S	$ 162,266	$ 162,266
3.	Creek By-Pass System (setup and operations, assumed 10,000 gpm)	1	L.S	$ 369,720	$ 369,720
4.	Water Treatment (setup, operations, carbon	1	L.S	$ 71,890	$ 71,890
5.	Excavation	1800	cubic yard	$ 102.70	$ 184,900
6.	Liner (GCL, HDPE Liner, Geotextile over Liner, Sand fill, fabric form concrete)	900	linear feet	$ 684.66	$ 616,200
7.	Install pipe within culvert	75	feet	$ 1,027	$ 77,025
8.	Transportation and Disposal of Sediment	3000	ton	77.03	231,100
9.	Transportation and Disposal of Water	25000	gallons	0.94	23,600
				Subtotal	$ 1,855,320
				Contingency (20%)	$ 371,100
				Engineering and Oversight (8%)	$ 148,400
				Total Estimated Capital Cost	$ 2,375,000
Future Capital Costs					
1.	HDPE Liner Re-installation (at year 20)				$ 2,375,000
Annual Operation and Maintenance Costs					
1.	Monitoring/Inspections	12	per event	$ 514	$ 6,162
2.	Semi-Annual Reporting	2	L.S	$ 2567.5	$ 5,135
				Estimated Annual Operation and Maintenance Cost	$ 11,297
				Contingency (20%)	$ 2,259
				Total Estimated Annual Operation and Maintenance Cost	$ 13,600

Table 6.2

Alternative 2 - Line Ditch with HDPE Liner - Cost Estimate
Cline Avenue Oil Spill Site
Glenn Springs Holdings
Gary, Indiana

Item	Task	Quantity	Unit	Unit Cost		Cost
Total Present Costs						
	Capital Cost - HDPE Liner				$	2,375,000
	Future Capital Cost - Replacement HDPE Liner (discount factor of 0.4% for 20 years)					2,192,751
	Monitoring/Inspections (discount factor of 0.4% for 30 years)				$	208,646
	Semi-Annual Reporting (discount factor of 0.4% for 30 years)				$	173,872
				Total Present Costs (1)	$	4,950,000

Notes:

(1) Total Costs have been rounded to three significant figures
cu yd cubic yard
ft feet
L.S. Lump Sum
Interest rates: https://www.whitehouse.gov/wp-content/uploads/2019/12/M-20-07.pdf

Table 6.3

Alternative 3 - Install Storm Sewer in Ditch and Backfill Ditch with Soil - Cost Estimate
Cline Avenue Oil Spill Site
Glenn Springs Holdings
Gary, Indiana

Item	Task	Quantity	Unit	Unit Cost	Cost
Capital Costs					
1.	Mobilization/Demobilization	1	L.S	$ 118,619	$ 118,619
2.	Site Setup (General Conditions, Erosion Controls, Staging Areas, surveying)	1	L.S	$ 162,266	$ 162,266
3.	Creek By-Pass System (setup and operations, assumed 10,000 gpm)	1	L.S	$ 369,720	$ 369,720
4.	Water Treatment (setup, operations, carbon)	1	L.S	$ 82,160	$ 82,160
5.	Excavation/Grading Ditch	1800	cubic yard	$ 102.70	$ 184,900
6.	Culvert Pipe Install (900 lineal feet, including 1,110 cubic yard of sand fill)	900	linear feet	$ 491.13	$ 442,000
7.	Culvert Connection at downstream end	1	L.S.	$ 205,400	205,400
8.	Cut-off Wall (25' long x 20' deep)	500	sq.ft.	$ 10.27	5,135
9.	Transportation and Disposal of Sediment	3000	ton	$ 77.03	231,100
10.	Transportation and Disposal of Water	25000	gallons	$ 0.94	23,600
11.	Seeding and Restoration	1	L.S.	$ 20,540	20,500
				Subtotal	$ 1,845,400
				Engineering and Oversight (8%)	147,600
				Contingency (20%)	$ 369,100
				Total Estimated Capital Cost	$ 2,362,000
Annual Operation and Maintenance Costs					
1.	Monitoring/Inspections	12	per event	$ 514	$ 6,162
2.	Semi-Annual Reporting	2	L.S	$ 2567.5	$ 5,135
				Estimated Annual Operation and Maintenance Cost	$ 11,297
				Contingency (20%)	$ 2,259
				Total Estimated Annual Operation and Maintenance Cost	$ 13,600

Table 6.3

Alternative 3 - Install Storm Sewer in Ditch and Backfill Ditch with Soil - Cost Estimate
Cline Avenue Oil Spill Site
Glenn Springs Holdings
Gary, Indiana

Item	Task	Quantity	Unit	Unit Cost		Cost
Total Present Costs						
	Capital Cost - Culvert Pipe				$	2,362,000
	Monitoring/Inspections (discount factor of 0.4% for 30 years)				$	208,646
	Semi-Annual Reporting (discount factor of 0.4% for 30 years)				$	173,872
				Total Present Costs (1)	$	2,745,000

Notes:

(1) Total Costs have been rounded to three significant figures
L.S. Lump Sum
Interest rates: https://www.whitehouse.gov/wp-content/uploads/2019/12/M-20-07.pdf

Table 6.4

Alternative 4 - Install Barrier Wall and Continue Boom Maintenance - Cost Estimate
Cline Avenue Oil Spill Site
Glenn Springs Holdings
Gary, Indiana

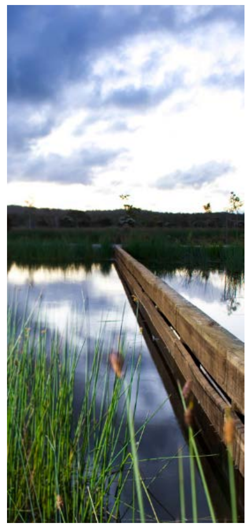
Item	Task	Quantity	Unit		Unit Cost		Cost
Capital Costs							
1.	Mobilization/Demobilization	1	L.S	$	51,350	$	51,350
2.	Site Setup (General Conditions, Erosion Controls, Staging Areas, surveying)	1	L.S	$	77,025	$	77,025
3.	Barrier Wall (slurry wall - 900' long x 20' deep)	18000	sq.ft.	$	10.27		184,860
4.	Transportation and Disposal of Soil	1500	ton	$	77.03		115,500
5.	Seeding and Restoration	1	L.S.	$	20,540		20,500
					Subtotal	$	449,235
					Engineering and Oversight (8%)		35,900
					Contingency (20%)	$	89,800
					Total Estimated Capital Cost	$	575,000
Annual Operation and Maintenance Costs							
1.	Boom Maintenance in Ditch (weekly maintenance for 8 months, twice a week maintenance for 4 months, and required reporting)	82	per visit	$	2,500	$	205,000
2.	Brush Clearing (for access to ditch)	1	L.S	$	8,730	$	8,730
3.	Bird Deterrents	1	L.S	$	13,865	$	13,865
4.	Aquatic Vegetation Control	1	L.S.	$	7,703	$	7,703
					Total Estimated Annual Operation and Maintenance Cost	$	235,000
Total Present Costs							
	Capital Cost - Barrier Wall					$	575,000
	Boom Maintenance in Ditch (discount factor of 0.4% for 30 years)					$	5,784,446
	Brush Clearing (for access to ditch) (discount factor of 0.4% for 30 years)					$	246,319
	Bird Deterrents (discount factor of 0.4% for 30 years)					$	391,212
	Aquatic Vegetation Control (discount factor of 0.4% for 30 years)					$	217,340
					Total Present Costs [1]	$	7,214,000

Notes:

(1) Total Costs have been rounded to three significant figures.
L.S. Lump Sum
Interest rates: https://www.whitehouse.gov/wp-content/uploads/2019/12/M-20-07.pdf

Appendices

Appendix A
Design Investigation Report



Design Investigation Report

Cline Avenue Oil Spill Site
Gary, Indiana

Glenn Springs Holdings (GSH)

GHD | 085886 | Report No 3 | September 19 2017

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Appendix Index

1. Introduction

On behalf of Glenn Springs Holdings (GSH), a subsidiary of Occidental Petroleum Corporation, GHD Services Inc. (GHD) has prepared this Design Investigation Report (Report) to summarize the results from implementation of the Design Investigation/Focused Feasibility Study (DI/FFS) Work Plan for the Cline Avenue Oil Spill Site, in Gary, Indiana. The Report has been prepared in accordance with the Administrative Order on Consent (AOC) dated March 3, 2017 between Oxy USA, Inc. and United States Environmental Protection Agency (USEPA) Region V (RCRA-05-2017-0009). Figure 1.1 presents the investigation area location and Figure 1.2 presents the investigation area plan.

As detailed in the AOC and further agreed upon by USEPA and GSH attorneys, the purpose of this study was to investigate LNAPL seeps to the Cline Avenue ditch and to collect additional information in support of a feasibility assessment for potential remedial actions designed to mitigate petroleum sheens from continuing to impact the ditch.

This report has been prepared in accordance with Section III – B of the Scope of Work (SOW) provided in the AOC. The outline is as follows:

Section 1 Introduction

Section 2 Design Investigation Activity Summary

Section 3 Conclusions and Recommendation

2. Design Investigation Activity Summary

The following sections summarize activities associated with assessing the extent of mobile LNAPL contributing to the Cline Avenue ditch and in support of the development of a feasibility assessment for potential remedial actions associated with preventing petroleum sheens from impacting the ditch in accordance with AOC.

2.1 Investigation Area Mapping

Investigation area mapping activities were completed to generate accurate figures depicting critical features including: seep locations, piezometer/well locations, buried pipelines/utilities, topography, etc. Investigation area mapping activities included both topographic geophysical surveys.

2.1.1 Topographic Mapping

A topographic survey of the investigation area was conducted between May 24th to May 26th, 2017 by C.M. Lavoie and Associates. The survey was completed in the Indiana West State Plane NAD83 horizontal coordinate system and the NAVD 88 vertical datum. The survey information obtained included the following:

- Piezometer, monitoring well, and staff gauge locations and elevations
- Seep locations and extents

- Ditch (top and bottom of bank and bridge/culverts)
- Proposed laser induced fluorescence (LIF) boring locations
- Utility locations (overhead and buried – based on existing pipeline markings)
- Spot elevations at 50-foot grid across investigation area (relatively flat ranging from 587 to 591 ft above mean sea level (AMSL))
- Setting three staff gauges at the culverts
- Other investigation area features including but not limited to: fencing, guard rails, edge of Cline Avenue Road

C.M. Lavoie remobilized to the Site on July 27, 2017 to survey the buried utility lines marked out by Blood Hound, additional spot elevations in and around the ditch, and final LIF boring locations that were adjusted due to utilities or accessibility. This information was used to complete an updated investigation area map, as presented on Figure 2.1.

2.1.2 Utility Clearances/Buried Utility Mapping

Utility clearance services were conducted to identify location, extent and configuration for mapping, and to provide assurance that they would not be contacted during intrusive investigations. In addition, data collected from the ground penetrating radar (GPR) survey tools were evaluated to determine if other subsurface information could be determined (e.g. presence of LNAPL, thickness, etc.). These services were provided by Blood Hound, Inc. (Blood Hound) from July 5th to 7th, 2017.

Utility clearance was completed using a Metrotech Vivax vLoc Pro 1 multi-frequency receiver and transmitter combination. Traditional electro-magnetic (EM) locating operations were conducted by attaching the transmitter to a target utility which then applied an electric current to the target line which generated a radio field around the target line at a specific frequency. For utilities where no connections were available, the signal was applied using inductive methods by generating a strong magnetic field at the surface which then induces a current onto the target utility. All utilities identified within the investigation area were marked with paint. These areas were subsequently surveyed per Section 2.1.1.

The following utilities were located in the investigation area:

- Buckeye Petroleum Pipeline
- BP Petroleum Pipeline
- NIPSCO Gas Pipeline
- Two underground electrical lines and
- Overhead electrical lines

In addition to the subsurface utilities identified above, two vertical 4-inch steel pipes, were identified. (see photos in Appendix A). The equipment Blood Hound was using could not trace the depth or direction of these pipes.

Individual LIF boring locations were cleared in the western most North-South row (refer to Figure 2.5). For the remaining LIF boring locations, 10' wide corridors were cleared in a grid pattern to provide flexibility to move LIF borings, should the real-time LIF field data require a change to the proposed locations.

On July 7th, 2017, advanced GPR surveying was performed by Blood Hound utilizing a SIR 4000 GPR unit with a 350 MHz antenna to determine whether the GPR data correlated with the LNAPL identified at the piezometers (P3, P4, P5, P6, P7, and P9) with measureable LNAPL (see Figure 2.5). Advanced GPR data was collected along 10 profiles aligned with the piezometers in the North-South direction, which covered the distances between piezometers 1 through 10. The data was provided to Environmental Geophysics Associates (EGA) for processing and is further discussed in Section 2.1.3.

2.1.3 Geophysical Analysis

The data collected from the advanced GPR survey was reviewed and assessed by EGA to determine if a better understanding of subsurface conditions could be obtained from the data.

Upon review, there was no reliable correlation between the advanced GPR survey data and Site conditions such as the presence or absence of LNAPL (e.g., as indicated by current/historical piezometer monitoring data). A copy of EGA's report is provided in Appendix B.

2.2 Investigation Observations

A GHD's LNAPL subject matter expert conducted a Site visit on July 12, 2017 to oversee the LIF boring installations and to observe conditions influencing LNAPL movement into the ditch. The following observations were made:

- The LIF borings are identifying hydrocarbon responses across most of the investigation area.
- Similar hydrocarbon responses have been identified across the investigation area as well as next to some of the piezometers that do not have measureable LNAPL. Therefore, the potential for LNAPL to be hydraulically mobile across the investigation area is not significant.
- Sheen/LNAPL is entering the ditch laterally from the sidewalls, which is likely from LNAPL in the immediate vicinity of the ditch.
- Sheen/LNAPL is also entering the ditch vertically from the bottom of the ditch through a process called ebullition (pressure/air bubbles dislodge otherwise immobile LNAPL).

2.3 LNAPL Fingerprint Analysis

In order to better understand the type and distribution of LNAPL, six samples of LNAPL were collected from existing piezometers with sufficient LNAPL during the initial gauging activities. The six samples were submitted to Pace Analytical Energy Services Laboratory for both chemical and physical property analysis.

2.3.1 Chemical Property Analysis

The six LNAPL samples were submitted on June 28th, 2017 and analyzed for C3 to C36 whole oil molecular characterization gas chromatography "fingerprint" by GC/FID as well as C8 to C40 full scan qualitative molecular characterization by GC/MS (refer to lab methods). The results of the chemical analysis are summarized in Appendix C.1. The following observations were made regarding analysis of the chromatograms:

- The chromatograms appear to show similar age and types of hydrocarbon material
- LNAPL samples appear to contain a wide mixture of hydrocarbons
- The hydrocarbon mixture appears to consist of weathered gasoline, weathered diesel, and heavier hydrocarbon material (e.g., weathered crude oil)

2.3.2 Physical Property Analysis

The six LNAPL samples were submitted to Pace Analytical on June 26th, 2017 and analyzed for viscosity, surface tension and liquid properties. The analyses were subcontracted to Clark Testing. The results of the physical property analysis are summarized in Appendix C.2. The chemical and physical property analysis results were also analyzed by GSI Environmental Inc. (GSI). GSI's observations were consistent with GHD's observations. A copy of GSI's evaluation is provided in Appendix C.3.

Upon review of the physical property data, the observations made on the chemical property analysis did not change (i.e., specific gravity and viscosity results were comparable and consistent with the mixture of petroleum LNAPL types described in Section 2.3.1).

2.4 Groundwater Investigation

The groundwater investigation activities included periodic gauging of piezometers and monitoring wells for LNAPL/groundwater level measurements. In addition, surface water level measurements were measured from the three staff gauges along the ditch.

2.4.1 Water/LNAPL Level Monitoring

Water level/LNAPL measurements were collected in May and August from the twelve piezometers (PZ-1 to PZ-12) and from two monitoring wells (MW-2 and MW-3) to evaluate trends in LNAPL thickness and groundwater levels. Measurements were taken with a dual phase probe with electrical sounding device and accuracy of ±0.01 feet, to determine the depth to water or oil (where present) and oil-water interface. The date, depth to product, and depth to water was recorded, and used to calculate the LNAPL thickness (where present) and corrected groundwater elevation (where LNAPL was present). These results are summarized in Table 2.1. Figures 2.2, 2.3 and 2.4 present a graphical depiction of LNAPL thicknesses and water table elevations.

2.4.2 Surface Water Level Monitoring

Three staff gauges were set during the surveying activities conducted in late May 2017 along the ditch (SG-1, SG-2, and SG-3), which are shown on Figure 2.1. The staff gauges consist of surveyed markings on the existing bridges/culverts that cross the ditch. The staff gauges were used to measure surface water levels/elevations in the ditch for comparison to the groundwater elevations from the piezometers/wells. The use of the bridges/culverts was to ensure longevity of the staff gauges through freezing conditions. Ditch water levels/elevations were measured in August at the same time as the piezometers and monitoring wells. Measurements were taken with an electrical sounding device with an accuracy of ±0.01 feet. The depth to water and the date of measurement were recorded and are also summarized in Table 2.1.

2.5 LIF Investigation

An LIF investigation was conducted to assist in determining the horizontal and vertical extent of residual hydrocarbons in soil. A total of 29 LIF borings were completed by Dakota Technologies (Dakota) between July 10 and 14, 2017, with the greater concentration of borings being completed adjacent to the ditch and fewer borings being completed further to the east.

2.5.1 Methodologies

Prior to mobilization, a representative sample of LNAPL was submitted to Dakota Technologies (Dakota) to verify the appropriate laser to be used as part of the LIF investigation. Dakota identified that the Tar Green Optical Screening Tool (TarGOST) LIF system was the appropriate unit for this investigation. The TarGOST is typically used to investigate weathered or heavier types of hydrocarbons. The LIF probe was advanced in the subsurface using a GeoProbe™. As such, no soil cuttings were produced during the LIF investigation. Locations were backfilled with cement-bentonite grout immediately following the completion of each LIF push with the appropriate surface restoration.

The LIF probe is equipped with a sapphire window through which a laser is directed. The probe is advanced using a specialized direct-push probe. The laser light is adsorbed by hydrocarbons as the probe is advanced. This addition of energy (photons) causes hydrocarbons to release excess energy as light (fluoresce). A portion of the fluorescence emitted from any encountered hydrocarbons is returned through the sapphire window and conveyed by a fiber optic cable to a detection system at the surface. The emission data from the pulsed laser light is averaged into one reading per one-second intervals and is recorded continuously. The emission data is reported as percent of the fluorescence intensity of a "reference emitter" (%RE). The Reference Emitter is a standard proprietary hydrocarbon mixture used to calibrate the equipment, and LIF readings are a quantification of intensity relative to the fluorescence produced by it. For example, an LIF location producing a reading of 100%RE is fluorescing at exactly the same intensity as the standard hydrocarbon mixture. Other things being equal, LIF response is proportional to the amount of hydrocarbons present (i.e., LIF response is proportional to hydrocarbon saturation). In addition, the LIF instrumentation measures the intensities of four different wavelengths of light produced when a given hydrocarbon fluoresces. The proportions of each wavelength that comprise the overall fluorescence response are unique to a given petroleum product type and are referred to as the spectral fingerprint. These wave lengths are illustrated on the individual LIF logs for each location.

2.5.2 Findings

The LIF boring locations and maximum response at each boring is presented on Figure 2.5. The %RE ranged from 6.6 to 744, confirming the typical scenario of highly variable LNAPL saturation levels across an old LNAPL site. The highest %RE was observed at TG-21-17 (approximately 300' east of the ditch). Other elevated %RE readings were not consistent with a single source area which may indicated multiple source events or preferential migration pathways for the LNAPL. It is noted that the spacing of the LIF points in the Site interior was large enough that additional investigation may produce results that adjust this interpretation. The northern, eastern, and southern boundaries of the investigation had lower %RE.

The intensity of the responses broadly indicates residual hydrocarbon saturation levels. Most of the hydrocarbon responses, including some of the highest responses, are below the water table, which typically signifies that the LNAPL is largely immobile residual. This suggests that much of the impact to the ditch is resulting from residual LNAPL impacts in the vicinity of the ditch, and is not due to bulk movement of LNAPL from the interior of the Site towards the ditch currently.

A review of the spectral fingerprints from the LIF borings that are presented on the TarGOST output logs indicate a somewhat consistent mixture of LNAPL types across the Site.

3. Conceptual Site Model of LNAPL Transport

Historical data as well as the data recently collected have been analyzed to develop a conceptual site model. These data indicate that LNAPL is entering the ditch through two transport models:

1. Laterally from sidewalls – immediate vicinity of ditch and not as bulk movement internal to the Site (due to the lack of resistance at the ditch bank surface that allows residual LNAPL movement, whereas similarly saturated soil would not allow LNAPL movement in the interior of the Site).
2. Ebullition – pressure/air bubbles periodically dislodge otherwise immobile residual hydrocarbons from beneath the ditch.

The LNAPL is old and primarily located below the water table; therefore, the bulk of the Site LNAPL is likely to be present as hydraulically immobile residual. Ditch booming activities have documented generally stable conditions of oil entering the ditch for several years with some fluctuations.

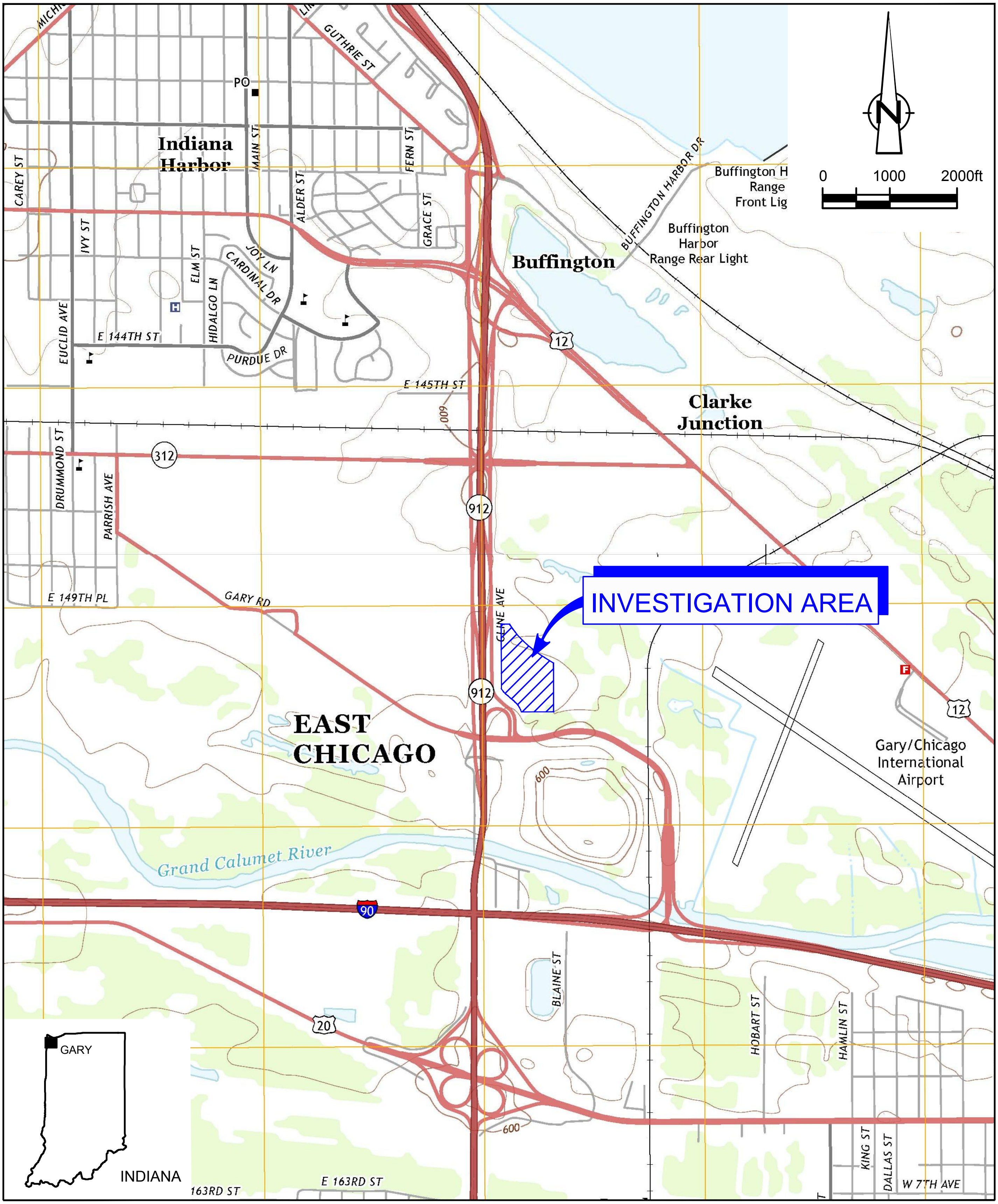
4. Conclusions

Evaluated data, including the LNAPL chromatograms, LNAPL physical property analysis, and the LIF results, indicate similar types/mixtures of hydrocarbons across the investigated area and a somewhat random geographic distribution and concentration gradient. The concentrations of hydrocarbons do not map from a centralized source. The concentration of mapped hydrocarbons appear higher near the existing hydrocarbon pipeline infrastructure.

The LIF results identified the presence of residual hydrocarbons across the area that was investigated, however, most of the LIF hydrocarbon responses were below the water table, which typically signifies that it the residual hydrocarbons are immobile.

Visual observation of LNAPL entering the ditch identified that LNAPL was entering the ditch both through lateral seepage and vertically from the bottom of the ditch through a process called ebullition.

Additional preliminary design investigation (PDI) activities are planned to support the evaluation of potential remedial alternatives.



Source: USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE; HIGHLAND AND WHITING, INDIANA 2013

CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

85886-D21105
Aug 30, 2017

INVESTIGATION AREA LOCATION

FIGURE 1.1

CAD File: P:\drawings\85000s\85886\85886-REPORT\85886-D21105(003)\85886-D21105(003)GN\85886-D21105(003)GN-WA003.dwg

LEGEND

- LIMITS OF CLINE DITCH
- NORTH — SEEP LOCATION (2017)
- E — SURVEYED UNDERGROUND ELECTRICAL LINE
- OH — SURVEYED OVERHEAD WIRE
- G — SURVEYED NIPSCO UNDERGROUND UTILITY LINE
- G — SURVEYED BP UNDERGROUND UTILITY LINE
- G — SURVEYED BUCKEYE UTILITY LINE

Source: AERIAL IMAGE BY TERRASERVER, 0.5m RESOLUTION, 2016-10-23.

0 200 400ft

Coordinate System: INDIANA WEST STATE PLANE NAD83

N

GHD

CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

INVESTIGATION AREA PLAN

85886-D21105
Jun 15, 2018

FIGURE 1.2

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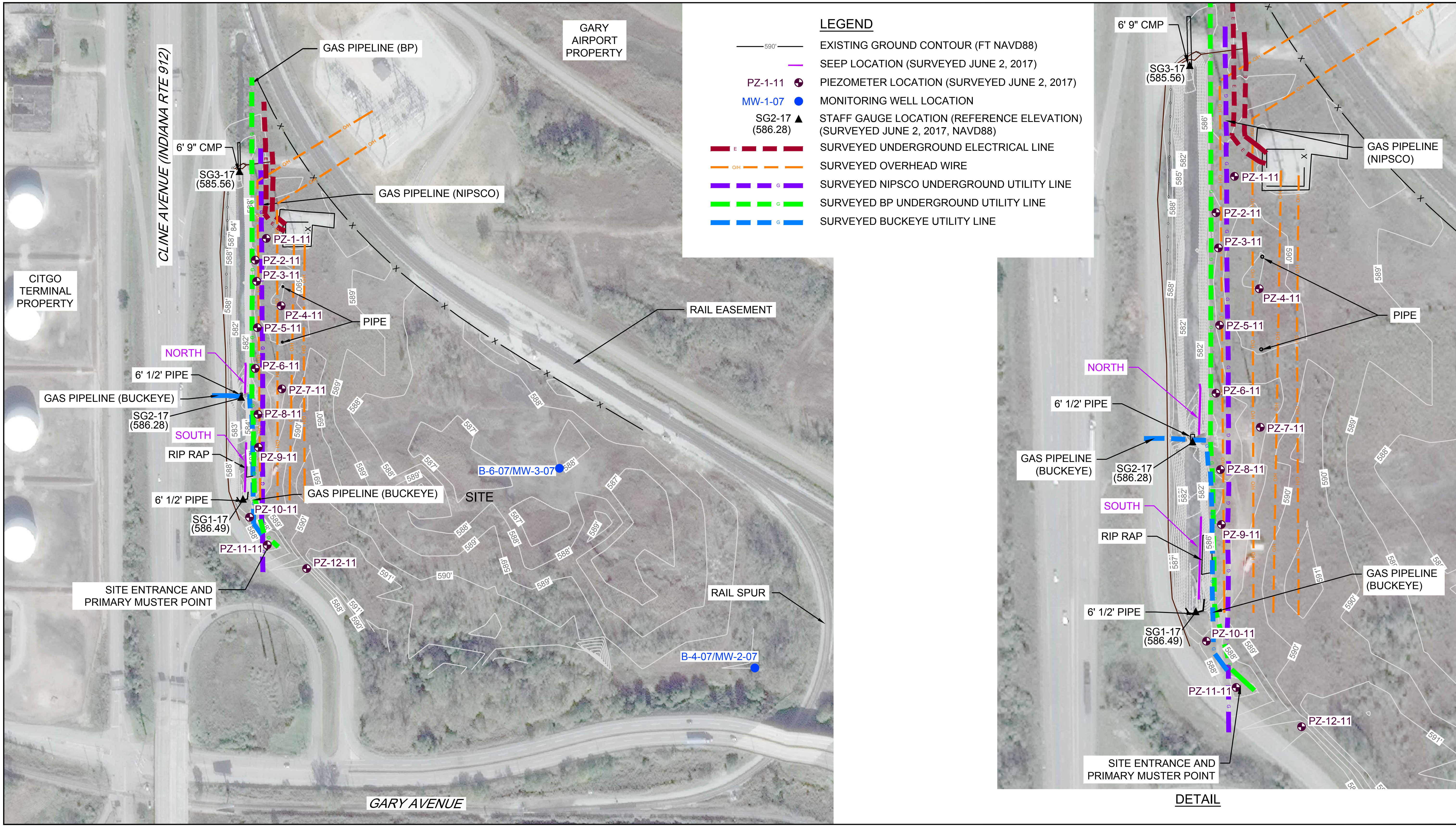

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0 125 250ft

Coordinate System: INDIANA WEST STATE PLANE NAD83

CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

BASE MAP

85886-D21105
Jun 15, 2018

FIGURE 2.1

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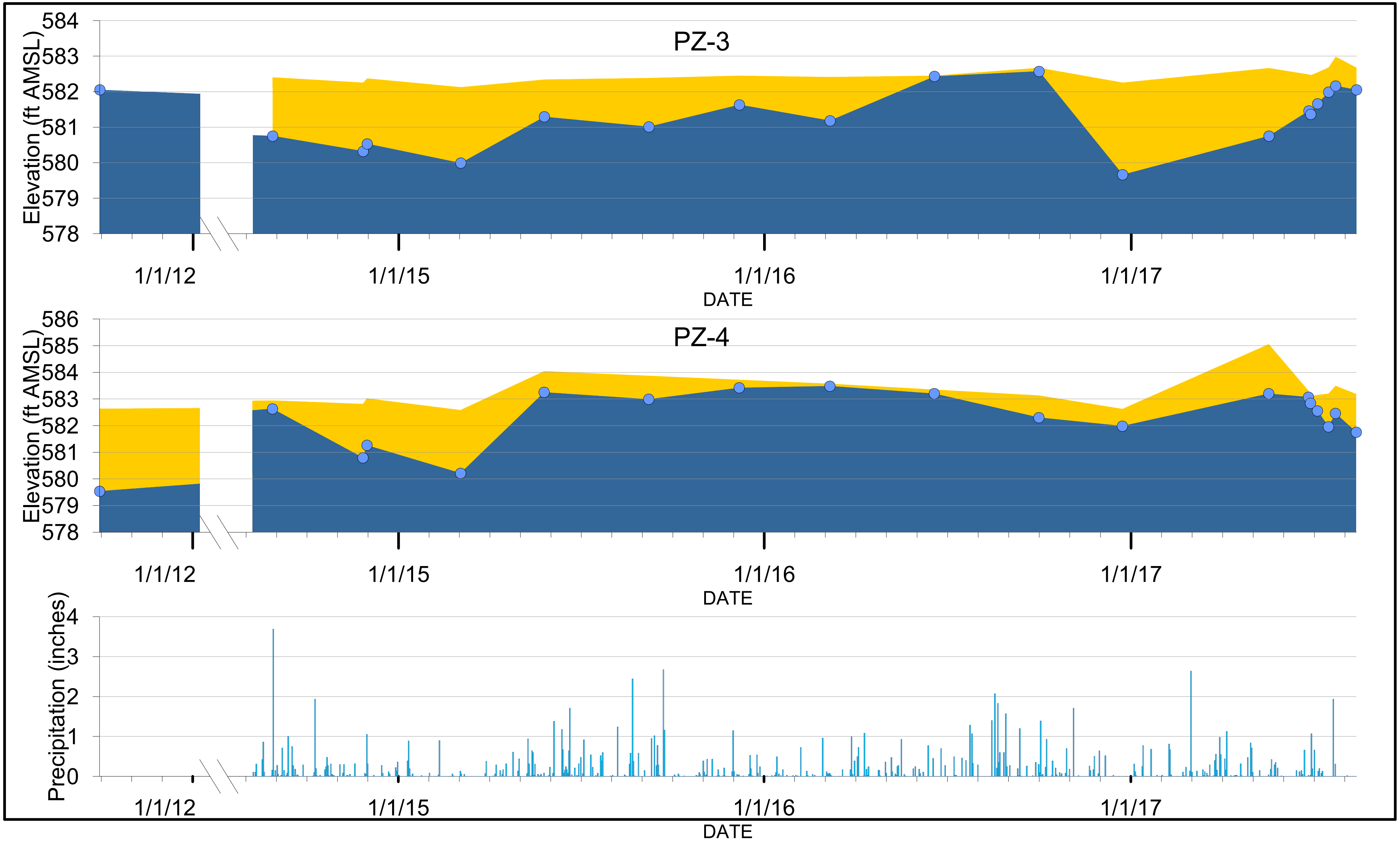

LEGEND
- LNAPL
- Groundwater
- Manual Reading

CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

085886-D21101
Aug 31, 2017

IN-WELL LNAPL THICKNESS AT PZ-3 AND PZ-4

FIGURE 2.2

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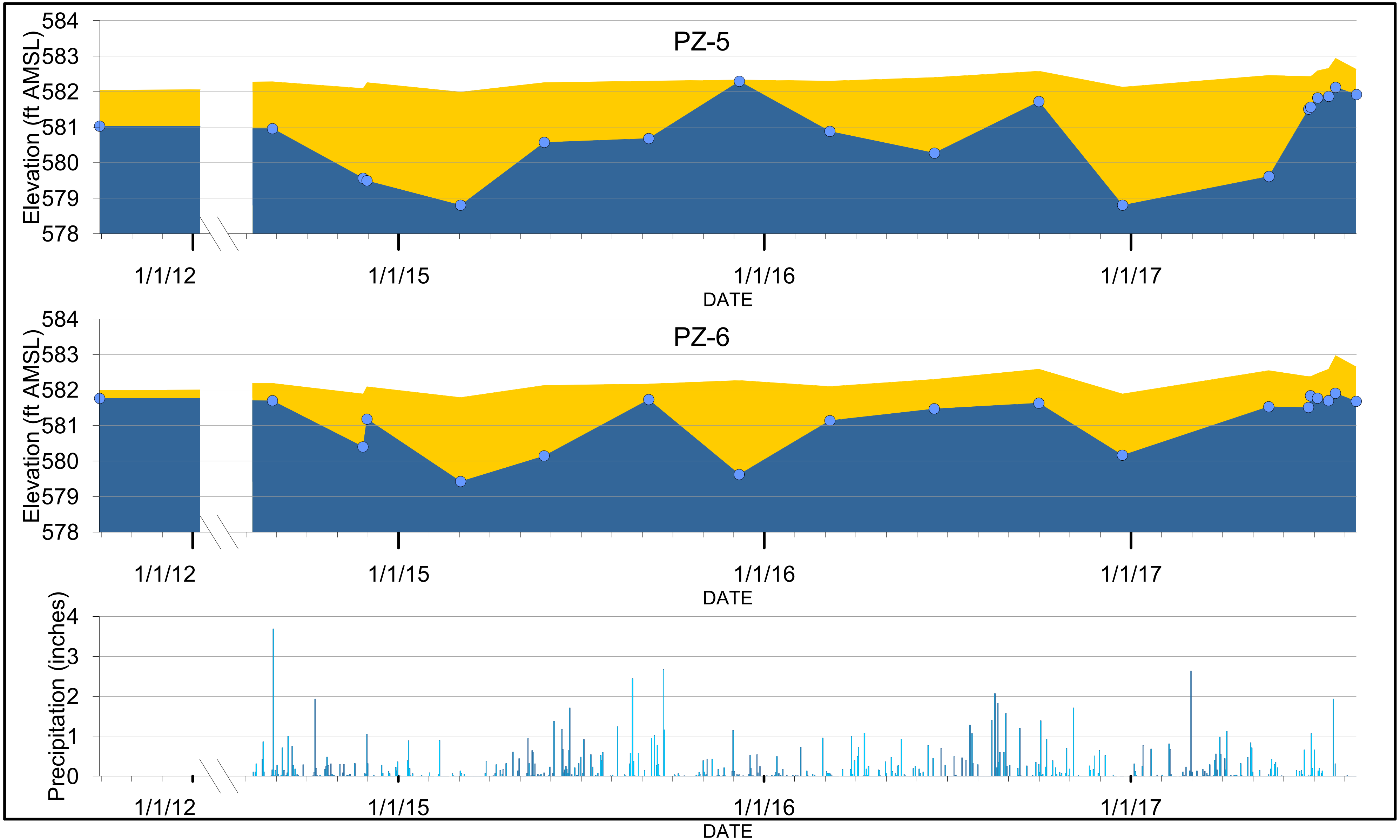


LEGEND
LNAPL
Groundwater
Manual Reading

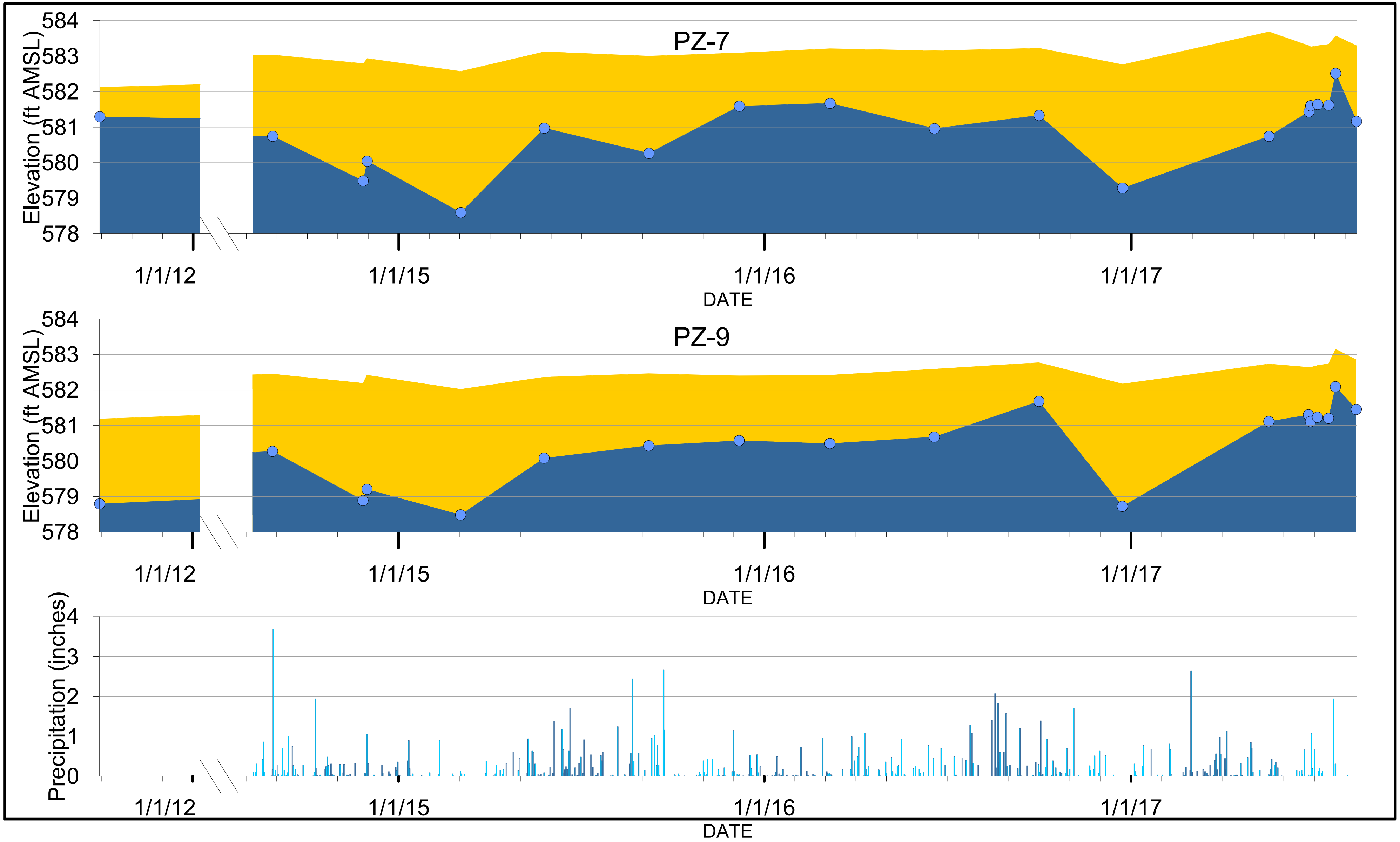
CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

085886-D21101
Aug 31, 2017

IN-WELL LNAPL THICKNESS AT PZ-5 AND PZ-6

FIGURE 2.3

WAT file: I:\IKRGROUP\6-chars\08----\85886-Cline Avenue Ditch\85886 - Data, Analysis\GRAPHER\85886-LNAPL Figure 2.3.grf



CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

085886-D21101
Aug 31, 2017

IN-WELL LNAPL THICKNESS AT PZ-7 AND PZ-9

FIGURE 2.4

WAT file: I:\IKRGROUP\6-chars\08----\85886-Cline Avenue Ditch\85886 - Data, Analysis\GRAPHER\85886-LNAPL Figure 2.4.grf

Source: CM LAVOIE & ASSOCIATES, INC., SURVEY DATED JUNE 2, 2017, UPDATED JULY 27, 2017 (INDIANA WEST NAD83, NAVD88). AERIAL IMAGE BY TERRASERVER, 0.5m RESOLUTION, 2016-10-23.

0 100 200ft

Coordinate System: INDIANA WEST STATE PLANE NAD83

CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

LASER INDUCED FLUORESCENCE RESULTS

85886-D21105
Aug 31, 2017

FIGURE 2.5

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Table 2.1

Gauging Summary
Cline Avenue Oil Spill Site
Gary, Indiana

Location ID	Reference Elevation (ft AMSL)[1]	9/30/2011 Depth to LNAPL (feet)	9/30/2011 LNAPL Thickness (feet)	8/21/2014 Depth to LNAPL (feet)	8/21/2014 LNAPL Thickness (feet)	11/20/2014 Depth to LNAPL (feet)	11/20/2014 LNAPL Thickness (feet)	11/24/2014 Depth to LNAPL (feet)	11/24/2014 LNAPL Thickness (feet)	2/26/2015 Depth to LNAPL (feet)	2/26/2015 LNAPL Thickness (feet)	5/21/2015 Depth to LNAPL (feet)	5/21/2015 LNAPL Thickness (feet)	9/3/2015 Depth to LNAPL (feet)	9/3/2015 LNAPL Thickness (feet)
Monitoring Wells															
MW-2	592.34	--	--	--	--	--	--	--	--						
MW-3	591.42	--	--	--	--	--	--	--	--						
Piezometers															
PZ-1	589.12	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-2	588.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-3	588.97	--	--	6.57	1.65	6.72	1.93	6.60	1.84	6.85	2.13	6.63	1.05	6.59	1.37
PZ-4	590.86	8.23	3.09	7.92	0.31	8.05	2.02	7.84	1.76	8.28	2.37	6.82	0.79	NA	NA
PZ-5	589.24	7.20	1.01	6.96	1.32	7.15	2.53	6.98	2.77	7.25	3.19	6.98	1.69	6.94	1.62
PZ-6	587.98	5.99	0.23	5.79	0.49	6.09	1.49	5.89	0.91	6.19	2.37	5.85	1.99	5.81	0.44
PZ-7	588.43	6.31	0.83	5.40	2.29	5.64	3.31	5.50	2.89	5.86	3.98	5.31	2.15	5.43	2.74
PZ-8	587.51	7.12	1.23	--	--	--	--	--	--	--	--	--	--	--	--
PZ-9	587.90	6.72	2.39	5.45	2.18	5.71	3.30	5.48	3.22	5.88	3.54	5.54	2.28	5.44	2.03
PZ-10	587.14	7.11	1.46	--	--	--	--	--	--	--	--	--	--	--	--
PZ-11	586.42	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-12	587.94	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Staff Gauges															
SG-1-17 (south culvert)	586.49	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-2-17 (mid-culvert)	586.28	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-3-17 (North Culvert)	585.56	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Location ID	Reference Elevation (ft AMSL)[1]	9/30/2011 Depth to Water (feet)	9/30/2011 Water Elevation (ft AMSL)	8/21/2014 Depth to Water (feet)	8/21/2014 Water Elevation (ft AMSL)	11/20/2014 Depth to Water (feet)	11/20/2014 Water Elevation (ft AMSL)	11/24/2014 Depth to Water (feet)	11/24/2014 Water Elevation (ft AMSL)	2/26/2015 Depth to Water (feet)	2/26/2015 Water Elevation (ft AMSL)	5/21/2015 Depth to Water (feet)	5/21/2015 Water Elevation (ft AMSL)	9/3/2015 Depth to Water (feet)	9/3/2015 Water Elevation (ft AMSL)
Monitoring Wells															
MW-2	592.34	-	-	-	-	-	-	4.64	587.70	--	--	--	--	--	--
MW-3	591.42	-	-	-	-	-	-	4.15	587.27	--	--	--	--	--	--
Piezometers															
PZ-1	589.12	6.81	582.31	6.61	582.51	6.73	582.39	6.63	582.49	6.93	582.19	6.52	582.60	6.61	582.51
PZ-2	588.24	6.16	582.08	6.02	582.22	6.15	582.09	6.03	582.21	6.31	581.93	5.99	582.25	6.00	582.24
PZ-3	588.97	6.92	582.05	8.22	582.24 (2)	8.65	582.06 (2)	8.44	582.19 (2)	8.98	581.91 (2)	7.68	582.24 (2)	7.96	582.24 (2)
PZ-4	590.86	11.32	582.32 (2)	8.23	582.91 (2)	10.07	582.61 (2)	9.60	582.84 (2)	10.65	582.34 (2)	7.61	583.96 (2)	7.87	582.99 (2)
PZ-5	589.24	8.21	581.94 (2)	8.28	582.15 (2)	9.68	581.84 (2)	9.75	581.98 (2)	10.44	581.67 (2)	8.67	582.09 (2)	8.56	582.14 (2)
PZ-6	587.98	6.22	581.97 (2)	6.28	582.14 (2)	7.58	581.74 (2)	6.80	582.00 (2)	8.56	581.55 (2)	7.84	581.93 (2)	6.25	582.13 (2)
PZ-7	588.43	7.14	582.04 (2)	7.69	582.80 (2)	8.95	582.46 (2)	8.39	582.64 (2)	9.84	582.17 (2)	7.46	582.91 (2)	8.17	582.73 (2)
PZ-8	587.51	8.35	580.27 (2)	5.25	582.26	5.56	581.95	5.23	582.28	5.74	581.77	5.33	582.18	5.23	582.28
PZ-9	587.90	9.11	580.94 (2)	7.63	582.23 (2)	9.01	581.86 (2)	8.70	582.10 (2)	9.42	581.67 (2)	7.82	582.13 (2)	7.47	582.26 (2)
PZ-10	587.14	8.57	579.88 (2)	4.02	583.12	4.38	582.76	4.02	583.12	4.67	582.47	4.06	583.08	4.10	583.04
PZ-11	586.42	8.55	577.87	2.37	584.05	2.94	583.48	2.36	584.06	3.31	583.11	2.44	583.98	2.77	583.65
PZ-12	587.94	8.91	579.03	3.51	584.43	3.82	584.12	3.34	584.60	4.24	583.70	3.16	584.78	3.81	584.13
Staff Gauges															
SG-1-17 (south culvert)	586.49			--	--	--	--	--	--	--	--	--	--	--	--
SG-2-17 (mid-culvert)	586.28			--	--	--	--	--	--	--	--	--	--	--	--
SG-3-17 (North Culvert)	585.56			--	--	--	--	--	--	--	--	--	--	--	--

Notes:

(1) ft AMSL - feet above mean sea level
(2) Correct Water Elevation due to the presence of LNAPL
NAVD88 - Datum for Elevations
NA - not available
Reference elevations surveyed by C. M. Lavoie on June 2, 2017

Table 2.1

Gauging Summary
Cline Avenue Oil Spill Site
Gary, Indiana

Location ID	Reference Elevation (ft AMSL)[1]	12/3/2015 Depth to LNAPL (feet)	12/3/2015 LNAPL Thickness (feet)	3/3/2016 Depth to LNAPL (feet)	3/3/2016 LNAPL Thickness (feet)	6/16/2016 Depth to LNAPL (feet)	6/16/2016 LNAPL Thickness (feet)	9/29/2016 Depth to LNAPL (feet)	9/29/2016 LNAPL Thickness (feet)	12/22/2016 Depth to LNAPL (feet)	12/22/2016 LNAPL Thickness (feet)	5/18/2017 Depth to LNAPL (feet)	5/18/2017 LNAPL Thickness (feet)	6/27/2017 Depth to LNAPL (feet)	6/27/2017 LNAPL Thickness (feet)
Monitoring Wells															
MW-2	592.34											--	--	--	--
MW-3	591.42											--	--	--	--
Piezometers															
PZ-1	589.12	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-2	588.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-3	588.97	6.52	0.82	6.56	1.23	6.52	0.02	6.30	0.10	6.72	2.59	6.31	1.91	6.49	1.02
PZ-4	590.86	NA	NA	7.29	0.09		--	7.73	0.83	8.24	0.64	5.81	1.85	7.56	0.23
PZ-5	589.24	6.91	0.04	6.94	1.42	6.84	2.13	6.66	0.86	7.11	3.33	6.78	2.85	6.81	0.92
PZ-6	587.98	5.71	2.65	5.88	0.96	5.68	0.83	5.39	0.96	6.09	1.73	5.43	1.02	5.60	0.87
PZ-7	588.43	5.34	1.50	5.22	1.54	5.28	2.19	5.21	1.89	5.67	3.48	4.75	2.94	5.14	1.86
PZ-8	587.51	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-9	587.90	5.50	1.83	5.48	1.93	5.31	1.91	5.13	1.09	5.73	3.45	5.17	1.62	5.26	1.34
PZ-10	587.14	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-11	586.42	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-12	587.94	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Staff Gauges															
SG-1-17 (south culvert)	586.49	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-2-17 (mid-culvert)	586.28	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-3-17 (North Culvert)	585.56	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Location ID	Reference Elevation (ft AMSL)[1]	12/3/2015 Depth to Water (feet)	12/3/2015 Water Elevation (ft AMSL)	3/3/2016 Depth to Water (feet)	3/3/2016 Water Elevation (ft AMSL)	6/16/2016 Depth to Water (feet)	6/16/2016 Water Elevation (ft AMSL)	9/29/2016 Depth to Water (feet)	9/29/2016 Water Elevation (ft AMSL)	12/22/2016 Depth to Water (feet)	12/22/2016 Water Elevation (ft AMSL)	5/18/2017 Depth to Water (feet)	5/18/2017 Water Elevation (ft AMSL)	6/27/2017 Depth to Water (feet)	6/27/2017 Water Elevation (ft AMSL)
Monitoring Wells															
MW-2	592.34	--	--	--	--	--	--	--	--	--	--	4.16	588.18	--	--
MW-3	591.42	--	--	--	--	--	--	--	--	--	--	3.63	587.79	--	--
Piezometers															
PZ-1	589.12	6.34	582.78	6.43	582.69	6.58	582.54	6.36	582.76	6.78	582.34	6.12	583.00	--	--
PZ-2	588.24	5.87	582.37	5.97	582.27	5.97	582.27	5.71	582.53	6.21	582.03	5.80	582.44	--	--
PZ-3	588.97	7.34	582.37 (2)	7.79	582.29 (2)	6.54	582.45 (2)	6.40	582.66 (2)	9.31	581.99 (2)	8.22	582.47 (2)	7.51	582.38 (2)
PZ-4	590.86	7.44	583.42 (2)	7.38	583.56 (2)	7.66	583.20 (2)	8.56	583.05 (2)	8.88	582.56 (2)	7.66	584.87 (2)	7.79	583.28 (2)
PZ-5	589.24	6.95	582.33 (2)	8.36	582.16 (2)	8.97	582.19 (2)	7.52	582.49 (2)	10.44	581.80 (2)	9.63	582.18 (2)	7.73	582.34 (2)
PZ-6	587.98	8.36	582.01 (2)	6.84	582.00 (2)	6.51	582.22 (2)	6.35	582.49 (2)	7.82	581.72 (2)	6.45	582.45 (2)	6.47	582.29 (2)
PZ-7	588.43	6.84	582.94 (2)	6.76	583.06 (2)	7.47	582.93 (2)	7.10	583.03 (2)	9.15	582.41 (2)	7.69	583.39 (2)	7.00	583.10 (2)
PZ-8	587.51	5.26	582.25	5.25	582.26	5.12	582.39	4.82	582.69	5.61	581.90	4.85	582.66	--	--
PZ-9	587.90	7.33	582.22 (2)	7.41	582.23 (2)	7.22	582.40 (2)	6.22	582.66 (2)	9.18	581.83 (2)	6.79	582.57 (2)	6.60	582.51 (2)
PZ-10	587.14	3.89	583.25	3.98	583.16	4.03	583.11	3.74	583.40	4.43	582.71	3.36	583.78	--	--
PZ-11	586.42	2.28	584.14	2.33	584.09	2.64	583.78	2.37	584.05	3.01	583.41	1.57	584.85	--	--
PZ-12	587.94	3.04	584.90	2.99	584.95	3.55	584.39	3.50	584.44	3.87	584.07	2.15	585.79	--	--
Staff Gauges															
SG-1-17 (south culvert)	586.49	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-2-17 (mid-culvert)	586.28	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-3-17 (North Culvert)	585.56	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Notes:

(1) ft AMSL - feet above mean sea level
(2) Correct Water Elevation due to the presence of LNAPL
NAVD88 - Datum for Elevations
NA - not available
Reference elevations surveyed by C. M. Lavoie on June 2, 2017

Table 2.1

Gauging Summary
Cline Avenue Oil Spill Site
Gary, Indiana

Location ID	Reference Elevation (ft AMSL)(1)	6/29/2017 Depth to LNAPL (feet)	6/29/2017 LNAPL Thickness (feet)	7/6/2017 Depth to LNAPL (feet)	7/6/2017 LNAPL Thickness (feet)	7/13/2017 Depth to LNAPL (feet)	7/13/2017 LNAPL Thickness (feet)	7/17/2017 Depth to LNAPL (feet)	7/17/2017 LNAPL Thickness (feet)	7/24/2017 Depth to LNAPL (feet)	7/24/2017 LNAPL Thickness (feet)	7/27/2017 Depth to LNAPL (feet)	7/27/2017 LNAPL Thickness (feet)	8/10/2017 Depth to LNAPL (feet)	8/10/2017 LNAPL Thickness (feet)	8/14/2017 Depth to LNAPL (feet)	8/14/2017 LNAPL Thickness (feet)
Monitoring Wells																	
MW-2	592.34	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	591.42	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Piezometers																	
PZ-1	589.12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-2	588.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-3	588.97	6.51	1.10	6.43	0.88			6.29	0.69	5.99	0.82	--	--	--	--	6.30	0.62
PZ-4	590.86	7.76	0.26	7.71	0.60			7.66	1.25	7.37	1.03	--	--	--	--	7.68	1.43
PZ-5	589.24	6.81	0.87	6.65	0.77			6.58	0.79	6.30	0.82	--	--	--	--	6.61	0.71
PZ-6	587.98	5.60	0.54	5.51	0.70			5.39	0.89	5.01	1.06	--	--	--	--	5.33	0.97
PZ-7	588.43	5.17	1.66	5.14	1.65			5.10	1.71	4.86	1.06	--	--	--	--	5.14	2.13
PZ-8	587.51	--	--		--				--	--	--	--	--	--	--	--	--
PZ-9	587.90	5.26	1.53	5.21	1.46			5.16	1.54	4.75	1.06	--	--	--	--	5.05	1.40
PZ-10	587.14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-11	586.42	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PZ-12	587.94	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Staff Gauges																	
SG-1-17 (south culvert)	586.49	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-2-17 (mid-culvert)	586.28	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SG-3-17 (North Culvert)	585.56	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Location ID	Reference Elevation (ft AMSL)(1)	6/29/2017 Depth to Water (feet)	6/29/2017 Water Elevation (ft AMSL)	7/6/2017 Depth to Water (feet)	7/6/2017 Water Elevation (ft AMSL)	7/13/2017 Depth to Water (feet)	7/13/2017 Water Elevation (ft AMSL)	7/17/2017 Depth to Water (feet)	7/17/2017 Water Elevation (ft AMSL)	7/24/2017 Depth to Water (feet)	7/24/2017 Water Elevation (ft AMSL)	7/27/2017 Depth to Water (feet)	7/27/2017 Water Elevation (ft AMSL)	8/10/2017 Depth to Water (feet)	8/10/2017 Water Elevation (ft AMSL)	8/14/2017 Depth to Water (feet)	8/14/2017 Water Elevation (ft AMSL)
Monitoring Wells																	
MW-2	592.34	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6.42	585.92
MW-3	591.42	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.84	585.58
Piezometers																	
PZ-1	589.12	--	--	--	--	--	--	--	--	--	--	6.05	583.07	--	--	6.32	582.80
PZ-2	588.24	--	--	--	--	--	--	--	--	--	--	5.48	582.76	--	--	5.65	582.59
PZ-3	588.97	7.61	582.35 (2)	7.31	582.45 (2)	--	--	6.98	582.61 (2)	6.81	582.90 (2)	--	--	--	--	6.92	582.61 (2)
PZ-4	590.86	8.02	583.07 (2)	8.31	583.09 (2)	--	--	8.91	583.08 (2)	8.40	583.39 (2)	--	--	--	--	9.11	583.04 (2)
PZ-5	589.24	7.68	582.34 (2)	7.42	582.51 (2)	--	--	7.37	582.58 (2)	7.12	582.86 (2)	--	--	--	--	7.32	582.56 (2)
PZ-6	587.98	6.14	582.33 (2)	6.21	582.40 (2)	--	--	6.28	582.50 (2)	6.07	582.86 (2)	--	--	--	--	6.30	582.55 (2)
PZ-7	588.43	6.83	583.09 (2)	6.79	583.13 (2)	--	--	6.81	583.16 (2)	5.92	583.46 (2)	--	--	--	--	7.27	583.08 (2)
PZ-8	587.51	--	--	--	--	--	--	--	--	--	--	4.61	582.90	--	--	4.78	582.73
PZ-9	587.90	6.79	582.49 (2)	6.67	582.54 (2)	--	--	6.70	582.59 (2)	5.81	583.04 (2)	--	--	--	--	6.45	582.71 (2)
PZ-10	587.14	--	--	--	--	--	--	--	--	--	--	3.54	583.60	--	--	3.86	583.28
PZ-11	586.42	--	--	--	--	--	--	--	--	--	--	2.21	584.21	--	--	2.68	583.74
PZ-12	587.94	--	--	--	--	--	--	--	--	--	--	3.19	584.75	--	--	3.78	584.16
Staff Gauges																	
SG-1-17 (south culvert)	586.49	--	--	4.41	582.08	4.32	582.17	4.27	582.22	4.00	582.49	--	--	4.34	582.15	4.25	582.24
SG-2-17 (mid-culvert)	586.28	--	--	4.17	582.11	4.09	582.19	4.06	582.22	3.79	582.49	--	--	4.10	582.18	4.06	582.22
SG-3-17 (North Culvert)	585.56	--	--	3.44	582.12	3.34	582.22	3.30	582.26	3.04	582.52	--	--	3.31	582.25	3.27	582.29

Notes:

(1) ft AMSL - feet above mean sea level
(2) Correct Water Elevation due to the presence of LNAPL
NAVD88 - Datum for Elevations
NA - not available
Reference elevations surveyed by C. M. Lavoie on June 2, 2017

Appendices

Appendix A
Utility Clearance Summary

BLOOD HOUND
Field Report
Vacant Lot – Gary, IN

Office # 888-858-9830 **Fax # 888-858-9829**

http://www.BHUG.com

Job Description – On July 5 through July 7, 2017, Brian R. Clem, Director EHS, conducted a Utility Locate and Ground Penetrating Radar (GPR) survey of a portion of the vacant property located to the west of the Gary Municipal Airport near the intersection of Gary Avenue and Cline Avenue in Gary, Indiana. The survey was conducted to clear potential obstructions near proposed soil sample locations scattered throughout the property. In addition several GPR transects were to be collected for later analysis to determine if the presence of a known contamination plume could be identified in the collected geophysical data.

Job Procedure –
Utility locating was completed using a Metrotech Vivax vLoc Pro I multi-frequency receiver and transmitter combination.. Traditional electro-magnetic (EM) locating operations were conducted by attaching the transmitter to the target utility which then applied an electric current to the target line which generated a radio field around the target line at a specific frequency. Alternatively for utilities where no connections were available, the signal was applied using inductive methods by generating a strong magnetic field at the surface which then induces a current onto the target utility. A receiver was then used to detect the resulting radio field on the designated frequency to locate the lateral position of the line. The lateral position of all located lines were marked with pink paint.

The Ground Penetrating Radar survey was conducted using a Geophysical Survey Systems Inc. (GSSI) SIR 400 Ground Penetrating Radar unit equipped with a digital Hyperstacking Antenna operating on a center frequency of 350 MHz. Dielectric constants (signal velocities) were adjusted and calibrated using visual hyperbola matching techniques on an observed gas line present within the survey area. It should be noted that since this value was established based on field observations at a specific location, the velocities in other portions of the site could vary from this established value.

BLOOD HOUND

Field Report

Vacant Lot – Gary, IN

Office # 888-858-9830 **Fax # 888-858-9829**

http://www.BHUG.com

Job Results –

Several proposed sample locations were moved due to conflicts with observed anomalies and/or marked utilities. Ground Penetrating Radar test data was collected based on a test plan developed on site based on consultation with Mustafa Saribudak with EGA, who will be performing the majority of the data analysis. Each data line was collected in straight lines starting at the north end of the project area in line with the previously established Piezometer location #. At the data line was collected a marker was placed in the data transect when passing each existing Piezometer location and offset measurements to each of these well locations was established. A total of 9 lines were collected with a 10th line collected by pushing the unit from Piezometer location 1 through 10 passing each one in a straight line between each well location.

The following chart shows the offsets from each established well for each collected line file. The values were given positive values if the well was located east of the GPR when the line passed the well location and negative values if the well was west of the GPR line.

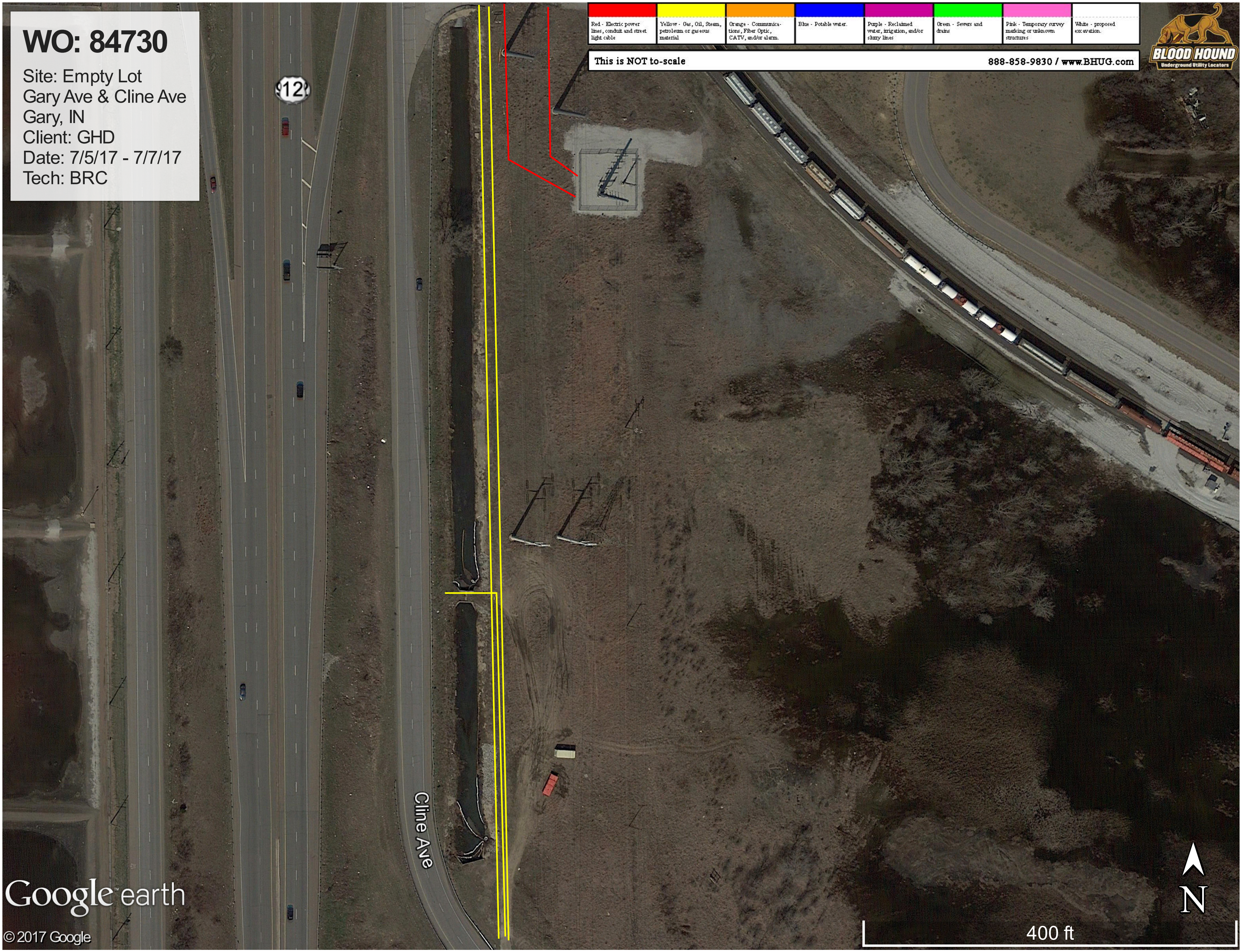
	Offset From (ft)									
GPR Line File	PZ-1	PZ-2	PZ-3	PZ-4	PZ-5	PZ-6	PZ-7	PZ-8	PZ-9	PZ-10
PR84730_008	36	4.5	8.8	76	9.5	4	77.9	11.7	10.5	-13.5
PR84730_009	31	-1	4	72	6	-1	73	6.3	10.5	-8.3
PR84730_010	26	-4	-1	68	1	-4	69	-1	1	-21.5
PR84730_011	21.5	-9	-4	64.5	-2.3	-8	66	-2.5	-4	
Rain Event										
PR84730_012	16	-15	-10.5	57.5	-10	-18	57	-10	-13.5	
PR84730_013	6	-26	-22.5	46.5	-20.5	-27	45	-23	-27	
PR84730_014	-4	-36	-33	35	-34	-42	31	-37	-41	
PR84730_015	-14	-47	-44.5	22	-48	-55	19	-48	-50	
PR84730_016	-24	-57	-54	13	-57	-69	4	-65	-70	

*Positive values indicates that the well is located to the East of the GPR line and negative values indicate the well is West of the GPR

There was a brief rain event that occurred after the collection of line 11 and before line 12. The event was brief, but intense and consequently signal velocity values may have been impacted due to the addition of moisture into the soil.

Job Conclusions –

Data was collected and provided to Mustafa with EGA for further analysis to be provided separately to determine if the contamination plume can be identified using Ground Penetrating Radar data.


WO: 84730
Site: Empty Lot
Gary Ave & Cline Ave
Gary, IN
Client: GHD
Date: 7/5/17 - 7/7/17
Tech: BRC
Red - Electric power lines, conduit and street light cable
Yellow - Gas, Oil, Steam, petroleum or gaseous material
Orange - Communications, Fiber Optic, CATV, and/or alarm.
Blue - Potable water.
Purple - Reclaimed water, irrigation, and/or slurry lines
Green - Sewers and drains
Pink - Temporary survey marking or unknown structures
White - proposed excavation.
This is NOT to-scale
888-858-9830 / www.BHUG.com
BLOOD HOUND
Underground Utility Locators
12
Cline Ave
Google earth
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Buffington Harbor Dr
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Columbus Dr
Airport Rd.


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Majestic Star Casino
Columbus Dr
Airport Rd


Buffington Harbor Dr
Majestic Star Casino
Columbus Dr
Airport Rd.


Columbus Dr
Airport Rd.


POWER CABLE
WARNING


Buffington Harbor Dr
Majestic Star Casino
Columbus Dr
Airport Rd.


BN SF
645 907


Buffington Harbor Dr
Majestic Star Casino
Columbus Dr
Airport Rd.


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RBM250445

Appendix B
Geophysical Analysis

ENVIRONMENTAL GEOPHYSICS ASSOCIATES

GLOBAL GEOPHYSICAL AND GEOLOGICAL CONSULTING

2000 Cullen Avenue, #7. Austin. Texas.

Mob:832-368-4004; ega@pdq.net · www.egatx.com

GPR Data Interpretation
Delineation of LNPAL Plume
Cline Ditch Site
Gary, Indiana

DRAFT

1.0 Purpose of GPR Survey and Survey Design

We collected GPR data, in conjunction of Blood Hound Utility Company, at the Cline Ditch site (Figure 1). The utility company used a SIR 4000 GPR unit-the newest system- with a 350 MHz antenna, which yielded more than 10 feet depth penetration. The purpose of the GPR surveys was to determine whether the GPR data correlate with the LNAPL products that are observed on the majority of the piezometers (P3, P4, P5, P6, P7, and P9), which are located along the ditch (Figure 1).

Figure 1.

First, we collected GPR data along a profile **A** (Figure 1). This profile covered the distances between the piezometers 1 through 10. Second, we collected GPR data along nine (9) profiles, which are established in the north-south direction and are aligned with the piezometers (Figure 2).

Fig. 2

2.0 GPR Data Interpretation-Profile A

We used Radan 7 GPR software to process the data. We used the following processing parameters: 1) IIR Filters – 1000 LP / 50 HP, 2) Position correction, 3) Range gain, and 4) Background removal.

We first processed the profile **A** whose location is shown in Figure 2. Location of the piezometers and the groundwater table (yellow line) are superimposed on the GPR sections in order to make a comparison with the presence of LNAPL products in the subsurface. The length of the GPR data was divided into six sections and are displayed as Figures 3A through 3F.

Locations of three piezometers (PZ-1 through 3) are labeled on Figure 3A. Oil thickness in in PZ-1 and PZ-2 piezometers is none; but PZ-3 contains LNAPL which has a thickness of 2.59 feet. It should be noted that “corrected water levels” were used whenever is applicable **(**The information is taken by a figure titled “**Cline Ditch Site Map**” which is provided by Mr. David Sweeten. The groundwater table approximately corresponds to the high-amplitude reflectors, which are shown with white and gray colors. The subsurface beneath the PZ-1 does not have high-amplitude reflectors, but PZ-2 has some.

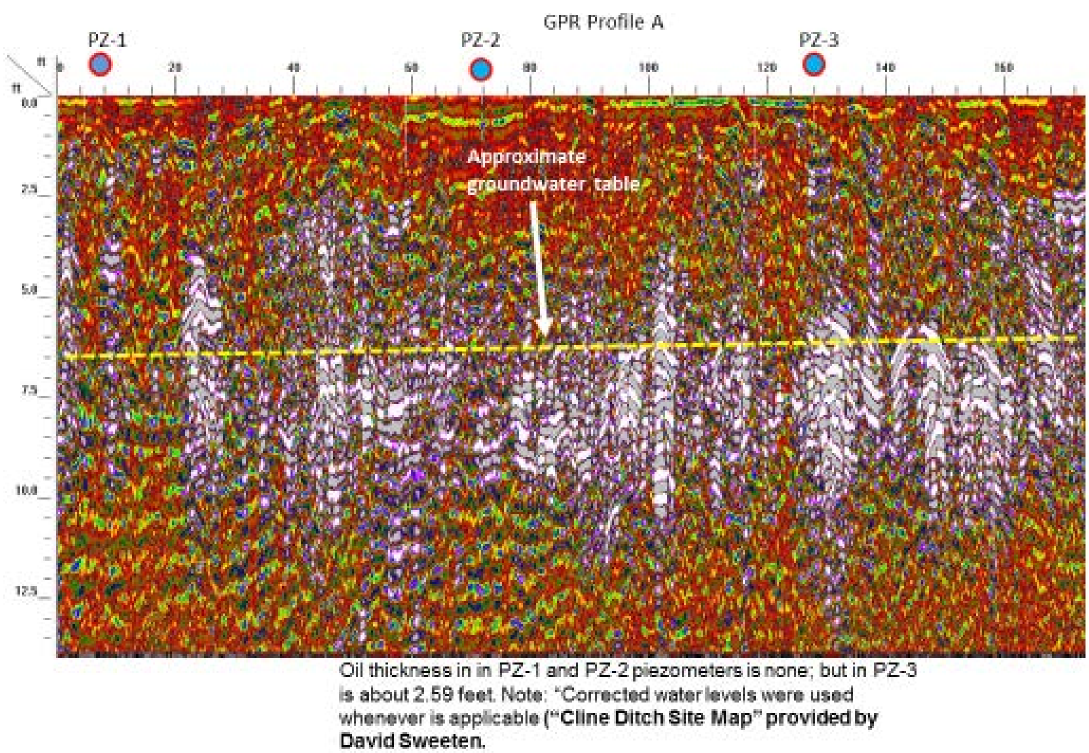
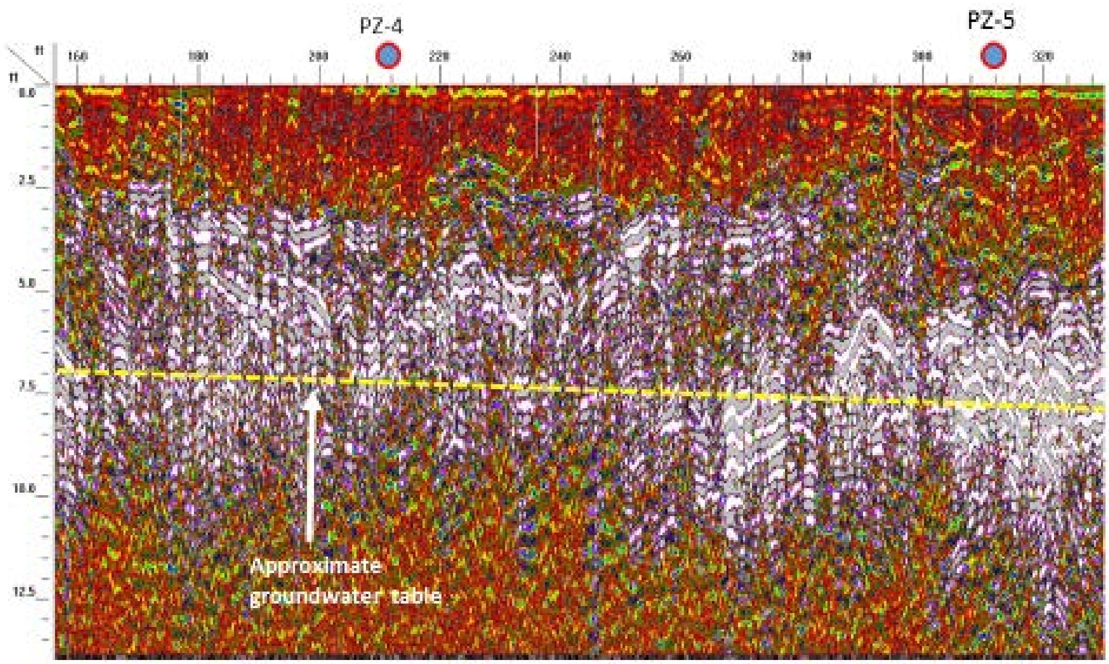


Fig. 3A.

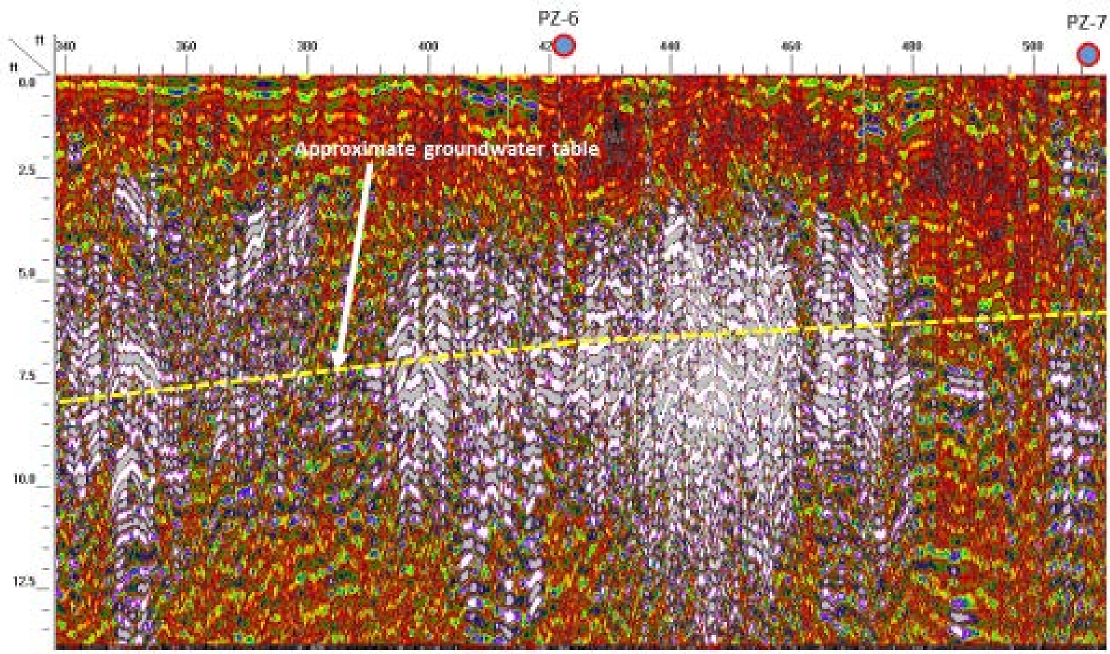
Figure 3B displays the GPR section between PZ-4 and PZ-5. The high-amplitude reflectors are well above the water table in the vicinity of PZ-4. Note that there is a hyperbolic shape of the reflectors in the vicinity of PZ-4. The oil thickness is not provided in this piezometer, but highly viscous oil and oil solids mix encountered in PZ-4 at about 8.24 feet. The oil thickness encountered in PZ-5 is 3.33 feet. The intensity of high reflectors increases beneath PZ-5.



Oil thickness in PZ-4 is 2.59 ft. Highly viscous oil, oil solids mix encountered in PZ-4. Oil thickness encountered in PZ-5 is 3.33 ft. Note the **hyperbolic shape** of the high magnitude reflections (white and gray) underlying the PZ-4.

Fig. 3B.

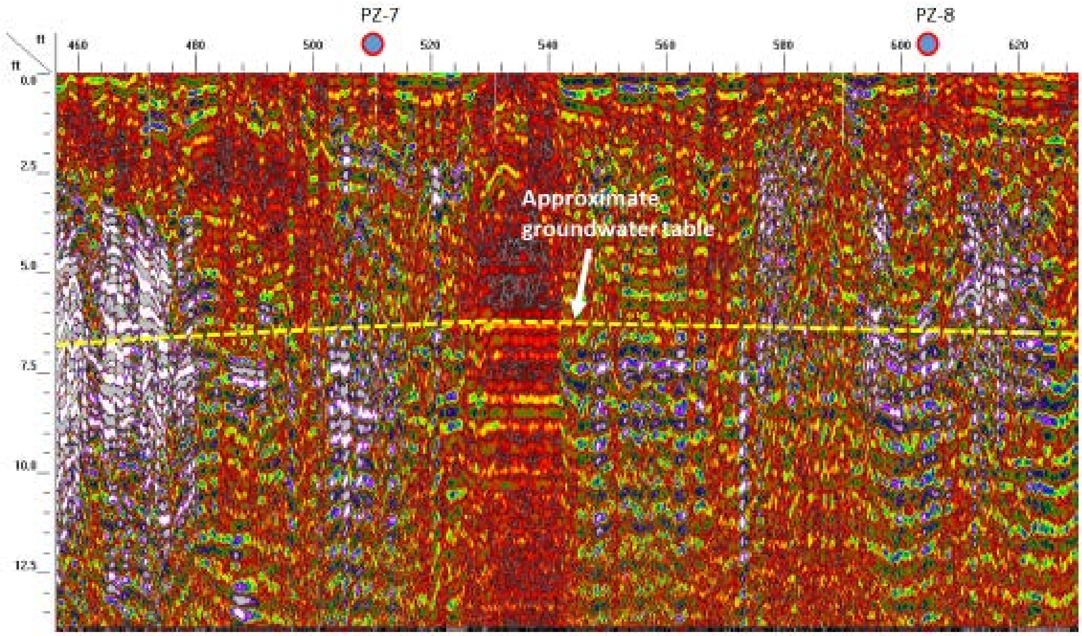
The GPR section, where PZ-6 and PZ-7 are located, is provided in Figure 3C. Oil thickness on both PZ-6 and PZ-7 piezometers is 1.73 and 3.48 feet, respectively. Note the presence and absence of high magnitude reflections beneath PZ-6 and PZ-7, respectively.



Oil thickness on both PZ-6 and PZ-7 piezometers is 1.73 and 3.48 feet, respectively. Note the absence of high magnitude reflections beneath PZ-7.

Fig. 3C.

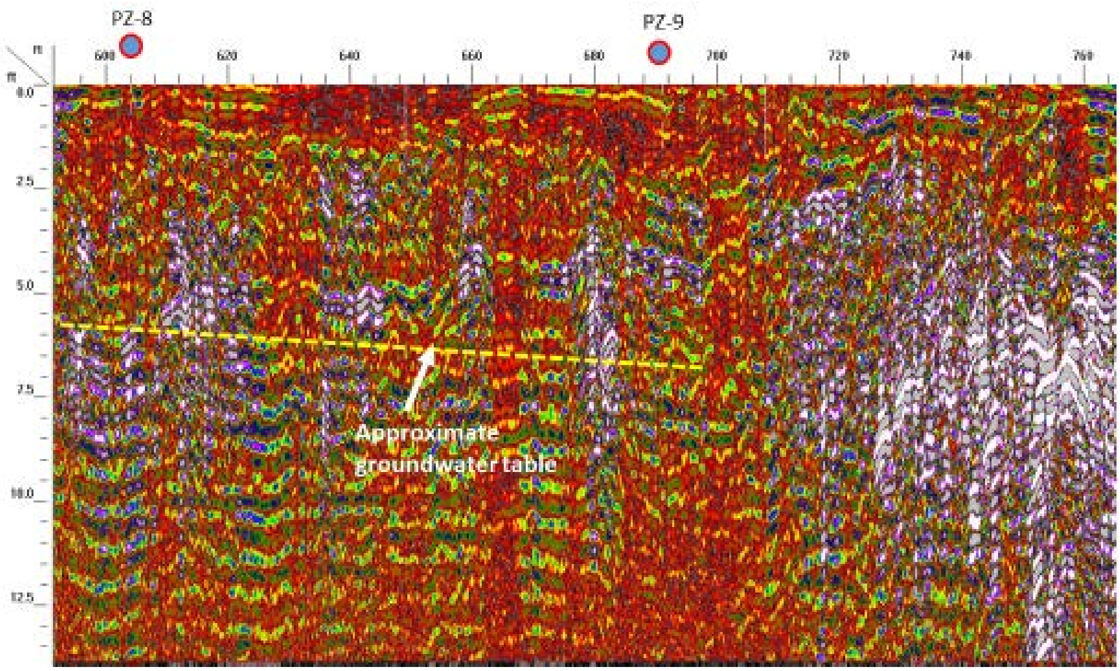
We purposely provide the overlapping Figure 3D where PZ-7 and PZ-8 are shown in one GPR section. The purpose is to be able to make a correlation between the two. PZ-7 has an oil thickness of 3.48 feet and PZ-8 has none. It is important to note that high-amplitude reflectors are absent beneath, and between these contaminated and uncontaminated piezometers.



Oil thickness in PZ-7 is 3.48 feet. Oil thickness in PZ-8 is none. Note the absence of high-magnitude reflections (white and gray) beneath the piezometers PZ-7 and PZ-8.

Fig. 3D.

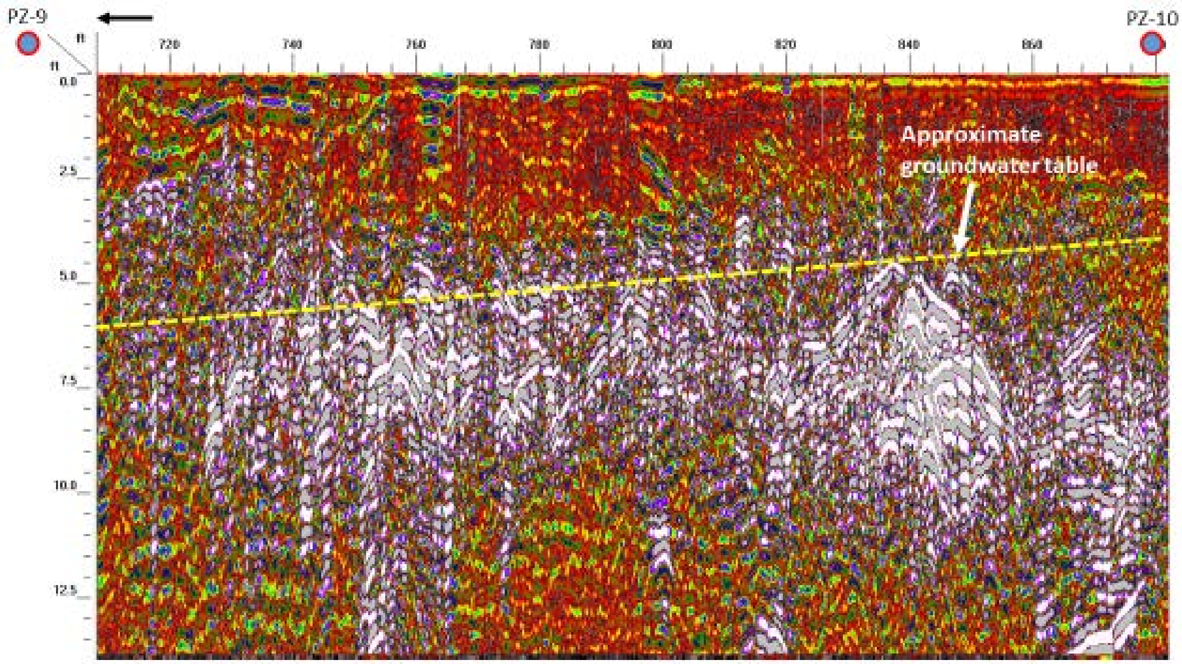
Again, we provide Figure 3E, with an overlap, showing the GPR data between piezometers PZ-8 and PZ-9. Oil thickness in PZ-8 is none. Oil thickness in PZ-9 is 3.45 feet. Note the absence of high-amplitude reflections of white/gray beneath the both contaminated and uncontaminated piezometers.



Oil thickness in PZ-8 is none; Oil thickness in PZ-9 is 3.45 feet. Note the absence of high-amplitude reflections of white/gray beneath the both piezometers.

Fig. 3E.

Figure 3F displays the GPR data between piezometers PZ-9 and PZ-10. Oil thickness in PZ-9 is 3.45 feet; in PZ-10 is none. Note that the water level in PZ-10 was “not corrected.” We know from Figure 3D that PZ-9 has 3.45 feet LNAPL products and does not show any high-amplitude reflectors. PZ10 also appear to correspond to a location where the high-amplitude reflections are present.



Oil thickness in PZ-9 is 3.45 feet; in PZ-10 is none. Note that the water level in PZ-10 was “not corrected.”

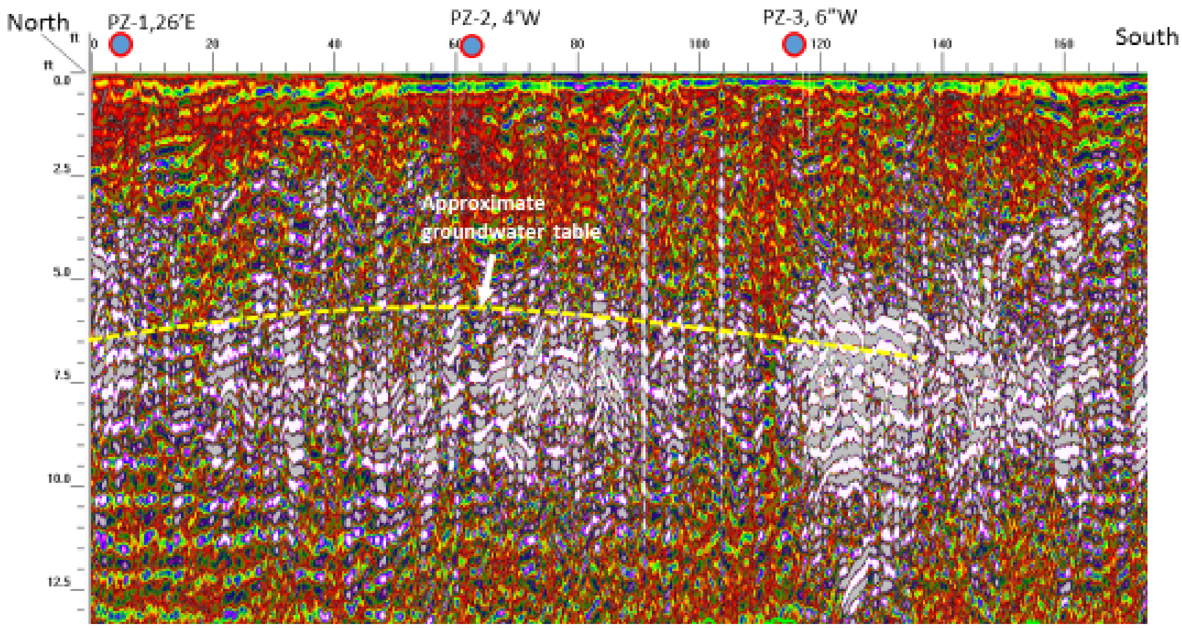
Fig. 3F.

3.0 Interpretation of GPR Profile L3

Out of nine GPR profiles that we collected at the study area (see Figure 2), we present here the GPR profile 3 (L3). We chose this profile because it crosses the area, from north to south, where there is no presence of pipelines (Figure 4).

Fig. 4. Location of GPR profile L3 and L4 with respect to the piezometers.

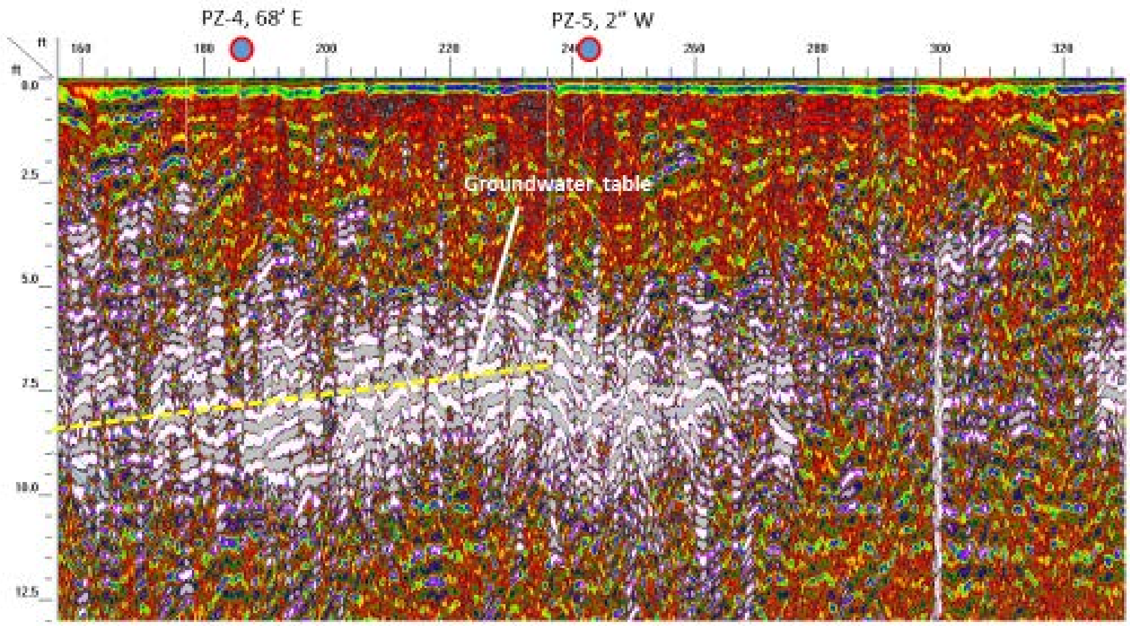
The first GPR section from profile L3 is provided in Figure 5A.
Piezometers PZ-1 and PZ-2 are located 26 feet east and 4 feet west of the GPR profile respectively. The location of PZ-3 is 6 inch to the west of the profile. It contains piezometers of PZ-1, 2 and 3. The groundwater level is superimposed on the profile. PZ-1 and PZ-2 do not contain any oil products but PZ-3 has 2.59 feet of oil-thickness. Note the much higher amplitude of reflections beneath PZ-3.



Piezometers PZ-1 and PZ-2 are located 26 feet east and 4 feet west of the GPR profile respectively. The location of PZ-3 is 6 inch to the west of the profile. PZ-1 and PZ-2 do not show any oil product, but PZ-3 has oil thickness of 2.59 feet. Note the relatively high-amplitude reflections beneath the contaminated PZ-3.

Fig. 5A.

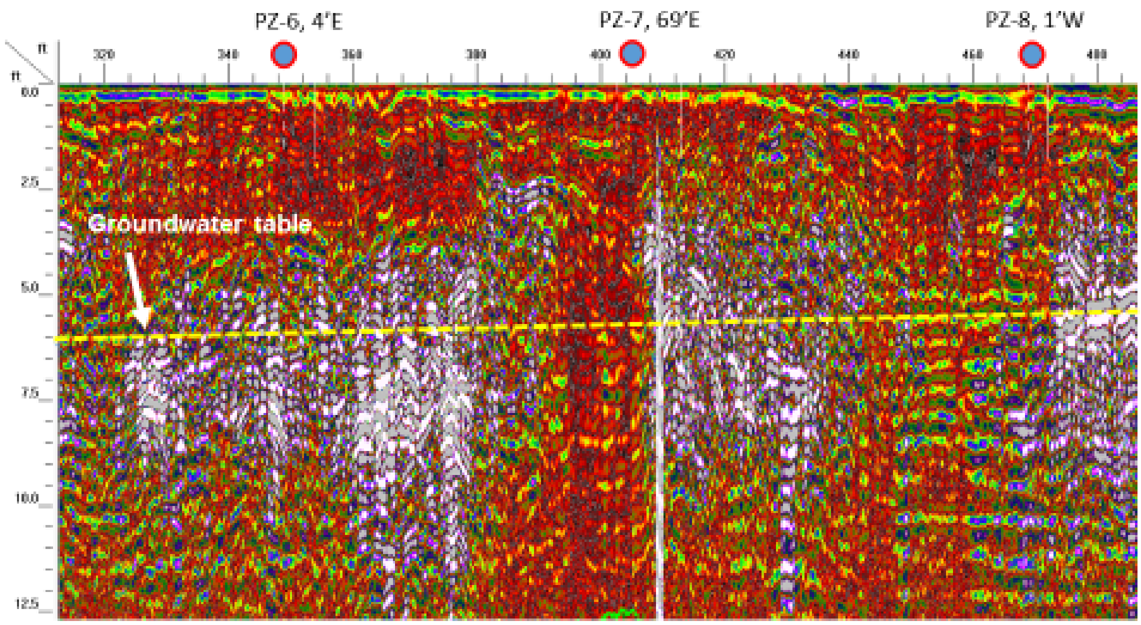
Figure 5B provides the GPR section containing the piezometers PZ-4 and 5. The approximate groundwater table is shown with a yellow line. The piezometer PZ-4 is located 68 feet to the east of the GPR profile whereas PZ-5 is located 2 inch to the west of the profile highly viscous oil, oil solids mix encountered in PZ-4. Oil thickness encountered in PZ-5 is 3.33 feet. Note the high-amplitude reflections beneath PZ-4 and PZ-5.



The piezometer PZ-4 is located 68 feet to the east of the GPR profile whereas PZ-5 is located 2 inch to the west of the profile Highly viscous oil, oil solids mix encountered in PZ-4. Oil thickness encountered in PZ-5 is 3.33 feet

Fig. 5B.

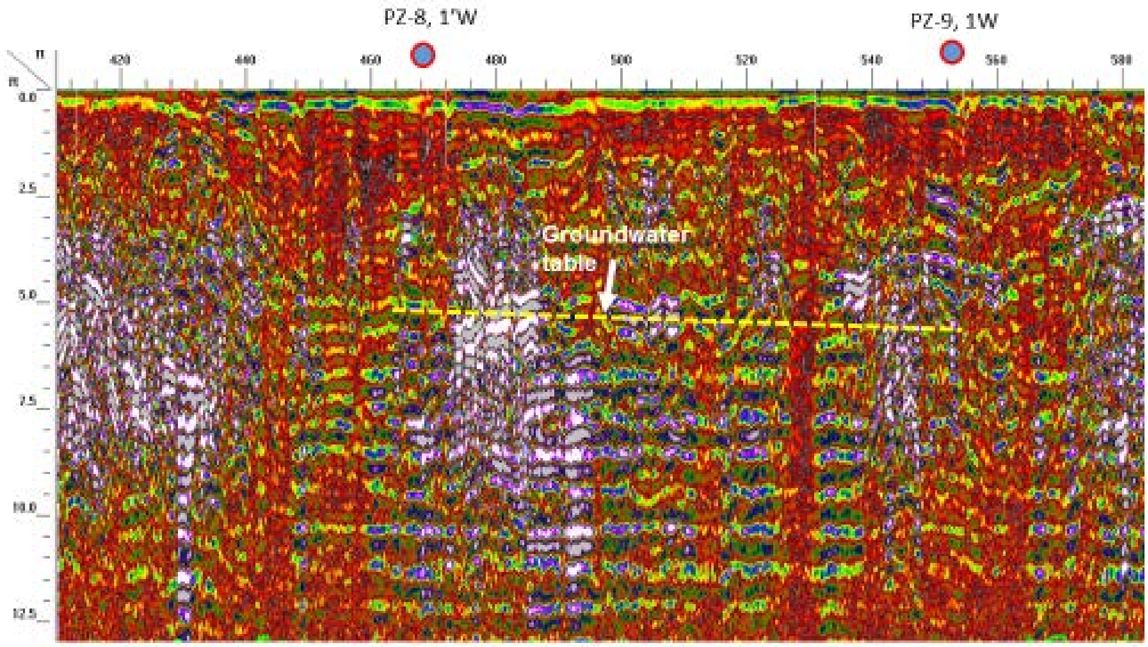
Figure 5C displays the GPR section containing PZ-6, PZ-7 and PZ-8. PZ-6 is located 4 feet to the east of GPR profile L3 whereas PZ-7 is located 69 feet to the east. Both piezometers contain LNAPL products of 1.73 and 3.48 feet in thickness. Note that the profile L3 is very close to PZ-6. Despite the piezometer contains LNAPL, GPR reflections are not as strong as the piezometer PZ-5 (see Figure 5B). PZ-8 is located 1 foot to the west of the profile it does not contain any LNAPL product.



PZ-6 is located 4 feet to the east of GPR profile L3 whereas PZ-7 is located 69 feet to the east. Both piezometers contain LNAPL products of 1.73 and 3.48 feet in thickness. Note that the profile L3 is very close to PZ-6. Despite the piezometer contains LNAPL, GPR reflections are not as strong as the piezometer PZ-5 (see Figure 5B). PZ-8 is located 1 foot to the west of the profile it does not contain any LNAPL product.

Fig. 5C.

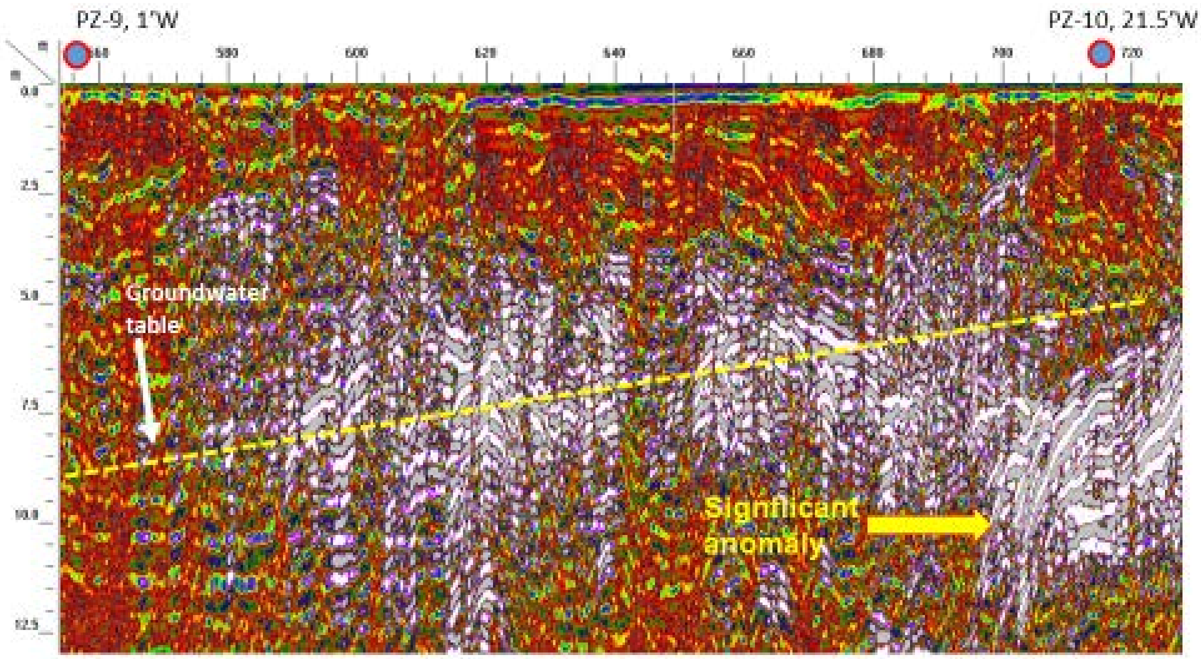
Figure 5D shows the GPR section containing piezometers PZ-8 and 9. Piezometers PZ-8 and PZ-9 are located 1 foot to the west of the profile L3. PZ-8 does not contain any LNAPL but PZ-9 has a thickness of 3, 45 feet LNAPL. Both piezometers do not have any significant high-amplitude reflections beneath them.



Piezometers PZ-8 and PZ-9 are located 1 foot to the west of the profile L3. PZ-8 does not contain any LNAPL but PZ-9 has a thickness of 3,45 feet LNAPL. Both piezometers do not have any significant high-amplitude reflections beneath them.

Fig. 5D.

The Figure 5E provides the GPR section containing piezometers PZ-9 and 10, which are located 1 and 21.5 feet to the west of the profile L3. PZ-9 contains LNAPL products but PZ-10 does not. However, there is a significant GPR anomaly (sharp, abrupt high amplitude reflections) in the vicinity of PZ-10. The source is not known.

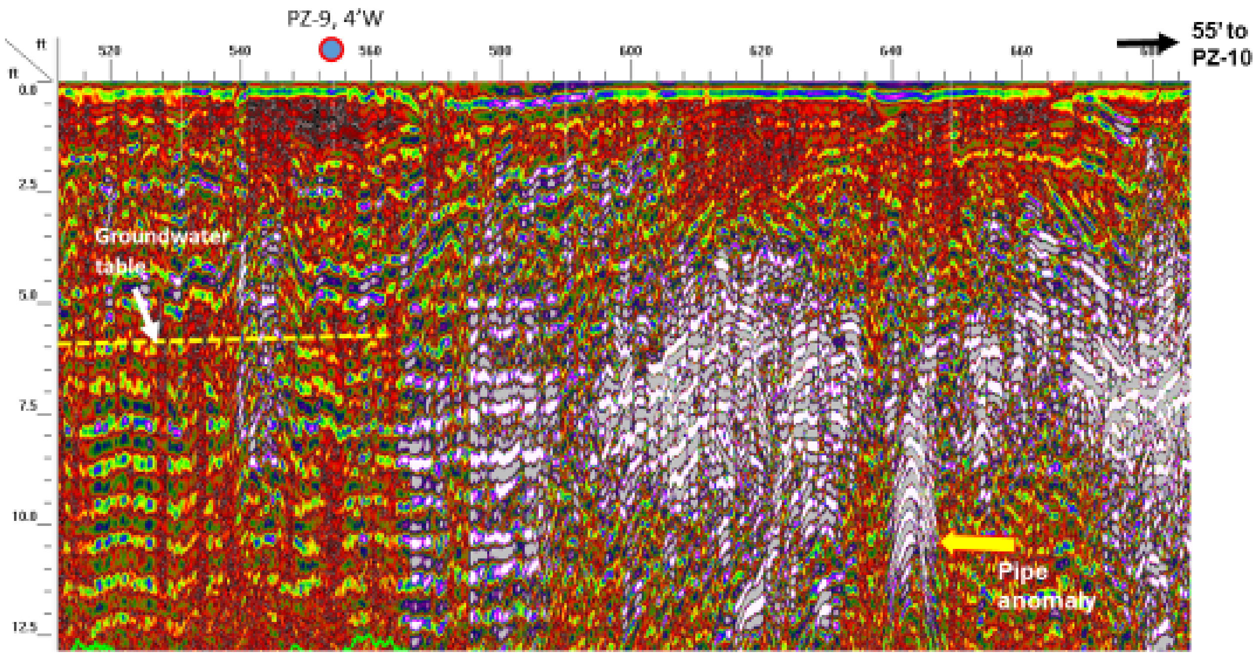


Piezometers PZ-9 and 10 are located 1 and 21.5 feet to the west of the profile L3. PZ-9 contains LNAPL products but PZ-10 does not. However, there is a significant GPR anomaly in the vicinity of PZ-10.

Fig. 5E.

4.0 Interpretation of a GPR Section- L4

In addition to profile L3, we present a here the last section of GPR data along profile L4 (see Figure 4 for location). The GPR profile L4 contains a significant metallic anomaly at the end of the profile (Figure 6). We did not see any other well-defined pipe anomaly along all GPR profiles. Profile L4 is located 5 feet east of profile L3. Note that although PZ-9 contains LNAPL, it does not show any high-amplitude reflections.



This profile is the last section of GPR profile L4, which is located 5 feet to the east of profile L3..PZ-10 is located 55 feet in the south direction. The survey was stopped due to a hindrance. Note that the piezometer PZ-9 has an oil thickness of 3.45 feet and does not contain any high-amplitude reflections. There is a significant metallic (pipe?) GPR anomaly at around station 640 feet.

Fig. 6.

5.0 Conclusion

The GPR data obtained from the Cline Ditch Site indicated significant anomalies these anomalies are due to high-amplitude reflections and appear to occur in the vicinity of water table and continued, in some cases, down to 10 feet. The cause of these anomalies **may b**e three fold: 1) A significant dielectric contrast, which the GPR method based on, between the groundwater and sand unit in the subsurface; 2) the presence of several pipelines along the majority of GPR profiles; 3) either the presence**-or absence-** of thick oil products floating in the groundwater.

The purpose of this study was to determine whether the GPR data would provide a recognizable pattern, such that either high-amplitude reflections or faded GPR signals, for the LNAPL products in the near-surface. The current state of research indicates that GPR data display either high- amplitude reflections or amplitude shadows depending on the age of the LNAPL products and near-surface geology (Sources from online research).

Based on the sample GPR data that we reviewed in this study, we present the following results:

1) The LNAPL products are located within the both high-amplitude reflections and areas where the GPR signals are attenuated;
2) The high-amplitude reflections mostly occur where piezometers PZ-3, PZ-4, PZ-5, and PZ-6 are located;
3) The **absence** of high-amplitude areas mostly occur where piezometers PZ-7, PZ-8 and PZ-9 are located. A picture of this area from the field is shown in Figure 7;
4) It should be noted that the presence of high-amplitude reflection in the vicinity of PZ-10 is quite extensive in the horizontal and vertical direction (see Figures 3F and 5E). The reason for this is unknown;
5) A well-defined metallic anomaly is observed along profile L4. The approximate depth of this anomaly is about 6 to 7 feet.

Picture showing where, **approximately**, the absence of high-amplitude reflections are located.

Fig. 7.

In conclusion, LNAPL product exist in the subsurface where presence of high-amplitude GPR reflections are recorded. **However,** GPR data does not shown any significant high-amplitude reflections, despite the presence of LNAPL products in some piezometers. A picture is shown in Figure 8 where we observed the absence of high-amplitude GPR data. It should also be noted that the GPR data in the vicinity of PZ-1 and PZ-2 does not show any significant reflections. Both these two piezometers do not contain any LNAPL products.

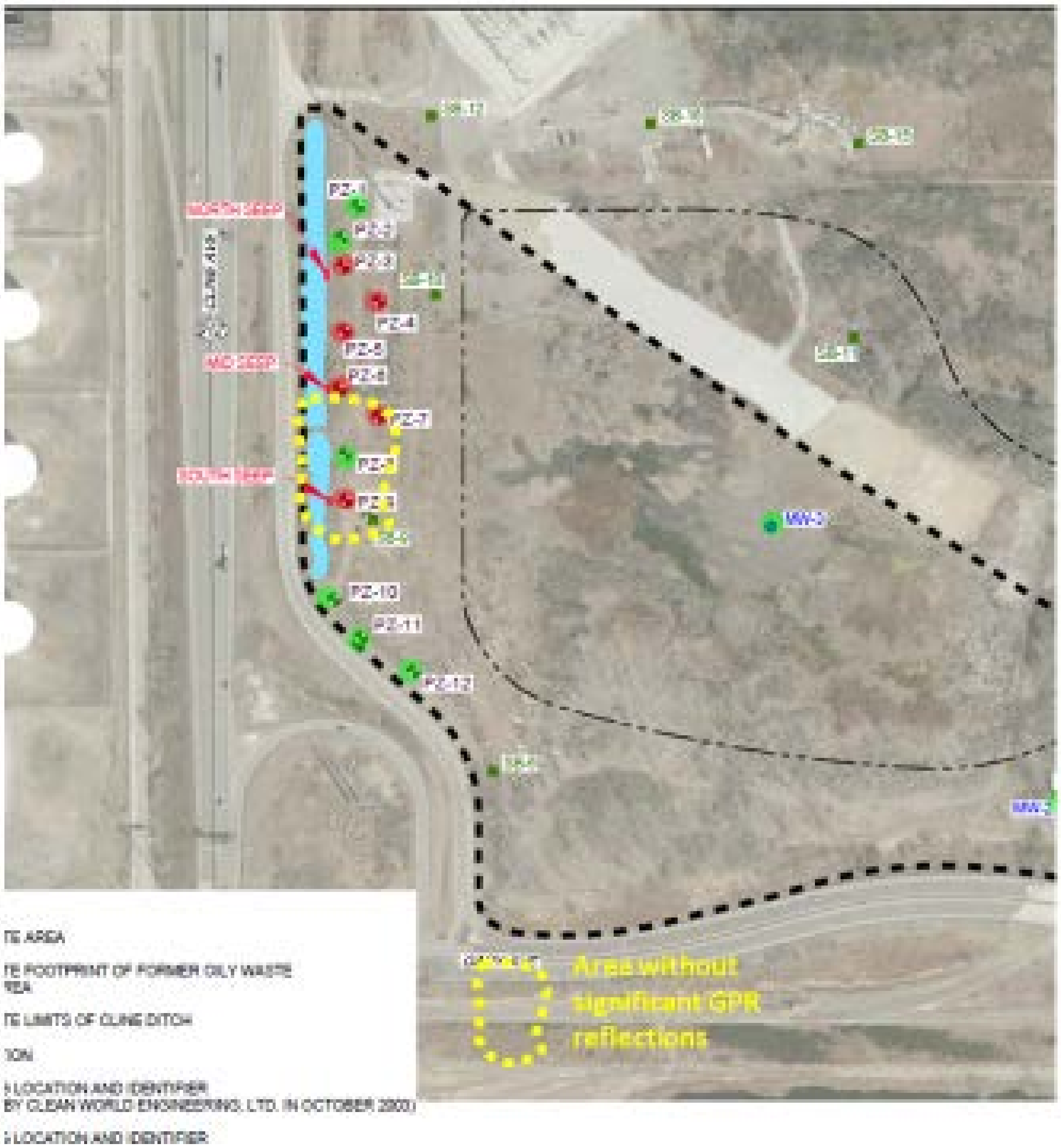


Fig. 8.

In summary, there is no pattern in the GPR data that allows us to determine the LNAPL products in the near-surface, with confidence, using the GPR method. We suggests a magnetic gradiometer (or similar) survey run along the GPR profiles to locate any ferrous sources in addition to known pipelines.

Appendix C
LNAPL Fingerprint Analysis

Appendix C.1
LNAPL Chromatograms

July 14th, 2017

Angela Bown
GHD
9033 Meridian Way
West Chester, OH 45069

RE: Cline Ave Ditch
Project Number: 85886-023101-403

Pace Analytical received six samples on June 28th, 2017 for analysis labeled 0-062217-JH-01, 0-062217-JH-02, 0-062217-JH-03, 0-062217-JH-04, 0-062217-JH-05, and 0-062217-JH-06. Per client request, the following analyses were performed:

1. C3-C36 Whole Oil Molecular Characterization Gas Chromatography "Fingerprint" by GC/FID
2. C8-C40 Full Scan Qualitative Molecular Characterization by GC/MS

The sample was performed in house under laboratory number **23114**.

Please call the lab at 412-826-5245, or you may email any questions or concerns to Lauren.McGrath@pacelabs.com regarding any analytical data reports.

Respectfully submitted,

Lauren E. McGrath

Lauren E. McGrath
Project Manager

Pace Analytical®
Energy Services™

(C3-C36) Whole-Oil Molecular Characterization
Gas Chromatography "Fingerprint"
by GC/FID

Includes Semi-quantitative screening of over 90 gasoline range PIANO compounds

6/29/2017

Pace ID	23114-1
Sample ID	O-062217-JH-01 PZ-9
Evaporation	
n-Pentane / n-Heptane	0.51
2-Methylpentane / 2-Methylheptane	0.20
Waterwashing	
Benzene / Cyclohexane	0.05
Toluene / Methylcyclohexane	0.23
Aromatics / Total Paraffins (n+iso+cyc)	1.21
Aromatics / Naphthenes	3.96
Biodegradation	
(C4 - C8 Para + Isopara) / C4 - C8 Olefins	127.31
3-Methylhexane / n-Heptane	6.35
Methylcyclohexane / n-Heptane	17.28
Isoparaffins + Naphthenes / Paraffins	16.50
Octane rating	
2,2,4,-Trimethylpentane / Methylcyclohexane	0.28
Relative percentages - Bulk hydrocarbon composition as PIANO	
% Paraffinic	2.53
% Isoparaffinic	28.30
% Aromatic	53.50
% Naphthenic	13.52
% Olefinic	2.14

6/29/2017

		Relative Area %
Pace ID		23114-1
Sample ID		O-062217-JH-01 PZ-9
1	Propane	0.00
2	Isobutane	0.00
3	Isobutene	0.00
4	Butane/Methanol	0.00
5	trans-2-Butene	0.00
6	cis-2-Butene	0.00
7	3-Methyl-1-butene	0.00
8	Isopentane	0.06
9	1-Pentene	0.00
10	2-Methyl-1-butene	0.01
11	Pentane	0.12
12	trans-2-Pentene	0.00
13	cis-2-Pentene/t-Butanol	0.00
14	2-Methyl-2-butene	0.01
15	2,2-Dimethylbutane	0.00
16	Cyclopentane	0.00
17	2,3-Dimethylbutane/MTBE	0.11
18	2-Methylpentane	0.52
19	3-Methylpentane	0.00
20	Hexane	0.52
21	trans-2-Hexene	0.06
22	3-Methylcyclopentene	0.04
23	3-Methyl-2-pentene	0.00
24	cis-2-Hexene	0.04
25	3-Methyl-trans-2-pentene	0.03
26	Methylcyclopentane	0.82
27	2,4-Dimethylpentane	0.00
28	Benzene	0.03
29	5-Methyl-1-hexene	0.05
30	Cyclohexane	0.76
31	2-Methylhexane/TAME	0.95
32	2,3-Dimethylpentane	0.61
33	3-Methylhexane	1.45
34A	1-trans-3-Dimethylcyclopentane	0.61
34B	1-cis-3-Dimethylcyclopentane	1.26
35	2,2,4-Trimethylpentane	1.11
I.S. #1	α,α,α-Trifluorotoluene	0.00

6/29/2017

Pace ID		23114-1	
Sample ID		O-062217-JH-01	PZ-9
		Relative Area %	
36	n-Heptane	0.23	
37	Methylcyclohexane	3.95	
38	2,5-Dimethylhexane	0.45	
39	2,4-Dimethylhexane	0.71	
40	2,3,4-Trimethylpentane	1.08	
41	Toluene/2,3,3-Trimethylpentane	0.90	
42	2,3-Dimethylhexane	0.45	
43	2-Methylheptane	2.62	
44	4-Methylheptane	0.74	
45	3,4-Dimethylhexane	0.24	
46A	3-Ethyl-3-methylpentane	2.81	
46B	1,4-Dimethylcyclohexane	1.54	
47	3-Methylheptane	0.64	
48	2,2,5-Trimethylhexane	1.09	
49	n-Octane	0.33	
50	2,2-Dimethylheptane	0.15	
51	2,4-Dimethylheptane	0.40	
52	Ethylcyclohexane	4.58	
53	2,6-Dimethylheptane	0.64	
54	Ethylbenzene	1.00	
55	m+p Xylenes	1.57	
56	4-Methyloctane	1.39	
57	2-Methyloctane	1.42	
58	3-Ethylheptane	0.15	
59	3-Methyloctane	2.16	
60	o-Xylene	0.00	
61	1-Nonene	0.80	
62	n-Nonane	0.33	
I.S.#2	p-Bromofluorobenzene	0.00	
63	Isopropylbenzene	0.17	
64	3,3,5-Trimethylheptane	0.74	
65	2,4,5-Trimethylheptane	2.88	
66	n-Propylbenzene	5.18	
67	1-Methyl-3-ethylbenzene	0.00	
68	1-Methyl-4-ethylbenzene	1.19	
69	1,3,5-Trimethylbenzene	3.97	
70	3,3,4-Trimethylheptane	2.68	

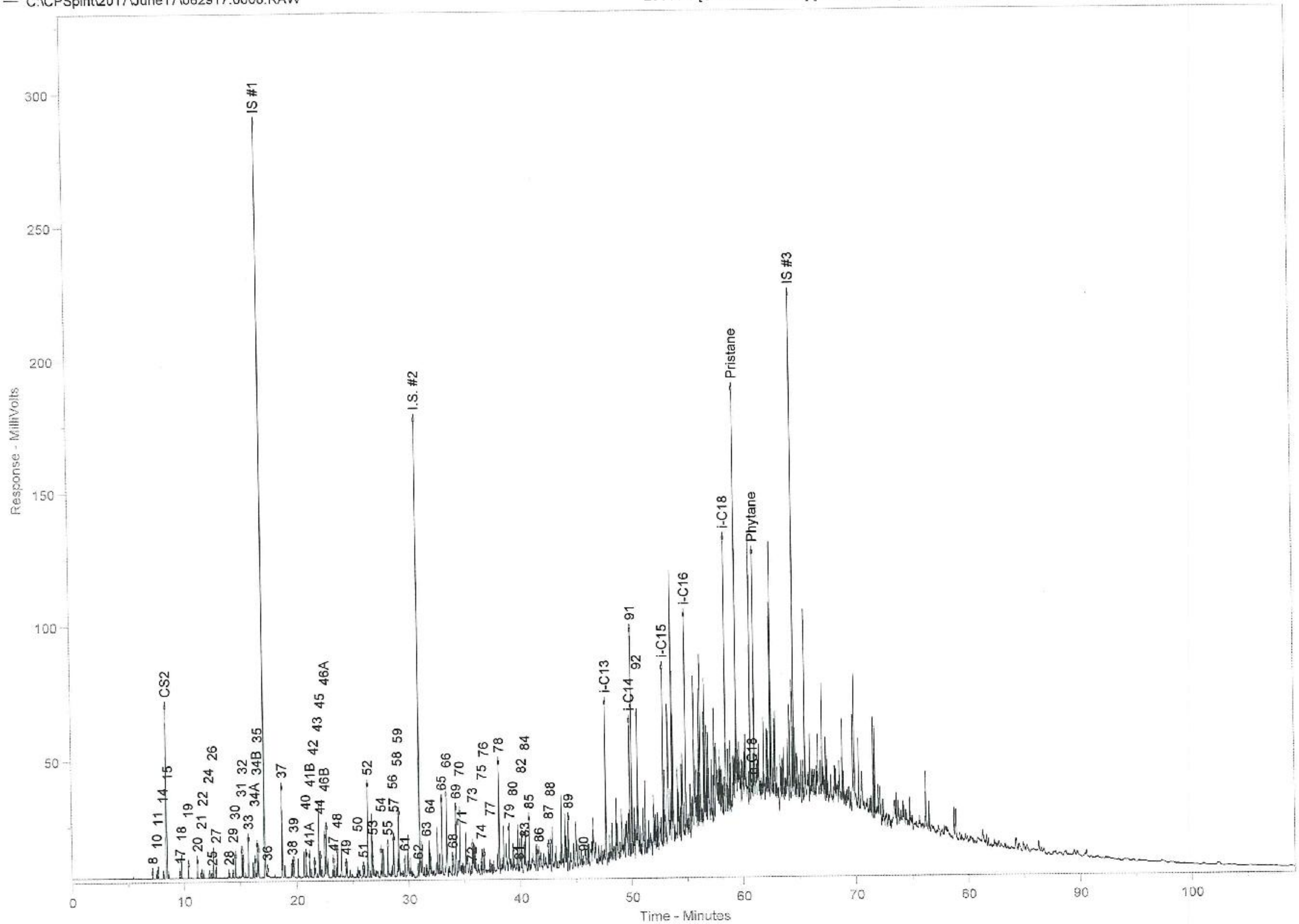
6/29/2017

Pace ID		23114-1
Sample ID		O-062217-JH-01 PZ-9
		Relative Area %
71	1-Methyl-2-ethylbenzene	0.00
72	3-Methylnonane	0.00
73	1,2,4-Trimethylbenzene	1.18
74	Isobutylbenzene	0.57
75	sec-Butylbenzene	1.09
76	n-Decane	1.01
77	1,2,3-Trimethylbenzene	0.22
78	Indan	5.66
79	1,3-Diethylbenzene	2.71
80	1,4-Diethylbenzene	0.71
81	n-Butylbenzene	0.00
82	1,3-Dimethyl-5-ethylbenzene	1.60
83	1,4-Dimethyl-2-ethylbenzene	1.65
84	1,3-Dimethyl-4-ethylbenzene	1.99
85	1,2-Dimethyl-4-ethylbenzene	2.21
86	Undecene	1.11
87	1,2,4,5-Tetramethylbenzene	1.03
88	1,2,3,5-Tetramethylbenzene	1.33
89	1,2,3,4-Tetramethylbenzene	2.98
90	Naphthalene	0.06
91	2-Methyl-naphthalene	8.46
92	1-Methyl-naphthalene	6.06
I.S.#3	5α-Androstane	0.00

Chrom Perfect Chromatogram Report PZ-9

— C:\CPSpirit\2017\June17\062917.0008.RAW

23114-1 [O-062217-JH-01] [400+600CS2]+ IS 315-1-2



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Chrom Perfect Chromatogram Report PZ-9

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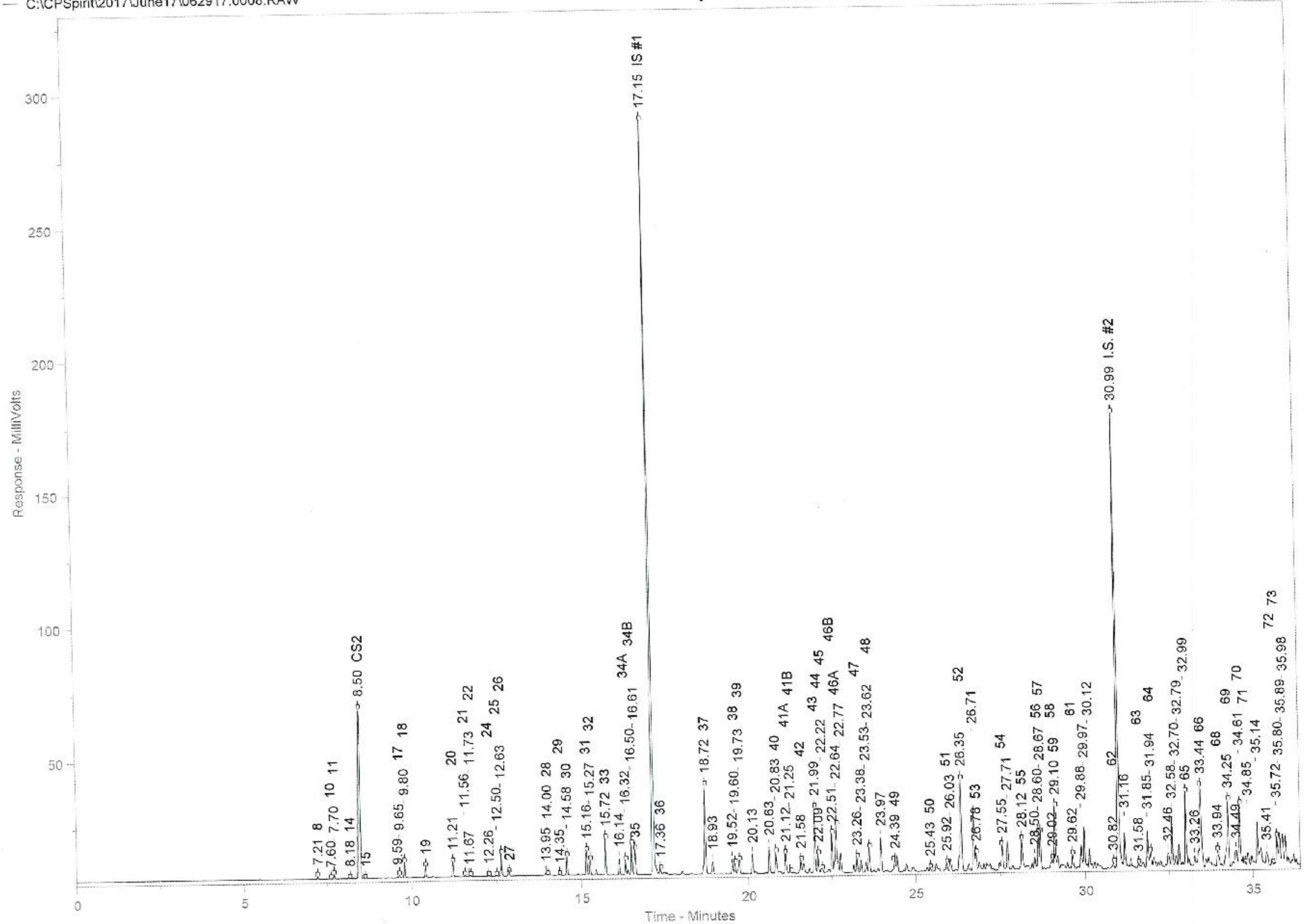
23114-1 [O-062217-JH-01] [400+600CS2]+ IS 315-1-2



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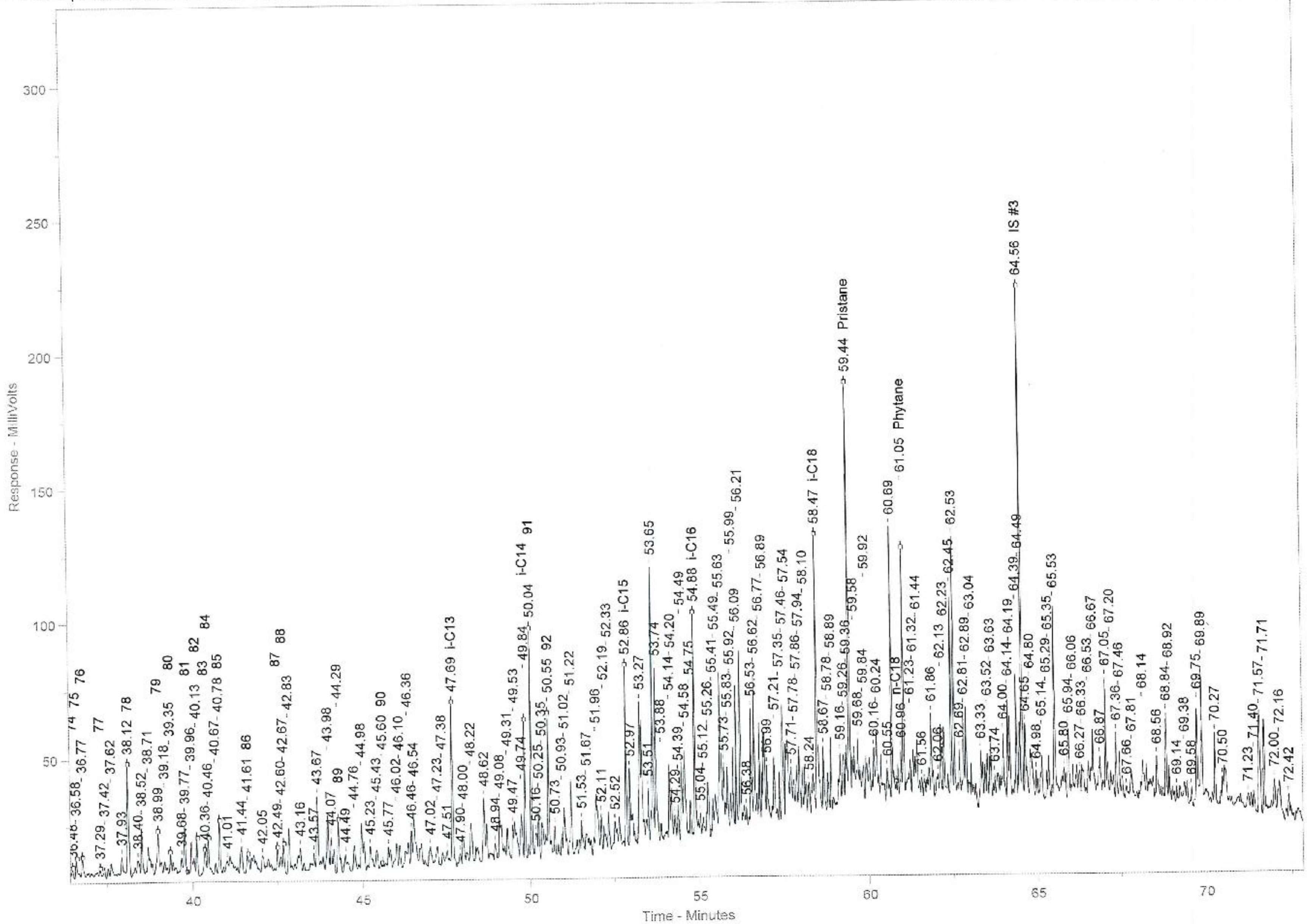
23114-1 [O-062217-JH-01] [400+600CS2]+ IS 315-1-2



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Chrom Perfect Chromatogram Report PZ-9

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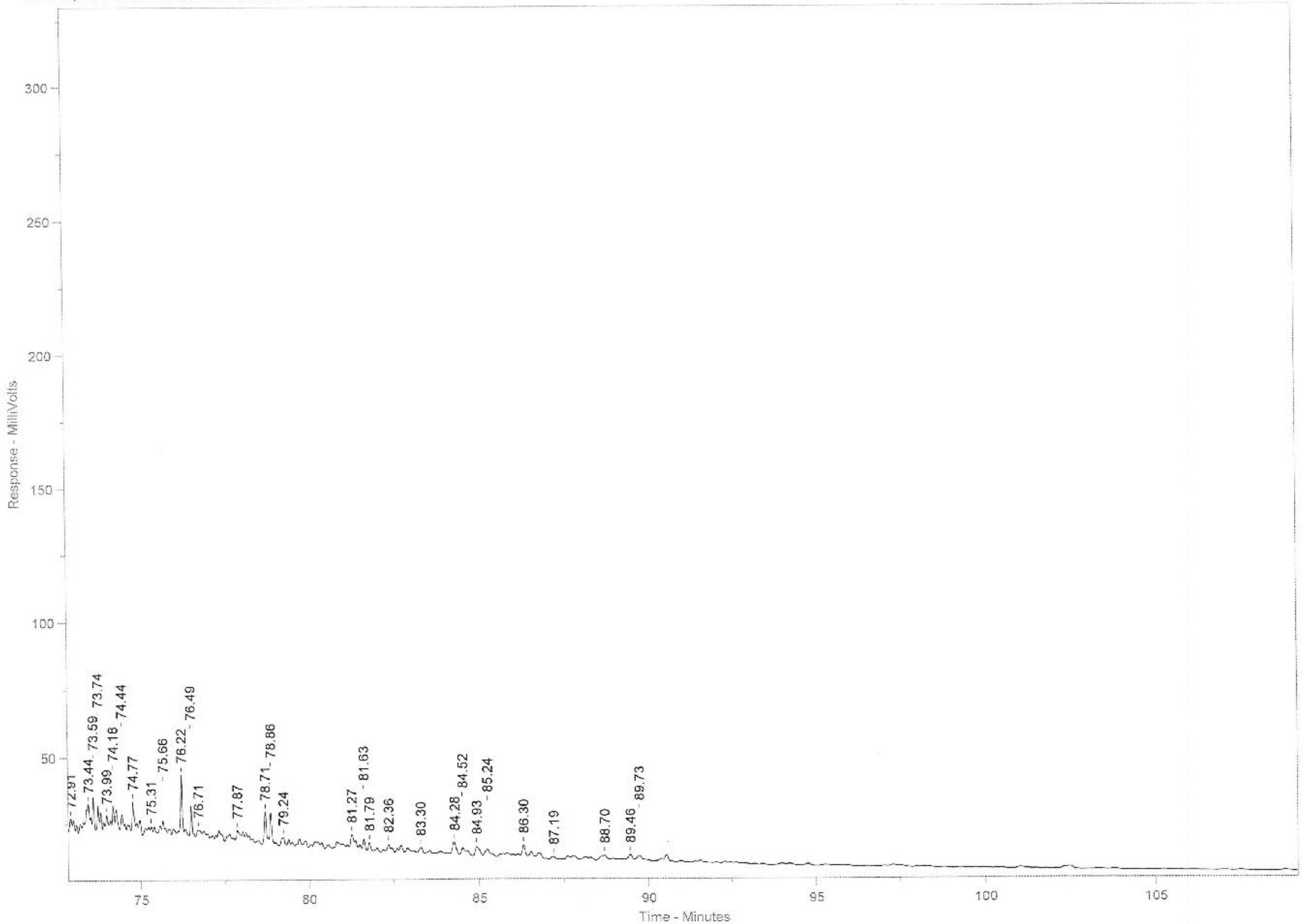
23114-1 [O-062217-JH-01] [400+600CS2]+ IS 315-1-2



Sample Name = **23114-1 [O-062217-JH-01] [400+600CS2]+ IS 315-1-2** PZ-9

Instrument = Instrument 1
Acquisition Port = DP#
Heading 1 =
Heading 2 =

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Method File Name = C:\CPSpirit\C344.met
Calibration File Name = C:\CPSpirit\061917.cal

Date Taken (end) = 6/30/2017 6:33:25 PM
Method Version = 44
Calibration Version = 1

Peak Name	Ret. Time	Area %	Area
8	7.21	0.0085	1524.87
10	7.60	0.0011	193.57
11	7.70	0.0155	2787.73
14	8.18	0.0016	294.48
CS2	8.50	1.3044	234429.90
	9.59	0.0074	1329.51
17	9.65	0.0140	2514.30
18	9.80	0.0684	12295.28
20	11.21	0.0685	12317.03
21	11.56	0.0075	1345.73
	11.67	0.0023	413.12
22	11.73	0.0047	849.42
24	12.26	0.0050	907.11
25	12.50	0.0042	755.42
26	12.63	0.1086	19524.60
	13.95	0.0117	2104.04
28	14.00	0.0046	832.49
29	14.35	0.0064	1149.27
30	14.58	0.0999	17961.71
31	15.16	0.1255	22554.30
32	15.27	0.0810	14561.39
33	15.72	0.1914	34405.06
	16.14	0.0857	15398.88
34A	16.32	0.0802	14413.47
34B	16.50	0.1658	29794.66
35	16.61	0.1468	26378.15
IS #1	17.15	3.9237	705152.80
36	17.36	0.0302	5420.67
37	18.72	0.5213	93681.20
	18.93	0.0740	13296.25
	19.52	0.0791	14216.84
38	19.60	0.0592	10643.51
39	19.73	0.0936	16830.05
	20.13	0.1032	18538.85
	20.63	0.1456	26174.55
40	20.83	0.1421	25529.06
41A	21.12	0.1188	21350.72
41B	21.25	0.0068	1229.04
42	21.58	0.0589	10585.86
43	21.99	0.3460	62182.48
44	22.09	0.0972	17467.63
45	22.22	0.0316	5672.82
46B	22.51	0.2027	36435.87
46A	22.64	0.3704	66575.15
	22.77	0.1078	19370.13
47	23.26	0.0847	15230.74
	23.38	0.0687	12351.77
	23.53	0.0546	9815.99
48	23.62	0.1437	25822.00
	23.97	0.1874	33680.20
49	24.39	0.0438	7866.13
50	25.43	0.0192	3448.49
51	25.92	0.0533	9576.20
	26.03	0.0804	14457.39
52	26.35	0.6045	108631.90

Peak Name	Ret. Time	Area %	Area
	26.71	0.3574	64225.15
53	26.78	0.0850	15273.32
54	27.55	0.1317	23663.71
	27.71	0.1538	27637.40
55	28.12	0.2068	37162.39
	28.50	0.0605	10875.53
56	28.60	0.1833	32939.23
57	28.67	0.1878	33755.03
58	29.02	0.0198	3562.11
59	29.10	0.2845	51137.30
61	29.62	0.1053	18918.71
	29.88	0.1580	28389.96
	29.97	0.2702	48553.79
	30.12	0.1247	22412.19
62	30.82	0.0438	7867.35
I.S. #2	30.99	2.5459	457550.10
	31.16	0.2163	38864.23
63	31.58	0.0219	3944.45
	31.85	0.2054	36915.87
64	31.94	0.0973	17478.23
	32.46	0.1093	19639.35
	32.58	0.2534	45543.29
	32.70	0.0576	10358.34
	32.79	0.1161	20859.10
65	32.99	0.3803	68350.15
	33.26	0.0659	11837.25
66	33.44	0.6833	122795.80
68	33.94	0.1575	28307.40
69	34.25	0.5236	94094.93
	34.49	0.1054	18945.46
70	34.61	0.3536	63555.89
	34.85	0.0934	16792.24
	35.14	0.1850	33239.80
	35.41	0.1056	18984.70
73	35.72	0.1551	27866.06
	35.80	0.1865	33517.48
	35.89	0.1661	29851.19
	35.98	0.1418	25490.29
74	36.48	0.0753	13529.74
75	36.58	0.1437	25834.20
76	36.77	0.1326	23833.34
77	37.29	0.0296	5320.73
	37.42	0.0657	11798.74
	37.62	0.1049	18845.41
	37.93	0.1849	33221.71
78	38.12	0.7462	134111.60
	38.40	0.2480	44564.80
	38.52	0.3063	55053.94
	38.71	0.2944	52910.98
79	38.99	0.3575	64249.01
	39.18	0.1219	21899.05
80	39.35	0.0939	16877.26
	39.68	0.0927	16667.14
	39.77	0.2954	53086.00
	39.96	0.1946	34973.55
82	40.13	0.2115	38019.16
83	40.36	0.2181	39200.17
84	40.46	0.2626	47193.12
	40.67	0.0661	11881.67
85	40.78	0.2911	52318.73
	41.01	0.0635	11413.67
	41.44	0.2598	46691.20
86	41.61	0.1467	26371.49
	42.05	0.1253	22513.17
87	42.49	0.1355	24345.42
	42.60	0.1258	22607.48
88	42.67	0.1748	31422.76

Peak Name	Ret. Time	Area %	Area
	42.83	0.3357	60335.09
	43.16	0.2701	48550.43
	43.57	0.0624	11220.91
	43.67	0.4846	87098.50
	43.98	0.3631	65247.50
	44.07	0.1382	24835.32
89	44.29	0.3929	70619.68
	44.49	0.0842	15131.68
	44.76	0.2035	36579.25
	44.98	0.1836	33003.95
	45.23	0.1889	33942.23
	45.43	0.1528	27458.59
90	45.60	0.0073	1311.17
	45.77	0.1962	35259.28
	46.02	0.2187	39304.51
	46.10	0.1407	25290.19
	46.36	0.2816	50609.68
	46.46	0.1802	32382.92
	46.54	0.4063	73010.67
	47.02	0.2286	41081.78
	47.23	0.2360	42409.16
	47.38	0.1124	20199.48
	47.51	0.1607	28883.27
i-C13	47.69	0.9791	175970.70
	47.90	0.0699	12557.88
	48.00	0.2007	36077.18
	48.22	0.3313	59543.07
	48.62	0.3414	61358.29
	48.94	0.1171	21039.55
	49.08	0.5485	98572.52
	49.31	0.2208	39683.45
	49.47	0.1760	31622.37
	49.53	0.4819	86609.30
	49.74	0.3691	66339.86
i-C14	49.84	0.6051	108745.60
91	50.04	1.1154	200455.50
	50.16	0.2338	42009.93
	50.25	0.2727	49008.29
	50.35	0.3198	57468.20
92	50.55	0.7995	143676.50
	50.73	0.1539	27650.44
	50.93	0.0894	16072.00
	51.02	0.4664	83814.80
	51.22	0.4685	84202.26
	51.53	0.3604	64769.64
	51.67	0.3946	70909.77
	51.96	0.7325	131644.10
	52.11	0.2441	43861.59
	52.19	0.2416	43417.82
	52.33	0.2169	38986.80
	52.52	0.1724	30991.09
i-C15	52.86	0.7516	135074.40
	52.97	0.6665	119790.20
	53.27	1.5778	283551.20
	53.51	0.4093	73554.59
	53.65	1.3072	234926.50
	53.74	0.9036	162397.80
	53.88	0.0830	14907.66
	54.14	0.3948	70960.09
	54.20	0.2595	46632.91
	54.29	0.1515	27219.35
	54.39	0.1811	32547.38
	54.49	0.4513	81110.04
	54.58	0.7555	135779.80
	54.75	0.2364	42492.35
i-C16	54.88	1.0255	184300.50
	55.04	0.1343	24137.09

Peak Name	Ret. Time	Area %	Area
	55.12	0.1650	29655.60
	55.26	0.4644	83455.24
	55.41	0.1369	24599.59
	55.49	0.3191	57346.89
	55.63	1.1383	204568.00
	55.73	0.3295	59216.87
	55.83	0.3170	56963.82
	55.92	0.1487	26729.52
	55.99	0.3550	63793.38
	56.09	0.5477	98430.30
	56.21	0.8250	148270.00
	56.38	0.0877	15769.48
	56.53	0.5828	104739.90
	56.62	0.5816	104516.60
	56.77	0.4205	75567.81
	56.89	0.8766	157538.90
	56.99	0.3189	57318.16
	57.21	0.3551	63826.21
	57.35	0.1779	31977.41
	57.46	0.7278	130791.80
	57.54	0.1256	22581.54
	57.71	0.1870	33608.79
	57.78	0.0982	17647.68
	57.86	0.1657	29786.56
	57.94	0.3556	63912.73
	58.10	0.2481	44586.64
	58.24	0.2176	39098.91
i-C18	58.47	1.5973	287065.00
	58.67	0.3480	62536.44
	58.78	0.2340	42049.82
	58.89	0.2710	48694.78
	59.16	0.3712	66704.33
	59.26	0.3317	59611.07
	59.36	0.4602	82710.74
Pristane	59.44	2.1003	377458.30
	59.58	0.5473	98361.09
	59.68	0.5907	106162.20
	59.84	0.2446	43962.17
	59.92	0.2213	39779.33
	60.16	0.1796	32273.19
	60.24	0.4000	71879.07
	60.55	0.2347	42188.17
	60.69	1.2464	223995.90
	60.96	0.2793	50196.41
Phytane	61.05	1.1760	211349.80
	61.23	0.3395	61005.64
	61.32	0.2882	51797.54
	61.44	0.3530	63443.26
	61.56	0.1069	19204.12
	61.86	0.3638	65388.44
	62.06	0.2059	37004.53
	62.13	0.3909	70243.44
	62.23	0.3693	66363.73
	62.45	0.8613	154786.30
	62.53	0.9639	173228.80
	62.69	0.1859	33415.63
	62.81	0.3616	64985.90
	62.89	0.3783	67986.91
	63.04	0.3477	62484.32
	63.33	0.5171	92927.73
	63.52	0.2027	36435.13
	63.63	0.3700	66502.14
	63.74	0.0569	10219.49
	64.00	0.4601	82684.27
	64.14	0.4271	76755.42
	64.19	0.3577	64290.18
	64.39	0.5923	106454.00

Peak Name	Ret. Time	Area %	Area
	64.49	0.4592	82520.76
IS #3	64.56	1.9140	343981.80
	64.65	0.5373	96564.31
	64.80	0.6016	108118.70
	64.98	0.2091	37579.40
	65.14	0.3389	60906.04
	65.29	0.1135	20398.87
	65.35	0.2260	40622.95
	65.53	1.0874	195430.40
	65.80	0.4772	85766.93
	65.94	0.4749	85344.09
	66.06	0.1826	32808.84
	66.27	0.1860	33431.96
	66.33	0.3102	55754.29
	66.53	0.1837	33008.78
	66.67	0.4235	76111.02
	66.87	0.2833	50920.46
	67.05	0.3590	64518.23
	67.20	0.2263	40671.55
	67.36	0.2754	49489.48
	67.46	0.1661	29852.86
	67.66	0.0894	16057.83
	67.81	0.2482	44610.25
	68.14	0.2814	50571.03
	68.56	0.3624	65138.00
	68.84	0.4877	87651.70
	68.92	0.1678	30164.41
	69.14	0.0626	11248.19
	69.38	0.1076	19345.70
	69.58	0.0982	17656.39
	69.75	0.5316	95545.74
	69.89	0.7622	136982.50
	70.27	0.3478	62508.82
	70.50	0.0571	10267.30
	71.23	0.1437	25827.46
	71.40	0.1330	23907.97
	71.57	0.8160	146658.00
	71.71	0.5641	101374.70
	72.00	0.3111	55907.92
	72.16	0.5125	92109.37
	72.42	0.0916	16466.97
	72.91	0.0682	12253.25
	73.44	0.6181	111084.50
	73.59	0.2035	36565.07
	73.74	0.1173	21085.47
	73.99	0.0655	11771.69
	74.18	0.0953	17129.32
	74.44	0.1678	30155.04
	74.77	0.1974	35481.80
	75.31	0.1986	35700.07
	75.66	0.1843	33118.68
	76.22	0.3848	69155.70
	76.49	0.2179	39165.06
	76.71	0.0803	14430.20
	77.87	0.0885	15902.28
	78.71	0.3120	56068.05
	78.86	0.3068	55129.02
	79.24	0.1104	19836.81
	81.27	0.0942	16929.62
	81.63	0.0823	14787.83
	81.79	0.0713	12817.91
	82.36	0.0519	9330.07
	83.30	0.0739	13287.80
	84.28	0.1771	31823.27
	84.52	0.0530	9523.70
	84.93	0.1755	31541.46
	85.24	0.1692	30405.14

Chrom Perfect Chromatogram Report PZ-9

Peak Name	Ret. Time	Area %	Area
	86.30	0.1172	21070.80
	87.19	0.0448	8049.02
	88.70	0.1177	21154.33
	89.46	0.0844	15170.03
	89.73	0.0714	12823.54

Total Area = 1.797182E+07 Total Height = 6082467 Total Amount = 0

6/29/2017

Pace ID	23114-2
Sample ID	O-062217-JH-02 PZ-3
Evaporation	
n-Pentane / n-Heptane	0.00
2-Methylpentane / 2-Methylheptane	0.06
Waterwashing	
Benzene / Cyclohexane	0.00
Toluene / Methylcyclohexane	0.55
Aromatics / Total Paraffins (n+iso+cyc)	2.34
Aromatics / Naphthenes	10.59
Biodegradation	
(C4 - C8 Para + Isopara) / C4 - C8 Olefins	438.43
3-Methylhexane / n-Heptane	1.40
Methylcyclohexane / n-Heptane	5.77
Isoparaffins + Naphthenes / Paraffins	11.47
Octane rating	
2,2,4,-Trimethylpentane / Methylcyclohexane	0.51
Relative percentages - Bulk hydrocarbon composition as PIANO	
% Paraffinic	2.34
% Isoparaffinic	20.39
% Aromatic	68.46
% Naphthenic	6.47
% Olefinic	2.35

6/29/2017

Pace ID			23114-2
Sample ID			O-062217-JH-02 PZ-3
			Relative Area %
1	Propane		0.00
2	Isobutane		0.00
3	Isobutene		0.00
4	Butane/Methanol		0.00
5	trans-2-Butene		0.00
6	cis-2-Butene		0.00
7	3-Methyl-1-butene		0.00
8	Isopentane		0.00
9	1-Pentene		0.00
10	2-Methyl-1-butene		0.00
11	Pentane		0.00
12	trans-2-Pentene		0.00
13	cis-2-Pentene/t-Butanol		0.00
14	2-Methyl-2-butene		0.00
15	2,2-Dimethylbutane		0.00
16	Cyclopentane		0.00
17	2,3-Dimethylbutane/MTBE		0.02
18	2-Methylpentane		0.05
19	3-Methylpentane		0.05
20	Hexane		0.03
21	trans-2-Hexene		0.01
22	3-Methylcyclopentene		0.01
23	3-Methyl-2-pentene		0.00
24	cis-2-Hexene		0.01
25	3-Methyl-trans-2-pentene		0.01
26	Methylcyclopentane		0.15
27	2,4-Dimethylpentane		0.07
28	Benzene		0.00
29	5-Methyl-1-hexene		0.02
30	Cyclohexane		0.23
31	2-Methylhexane/TAME		0.17
32	2,3-Dimethylpentane		0.24
33	3-Methylhexane		0.37
34A	1-trans-3-Dimethylcyclopentane		0.19
34B	1-cis-3-Dimethylcyclopentane		0.60
35	2,2,4-Trimethylpentane		0.79
I.S. #1	α,α,α-Trifluorotoluene		0.00

6/29/2017

		Relative Area %
Pace ID		23114-2
Sample ID		O-062217-JH-02 PZ-3
36	n-Heptane	0.27
37	Methylcyclohexane	1.54
38	2,5-Dimethylhexane	0.20
39	2,4-Dimethylhexane	0.41
40	2,3,4-Trimethylpentane	0.92
41	Toluene/2,3,3-Trimethylpentane	0.84
42	2,3-Dimethylhexane	0.42
43	2-Methylheptane	0.84
44	4-Methylheptane	0.35
45	3,4-Dimethylhexane	0.17
46A	3-Ethyl-3-methylpentane	1.84
46B	1,4-Dimethylcyclohexane	0.61
47	3-Methylheptane	0.48
48	2,2,5-Trimethylhexane	0.75
49	n-Octane	0.53
50	2,2-Dimethylheptane	0.13
51	2,4-Dimethylheptane	0.30
52	Ethylcyclohexane	3.15
53	2,6-Dimethylheptane	0.50
54	Ethylbenzene	1.03
55	m+p Xylenes	1.40
56	4-Methyloctane	1.08
57	2-Methyloctane	1.02
58	3-Ethylheptane	1.63
59	3-Methyloctane	0.57
60	o-Xylene	0.04
61	1-Nonene	0.85
62	n-Nonane	0.43
I.S.#2	p-Bromofluorobenzene	0.00
63	Isopropylbenzene	0.00
64	3,3,5-Trimethylheptane	0.78
65	2,4,5-Trimethylheptane	3.18
66	n-Propylbenzene	5.35
67	1-Methyl-3-ethylbenzene	0.12
68	1-Methyl-4-ethylbenzene	1.27
69	1,3,5-Trimethylbenzene	4.79
70	3,3,4-Trimethylheptane	3.05

6/29/2017

Pace ID		23114-2
Sample ID		O-062217-JH-02 PZ-3
		Relative Area %
71	1-Methyl-2-ethylbenzene	2.16
72	3-Methylnonane	0.00
73	1,2,4-Trimethylbenzene	2.88
74	Isobutylbenzene	0.74
75	sec-Butylbenzene	1.23
76	n-Decane	1.09
77	1,2,3-Trimethylbenzene	0.94
78	Indan	7.03
79	1,3-Diethylbenzene	3.38
80	1,4-Diethylbenzene	1.16
81	n-Butylbenzene	3.18
82	1,3-Dimethyl-5-ethylbenzene	2.26
83	1,4-Dimethyl-2-ethylbenzene	4.69
84	1,3-Dimethyl-4-ethylbenzene	3.21
85	1,2-Dimethyl-4-ethylbenzene	3.12
86	Undecene	1.45
87	1,2,4,5-Tetramethylbenzene	1.49
88	1,2,3,5-Tetramethylbenzene	2.49
89	1,2,3,4-Tetramethylbenzene	3.55
90	Naphthalene	0.25
91	2-Methyl-naphthalene	4.00
92	1-Methyl-naphthalene	5.86
I.S.#3	5α-Androstane	0.00

Chrom Perfect Chromatogram Report PZ-3

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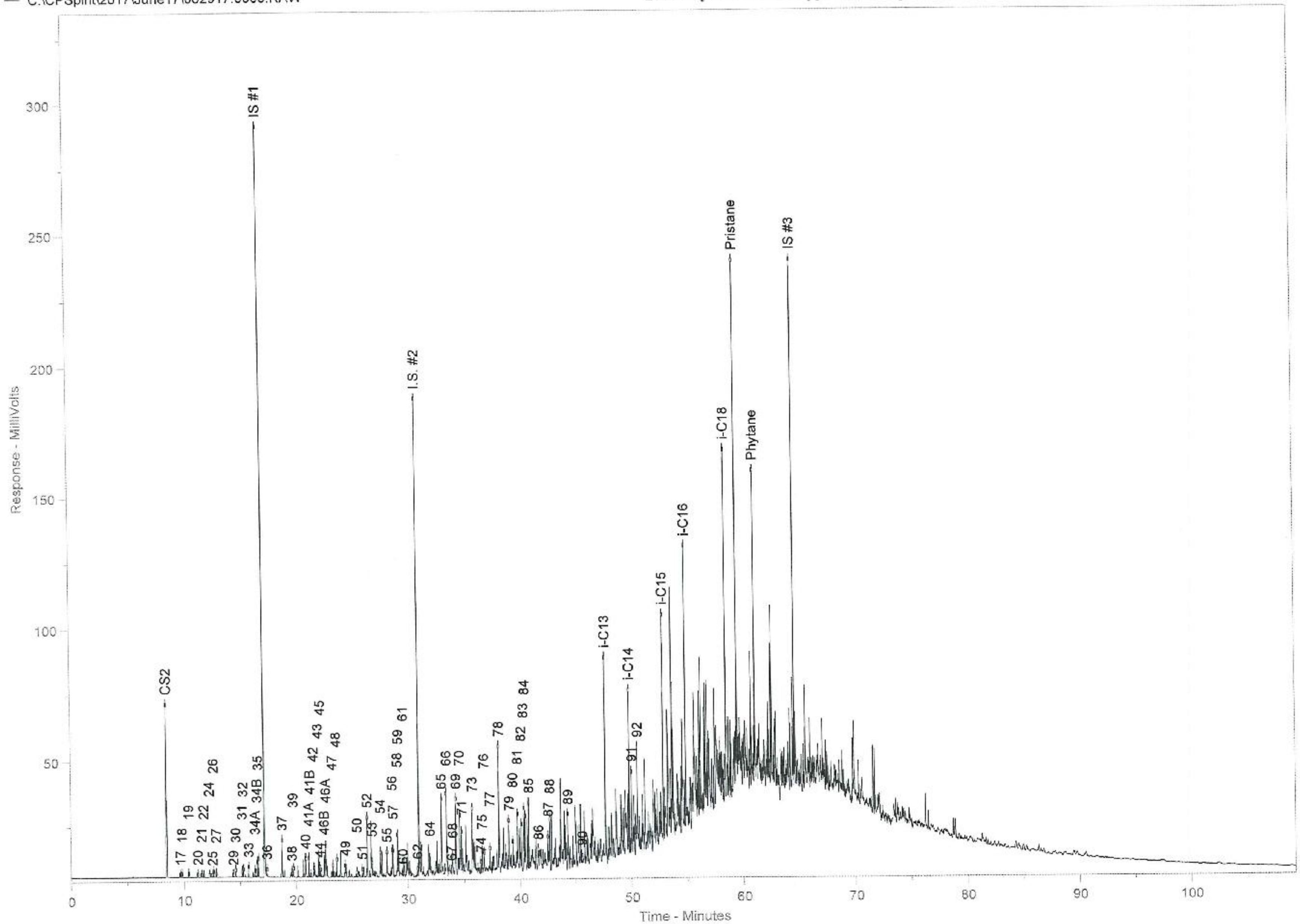
23114-2 [O-062217-JH-02] [400+600CS2]+ IS 315-1-2



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Chrom Perfect Chromatogram Report PZ-3

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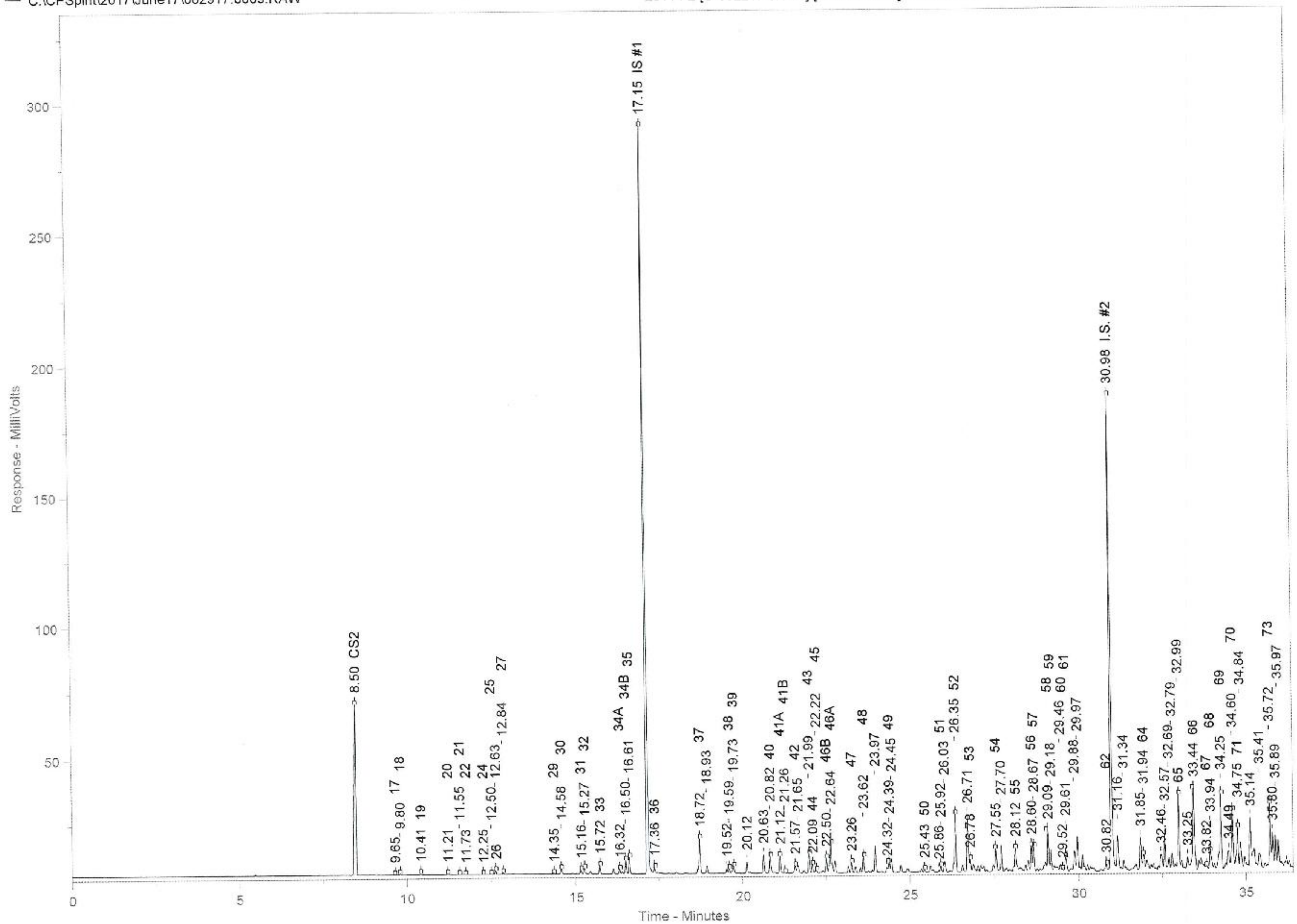
23114-2 [O-062217-JH-02] [400+600CS2]+ IS 315-1-2



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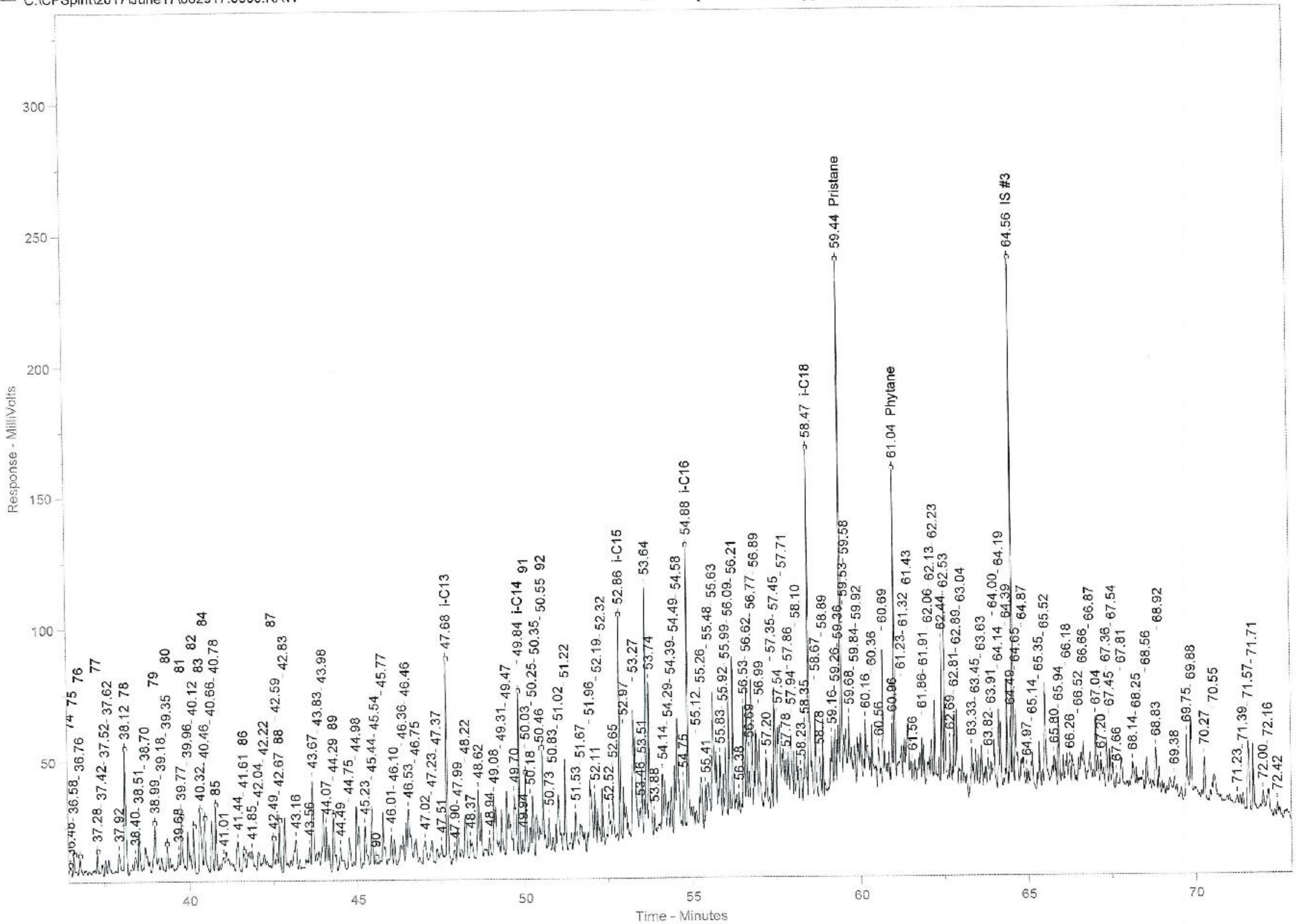
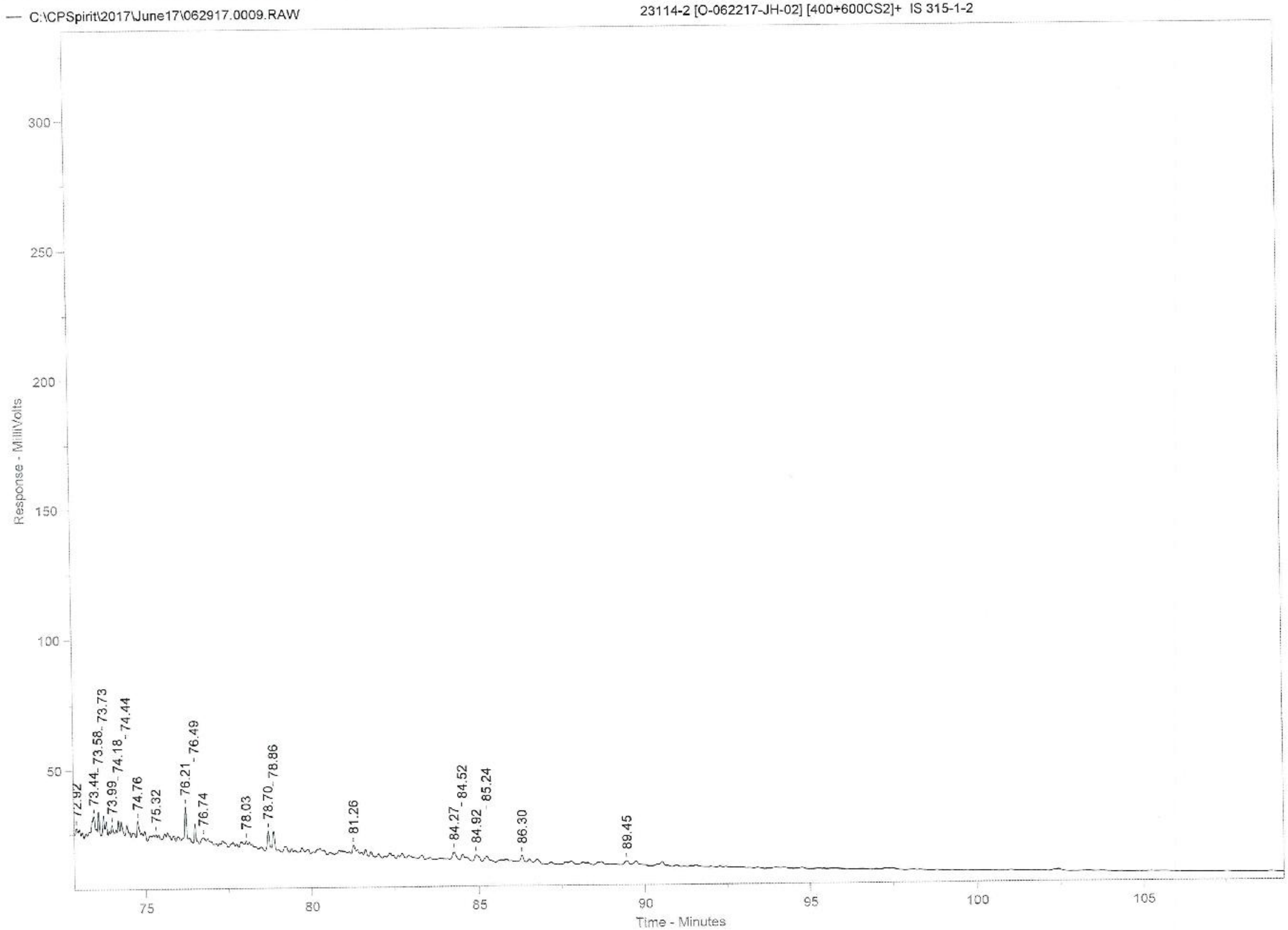
23114-2 [O-062217-JH-02] [400+600CS2]+ IS 315-1-2



Chrom Perfect Chromatogram Report PZ-3



Chrom Perfect Chromatogram Report

Sample Name = **23114-2 [O-062217-JH-02] [400+600CS2]+ IS 315-1-2** PZ-3

Instrument = Instrument 1

Heading 1 =

Heading 2 =

Acquisition Port = DP#

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Method File Name = C:\CPSpirit\C344.met

Calibration File Name = C:\CPSpirit\061917.cal

Date Taken (end) = 6/30/2017 8:41:42 PM

Method Version = 44

Calibration Version = 1

Peak Name	Ret. Time	Area %	Area
CS2	8.50	1.3019	245049.70
17	9.65	0.0019	358.42
18	9.80	0.0057	1069.87
19	10.41	0.0063	1192.06
20	11.21	0.0037	691.51
21	11.55	0.0011	203.02
22	11.73	0.0008	148.18
24	12.25	0.0008	144.82
25	12.50	0.0010	181.36
26	12.63	0.0172	3240.96
27	12.84	0.0081	1528.37
29	14.35	0.0020	378.88
30	14.58	0.0264	4968.54
31	15.16	0.0192	3611.56
32	15.27	0.0274	5163.70
33	15.72	0.0433	8148.80
34A	16.32	0.0223	4197.84
34B	16.50	0.0693	13043.67
35	16.61	0.0912	17168.16
IS #1	17.15	3.7492	705714.10
36	17.36	0.0309	5813.27
37	18.72	0.1781	33517.82
	18.93	0.0435	8183.86
	19.52	0.0252	4741.37
38	19.59	0.0232	4370.04
39	19.73	0.0475	8942.31
	20.12	0.0607	11423.31
	20.63	0.0979	18423.74
40	20.82	0.1064	20030.32
41A	21.12	0.0979	18425.02
41B	21.26	0.0032	594.63
42	21.57	0.0490	9224.40
	21.65	0.0585	11009.62
43	21.99	0.0977	18388.08
44	22.09	0.0401	7539.95
45	22.22	0.0195	3662.92
46B	22.50	0.0706	13297.35
46A	22.64	0.2131	40110.09
47	23.26	0.0560	10536.03
48	23.62	0.0867	16314.31
	23.97	0.1410	26542.99
	24.32	0.0297	5594.41
49	24.39	0.0615	11584.31
	24.45	0.0757	14258.27
50	25.43	0.0152	2862.38
	25.86	0.0073	1372.02
51	25.92	0.0347	6531.16
	26.03	0.0680	12793.85
52	26.35	0.3656	68822.38
	26.71	0.3087	58104.26
53	26.78	0.0582	10953.24
54	27.55	0.1189	22375.91
	27.70	0.1342	25260.02
55	28.12	0.1622	30539.73
56	28.60	0.1253	23592.96

Peak Name	Ret. Time	Area %	Area
57	28.67	0.1188	22368.26
58	29.09	0.1884	35470.12
59	29.18	0.0655	12336.43
	29.46	0.0313	5890.03
60	29.52	0.0047	885.59
61	29.61	0.0980	18448.41
	29.88	0.1186	22319.48
	29.97	0.2012	37866.20
62	30.82	0.0493	9281.06
I.S. #2	30.98	2.6115	491560.60
	31.16	0.2386	44909.65
	31.34	0.0829	15612.71
	31.85	0.1786	33624.98
64	31.94	0.0900	16940.69
	32.46	0.1137	21398.52
	32.57	0.1747	32891.17
	32.69	0.0587	11045.26
	32.79	0.0815	15350.03
65	32.99	0.3686	69380.88
	33.25	0.0825	15530.91
66	33.44	0.6207	116830.70
67	33.82	0.0139	2614.95
68	33.94	0.1476	27787.11
69	34.25	0.5552	104507.80
	34.49	0.1239	23323.04
70	34.60	0.3533	66500.23
71	34.75	0.2505	47142.83
	34.84	0.1617	30429.05
	35.14	0.2097	39476.50
	35.41	0.1137	21407.53
73	35.72	0.3344	62935.38
	35.80	0.1915	36038.33
	35.89	0.1662	31287.44
	35.97	0.1261	23739.57
74	36.48	0.0854	16082.92
75	36.58	0.1429	26889.22
76	36.76	0.1261	23735.78
77	37.28	0.1087	20460.23
	37.42	0.0747	14065.11
	37.52	0.0964	18145.90
	37.62	0.1562	29410.17
	37.92	0.2134	40166.96
78	38.12	0.8152	153439.40
	38.40	0.1169	22006.08
	38.51	0.2361	44440.78
	38.70	0.3153	59355.27
79	38.99	0.3917	73728.29
	39.18	0.1101	20719.22
80	39.35	0.1344	25306.00
	39.68	0.1012	19047.02
81	39.77	0.3686	69388.70
	39.96	0.2495	46966.21
82	40.12	0.2622	49348.31
83	40.32	0.5441	102413.60
84	40.46	0.3716	69938.14
	40.66	0.2847	53595.31
85	40.78	0.3614	68019.68
	41.01	0.0674	12678.58
	41.44	0.2831	53291.05
86	41.61	0.1684	31701.55
	41.85	0.3095	58261.45
	42.04	0.1511	28450.22
	42.22	0.0740	13933.96
87	42.49	0.1729	32554.04
	42.59	0.1354	25487.05
88	42.67	0.2882	54244.72
	42.83	0.3925	73888.65

Peak Name	Ret. Time	Area %	Area
	43.16	0.3296	62039.28
	43.56	0.1957	36829.96
	43.67	0.6147	115704.40
	43.83	0.0868	16333.68
	43.98	0.3723	70081.00
	44.07	0.1731	32580.08
89	44.29	0.4111	77373.27
	44.49	0.2782	52368.98
	44.75	0.2430	45737.79
	44.98	0.2292	43133.40
	45.23	0.2791	52536.51
	45.44	0.3813	71764.11
90	45.54	0.0288	5416.95
	45.77	0.3511	66095.99
	46.01	0.1648	31023.63
	46.10	0.1454	27371.79
	46.36	0.3878	72995.15
	46.46	0.2605	49039.06
	46.53	0.5977	112499.70
	46.75	0.2956	55646.54
	47.02	0.2795	52604.38
	47.23	0.2942	55383.78
	47.37	0.1313	24712.02
	47.51	0.2421	45564.52
i-C13	47.68	1.1872	223463.10
	47.90	0.0753	14165.87
	47.99	0.2306	43401.56
	48.22	0.3979	74899.20
	48.37	0.2138	40249.69
	48.62	0.3586	67495.85
	48.94	0.1111	20905.02
	49.08	0.1749	32925.37
	49.31	0.2426	45672.98
	49.47	0.1938	36488.39
	49.70	0.4581	86232.37
i-C14	49.84	0.6802	128027.90
	49.94	0.0724	13633.46
91	50.03	0.4635	87241.55
	50.18	0.2299	43275.71
	50.25	0.3126	58833.60
	50.35	0.3690	69451.78
	50.46	0.2491	46888.21
92	50.55	0.6791	127822.80
	50.73	0.2285	43003.02
	50.83	0.1083	20378.97
	51.02	0.7045	132601.60
	51.22	0.6059	114050.50
	51.53	0.4353	81937.18
	51.67	0.4759	89587.37
	51.96	0.8595	161775.10
	52.11	0.3453	64995.64
	52.19	0.3296	62043.41
	52.32	0.3327	62617.66
	52.52	0.4620	86954.02
	52.65	0.4426	83317.49
i-C15	52.86	0.9833	185093.20
	52.97	0.6873	129364.20
	53.27	1.6168	304327.50
	53.46	0.2274	42802.47
	53.51	0.3205	60330.40
	53.64	1.2680	238671.70
	53.74	0.8937	168218.10
	53.88	0.1809	34042.79
	54.14	0.3741	70414.63
	54.29	0.2169	40836.51
	54.39	0.2429	45717.94
	54.49	0.4206	79173.29

Peak Name	Ret. Time	Area %	Area
	54.58	0.9057	170479.50
	54.75	0.2300	43292.50
i-C16	54.88	1.1254	211834.00
	55.12	0.1052	19803.87
	55.26	0.4772	89822.81
	55.41	0.2007	37770.06
	55.48	0.4196	78981.42
	55.63	1.1605	218436.00
	55.83	0.5073	95497.71
	55.92	0.1984	37347.38
	55.99	0.3427	64505.71
	56.09	0.5071	95452.22
	56.21	0.7574	142556.80
	56.38	0.1116	21012.79
	56.53	0.6379	120067.20
	56.62	0.5553	104528.60
	56.69	0.1973	37133.88
	56.77	0.6187	116450.90
	56.89	0.6330	119146.90
	56.99	0.4135	77828.66
	57.20	0.2965	55806.88
	57.35	0.1604	30192.09
	57.45	0.7645	143899.00
	57.54	0.1317	24781.62
	57.71	0.2056	38691.68
	57.78	0.1167	21973.73
	57.86	0.1583	29797.35
	57.94	0.4903	92291.33
	58.10	0.2834	53345.95
	58.23	0.2336	43968.67
	58.35	0.4630	87149.90
i-C18	58.47	1.9967	375838.40
	58.67	0.4522	85118.48
	58.78	0.2687	50569.90
	58.89	0.2887	54344.82
	59.16	0.4094	77052.92
	59.26	0.3657	68831.19
	59.36	0.4634	87218.71
Pristane	59.44	2.4848	467721.00
	59.53	0.2955	55614.75
	59.58	0.2908	54743.93
	59.68	0.6364	119781.30
	59.84	0.2657	50005.46
	59.92	0.2255	42441.36
	60.16	0.1579	29730.80
	60.36	0.3700	69638.26
	60.56	0.3577	67328.49
	60.69	0.7940	149449.00
	60.96	0.3352	63101.34
Phytane	61.04	1.4227	267788.70
	61.23	0.2725	51292.15
	61.32	0.2771	52155.41
	61.43	0.3824	71985.06
	61.56	0.1108	20846.91
	61.86	0.1254	23601.89
	61.91	0.1491	28069.61
	62.06	0.2375	44709.02
	62.13	0.3018	56805.84
	62.23	0.4465	84051.80
	62.44	0.6640	124980.30
	62.53	0.6954	130901.50
	62.69	0.1787	33631.95
	62.81	0.2781	52349.61
	62.89	0.3394	63884.31
	63.04	0.3345	62972.03
	63.33	0.5044	94952.38
	63.45	0.3062	57642.66

Peak Name	Ret. Time	Area %	Area
	63.63	0.4169	78481.34
	63.82	0.3155	59390.63
	63.91	0.2041	38416.45
	64.00	0.4526	85185.96
	64.14	0.4319	81290.52
	64.19	0.3480	65507.06
	64.39	0.6187	116463.60
	64.49	0.4693	88334.73
IS #3	64.56	1.9706	370928.00
	64.65	0.6147	115699.80
	64.87	0.4967	93486.74
	64.97	0.1948	36662.28
	65.14	0.3365	63344.93
	65.35	0.3188	60007.95
	65.52	0.8467	159378.70
	65.80	0.4474	84220.55
	65.94	0.4402	82850.71
	66.18	0.2068	38926.11
	66.26	0.1492	28087.40
	66.52	0.1359	25577.84
	66.66	0.4120	77554.73
	66.87	0.1422	26767.59
	67.04	0.1938	36480.71
	67.20	0.2230	41981.40
	67.36	0.2462	46347.68
	67.45	0.1879	35371.35
	67.54	0.1625	30578.64
	67.66	0.1044	19650.56
	67.81	0.3081	57995.57
	68.14	0.3120	58722.41
	68.25	0.2850	53645.94
	68.56	0.2910	54775.06
	68.83	0.2929	55126.23
	68.92	0.1353	25458.56
	69.38	0.0614	11554.46
	69.75	0.3901	73422.48
	69.88	0.4069	76595.76
	70.27	0.2104	39609.98
	70.55	0.3593	67636.40
	71.23	0.0816	15361.38
	71.39	0.0862	16218.15
	71.57	0.5081	95644.92
	71.71	0.4093	77051.16
	72.00	0.1884	35463.87
	72.16	0.3478	65459.41
	72.42	0.0967	18210.24
	72.92	0.0464	8735.27
	73.44	0.2295	43205.18
	73.58	0.1356	25518.16
	73.73	0.0908	17082.01
	73.99	0.0521	9810.22
	74.18	0.0580	10918.20
	74.44	0.1141	21475.94
	74.76	0.1099	20679.40
	75.32	0.1878	35343.23
	76.21	0.2127	40027.56
	76.49	0.1372	25822.13
	76.74	0.0657	12373.19
	78.03	0.0852	16041.63
	78.70	0.1888	35545.50
	78.86	0.1622	30528.77
	81.26	0.0623	11723.97
	84.27	0.1134	21346.43
	84.52	0.0474	8916.25
	84.92	0.1162	21865.97
	85.24	0.1217	22905.02
	86.30	0.0690	12991.63

Chrom Perfect Chromatogram Report PZ-3

Peak Name	Ret. Time	Area %	Area
	89.45	0.0633	11922.55

Total Area = 1.88231E+07 Total Height = 6063803 Total Amount = 0

6/29/2017

Pace ID	23114-3
Sample ID	O-062217-JH-03 PZ-4
Evaporation	
n-Pentane / n-Heptane	0.02
2-Methylpentane / 2-Methylheptane	0.08
Waterwashing	
Benzene / Cyclohexane	0.13
Toluene / Methylcyclohexane	0.37
Aromatics / Total Paraffins (n+iso+cyc)	1.80
Aromatics / Naphthenes	7.40
Biodegradation	
(C4 - C8 Para + Isopara) / C4 - C8 Olefins	298.16
3-Methylhexane / n-Heptane	0.55
Methylcyclohexane / n-Heptane	1.60
Isoparaffins + Naphthenes / Paraffins	9.13
Octane rating	
2,2,4,-Trimethylpentane / Methylcyclohexane	0.39
Relative percentages - Bulk hydrocarbon composition as PIANO	
% Paraffinic	3.45
% Isoparaffinic	23.01
% Aromatic	63.00
% Naphthenic	8.51
% Olefinic	2.02

6/29/2017

		Relative Area %
Pace ID		23114-3
Sample ID		O-062217-JH-03 PZ-4
1	Propane	0.00
2	Isobutane	0.00
3	Isobutene	0.00
4	Butane/Methanol	0.00
5	trans-2-Butene	0.00
6	cis-2-Butene	0.00
7	3-Methyl-1-butene	0.00
8	Isopentane	0.01
9	1-Pentene	0.00
10	2-Methyl-1-butene	0.00
11	Pentane	0.02
12	trans-2-Pentene	0.00
13	cis-2-Pentene/t-Butanol	0.00
14	2-Methyl-2-butene	0.00
15	2,2-Dimethylbutane	0.00
16	Cyclopentane	0.00
17	2,3-Dimethylbutane/MTBE	0.03
18	2-Methylpentane	0.13
19	3-Methylpentane	0.13
20	Hexane	0.25
21	trans-2-Hexene	0.02
22	3-Methylcyclopentene	0.01
23	3-Methyl-2-pentene	0.00
24	cis-2-Hexene	0.02
25	3-Methyl-trans-2-pentene	0.01
26	Methylcyclopentane	0.36
27	2,4-Dimethylpentane	0.11
28	Benzene	0.05
29	5-Methyl-1-hexene	0.02
30	Cyclohexane	0.41
31	2-Methylhexane/TAME	0.42
32	2,3-Dimethylpentane	0.30
33	3-Methylhexane	0.71
34A	1-trans-3-Dimethylcyclopentane	0.35
34B	1-cis-3-Dimethylcyclopentane	0.75
35	2,2,4-Trimethylpentane	0.80
I.S. #1	α,α,α-Trifluorotoluene	0.00

6/29/2017

		Relative Area %
Pace ID		23114-3
Sample ID		O-062217-JH-03 PZ-4
36	n-Heptane	1.29
37	Methylcyclohexane	2.07
38	2,5-Dimethylhexane	0.31
39	2,4-Dimethylhexane	0.49
40	2,3,4-Trimethylpentane	0.87
41	Toluene/2,3,3-Trimethylpentane	0.77
42	2,3-Dimethylhexane	0.32
43	2-Methylheptane	1.73
44	4-Methylheptane	0.49
45	3,4-Dimethylhexane	0.16
46A	3-Ethyl-3-methylpentane	2.04
46B	1,4-Dimethylcyclohexane	1.02
47	3-Methylheptane	0.47
48	2,2,5-Trimethylhexane	0.74
49	n-Octane	0.51
50	2,2-Dimethylheptane	0.10
51	2,4-Dimethylheptane	0.35
52	Ethylcyclohexane	3.55
53	2,6-Dimethylheptane	0.46
54	Ethylbenzene	1.84
55	m+p Xylenes	1.38
56	4-Methyloctane	1.23
57	2-Methyloctane	1.41
58	3-Ethylheptane	0.52
59	3-Methyloctane	2.30
60	o-Xylene	0.10
61	1-Nonene	0.66
62	n-Nonane	0.29
I.S.#2	p-Bromofluorobenzene	0.00
63	Isopropylbenzene	0.25
64	3,3,5-Trimethylheptane	0.65
65	2,4,5-Trimethylheptane	2.76
66	n-Propylbenzene	4.80
67	1-Methyl-3-ethylbenzene	0.09
68	1-Methyl-4-ethylbenzene	1.32
69	1,3,5-Trimethylbenzene	4.10
70	3,3,4-Trimethylheptane	2.94

6/29/2017

Pace ID		23114-3	
Sample ID		O-062217-JH-03	PZ-4
		Relative Area %	
71	1-Methyl-2-ethylbenzene	2.06	
72	3-Methylnonane	0.00	
73	1,2,4-Trimethylbenzene	0.96	
74	Isobutylbenzene	0.62	
75	sec-Butylbenzene	0.84	
76	n-Decane	1.09	
77	1,2,3-Trimethylbenzene	1.45	
78	Indan	6.18	
79	1,3-Diethylbenzene	2.76	
80	1,4-Diethylbenzene	0.92	
81	n-Butylbenzene	0.00	
82	1,3-Dimethyl-5-ethylbenzene	2.12	
83	1,4-Dimethyl-2-ethylbenzene	4.39	
84	1,3-Dimethyl-4-ethylbenzene	2.14	
85	1,2-Dimethyl-4-ethylbenzene	3.11	
86	Undecene	1.27	
87	1,2,4,5-Tetramethylbenzene	1.39	
88	1,2,3,5-Tetramethylbenzene	1.58	
89	1,2,3,4-Tetramethylbenzene	3.22	
90	Naphthalene	0.20	
91	2-Methyl-naphthalene	7.67	
92	1-Methyl-naphthalene	6.69	
I.S.#3	5α-Androstane	0.00	

Chrom Perfect Chromatogram Report PZ-4

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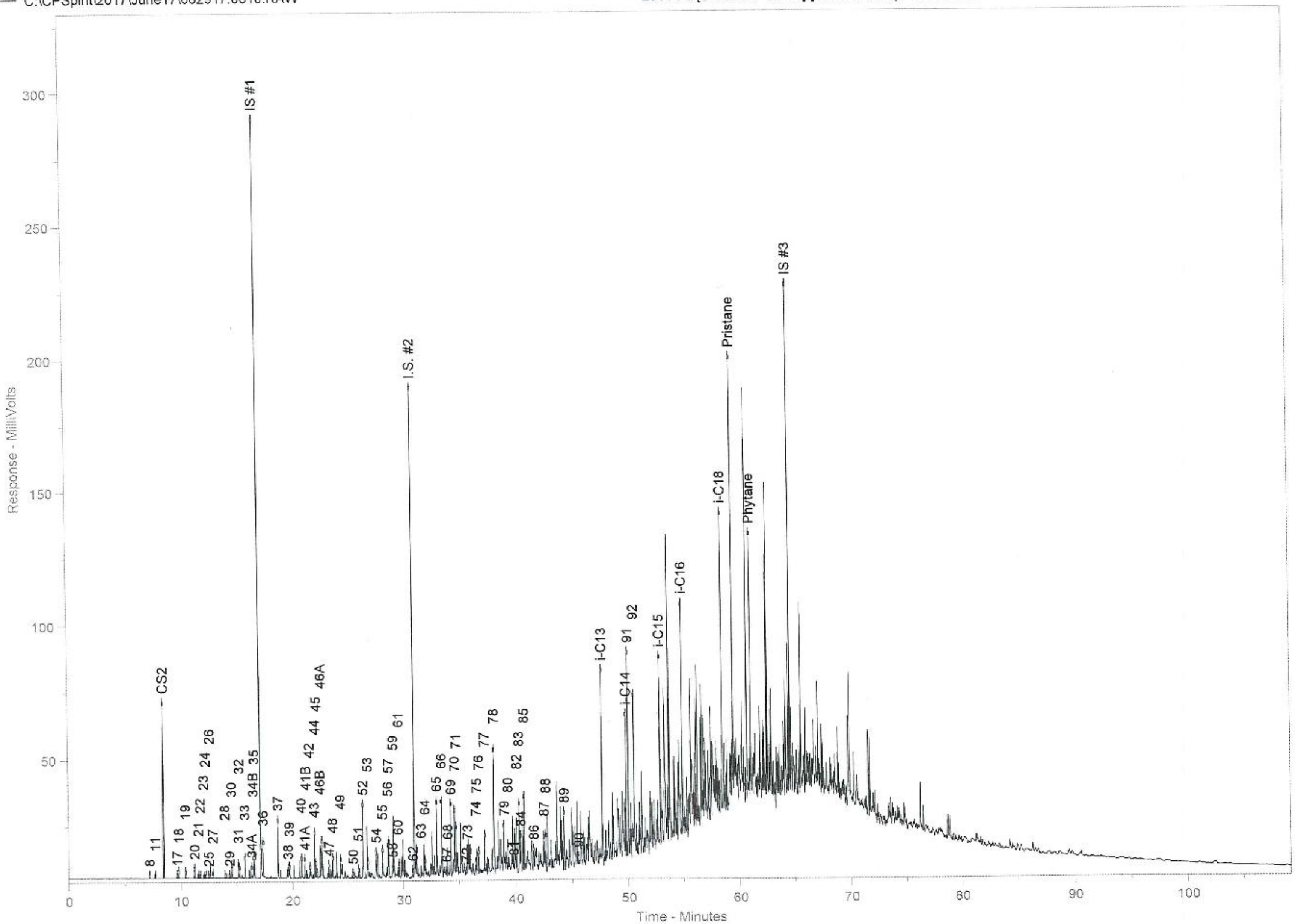
23114-3 [O-062217-JH-03] [400+600CS2]+ IS 315-1-2



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Chrom Perfect Chromatogram Report PZ-4

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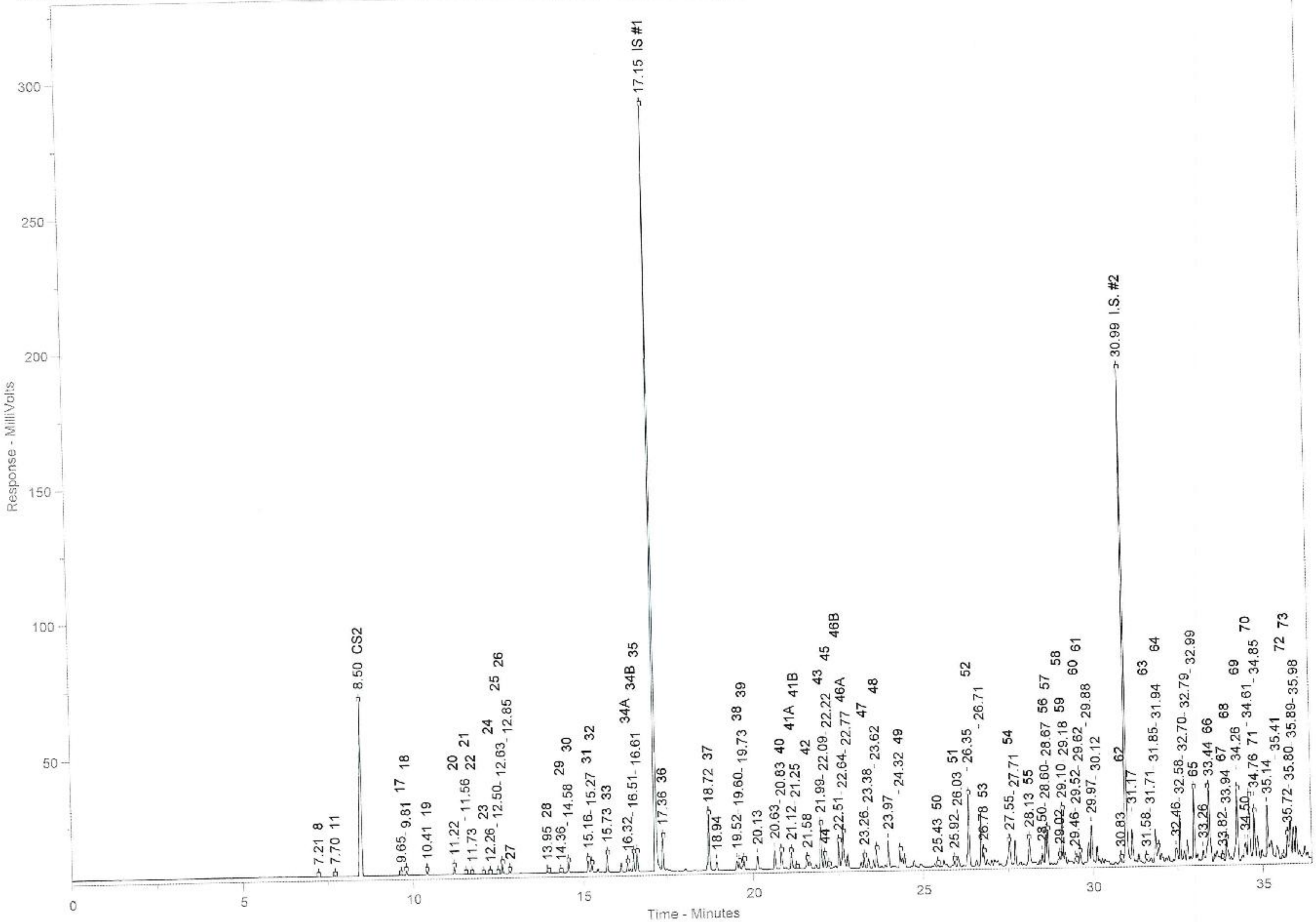

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 PZ-4

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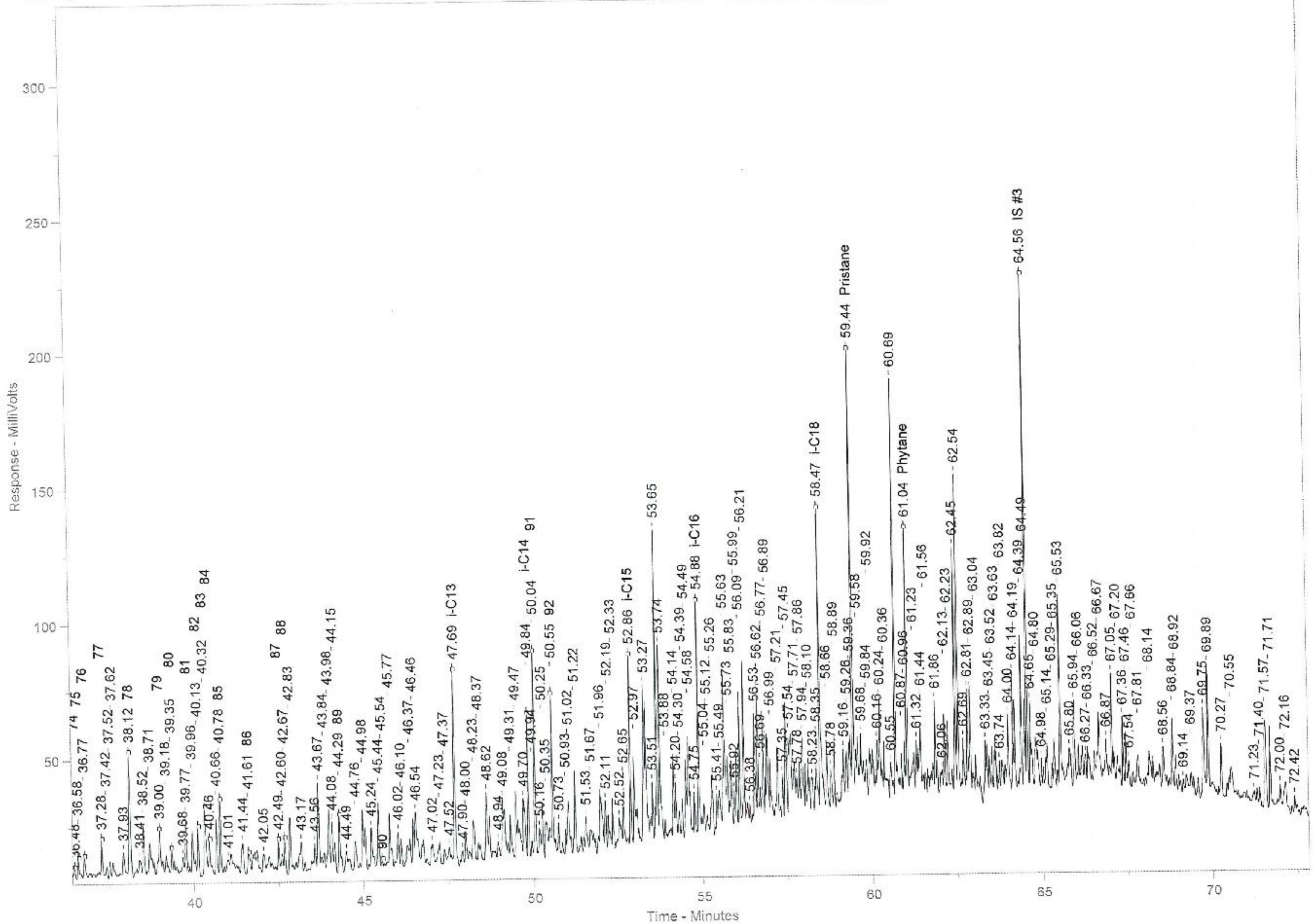
23114-3 [O-062217-JH-03] [400+600CS2]+ IS 315-1-2



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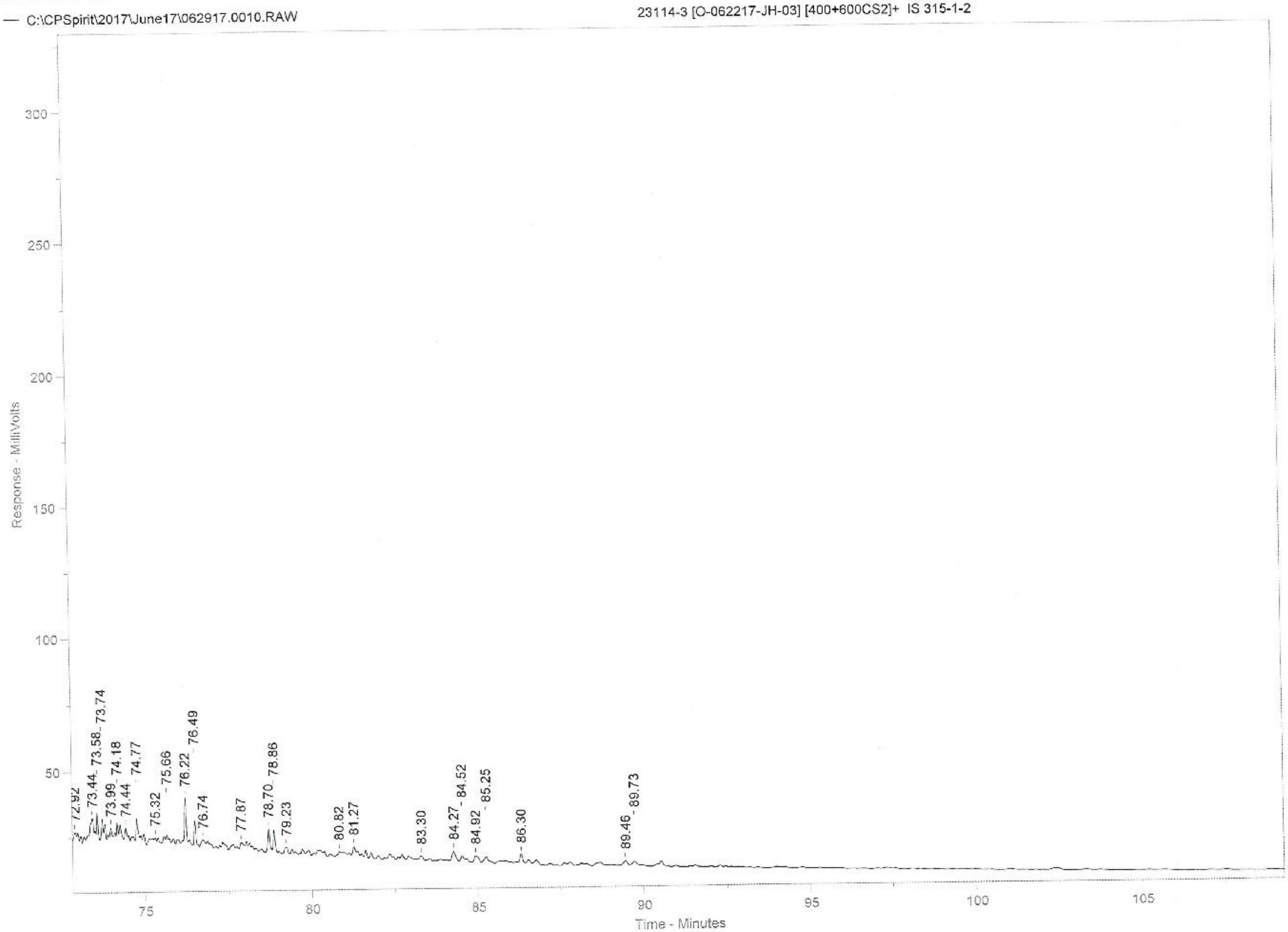
Chrom Perfect Chromatogram Report PZ-4



Sample Name = **23114-3 [O-062217-JH-03] [400+600CS2]+ IS 315-1-2** PZ-4

Instrument = Instrument 1
Acquisition Port = DP#
Heading 1 =
Heading 2 =

Raw File Name = **C:\CPSpirit\2017\June17\062917.0010.RAW**
Method File Name = C:\CPSpirit\C344.met
Calibration File Name = C:\CPSpirit\061917.cal

Date Taken (end) = 6/30/2017 10:49:39 PM
Method Version = 44
Calibration Version = 1

Peak Name	Ret. Time	Area %	Area
8	7.21	0.0015	285.87
11	7.70	0.0026	506.16
CS2	8.50	1.2433	243571.10
17	9.65	0.0034	673.42
18	9.81	0.0164	3207.40
19	10.41	0.0156	3051.03
20	11.22	0.0305	5976.90
21	11.56	0.0026	507.79
22	11.73	0.0015	299.78
24	12.26	0.0023	447.03
25	12.50	0.0014	279.17
26	12.63	0.0436	8547.66
27	12.85	0.0131	2574.06
28	13.95	0.0063	1237.94
29	14.36	0.0024	471.54
30	14.58	0.0501	9805.42
31	15.16	0.0515	10094.51
32	15.27	0.0363	7111.89
33	15.73	0.0860	16856.26
34A	16.32	0.0432	8455.50
34B	16.51	0.0912	17870.35
35	16.61	0.0979	19176.88
IS #1	17.15	3.6006	705398.40
36	17.36	0.1574	30826.78
37	18.72	0.2523	49430.53
	18.94	0.0449	8795.96
	19.52	0.0443	8669.94
38	19.60	0.0372	7284.05
39	19.73	0.0591	11577.36
	20.13	0.0654	12817.25
	20.63	0.0947	18560.52
40	20.83	0.1064	20851.29
41A	21.12	0.0934	18307.66
41B	21.25	0.0042	814.15
42	21.58	0.0384	7516.06
43	21.99	0.2105	41241.05
44	22.09	0.0597	11703.52
45	22.22	0.0193	3790.04
46B	22.51	0.1241	24307.22
46A	22.64	0.2488	48734.93
	22.77	0.0735	14391.11
47	23.26	0.0567	11101.10
	23.38	0.0491	9615.47
48	23.62	0.0903	17689.08
	23.97	0.1326	25968.48
49	24.32	0.0617	12096.84
50	25.43	0.0125	2452.99
51	25.92	0.0422	8258.22
	26.03	0.0619	12133.02
52	26.35	0.4315	84541.66
	26.71	0.2723	53337.38
53	26.78	0.0563	11038.31
54	27.55	0.2237	43822.40
	27.71	0.1278	25033.23
55	28.13	0.1675	32810.75

Peak Name	Ret. Time	Area %	Area
	28.50	0.0660	12936.35
56	28.60	0.1492	29227.56
57	28.67	0.1720	33695.80
58	29.02	0.0631	12363.80
59	29.10	0.2802	54902.36
	29.18	0.0601	11764.69
	29.46	0.0293	5745.13
60	29.52	0.0121	2371.93
61	29.62	0.0807	15814.51
	29.88	0.1200	23506.64
	29.97	0.2147	42068.88
	30.12	0.1029	20165.20
62	30.83	0.0353	6913.43
I.S. #2	30.99	2.4761	485090.50
	31.17	0.1835	35943.04
63	31.58	0.0309	6050.63
	31.71	0.0454	8901.42
	31.85	0.1771	34689.50
64	31.94	0.0786	15400.91
	32.46	0.0989	19385.18
	32.58	0.2182	42747.56
	32.70	0.0518	10154.27
	32.79	0.1015	19886.84
65	32.99	0.3364	65894.09
	33.26	0.0622	12178.31
66	33.44	0.5847	114554.10
67	33.82	0.0105	2061.41
68	33.94	0.1601	31359.43
69	34.26	0.4991	97781.81
	34.50	0.1149	22511.76
70	34.61	0.3580	70142.11
71	34.76	0.2505	49078.94
	34.85	0.1417	27759.93
	35.14	0.2165	42417.49
	35.41	0.0964	18890.20
73	35.72	0.1167	22868.09
	35.80	0.1963	38452.17
	35.89	0.1543	30234.81
	35.98	0.1393	27283.82
74	36.48	0.0754	14777.78
75	36.58	0.1028	20135.29
76	36.77	0.1328	26008.41
77	37.28	0.1759	34455.37
	37.42	0.0661	12953.38
	37.52	0.0940	18415.01
	37.62	0.1352	26495.84
	37.93	0.2116	41452.65
78	38.12	0.7517	147266.80
	38.41	0.1092	21395.15
	38.52	0.2694	52768.48
	38.71	0.1911	37443.72
79	39.00	0.3356	65744.07
	39.18	0.1481	29023.71
80	39.35	0.1123	21991.75
	39.68	0.0900	17639.59
	39.77	0.3205	62790.68
	39.96	0.2438	47772.30
82	40.13	0.2582	50577.14
83	40.32	0.5339	104586.20
84	40.46	0.2607	51073.10
	40.66	0.2852	55865.28
85	40.78	0.3788	74212.54
	41.01	0.0619	12119.85
	41.44	0.2678	52465.53
86	41.61	0.1550	30357.65
	42.05	0.1279	25051.89
87	42.49	0.1690	33102.75

Peak Name	Ret. Time	Area %	Area
	42.60	0.1305	25566.84
88	42.67	0.1929	37796.78
	42.83	0.3769	73840.94
	43.17	0.2960	57983.56
	43.56	0.0961	18817.95
	43.67	0.5428	106332.40
	43.84	0.0946	18535.70
	43.98	0.4421	86619.73
	44.08	0.2702	52936.73
	44.15	0.1642	32164.79
89	44.29	0.3924	76880.89
	44.49	0.0847	16602.54
	44.76	0.2122	41569.81
	44.98	0.2048	40118.67
	45.24	0.2609	51118.03
	45.44	0.3828	74996.46
90	45.54	0.0249	4880.90
	45.77	0.3279	64234.38
	46.02	0.1728	33859.98
	46.10	0.1452	28452.83
	46.37	0.3127	61269.11
	46.46	0.2152	42161.89
	46.54	0.4147	81248.72
	47.02	0.2335	45741.75
	47.23	0.2506	49102.36
	47.37	0.1161	22740.18
	47.52	0.2213	43353.09
i-C13	47.69	1.0429	204305.10
	47.90	0.0710	13919.07
	48.00	0.2065	40455.90
	48.23	0.3430	67194.98
	48.37	0.1871	36650.53
	48.62	0.3452	67618.80
	48.94	0.1062	20804.84
	49.08	0.6156	120593.00
	49.31	0.2401	47028.08
	49.47	0.1973	38657.86
	49.70	0.4180	81892.34
i-C14	49.84	0.5547	108667.80
	49.94	0.0689	13491.14
91	50.04	0.9333	182847.00
	50.16	0.2216	43407.57
	50.25	0.2672	52354.71
	50.35	0.3107	60860.82
92	50.55	0.8143	159535.00
	50.73	0.1548	30327.17
	50.93	0.0970	19000.43
	51.02	0.4752	93097.79
	51.22	0.4800	94037.93
	51.53	0.3546	69467.60
	51.67	0.3982	78012.70
	51.96	0.7175	140568.40
	52.11	0.2868	56183.02
	52.19	0.2815	55152.84
	52.33	0.2671	52326.29
	52.52	0.3717	72820.28
	52.65	0.2854	55905.41
i-C15	52.86	0.7654	149947.00
	52.97	0.7324	143474.20
	53.27	1.6182	317019.60
	53.51	0.4062	79578.95
	53.65	1.3278	260124.30
	53.74	0.9155	179358.30
	53.88	0.0843	16515.17
	54.14	0.3963	77635.01
	54.20	0.2471	48409.69
	54.30	0.1470	28798.97

Peak Name	Ret. Time	Area %	Area
	54.39	0.1836	35962.21
	54.49	0.4414	86483.14
	54.58	0.7808	152959.30
	54.75	0.2498	48933.90
i-C16	54.88	0.9818	192350.10
	55.04	0.1596	31271.48
	55.12	0.1551	30394.68
	55.26	0.4539	88916.74
	55.41	0.1314	25745.58
	55.49	0.3016	59094.57
	55.63	1.0339	202545.00
	55.73	0.3191	62513.09
	55.83	0.3102	60768.01
	55.92	0.1361	26657.29
	55.99	0.3134	61407.38
	56.09	0.4639	90887.49
	56.21	0.7200	141061.40
	56.38	0.0813	15924.55
	56.53	0.5159	101077.50
	56.62	0.5065	99233.18
	56.69	0.1276	24996.26
	56.77	0.4506	88285.41
	56.89	0.5884	115279.90
	56.99	0.3011	58980.81
	57.21	0.3646	71420.81
	57.35	0.1455	28495.53
	57.45	0.6850	134189.20
	57.54	0.1215	23807.14
	57.71	0.1769	34665.51
	57.78	0.0934	18291.05
	57.86	0.1585	31058.86
	57.94	0.3516	68878.76
	58.10	0.2299	45044.80
	58.23	0.2188	42870.23
	58.35	0.3981	78000.74
i-C18	58.47	1.6177	316920.60
	58.66	0.3616	70839.34
	58.78	0.2348	46000.13
	58.89	0.2569	50321.65
	59.16	0.3498	68520.87
	59.26	0.3122	61170.03
	59.36	0.4715	92361.62
Pristane	59.44	2.0793	407356.10
	59.58	0.5390	105598.50
	59.68	0.5662	110924.90
	59.84	0.2447	47936.62
	59.92	0.2240	43890.28
	60.16	0.1760	34479.23
	60.24	0.5018	98297.95
	60.36	0.3446	67500.95
	60.55	0.2999	58757.75
	60.69	1.6248	318321.00
	60.87	0.1662	32563.79
	60.96	0.2766	54198.23
Phytane	61.04	1.1397	223284.00
	61.23	0.3762	73708.51
	61.32	0.2827	55379.11
	61.44	0.3529	69140.23
	61.56	0.1022	20029.41
	61.86	0.3837	75168.09
	62.06	0.1903	37279.19
	62.13	0.3856	75542.15
	62.23	0.3456	67701.95
	62.45	0.9616	188392.60
	62.54	1.0717	209952.50
	62.69	0.1961	38410.76
	62.81	0.3650	71507.37

Peak Name	Ret. Time	Area %	Area
	62.89	0.4313	84492.08
	63.04	0.3518	68913.72
	63.33	0.5951	116575.80
	63.45	0.2787	54607.57
	63.52	0.2405	47124.57
	63.63	0.4594	90009.46
	63.74	0.1609	31513.72
	63.82	0.3262	63897.54
	64.00	0.5903	115636.50
	64.14	0.5367	105147.10
	64.19	0.4213	82540.47
	64.39	0.7580	148493.10
	64.49	0.5536	108461.80
IS #3	64.56	1.8220	356950.80
	64.65	0.6429	125949.00
	64.80	0.6357	124539.90
	64.98	0.2372	46474.37
	65.14	0.3816	74763.34
	65.29	0.1081	21172.24
	65.35	0.2503	49034.69
	65.53	1.1054	216556.10
	65.80	0.4863	95266.13
	65.94	0.4658	91255.02
	66.06	0.1101	21578.30
	66.27	0.1340	26254.44
	66.33	0.2441	47816.31
	66.52	0.1525	29871.77
	66.67	0.4938	96734.43
	66.87	0.1965	38495.00
	67.05	0.3035	59468.12
	67.20	0.2327	45589.92
	67.36	0.2977	58320.04
	67.46	0.2351	46063.33
	67.54	0.1627	31875.14
	67.66	0.0945	18521.77
	67.81	0.2592	50774.61
	68.14	0.2415	47321.85
	68.56	0.3296	64571.29
	68.84	0.3831	75043.98
	68.92	0.1548	30335.17
	69.14	0.0468	9172.10
	69.37	0.0709	13897.29
	69.75	0.4772	93480.52
	69.89	0.6225	121960.30
	70.27	0.2469	48372.21
	70.55	0.3917	76744.64
	71.23	0.0959	18779.58
	71.40	0.1008	19750.69
	71.57	0.6207	121604.90
	71.71	0.4511	88379.82
	72.00	0.2045	40064.55
	72.16	0.3746	73382.85
	72.42	0.0607	11886.97
	72.92	0.1211	23715.46
	73.44	0.2450	47999.69
	73.58	0.1430	28012.05
	73.74	0.0929	18192.56
	73.99	0.0543	10630.38
	74.18	0.0601	11774.18
	74.44	0.0680	13314.35
	74.77	0.1398	27381.39
	75.32	0.2075	40654.81
	75.66	0.1325	25957.17
	76.22	0.2791	54680.91
	76.49	0.1689	33083.91
	76.74	0.0685	13420.20
	77.87	0.0511	10012.61

Chrom Perfect Chromatogram Report PZ-4

Peak Name	Ret. Time	Area %	Area
	78.70	0.2032	39801.80
	78.86	0.1784	34944.23
	79.23	0.0854	16732.31
	80.82	0.0831	16275.74
	81.27	0.0604	11832.39
	83.30	0.0579	11345.12
	84.27	0.1302	25507.08
	84.52	0.1109	21725.68
	84.92	0.1193	23368.44
	85.25	0.1222	23943.38
	86.30	0.0901	17652.00
	89.46	0.0829	16242.13
	89.73	0.1189	23294.57

Total Area = 1.959092E+07 Total Height = 6608643 Total Amount = 0

6/29/2017

Pace ID	23114-4
Sample ID	O-062217-JH-04 PZ-5
Evaporation	
n-Pentane / n-Heptane	0.02
2-Methylpentane / 2-Methylheptane	0.08
Waterwashing	
Benzene / Cyclohexane	0.13
Toluene / Methylcyclohexane	0.37
Aromatics / Total Paraffins (n+iso+cyc)	1.97
Aromatics / Naphthenes	8.01
Biodegradation	
(C4 - C8 Para + Isopara) / C4 - C8 Olefins	291.31
3-Methylhexane / n-Heptane	0.55
Methylcyclohexane / n-Heptane	1.60
Isoparaffins + Naphthenes / Paraffins	8.95
Octane rating	
2,2,4,-Trimethylpentane / Methylcyclohexane	0.36
Relative percentages - Bulk hydrocarbon composition as PIANO	
% Paraffinic	3.32
% Isoparaffinic	21.58
% Aromatic	65.02
% Naphthenic	8.12
% Olefinic	1.96

6/29/2017

Pace ID		23114-4
Sample ID		O-062217-JH-04 PZ-5
		Relative Area %
1	Propane	0.00
2	Isobutane	0.00
3	Isobutene	0.00
4	Butane/Methanol	0.00
5	trans-2-Butene	0.00
6	cis-2-Butene	0.00
7	3-Methyl-1-butene	0.00
8	Isopentane	0.01
9	1-Pentene	0.00
10	2-Methyl-1-butene	0.00
11	Pentane	0.02
12	trans-2-Pentene	0.00
13	cis-2-Pentene/t-Butanol	0.00
14	2-Methyl-2-butene	0.00
15	2,2-Dimethylbutane	0.00
16	Cyclopentane	0.00
17	2,3-Dimethylbutane/MTBE	0.03
18	2-Methylpentane	0.13
19	3-Methylpentane	0.12
20	Hexane	0.24
21	trans-2-Hexene	0.02
22	3-Methylcyclopentene	0.01
23	3-Methyl-2-pentene	0.00
24	cis-2-Hexene	0.02
25	3-Methyl-trans-2-pentene	0.01
26	Methylcyclopentane	0.35
27	2,4-Dimethylpentane	0.11
28	Benzene	0.05
29	5-Methyl-1-hexene	0.02
30	Cyclohexane	0.42
31	2-Methylhexane/TAME	0.43
32	2,3-Dimethylpentane	0.30
33	3-Methylhexane	0.69
34A	1-trans-3-Dimethylcyclopentane	0.34
34B	1-cis-3-Dimethylcyclopentane	0.68
35	2,2,4-Trimethylpentane	0.72
I.S. #1	α,α,α-Trifluorotoluene	0.00

6/29/2017

Pace ID		23114-4
Sample ID		O-062217-JH-04 PZ-5
		Relative Area %
36	n-Heptane	1.24
37	Methylcyclohexane	1.99
38	2,5-Dimethylhexane	0.29
39	2,4-Dimethylhexane	0.47
40	2,3,4-Trimethylpentane	0.84
41	Toluene/2,3,3-Trimethylpentane	0.74
42	2,3-Dimethylhexane	0.87
43	2-Methylheptane	1.66
44	4-Methylheptane	0.47
45	3,4-Dimethylhexane	0.15
46A	3-Ethyl-3-methylpentane	1.79
46B	1,4-Dimethylcyclohexane	0.94
47	3-Methylheptane	0.45
48	2,2,5-Trimethylhexane	0.72
49	n-Octane	0.49
50	2,2-Dimethylheptane	0.10
51	2,4-Dimethylheptane	0.21
52	Ethylcyclohexane	3.41
53	2,6-Dimethylheptane	0.45
54	Ethylbenzene	1.72
55	m+p Xylenes	1.33
56	4-Methyloctane	1.12
57	2-Methyloctane	1.27
58	3-Ethylheptane	0.11
59	3-Methyloctane	1.78
60	o-Xylene	0.11
61	1-Nonene	0.62
62	n-Nonane	0.26
I.S.#2	p-Bromofluorobenzene	0.00
63	Isopropylbenzene	0.16
64	3,3,5-Trimethylheptane	0.62
65	2,4,5-Trimethylheptane	2.66
66	n-Propylbenzene	4.63
67	1-Methyl-3-ethylbenzene	0.09
68	1-Methyl-4-ethylbenzene	1.28
69	1,3,5-Trimethylbenzene	3.97
70	3,3,4-Trimethylheptane	2.84

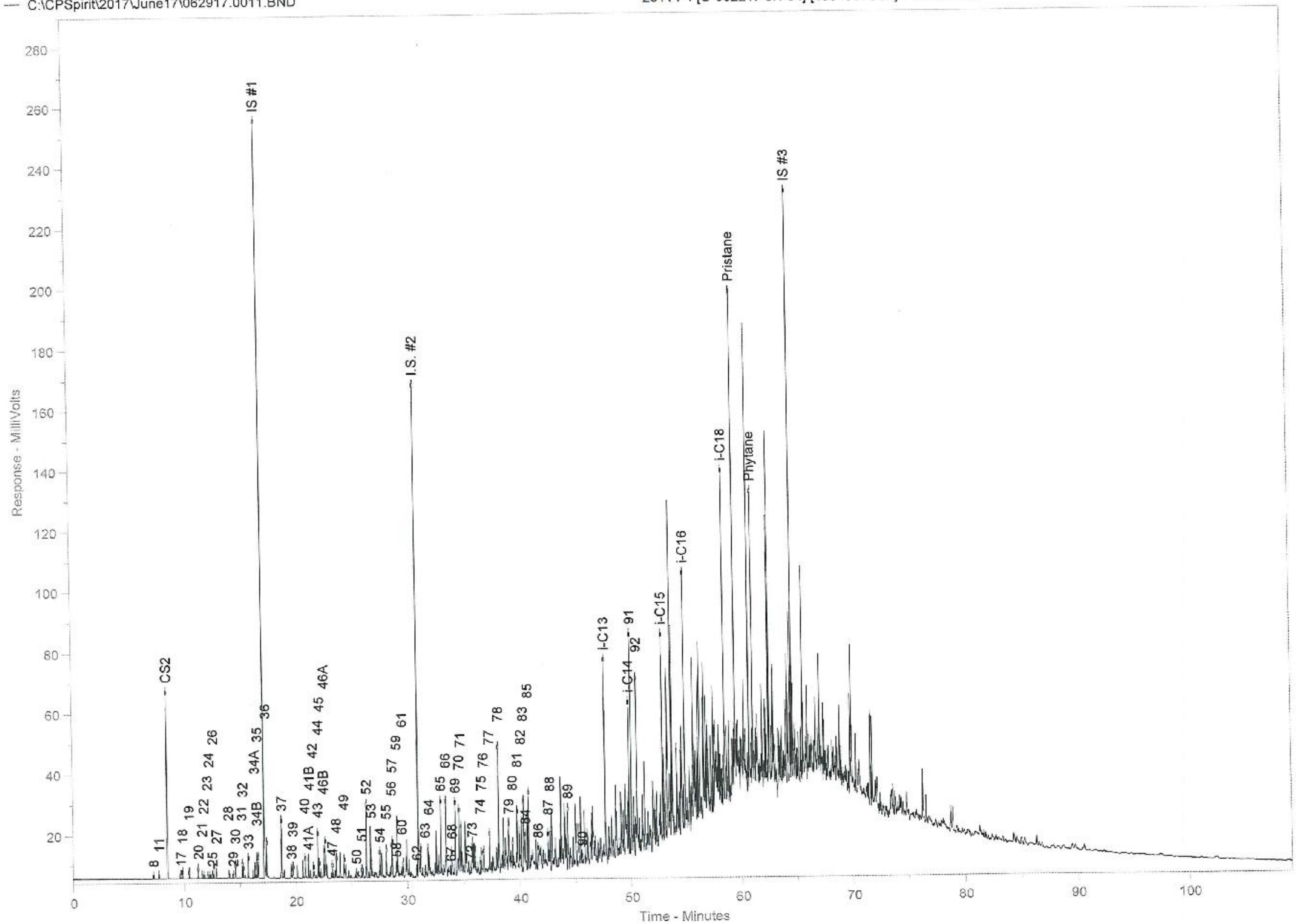
6/29/2017

Pace ID		23114-4
Sample ID		O-062217-JH-04 PZ-5
		Relative Area %
71	1-Methyl-2-ethylbenzene	1.98
72	3-Methylnonane	0.15
73	1,2,4-Trimethylbenzene	0.92
74	Isobutylbenzene	0.61
75	sec-Butylbenzene	1.08
76	n-Decane	1.06
77	1,2,3-Trimethylbenzene	1.34
78	Indan	6.02
79	1,3-Diethylbenzene	2.69
80	1,4-Diethylbenzene	0.91
81	n-Butylbenzene	2.60
82	1,3-Dimethyl-5-ethylbenzene	2.07
83	1,4-Dimethyl-2-ethylbenzene	4.31
84	1,3-Dimethyl-4-ethylbenzene	2.11
85	1,2-Dimethyl-4-ethylbenzene	3.08
86	Undecene	1.26
87	1,2,4,5-Tetramethylbenzene	1.37
88	1,2,3,5-Tetramethylbenzene	1.57
89	1,2,3,4-Tetramethylbenzene	3.24
90	Naphthalene	0.21
91	2-Methyl-naphthalene	7.92
92	1-Methyl-naphthalene	6.93
I.S.#3	5α-Androstane	0.00

Chrom Perfect Chromatogram Report PZ-5

— C:\CPSpirit\2017\June17\062917.0011.BND

23114-4 [O-062217-JH-04] [400+600CS2]+ IS 315-1-2



Chrom Perfect Chromatogram Report PZ-5

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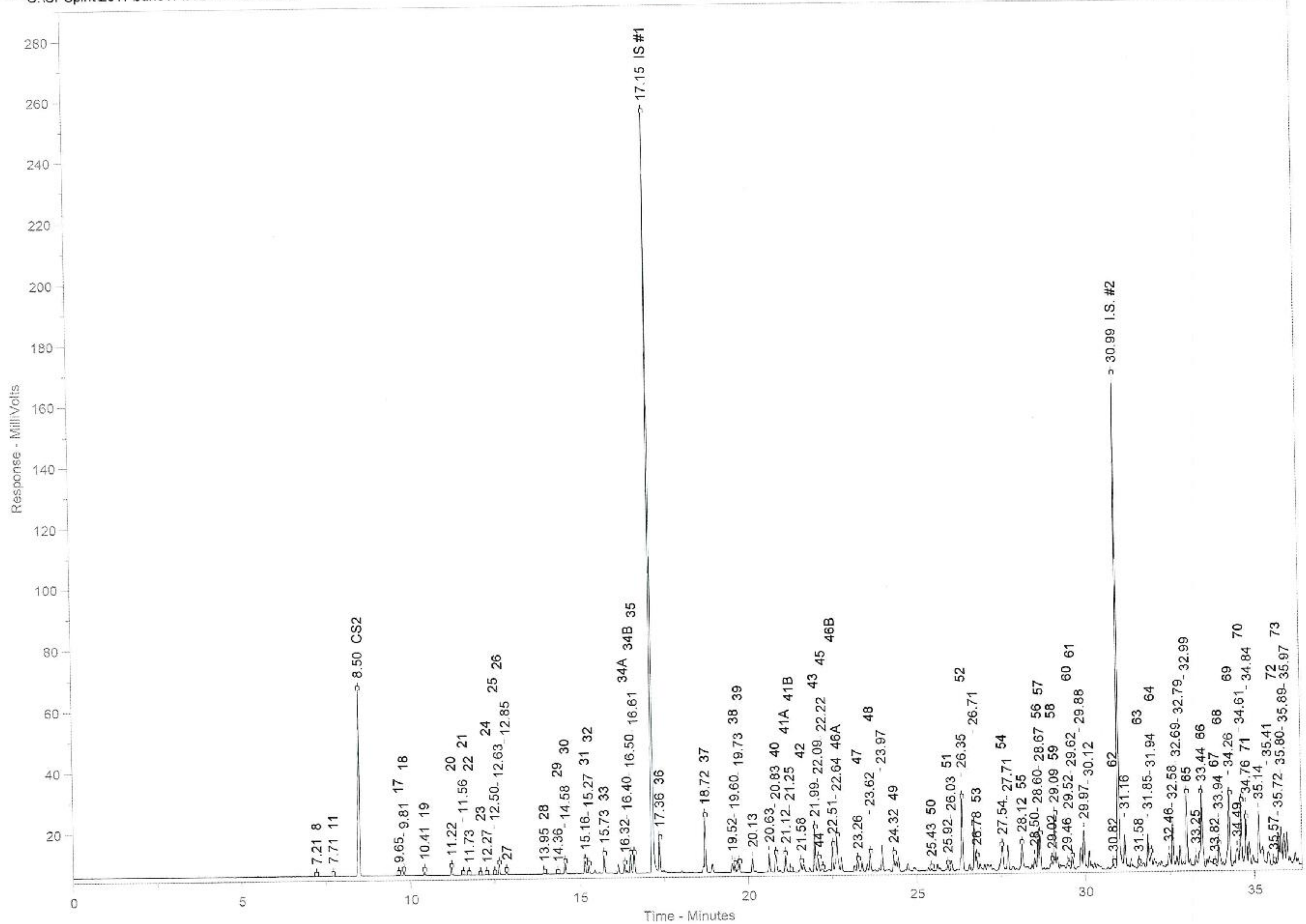
23114-4 [O-062217-JH-04] [400+600CS2]+ IS 315-1-2



Chrom Perfect Chromatogram Report PZ-5

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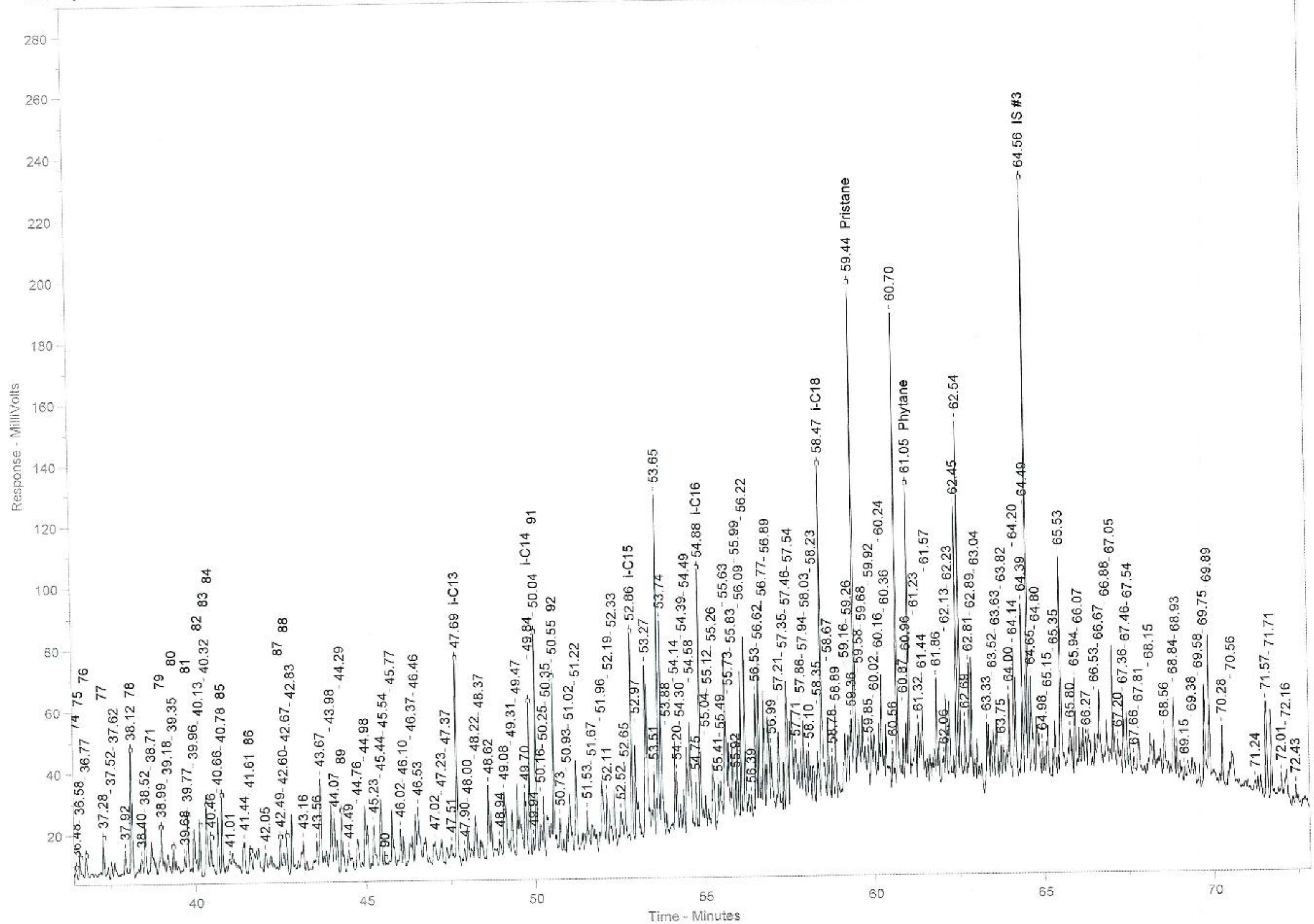
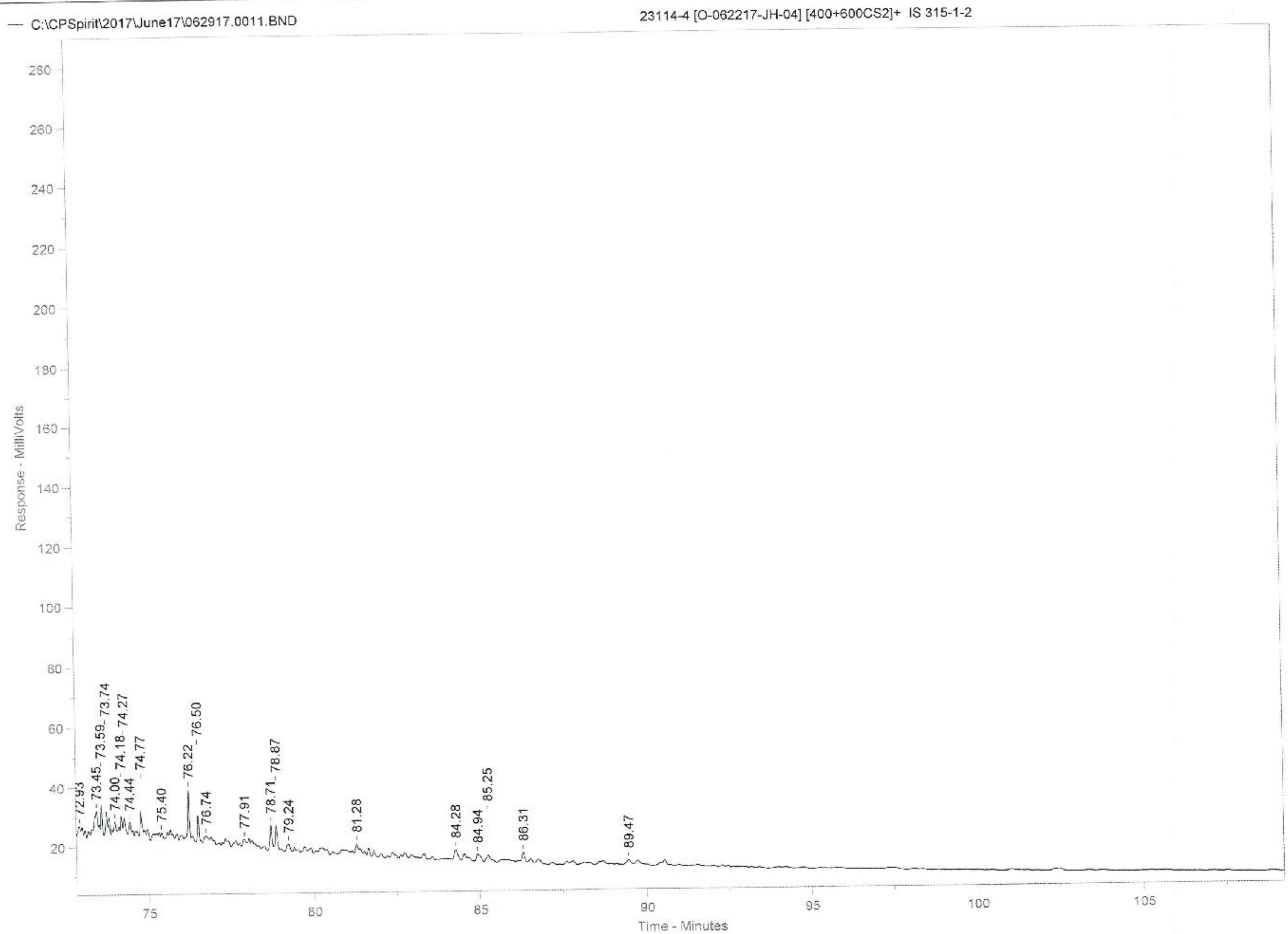
23114-4 [O-062217-JH-04] [400+600CS2]+ IS 315-1-2





— C:\CPSpirit\2017\June17\062917.0011.BND
23114-4 [O-062217-JH-04] [400+600CS2]+ IS 315-1-2
Response - MilliVolts
Time - Minutes
72.93
73.45
73.59
73.74
74.00
74.18
74.27
74.44
74.77
75.40
76.22
76.50
76.74
77.91
78.71
78.87
79.24
81.28
84.28
84.94
85.25
86.31
89.47

 PZ-5

Sample Name = **23114-4 [O-062217-JH-04] [400+600CS2]+ IS 315-1-2**

Instrument = Instrument 1
Heading 1 =
Heading 2 =

Acquisition Port = DP#

Raw File Name = **C:\CPSpirit\2017\June17\062917.0011.RAW**
Method File Name = C:\CPSpirit\C344.met
Calibration File Name = C:\CPSpirit\061917.cal

Date Taken (end) = 7/1/2017 12:57:05 AM
Method Version = 44
Calibration Version = 1

Peak Name	Ret. Time	Area %	Area
8	7.21	0.0012	216.61
11	7.71	0.0024	442.97
CS2	8.50	1.1710	215800.40
17	9.65	0.0034	632.29
18	9.81	0.0159	2933.05
19	10.41	0.0146	2697.20
20	11.22	0.0283	5215.24
21	11.56	0.0021	387.24
22	11.73	0.0013	247.74
24	12.27	0.0022	398.27
25	12.50	0.0016	289.82
26	12.63	0.0412	7585.91
27	12.85	0.0126	2326.51
28	13.95	0.0064	1174.50
29	14.36	0.0025	455.57
30	14.58	0.0496	9131.98
31	15.16	0.0517	9533.38
32	15.27	0.0355	6539.22
33	15.73	0.0818	15072.19
34A	16.32	0.0401	7389.45
	16.40	0.0116	2137.43
34B	16.50	0.0815	15027.62
35	16.61	0.0862	15887.90
IS #1	17.15	3.3767	622254.80
36	17.36	0.1485	27370.61
37	18.72	0.2372	43706.00
	19.52	0.0436	8034.98
38	19.60	0.0343	6314.99
39	19.73	0.0563	10374.50
	20.13	0.0614	11315.16
	20.63	0.0858	15805.45
40	20.83	0.1005	18512.10
41A	21.12	0.0877	16154.18
41B	21.25	0.0045	832.79
42	21.58	0.1033	19043.83
43	21.99	0.1977	36428.52
44	22.09	0.0564	10389.85
45	22.22	0.0179	3298.77
46B	22.51	0.1126	20756.91
46A	22.64	0.2140	39430.67
47	23.26	0.0538	9905.30
48	23.62	0.0853	15718.30
	23.97	0.1252	23067.95
49	24.32	0.0581	10714.33
50	25.43	0.0116	2140.71
51	25.92	0.0245	4520.43
	26.03	0.0586	10794.04
52	26.35	0.4063	74873.47
	26.71	0.2543	46864.17
53	26.78	0.0541	9970.57
54	27.54	0.2057	37913.91
	27.71	0.1242	22890.05
55	28.12	0.1583	29170.73
	28.50	0.0521	9600.52
56	28.60	0.1338	24665.93

Peak Name	Ret. Time	Area %	Area
57	28.67	0.1513	27884.79
58	29.02	0.0129	2368.19
59	29.09	0.2122	39106.13
	29.46	0.0261	4805.04
60	29.52	0.0132	2434.62
61	29.62	0.0743	13689.95
	29.88	0.1139	20993.15
	29.97	0.2018	37186.28
	30.12	0.0971	17898.50
62	30.82	0.0314	5780.57
I.S. #2	30.99	2.3532	433655.10
	31.16	0.1748	32220.78
63	31.58	0.0193	3558.13
	31.85	0.1682	30995.40
64	31.94	0.0738	13593.00
	32.46	0.0936	17257.48
	32.58	0.2064	38027.98
	32.69	0.0483	8901.18
	32.79	0.0955	17599.35
65	32.99	0.3172	58448.41
	33.25	0.0591	10882.12
66	33.44	0.5521	101737.60
67	33.82	0.0107	1975.77
68	33.94	0.1524	28078.56
69	34.26	0.4732	87199.55
	34.49	0.1079	19887.75
70	34.61	0.3392	62508.23
71	34.76	0.2363	43537.75
	34.84	0.1339	24671.55
	35.14	0.2040	37601.56
	35.41	0.0918	16909.79
72	35.57	0.0173	3196.05
73	35.72	0.1096	20191.32
	35.80	0.1898	34980.03
	35.89	0.1460	26900.97
	35.97	0.1338	24651.68
74	36.48	0.0724	13347.44
75	36.58	0.1289	23760.58
76	36.77	0.1270	23410.68
77	37.28	0.1600	29491.13
	37.52	0.0898	16549.33
	37.62	0.1287	23711.01
	37.92	0.2023	37273.20
78	38.12	0.7184	132378.50
	38.40	0.1042	19199.08
	38.52	0.2589	47709.59
	38.71	0.1837	33852.07
79	38.99	0.3211	59170.70
	39.18	0.1415	26066.79
80	39.35	0.1080	19896.17
	39.68	0.0834	15360.57
81	39.77	0.3097	57079.63
	39.96	0.2300	42389.02
82	40.13	0.2469	45491.95
83	40.32	0.5142	94752.07
84	40.46	0.2514	46326.30
	40.66	0.2745	50581.76
85	40.78	0.3671	67656.02
	41.01	0.0597	11005.15
	41.44	0.2591	47742.14
86	41.61	0.1505	27727.44
	42.05	0.1235	22766.75
87	42.49	0.1631	30058.54
	42.60	0.1293	23832.39
88	42.67	0.1872	34497.66
	42.83	0.3694	68068.02
	43.16	0.2869	52862.42

Peak Name	Ret. Time	Area %	Area
	43.56	0.0952	17538.63
	43.67	0.5026	92622.95
	43.98	0.3553	65475.71
	44.07	0.1829	33703.95
89	44.29	0.3860	71138.51
	44.49	0.0823	15169.26
	44.76	0.2081	38352.32
	44.98	0.2021	37248.12
	45.23	0.2561	47191.61
	45.44	0.3763	69346.26
90	45.54	0.0251	4627.63
	45.77	0.3222	59373.06
	46.02	0.1721	31715.97
	46.10	0.1440	26545.41
	46.37	0.3104	57198.97
	46.46	0.2154	39698.07
	46.53	0.4091	75390.37
	47.02	0.2315	42659.63
	47.23	0.2509	46232.89
	47.37	0.1185	21839.33
	47.51	0.2181	40185.65
i-C13	47.69	1.0341	190564.40
	47.90	0.0709	13059.57
	48.00	0.2050	37782.84
	48.22	0.3437	63338.29
	48.37	0.1865	34375.69
	48.62	0.3455	63676.56
	48.94	0.1057	19474.89
	49.08	0.6168	113662.40
	49.31	0.2414	44477.77
	49.47	0.1975	36397.24
	49.70	0.4208	77548.27
i-C14	49.84	0.5579	102807.50
	49.94	0.0695	12805.84
91	50.04	0.9446	174075.90
	50.16	0.2246	41380.54
	50.25	0.2711	49965.18
	50.35	0.3148	58018.25
92	50.55	0.8271	152411.00
	50.73	0.1572	28978.01
	50.93	0.0984	18128.67
	51.02	0.4843	89248.77
	51.22	0.4886	90031.19
	51.53	0.3608	66481.34
	51.67	0.4072	75042.21
	51.96	0.7328	135034.50
	52.11	0.2941	54191.61
	52.19	0.2912	53660.59
	52.33	0.2715	50024.66
	52.52	0.3843	70818.09
	52.65	0.3572	65818.33
i-C15	52.86	0.7867	144982.80
	52.97	0.7515	138494.10
	53.27	1.6634	306534.60
	53.51	0.4196	77328.99
	53.65	1.3657	251679.20
	53.74	0.9442	174001.80
	53.88	0.0871	16048.59
	54.14	0.4055	74730.95
	54.20	0.2555	47085.00
	54.30	0.1515	27922.19
	54.39	0.1895	34912.84
	54.49	0.4509	83088.89
	54.58	0.7943	146383.00
	54.75	0.2349	43288.27
i-C16	54.88	0.9990	184101.50
	55.04	0.1427	26294.72

Peak Name	Ret. Time	Area %	Area
	55.12	0.1202	22153.24
	55.26	0.4204	77475.30
	55.41	0.1507	27769.73
	55.49	0.3451	63591.14
	55.63	1.0949	201761.40
	55.73	0.3442	63432.41
	55.83	0.3381	62306.49
	55.92	0.1475	27187.42
	55.99	0.3375	62196.70
	56.09	0.4872	89776.81
	56.22	0.7598	140022.50
	56.39	0.0853	15710.87
	56.53	0.5335	98313.55
	56.62	0.5257	96867.41
	56.77	0.4704	86678.96
	56.89	0.7580	139676.40
	56.99	0.3145	57957.05
	57.21	0.3776	69592.43
	57.35	0.1508	27795.15
	57.46	0.7144	131643.40
	57.54	0.1219	22470.95
	57.71	0.1817	33480.26
	57.86	0.1625	29948.88
	57.94	0.3644	67149.62
	58.03	0.1503	27688.86
	58.10	0.2730	50307.32
	58.23	0.2299	42370.42
	58.35	0.2652	48875.08
i-C18	58.47	1.6194	298426.30
	58.67	0.3497	64438.11
	58.78	0.2368	43639.24
	58.89	0.2661	49033.09
	59.16	0.3663	67496.71
	59.26	0.3374	62178.20
	59.36	0.5001	92153.02
Pristane	59.44	2.1972	404897.60
	59.58	0.6045	111390.70
	59.68	0.6585	121348.40
	59.85	0.2969	54708.31
	59.92	0.4032	74296.51
	60.02	0.3454	63648.94
	60.16	0.2960	54546.64
	60.24	0.6965	128360.20
	60.36	0.4315	79517.55
	60.56	0.2312	42614.04
	60.70	1.6964	312622.00
	60.87	0.1742	32095.44
	60.96	0.2849	52508.50
Phytane	61.05	1.1953	220264.30
	61.23	0.3965	73068.19
	61.32	0.4848	89337.51
	61.44	0.3663	67500.22
	61.57	0.1053	19405.71
	61.86	0.4049	74610.37
	62.06	0.1641	30247.00
	62.13	0.3768	69443.77
	62.23	0.3354	61801.23
	62.45	0.9940	183170.90
	62.54	1.1150	205478.20
	62.69	0.2014	37119.69
	62.81	0.4281	78890.66
	62.89	0.4506	83044.09
	63.04	0.3682	67859.51
	63.33	0.6255	115273.70
	63.52	0.2585	47627.46
	63.63	0.4821	88850.42
	63.75	0.1759	32417.39

PZ-5

Peak Name	Ret. Time	Area %	Area
	55.12	0.1202	22153.24
	55.26	0.4204	77475.30
	55.41	0.1507	27769.73
	55.49	0.3451	63591.14
	55.63	1.0949	201761.40
	55.73	0.3442	63432.41
	55.83	0.3381	62306.49
	55.92	0.1475	27187.42
	55.99	0.3375	62196.70
	56.09	0.4872	89776.81
	56.22	0.7598	140022.50
	56.39	0.0853	15710.87
	56.53	0.5335	98313.55
	56.62	0.5257	96867.41
	56.77	0.4704	86678.96
	56.89	0.7580	139676.40
	56.99	0.3145	57957.05
	57.21	0.3776	69592.43
	57.35	0.1508	27795.15
	57.46	0.7144	131643.40
	57.54	0.1219	22470.95
	57.71	0.1817	33480.26
	57.86	0.1625	29948.88
	57.94	0.3644	67149.62
	58.03	0.1503	27688.86
	58.10	0.2730	50307.32
	58.23	0.2299	42370.42
	58.35	0.2652	48875.08
i-C18	58.47	1.6194	298426.30
	58.67	0.3497	64438.11
	58.78	0.2368	43639.24
	58.89	0.2661	49033.09
	59.16	0.3663	67496.71
	59.26	0.3374	62178.20
	59.36	0.5001	92153.02
Pristane	59.44	2.1972	404897.60
	59.58	0.6045	111390.70
	59.68	0.6585	121348.40
	59.85	0.2969	54708.31
	59.92	0.4032	74296.51
	60.02	0.3454	63648.94
	60.16	0.2960	54546.64
	60.24	0.6965	128360.20
	60.36	0.4315	79517.55
	60.56	0.2312	42614.04
	60.70	1.6964	312622.00
	60.87	0.1742	32095.44
	60.96	0.2849	52508.50
Phytane	61.05	1.1953	220264.30
	61.23	0.3965	73068.19
	61.32	0.4848	89337.51
	61.44	0.3663	67500.22
	61.57	0.1053	19405.71
	61.86	0.4049	74610.37
	62.06	0.1641	30247.00
	62.13	0.3768	69443.77
	62.23	0.3354	61801.23
	62.45	0.9940	183170.90
	62.54	1.1150	205478.20
	62.69	0.2014	37119.69
	62.81	0.4281	78890.66
	62.89	0.4506	83044.09
	63.04	0.3682	67859.51
	63.33	0.6255	115273.70
	63.52	0.2585	47627.46
	63.63	0.4821	88850.42
	63.75	0.1759	32417.39

Peak Name	Ret. Time	Area %	Area
	63.82	0.3447	63530.68
	64.00	0.6174	113772.60
	64.14	0.5662	104336.30
	64.20	0.4395	80998.59
	64.39	0.7967	146824.30
	64.49	0.5836	107555.30
IS #3	64.56	1.9590	361002.70
	64.65	0.6700	123462.50
	64.80	0.6682	123130.90
	64.98	0.2498	46039.82
	65.15	0.3968	73125.98
	65.35	0.2618	48240.27
	65.53	1.2593	232070.10
	65.80	0.5030	92699.09
	65.94	0.4601	84785.62
	66.07	0.1144	21083.98
	66.27	0.1419	26149.65
	66.53	0.1559	28735.21
	66.67	0.4109	75729.91
	66.88	0.2521	46451.13
	67.05	0.3178	58573.17
	67.20	0.0953	17560.67
	67.36	0.3109	57288.92
	67.46	0.2456	45257.44
	67.54	0.1718	31652.37
	67.66	0.0960	17696.02
	67.81	0.2677	49324.54
	68.15	0.1714	31584.01
	68.56	0.3073	56627.90
	68.84	0.4074	75079.96
	68.93	0.1661	30617.70
	69.15	0.0513	9454.20
	69.38	0.0740	13643.88
	69.58	0.1085	20000.13
	69.75	0.4834	89090.16
	69.89	0.6496	119717.50
	70.28	0.2583	47607.16
	70.56	0.1666	30692.19
	71.24	0.0737	13579.94
	71.57	0.6463	119096.10
	71.71	0.5092	93838.38
	72.01	0.2184	40249.88
	72.16	0.3993	73586.34
	72.43	0.1525	28106.89
	72.93	0.1282	23630.71
	73.45	0.2542	46840.58
	73.59	0.1468	27059.46
	73.74	0.0982	18088.03
	74.00	0.0658	12132.86
	74.18	0.0967	17822.64
	74.27	0.1163	21427.25
	74.44	0.0704	12966.27
	74.77	0.1437	26488.75
	75.40	0.2000	36853.07
	76.22	0.2823	52026.34
	76.50	0.1746	32167.12
	76.74	0.0669	12333.74
	77.91	0.0511	9421.24
	78.71	0.2087	38467.53
	78.87	0.1835	33823.11
	79.24	0.0886	16329.72
	81.28	0.0599	11033.82
	84.28	0.1319	24308.54
	84.94	0.1171	21579.24
	85.25	0.1219	22456.10
	86.31	0.0891	16427.17
	89.47	0.0659	12141.32

Total Area = 1.84281E+07 | Total Height = 6243221 | Total Amount = 0

6/29/2017

Pace ID	23114-5	
Sample ID	O-062217-JH-05	PZ-6

Evaporation

n-Pentane / n-Heptane	0.02
2-Methylpentane / 2-Methylheptane	0.10

Waterwashing

Benzene / Cyclohexane	0.03
Toluene / Methylcyclohexane	0.36
Aromatics / Total Paraffins (n+iso+cyc)	2.01
Aromatics / Naphthenes	7.98

Biodegradation

(C4 - C8 Para + Isopara) / C4 - C8 Olefins	268.23
3-Methylhexane / n-Heptane	0.56
Methylcyclohexane / n-Heptane	1.56
Isoparaffins + Naphthenes / Paraffins	7.74

Octane rating

2,2,4,-Trimethylpentane / Methylcyclohexane	0.39

Relative percentages - Bulk hydrocarbon composition as PIANO

% Paraffinic	3.72
% Isoparaffinic	20.60
% Aromatic	65.50
% Naphthenic	8.21
% Olefinic	1.97

6/29/2017

		Relative Area %
Pace ID		23114-5
Sample ID		O-062217-JH-05 PZ-6
1	Propane	0.00
2	Isobutane	0.00
3	Isobutene	0.00
4	Butane/Methanol	0.00
5	trans-2-Butene	0.00
6	cis-2-Butene	0.00
7	3-Methyl-1-butene	0.00
8	Isopentane	0.02
9	1-Pentene	0.00
10	2-Methyl-1-butene	0.00
11	Pentane	0.03
12	trans-2-Pentene	0.00
13	cis-2-Pentene/t-Butanol	0.00
14	2-Methyl-2-butene	0.00
15	2,2-Dimethylbutane	0.00
16	Cyclopentane	0.00
17	2,3-Dimethylbutane/MTBE	0.04
18	2-Methylpentane	0.17
19	3-Methylpentane	0.14
20	Hexane	0.30
21	trans-2-Hexene	0.02
22	3-Methylcyclopentene	0.01
23	3-Methyl-2-pentene	0.00
24	cis-2-Hexene	0.02
25	3-Methyl-trans-2-pentene	0.01
26	Methylcyclopentane	0.38
27	2,4-Dimethylpentane	0.11
28	Benzene	0.01
29	5-Methyl-1-hexene	0.02
30	Cyclohexane	0.41
31	2-Methylhexane/TAME	0.44
32	2,3-Dimethylpentane	0.30
33	3-Methylhexane	0.72
34A	1-trans-3-Dimethylcyclopentane	0.37
34B	1-cis-3-Dimethylcyclopentane	0.75
35	2,2,4-Trimethylpentane	0.79
I.S. #1	α,α,α-Trifluorotoluene	0.00

6/29/2017

Pace ID		23114-5
Sample ID		O-062217-JH-05 PZ-6
		Relative Area %
36	n-Heptane	1.29
37	Methylcyclohexane	2.01
38	2,5-Dimethylhexane	0.29
39	2,4-Dimethylhexane	0.47
40	2,3,4-Trimethylpentane	0.83
41	Toluene/2,3,3-Trimethylpentane	0.73
42	2,3-Dimethylhexane	0.30
43	2-Methylheptane	1.65
44	4-Methylheptane	0.47
45	3,4-Dimethylhexane	0.15
46A	3-Ethyl-3-methylpentane	1.77
46B	1,4-Dimethylcyclohexane	0.94
47	3-Methylheptane	0.44
48	2,2,5-Trimethylhexane	0.70
49	n-Octane	0.73
50	2,2-Dimethylheptane	0.09
51	2,4-Dimethylheptane	0.25
52	Ethylcyclohexane	3.34
53	2,6-Dimethylheptane	0.00
54	Ethylbenzene	1.71
55	m+p Xylenes	1.31
56	4-Methyloctane	1.10
57	2-Methyloctane	1.26
58	3-Ethylheptane	0.10
59	3-Methyloctane	1.78
60	o-Xylene	0.11
61	1-Nonene	0.62
62	n-Nonane	0.32
I.S.#2	p-Bromofluorobenzene	0.00
63	Isopropylbenzene	0.16
64	3,3,5-Trimethylheptane	0.58
65	2,4,5-Trimethylheptane	2.63
66	n-Propylbenzene	4.58
67	1-Methyl-3-ethylbenzene	0.09
68	1-Methyl-4-ethylbenzene	1.28
69	1,3,5-Trimethylbenzene	3.93
70	3,3,4-Trimethylheptane	2.82

6/29/2017

Pace ID		23114-5
Sample ID		O-062217-JH-05 PZ-6
		Relative Area %
71	1-Methyl-2-ethylbenzene	1.97
72	3-Methylnonane	0.14
73	1,2,4-Trimethylbenzene	0.96
74	Isobutylbenzene	0.60
75	sec-Butylbenzene	1.07
76	n-Decane	1.06
77	1,2,3-Trimethylbenzene	1.43
78	Indan	5.97
79	1,3-Diethylbenzene	2.71
80	1,4-Diethylbenzene	0.91
81	n-Butylbenzene	2.58
82	1,3-Dimethyl-5-ethylbenzene	2.08
83	1,4-Dimethyl-2-ethylbenzene	4.31
84	1,3-Dimethyl-4-ethylbenzene	2.11
85	1,2-Dimethyl-4-ethylbenzene	3.10
86	Undecene	1.26
87	1,2,4,5-Tetramethylbenzene	1.39
88	1,2,3,5-Tetramethylbenzene	1.59
89	1,2,3,4-Tetramethylbenzene	3.25
90	Naphthalene	0.00
91	2-Methyl-naphthalene	8.16
92	1-Methyl-naphthalene	7.39
I.S.#3	5α-Androstane	0.00

Chrom Perfect Chromatogram Report PZ-6

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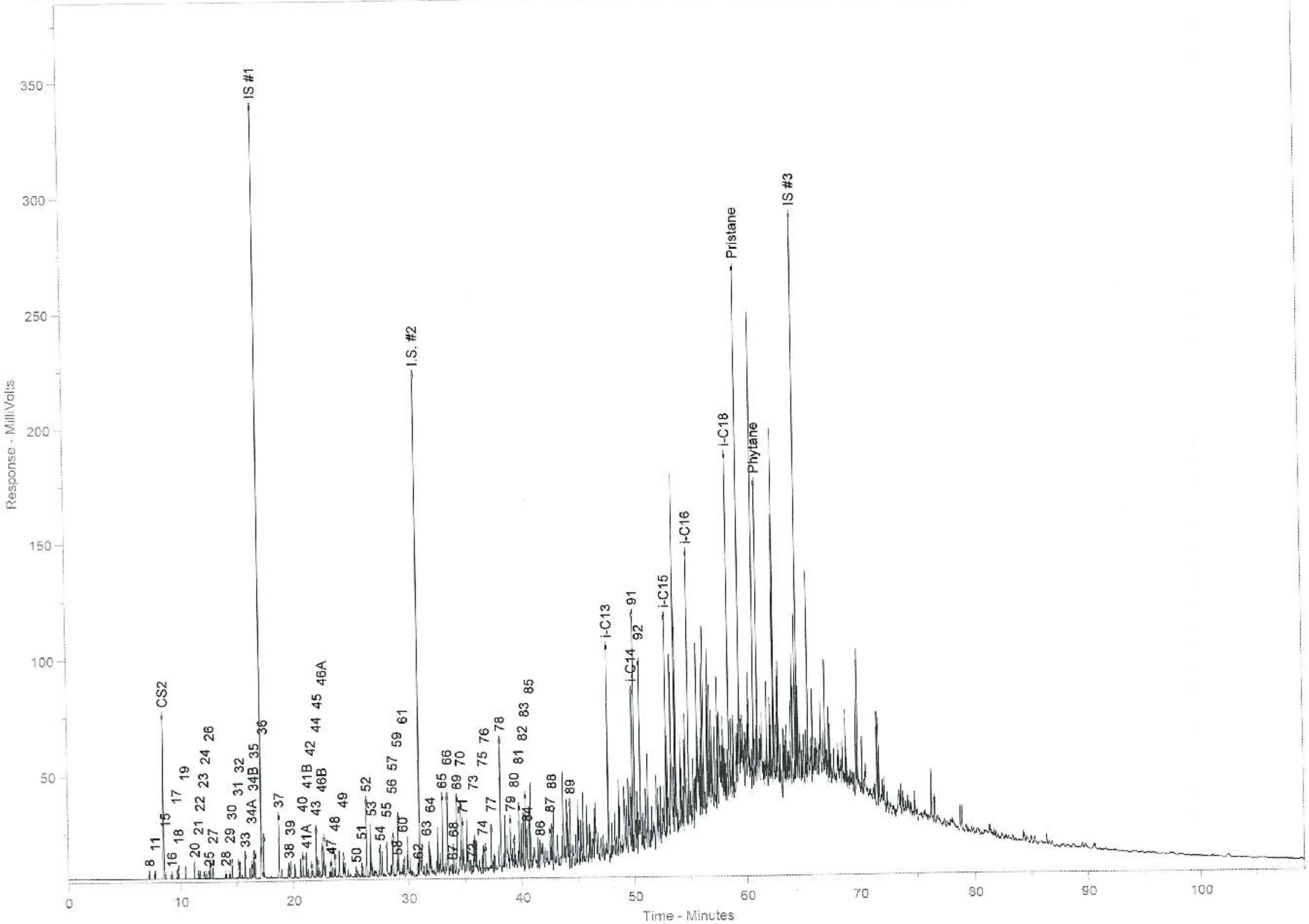

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Chrom Perfect Chromatogram Report PZ-6

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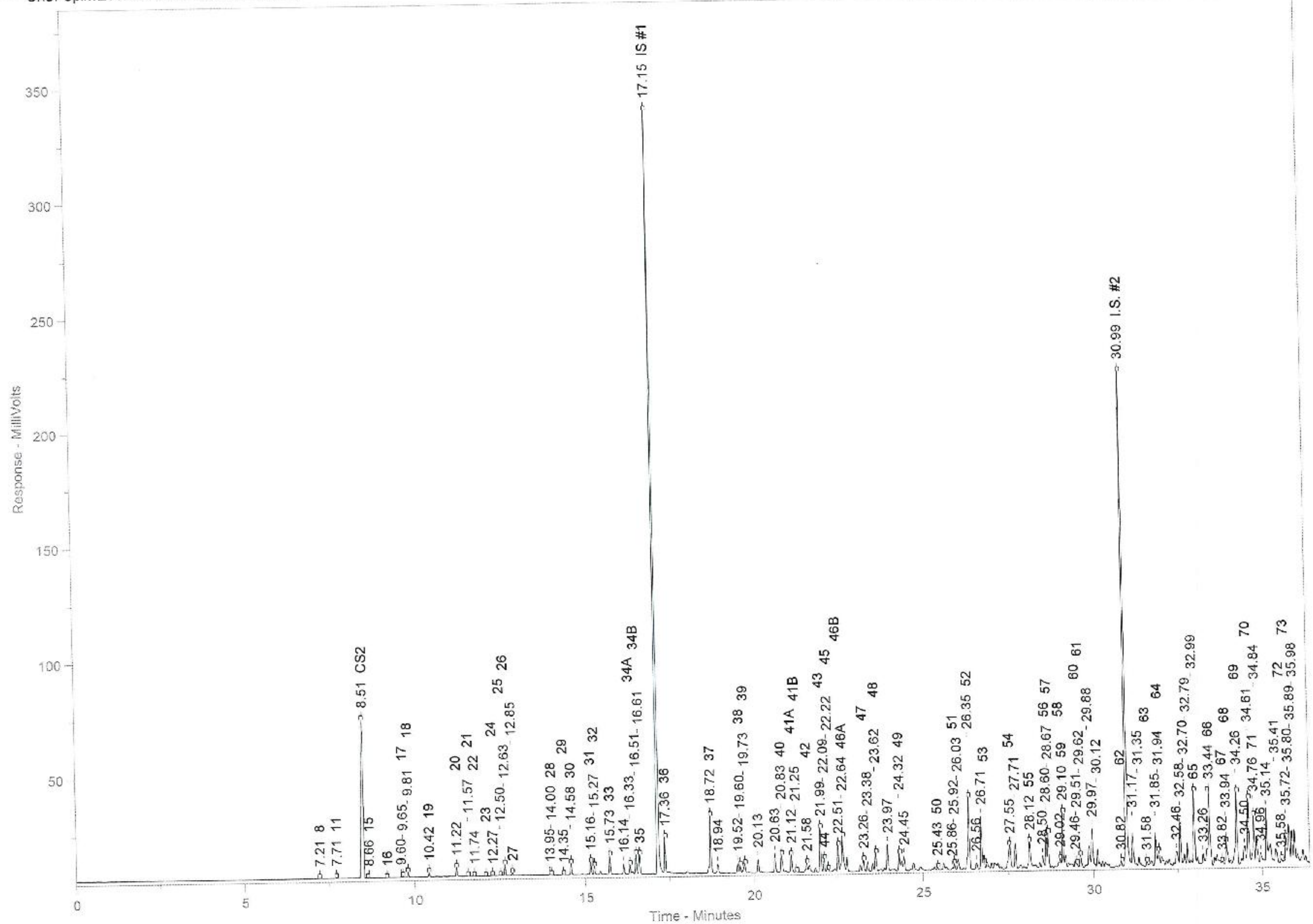

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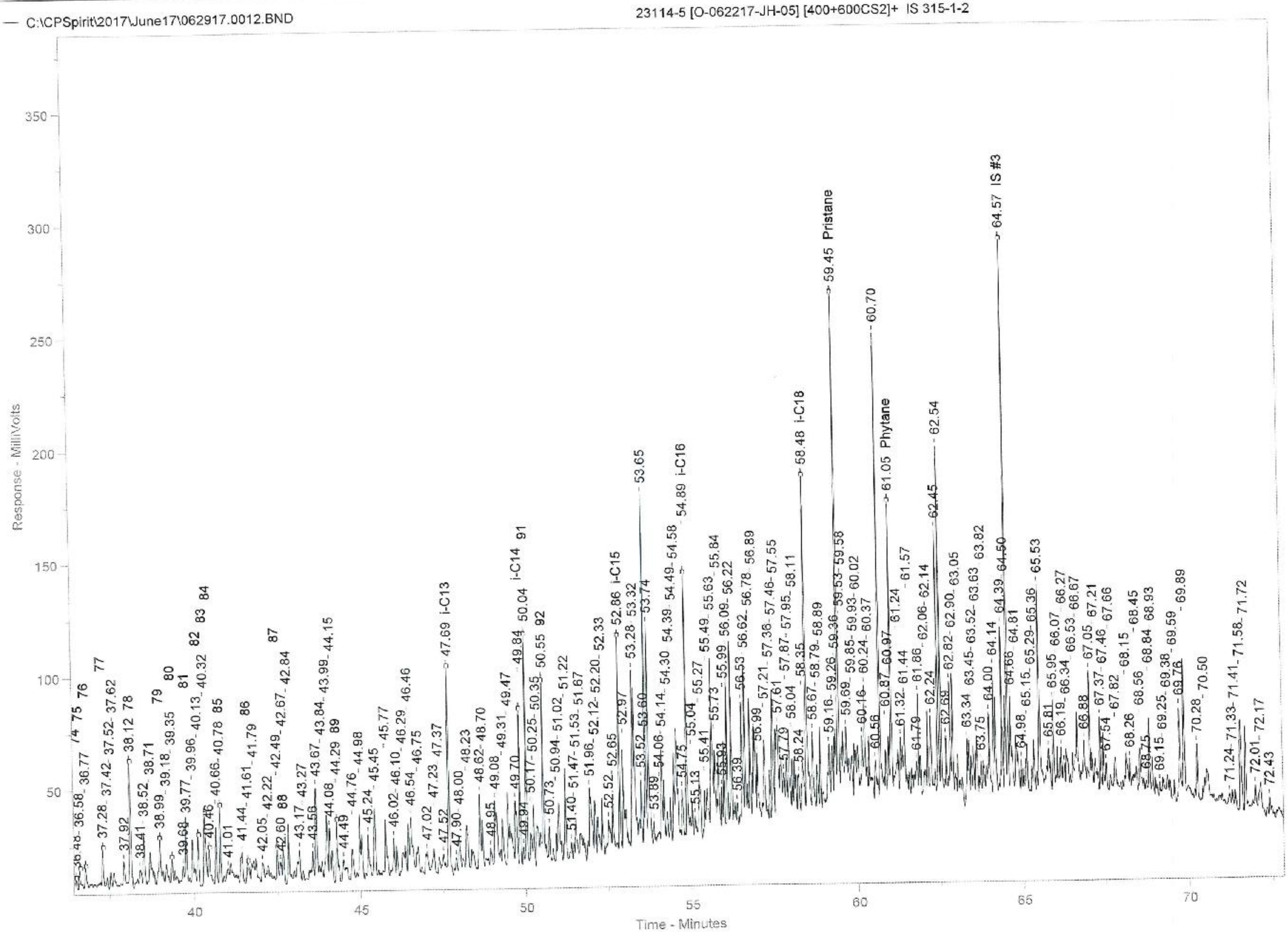

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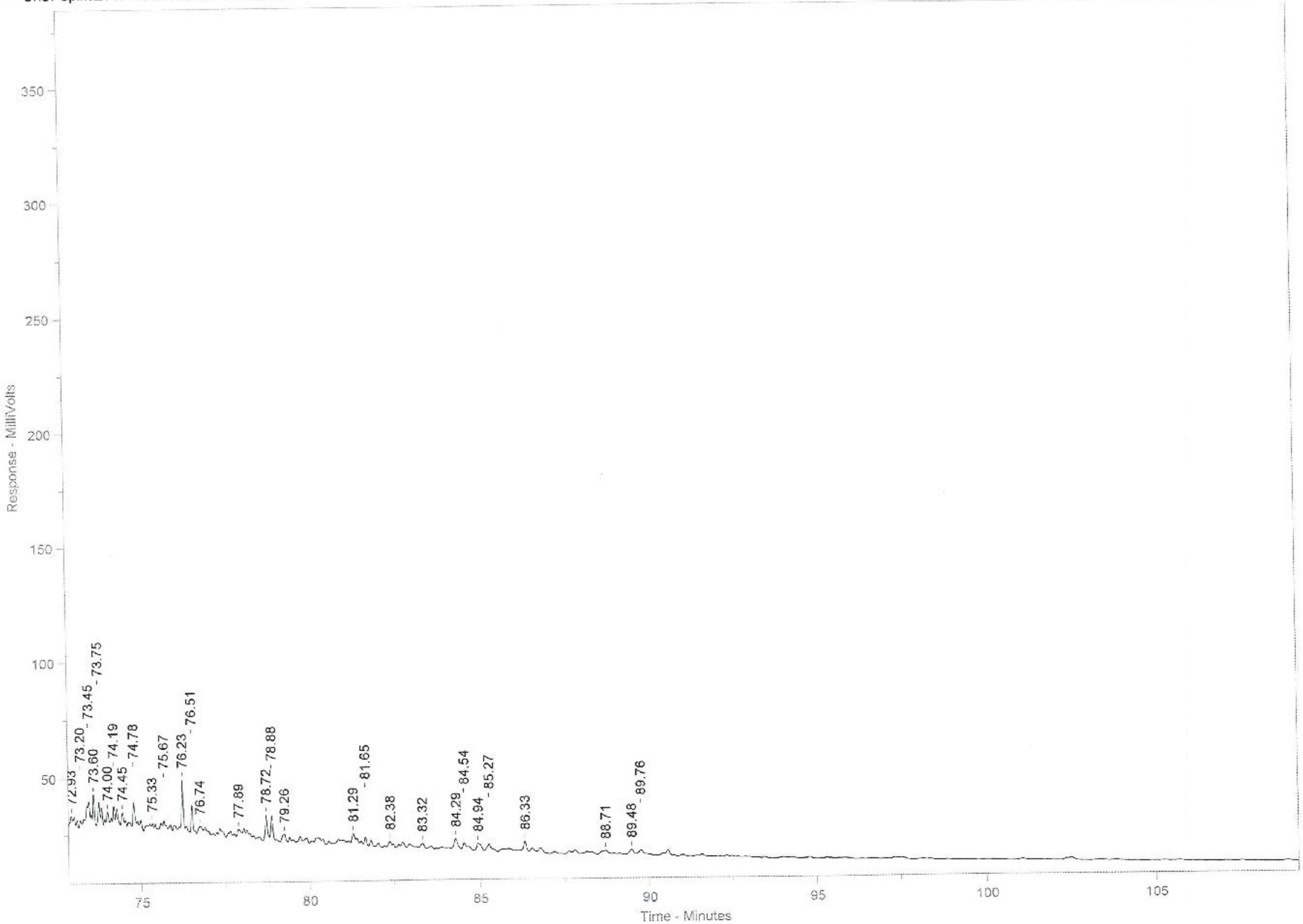
23114-5 [O-062217-JH-05] [400+600CS2]+ IS 315-1-2



 PZ-6

Sample Name = **23114-5 [O-062217-JH-05] [400+600CS2]+ IS 315-1-2**

Instrument = Instrument 1
Heading 1 =
Heading 2 =

Acquisition Port = DP#

Raw File Name = **C:\CPSpirit\2017\June17\062917.0012.RAW**
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Calibration File Name = C:\CPSpirit\061917.cal

Date Taken (end) = 7/1/2017 3:03:23 AM
Method Version = 44
Calibration Version = 1

Peak Name	Ret. Time	Area %	Area
8	7.21	0.0021	581.88
11	7.71	0.0034	934.19
CS2	8.51	1.0036	279291.80
15	8.66	0.0004	121.95
	9.60	0.0020	551.81
17	9.65	0.0042	1177.57
18	9.81	0.0178	4950.23
19	10.42	0.0153	4262.79
20	11.22	0.0321	8921.12
21	11.57	0.0021	588.02
22	11.74	0.0012	336.04
24	12.27	0.0020	558.36
25	12.50	0.0015	403.80
26	12.63	0.0408	11354.61
27	12.85	0.0117	3268.58
	13.95	0.0041	1130.64
28	14.00	0.0015	404.38
29	14.35	0.0024	677.47
30	14.58	0.0445	12392.58
31	15.16	0.0471	13103.69
32	15.27	0.0322	8953.70
33	15.73	0.0775	21557.66
	16.14	0.0421	11714.07
34A	16.33	0.0400	11133.68
34B	16.51	0.0807	22468.70
35	16.61	0.0847	23567.40
IS #1	17.15	2.9568	822798.90
36	17.36	0.1385	38531.08
37	18.72	0.2161	60133.45
	18.94	0.0383	10660.24
	19.52	0.0390	10853.83
38	19.60	0.0314	8726.42
39	19.73	0.0507	14107.65
	20.13	0.0552	15353.54
	20.63	0.0765	21281.22
40	20.83	0.0896	24930.33
41A	21.12	0.0781	21719.53
41B	21.25	0.0039	1094.43
42	21.58	0.0321	8936.63
43	21.99	0.1781	49567.10
44	22.09	0.0505	14057.53
45	22.22	0.0165	4603.71
46B	22.51	0.1017	28310.32
46A	22.64	0.1901	52911.60
47	23.26	0.0478	13298.08
	23.38	0.0410	11419.27
48	23.62	0.0755	21013.67
	23.97	0.1106	30789.06
49	24.32	0.0783	21798.40
	24.45	0.0630	17524.17
50	25.43	0.0102	2852.10
	25.86	0.0074	2053.73
51	25.92	0.0269	7495.91
	26.03	0.0520	14459.06
52	26.35	0.3597	100105.10

Peak Name	Ret. Time	Area %	Area
	26.56	0.0296	8245.86
	26.71	0.2728	75904.80
54	27.55	0.1841	51243.32
	27.71	0.1087	30256.34
55	28.12	0.1414	39362.01
	28.50	0.0460	12811.25
56	28.60	0.1184	32941.70
57	28.67	0.1360	37854.26
58	29.02	0.0113	3130.76
59	29.10	0.1915	53288.66
	29.46	0.0241	6698.60
60	29.51	0.0116	3231.04
61	29.62	0.0672	18700.46
	29.88	0.1003	27912.64
	29.97	0.1790	49813.46
	30.12	0.0861	23963.54
62	30.82	0.0345	9605.67
I.S. #2	30.99	2.0923	582247.30
	31.17	0.1778	49469.95
	31.35	0.0615	17115.69
63	31.58	0.0174	4841.97
	31.85	0.1382	38449.81
64	31.94	0.0626	17426.61
	32.46	0.0827	23018.12
	32.58	0.1841	51233.42
	32.70	0.0432	12012.78
	32.79	0.0853	23734.31
65	32.99	0.2828	78699.68
	33.26	0.0525	14616.52
66	33.44	0.4932	137236.00
67	33.82	0.0099	2749.49
68	33.94	0.1375	38256.73
69	34.26	0.4231	117742.50
	34.50	0.0973	27076.71
70	34.61	0.3036	84479.32
71	34.76	0.2126	59175.27
	34.84	0.1207	33601.01
	34.96	0.0395	10991.22
	35.14	0.1841	51229.25
	35.41	0.0821	22857.19
72	35.58	0.0155	4314.38
73	35.72	0.1032	28719.66
	35.80	0.1666	46358.36
	35.89	0.1311	36479.92
	35.98	0.1186	33008.47
74	36.48	0.0650	18097.64
75	36.58	0.1153	32083.34
76	36.77	0.1139	31707.76
77	37.28	0.1540	42856.15
	37.42	0.0563	15669.10
	37.52	0.0808	22483.27
	37.62	0.1162	32322.50
	37.92	0.1838	51140.77
78	38.12	0.6428	178876.20
	38.41	0.2041	56803.06
	38.52	0.2653	73837.20
	38.71	0.2497	69472.45
79	38.99	0.2914	81088.65
	39.18	0.1324	36832.64
80	39.35	0.0979	27237.28
	39.68	0.0757	21059.44
81	39.77	0.2774	77197.13
	39.96	0.2108	58652.04
82	40.13	0.2236	62221.76
83	40.32	0.4644	129240.30
84	40.46	0.2277	63350.65
	40.66	0.2482	69060.20

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Chrom Perfect Chromatogram Report

Peak Name	Ret. Time	Area %	Area
85	40.78	0.3340	92954.80
	41.01	0.0532	14810.25
	41.44	0.2335	64989.70
86	41.61	0.1362	37913.06
	41.79	0.1013	28190.96
	42.05	0.1236	34386.12
	42.22	0.0783	21787.82
87	42.49	0.1496	41633.95
	42.60	0.1147	31906.64
88	42.67	0.1717	47773.40
	42.84	0.3360	93505.31
	43.17	0.2692	74904.55
	43.27	0.0412	11451.93
	43.56	0.2182	60731.75
	43.67	0.5295	147350.10
	43.84	0.1088	30288.88
	43.99	0.4232	117767.30
	44.08	0.2511	69883.27
	44.15	0.1492	41531.77
89	44.29	0.3505	97548.38
	44.49	0.0745	20737.43
	44.76	0.1896	52749.52
	44.98	0.1858	51713.31
	45.24	0.2316	64454.00
	45.45	0.3431	95478.29
	45.77	0.2928	81476.52
	46.02	0.1570	43677.34
	46.10	0.1312	36508.00
	46.29	0.1945	54113.01
	46.46	0.2401	66811.90
	46.54	0.4821	134150.50
	46.75	0.2541	70721.43
	47.02	0.2294	63834.63
	47.23	0.2475	68869.84
	47.37	0.1137	31638.64
	47.52	0.2062	57379.48
i-C13	47.69	0.9473	263599.70
	47.90	0.0655	18232.17
	48.00	0.1862	51805.71
	48.23	0.2967	82553.95
	48.62	0.4118	114592.60
	48.70	0.1856	51637.07
	48.95	0.0969	26975.38
	49.08	0.6273	174575.90
	49.31	0.2206	61374.50
	49.47	0.1802	50144.08
	49.70	0.3874	107815.40
i-C14	49.84	0.5122	142538.30
	49.94	0.0653	18176.97
91	50.04	0.8792	244653.00
	50.17	0.2027	56404.49
	50.25	0.2510	69855.78
	50.35	0.2957	82273.37
92	50.55	0.7954	221346.10
	50.73	0.1671	46489.39
	50.94	0.0944	26270.87
	51.02	0.4382	121950.40
	51.22	0.4457	124023.70
	51.40	0.0841	23403.10
	51.47	0.0545	15152.29
	51.53	0.1846	51379.72
	51.67	0.1027	28582.72
	51.96	0.6811	189528.60
	52.12	0.2752	76570.72
	52.20	0.2775	77225.55
	52.33	0.2629	73161.65
	52.52	0.3827	106502.60

Peak Name	Ret. Time	Area %	Area
	52.65	0.3673	102215.40
i-C15	52.86	0.7535	209693.90
	52.97	0.7624	212162.90
	53.28	0.8749	243462.80
	53.32	0.7339	204213.50
	53.52	0.4352	121100.70
	53.60	0.1616	44956.78
	53.65	1.1589	322485.20
	53.74	0.9282	258290.60
	53.89	0.1329	36972.46
	54.06	0.1502	41793.27
	54.14	0.7078	196955.40
	54.30	0.1784	49656.91
	54.39	0.2032	56555.01
	54.49	0.4463	124197.60
	54.58	0.7748	215613.50
	54.75	0.2579	71755.13
i-C16	54.89	0.9543	265559.60
	55.04	0.1581	43992.05
	55.13	0.1533	42653.78
	55.27	0.4386	122062.80
	55.41	0.1376	38284.39
	55.49	0.2968	82588.22
	55.63	0.9953	276956.90
	55.73	0.4096	113992.70
	55.84	0.2992	83248.58
	55.93	0.1322	36792.68
	55.99	0.3001	83514.71
	56.09	0.4405	122585.10
	56.22	0.7652	212935.10
	56.39	0.0776	21600.43
	56.53	0.4872	135563.20
	56.62	0.4812	133917.40
	56.78	0.4313	120023.50
	56.89	0.6911	192324.20
	56.99	0.2867	79795.09
	57.21	0.2609	72593.47
	57.36	0.1385	38542.73
	57.46	0.6725	187142.80
	57.55	0.2881	80180.48
	57.61	0.5836	162397.50
	57.79	0.2313	64366.93
	57.87	0.2736	76144.77
	57.95	0.4395	122291.90
	58.04	0.1798	50039.34
	58.11	0.2962	82422.57
	58.24	0.2319	64534.07
	58.35	0.3823	106382.10
i-C18	58.48	1.5453	430010.50
	58.67	0.3479	96811.41
	58.79	0.2245	62481.89
	58.89	0.2408	66997.64
	59.16	0.3322	92449.41
	59.26	0.3016	83932.41
	59.36	0.4554	126713.60
Pristane	59.45	1.9771	550178.80
	59.53	0.2544	70783.96
	59.58	0.2803	78013.80
	59.69	0.5996	166846.30
	59.85	0.2643	73550.96
	59.93	0.3558	99019.04
	60.02	0.3129	87073.52
	60.16	0.2581	71828.37
	60.24	0.6265	174330.40
	60.37	0.3860	107406.40
	60.56	0.2718	75632.89
	60.70	1.4786	411471.50

Peak Name	Ret. Time	Area %	Area
	60.87	0.1380	38389.25
	60.97	0.2259	62870.74
Phytane	61.05	1.0732	298658.90
	61.24	0.2861	79627.84
	61.32	0.3383	94137.59
	61.44	0.2417	67250.05
	61.57	0.0808	22472.87
	61.79	0.0766	21321.80
	61.86	0.2097	58356.84
	62.06	0.1782	49581.66
	62.14	0.3588	99856.55
	62.24	0.3253	90524.46
	62.45	0.8968	249550.40
	62.54	0.9977	277637.80
	62.69	0.2446	68059.13
	62.82	0.3519	97913.53
	62.90	0.5049	140504.00
	63.05	0.1496	41640.93
	63.34	0.5492	152821.20
	63.45	0.2526	70294.95
	63.52	0.2294	63849.00
	63.63	0.5352	148935.60
	63.75	0.1624	45186.48
	63.82	0.3137	87296.46
	64.00	0.7510	208998.70
	64.14	0.9269	257922.40
	64.39	0.7370	205095.90
	64.50	0.5461	151959.80
IS #3	64.57	1.6997	472988.80
	64.66	0.6620	184232.60
	64.81	0.6852	190681.60
	64.98	0.3022	84084.23
	65.15	0.4967	138217.40
	65.29	0.1509	42001.12
	65.36	0.3047	84777.03
	65.53	1.1271	313642.60
	65.81	0.7100	197573.30
	65.95	0.6245	173794.00
	66.07	0.2645	73612.70
	66.19	0.3340	92951.43
	66.27	0.2919	81217.74
	66.34	0.4190	116592.50
	66.53	0.2884	80242.43
	66.67	0.5341	148626.90
	66.88	0.6666	185499.40
	67.05	0.6589	183355.20
	67.21	0.4056	112859.10
	67.37	0.3399	94581.21
	67.46	0.2666	74178.68
	67.54	0.2233	62144.46
	67.66	0.1699	47276.36
	67.82	0.3988	110983.20
	68.15	0.3185	88630.05
	68.26	0.2127	59195.10
	68.45	0.1303	36263.46
	68.56	0.3246	90323.14
	68.75	0.0766	21322.86
	68.84	0.3682	102454.90
	68.93	0.1440	40062.62
	69.15	0.0574	15970.83
	69.25	0.1049	29180.73
	69.38	0.0703	19551.10
	69.59	0.0769	21392.89
	69.76	0.4222	117501.60
	69.89	0.5549	154414.80
	70.28	0.2198	61159.46
	70.50	0.0317	8811.66

Chrom Perfect Chromatogram Report PZ-6

Peak Name	Ret. Time	Area %	Area
	71.24	0.0879	24454.00
	71.33	0.0795	22132.07
	71.41	0.0905	25178.36
	71.58	0.5527	153796.60
	71.72	0.4026	112035.20
	72.01	0.1915	53288.63
	72.17	0.3385	94202.93
	72.43	0.0526	14647.24
	72.93	0.0383	10654.15
	73.20	0.0471	13095.91
	73.45	0.2673	74385.89
	73.60	0.1411	39252.54
	73.75	0.0869	24176.51
	74.00	0.0497	13818.25
	74.19	0.0548	15237.32
	74.45	0.0607	16897.88
	74.78	0.1264	35182.76
	75.33	0.1429	39752.78
	75.67	0.1174	32667.25
	76.23	0.2458	68388.87
	76.51	0.1525	42425.39
	76.74	0.0624	17361.97
	77.89	0.0457	12725.48
	78.72	0.1822	50692.96
	78.88	0.1592	44307.67
	79.26	0.0805	22405.14
	81.29	0.0550	15294.60
	81.65	0.0494	13750.75
	82.38	0.0790	21983.06
	83.32	0.0502	13975.66
	84.29	0.1192	33179.29
	84.54	0.1029	28621.12
	84.94	0.1039	28908.71
	85.27	0.1130	31445.08
	86.33	0.0812	22603.46
	88.71	0.1438	40007.26
	89.48	0.0907	25250.23
	89.76	0.1071	29790.93

Total Area = 2.782768E+07 Total Height = 9005942 Total Amount = 0

6/29/2017

Pace ID	23114-6	PZ-7
Sample ID	O-062217-JH-06	
Evaporation		
n-Pentane / n-Heptane	0.23	
2-Methylpentane / 2-Methylheptane	0.36	
Waterwashing		
Benzene / Cyclohexane	0.09	
Toluene / Methylcyclohexane	0.17	
Aromatics / Total Paraffins (n+iso+cyc)	1.39	
Aromatics / Naphthenes	4.75	
Biodegradation		
(C4 - C8 Para + Isopara) / C4 - C8 Olefins	93.40	
3-Methylhexane / n-Heptane	1.23	
Methylcyclohexane / n-Heptane	3.15	
Isoparaffins + Naphthenes / Paraffins	9.19	
Octane rating		
2,2,4,-Trimethylpentane / Methylcyclohexane	0.24	
Relative percentages - Bulk hydrocarbon composition as PIANO		
% Paraffinic	4.04	
% Isoparaffinic	25.06	
% Aromatic	57.05	
% Naphthenic	12.02	
% Olefinic	1.84	

6/29/2017

Pace ID		23114-6	PZ-7
Sample ID		O-062217-JH-06	
		Relative Area %	
1	Propane	0.00	
2	Isobutane	0.01	
3	Isobutene	0.00	
4	Butane/Methanol	0.01	
5	trans-2-Butene	0.00	
6	cis-2-Butene	0.00	
7	3-Methyl-1-butene	0.00	
8	Isopentane	0.15	
9	1-Pentene	0.00	
10	2-Methyl-1-butene	0.01	
11	Pentane	0.26	
12	trans-2-Pentene	0.01	
13	cis-2-Pentene/t-Butanol	0.00	
14	2-Methyl-2-butene	0.03	
15	2,2-Dimethylbutane	0.01	
16	Cyclopentane	0.01	
17	2,3-Dimethylbutane/MTBE	0.16	
18	2-Methylpentane	0.75	
19	3-Methylpentane	0.56	
20	Hexane	1.09	
21	trans-2-Hexene	0.08	
22	3-Methylcyclopentene	0.04	
23	3-Methyl-2-pentene	0.00	
24	cis-2-Hexene	0.05	
25	3-Methyl-trans-2-pentene	0.03	
26	Methylcyclopentane	0.98	
27	2,4-Dimethylpentane	0.29	
28	Benzene	0.07	
29	5-Methyl-1-hexene	0.04	
30	Cyclohexane	0.82	
31	2-Methylhexane/TAME	0.97	
32	2,3-Dimethylpentane	0.61	
33	3-Methylhexane	1.39	
34A	1-trans-3-Dimethylcyclopentane	0.59	
34B	1-cis-3-Dimethylcyclopentane	1.17	
35	2,2,4-Trimethylpentane	0.84	
I.S. #1	α,α,α-Trifluorotoluene	0.00	

6/29/2017

Pace ID		23114-6	PZ-7
Sample ID		O-062217-JH-06	
		Relative Area %	
36	n-Heptane	1.13	
37	Methylcyclohexane	3.57	
38	2,5-Dimethylhexane	0.37	
39	2,4-Dimethylhexane	0.61	
40	2,3,4-Trimethylpentane	0.79	
41	Toluene/2,3,3-Trimethylpentane	0.62	
42	2,3-Dimethylhexane	0.36	
43	2-Methylheptane	2.11	
44	4-Methylheptane	0.59	
45	3,4-Dimethylhexane	0.18	
46A	3-Ethyl-3-methylpentane	2.32	
46B	1,4-Dimethylcyclohexane	1.51	
47	3-Methylheptane	0.57	
48	2,2,5-Trimethylhexane	0.84	
49	n-Octane	0.45	
50	2,2-Dimethylheptane	0.10	
51	2,4-Dimethylheptane	0.31	
52	Ethylcyclohexane	3.37	
53	2,6-Dimethylheptane	0.47	
54	Ethylbenzene	1.55	
55	m+p Xylenes	1.15	
56	4-Methyloctane	1.00	
57	2-Methyloctane	1.16	
58	3-Ethylheptane	0.47	
59	3-Methyloctane	1.92	
60	o-Xylene	0.07	
61	1-Nonene	0.58	
62	n-Nonane	0.29	
I.S.#2	p-Bromofluorobenzene	0.00	
63	Isopropylbenzene	0.12	
64	3,3,5-Trimethylheptane	0.51	
65	2,4,5-Trimethylheptane	2.16	
66	n-Propylbenzene	3.74	
67	1-Methyl-3-ethylbenzene	0.07	
68	1-Methyl-4-ethylbenzene	0.93	
69	1,3,5-Trimethylbenzene	3.21	
70	3,3,4-Trimethylheptane	2.28	

6/29/2017

Pace ID		23114-6 PZ-7
Sample ID		O-062217-JH-06
		Relative Area %
71	1-Methyl-2-ethylbenzene	1.68
72	3-Methylnonane	0.13
73	1,2,4-Trimethylbenzene	0.37
74	Isobutylbenzene	0.50
75	sec-Butylbenzene	0.87
76	n-Decane	0.80
77	1,2,3-Trimethylbenzene	0.77
78	Indan	4.81
79	1,3-Diethylbenzene	2.29
80	1,4-Diethylbenzene	0.71
81	n-Butylbenzene	1.91
82	1,3-Dimethyl-5-ethylbenzene	1.65
83	1,4-Dimethyl-2-ethylbenzene	3.29
84	1,3-Dimethyl-4-ethylbenzene	1.60
85	1,2-Dimethyl-4-ethylbenzene	2.32
86	Undecene	0.96
87	1,2,4,5-Tetramethylbenzene	1.05
88	1,2,3,5-Tetramethylbenzene	1.02
89	1,2,3,4-Tetramethylbenzene	2.67
90	Naphthalene	0.00
91	2-Methyl-naphthalene	10.54
92	1-Methyl-naphthalene	7.46
I.S.#3	5α-Androstane	0.00

Chrom Perfect Chromatogram Report PZ-7

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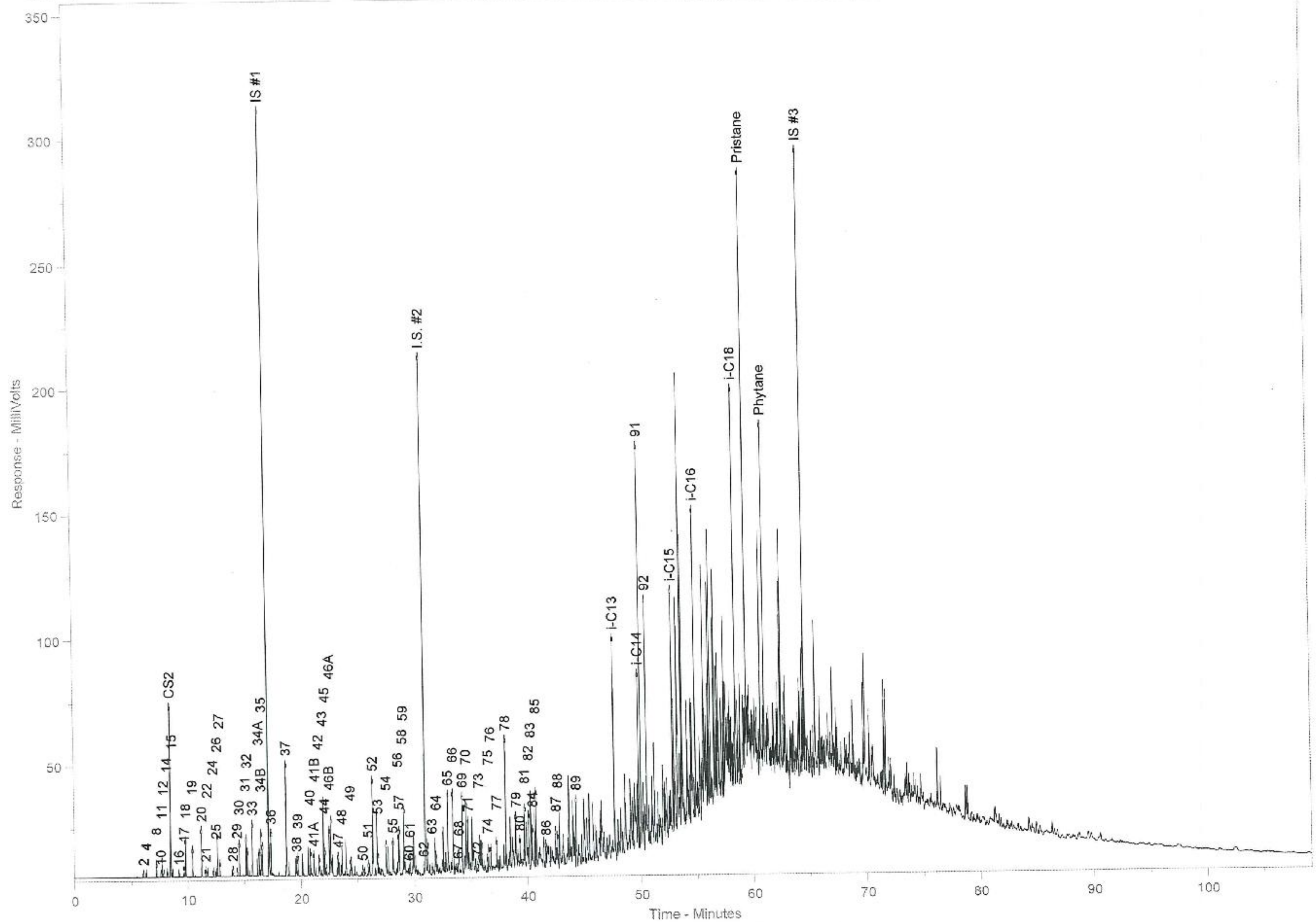

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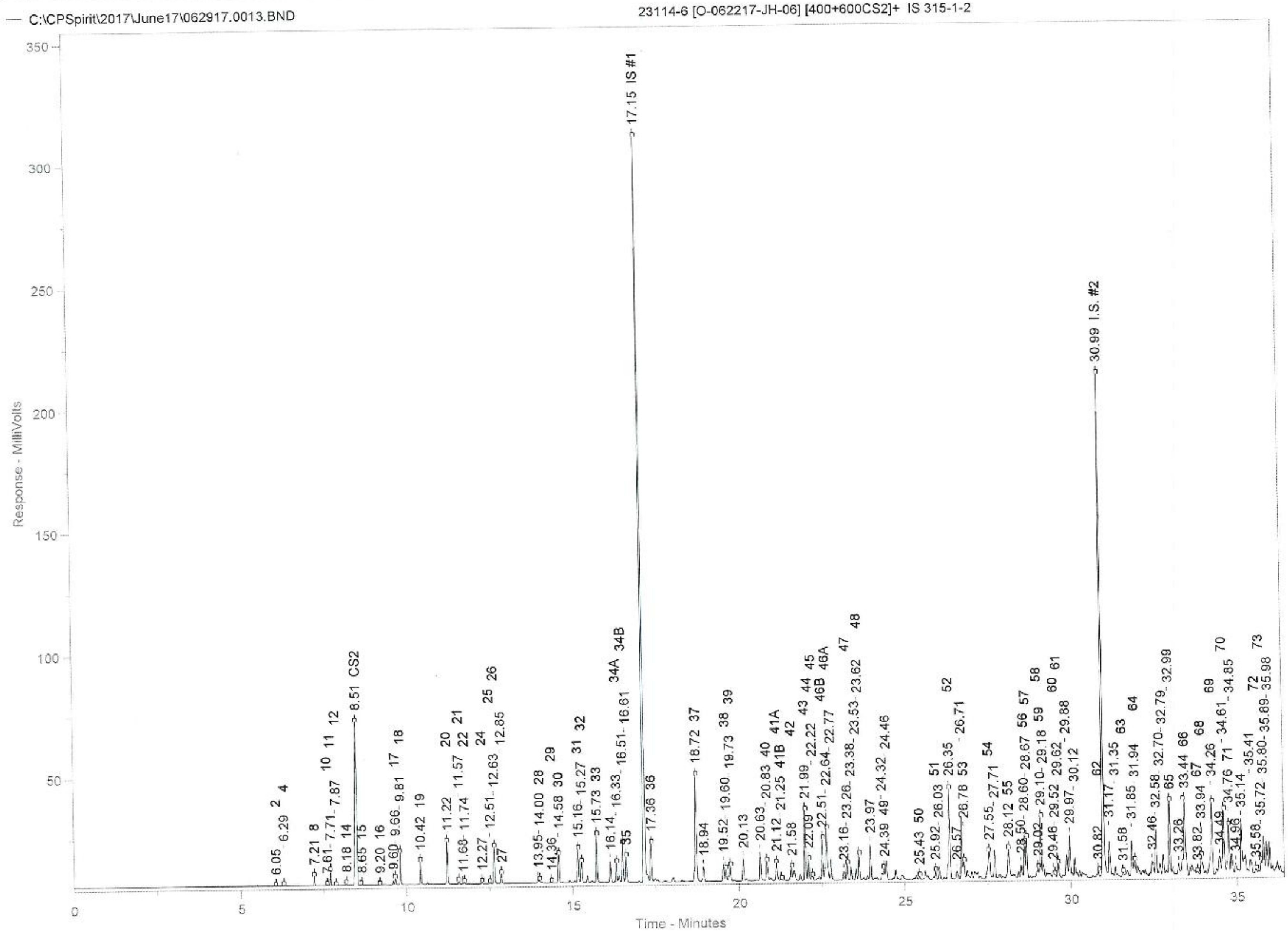
Chrom Perfect Chromatogram Report

PZ-7



Chrom Perfect Chromatogram Report PZ-7

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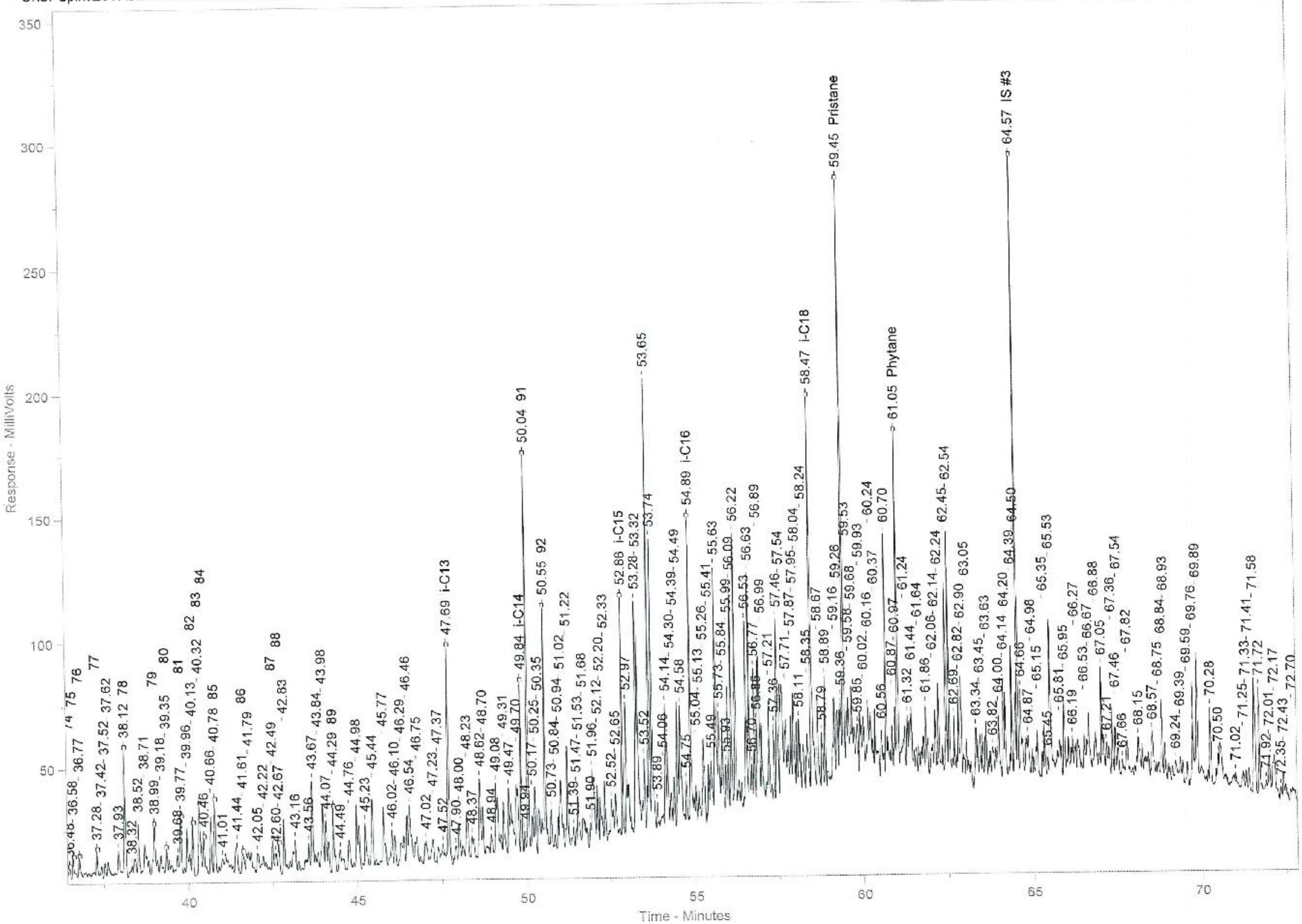

Chrom Perfect Chromatogram Report

PZ-7

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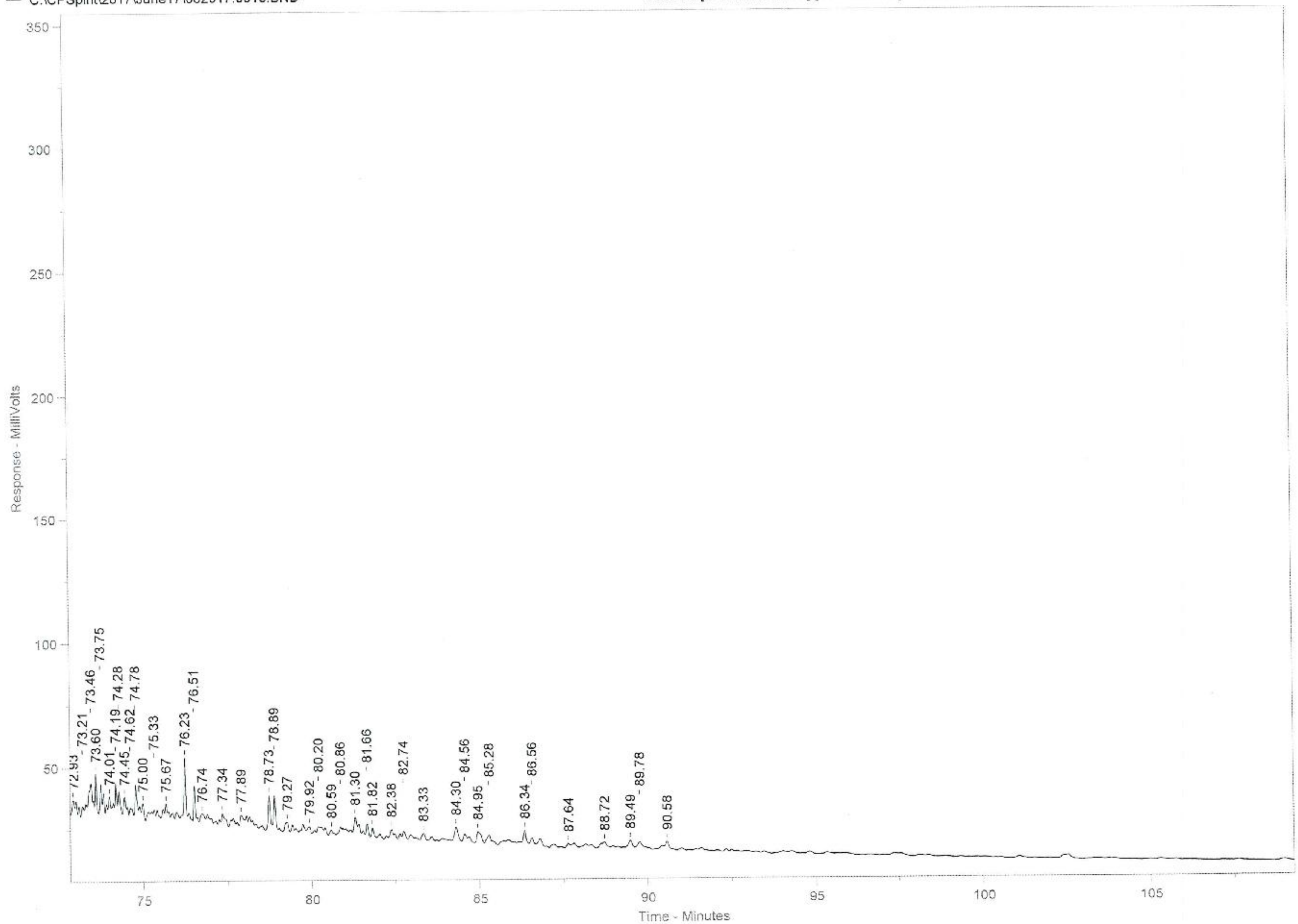

PZ-7

Sample Name = **23114-6 [O-062217-JH-06] [400+600CS2]+ IS 315-1-2**

Instrument = Instrument 1
Heading 1 =
Heading 2 =

Acquisition Port = DP#

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Method File Name = C:\CPSpirit\C344.met
Calibration File Name = C:\CPSpirit\061917.cal

Date Taken (end) = 7/1/2017 5:09:08 AM
Method Version = 44
Calibration Version = 1

Peak Name	Ret. Time	Area %	Area
2	6.05	0.0009	235.26
4	6.29	0.0015	410.95
8	7.21	0.0195	5331.62
10	7.61	0.0011	309.41
11	7.71	0.0324	8873.94
12	7.87	0.0010	260.76
14	8.18	0.0040	1090.29
CS2	8.51	0.9509	260337.60
15	8.65	0.0015	406.45
16	9.20	0.0008	224.40
	9.60	0.0108	2958.33
17	9.66	0.0199	5440.73
18	9.81	0.0947	25917.19
19	10.42	0.0708	19377.22
20	11.22	0.1370	37499.74
21	11.57	0.0100	2747.51
	11.68	0.0030	825.56
22	11.74	0.0055	1514.51
24	12.27	0.0068	1849.25
25	12.51	0.0041	1115.39
26	12.63	0.1239	33922.14
27	12.85	0.0361	9877.57
	13.95	0.0127	3475.37
28	14.00	0.0092	2525.84
29	14.36	0.0053	1461.09
30	14.58	0.1028	28154.00
31	15.16	0.1220	33410.70
32	15.27	0.0763	20876.38
33	15.73	0.1758	48123.52
	16.14	0.0803	21984.20
34A	16.33	0.0745	20392.22
34B	16.51	0.1480	40520.28
35	16.61	0.1064	29117.08
IS #1	17.15	2.7625	756278.40
36	17.36	0.1429	39122.29
37	18.72	0.4496	123087.40
	18.94	0.0625	17100.77
	19.52	0.0678	18566.71
38	19.60	0.0468	12813.13
39	19.73	0.0764	20907.66
	20.13	0.0836	22895.38
	20.63	0.1099	30083.26
40	20.83	0.1002	27440.30
41A	21.12	0.0787	21538.70
41B	21.25	0.0063	1720.03
42	21.58	0.0449	12287.43
43	21.99	0.2657	72751.90
44	22.09	0.0750	20544.22
45	22.22	0.0233	6380.25
46B	22.51	0.1909	52267.45
46A	22.64	0.2931	80247.50
	22.77	0.0864	23655.69
	23.16	0.0361	9887.37
47	23.26	0.0719	19670.77
	23.38	0.0565	15465.12

Peak Name	Ret. Time	Area %	Area
	23.53	0.0419	11473.89
48	23.62	0.1065	29163.15
	23.97	0.1392	38115.29
	24.32	0.0300	8221.66
49	24.39	0.0567	15524.12
	24.46	0.0746	20429.44
50	25.43	0.0126	3459.12
51	25.92	0.0396	10851.33
	26.03	0.0595	16290.88
52	26.35	0.4247	116281.80
	26.57	0.0343	9398.52
	26.71	0.2512	68769.56
53	26.78	0.0594	16269.44
54	27.55	0.1951	53401.99
	27.71	0.1182	32365.14
55	28.12	0.1455	39841.91
	28.50	0.0481	13179.13
56	28.60	0.1263	34568.46
57	28.67	0.1462	40018.62
58	29.02	0.0593	16226.96
59	29.10	0.2419	66225.95
	29.18	0.0529	14476.55
	29.46	0.0232	6339.73
60	29.52	0.0085	2336.47
61	29.62	0.0733	20057.73
	29.88	0.1023	28006.46
	29.97	0.1894	51862.13
	30.12	0.0871	23854.56
62	30.82	0.0368	10083.05
I.S. #2	30.99	2.0286	555369.70
	31.17	0.1763	48271.06
	31.35	0.0594	16252.55
63	31.58	0.0148	4044.63
	31.85	0.1430	39144.75
64	31.94	0.0647	17717.67
	32.46	0.0806	22074.62
	32.58	0.1705	46663.54
	32.70	0.0428	11710.39
	32.79	0.0777	21278.50
65	32.99	0.2721	74485.98
	33.26	0.0492	13474.09
66	33.44	0.4718	129174.60
67	33.82	0.0092	2518.16
68	33.94	0.1173	32103.58
69	34.26	0.4045	110745.30
	34.49	0.0904	24750.51
70	34.61	0.2869	78556.44
71	34.76	0.2121	58063.47
	34.85	0.0952	26054.46
	34.96	0.0455	12443.80
	35.14	0.1724	47193.57
	35.41	0.0809	22142.63
72	35.58	0.0169	4616.45
73	35.72	0.0471	12907.12
	35.80	0.1557	42620.75
	35.89	0.1251	34234.73
	35.98	0.1076	29461.44
74	36.48	0.0627	17155.66
75	36.58	0.1091	29880.39
76	36.77	0.1015	27788.99
77	37.28	0.0973	26643.53
	37.42	0.0537	14707.78
	37.52	0.0657	17974.36
	37.62	0.1101	30131.51
	37.93	0.1732	47412.43
78	38.12	0.6062	165958.50
	38.32	0.0767	20989.77

Peak Name	Ret. Time	Area %	Area
	38.52	0.2360	64618.65
	38.71	0.2441	66830.20
79	38.99	0.2886	79004.70
	39.18	0.1101	30145.61
80	39.35	0.0892	24410.21
	39.68	0.0685	18746.14
81	39.77	0.2404	65814.24
	39.96	0.1866	51080.06
82	40.13	0.2084	57056.18
83	40.32	0.4151	113637.70
84	40.46	0.2021	55316.06
	40.66	0.2329	63747.16
85	40.78	0.2928	80150.27
	41.01	0.0498	13626.53
	41.44	0.2118	57995.36
86	41.61	0.1213	33217.24
	41.79	0.0908	24864.83
	42.05	0.1131	30968.98
	42.22	0.0552	15104.93
87	42.49	0.1326	36298.21
	42.60	0.1031	28237.94
88	42.67	0.1290	35321.52
	42.83	0.2870	78573.09
	43.16	0.2411	65995.15
	43.56	0.1729	47320.92
	43.67	0.4509	123449.60
	43.84	0.0641	17556.48
	43.98	0.2972	81375.38
	44.07	0.1469	40223.50
89	44.29	0.3365	92135.62
	44.49	0.0713	19515.63
	44.76	0.1718	47040.49
	44.98	0.1712	46867.32
	45.23	0.2172	59467.89
	45.44	0.3170	86795.47
	45.77	0.2925	80075.94
	46.02	0.2087	57121.55
	46.10	0.1328	36353.74
	46.29	0.1753	47986.31
	46.46	0.2075	56806.43
	46.54	0.4584	125489.40
	46.75	0.2298	62911.63
	47.02	0.2150	58848.59
	47.23	0.2226	60943.29
	47.37	0.1015	27799.98
	47.52	0.1895	51873.80
i-C13	47.69	0.9181	251348.30
	47.90	0.0655	17941.47
	48.00	0.1809	49513.40
	48.23	0.3048	83432.24
	48.37	0.1686	46161.51
	48.62	0.4056	111039.40
	48.70	0.1734	47475.25
	48.94	0.1046	28636.96
	49.08	0.5646	154566.70
	49.31	0.2285	62556.16
	49.47	0.1434	39269.63
	49.70	0.4106	112404.10
i-C14	49.84	0.5183	141901.30
	49.94	0.0722	19759.26
91	50.04	1.3291	363861.70
	50.17	0.2201	60266.98
	50.25	0.2555	69933.70
	50.35	0.3024	82779.59
92	50.55	0.9412	257673.90
	50.73	0.1708	46758.84
	50.84	0.0670	18355.44

Peak Name	Ret. Time	Area %	Area
	50.94	0.1017	27828.73
	51.02	0.4868	133263.20
	51.22	0.4650	127310.30
	51.39	0.1034	28309.13
	51.47	0.0561	15368.45
	51.53	0.2136	58462.84
	51.68	0.1021	27954.17
	51.90	0.1075	29426.31
	51.96	0.6161	168664.70
	52.12	0.2632	72066.34
	52.20	0.3057	83684.84
	52.33	0.2685	73501.50
	52.52	0.2067	56583.24
	52.65	0.3334	91285.21
i-C15	52.86	0.7693	210615.10
	52.97	0.8765	239962.10
	53.28	0.9908	271235.00
	53.32	0.8069	220912.40
	53.52	0.4507	123389.90
	53.65	1.5318	419353.60
	53.74	1.0696	292807.20
	53.89	0.1395	38186.69
	54.06	0.1613	44149.64
	54.14	0.8314	227620.60
	54.30	0.1810	49542.75
	54.39	0.2127	58242.05
	54.49	0.5091	139373.20
	54.58	0.7320	200395.00
	54.75	0.2322	63558.53
i-C16	54.89	1.0112	276823.80
	55.04	0.1436	39324.61
	55.13	0.1835	50230.25
	55.26	0.4758	130270.20
	55.41	0.1541	42188.14
	55.49	0.3193	87414.34
	55.63	1.1761	321985.00
	55.73	0.4402	120513.60
	55.84	0.3107	85055.39
	55.93	0.1245	34087.74
	55.99	0.3452	94502.61
	56.09	0.5857	160347.30
	56.22	0.8834	241857.70
	56.53	0.7170	196280.10
	56.63	0.6627	181420.50
	56.70	0.1210	33136.80
	56.77	0.4169	114136.10
	56.85	0.2189	59914.18
	56.89	0.7873	215533.10
	56.99	0.3226	88323.49
	57.21	0.2903	79486.24
	57.36	0.1936	53007.56
	57.46	0.7796	213435.20
	57.54	0.1391	38082.34
	57.71	0.1972	53979.18
	57.87	0.1852	50712.01
	57.95	0.3646	99820.46
	58.04	0.1639	44882.57
	58.11	0.2973	81389.59
	58.24	0.2161	59164.48
	58.35	0.3512	96148.62
i-C18	58.47	1.6676	456526.40
	58.67	0.3437	94089.71
	58.79	0.2407	65898.88
	58.89	0.2938	80443.32
	59.16	0.3915	107172.20
	59.26	0.3515	96236.66
	59.36	0.4724	129314.00

Peak Name	Ret. Time	Area %	Area
Pristane	59.45	2.1101	577686.40
	59.53	0.3040	83233.90
	59.58	0.3162	86576.18
	59.68	0.7013	191997.50
	59.85	0.3323	90963.55
	59.93	0.3998	109438.20
	60.02	0.3523	96455.84
	60.16	0.4699	128636.20
	60.24	0.3757	102855.60
	60.37	0.4932	135021.40
	60.56	0.2772	75878.62
	60.70	0.9948	272354.80
	60.87	0.1939	53093.38
	60.97	0.3402	93137.38
Phytane	61.05	1.2169	333137.20
	61.24	0.4225	115655.50
	61.32	0.5452	149245.50
	61.44	0.3930	107583.70
	61.64	0.3825	104707.20
	61.86	0.4562	124889.40
	62.06	0.3382	92589.00
	62.14	0.4117	112720.10
	62.24	0.4944	135339.20
	62.45	0.7614	208437.50
	62.54	0.7811	213849.60
	62.69	0.2686	73532.02
	62.82	0.3195	87468.17
	62.90	0.6345	173705.00
	63.05	0.4255	116476.00
	63.34	0.4500	123191.50
	63.45	0.2418	66204.77
	63.63	0.4581	125400.80
	63.82	0.2592	70963.46
	64.00	0.5784	158351.00
	64.14	0.3676	100640.30
	64.20	0.3196	87487.52
	64.39	0.5185	141954.60
	64.50	0.4116	112688.50
IS #3	64.57	1.6784	459476.70
	64.66	0.4957	135699.50
	64.87	0.4548	124513.90
	64.98	0.1680	45999.64
	65.15	0.2941	80501.48
	65.35	0.2072	56734.45
	65.45	0.0699	19142.98
	65.53	0.7306	200003.60
	65.81	0.3855	105546.30
	65.95	0.3813	104375.20
	66.19	0.1818	49780.63
	66.27	0.1267	34673.15
	66.53	0.1375	37646.56
	66.67	0.2570	70365.34
	66.88	0.2861	78335.64
	67.05	0.3788	103702.10
	67.21	0.0670	18343.57
	67.36	0.2187	59871.59
	67.46	0.1593	43610.07
	67.54	0.1281	35070.14
	67.66	0.0774	21183.94
	67.82	0.1994	54597.84
	68.15	0.2111	57780.53
	68.57	0.2476	67794.15
	68.75	0.0658	18013.11
	68.84	0.3354	91815.43
	68.93	0.1255	34366.12
	69.24	0.0885	24231.09
	69.39	0.1198	32784.38

Peak Name	Ret. Time	Area %	Area
	69.59	0.0936	25623.29
	69.76	0.4413	120813.40
	69.89	0.4816	131847.00
	70.28	0.2628	71949.29
	70.50	0.0407	11139.44
	71.02	0.1197	32771.23
	71.25	0.1092	29892.96
	71.33	0.0796	21785.25
	71.41	0.1018	27869.82
	71.58	0.6257	171299.00
	71.72	0.4465	122250.10
	71.92	0.1224	33510.54
	72.01	0.2207	60425.66
	72.17	0.4223	115608.10
	72.35	0.0416	11375.57
	72.43	0.0647	17699.38
	72.70	0.1722	47137.30
	72.93	0.0547	14977.37
	73.21	0.0655	17927.13
	73.46	0.3671	100505.10
	73.60	0.1743	47708.89
	73.75	0.0990	27106.48
	74.01	0.0627	17164.71
	74.19	0.1259	34471.12
	74.28	0.1290	35305.52
	74.45	0.1109	30372.07
	74.62	0.0719	19695.20
	74.78	0.2089	57199.70
	75.00	0.0995	27231.23
	75.33	0.1241	33963.32
	75.67	0.0747	20459.43
	76.23	0.2795	76530.13
	76.51	0.1804	49380.62
	76.74	0.0681	18632.14
	77.34	0.1034	28301.07
	77.89	0.0657	17999.71
	78.73	0.2365	64751.61
	78.89	0.2420	66244.28
	79.27	0.0974	26651.18
	79.92	0.0433	11853.01
	80.20	0.0564	15448.83
	80.59	0.0464	12696.25
	80.86	0.1047	28651.33
	81.30	0.0797	21816.37
	81.66	0.0697	19078.19
	81.82	0.0606	16587.78
	82.38	0.0472	12911.48
	82.74	0.0994	27207.34
	83.33	0.0626	17124.26
	84.30	0.1553	42517.41
	84.56	0.0433	11861.29
	84.95	0.1575	43122.86
	85.28	0.1488	40733.68
	86.34	0.0929	25441.86
	86.56	0.0453	12413.65
	87.64	0.0250	6836.44
	88.72	0.1379	37757.08
	89.49	0.1253	34310.11
	89.78	0.1543	42255.38
	90.58	0.1142	31257.56

Total Area = 2.737661E+07 Total Height = 8963582 Total Amount = 0

Pace Analytical®
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(C8-C40) Qualitative Molecular Characterization
by GC/MS - full scan mode
TIC, n-Alkanes, Iso-Alkanes, Isoprenoids, Alkylcyclohexanes,
C4-monoaromatics, Bicyclanes, Terpanes, Steranes

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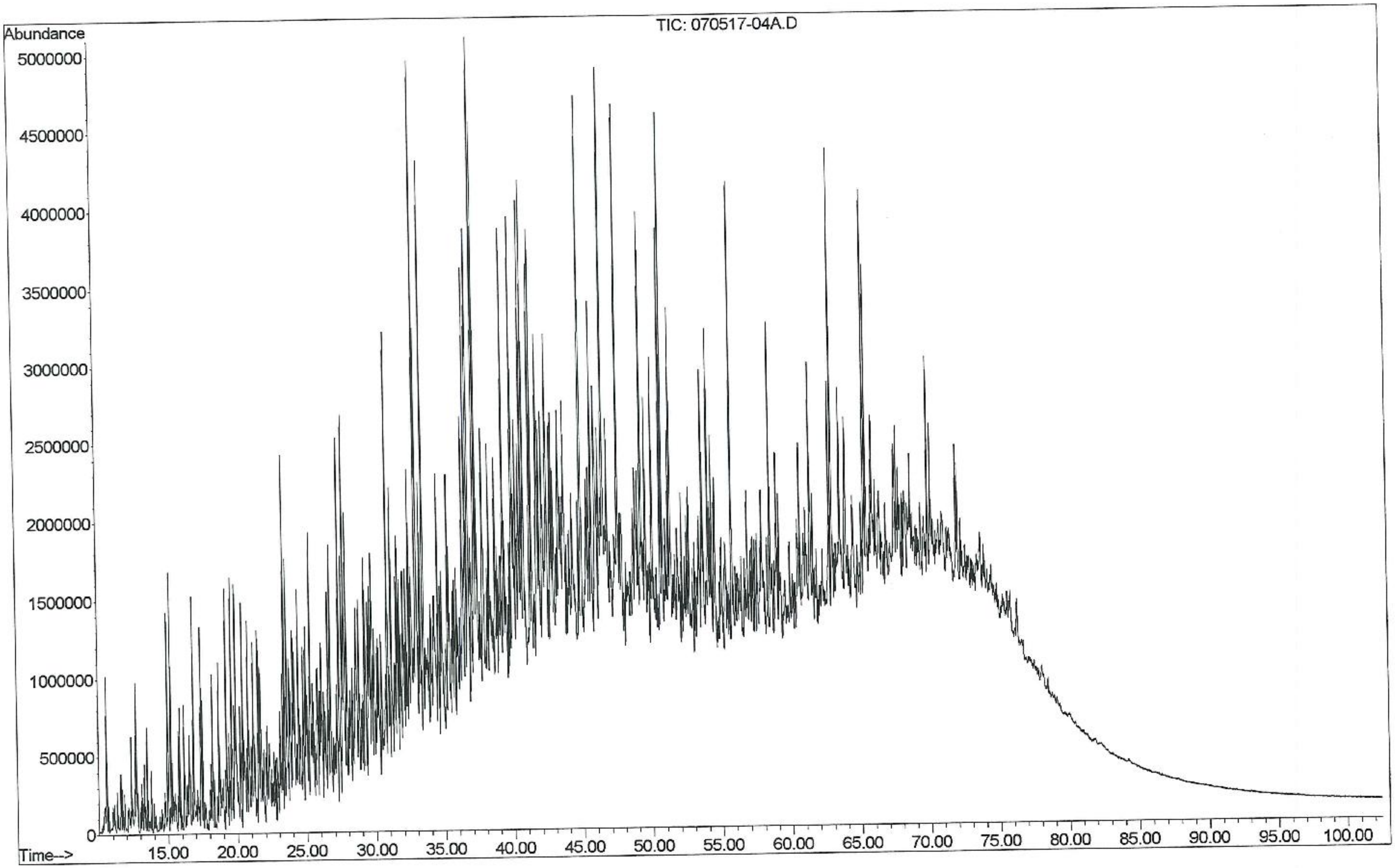
C8-C40 - Qualitative Hydrocarbons Characterization by GC/MS - full scan mode

ION (m/z)	Mass Chromatograms COMPOUND CLASS
TIC	All Compounds
85	n-Alkanes (Paraffins)
113	Iso-Alkanes (Isoparaffins) & Isoprenoids
83	Alkylcyclohexanes
134	C_4-benzenes (monoaromatics)
123	Bicyclanes
191	Terpanes
217	Steranes
Bar Diagram	Monoaromatic and Polyaromatic Hydrocarbon Distribution

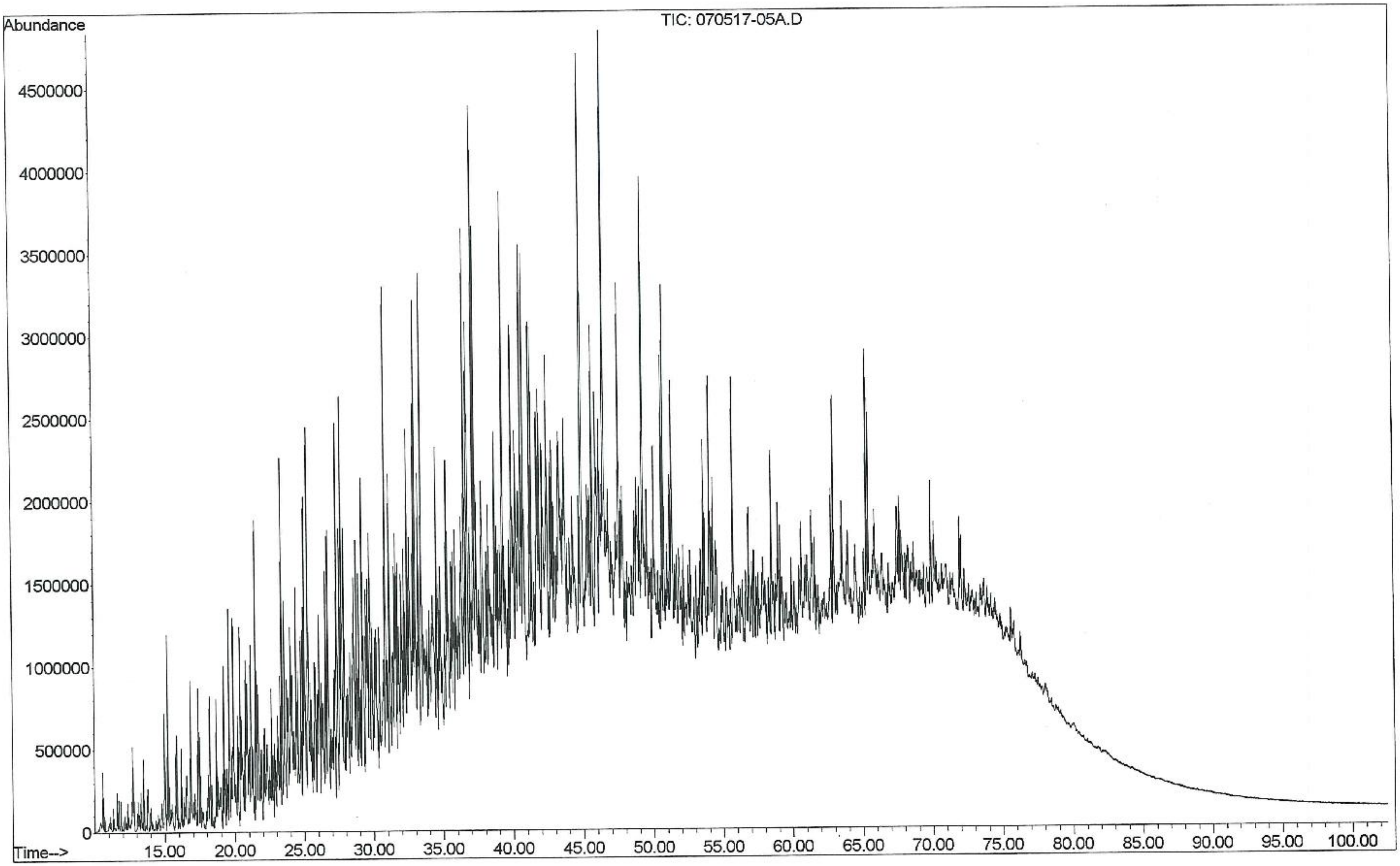
note: Chromatograms and data follow this cover page.

Submitted by,
Pace Analytical Energy Services

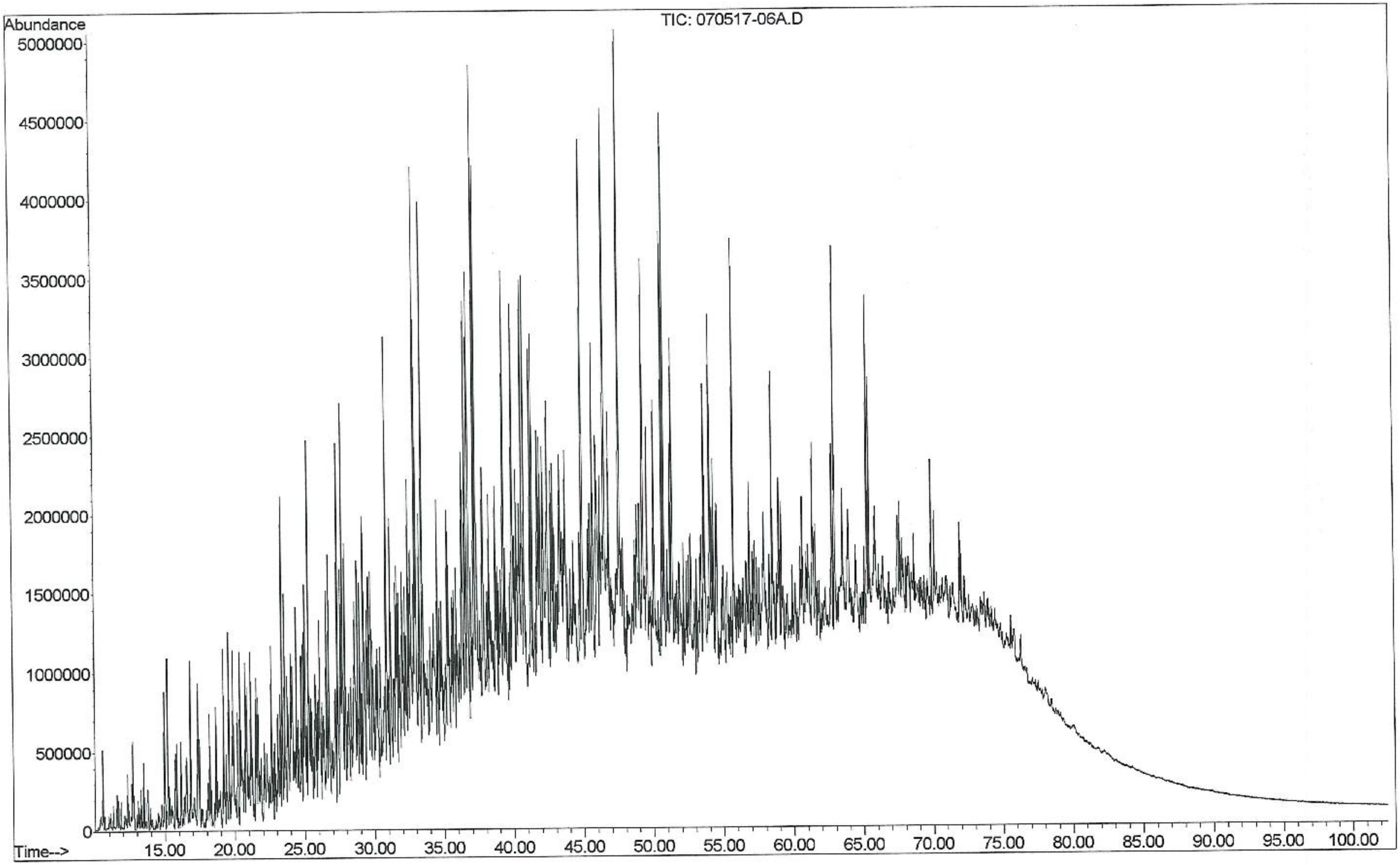
Sample Name: 23114-1 [O-062217-JH-01] 1/5 DILUTION PZ-9
Misc Info :



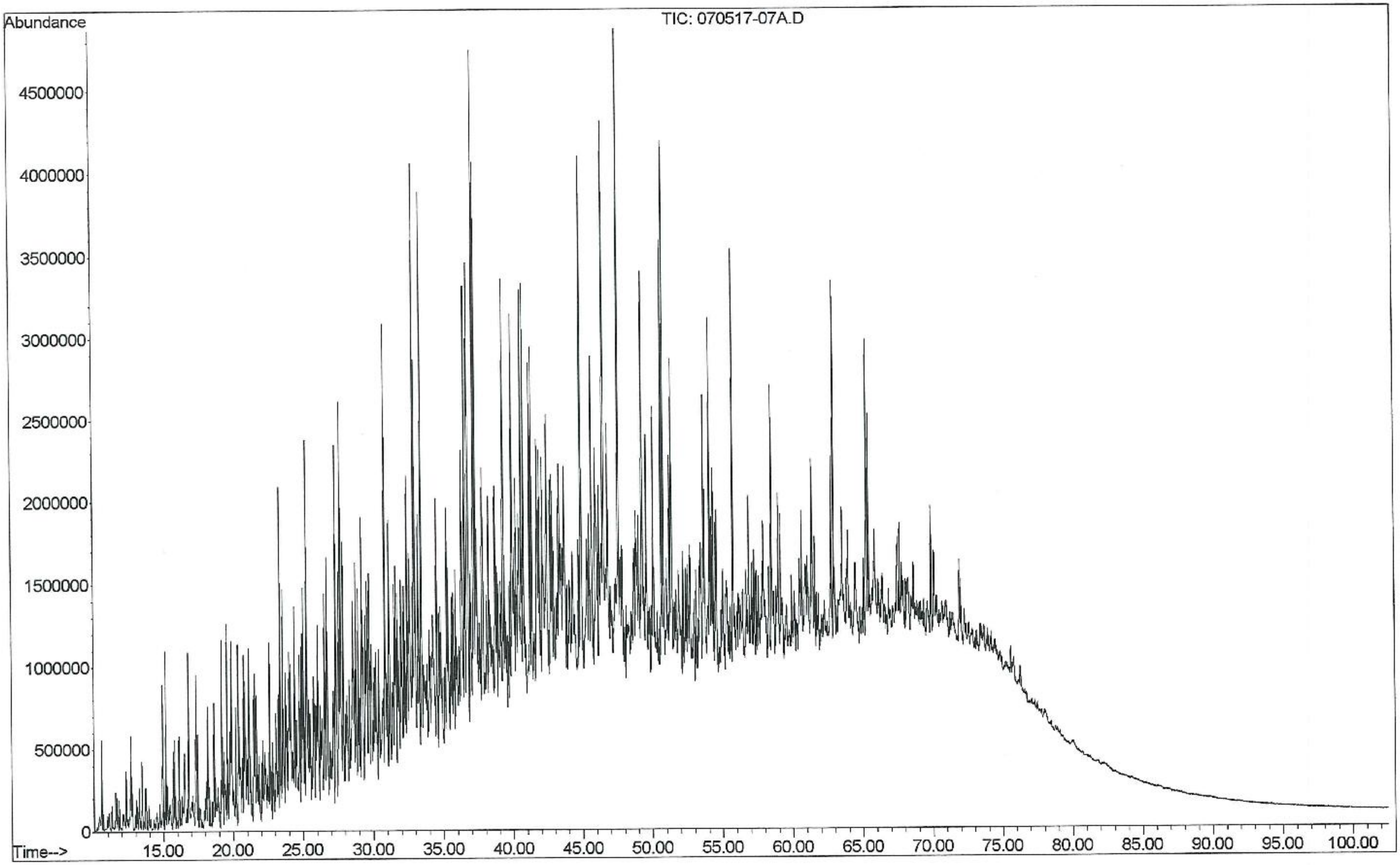
Sample Name: 23114-2 [O-062217-JH-02] 1/5 DILUTION PZ-3
Misc Info :



Sample Name: 23114-3 [O-062217-JH-03] 1/5 DILUTION PZ-4
Misc Info :



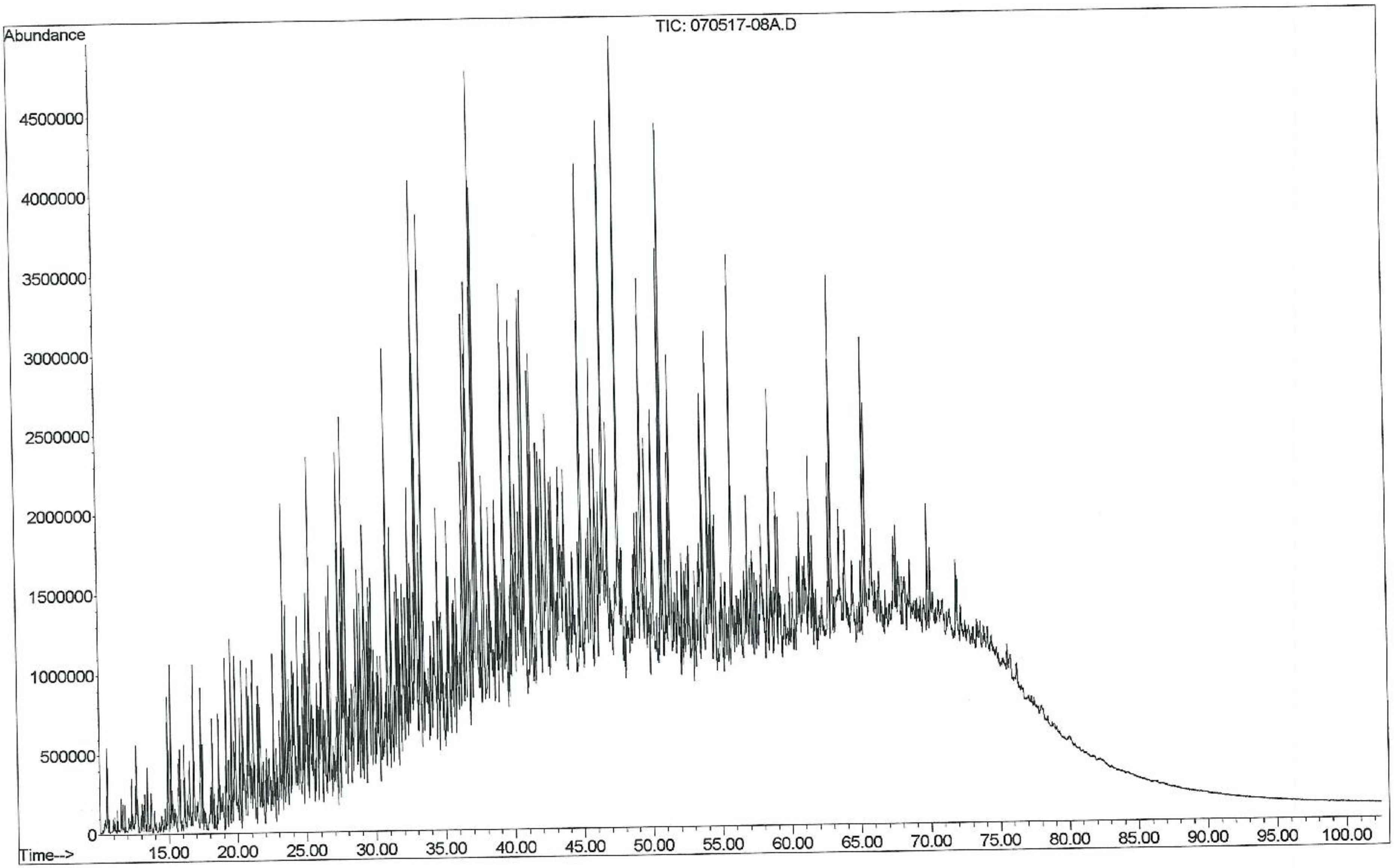
Sample Name: 23114-4 [O-062217-JH-04] 1/5 DILUTION PZ-5
Misc Info :



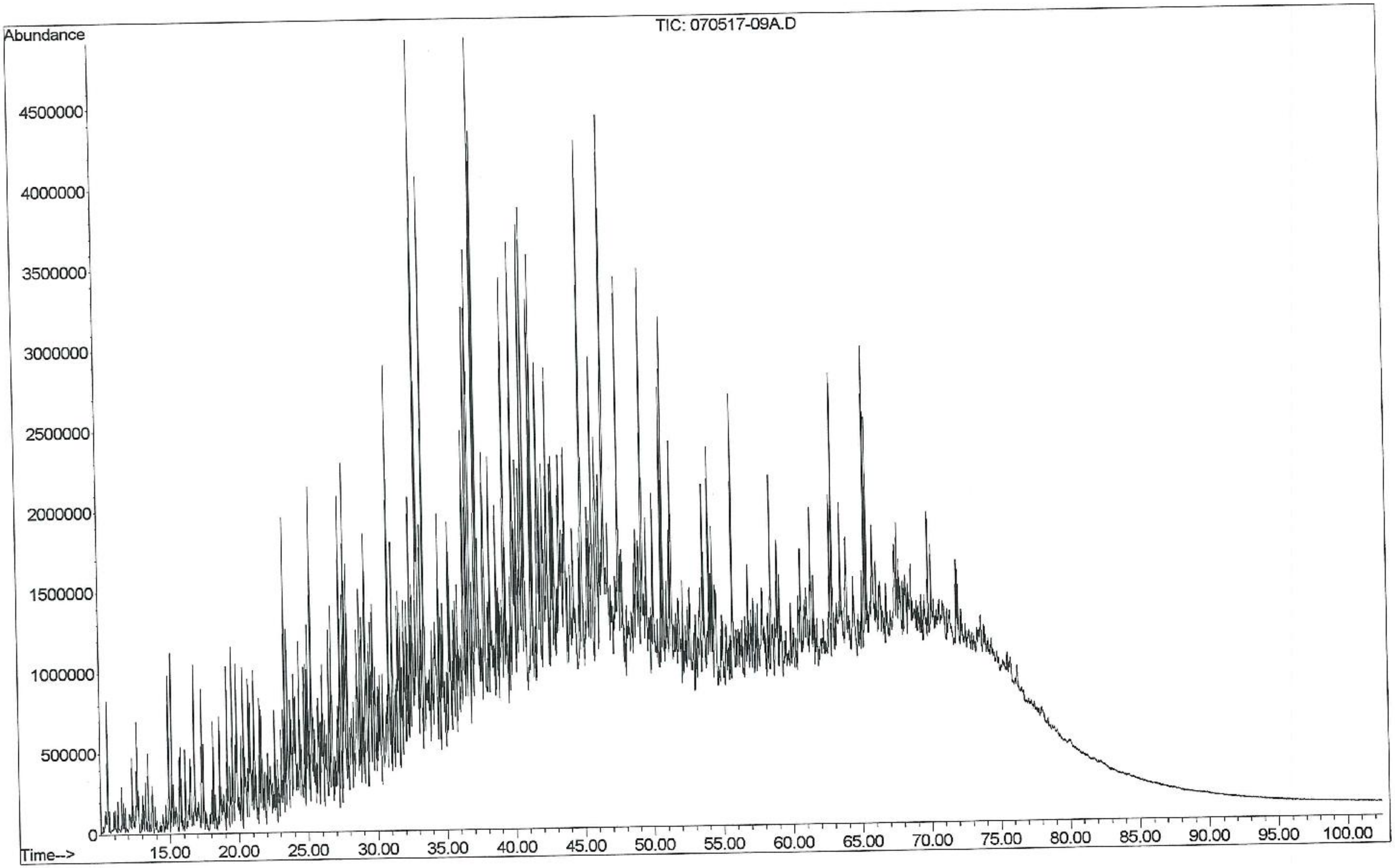
Sample Name: 23114-5 [O-062217-JH-05] 1/5 DILUTION

PZ-6

Misc Info :



Sample Name: 23114-6 [O-062217-JH-06] 1/5 DILUTION PZ-7
Misc Info :



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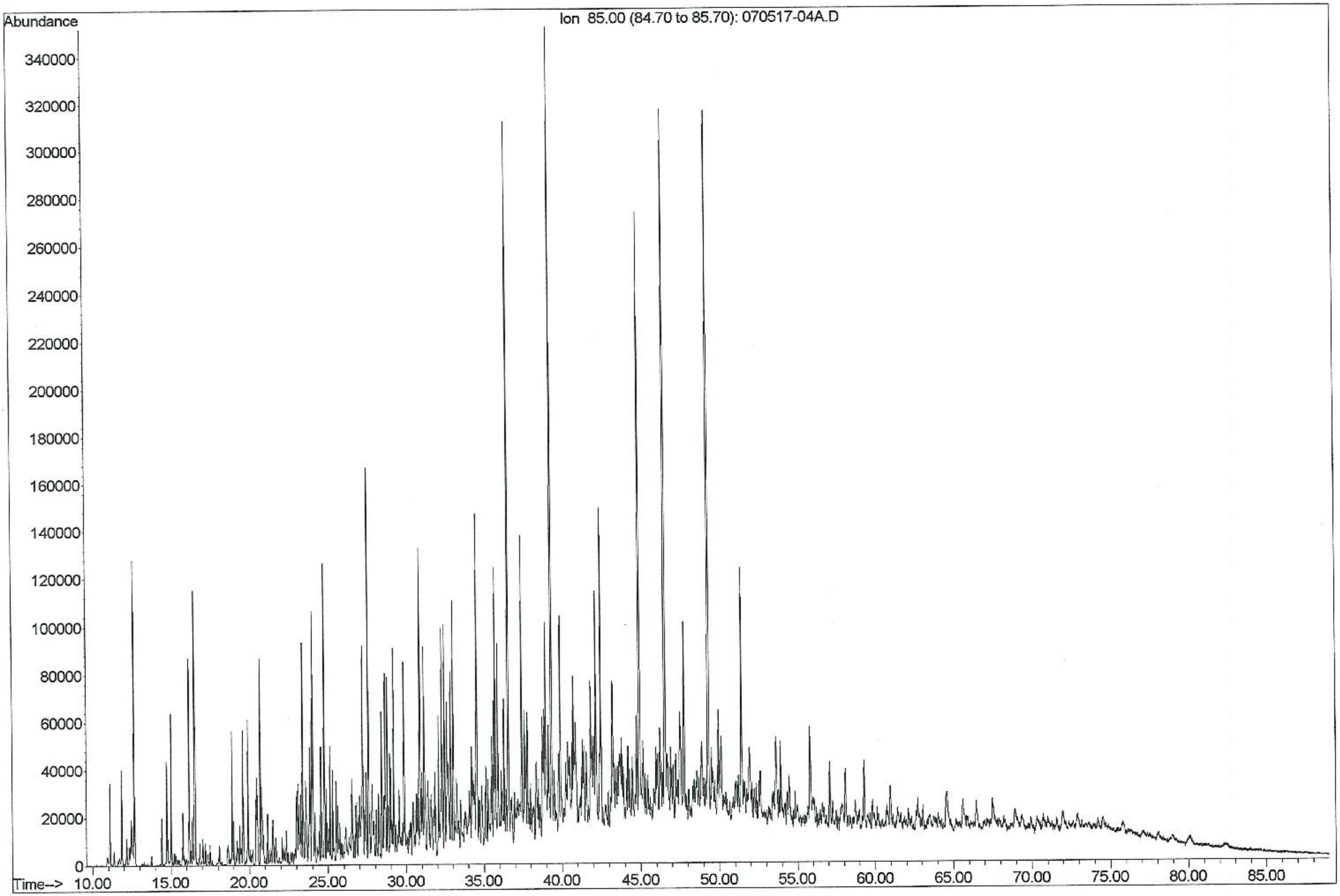
Key to Chromatogram Symbol Identification

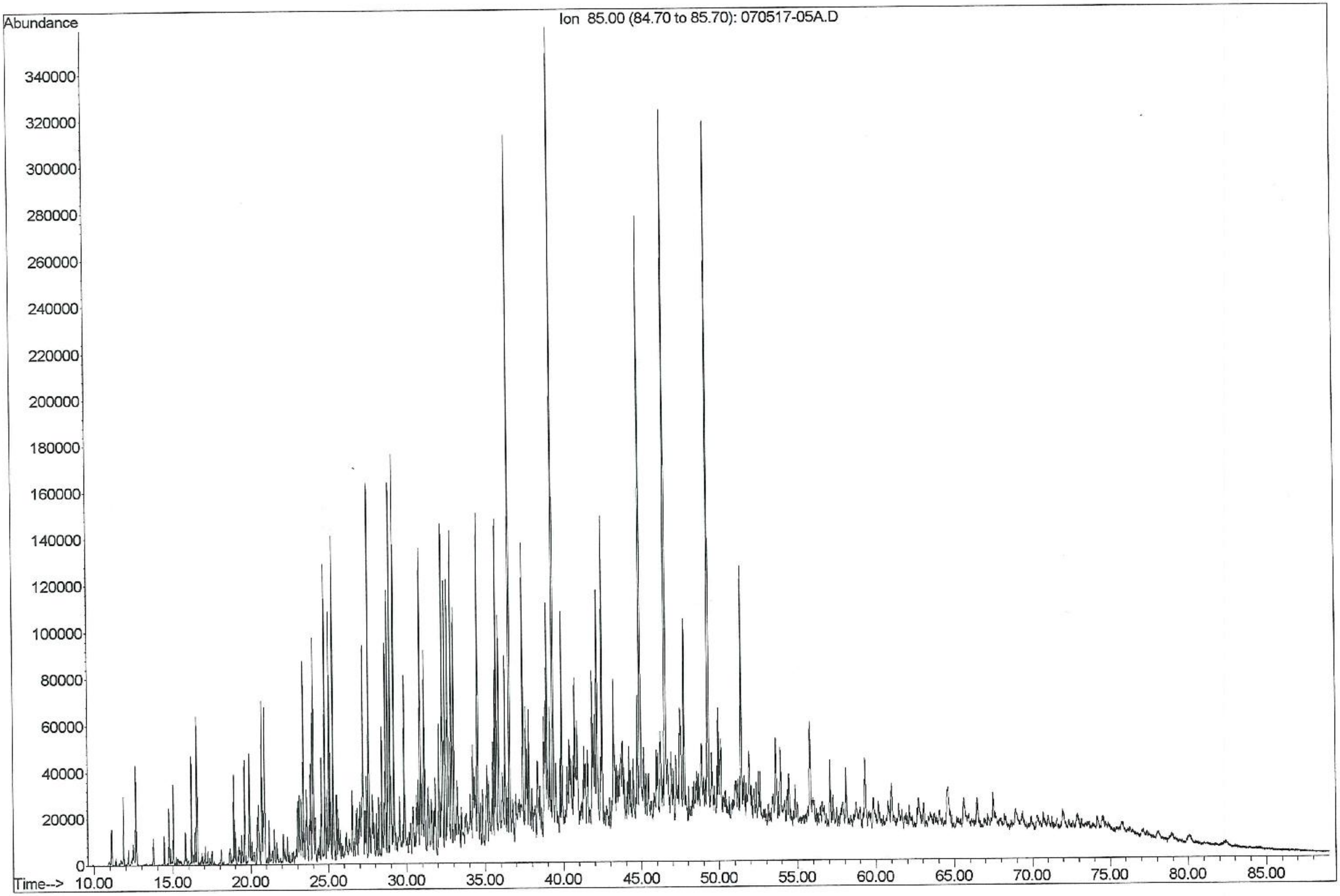
For m/z 85 and m/z 113 Paraffins and Isoparaffins

Symbol	Detail
i-10	Iso-alkane with 10 carbon atoms
i-15	Farnesane (isoprenoid with 15 carbon atoms)
i-16	Isoprenoid with 16 carbon atoms
Pr	Pristane (isoprenoid with 19 carbon atoms)
Ph	Phytane (isoprenoid with 20 carbon atoms)
nC_8	$n\text{-}C_8$ normal Alkane
nC_{15}	$_{n\text{-}C}15$ normal Alkane
i-8	2,5-(2,4)-Dimethylhexane
i-8'	2,3,4-Trimethylpentane
i-8"	2-3-Dimethylhexane
CH-n	Alkylcyclohexane (where n indicates the number of carbon atoms in the side chain)

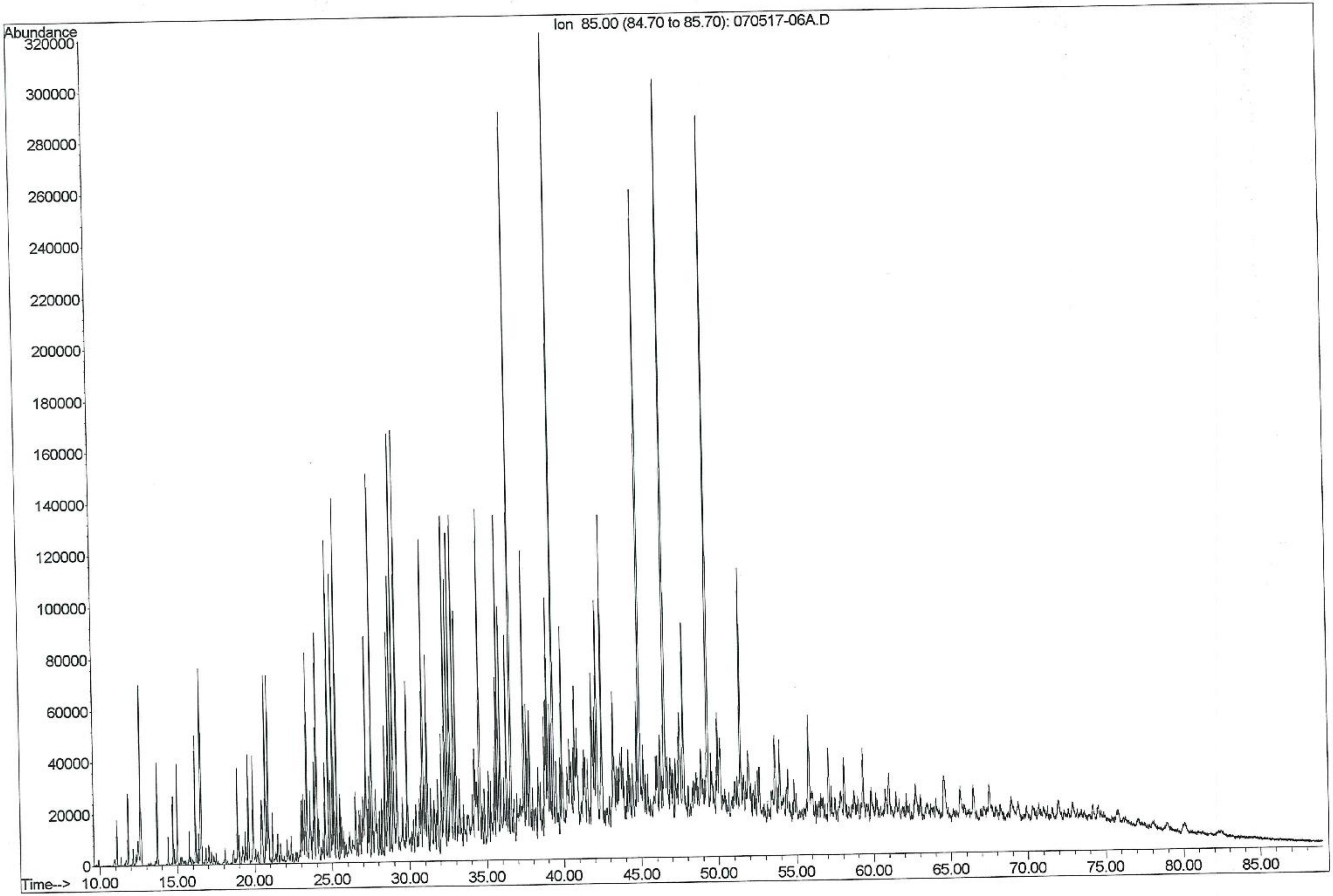
23114-1 [O-062217-JH-01] 1/5 DILUTION PZ-9



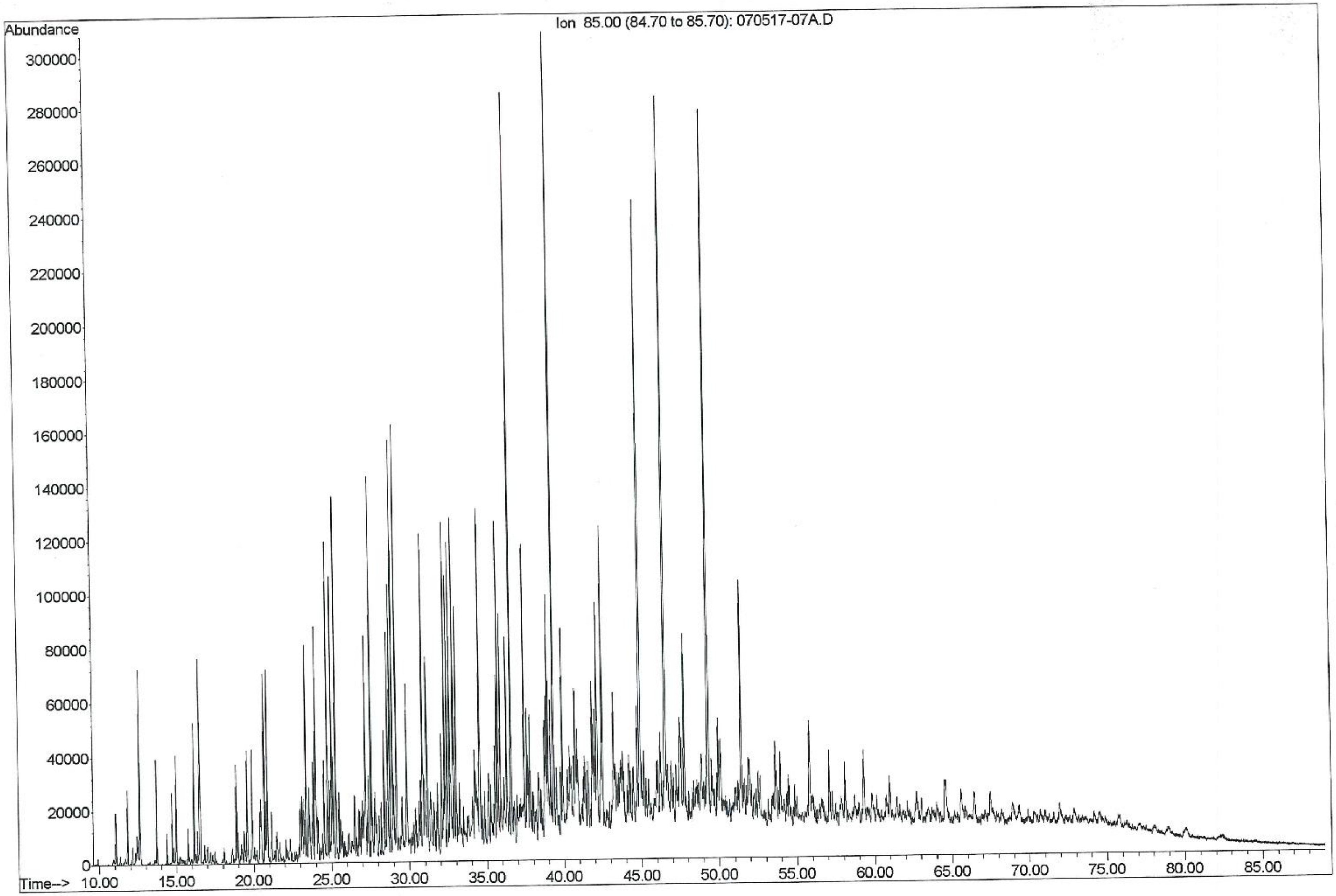
23114-2 [O-062217-JH-02] 1/5 DILUTION PZ-3



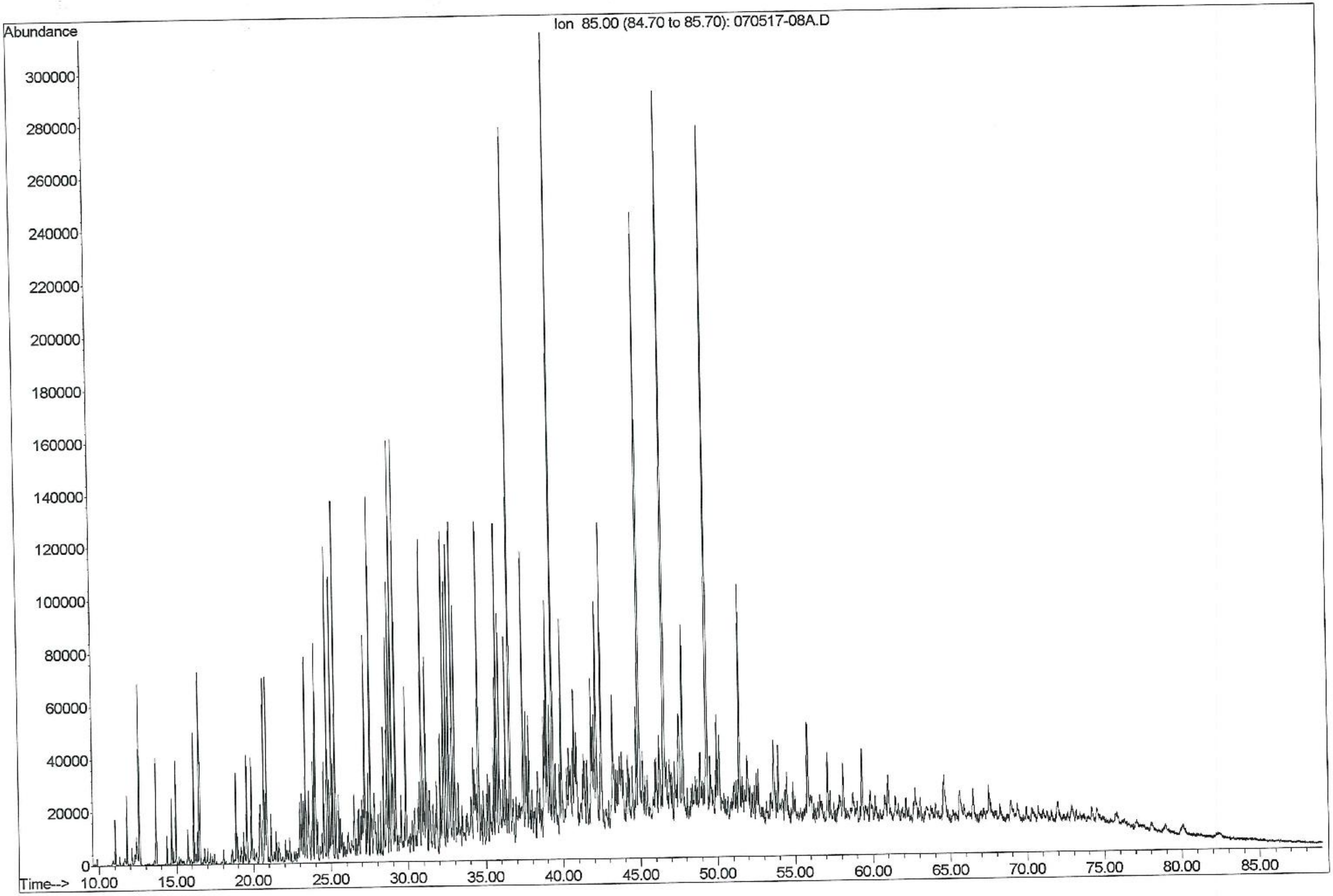
23114-3 [O-062217-JH-03] 1/5 DILUTION PZ-4



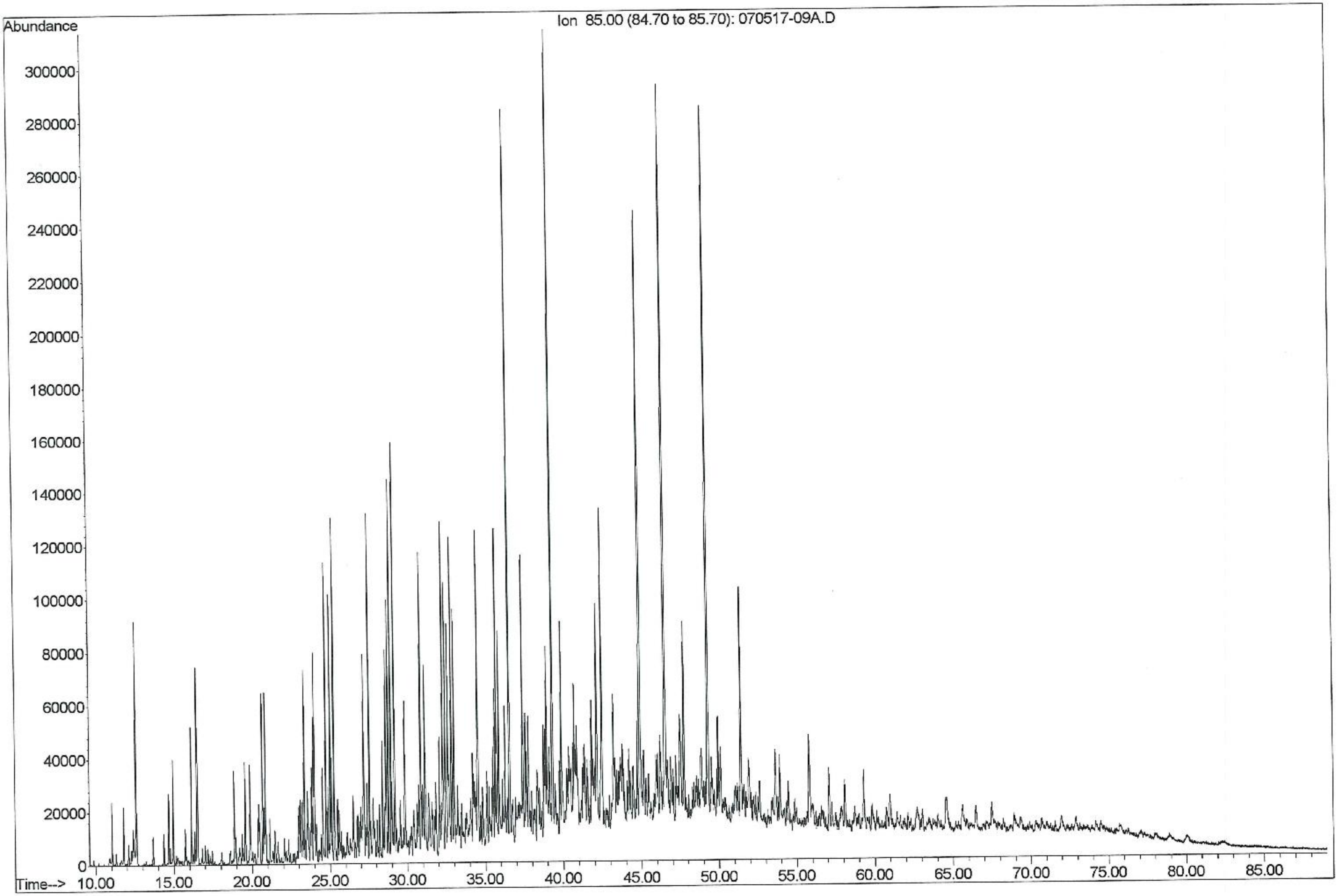
23114-4 [O-062217-JH-04] 1/5 DILUTION PZ-5



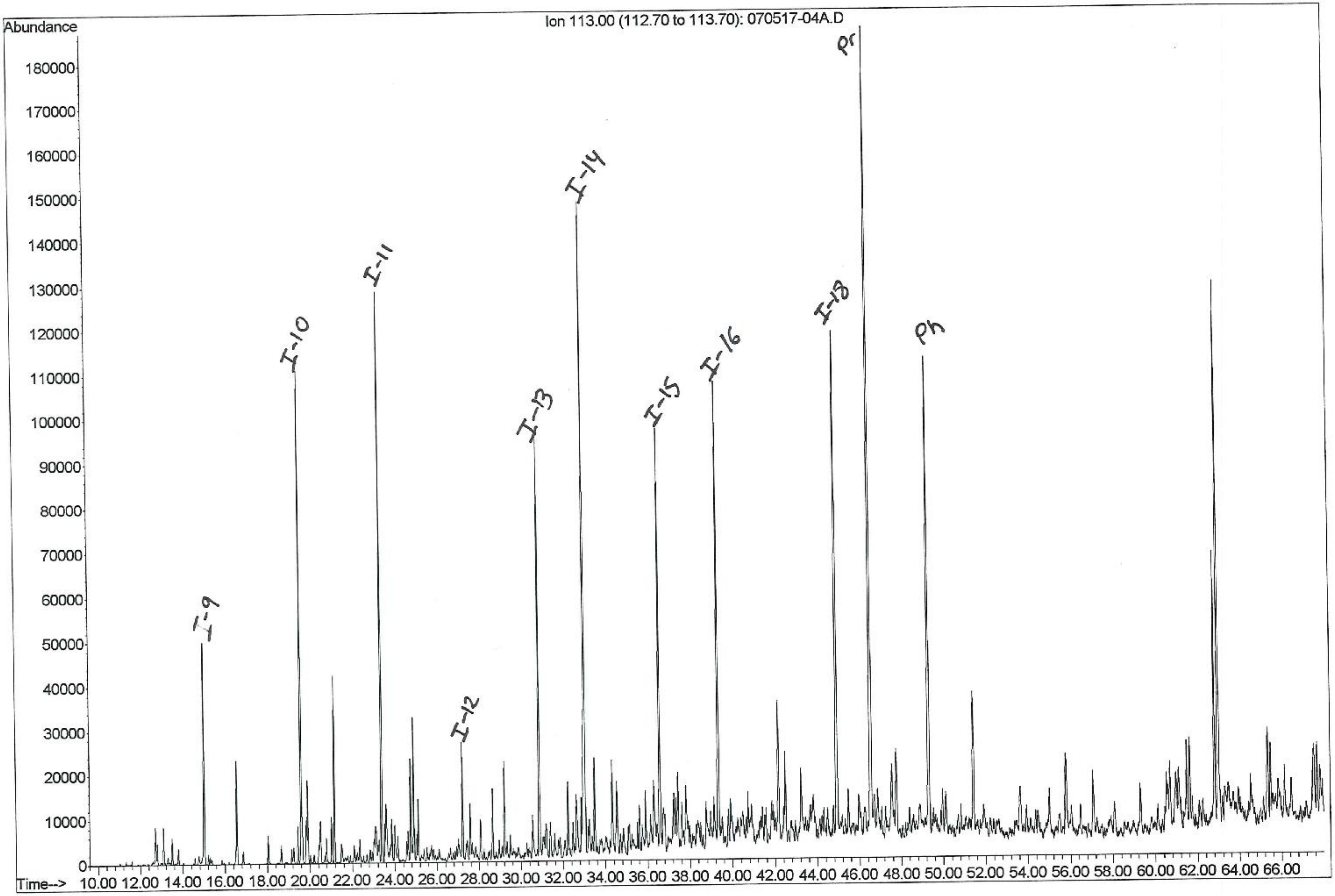
23114-5 [O-062217-JH-05] 1/5 DILUTION PZ-6



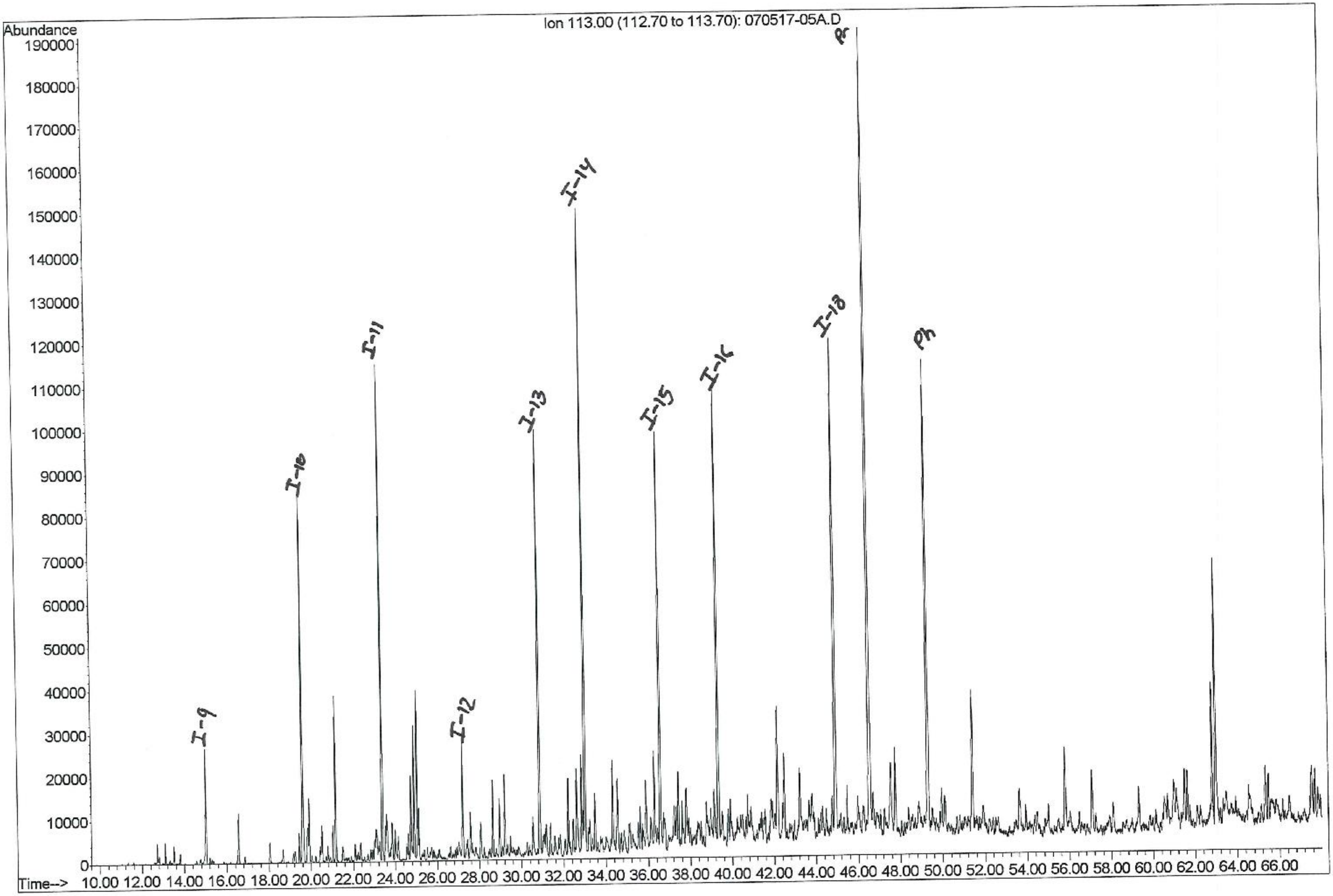
23114-6 [O-062217-JH-06] 1/5 DILUTION PZ-7



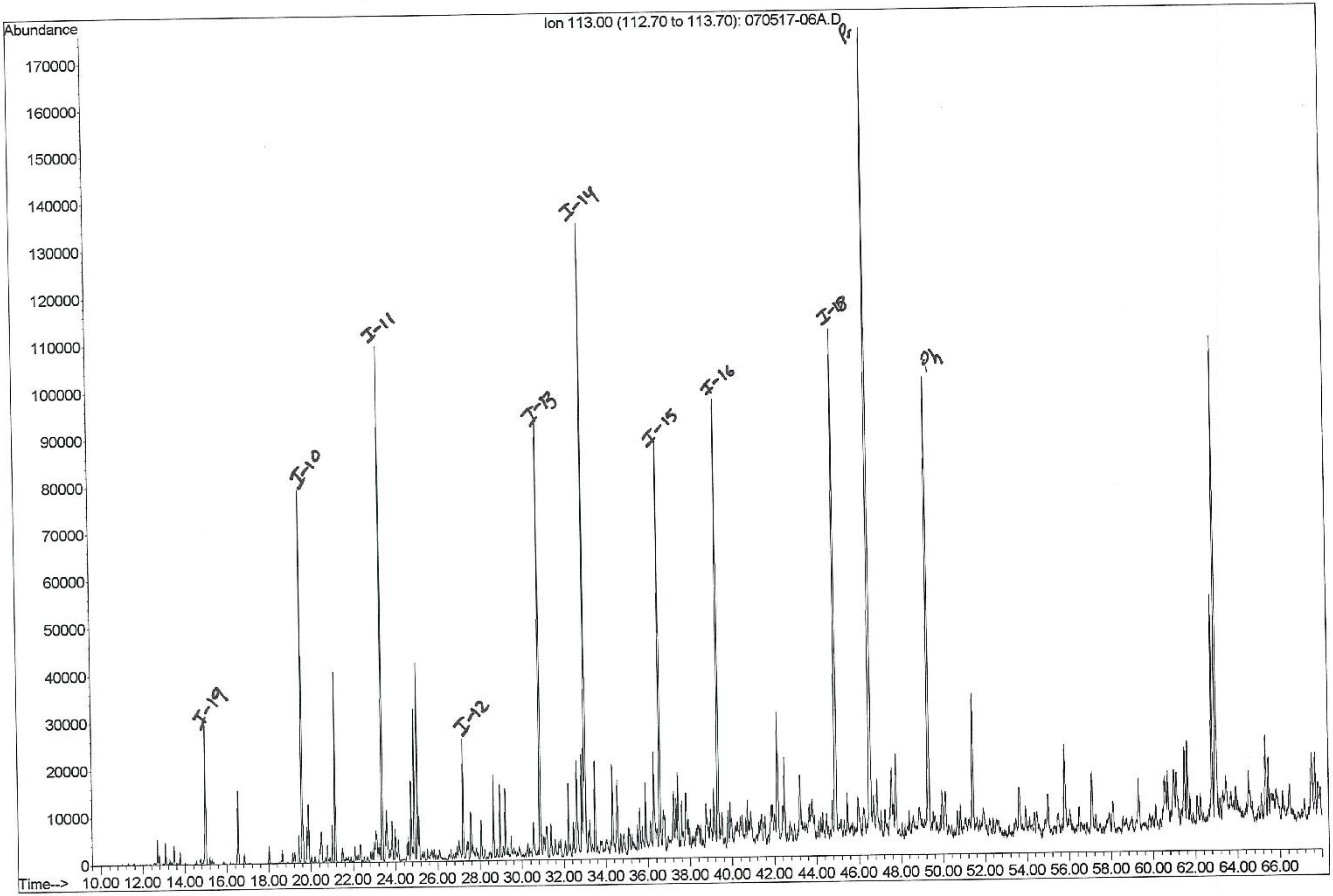
23114-1 [O-062217-JH-01] 1/5 DILUTION PZ-9



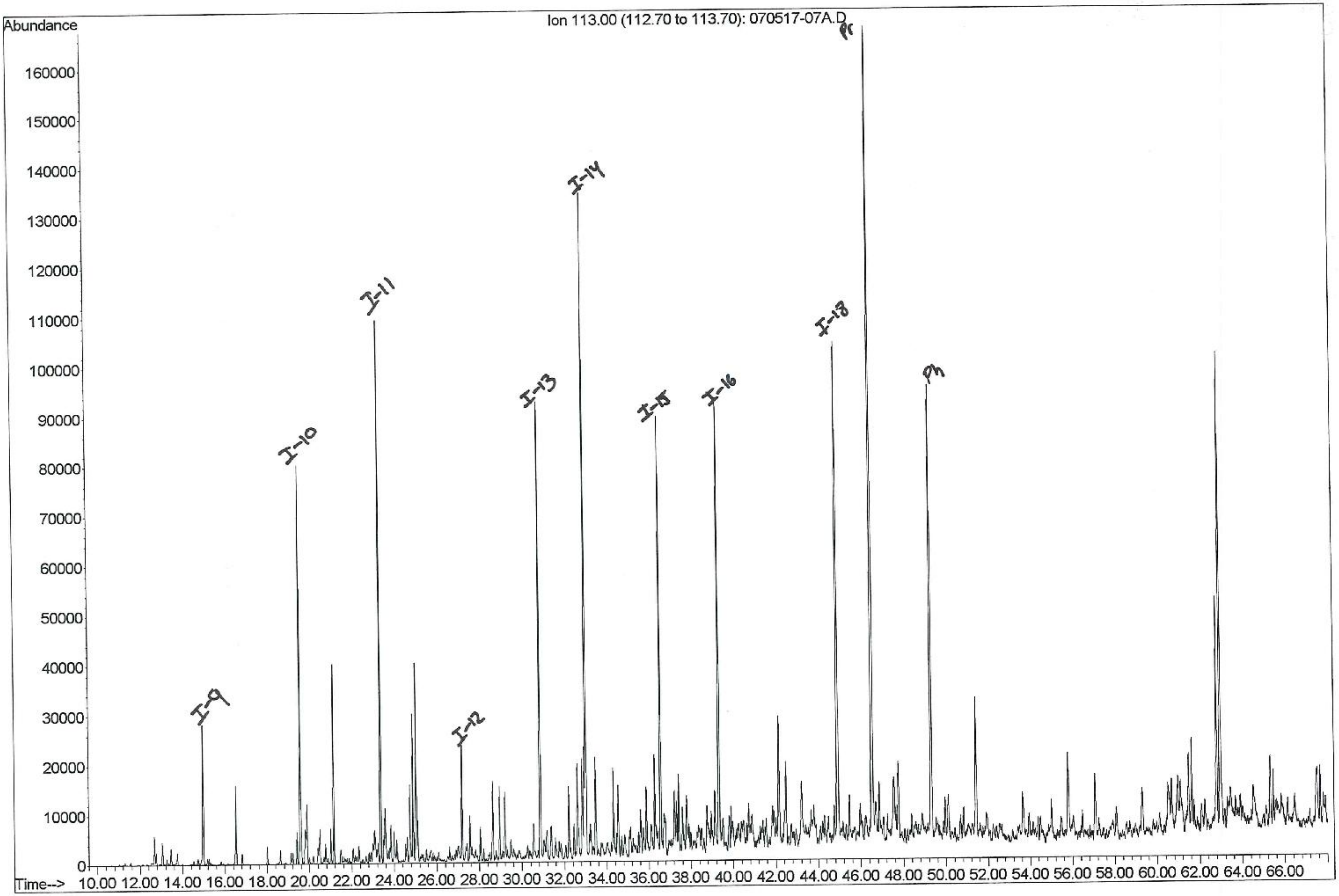
23114-2 [O-062217-JH-02] 1/5 DILUTION PZ-3



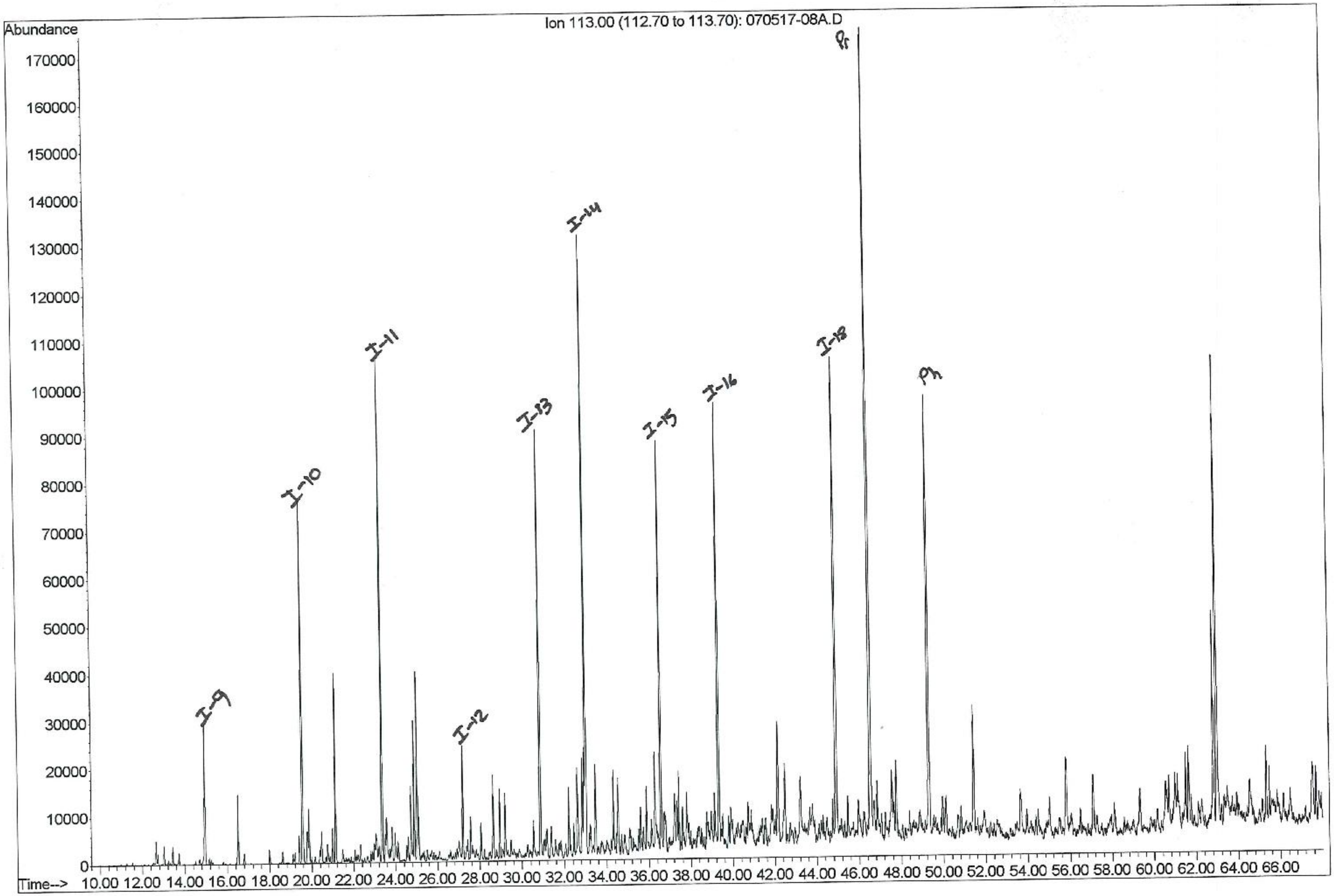
23114-3 [O-062217-JH-03] 1/5 DILUTION PZ-4



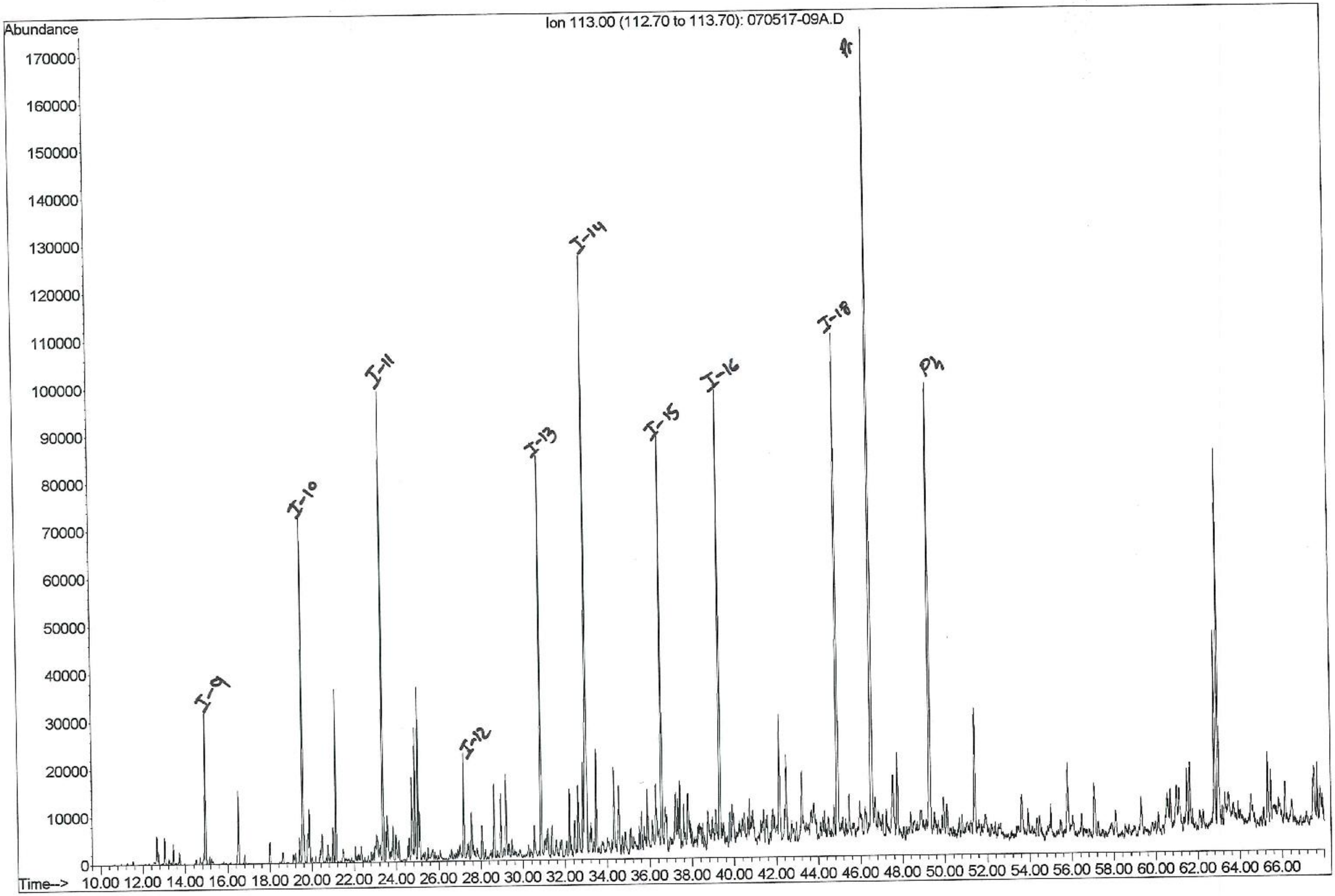
23114-4 [O-062217-JH-04] 1/5 DILUTION PZ-5



23114-5 [O-062217-JH-05] 1/5 DILUTION PZ-6



23114-6 [O-062217-JH-06] 1/5 DILUTION PZ-7



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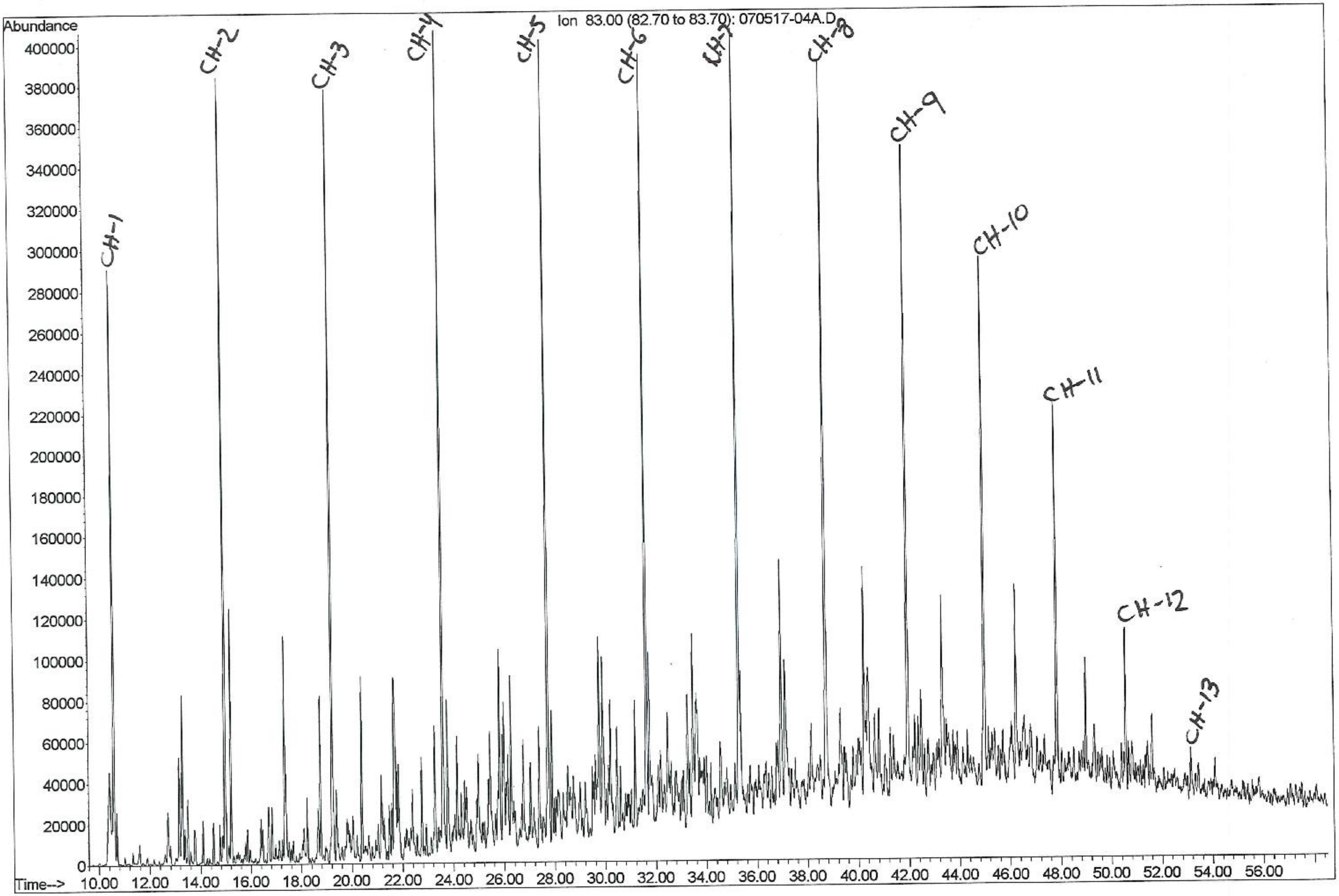
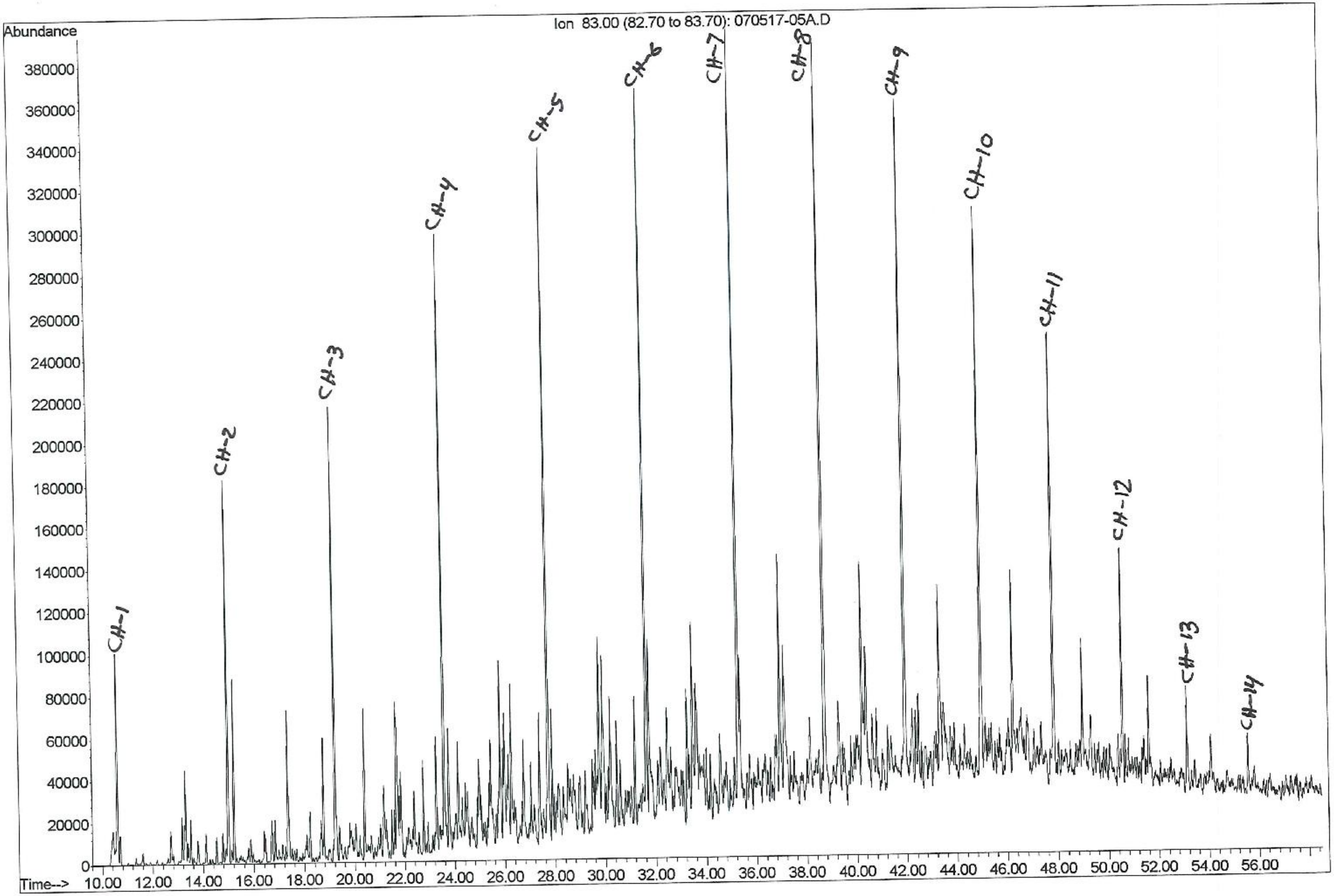
Key for Alkylcyclohexanes at m/z 83

Symbol	Detail
CH-1	Methylcyclohexane
CH-2	Ethylcyclohexane
CH-3	Propylcyclohexane
CH-4	Butylcyclohexane
CH-5	Pentylcyclohexane
CH-6	Hexylcyclohexane
CH-7	Heptylcyclohexane
CH-8	Octylcyclohexane
CH-9	Nonylcyclohexane
CH-10	Decylcyclohexane
CH-11	Undecylcyclohexane
CH-12	Dodecylcyclohexane
CH-13	Tridecylcyclohexane
CH-14	Tetradecylcyclohexane

23114-1 [O-062217-JH-01] 1/5 DILUTION PZ-9

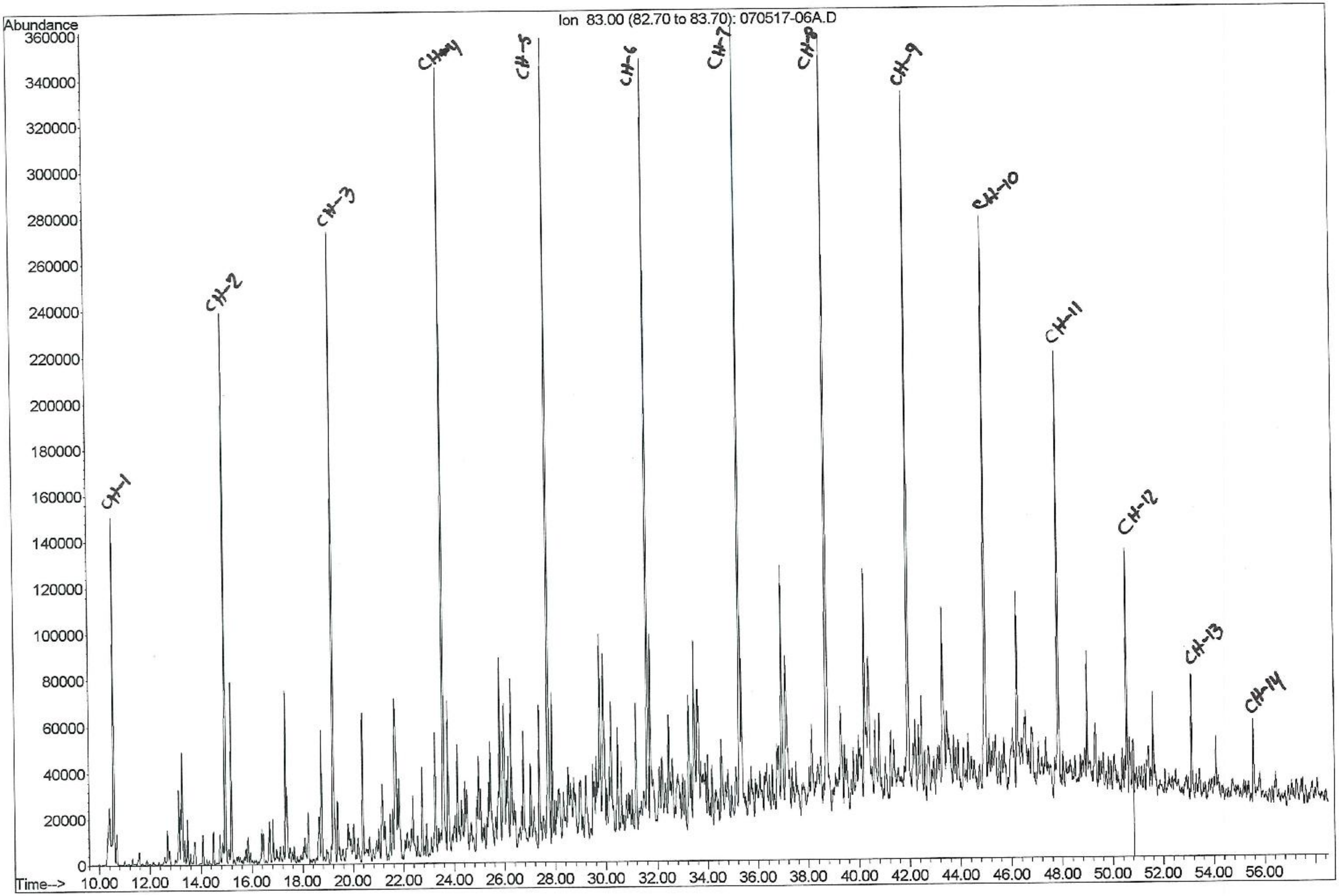


23114-2 [O-062217-JH-02] 1/5 DILUTION PZ-3

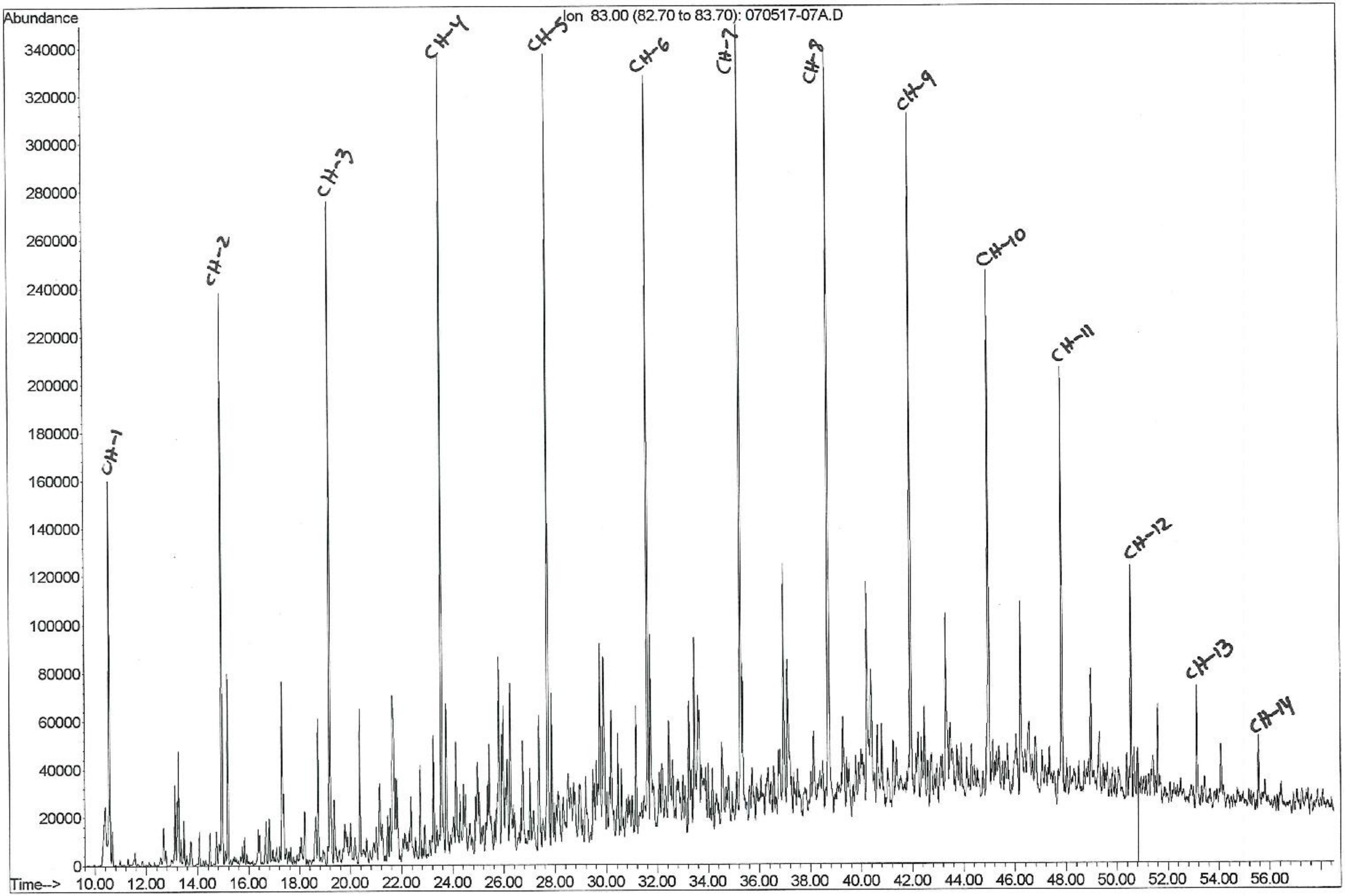


23114-3 [O-062217-JH-03] 1/5 DILUTION

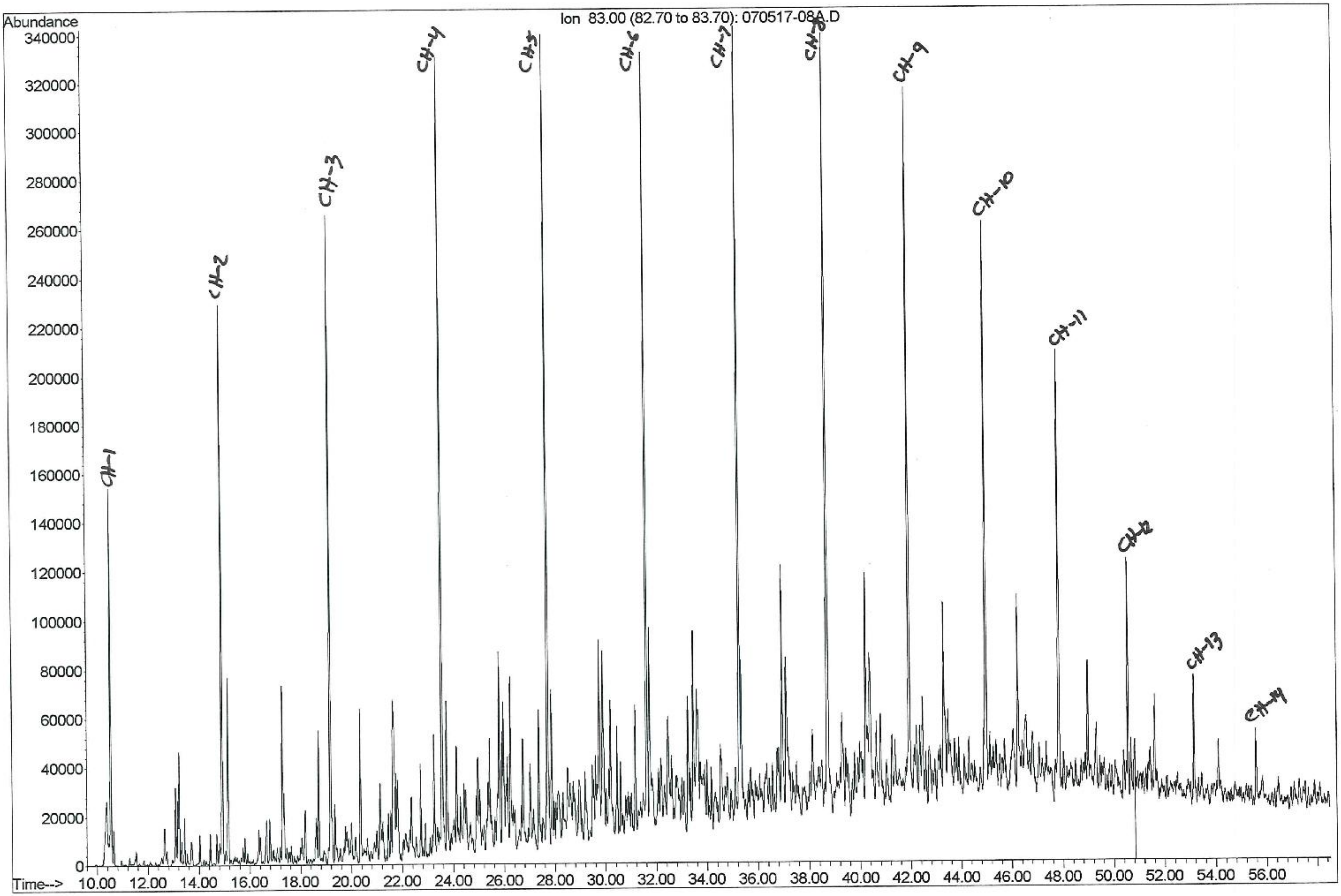
PZ-4



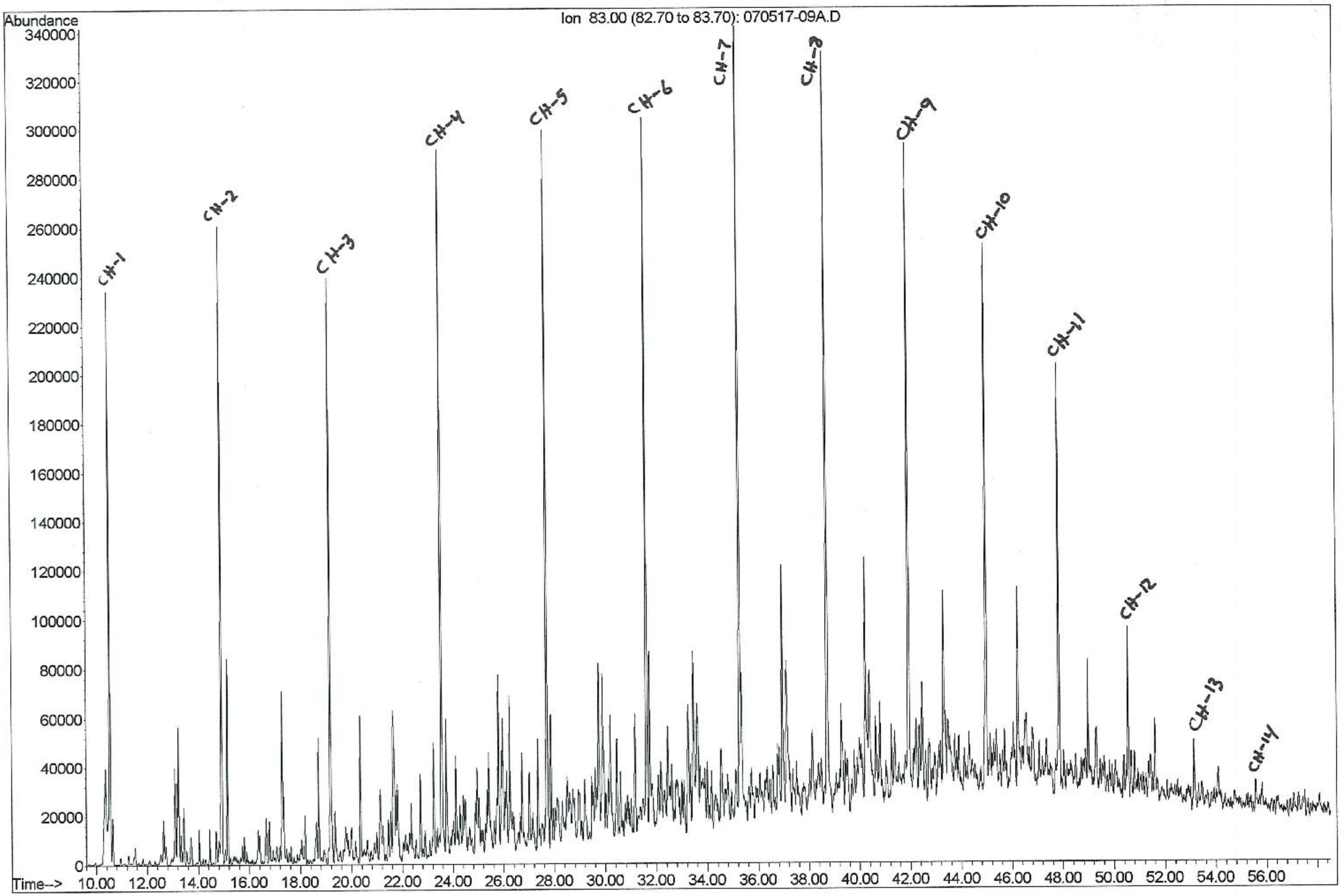
23114-4 [O-062217-JH-04] 1/5 DILUTION PZ-5



23114-5 [O-062217-JH-05] 1/5 DILUTION PZ-6



23114-6 [O-062217-JH-06] 1/5 DILUTION PZ-7



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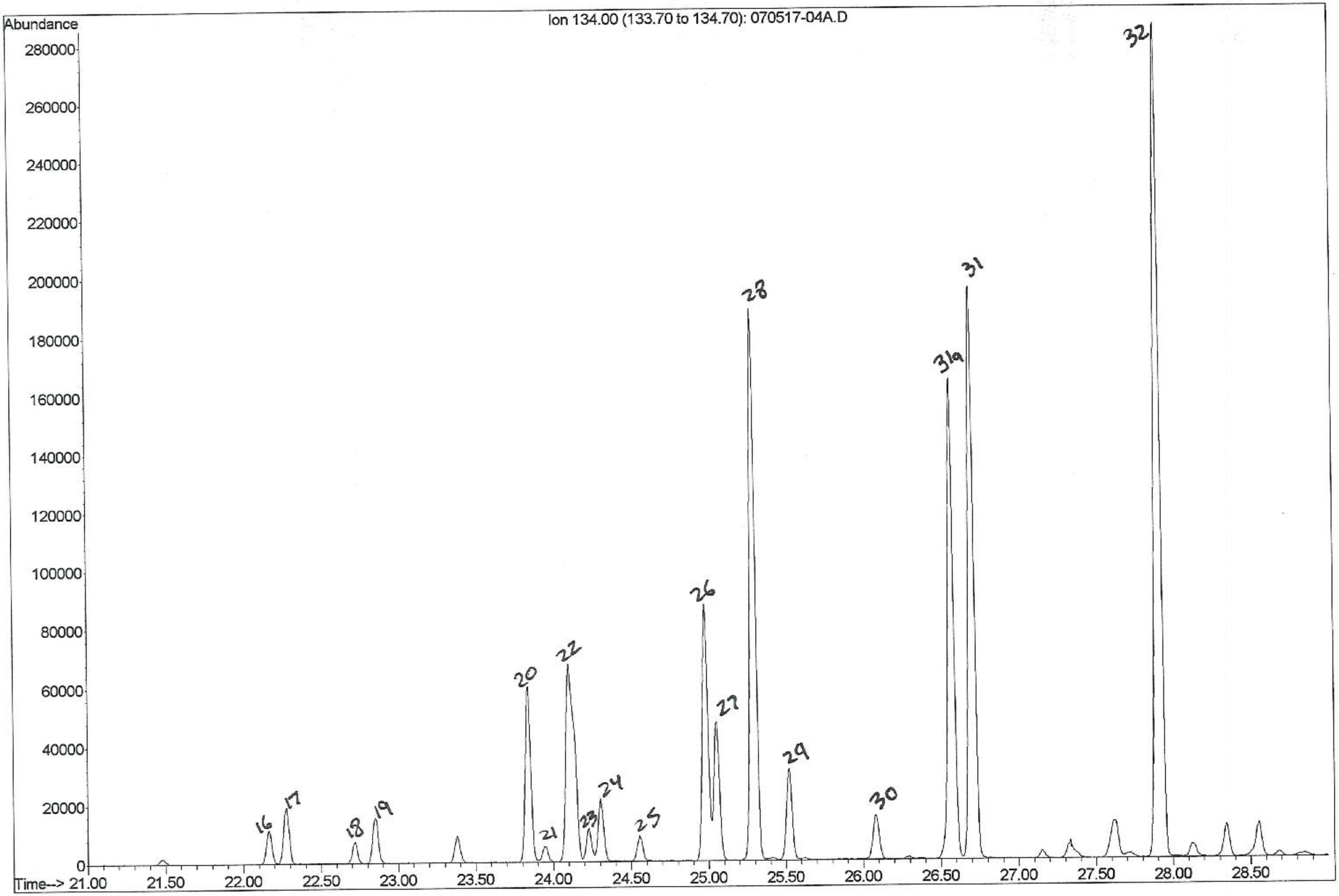
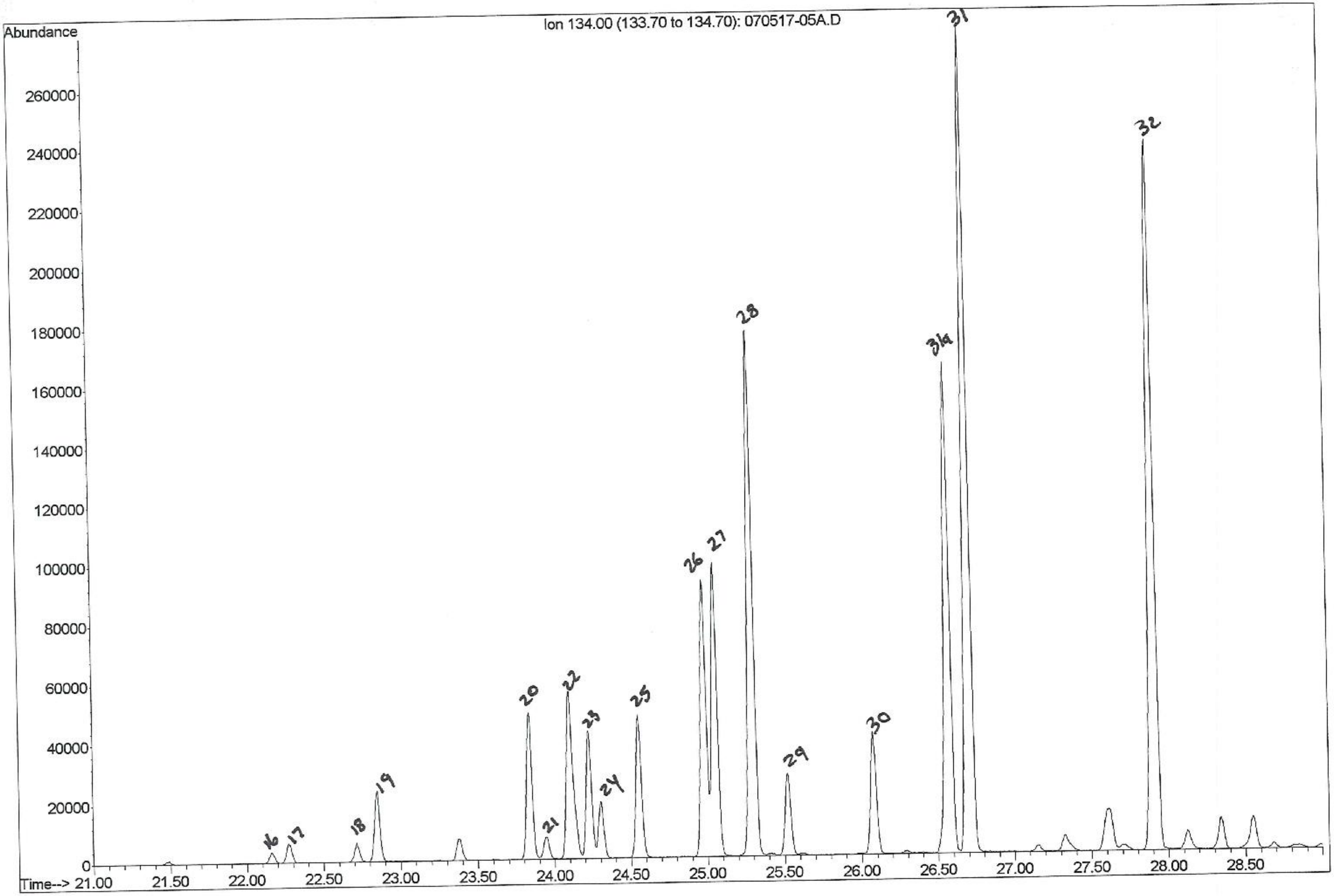
Key for C_4-Alkylbenzenes (m/z 134)

Symbol	Detail
16	Sec-Butylbenzene
17	1-Methyl-3-Isopropylbenzene
18	1-Methyl-4-Isopropylbenzene
19	1-Methyl-2-Isopropylbenzene
20	1,3-Diethylbenzene
21	1-Methyl-3-Propylbenzene
22	Butylbenzene
23	1,3-Diethyl-5-Ethylbenzene
24	1,2-Diethylbenzene
25	1-Methyl-2-Propylbenzene
26	1,4-Dimethyl-2-Ethylbenzene
27	1,3-Dimethyl-4-Ethylbenzene
28	1,2-Dimethyl-4-Ethylbenzene
29	1,3-Dimethyl-2-Ethylbenzene
30	1,2-Dimethyl-3-Ethylbenzene
31a	1,2,4,5-Tetramethylbenzene
31	1,2,3,5-Tetramethylbenzene
32	1,2,3,4-Tetramethylbenzene

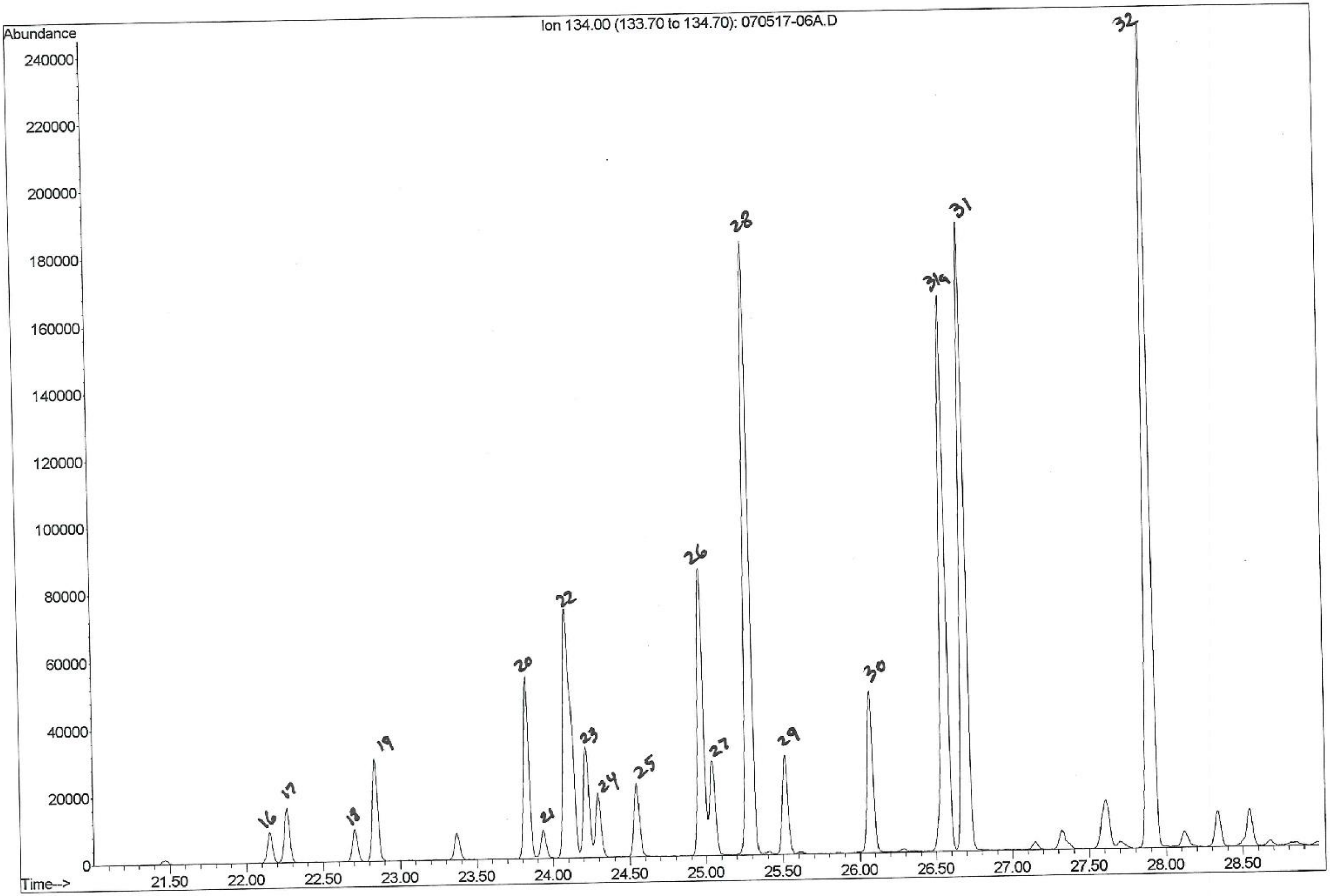
23114-1 [O-062217-JH-01] 1/5 DILUTION PZ-9



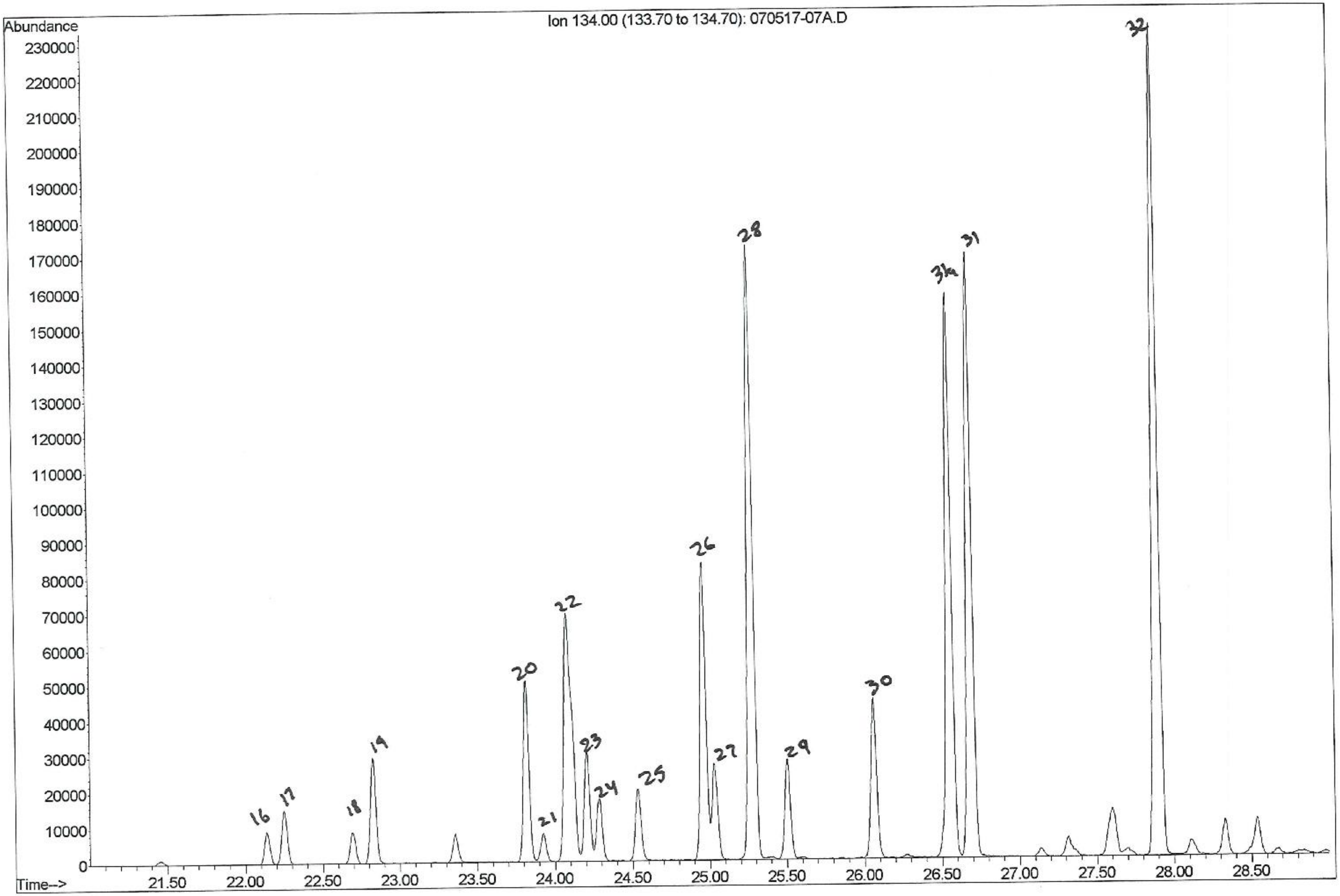
23114-2 [O-062217-JH-02] 1/5 DILUTION PZ-3



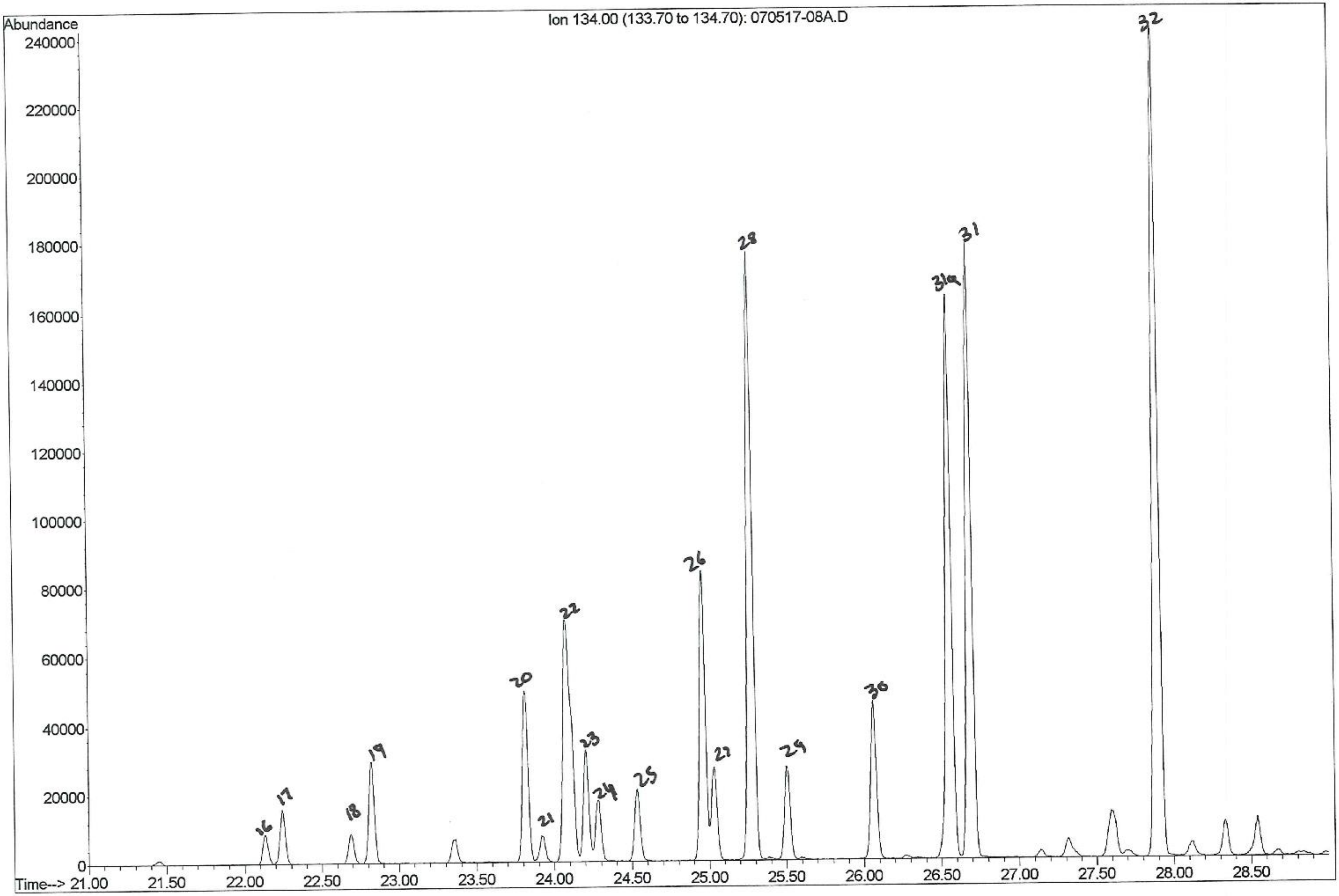
23114-3 [O-062217-JH-03] 1/5 DILUTION PZ-4



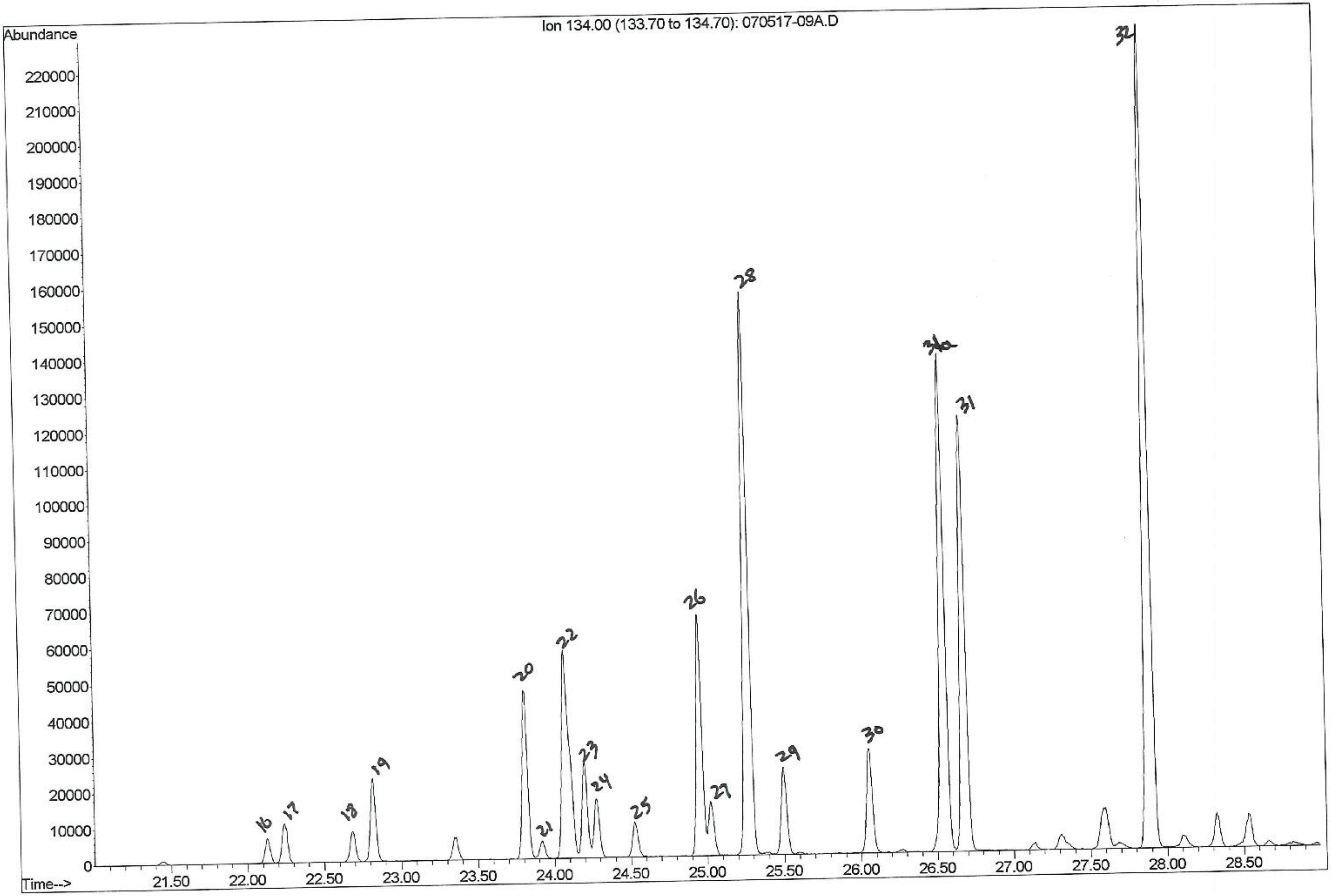
23114-4 [O-062217-JH-04] 1/5 DILUTION PZ-5



23114-5 [O-062217-JH-05] 1/5 DILUTION PZ-6



23114-6 [O-062217-JH-06] 1/5 DILUTION PZ-7



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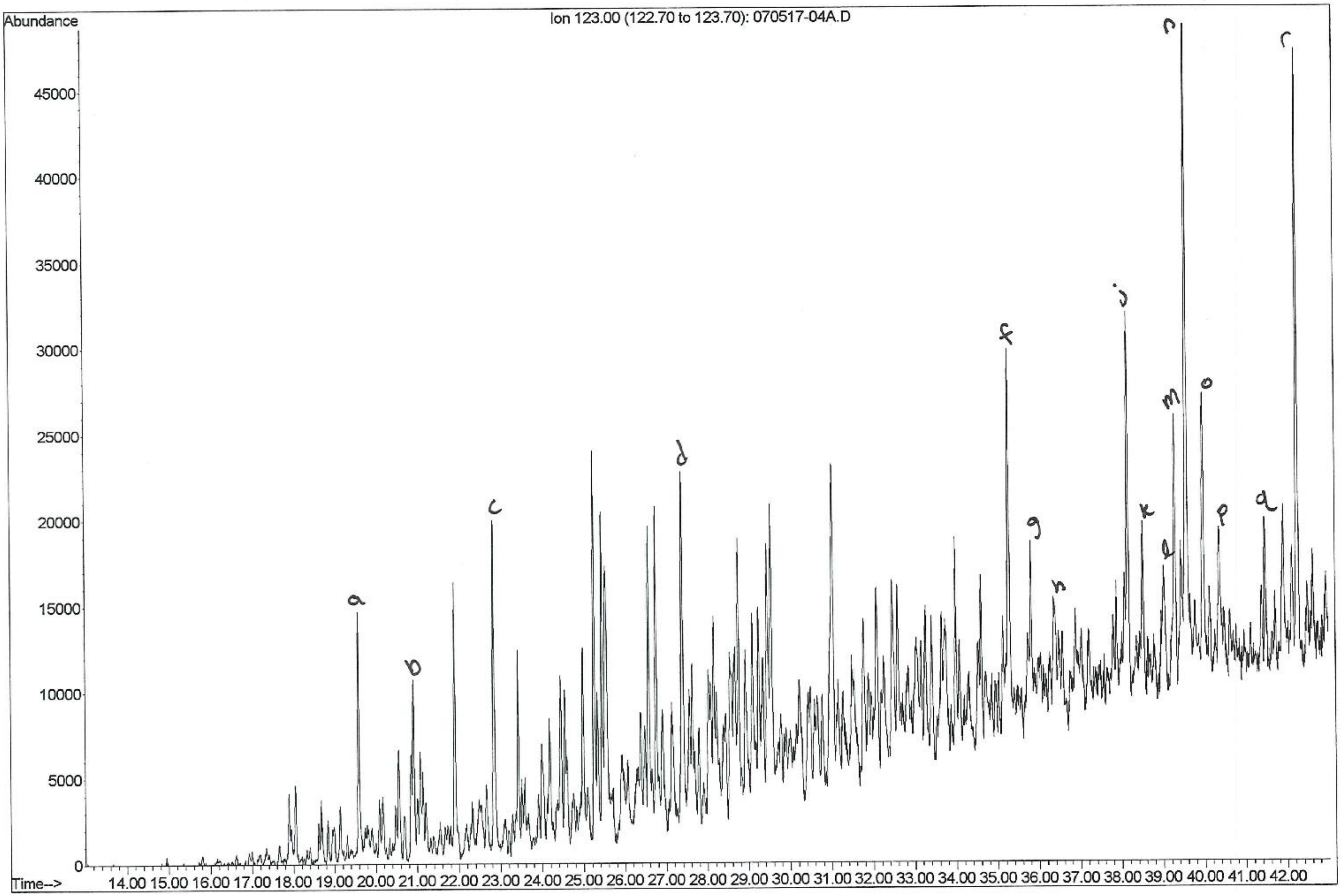
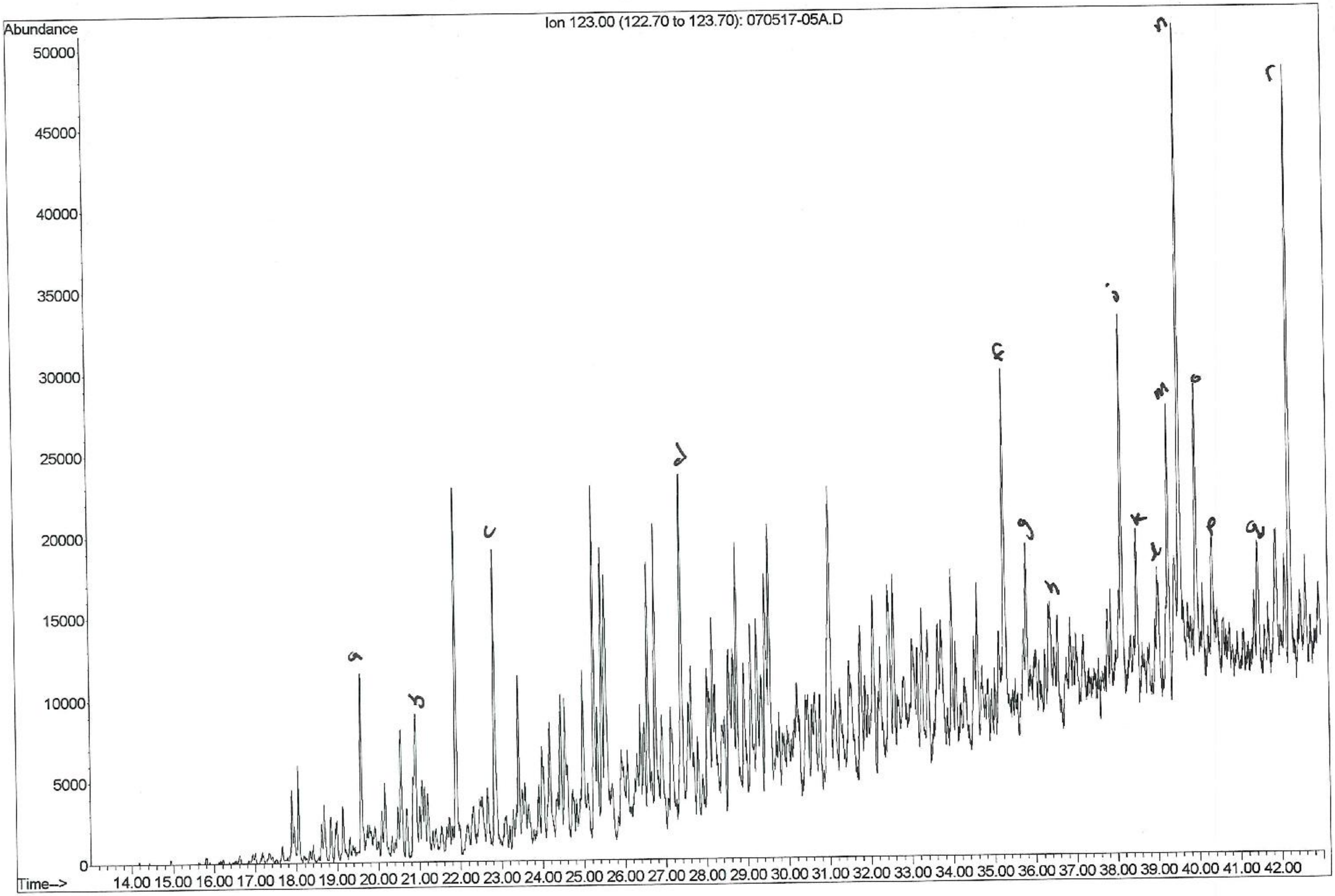
Key for Identification of the Bicyclanes (m/z 123)

Peak No.	Identity	Formula	M.W.
a	2,2,3-Trimethylbicycloheptane	$C_{10}H_{18}$	138
b	C_{10} bicycloalkane	$C_{10}H_{18}$	138
c	3,3,7-Trimethylbicycloheptane	$C_{10}H_{18}$	138
d	C_{11} Decalin	$C_{11}H_{20}$	152
f	Nordrimane	$C_{14}H_{26}$	194
g	Nordrimane	$C_{14}H_{26}$	194
h	Rearranged drimane	$C_{15}H_{28}$	208
j	Rearranged drimane	$C_{15}H_{28}$	208
k	Isomer of Eudesmane	$C_{15}H_{28}$	208
l	4β (H) Eudesmane	$C_{15}H_{28}$	208
m	C_{15} Bicyclic Sesquiterpane	$C_{15}H_{28}$	208
n	8β (H) Drimane	$C_{15}H_{28}$	208
o	C_{15} Bicyclic Sesquiterpane	$C_{15}H_{28}$	208
p	C_{16} Bicyclic Sesquiterpane	$C_{16}H_{30}$	222
q	C_{16} Bicyclic Sesquiterpane	$C_{16}H_{30}$	222
r	8β (H) Homodrimane	$C_{16}H_{30}$	222

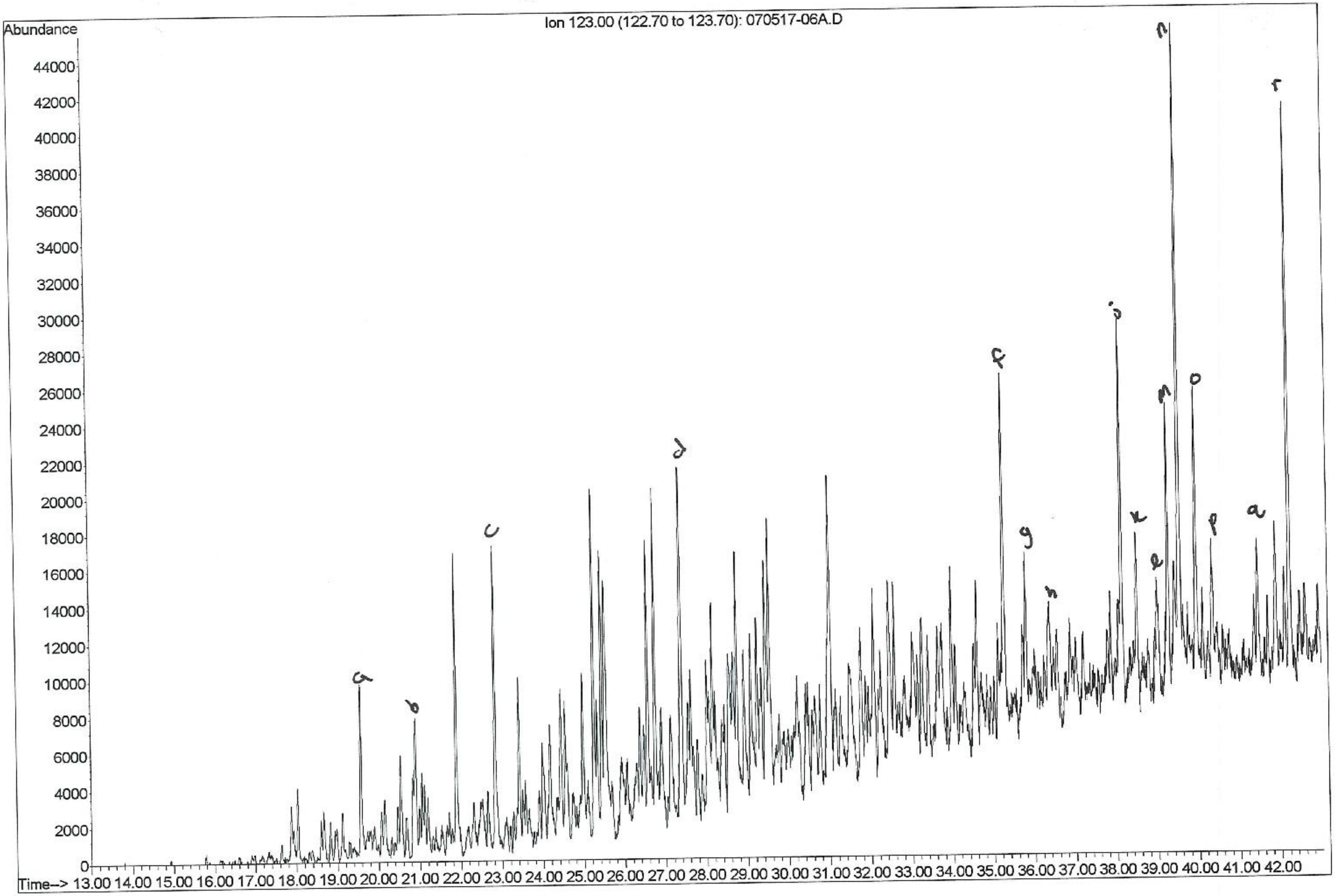
23114-1 [O-062217-JH-01] 1/5 DILUTION PZ-9



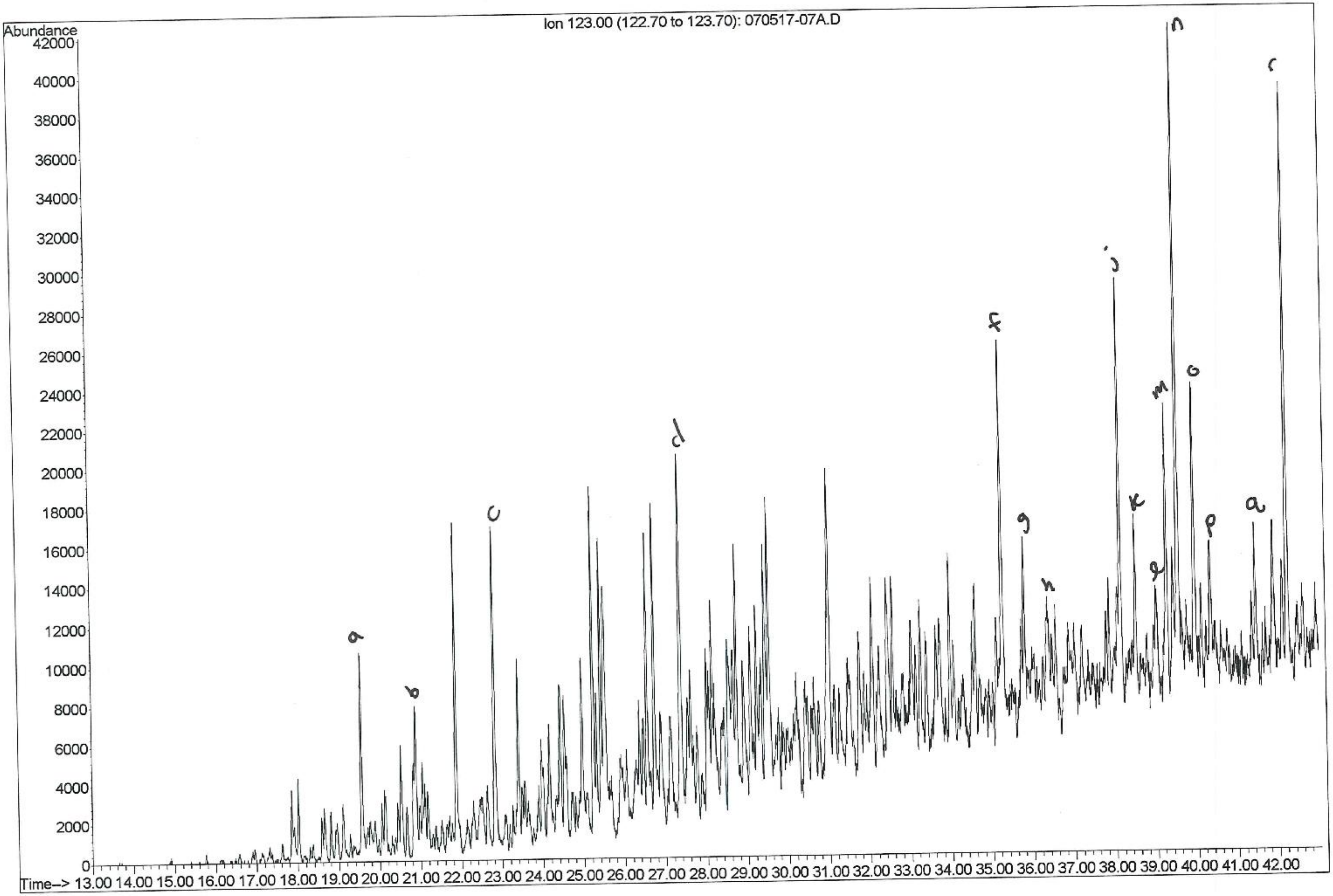
23114-2 [O-062217-JH-02] 1/5 DILUTION PZ-3



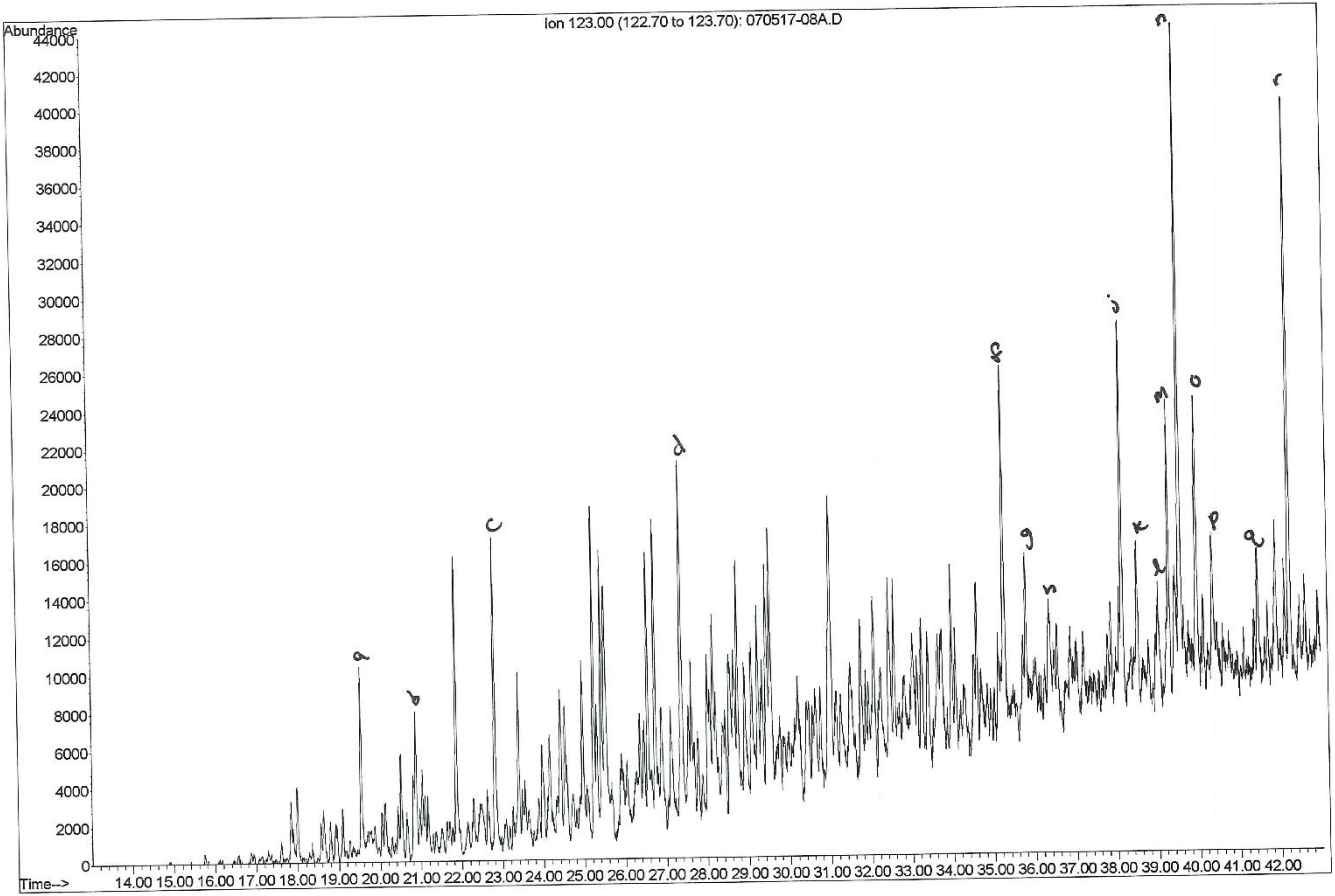
23114-3 [O-062217-JH-03] 1/5 DILUTION PZ-4



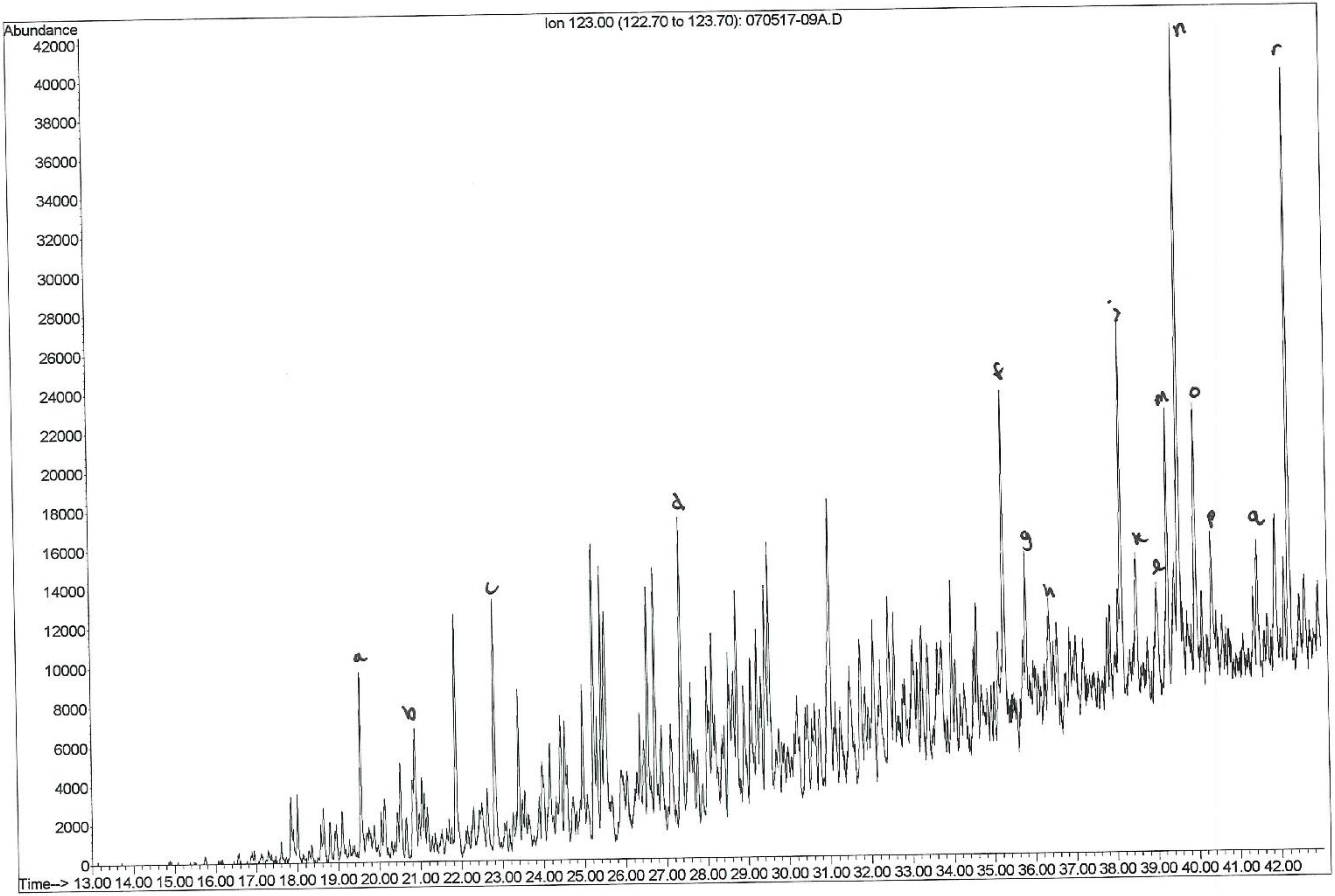
23114-4 [O-062217-JH-04] 1/5 DILUTION PZ-5



23114-5 [O-062217-JH-05] 1/5 DILUTION PZ-6



23114-6 [O-062217-JH-06] 1/5 DILUTION PZ-7



Pace Analytical®
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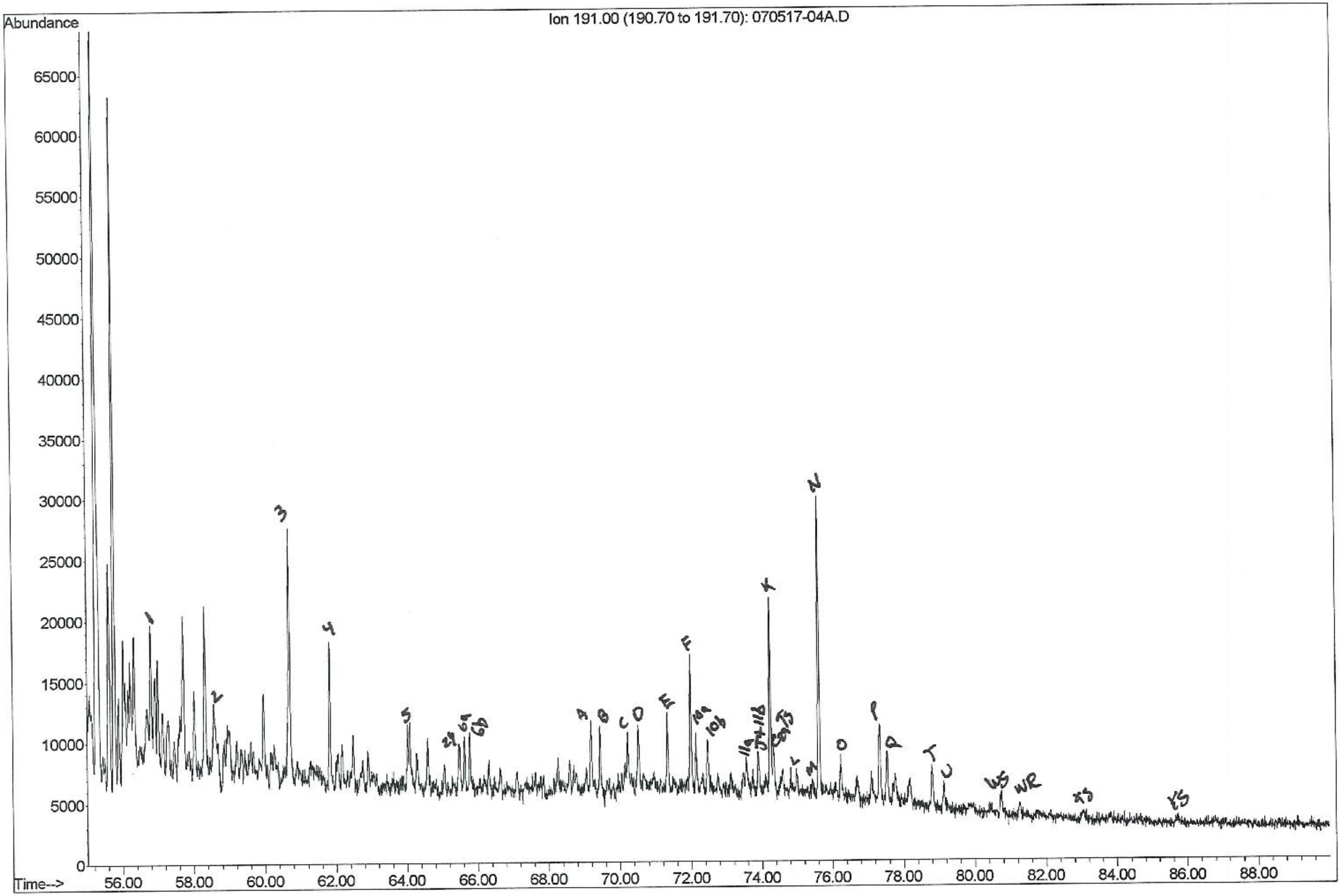
Key for Tricyclic, Tetracyclic, and Pentacyclic Terpanes Identification (m/z 191 Mass chromatograms)

Code	Identity	Carbon #
0	C_{20}-Tricyclic Terpane	20
1	C_{21}-Tricyclic Terpane	21
2	C_{22}-Tricyclic Terpane	22
3	C_{23}-Tricyclic Terpane	23
4	C_{24}-Tricyclic Terpane	24
5	C_{25}-Tricyclic Terpane	25
Z4	C_{24}-Tetracyclic Terpane	24
6a	C_{26}-Tricyclic Terpane	26
6b	C_{26}-Tricyclic Terpane	26
7	C_{27}-Tricyclic Terpane	27
A	C_{28}-Tricyclic Terpane #1	28
B	C_{28}-Tricyclic Terpane #2	28
C	C_{29}-Tricyclic Terpane #1	29
D	C_{29}-Tricyclic Terpane #2	29
E	18 α-22,29,30-Trisnorneohopane (Ts)	27
F	17 α-22,29,30-Trisnorhopane (Tm)	27
G	17 β-22,29,30-Trisnorhopane	27
H	17 α-23,28-Bisnorlupane	28
10a	C_{30}-Tricyclic Terpane #1	30
10b	C_{30}-Tricyclic Terpane #2	30
I	17 α-28,30 Bisnorhopane	28
11a	C_{31}-Tricyclic Terpane #1	31
J	17α-25-Norhopane	29
11b	C_{31}-Tricyclic Terpane #2	31
K	17 α,21β-30-Norhopane	29
C_{29}Ts	18α-30-Norneohopane	29
C_{30}^{*}	17α-Diahopane	30
L	17β-21α-30-Normoretane	29
Ma	18α-Oleanane	30
Mb	18β-Oleanane	30
N	17α-21β-Hopane	30
O	17β-21α-Moretane	30
13a	C_{33}-Tricyclic Terpane #1	33
13b	C_{33}-Tricyclic Terpane #2	33

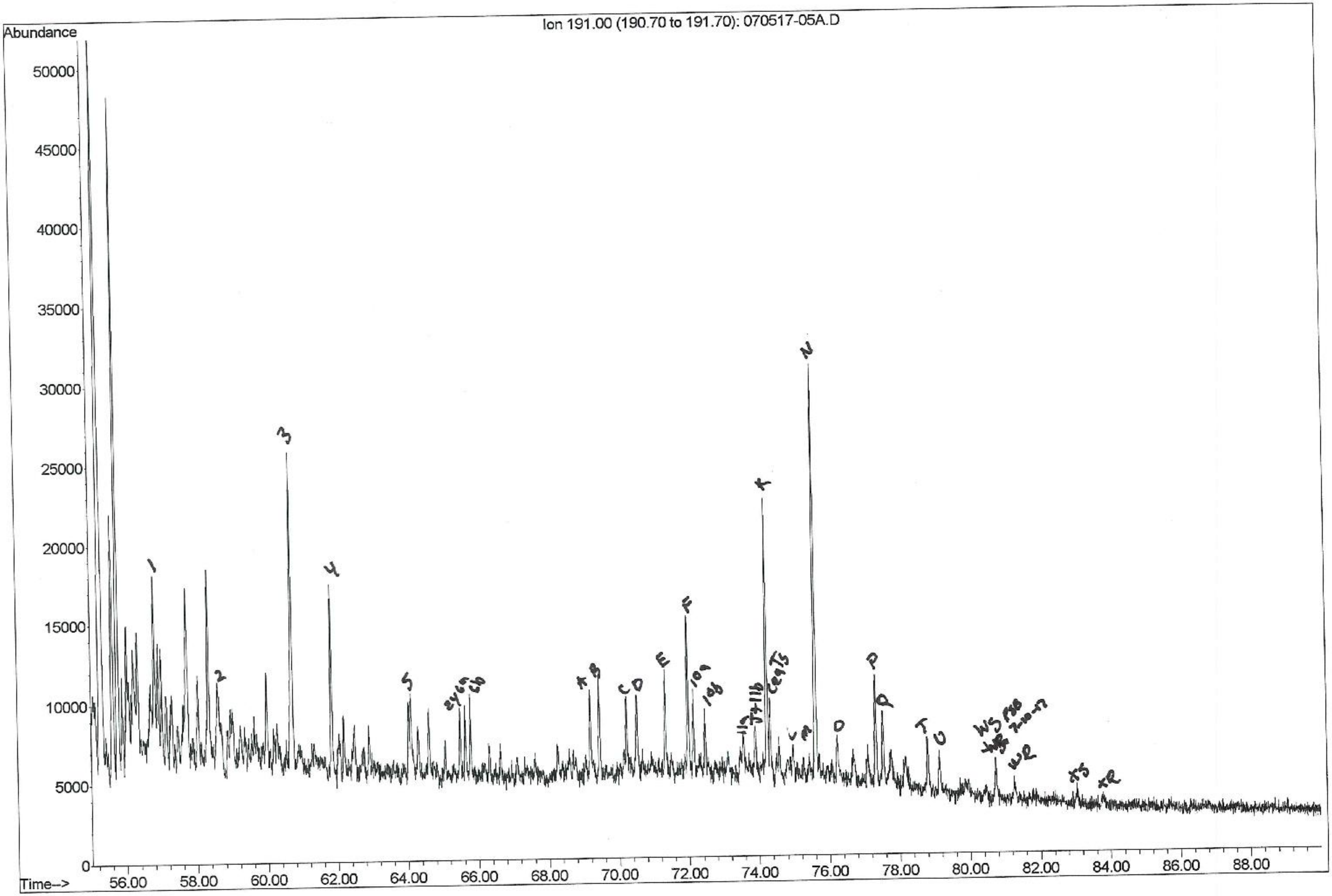
Key for Tricyclic, Tetracyclic, and Pentacyclic Terpanes Identification (m/z 191 Mass chromatograms) – Cont.

Code	Identity	Carbon #
P	22S-17α,21β-30-Homohopane	31
Q	22R-17α,21β-30-Homohopane	31
R	Gammacerane	30
14a	C_{34}-Tricyclic Terpane #1	34
S	17β,21α-Homomoretane	31
14b	C_{34}-Tricyclic Terpane #2	34
T	22S-17α,21β-30-Bishomohopane	32
U	22R-17α,21β-30-Bishomohopane	32
15a	C_{35}-Tricyclic Terpane #1	35
15b	C_{34}-Tricyclic Terpane #2	35
V	17β,21α-C_{32}-Bishomomoretane	32
WS	22S-17α,21β-30-Bishomohopane	33
WR	22R-17α,21β-30,31,32-Trishomohopane	33
16a	C_{36}-Tricyclic Terpane #1	36
16b	C_{36}-Tricyclic Terpane #2	36
XS	22S-17α,21β-30,31,32,33-Tetrahomohopane	34
XR	22R-17α,21β-30,31,32,33-Tetrahomohopane	34
YS	22S-17α,21β-30,31,32,33,34-Pentahomohopane	35
YR	22R-17α,21β-30,31,32,33,34-Pentahomohopane	35

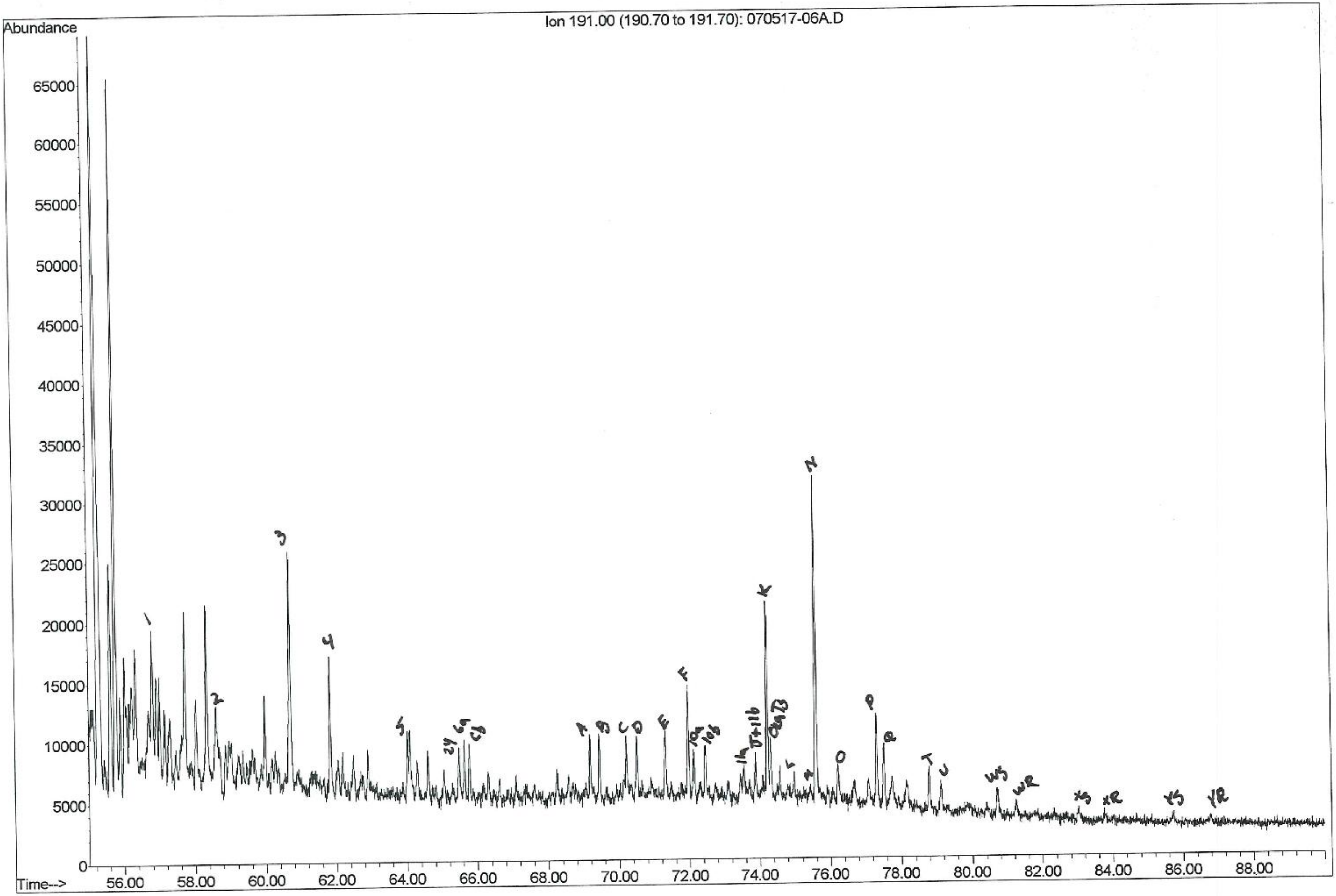
23114-1 [O-062217-JH-01] 1/5 DILUTION PZ-9



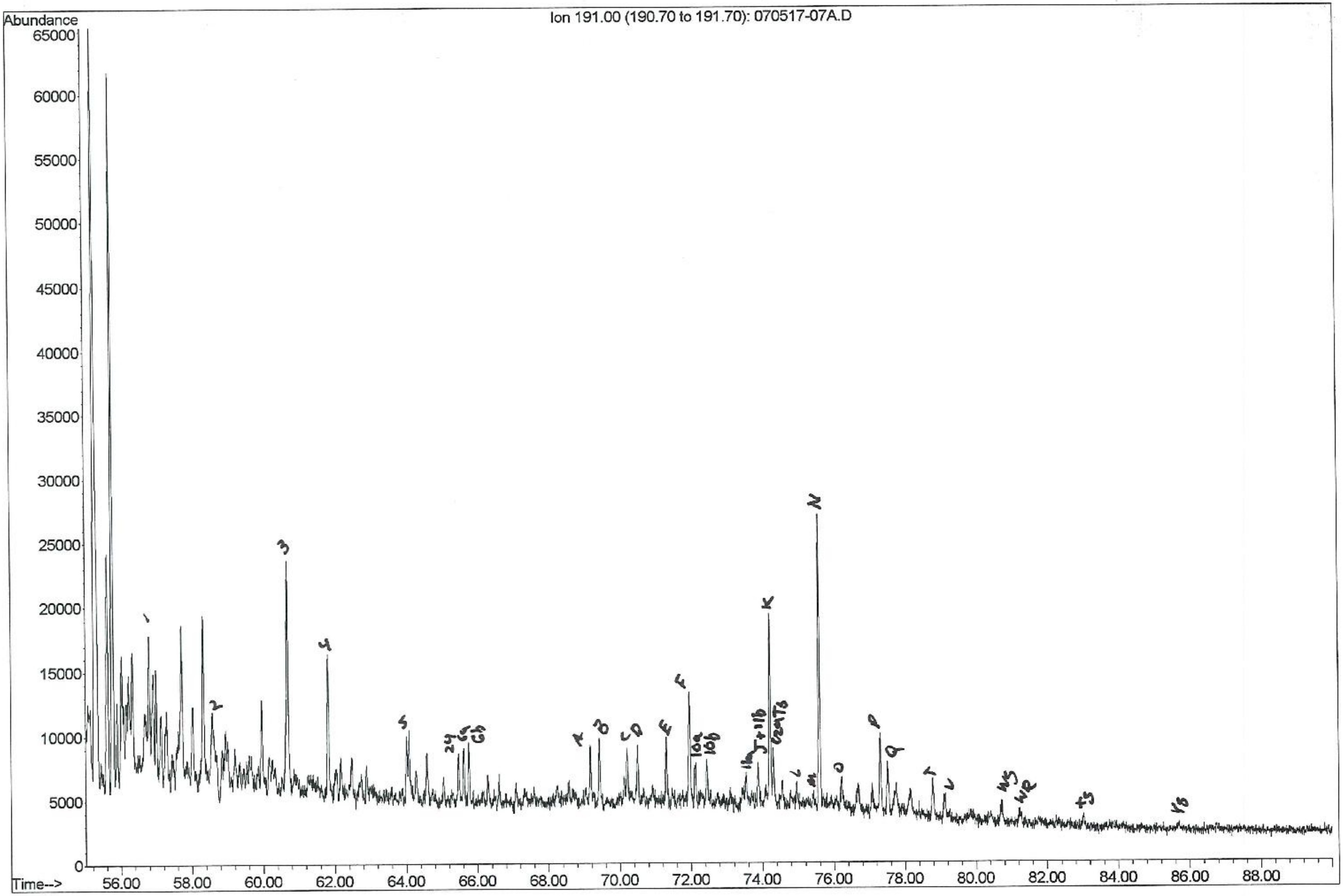
23114-2 [O-062217-JH-02] 1/5 DILUTION PZ-3



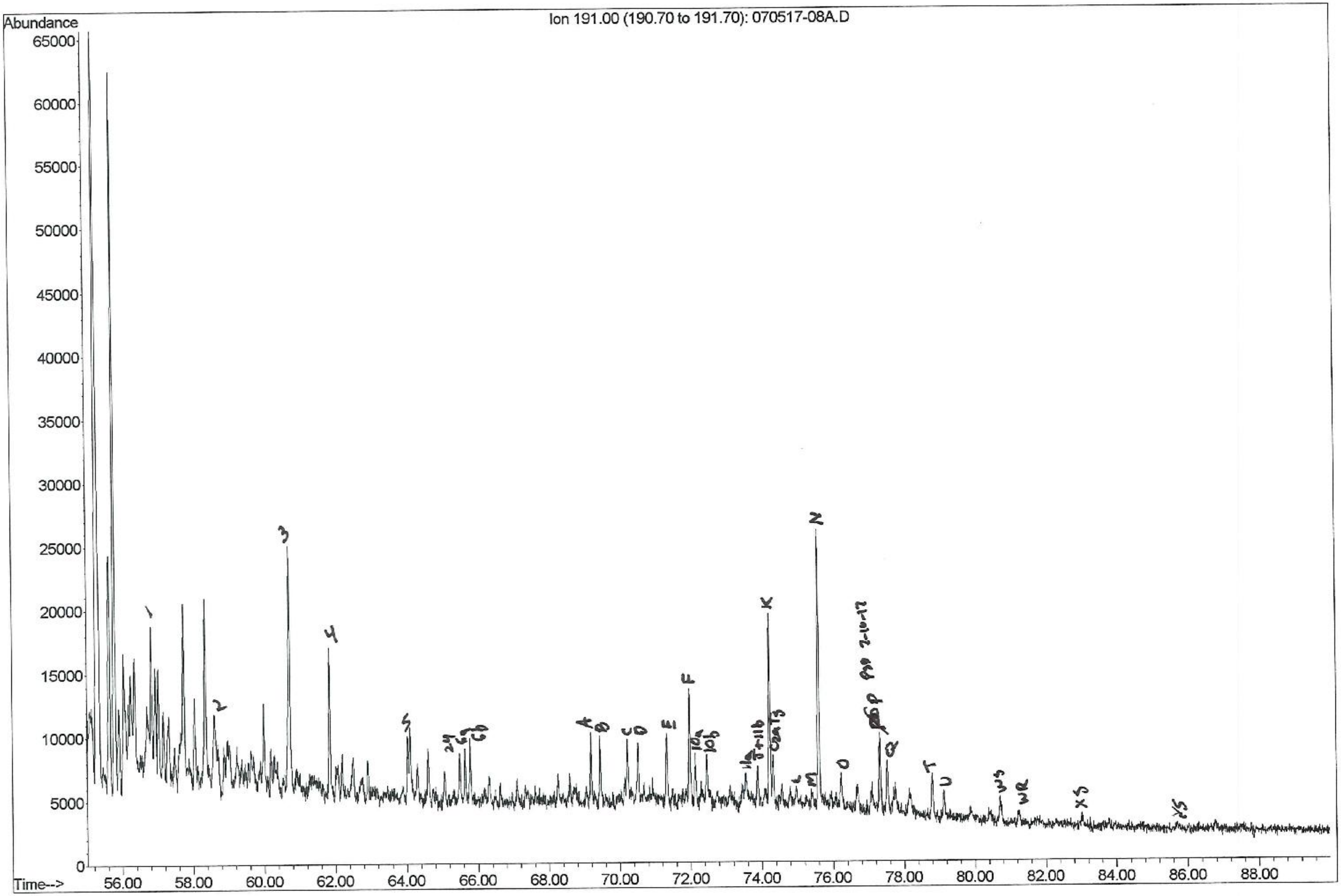
23114-3 [O-062217-JH-03] 1/5 DILUTION PZ-4



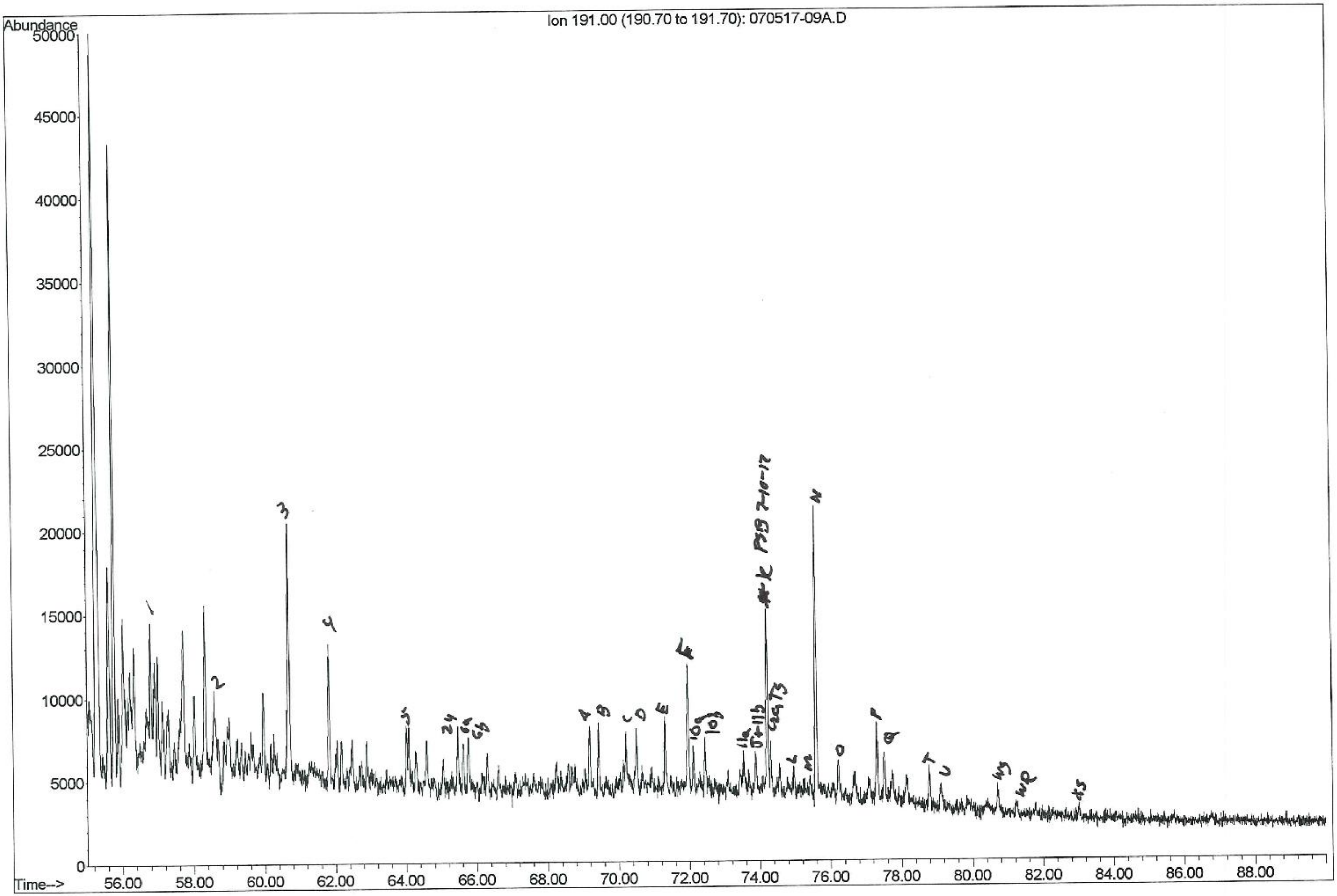
23114-4 [O-062217-JH-04] 1/5 DILUTION PZ-5



23114-5 [O-062217-JH-05] 1/5 DILUTION PZ-6



23114-6 [O-062217-JH-06] 1/5 DILUTION PZ-7



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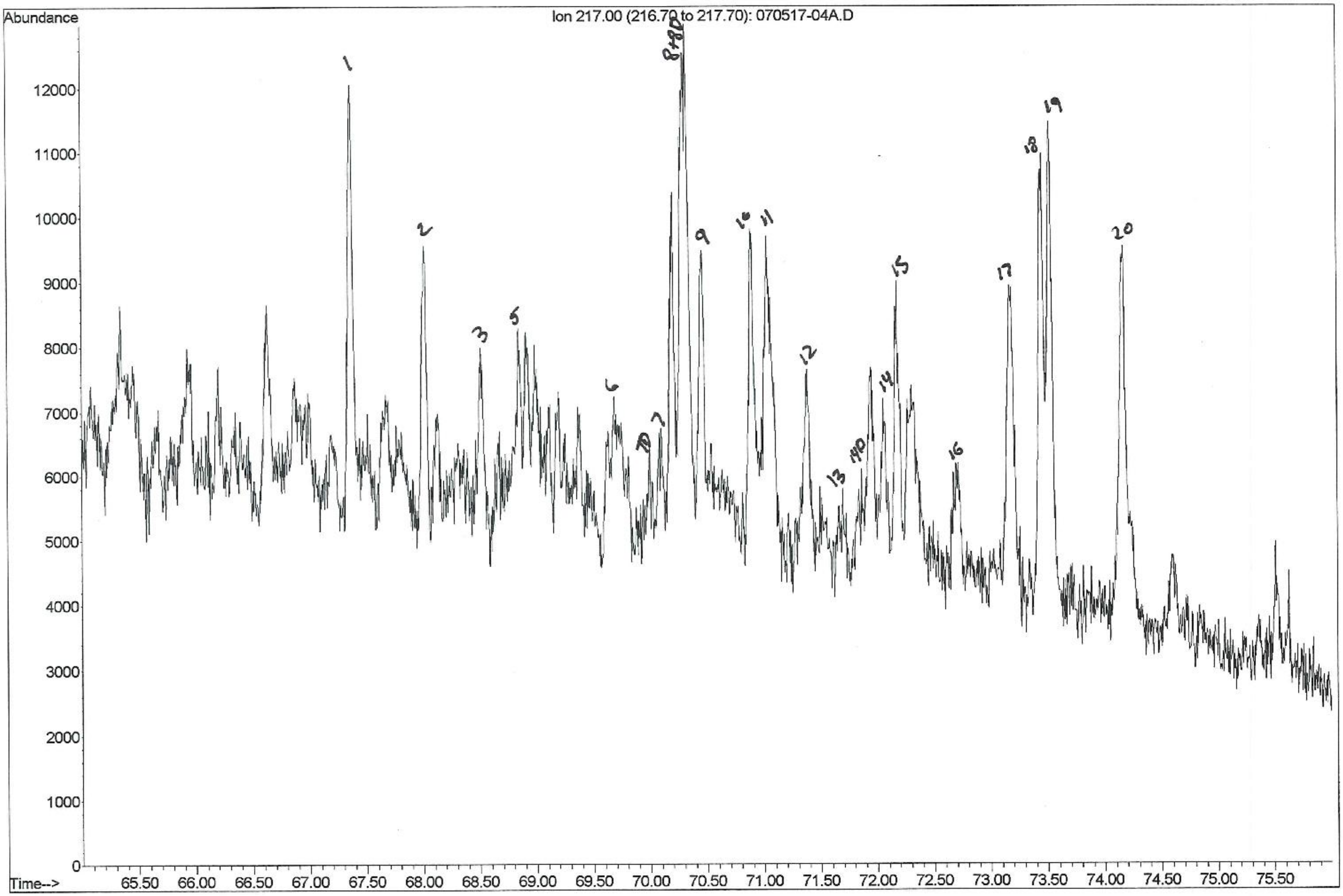
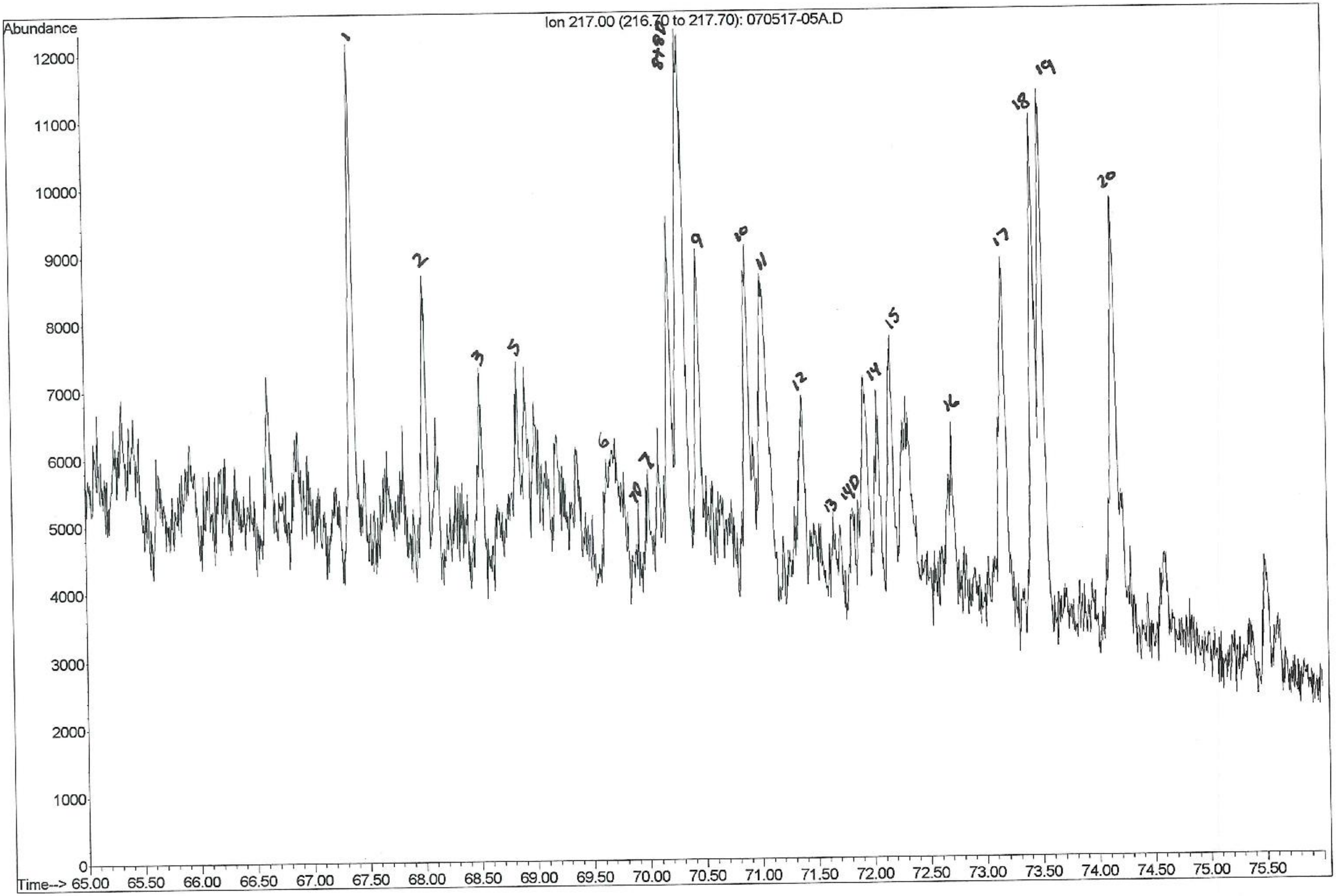
Key for Steranes Identification (m/z 217 Mass Chromatogram)

Code	Identity	Carbon #
1	13β, 17α-Diacholestane (20S)	27
2	13β, 17α-Diacholestane (20R)	27
3	13α, 17β-Diacholestane (20S)	27
4	13α, 17β-Diacholestane (20R)	27
5	24-methyl-13β,17α-Diacholestane (20S)	28
6	24-methyl-13β,17α-Diacholestane (20S)	28
7D	24-methyl-13α,17β-Diacholestane (20S)	28
7	14α,17α-Cholestane (20S)	27
8D	24-ethyl-13β, 17α-Diacholestane (20S)	29
8	14β,17β-Cholestane (20R)	27
9	14β,17β-Cholestane (20S)	27
9D	24-methyl-13α,17β-Diacholestane (20R)	28
10	14α,17α-Cholestane (20R)	27
11	24-ethyl-13β, 17α-Diacholestane (20R)	29
12	24-ethyl-13α, 17β-Diacholestane (20S)	29
13	24-ethyl-13α, 17α-Diacholestane (20S)	28
14D	24-ethyl-13α, 17β-Diacholestane (20R)	29
14	24-methyl-14β, 17β-Cholestane (20R)	28
15	24-methyl-14β, 17β-Cholestane (20S)	28
16	24-methyl-14α, 17α-Cholestane (20R)	28
17	24-ethyl-14α-Cholestane (20S)	29
18	24-ethyl-14β, 17β-Cholestane (20R)	29
19	24-ethyl-14β, 17β-Cholestane (20S)	29
20	24-ethyl-14α, 17α-Cholestane (20R)	29
21A	24-n-Propylcholestane (20S)	30
21B	4-methyl-24-ethylcholestane (20S)	30
22A	4α-methyl-24-ethyl-14β,17β-cholestane (20S)	30
22B	24-n-Propyl-14β,17β-cholestane (20S)	30
23A	4α-methyl-24-ethyl-14β,17β-cholestane (20R)	30
23B	24-n-propyl-14β,17β-cholestane (20R)	30
24A	4α-methyl-24-ethylcholestane (20R)	30
24B	24-n-propylcholestane (20R)	30

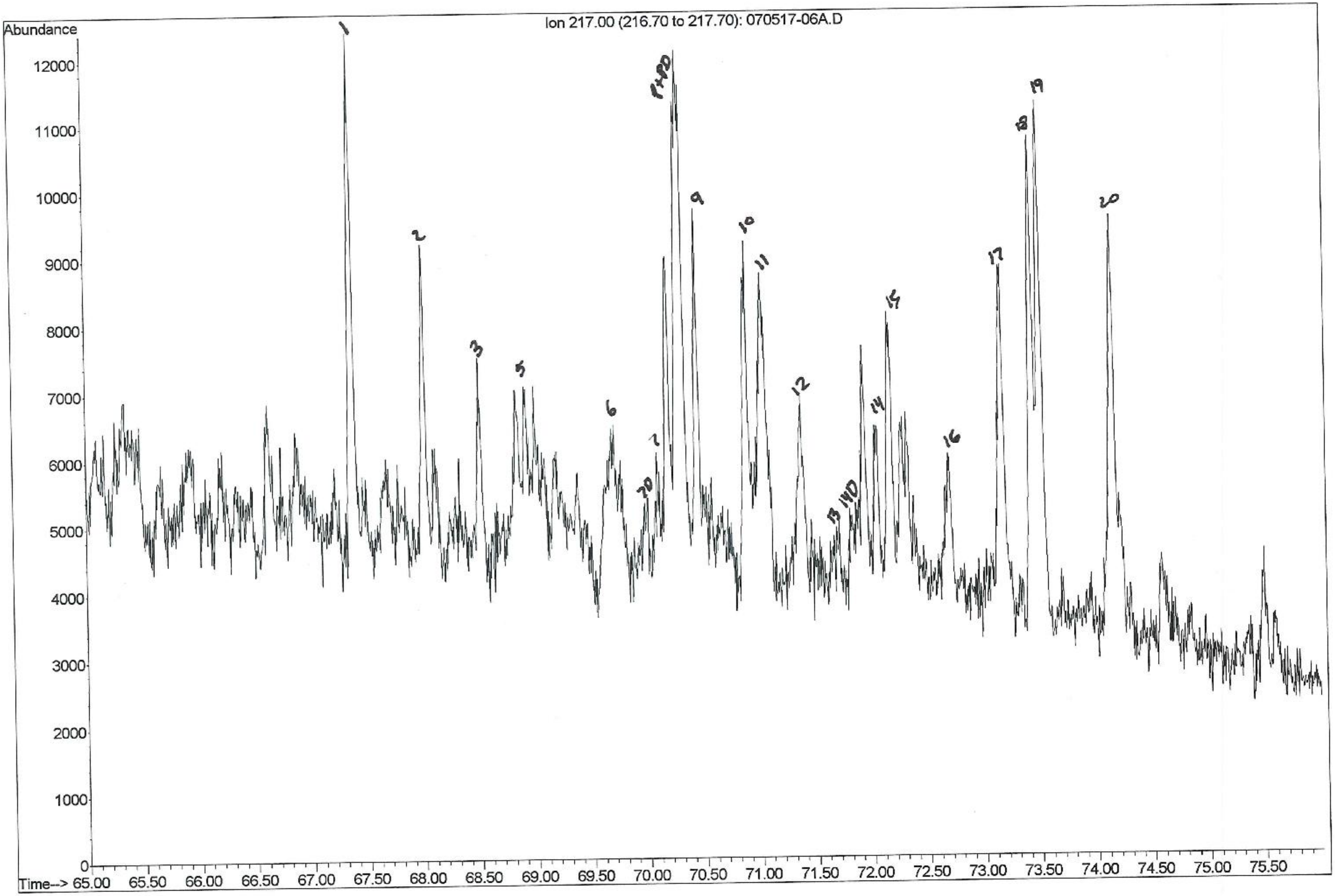
23114-1 [O-062217-JH-01] 1/5 DILUTION PZ-9



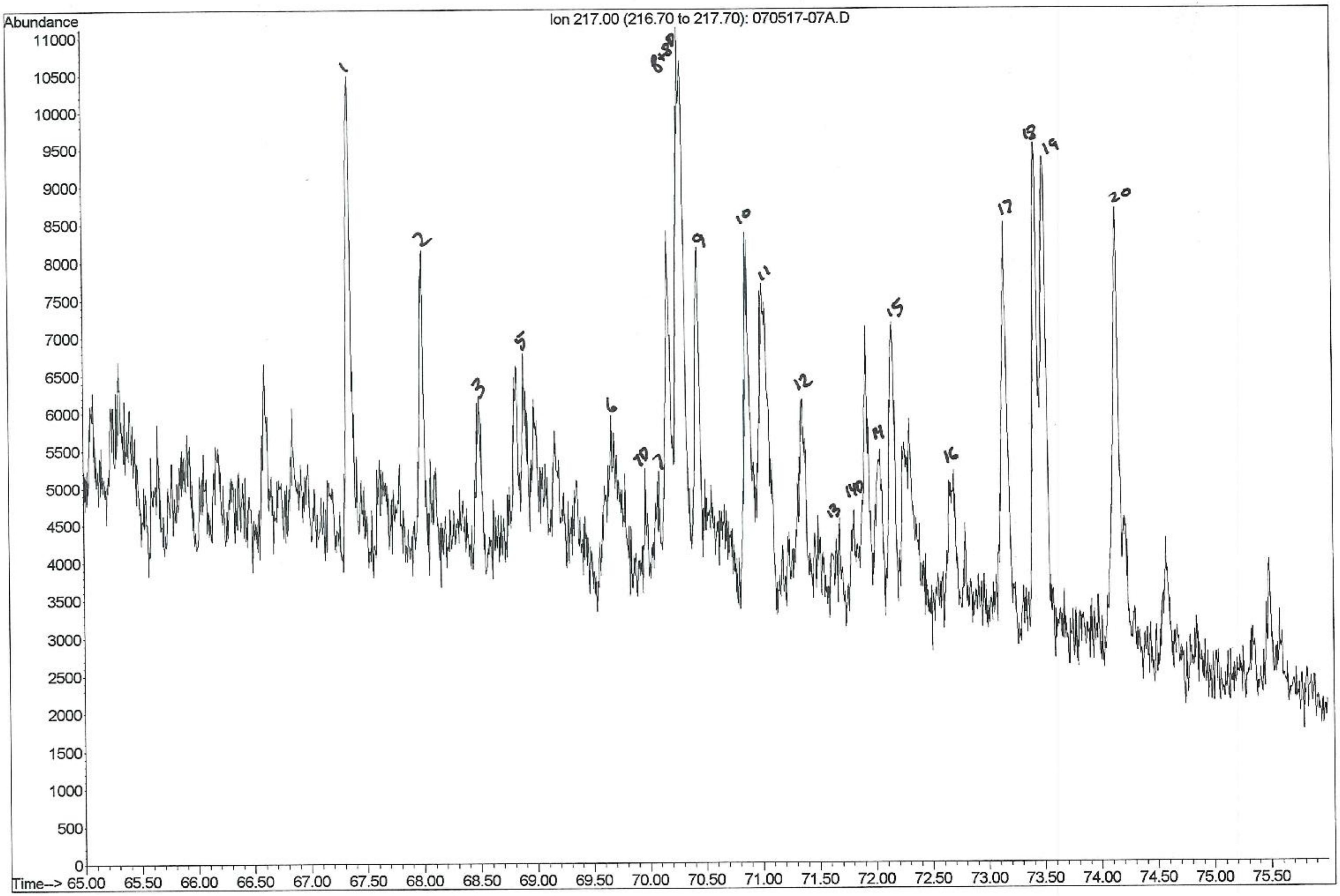
23114-2 [O-062217-JH-02] 1/5 DILUTION PZ-3



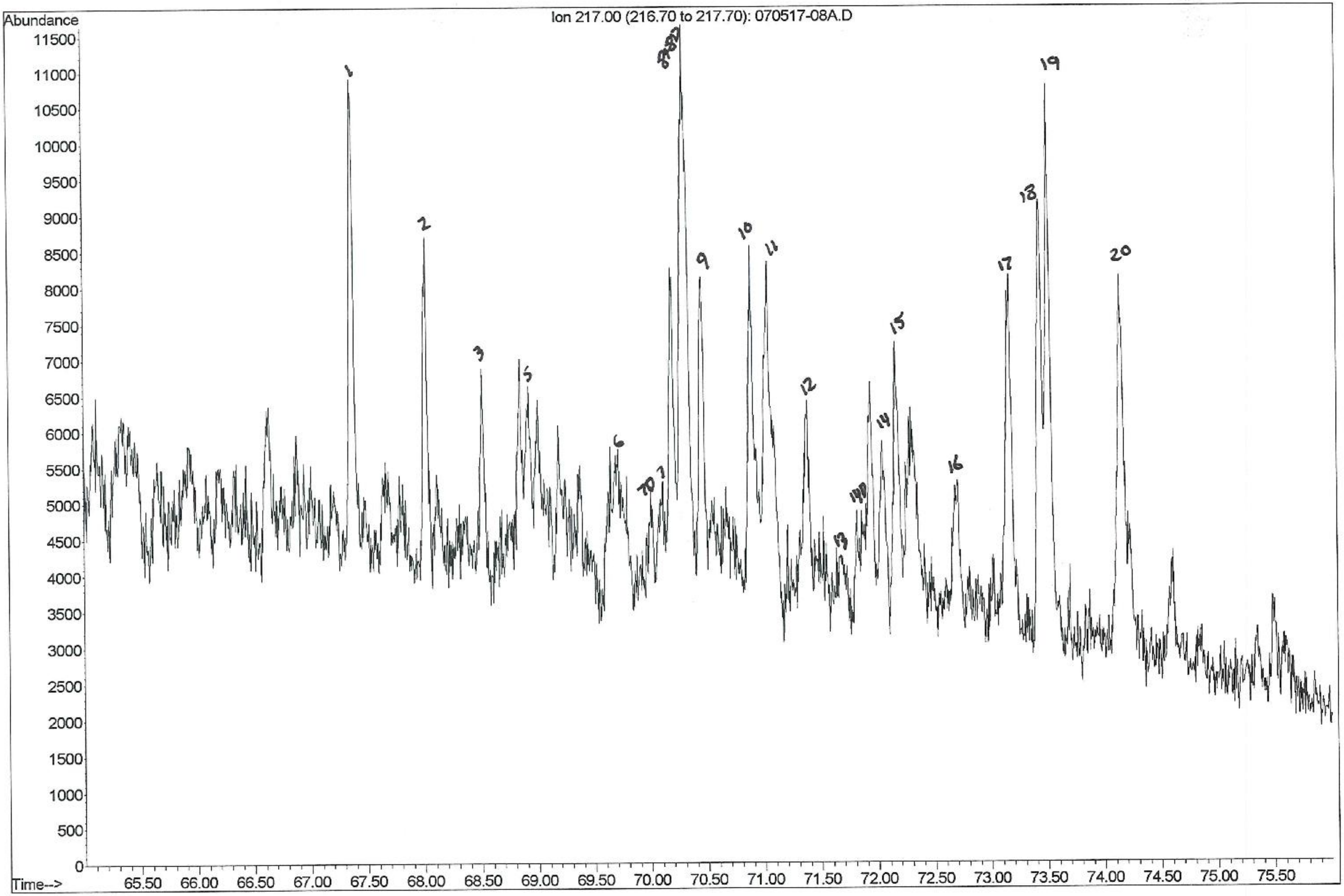
23114-3 [O-062217-JH-03] 1/5 DILUTION PZ-4



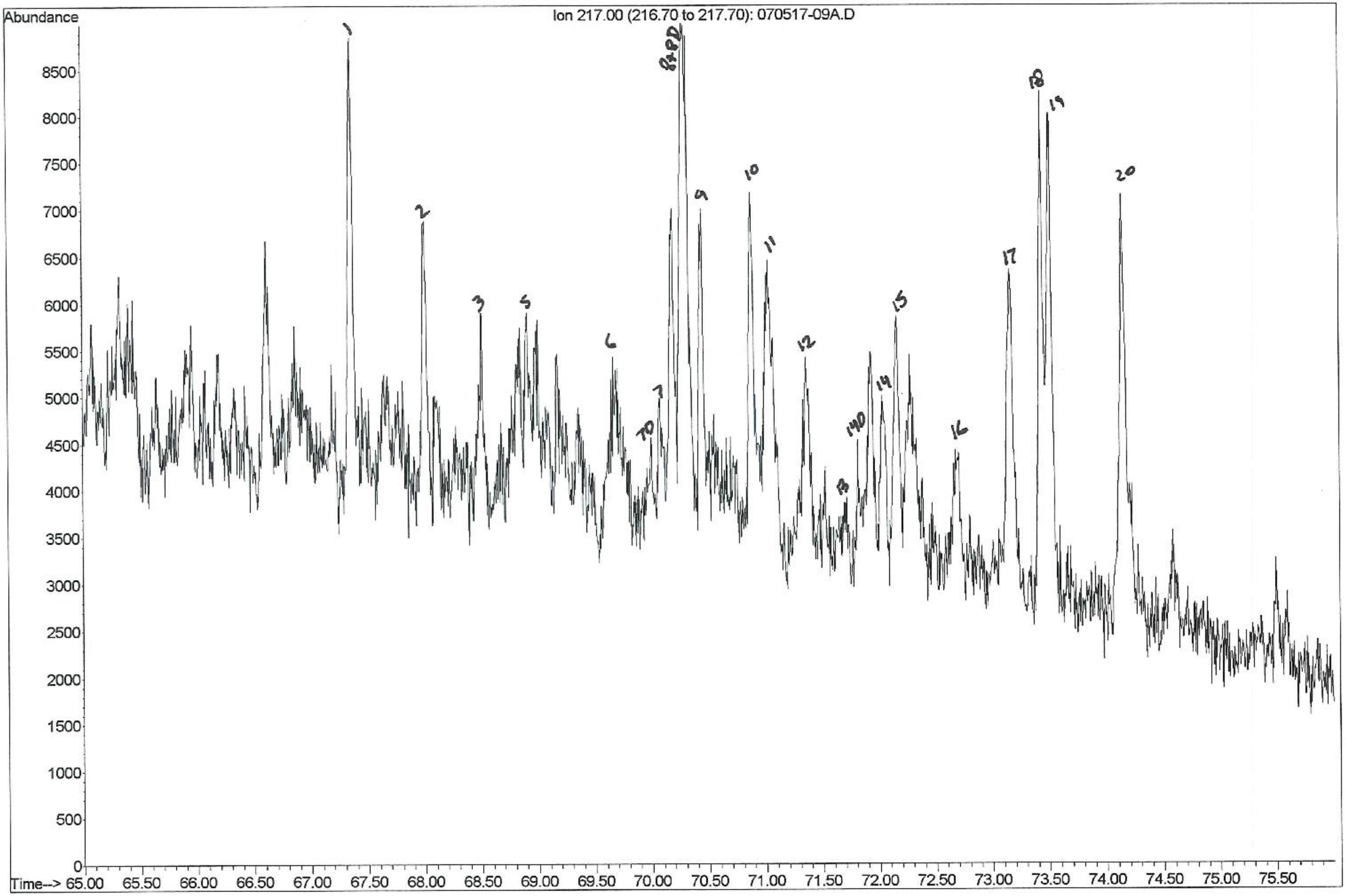
23114-4 [O-062217-JH-04] 1/5 DILUTION PZ-5



23114-5 [O-062217-JH-05] 1/5 DILUTION PZ-6



23114-6 [O-062217-JH-06] 1/5 DILUTION PZ-7

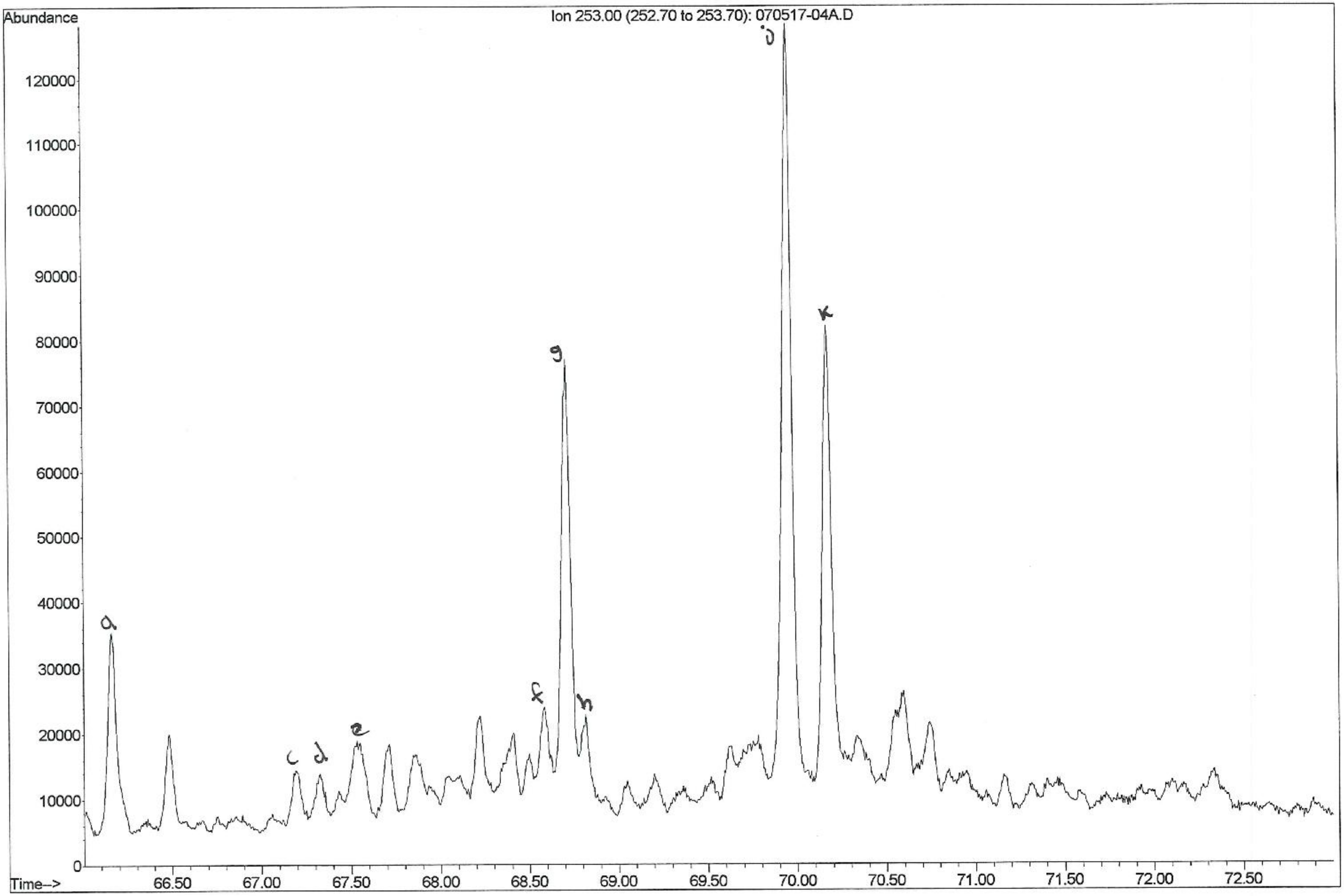


Pace Analytical® Energy Services™

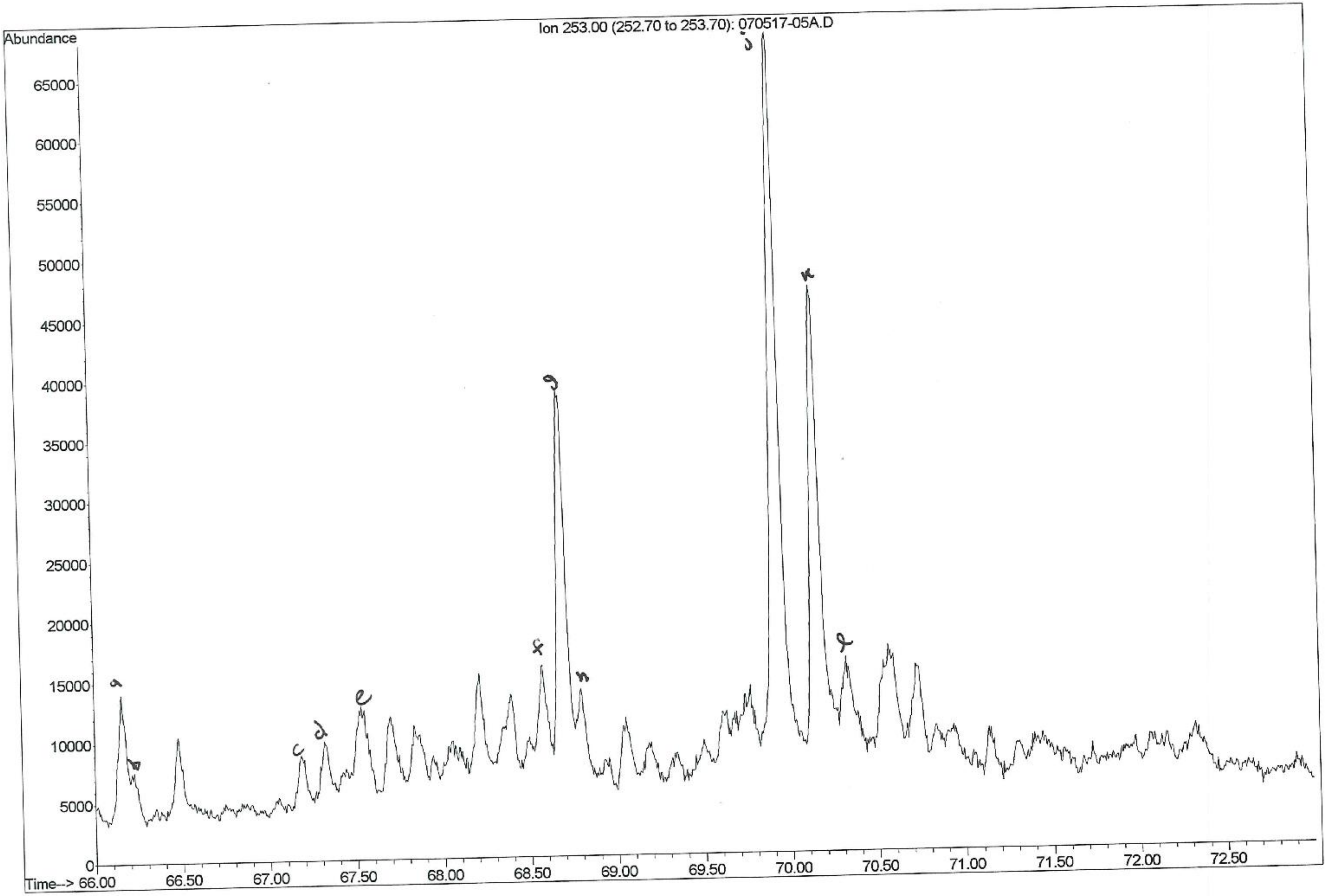
Key for Monoaromatic Steranes Identification (m/z 253 Mass Chromatogram)

Code	Identity	Elemental Composition
a	20S, 5β C_{27}-Monoaromatic Sterane	$C_{27}H_{42}$
b	20S, dia C_{27}-Monoaromatic Sterane	$C_{27}H_{42}$
c	20R, 5β C_{27}-Monoaromatic Sterane + 20R C_{27} dia MAS	$C_{27}H_{42}$
d	20S, 5α C_{27}-Monoaromatic Sterane	$C_{27}H_{42}$
e	20R, 5β C_{28}-Monoaromatic Sterane + 20S C_{28} dia MAS	$C_{28}H_{44}$
f	20R, 5α C_{27}-Monoaromatic Sterane	$C_{27}H_{42}$
g	20S, 5α C_{28}-Monoaromatic Sterane	$C_{28}H_{44}$
h	20R, 5β C_{28}-Monoaromatic Sterane + 20R C_{28} dia MAS	$C_{28}H_{44}$
i	20S, 5β C_{29}-Monoaromatic Sterane + 20S C_{29} dia MAS	$C_{29}H_{46}$
j	20S, 5α C_{29}-Monoaromatic Sterane	$C_{29}H_{46}$
k	20R, 5α C_{28}-Monoaromatic Sterane	$C_{28}H_{44}$
l	20R, 5β C_{29}-Monoaromatic Sterane + 20R C_{29} dia MAS	$C_{29}H_{46}$
m	20R, 5α C_{29}-Monoaromatic Sterane	$C_{29}H_{46}$

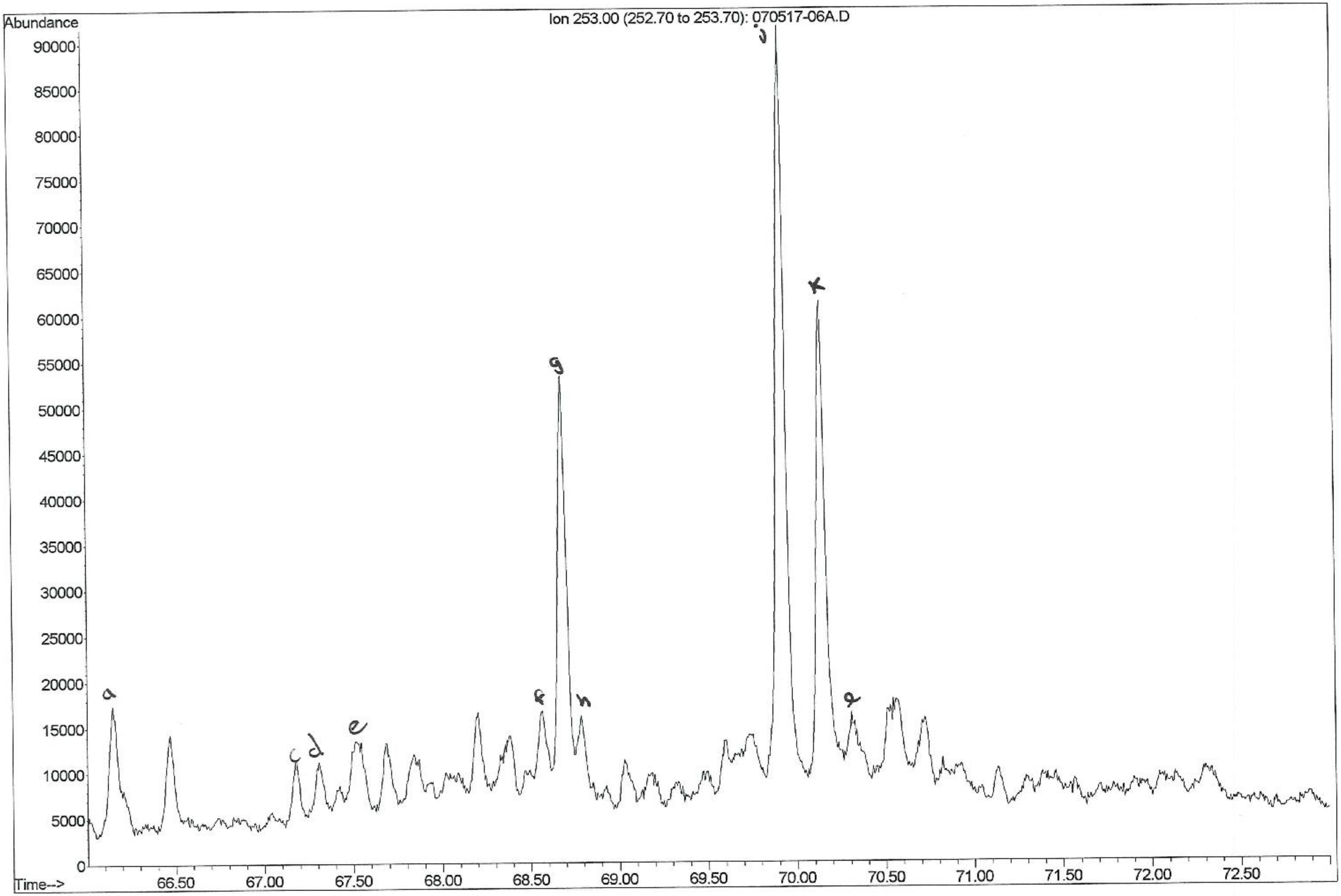
23114-1 [O-062217-JH-01] 1/5 DILUTION PZ-9



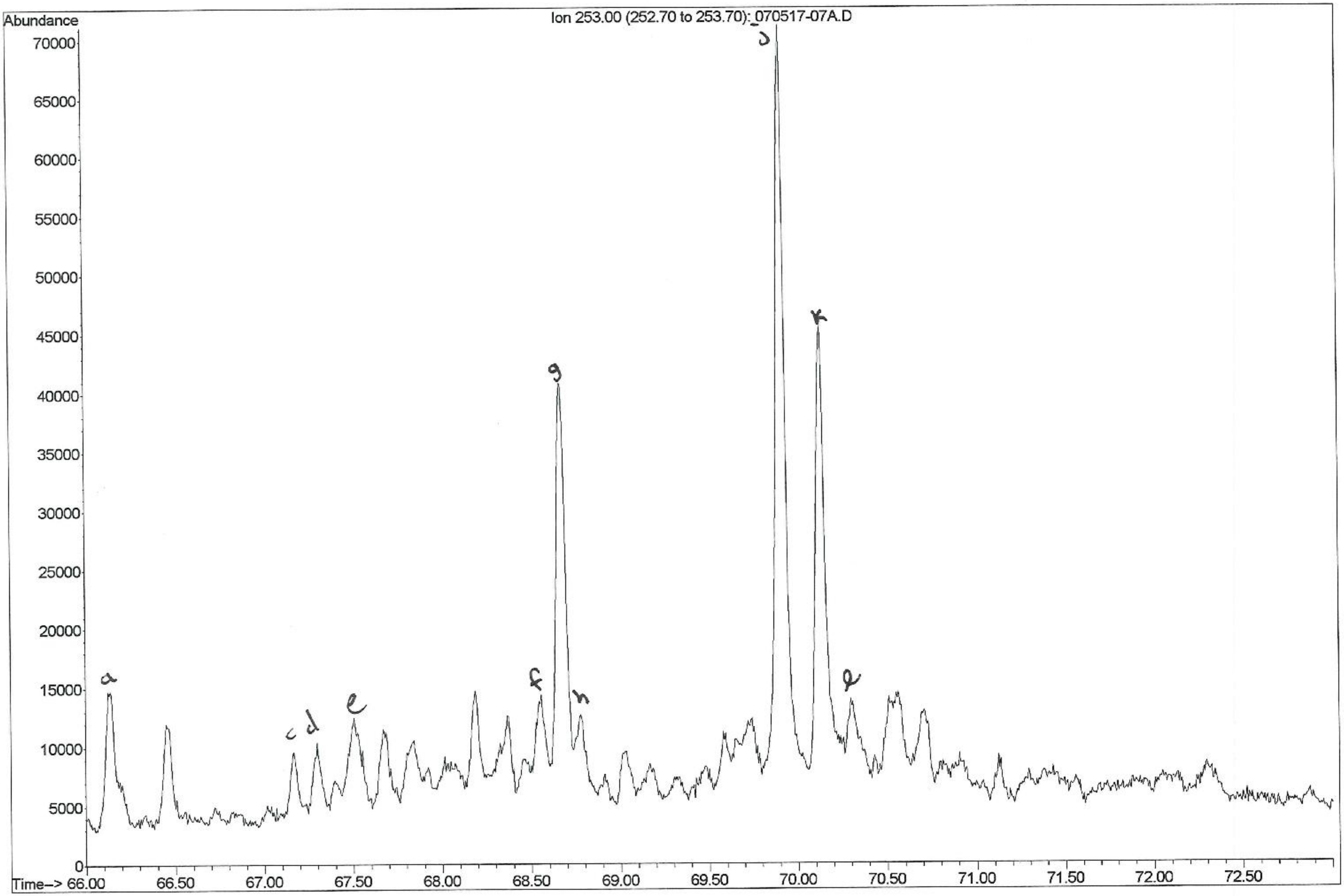
23114-2 [O-062217-JH-02] 1/5 DILUTION PZ-3



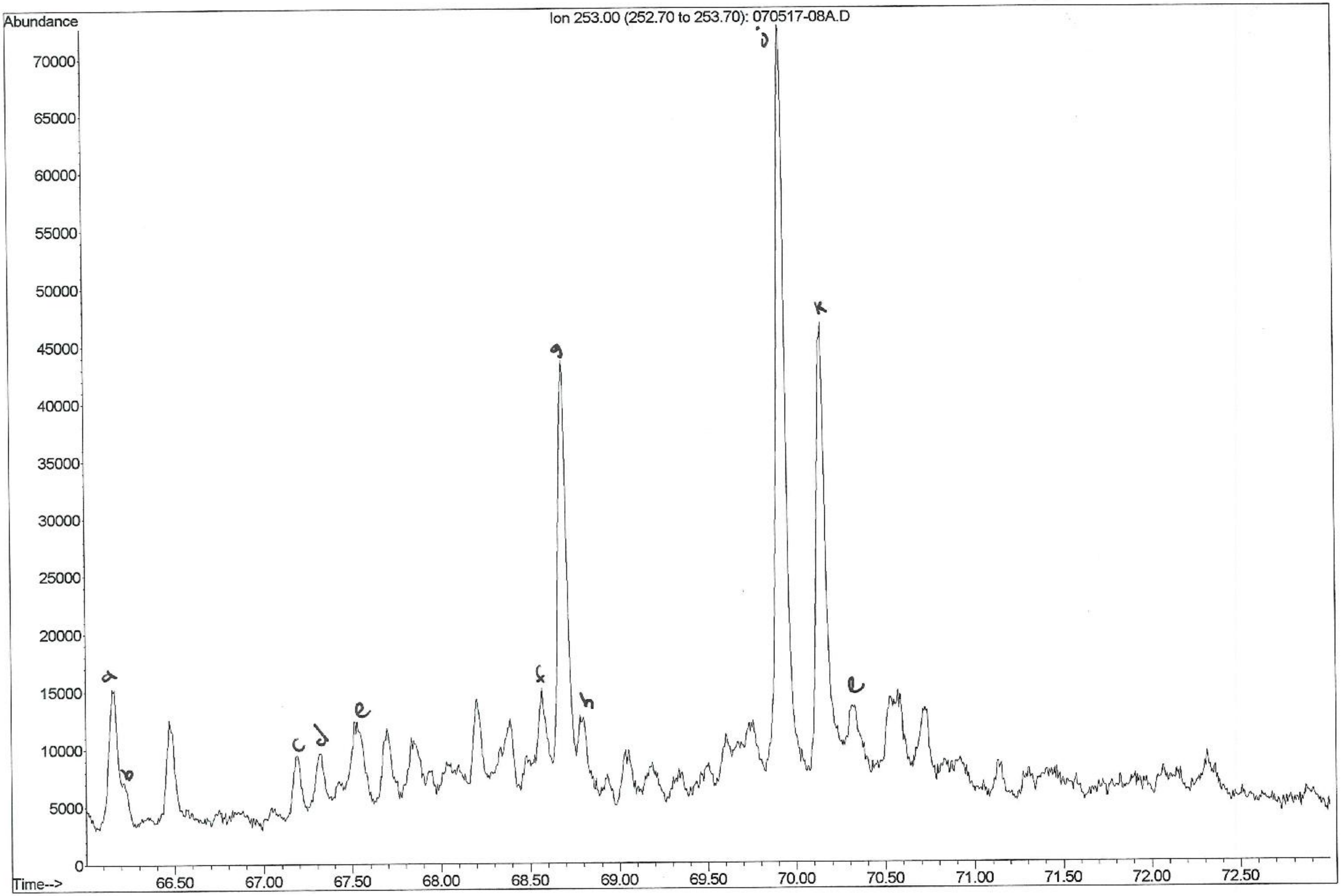
23114-3 [O-062217-JH-03] 1/5 DILUTION PZ-4



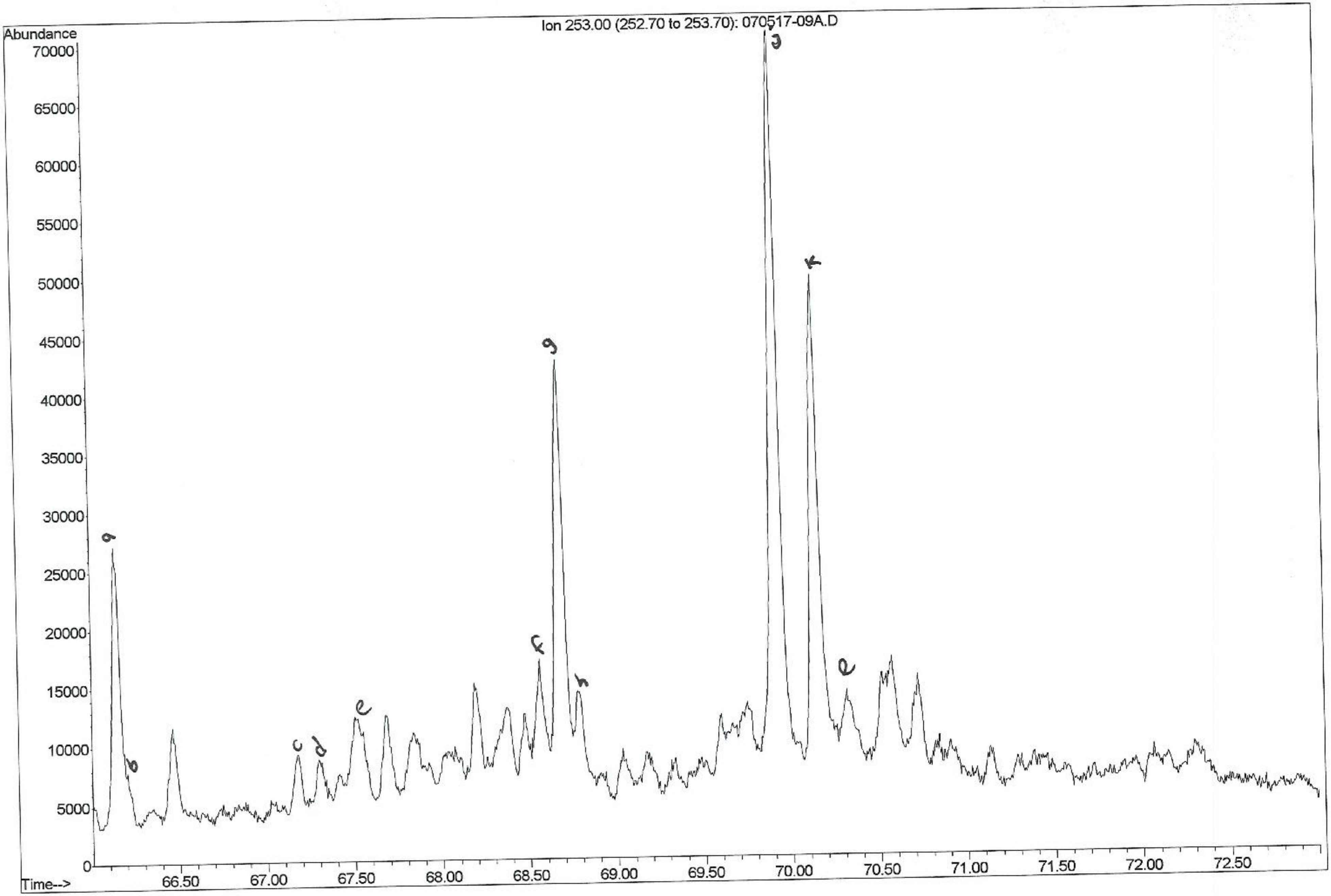
23114-4 [O-062217-JH-04] 1/5 DILUTION PZ-5



23114-5 [O-062217-JH-05] 1/5 DILUTION PZ-6



23114-6 [O-062217-JH-06] 1/5 DILUTION PZ-7



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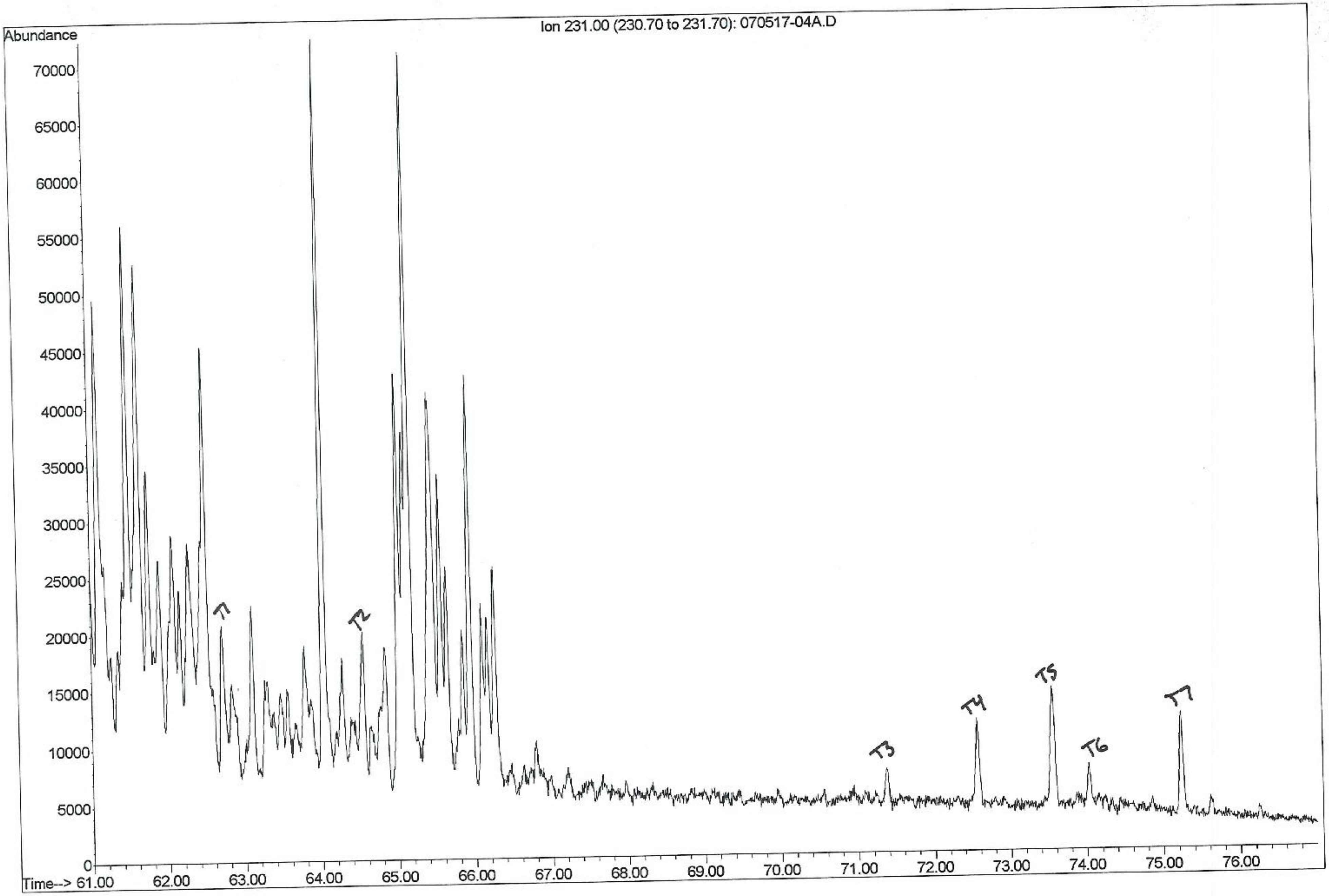
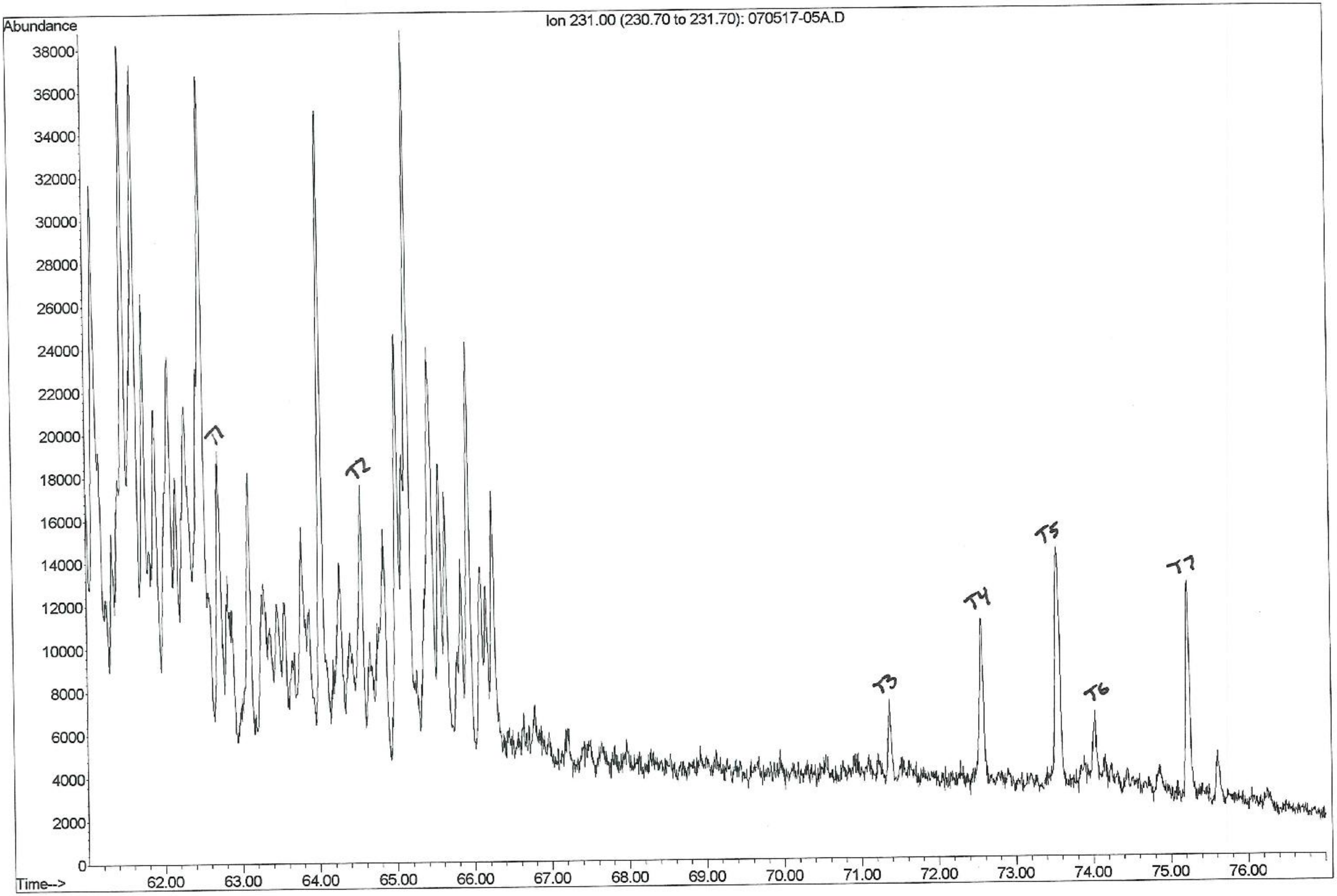
Key for Triaromatic Steranes Identification (m/z 231 Mass Chromatogram)

Code	Identity	Elemental Composition
T1	C_{20} Triaromatic Sterane	$C_{20}H_{20}$
T2	C_{21} Triaromatic Sterane	$C_{21}H_{22}$
T3	20S C_{26} Triaromatic Sterane	$C_{26}H_{32}$
T4	20R C_{26} + 20S C_{27} Triaromatic Steranes	$C_{26}H_{32}$ + $C_{27}H_{34}$
T5	20S C_{28} Triaromatic Sterane	$C_{28}H_{36}$
T6	20R C_{27} Triaromatic Sterane	$C_{27}H_{34}$
T7	20R C_{28} Triaromatic Sterane	$C_{28}H_{36}$

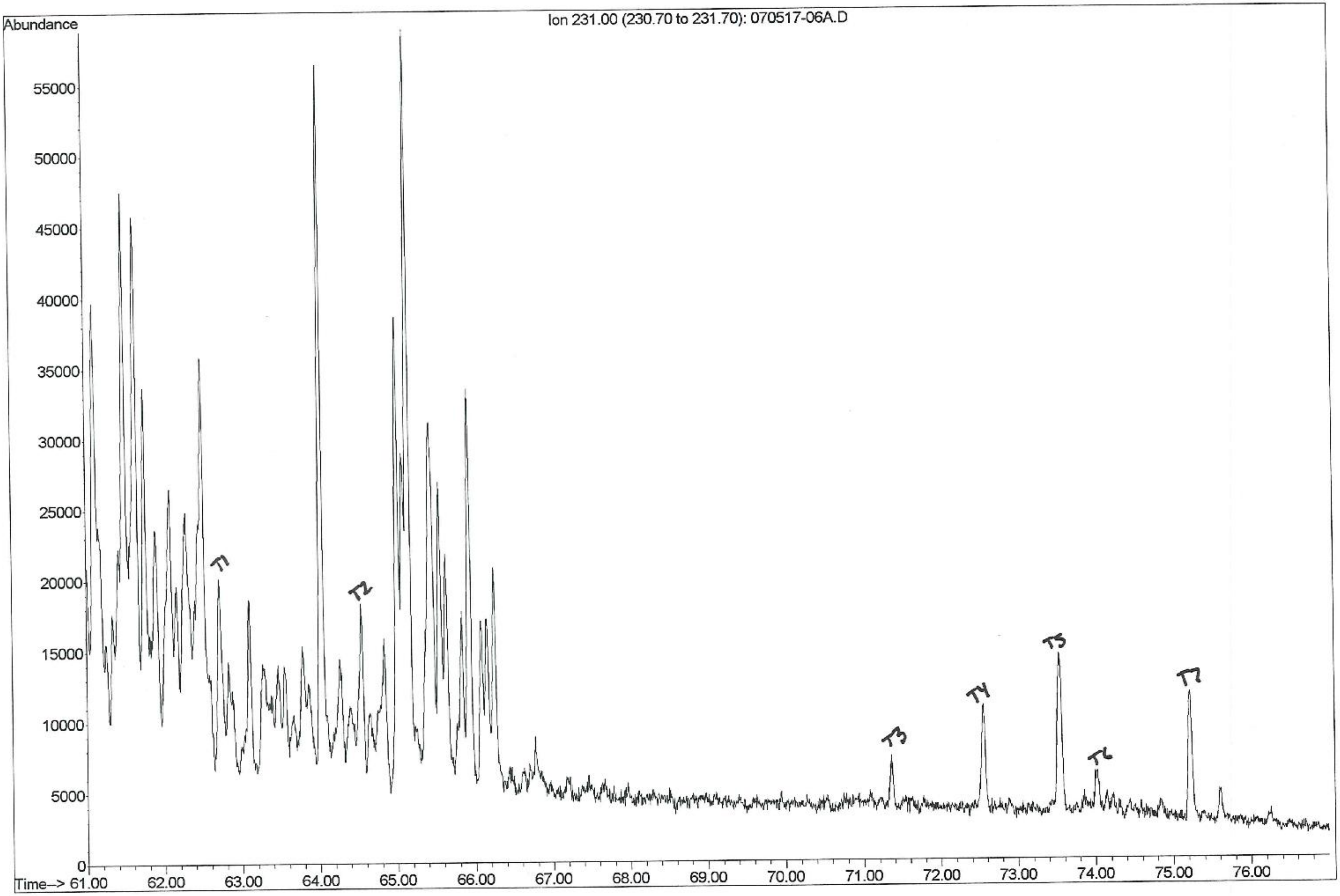
23114-1 [O-062217-JH-01] 1/5 DILUTION PZ-9



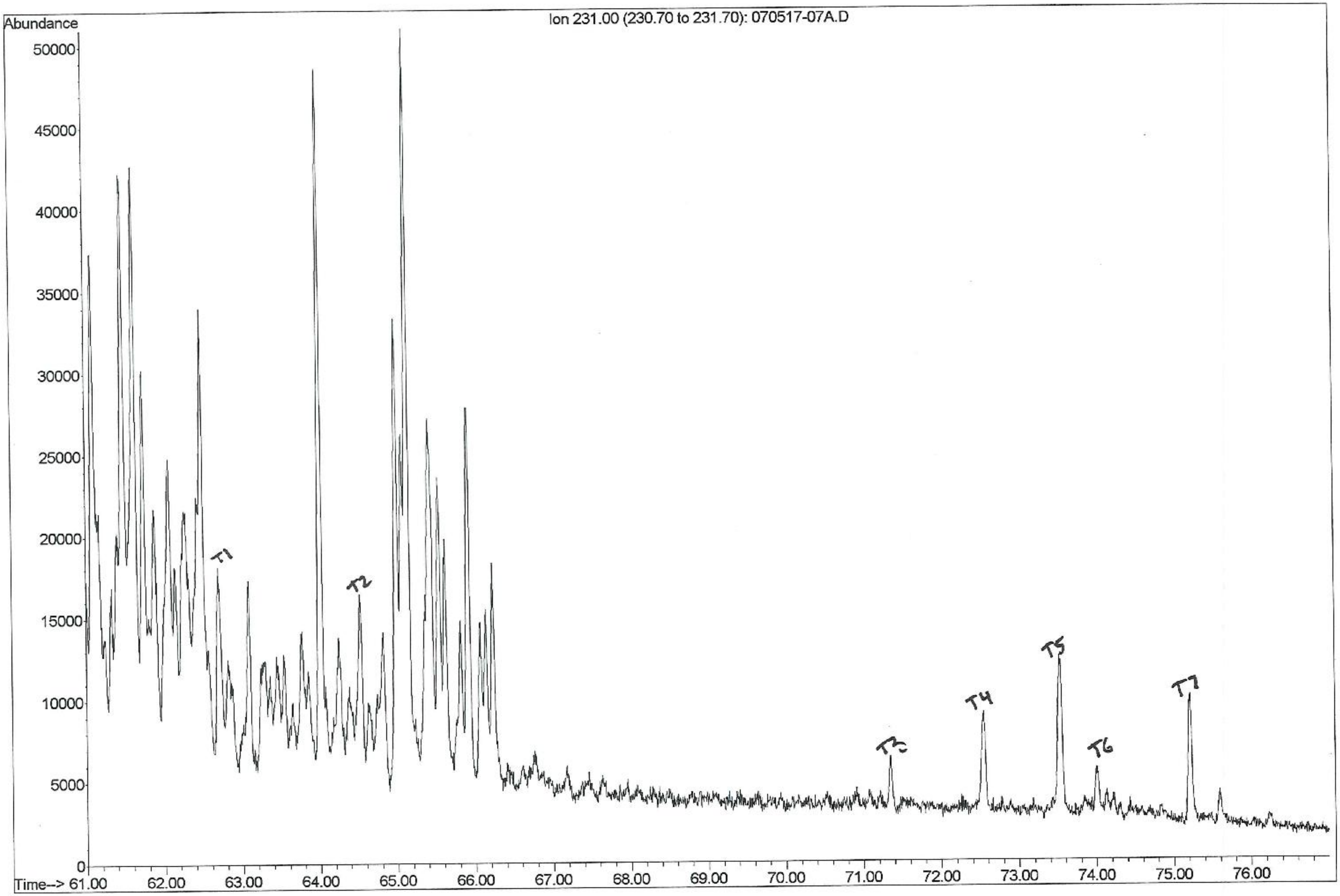
23114-2 [O-062217-JH-02] 1/5 DILUTION PZ-3



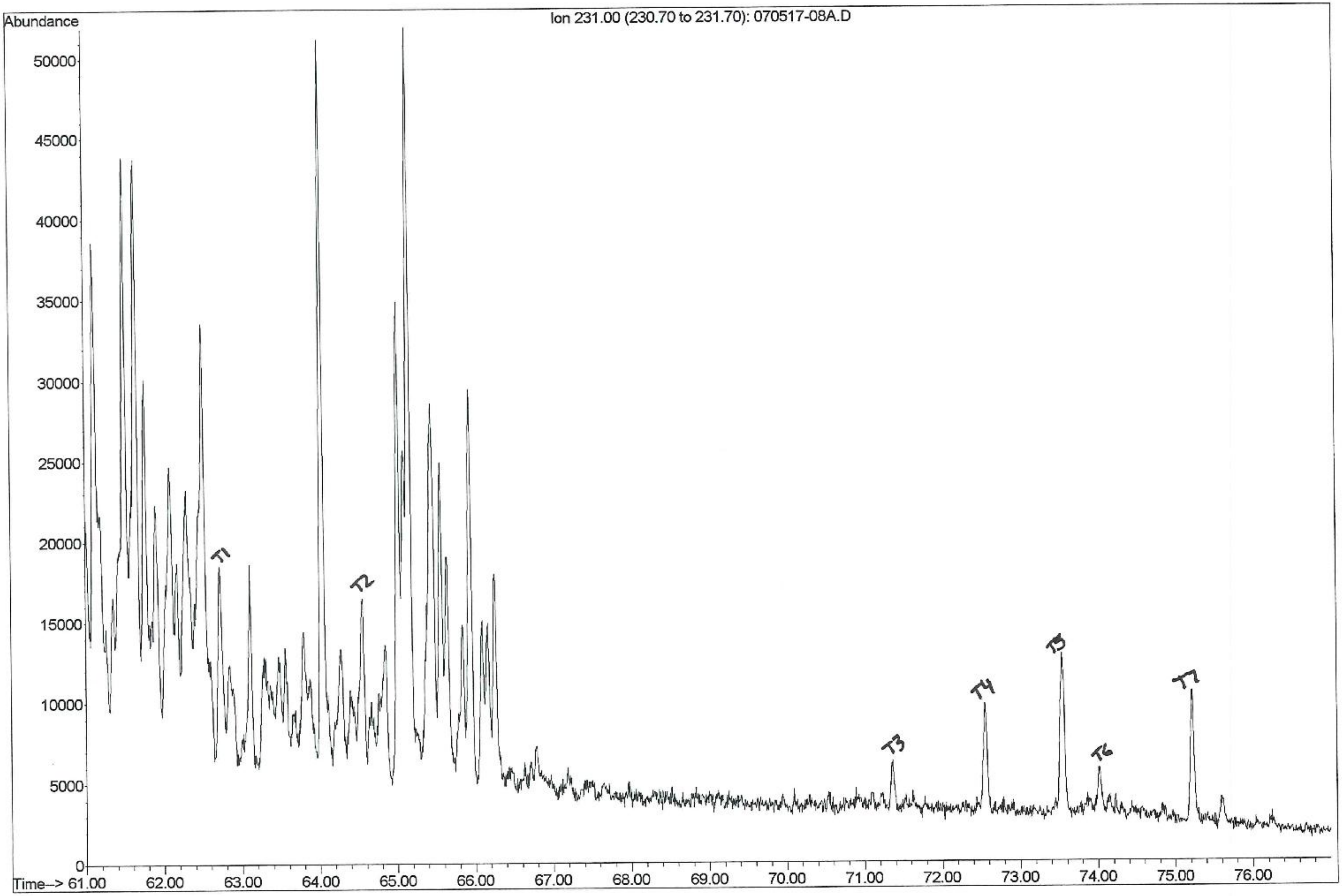
23114-3 [O-062217-JH-03] 1/5 DILUTION PZ-4



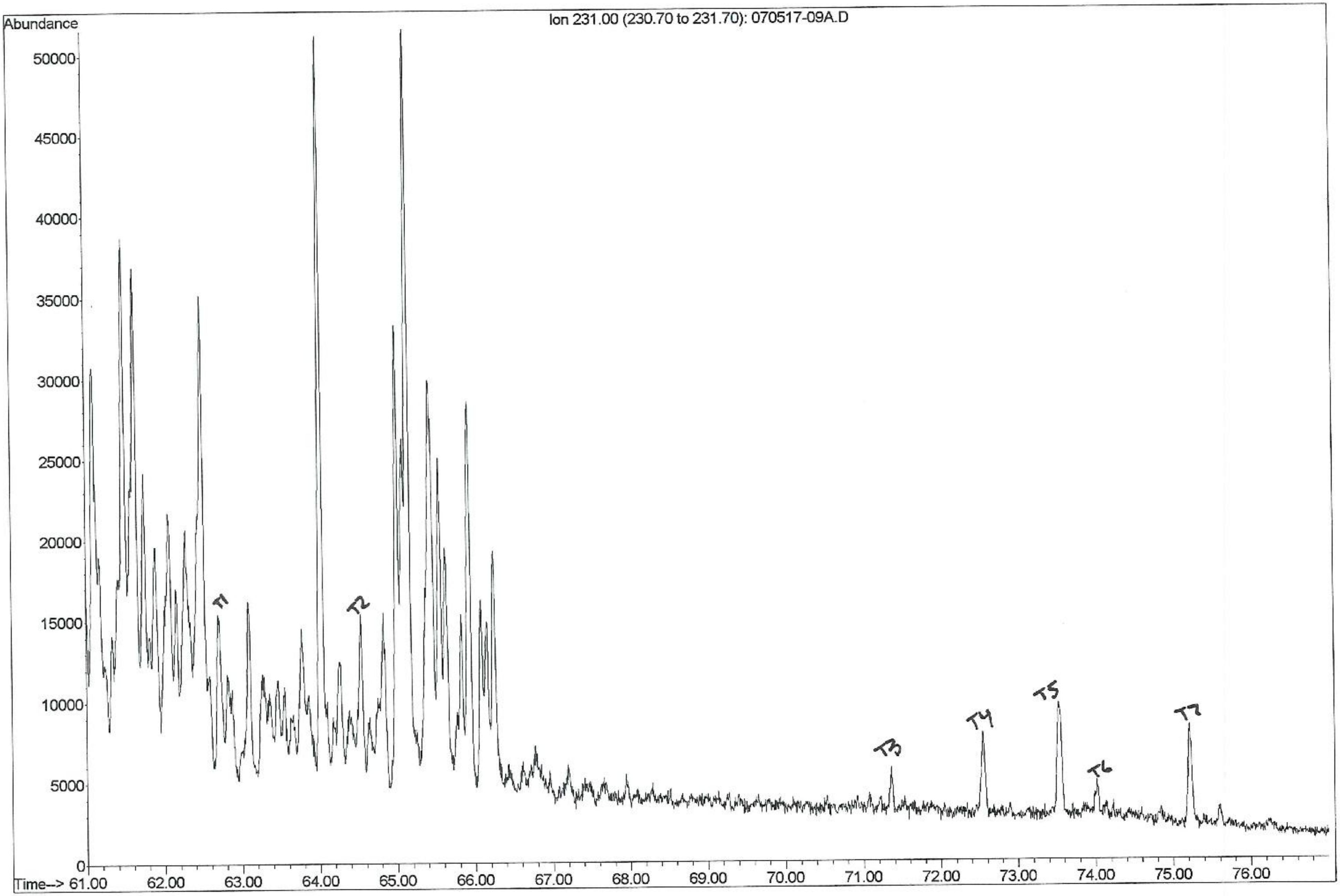
23114-4 [O-062217-JH-04] 1/5 DILUTION PZ-5



23114-5 [O-062217-JH-05] 1/5 DILUTION PZ-6



23114-6 [O-062217-JH-06] 1/5 DILUTION PZ-7



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Key for Identifying Aromatic Hydrocarbons

No	m/z	Abbreviation	Compound
1	120	AB	C_3-alkylbenzenes
2	134		C_4-alkylbenzenes
3	148		C_5-alkylbenzenes
4	162		C_6-alkylbenzenes
5	128	NAPH	C_0-naphthalene
6	142		C_1-naphthalenes
7	156		C_2-naphthalenes
8	170		C_3-naphthalenes
9	184		C_4-naphthalenes
10	166	FL	C_0-fluorene
11	180		C_1-fluorenes
12	194		C_2-fluorenes
13	208		C_3-fluorenes
14	222		C_4-fluorenes
15	154	BP	C_0-biphenyl
16	168		C_1-biphenyls + dibenzofuran
17	182		C_2-biphenyls + C1 Dibenzofuran
18	178	PHEN	C_0-phenanthrene
19	192		C_1-phenanthrenes
20	206		C_2-phenanthrenes
21	220		C_3-phenanthrenes
22	234		C_4-phenanthrenes
23	202	PY	C_0-pyrene/fluoranthene
24	216		C_1-pyrenes/fluoranthenes
25	230		C_2-pyrenes/fluoranthenes
26	244		C_3-pyrenes/fluoranthenes
27	258		C_4-pyrenes/fluoranthenes
28	228	CHR	C_0-chrysene
29	242		C_1-chrysenes
30	256		C_2-chrysenes
31	270		C_3-chrysenes
32	284		C_4-chrysenes
33	148	BT	C_1-benzothiophenes
34	162		C_2-benzothiophenes
35	176		C_3-benzothiophenes
36	190		C_4-benzothiophenes
37	204		C_5-benzothiophenes

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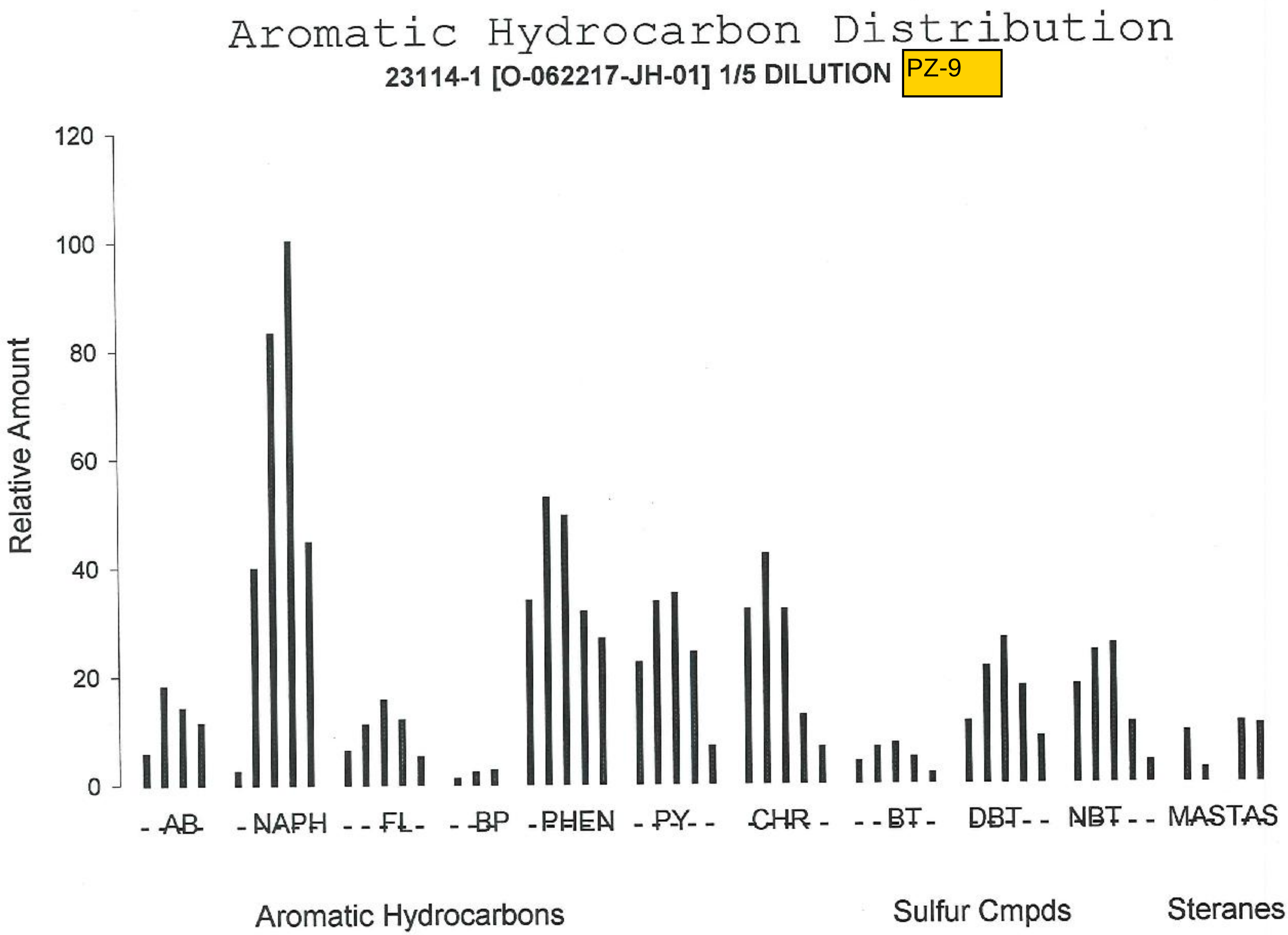
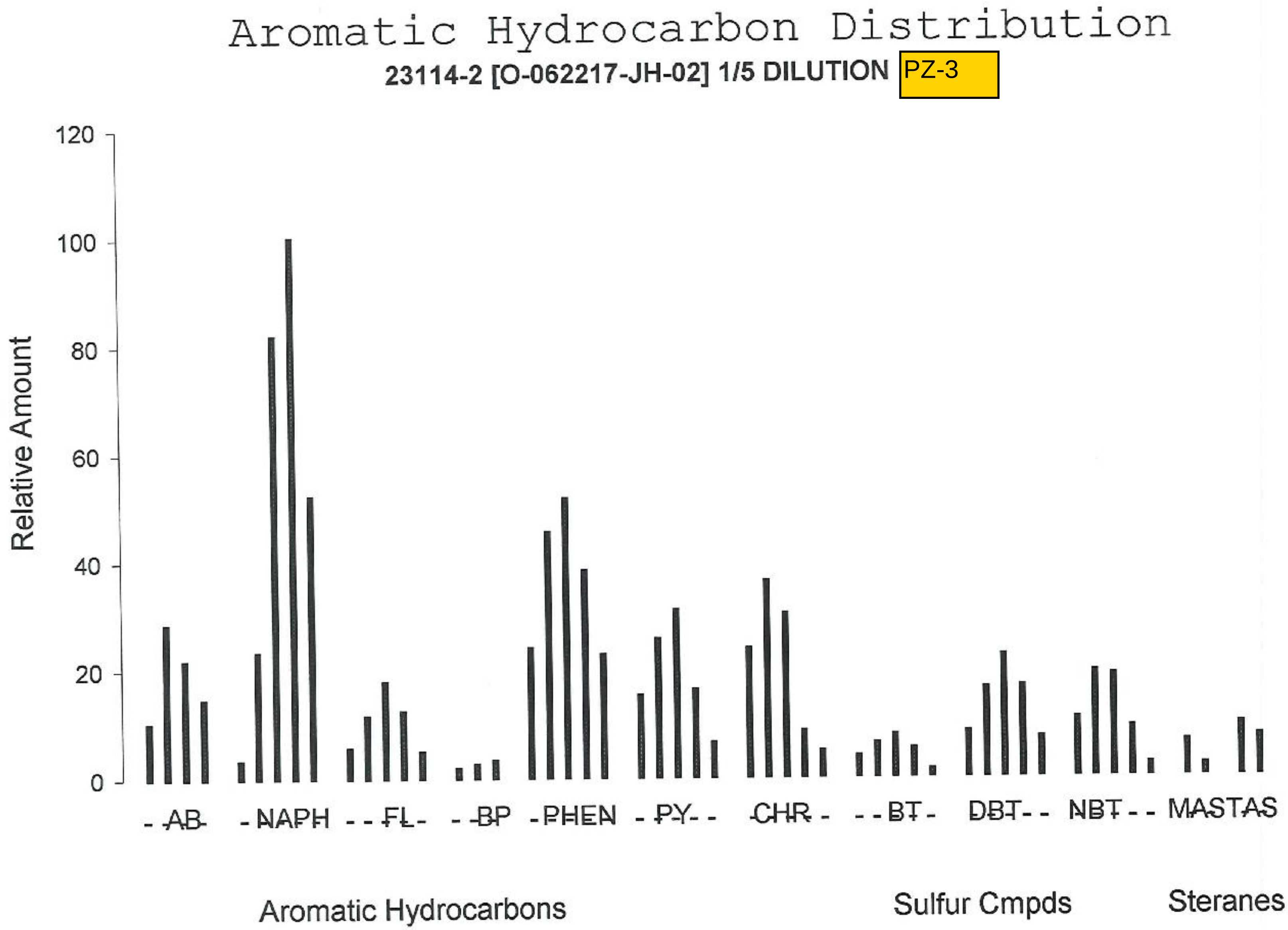
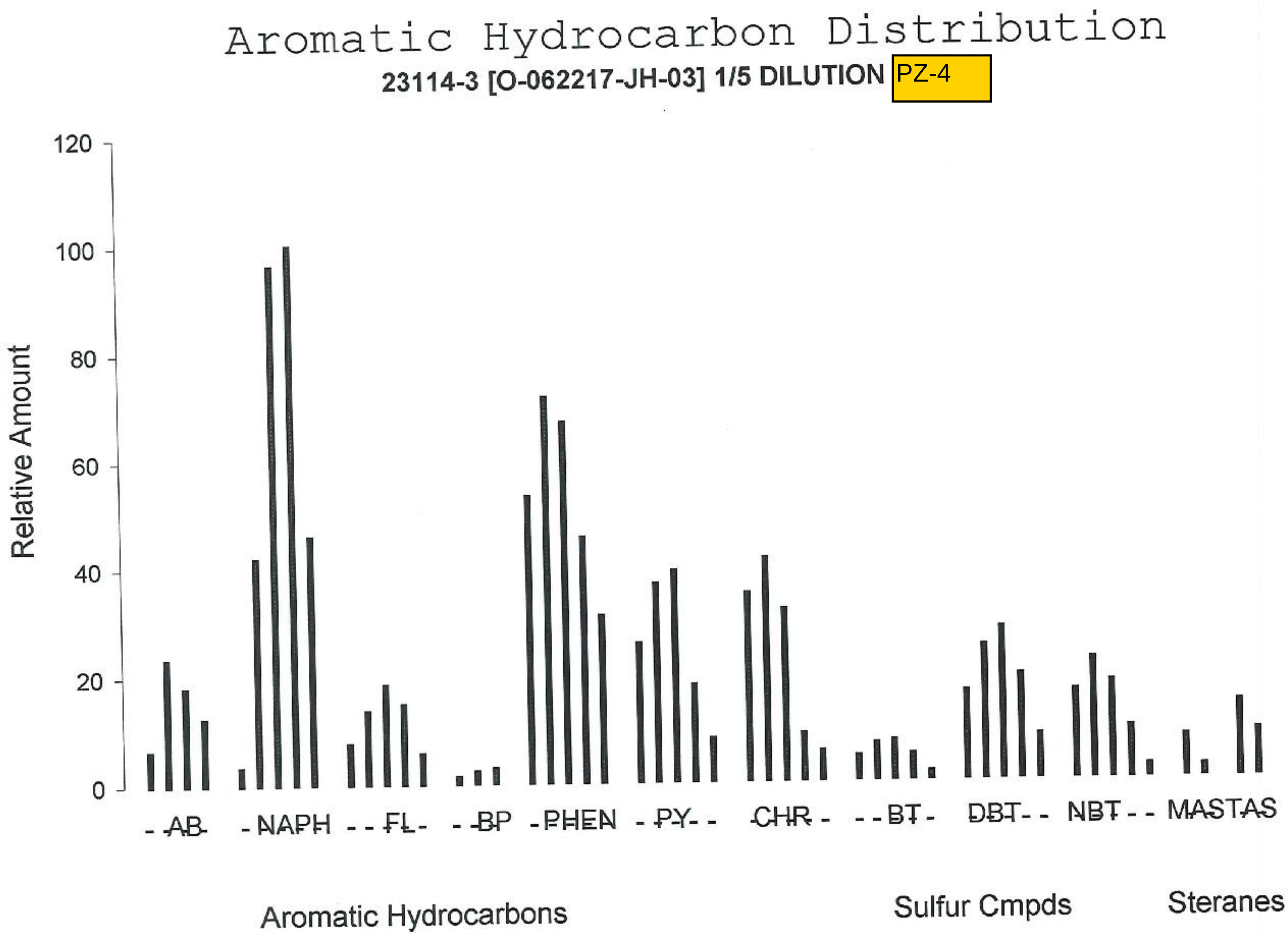
Key for Identifying Aromatic Hydrocarbons – Cont.

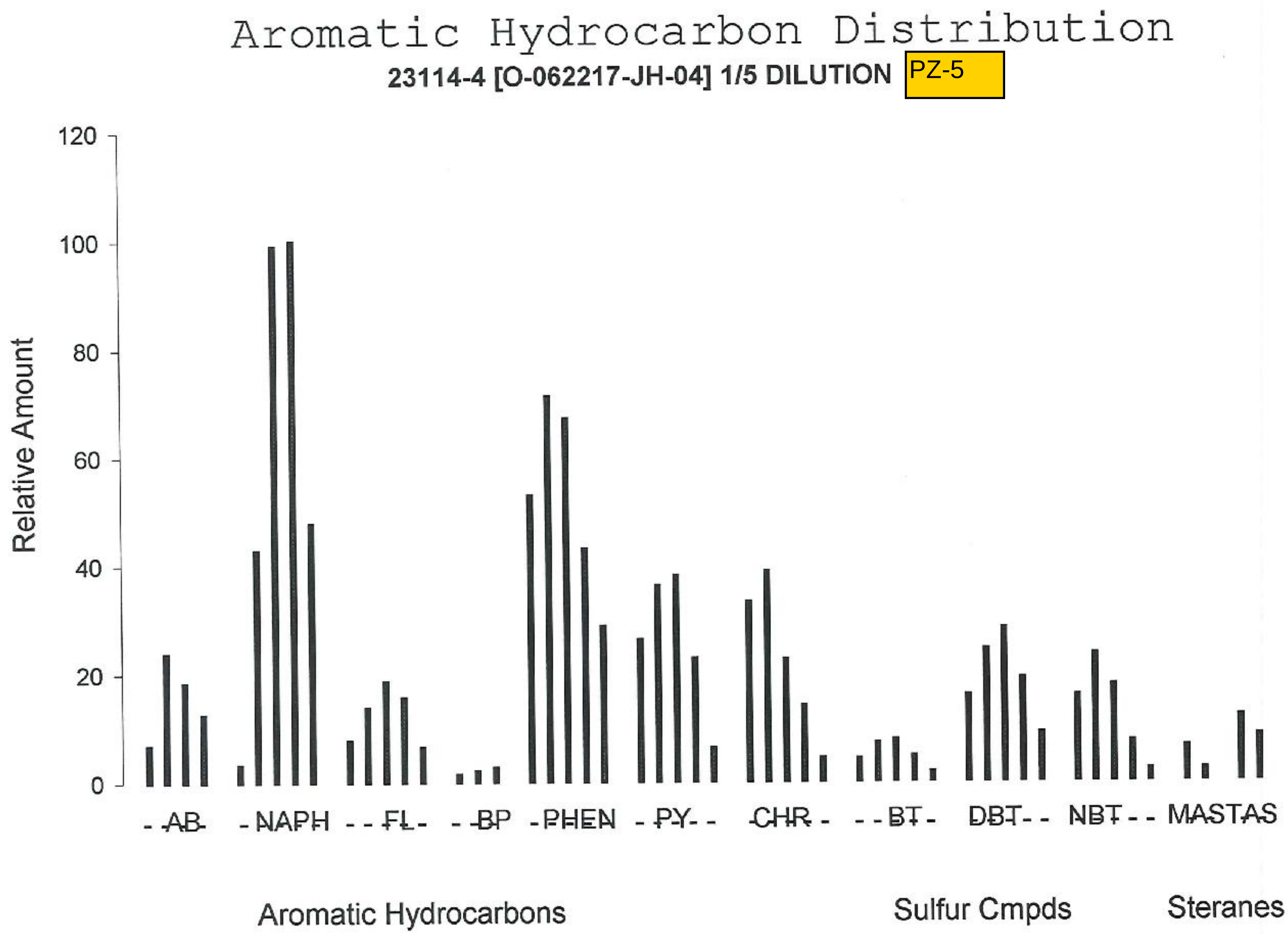
No	m/z	Abbreviation	Compound
38	184	DBT	C_0-dibenzothiophene
39	198		C_1-dibenzothiophenes
40	212		C_2-dibenzothiophenes
41	226		C_3-dibenzothiophenes
42	240		C_4-dibenzothiophenes
43	234	NBT	C_0-naphthobenzthiophene
44	248		C_1-naphthobenzthiophenes
45	262		C_2-naphthobenzthiophenes
46	276		C_3-naphthobenzthiophenes
47	290		C_4-naphthobenzthiophenes
48	253	MAS	Monoaromatic steranes
49	267		Monoaromatic steranes
50	239		Monoaromatic steranes
51	231	TAS	Triaromatic steranes
52	245		Triaromatic steranes

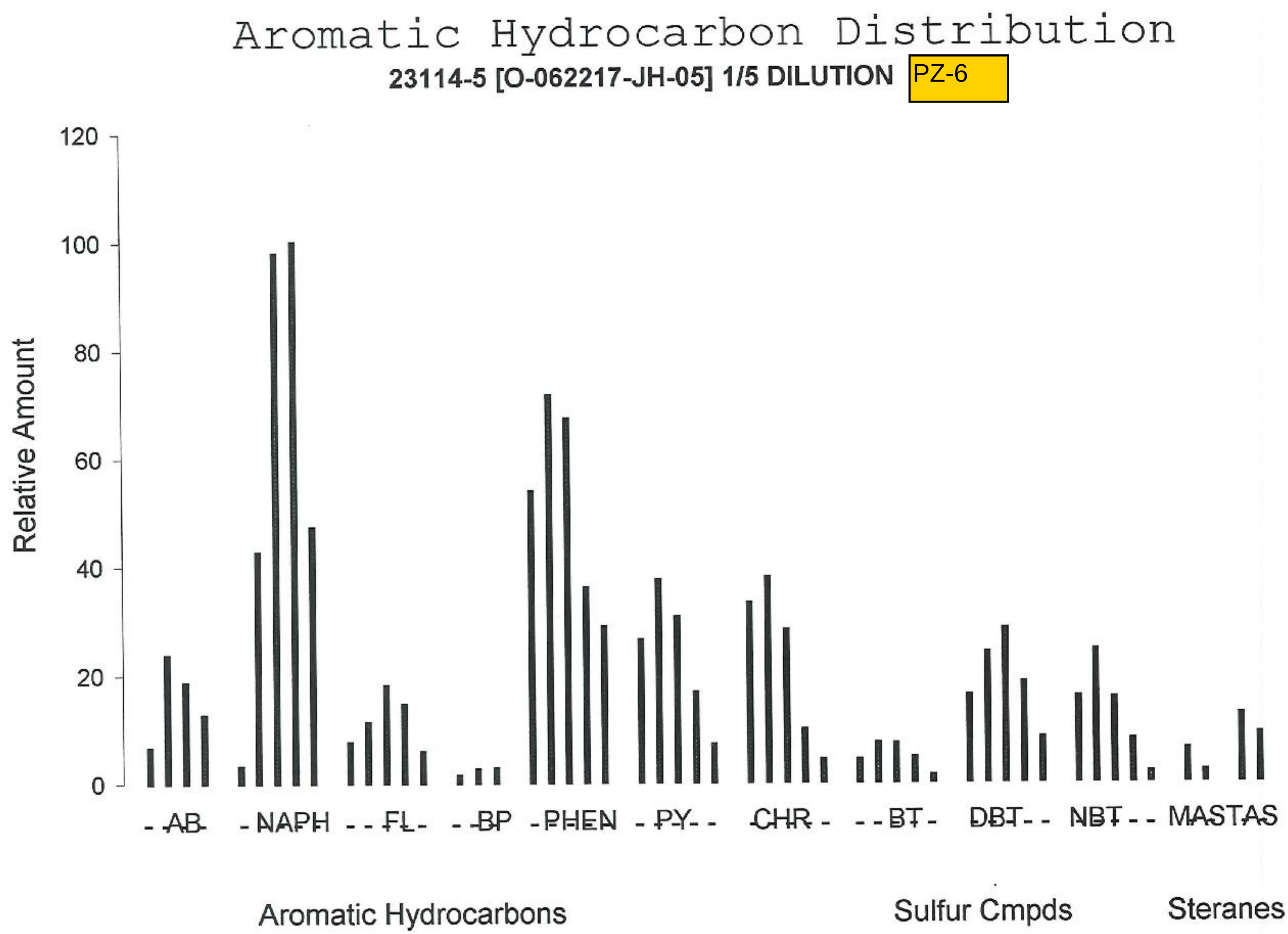

Aromatic Hydrocarbon Distribution
23114-1 [O-062217-JH-01] 1/5 DILUTION
PZ-9
Relative Amount
120
100
80
60
40
20
0
AB
NAPH
FL
BP
PHEN
PY
CHR
BT
DBT
NBT
MASTAS
Aromatic Hydrocarbons
Sulfur Cmpds
Steranes


Aromatic Hydrocarbon Distribution
23114-2 [O-062217-JH-02] 1/5 DILUTION
PZ-3
120
100
80
60
40
20
0
Relative Amount
AB
NAPH
FL
BP
PHEN
PY
CHR
BT
DBT
NBT
MASTAS
Aromatic Hydrocarbons
Sulfur Cmpds
Steranes



Aromatic Hydrocarbon Distribution
23114-3 [O-062217-JH-03] 1/5 DILUTION PZ-4
Relative Amount
120
100
80
60
40
20
0
- - AB -
- NAPH
- - FL -
- - BP
- PHEN
- PY - -
CHR -
- - BT -
DBT - -
NBT - -
MASTAS
Aromatic Hydrocarbons
Sulfur Cmpds
Steranes

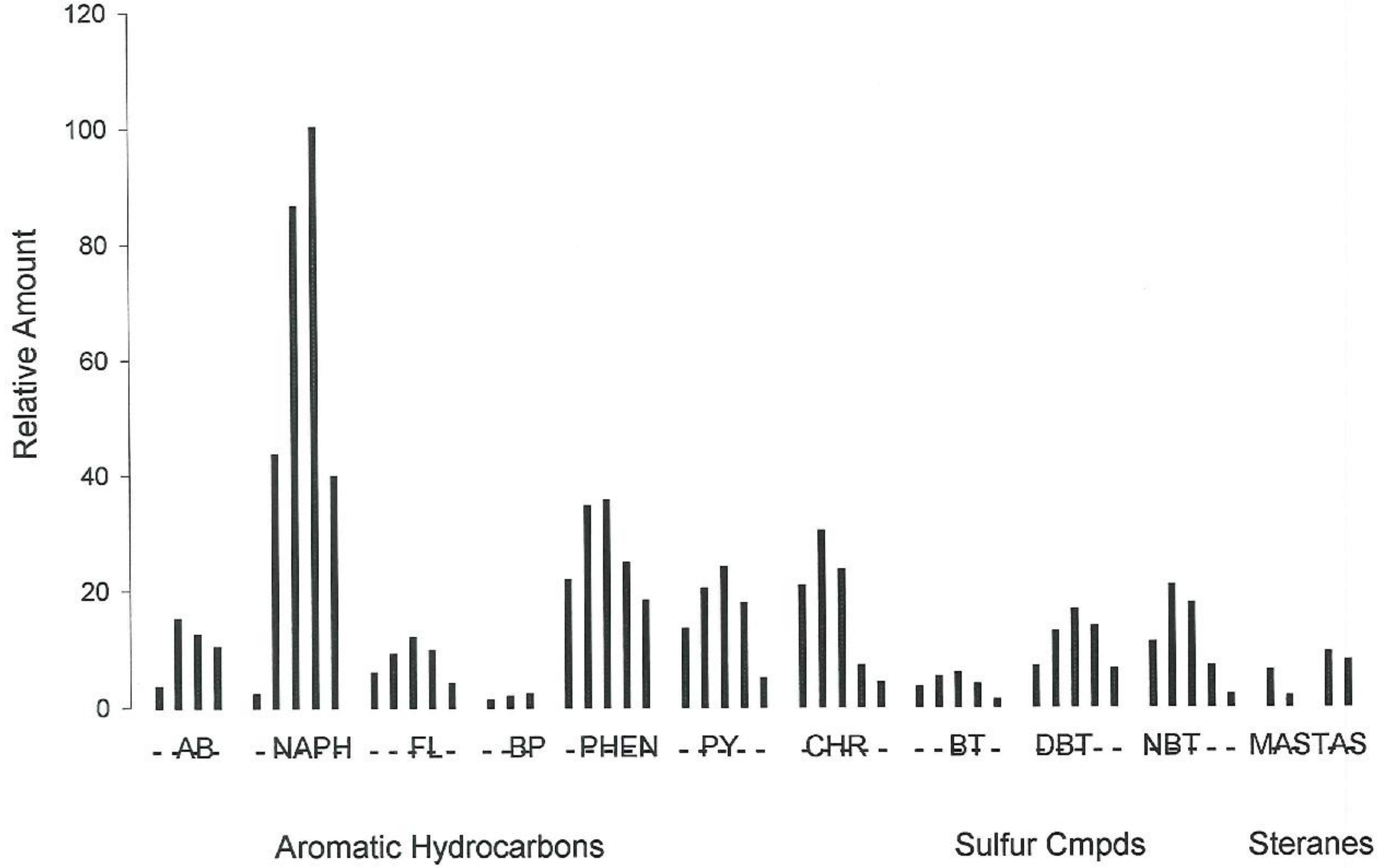

Aromatic Hydrocarbon Distribution
23114-4 [O-062217-JH-04] 1/5 DILUTION
PZ-5
Relative Amount
120
100
80
60
40
20
0
AB
NAPH
FL
BP
PHEN
PY
CHR
BT
DBT
NBT
MASTAS
Aromatic Hydrocarbons
Sulfur Cmpds
Steranes



Aromatic Hydrocarbon Distribution
23114-5 [O-062217-JH-05] 1/5 DILUTION
PZ-6
Relative Amount
120
100
80
60
40
20
0
AB
NAPH
FL
BP
PHEN
PY
CHR
BT
DBT
NBT
MASTAS
Aromatic Hydrocarbons
Sulfur Cmpds
Steranes

Aromatic Hydrocarbon Distribution

23114-6 [O-062217-JH-06] 1/5 DILUTION PZ-7



CHAIN OF CUSTODY RECORD

GHD

23114

Address: ____ Phone: ____ Fax: ____

COC NO.: 53457 PAGE ___ OF ___

Project No/ Phase/Task Code: 85886 – 023101 – 403	Laboratory Name: Pace	Lab Location:	SSOW ID: 706-402-D02-1100
Project Name: Cline Ave Ditch	Lab Contact: Ruth Welsh		Cooler No:
Project Location: Gary In			Carrier: Fed-X
GHD Chemistry Contact: Angela Bown			Airbill No: 808906007787
Sampler(s):			Total # of Containers: 1

ANALYSIS REQUESTED (See Back of COC for Definitions)

Item	SAMPLE IDENTIFICATION (Containers for each sample may be combined on one line)	DATE (mm/dd/yy)	TIME (hh:mm)	Matrix Code (see back of COC)	Grab (G) or Comp (C)	Filtered (Y/N)	Finger print	Whole oil Anal	Finger print	Full scan	Total Containers/sample	MS/MSD Request	COMMENTS/ SPECIAL INSTRUCTIONS:
	PRESERVATION - (SEE BACK OF COC FOR ABBREVIATIONS)												
1	O-062217-JH-01	6-22-17		O	G	N	✓	✓	✓	✓	2		
2	02	↓		↓	↓	↓	✓	✓	✓	✓	2		
3	03						✓	✓	✓	✓	2		
4	04						✓	✓	✓	✓	2		
5	05						✓	✓	✓	✓	2		
6	06						✓	✓	✓	✓	2		
7													
8													
9													
10													
11													
12													

TAT Required in business days (use separate COCs for different TATs):

☐ 1 Day ☐ 2 Days ☐ 3 Days ☐ 1 Week ☐ 2 Week ☐ Other:

Notes/ Special Requirements:

RELINQUISHED BY	COMPANY	DATE	TIME	RECEIVED BY	COMPANY	DATE	TIME
1. John Hargens	GHD	6-27-17	1400	1. [signature] PACE	6	6.28.17	11 30
2.				2.			
3.				3.			

THE CHAIN OF CUSTODY IS A LEGAL DOCUMENT – ALL FIELDS MUST BE COMPLETED ACCURATELY

Distribution: WHITE – Fully Executed Copy (CRA) YELLOW – Receiving Laboratory Copy PINK – Shipper GOLDENROD – Sampling Crew

GHD Form: COC-10B (20110804)

Cooler Receipt Form

Client Name: GSCD Project: Cline Ave Ditch Lab Work Order: 23114

A. Shipping/Container Information (circle appropriate response)

Courier: (FedEx) UPS USPS Client Other:__________ Air bill Present: Yes No

Tracking Number:____________________

Custody Seal on Cooler/Box Present: Yes No Seals Intact: Yes No

Cooler/Box Packing Material: (Bubble Wrap) Absorbent Foam Other:__________

Type of Ice: Wet Blue (None) Ice Intact: Yes Melted

Cooler Temperature: n/a Radiation Screened: Yes (No) Chain of Custody Present: (Yes) No

Comments:____________________

B. Laboratory Assignment/Log-in (check appropriate response)

	YES	NO	N/A	Comment Reference non-Conformance
Chain of Custody properly filled out	✓			
Chain of Custody relinquished	✓			
Sampler Name & Signature on COC			✓	
Containers intact	✓			
Were samples in separate bags	✓			
Sample container labels match COC Sample name/date and time collected		✓		
Sufficient volume provided	✓			
PAES containers used	✓			
Are containers properly preserved for the requested testing? (as labeled)			✓	
If an unknown preservation state, were containers checked? Exception: VOA's coliform			✓	If yes, see pH form
Was volume for dissolved testing field filtered, as noted on the COC? Was volume received in a preserved container?			✓	

Comments:____________________

Cooler contents examined/received by: LG Date: 6.28.17

Project Manager Review: Jem Date: 6/28/17

NON-CONFORMANCE FORM

PAES Work Order #: 23114

Date: 6.28.17 Time of Receipt: 11:30 Receiver: LY

Client: GHD.

REASON FOR NON-CONFORMANCE:

No time of collection available.

ACTION TAKEN:

Client name: GHD Date: 6/29/17 Time: 9:03

Approved to continue with analyses

Customer Service Initials: Jen Date: 6/29/17

Appendix C.2
LNAPL Physical Properties Analytical Reports

th

July 21st, 2017

Angela Bown
GHD
9033 Meridian Way
West Chester, OH 45069

RE: Cline Ave Ditch
Project Number: 0856886 D21103

Pace Analytical received six samples on June 26th, 2017 for analysis labeled GW-062217-JH-01, GW-062217-JH-02, GW-062217-JH-03, GW-062217-JH-04, GW-062217-JH-05, and GW-062217-JH-06. Additional volume was received on June 29th. Per client request, the following analyses were performed:

1. Viscosity – Subcontracted to Clark Testing
2. Surface Tension – Subcontracted to Clark Testing
3. Liquid Properties – Subcontracted to Clark Testing

The sample was performed in house under laboratory number **23078**.

Please call the lab at 412-826-5245, or you may email any questions or concerns to Lauren.McGrath@pacelabs.com regarding any analytical data reports.

Respectfully submitted,

Lauren E. McGrath

Lauren E. McGrath
Project Manager

Pace Analytical Energy Services
Contact: Ruth Welsh
Ph: 412-826-4482 Fax: 412-826-3433
Email: Ruth.Welsh@pacelabs.com

FINAL REPORT
This report and the data within has completed QA/QC review

Fuels & Lubrication Lab
1801 Route 51 South
Building 9
Jefferson Hills, PA 15025
Ph: 412-387-1001
Fax: 412-387-1028

Primary Contact	Pittsburgh, PA
PO#	23078
Tracking #	406941-1
Client Sample #	230780001 GW-062217-JH-01 PZ-9
Received Date	06/27/2017

Kinematic Viscosity (40C, 100C, and VI) - new oil
Test Code: D445 / Method: D445/D2270

Result Date		07/20/2017
Viscosity @ 40C	*cSt*	10.874

Comments

Viscosity @ 100 degrees fails.

Oil/Water Interface, Interfacial Tension
Test Code: D971 / Method: D971

Result Date		07/20/2017
Result	*Dynes/centimeter*	3.61

Surface Tension
Test Code: D971B / Method: D971B

Result Date		07/20/2017
Surface Tension	*Dynes/centimeter*	27.80

Digital Density at 15C
Test Code: D4052 / Method: D4052

Result Date		07/19/2017
Result	*g/cm3*	0.92548

Sample Preparation Fee/Extraction
Test Code: Prep / Method:

Result Date	07/20/2017
Result	Prep Required

General Diagnostic Notes

Additional detail may be available if requested, at standard Clark consulting rates.

Pace Analytical Energy Services
Contact: Ruth Welsh
Ph: 412-826-4482 Fax: 412-826-3433
Email: Ruth.Welsh@pacelabs.com

FINAL REPORT
This report and the data within has completed QA/QC review

CLARK TESTING

Fuels & Lubrication Lab
1801 Route 51 South
Building 9
Jefferson Hills, PA 15025
Ph: 412-387-1001
Fax: 412-387-1028

Primary Contact	Pittsburgh, PA
PO#	23078
Tracking #	406941-2
Client Sample #	230780002 GW-062217-JH-02 PZ-3
Received Date	06/27/2017

Kinematic Viscosity (40C, 100C, and VI) - new oil
Test Code: D445 / Method: D445/D2270

Result Date		07/20/2017
Viscosity @ 40C	*cSt*	9.2929

Comments
Viscosity @ 100 degrees fails.

Oil/Water Interface, Interfacial Tension
Test Code: D971 / Method: D971

Result Date		07/20/2017
Result	*Dynes/centimeter*	5.52

Surface Tension
Test Code: D971B / Method: D971B

Result Date		07/20/2017
Surface Tension	*Dynes/centimeter*	24.88

Digital Density at 15C
Test Code: D4052 / Method: D4052

Result Date		07/19/2017
Result	*g/cm3*	0.90983

Sample Preparation Fee/Extraction
Test Code: Prep / Method:

Result Date	07/20/2017
Result	Prep Required

General Diagnostic Notes
Additional detail may be available if requested, at standard Clark consulting rates.

Pace Analytical Energy Services
Contact: Ruth Welsh
Ph: 412-826-4482 Fax: 412-826-3433
Email: Ruth.Welsh@pacelabs.com

FINAL REPORT
This report and the data within has completed QA/QC review

CLARK TESTING

Fuels & Lubrication Lab
1801 Route 51 South
Building 9
Jefferson Hills, PA 15025
Ph: 412-387-1001
Fax: 412-387-1028

Primary Contact	Pittsburgh, PA
PO#	23078
Tracking #	406941-3
Client Sample #	230780003 GW-062217-JH-03 PZ-4
Received Date	06/27/2017

Kinematic Viscosity (40C, 100C, and VI) - new oil	Test Code: D445 / Method: D445/D2270
Result Date	07/20/2017
Viscosity @ 40C *cSt*	10.653

Comments

Viscosity @ 100 degrees fails.

Oil/Water Interface, Interfacial Tension	Test Code: D971 / Method: D971
Result Date	07/20/2017
Result *Dynes/centimeter*	3.66

Surface Tension	Test Code: D971B / Method: D971B
Result Date	07/20/2017
Surface Tension *Dynes/centimeter*	26.25

Digital Density at 15C	Test Code: D4052 / Method: D4052
Result Date	07/19/2017
Result *g/cm3*	0.96344

Sample Preparation Fee/Extraction	Test Code: Prep / Method:
Result Date	07/20/2017
Result	Prep Required

General Diagnostic Notes

Additional detail may be available if requested, at standard Clark consulting rates.

Pace Analytical Energy Services
Contact: Ruth Welsh
Ph: 412-826-4482 Fax: 412-826-3433
Email: Ruth.Welsh@pacelabs.com

FINAL REPORT
This report and the data within has completed QA/QC review

CLARK TESTING

Fuels & Lubrication Lab
1801 Route 51 South
Building 9
Jefferson Hills, PA 15025
Ph: 412-387-1001
Fax: 412-387-1028

Primary Contact	Pittsburgh, PA
PO#	23078
Tracking #	406941-4
Client Sample #	230780004 GW-062217-JH-04 PZ-5
Received Date	06/27/2017

Kinematic Viscosity (40C, 100C, and VI) - new oil
Test Code: D445 / Method: D445/D2270

Result Date		07/20/2017
Viscosity @ 40C	*cSt*	12.375

Comments

Viscosity @ 100 degrees fails.

Oil/Water Interface, Interfacial Tension
Test Code: D971 / Method: D971

Result Date		07/20/2017
Result	*Dynes/centimeter*	1.85

Surface Tension
Test Code: D971B / Method: D971B

Result Date		07/20/2017
Surface Tension	*Dynes/centimeter*	26.67

Digital Density at 15C
Test Code: D4052 / Method: D4052

Result Date		07/19/2017
Result	*g/cm3*	0.92532

Sample Preparation Fee/Extraction
Test Code: Prep / Method:

Result Date	07/20/2017
Result	Prep Required

General Diagnostic Notes

Additional detail may be available if requested, at standard Clark consulting rates.

Pace Analytical Energy Services
Contact: Ruth Welsh
Ph: 412-826-4482 Fax: 412-826-3433
Email: Ruth.Welsh@pacelabs.com

FINAL REPORT
This report and the data within has completed QA/QC review

CLARK TESTING
Fuels & Lubrication Lab
1801 Route 51 South
Building 9
Jefferson Hills, PA 15025
Ph: 412-387-1001
Fax: 412-387-1028

Primary Contact	Pittsburgh, PA
PO#	23078
Tracking #	406941-5
Client Sample #	230780005 GW-062217-JH-05 PZ-6
Received Date	06/27/2017

Kinematic Viscosity (40C, 100C, and VI) - new oil
Test Code: D445 / Method: D445/D2270

Result Date		07/20/2017
Viscosity @ 40C	*cSt*	9.4691

Comments

Viscosity @ 100 degrees fails.

Oil/Water Interface, Interfacial Tension
Test Code: D971 / Method: D971

Result Date		07/20/2017
Result	*Dynes/centimeter*	12.25

Surface Tension
Test Code: D971B / Method: D971B

Result Date		07/20/2017
Surface Tension	*Dynes/centimeter*	26.88

Digital Density at 15C
Test Code: D4052 / Method: D4052

Result Date		07/19/2017
Result	*g/cm3*	0.91559

Sample Preparation Fee/Extraction
Test Code: Prep / Method:

Result Date	07/20/2017
Result	Prep Required

General Diagnostic Notes

Additional detail may be available if requested, at standard Clark consulting rates.

Pace Analytical Energy Services
Contact: Ruth Welsh
Ph: 412-826-4482 Fax: 412-826-3433
Email: Ruth.Welsh@pacelabs.com

FINAL REPORT
This report and the data within has completed QA/QC review

CLARK TESTING
Fuels & Lubrication Lab
1801 Route 51 South
Building 9
Jefferson Hills, PA 15025
Ph: 412-387-1001
Fax: 412-387-1028

Primary Contact	Pittsburgh, PA
PO#	23078
Tracking #	406941-6
Client Sample #	230780006 GW-062217-JH-06 PZ-7
Received Date	06/27/2017

Kinematic Viscosity (40C, 100C, and VI) - new oil
Test Code: D445 / Method: D445/D2270

Result Date		07/20/2017
Viscosity @ 40C	*cSt*	10.722

Comments
Viscosity @ 100 degrees fails.

Oil/Water Interface, Interfacial Tension
Test Code: D971 / Method: D971

Result Date		07/20/2017
Result	*Dynes/centimeter*	5.45

Surface Tension
Test Code: D971B / Method: D971B

Result Date		07/20/2017
Surface Tension	*Dynes/centimeter*	24.18

Digital Density at 15C
Test Code: D4052 / Method: D4052

Result Date		07/19/2017
Result	*g/cm3*	0.92665

Sample Preparation Fee/Extraction
Test Code: Prep / Method:

Result Date	07/20/2017
Result	Prep Required

General Diagnostic Notes
Additional detail may be available if requested, at standard Clark consulting rates.

GHD

CHAIN OF CUSTODY RECORD

COC NO.: 53484

Address:

PAGE 1 OF 1

Phone:

Fax:

Project No/ Phase/Task Code: 085886 D21103	Laboratory Name: Pace
Project Name: Cline Ave Ditch	Lab Contact: Ruth Welsh
Project Location: Gary In	Lab Location: 220 William Pitt Way, Pittsburgh PA
GHD Chemistry Contact: Angela Bown	SSOW ID: 70L-402-002-1100
Sampler(s): John Hargens	Cooler No:
	Carrier: Fed-X
	Airbill No:
	Total # of Containers: 1

Item	SAMPLE IDENTIFICATION (Containers for each sample may be combined on one line)	DATE (mm/dd/yy)	TIME (hh:mm)	Matrix Code (see back of COC)	Grab (G) or Comp (C)	Filtered (Y/N)	[illegible]	[illegible]	Fluid properties	Dynamic Viscosity	Surface Tension	Interfacial Tension							Total Containers/sample	MS/MSD Request	COMMENTS/ SPECIAL INSTRUCTIONS:
	PRESERVATION - (SEE BACK OF COC FOR ABBREVIATIONS)																				
1	GW-062217-JH-01	6-22-17	1045	WG	G	N	[illegible]	[illegible]	✓	✓	✓	✓							1		small quantities of
2	02	↓	1310	↓	↓	↓	[illegible]	[illegible]	✓	✓	✓	✓							1		Free product in
3	03	↓	1330	↓	↓	↓	[illegible]	[illegible]	✓	✓	✓	✓							1		all containers
4	04	↓	1355	↓	↓	↓	[illegible]	[illegible]	✓	✓	✓	✓							1		
5	05	↓	1425	↓	↓	↓	[illegible]	[illegible]	✓	✓	✓	✓							1		
6	06	↓	1500	↓	↓	↓	[illegible]	[illegible]	✓	✓	✓	✓							1		
7																					
8																					
9																					
10																					
11																					
12																					

TAT Required in business days (use separate COCs for different TATs):

☐ 1 Day ☐ 2 Days ☐ 3 Days ☐ 1 Week ☒ 2 Week ☐ Other:

Notes/ Special Requirements:

	RELINQUISHED BY	COMPANY	DATE	TIME	RECEIVED BY	COMPANY	DATE	TIME
1.	John Hargens	GHD	6-23-17	1600	1.			
2.					2.			
3.					3.			

THE CHAIN OF CUSTODY IS A LEGAL DOCUMENT – ALL FIELDS MUST BE COMPLETED ACCURATELY

Distribution: WHITE – Fully Executed Copy (CRA) YELLOW – Receiving Laboratory Copy PINK – Shipper GOLDENROD – Sampling Crew

GHD Form: COC-10B (20110804)

CHAIN OF CUSTODY RECORD

GHD

23078

Address:
Phone:
Fax:

COC NO.: 53464
PAGE 1 OF 1

Project No/ Phase/Task Code: 085886 D21103	**Laboratory Name:** Pace
Project Name: Cline Ave Ditch	**Lab Contact:** Ruth Welsh
Project Location: Gary In.	**Lab Location:** 220 William P.TT way P.Ttsburgh PA
GHD Chemistry Contact: Angela Bown	**SSOW ID:** 70L-402-002-1100
Sampler(s): John Hargens	**Cooler No:**
	Carrier: Fed-X
	Airbill No:
	Total # of Containers: 1

ANALYSIS REQUESTED (See Back of COC for Definitions)

Item	SAMPLE IDENTIFICATION (Containers for each sample may be combined on one line)	DATE (mm/dd/yy)	TIME (hh:mm)	Matrix Code (see back of COC)	Grab (G) or Comp (C)	Filtered (Y/N)	Full scan C8-C40	PAHs	Total Containers/sample	MS/MSD Request	COMMENTS/ SPECIAL INSTRUCTIONS:
	PRESERVATION - (SEE BACK OF COC FOR ABBREVIATIONS)										
1	GW-062217-JH-01	6-22-17	1045	WG	G	N	✓	✓	1		small quantities of
2	02	↓	1310	↓	↓	↓	✓	✓	1		Free product in
3	03	↓	1330	↓	↓	↓	✓	✓	1		all containers
4	04	↓	1355	↓	↓	↓	✓	✓	1		
5	05	↓	1425	↓	↓	↓	✓	✓	1		
6	06	↓	1500	↓	↓	↓	✓	✓	1		
7											
8											
9											
10											
11											
12											

TAT Required in business days (use separate COCs for different TATs):
☐ 1 Day ☐ 2 Days ☐ 3 Days ☐ 1 Week ☒ 2 Week ☐ Other:

Notes/ Special Requirements:

	RELINQUISHED BY	COMPANY	DATE	TIME		RECEIVED BY	COMPANY	DATE	TIME
1.	John Hargens	GHD	6-23-17	1600	1.	[illegible signature]	PACE	6.26.17	08:00
2.					2.				
3.					3.				

THE CHAIN OF CUSTODY IS A LEGAL DOCUMENT – ALL FIELDS MUST BE COMPLETED ACCURATELY

Distribution: WHITE – Fully Executed Copy (CRA) YELLOW – Receiving Laboratory Copy PINK – Shipper GOLDENROD – Sampling Crew

GHD Form: COC-10B (20110804)

Cooler Receipt Form

Client Name: GHED Project: 085886 D21103 Lab Work Order: 23078

A. Shipping/Container Information (circle appropriate response)

Courier: (FedEx) UPS USPS Client Other:____________ Air bill Present: (Yes) No

Tracking Number: 9053 42757948

Custody Seal on Cooler/Box Present: Yes (No) Seals Intact: Yes No

Cooler/Box Packing Material: (Bubble Wrap) Absorbent Foam Other:____________

Type of Ice: (Wet) Blue None Ice Intact: (Yes) Melted

Cooler Temperature: 4.1°C Radiation Screened: Yes (No) Chain of Custody Present: (Yes) No

Comments:____________

B. Laboratory Assignment/Log-in (check appropriate response)

	YES	NO	N/A	Comment Reference non-Conformance
Chain of Custody properly filled out	✓			
Chain of Custody relinquished	✓			
Sampler Name & Signature on COC	✓			
Containers intact	✓			
Were samples in separate bags	✓			
Sample container labels match COC Sample name/date and time collected		✓		
Sufficient volume provided	✓			
PAES containers used	✓			
Are containers properly preserved for the requested testing? (as labeled)			✓	
If an unknown preservation state, were containers checked? Exception: VOA's coliform			✓	If yes, see pH form
Was volume for dissolved testing field filtered, as noted on the COC? Was volume received in a preserved container?			✓	

Comments:____________

Cooler contents examined/received by: CJ Date: 6.26.17

Project Manager Review: AW Date: 6-26-17

F-PAE-Q-009-rev.00, 20 Nov2014

NON-CONFORMANCE FORM

PAES Work Order #: 23078

Date: 6.26.17 Time of Receipt: 08:00 Receiver: LY

Client: GHD

REASON FOR NON-CONFORMANCE:

1. No time & collection on bottles
2. Samples did have product in them.

ACTION TAKEN:

Client name: GHD Date: 6/26/17 Time: 16:00

Approved

Customer Service Initials: Lu Date: 6/26/17

F-PAE-Q-014-rev.00, 20 Nov 2014

Appendix C.3
Analysis of NAPL Samples (GSI Environmental)

GSI Job No. G-4597
Issued: 15 August 2017

MEMORANDUM ENCLOSURES

TO: Mr. David Sweeten, Glenn Spring Holdings, Inc.

FROM: Ileana Rhodes, Ph.D., GSI Environmental Inc.

RE: Analysis of NAPL Samples Collected 22 June 2017 from the Cline Avenue Site, Gary, Indiana

---

INTRODUCTION

As requested by Glenn Springs Holdings, Inc. (Glenn Springs), GSI Environmental Inc. (GSI) has reviewed the results from a forensics analysis of six LNAPL samples collected from piezometers at the Cline Avenue site. The objective of this additional sampling and analysis was to provide further information on hydrocarbon composition, potential sources, and degree of weathering, as well as to evaluate the consistency of the hydrocarbon impacts across the site. This memorandum summarizes our findings. Please refer to the GSI memorandum dated 4 April 2017 for findings related to the December 2014 hydrocarbon analysis data.

SAMPLING AND ANALYSIS

As recommended by GSI, Glenn Springs collected additional samples from piezometers where LNAPL was encountered at the site. Samples were collected from six piezometers on 22 June 2017. The samples were delivered to Pace Analytical in Pittsburg, Pennsylvania, for the following analyses:

- C3 to C36 whole oil analysis by GC/FID
- C8 to C40 full scan by GC/MS, including PAHs and biomarkers

The laboratory reports are included in Appendix 1 and 2.

DATA REVIEW

Figure 1 shows the chromatograms obtained from the whole oil analysis (gas chromatography with flame ionization detection, GC/FID). Figure 2 shows the total ion current chromatograms (analogous to the whole oil chromatograms) from the full scan qualitative molecular characterization by gas chromatography with mass spectrometry detection (GC/MS). Review of the two gas chromatographic analyses indicates that all six samples contain a wide range of hydrocarbons spanning from C5 to C36 in the whole oil analysis (C3-C36). The full scan analysis (C8-C40) confirmed the presence of hydrocarbons to C40. The chromatograms for all six samples are visually similar and indicate that all samples contain mixtures of weathered gasoline (<10%), biodegraded diesel/middle distillate, and heavier hydrocarbons (residual oil or crude oil). As further discussed below, forensic analysis of the testing data indicates that, in general, the samples appear to share a common source or sources.

Gasoline Range

The presence of small amounts (<10%) of hydrocarbons in the gasoline range is indicated in Figure 1. Figure 3 includes a summary of the relative distribution of paraffins, isoparaffins, aromatics, naphthenes (cycloalkanes) and olefins normalized to the gasoline range only. This information is obtained from the whole oil analysis. There are some differences among the relative distributions of compound classes that could be attributed to weathering or different sources of gasoline with time. The presence of olefins (alkenes) indicates that this portion of the sample is a refined material and likely a gasoline as olefins are not present in condensates or petroleum.

Figures 4a-4f show plots of the relative distribution of selected target compounds. The most prevalent compounds are aromatics which are expected in gasoline, but the samples are relatively depleted of lighter aromatics, such as BTEX, which indicates the LNAPL has undergone weathering by evaporation. Further weathering is evident by the relatively high abundance of methylcyclohexane (MCYH) and ethylcyclohexane (ECYH) in the samples. These cycloalkanes, or naphtheno compounds are less susceptible to biodegradation. They are typically present at low concentrations in gasoline, but become more dominant as gasoline biodegrades in the subsurface.

Diesel/Middle Distillate and Heavier Material

As shown in Figure 1 and Figure 2, the samples are primarily composed of material in the diesel/middle distillate range and residual oil/crude oil. The diesel/middle distillate range of the samples exhibit depleted n-alkanes (readily biodegraded) and a predominance of isoprenoids. Isoprenoids are highly branched alkanes that are more resistant to biodegradation and ratios of various isoprenoids can be very useful for source assessment.

Figure 5 shows the extracted ion chromatograms from the full scan GC/MS analysis for isoprenoids (ion 113). The relative distribution of isoprenoids is very similar for all samples indicating a common source and/or production from the same type of crude oil. Figure 6 presents a cross plot of pairs of ratios of isoprenoids from the whole oil GC/FID analysis and from the full scan GC/MS analysis. Both sets of ratios are in relatively tight clusters suggesting a common source. Also, included in Figure 6 is the cross plot of a pair of ratios of bicyclanes (ion 123). Similar to the isoprenoids, these cyclo-compounds are in the diesel/middle distillate carbon range, are also resistant to biodegradation, and are good source indicators. Like the isoprenoids, the bicyclanes also plot in a tight cluster suggesting a common source.

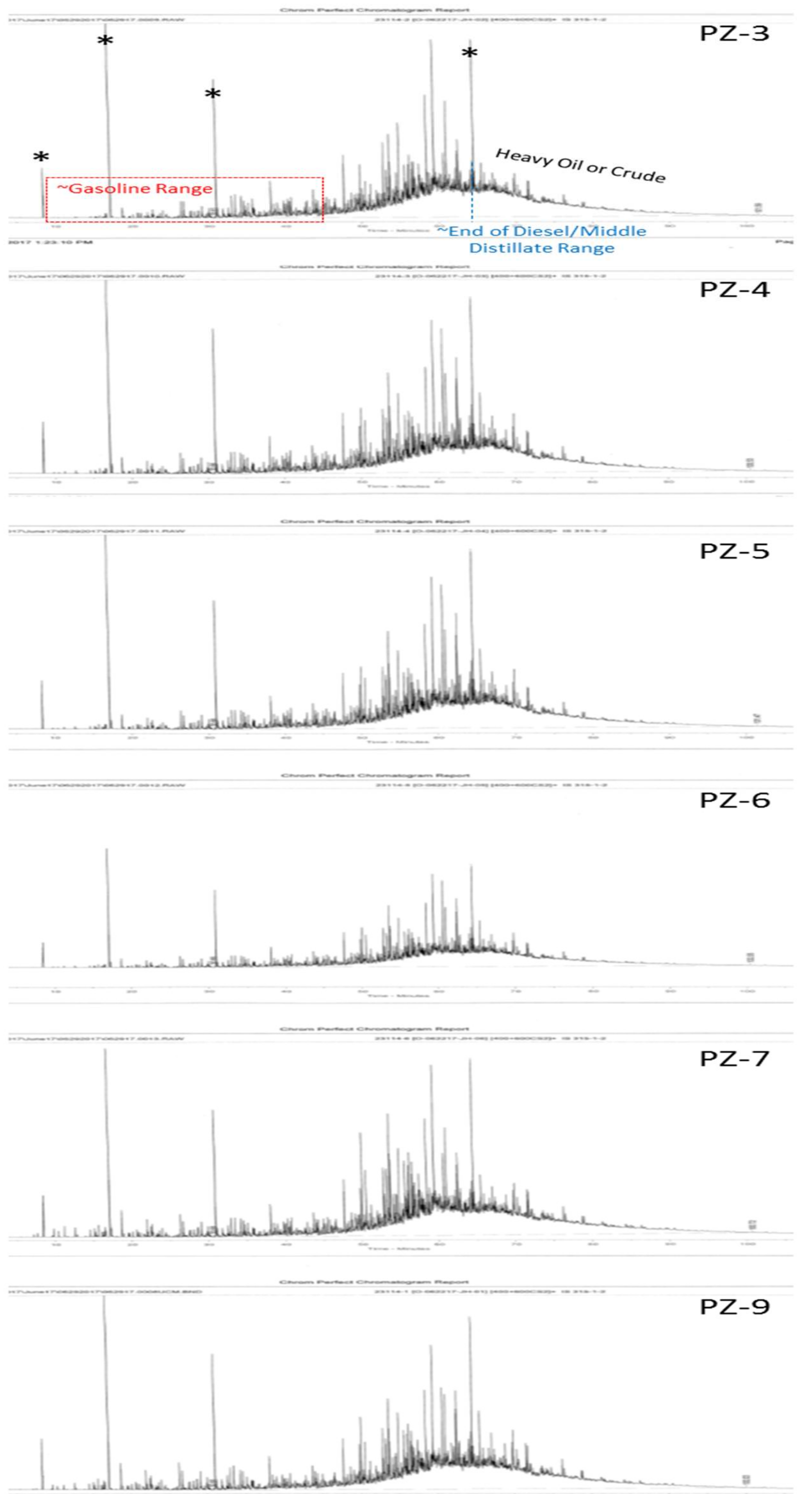
As previously discussed, the presence of heavier than diesel hydrocarbons in evident in Figure 1 and Figure 2. This is further confirmed by the detection of biomarkers like triaromatic steranes (ion 231), steranes (ion 217) and terpanes/hopanes (ion 191, tricyclic, tetracyclic and pentacyclic terpanes) in the full scan by GC/MS. These compounds are typically in crude oils and residual fuels but are removed from lighter products in the refining process.

Figure 6 includes the cross plots of pairs of ratios of these three types of biomarkers. The clusters, while not as tight as those for the diesel range, also indicate a common source. Figure 7 shows the extracted ion chromatograms from the full scan GC/MS analysis for the tricyclic, tetracyclic and pentacyclic terpanes (ion 191) as an example of what these “fingerprints” look like. Similar to the isoprenoids discussed above, the chromatogram patterns, or fingerprints, were similar for all samples indicating a common source.

SUMMARY

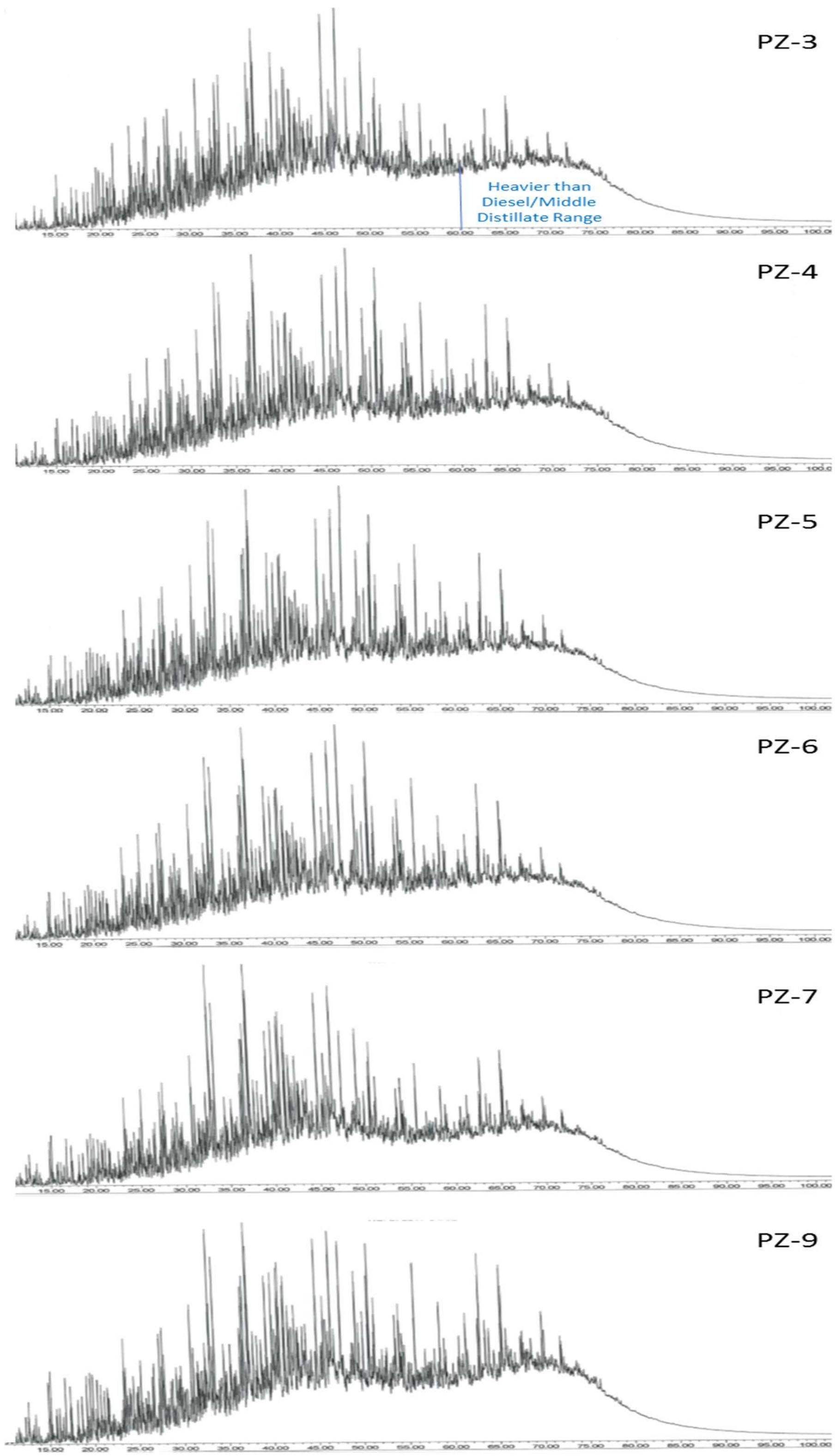
- All samples contained mixtures of weathered gasoline (<10%) and biodegraded diesel/middle distillate and heavier hydrocarbons (residual oil or crude oil). In general, the samples appear to share a common source or sources.
- There are no indications of a recent release.

Figure 1: C3-C36 Whole Oil Analysis by GC/FID



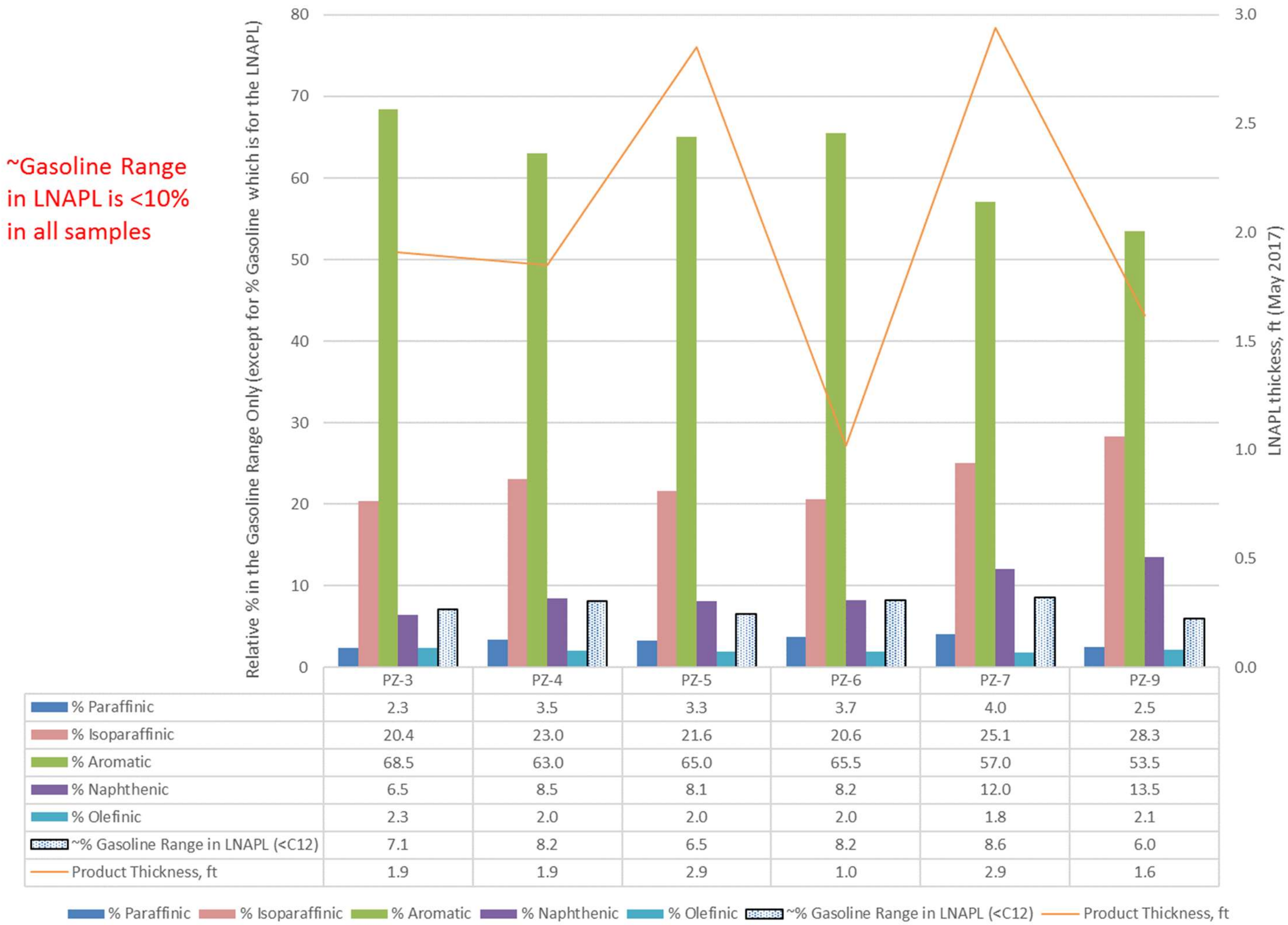
*: Lab added solvent or internal standard

Figure 2: C8-C40 Molecular Analysis by GC/MS – Total Ion Current



GSI ENVIRONMENTAL

Figure 3. Relative distribution of compound classes in the gasoline range only (<nC12), calculated approximate % gasoline range material in the whole LNAPL (C3 to C36 range) and LNAPL thickness (ft.)



	PZ-3	PZ-4	PZ-5	PZ-6	PZ-7	PZ-9
% Paraffinic	2.3	3.5	3.3	3.7	4.0	2.5
% Isoparaffinic	20.4	23.0	21.6	20.6	25.1	28.3
% Aromatic	68.5	63.0	65.0	65.5	57.0	53.5
% Naphthenic	6.5	8.5	8.1	8.2	12.0	13.5
% Olefinic	2.3	2.0	2.0	2.0	1.8	2.1
~% Gasoline Range in LNAPL (<C12)	7.1	8.2	6.5	8.2	8.6	6.0
Product Thickness, ft	1.9	1.9	2.9	1.0	2.9	1.6

Figure 4a: Relative distribution of selected target compounds in the gasoline range (<nC12) for PZ-3

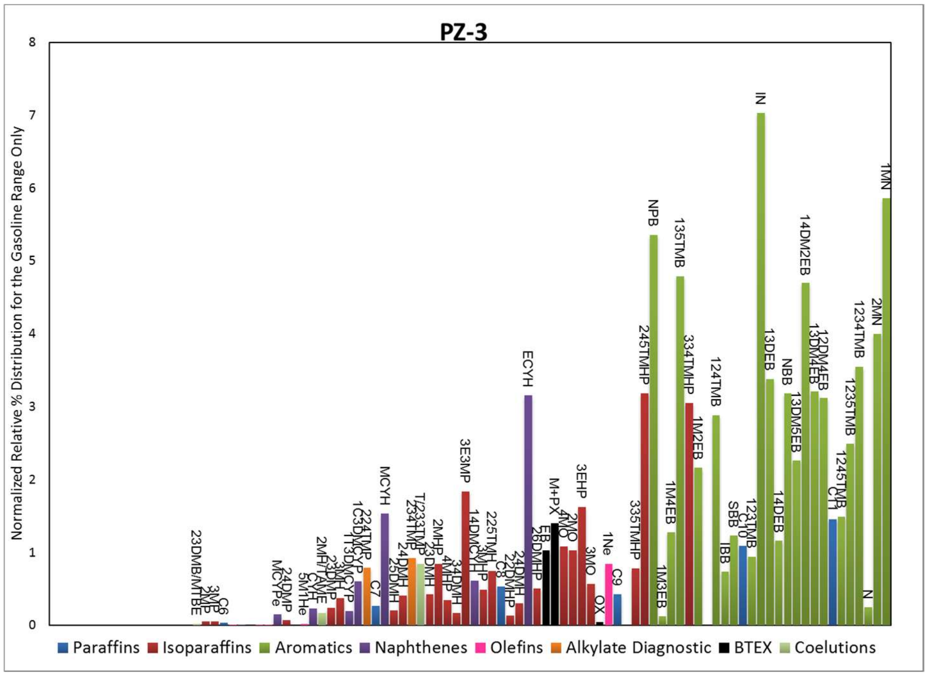


Figure 4b: Relative distribution of selected target compounds in the gasoline range (<nC12) for PZ-4

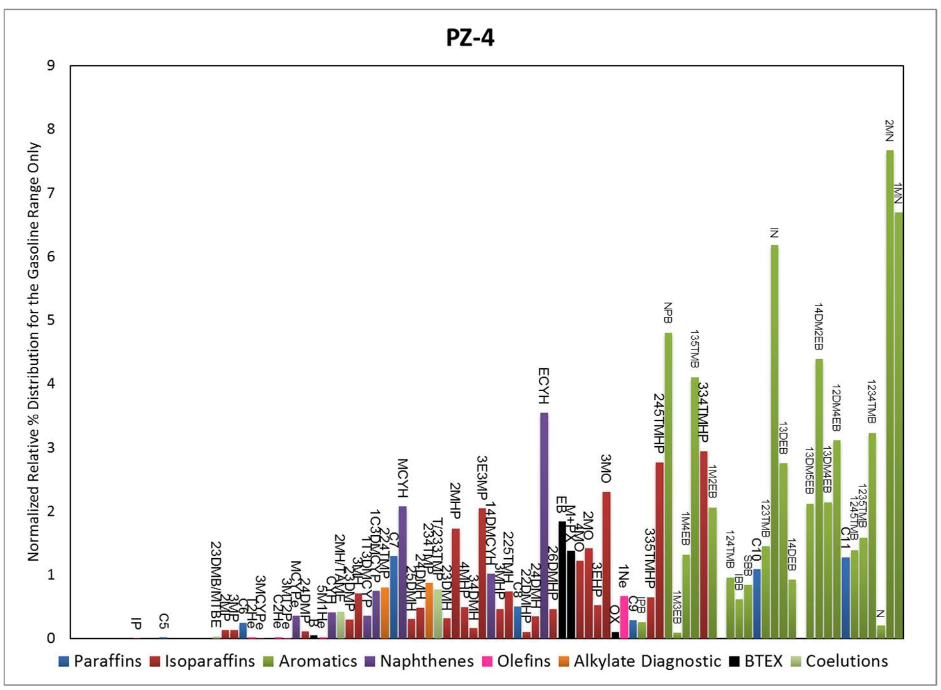


Figure 4c: Relative distribution of selected target compounds in the gasoline range (<nC12) for PZ-5

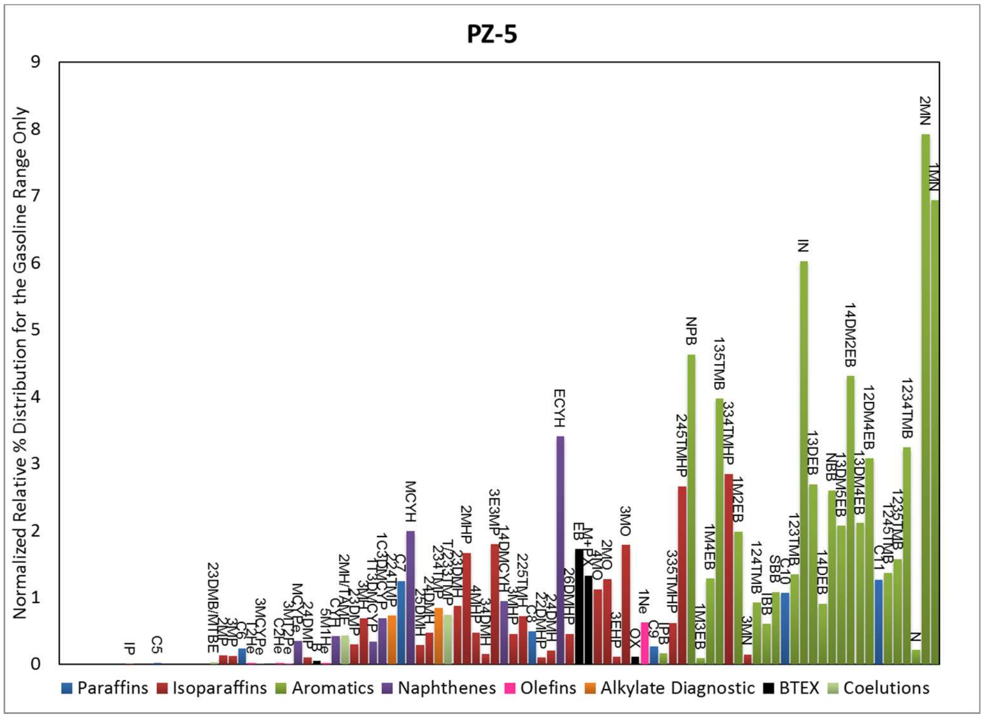


Figure 4d: Relative distribution of selected target compounds in the gasoline range (<nC12) for PZ-6

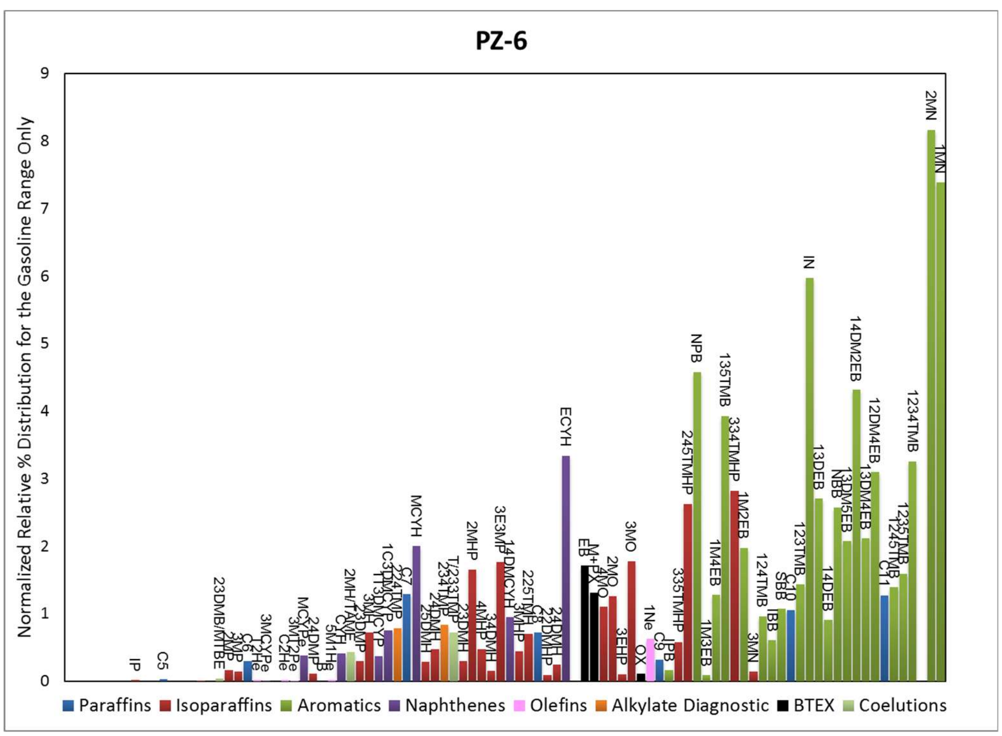


Figure 4e: Relative distribution of selected target compounds in the gasoline range (<nC12) for PZ-7

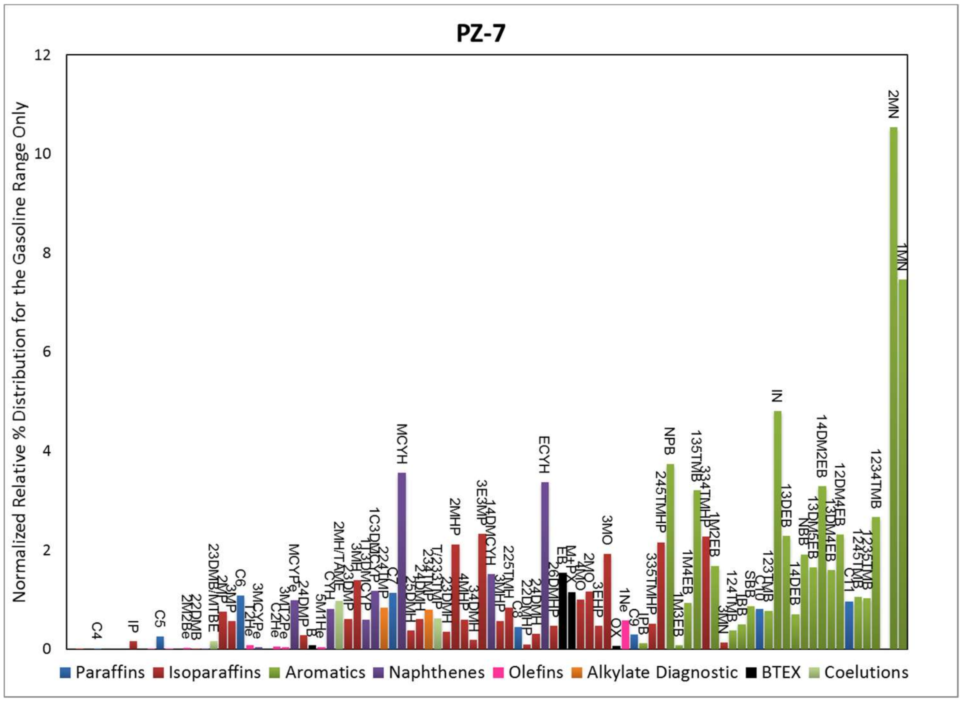


Figure 4f: Relative distribution of selected target compounds in the gasoline range (<nC12) for PZ-9

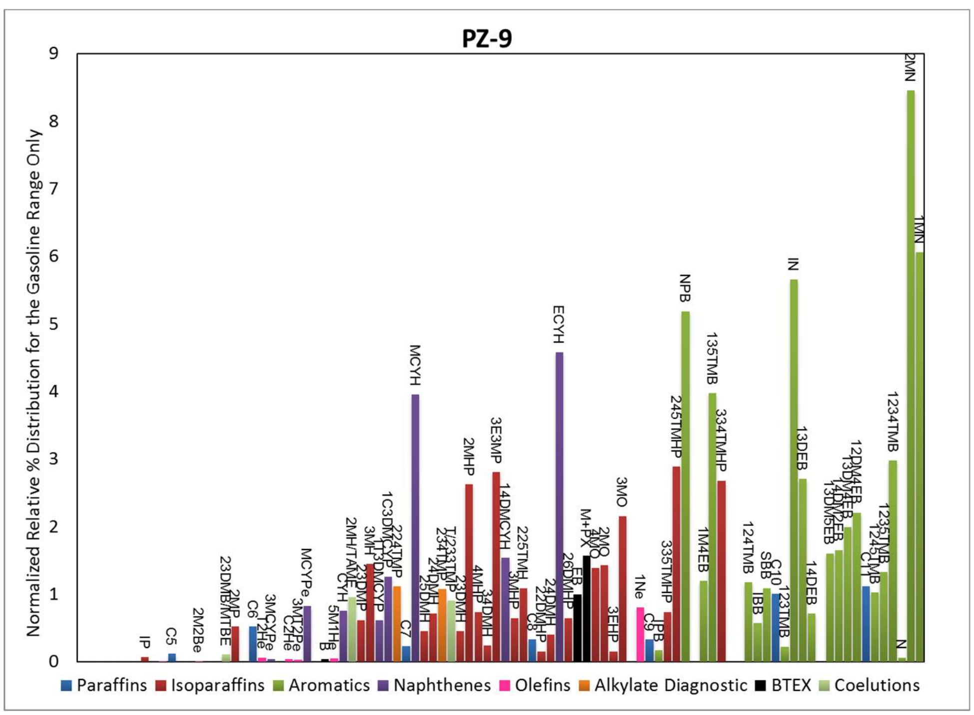


Figure 5: Selective ion (m/z 113) mass chromatogram for identification isoprenoids (highly branched alkanes).

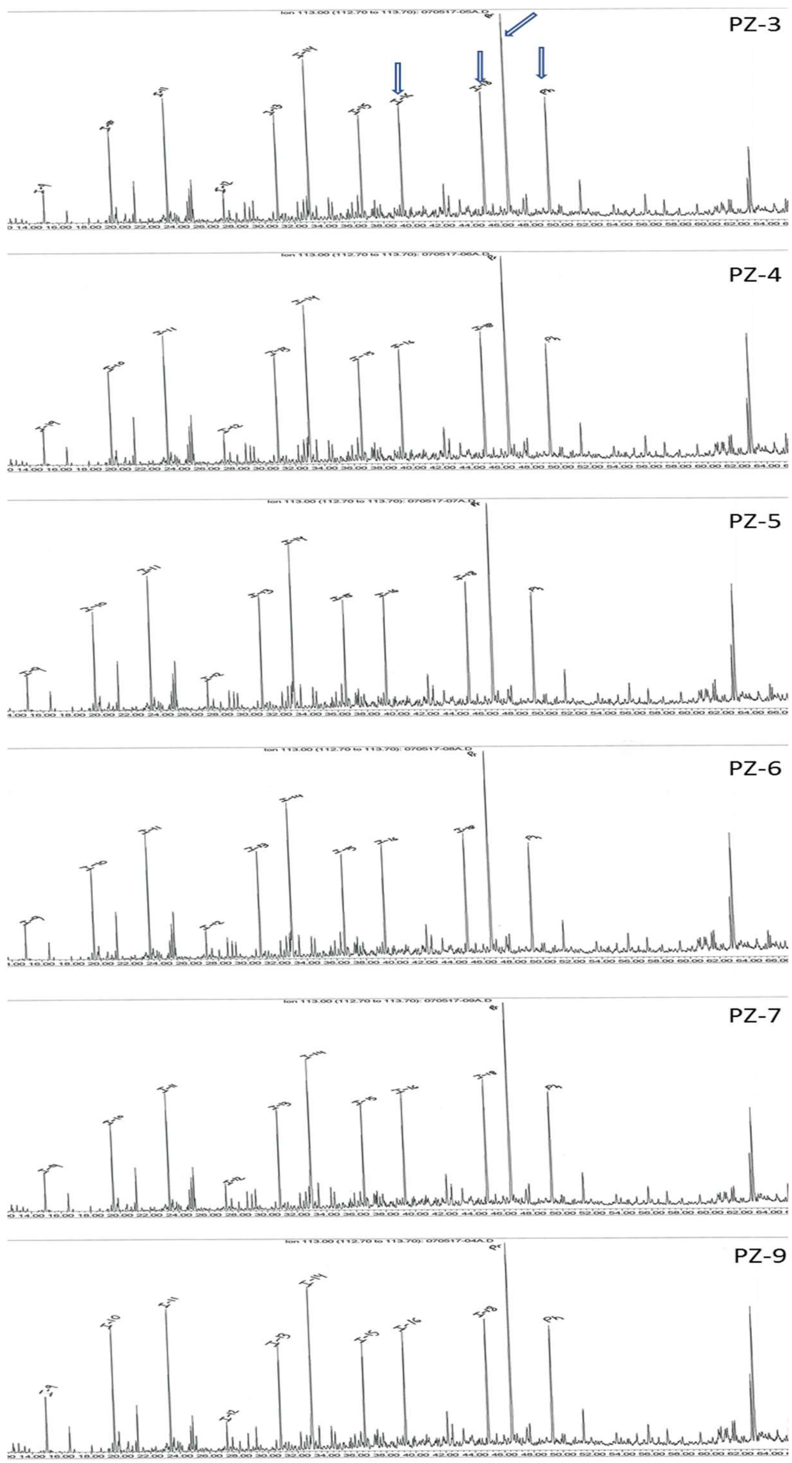
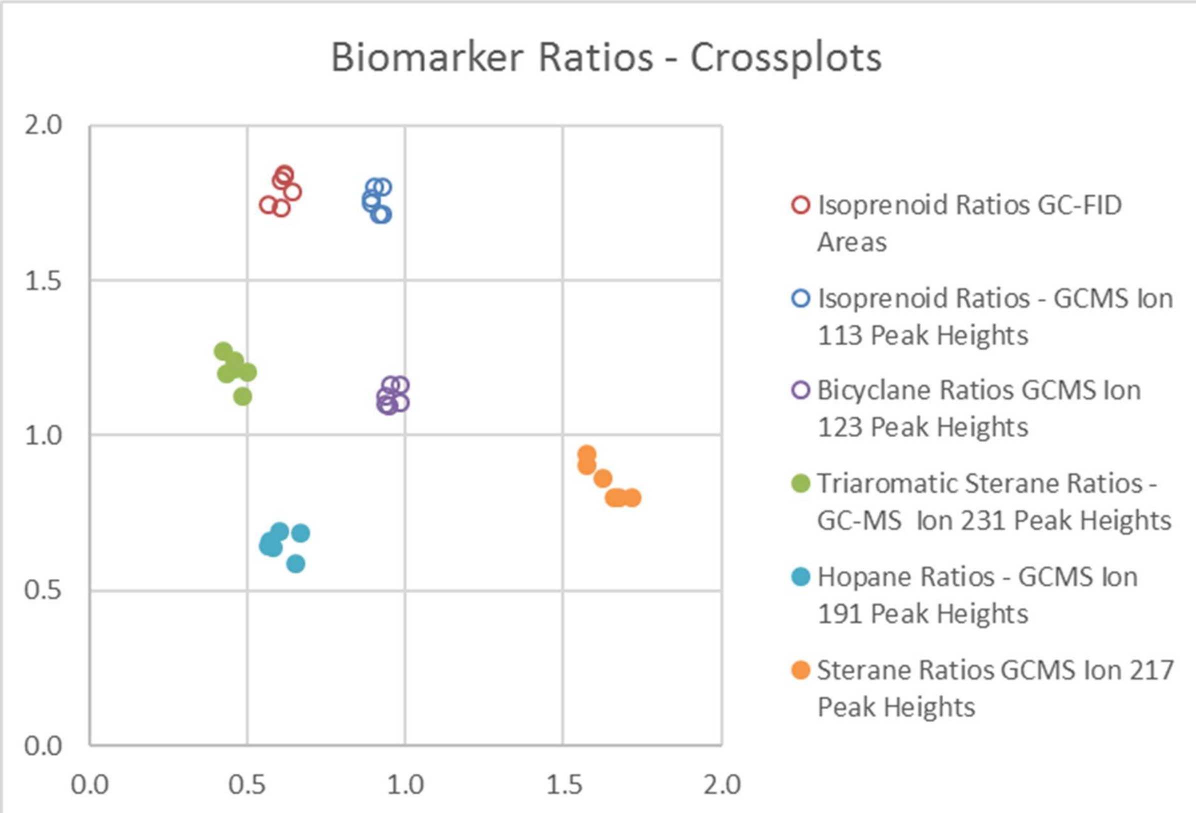


Figure 6: Source diagnostic biomarker cross plots. Open circles are ratios of biomarkers in the diesel/middle distillate range and solid circles are ratios of biomarkers in the heavier oils



Isoprenoid Ratios:
- Farnesane (iC16)/Norpristane (iC_{18})
- Pristane/Phytane

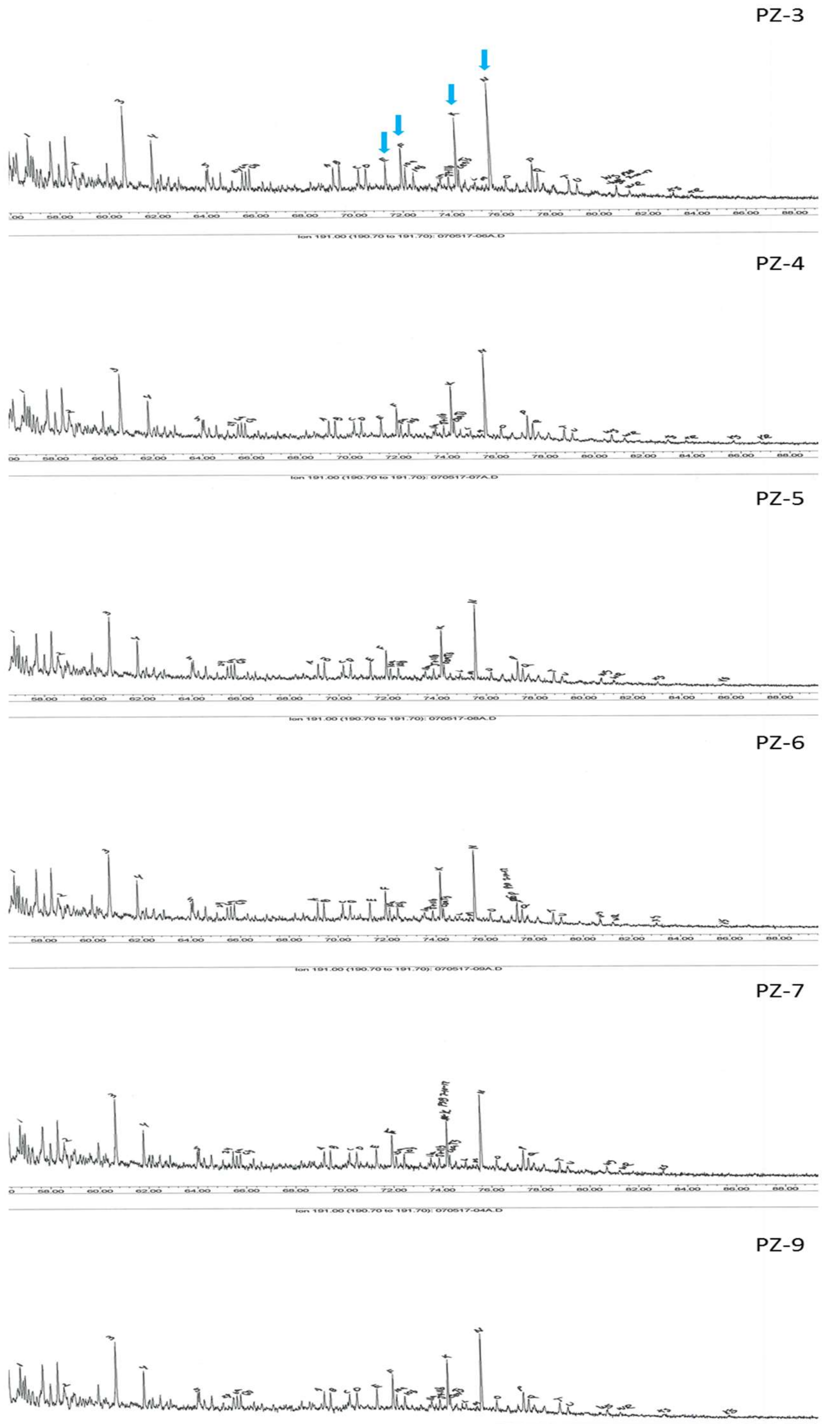
Bicyclane Ratios:
- $C_{15}H_{28}$ Bicyclic Sesquiterpanes
- 8β(H)Drimane/8β(H)Homodrimane

Triaromatic Sterane Ratios:
- 20S C26 Triaromatic Sterane/20R C26 + 20S C27 Triaromatic Steranes
- 20S C28 Triaromatic Sterane/20R C28 Triaromatic Sterane

Hopane Ratios:
- 18α-22,29,30-Trisnorneohopane (Ts)/17α-22,29,30-Trisnorhopane
- 17α,21β-30-Norhopane/17α,21β-Hopane

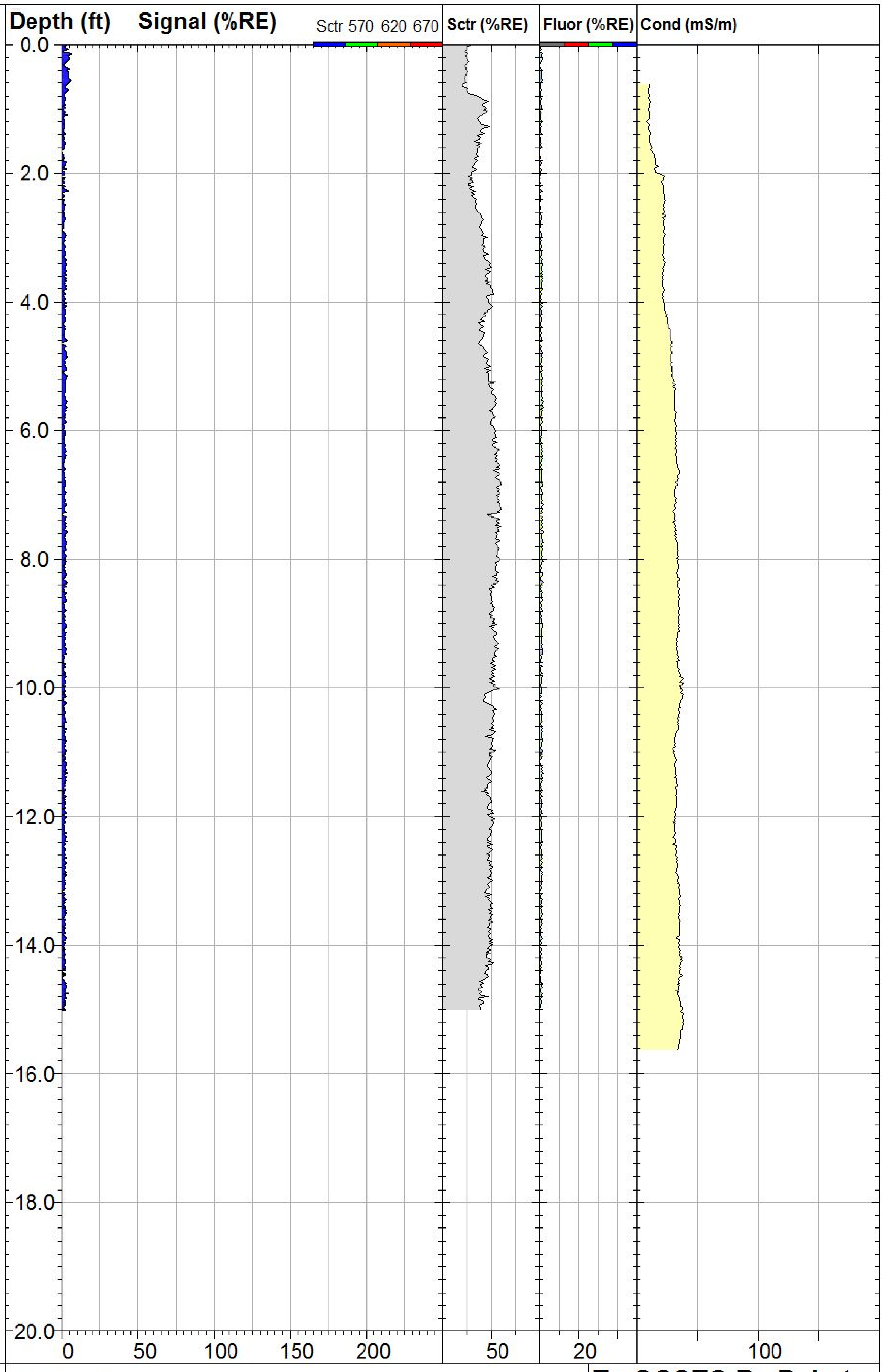
Sterane Ratios:
- 13β,17α-Diacholestane (20S)/13β,17α-Diacholestane (20R)
- 24-ethyl-14α-Cholestane (20S)/24-ethyl-14α,17β-Cholestane (20R)

Figure 7: Selective ion (m/z 191) mass chromatogram for identification of tri-, tetra, and pentacyclic terpanes.



Appendix D
LIF Results

Callouts



TG-01

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Site:	Y Coord.(Lat-N) / System:	Final depth:
CLINE AVE DITCH	**Unavailable / NA**	**15.01 ft**
Client / Job:	*X Coord.(Lng-E) / Fix:*	*Max signal:*
GHD / 160.17	**Unavailable / NA**	**6.6 %RE @ 0.14 ft**
Operator / Unit:	*Elevation:*	*Date & Time:*
SWM / TG1002	**Unavailable**	**2017-07-13 17:52 CDT**

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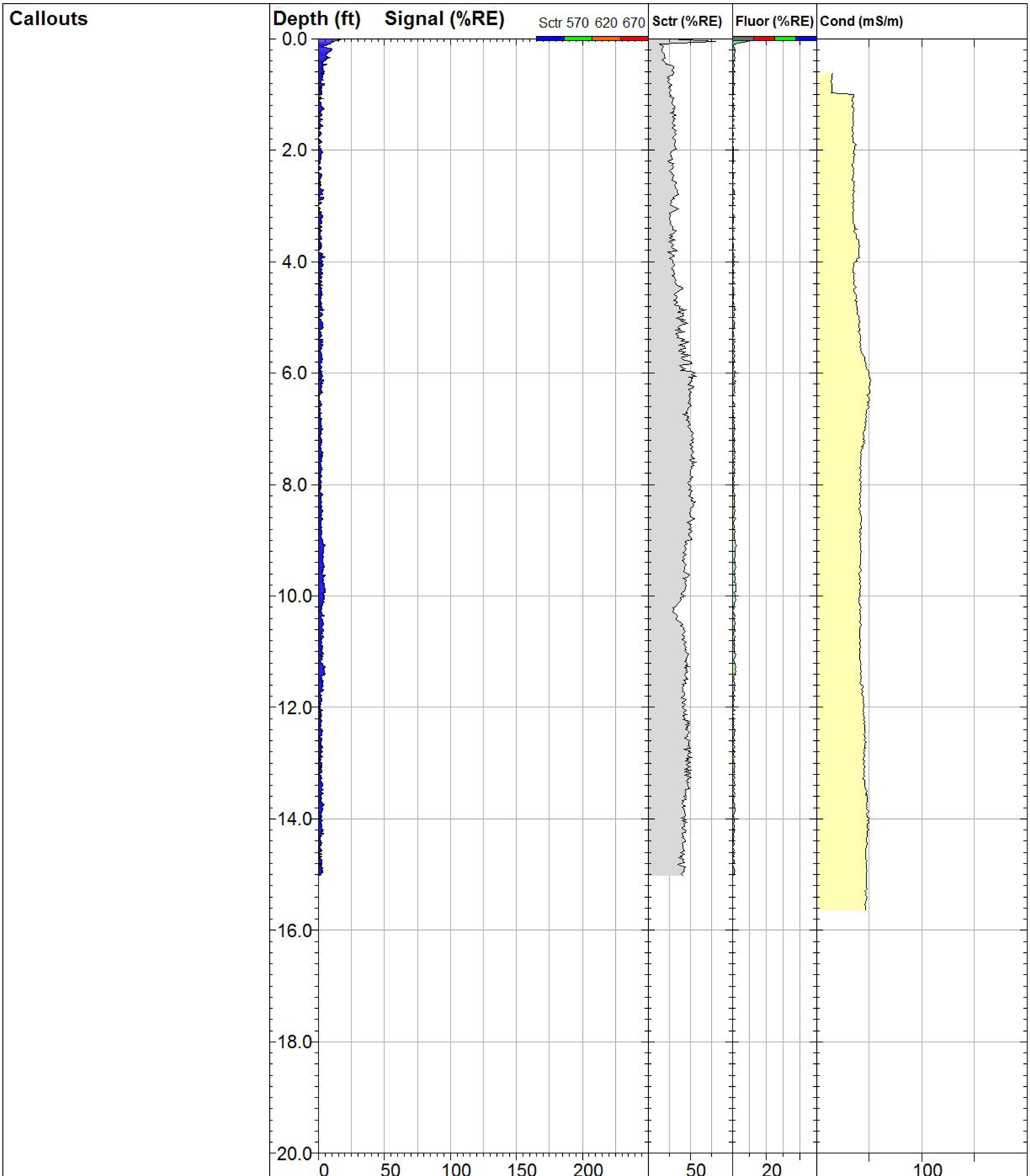

TG-02		**TarGOST® By Dakota** www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.01 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **16.9 %RE @ 0.01 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-13 17:26 CDT**

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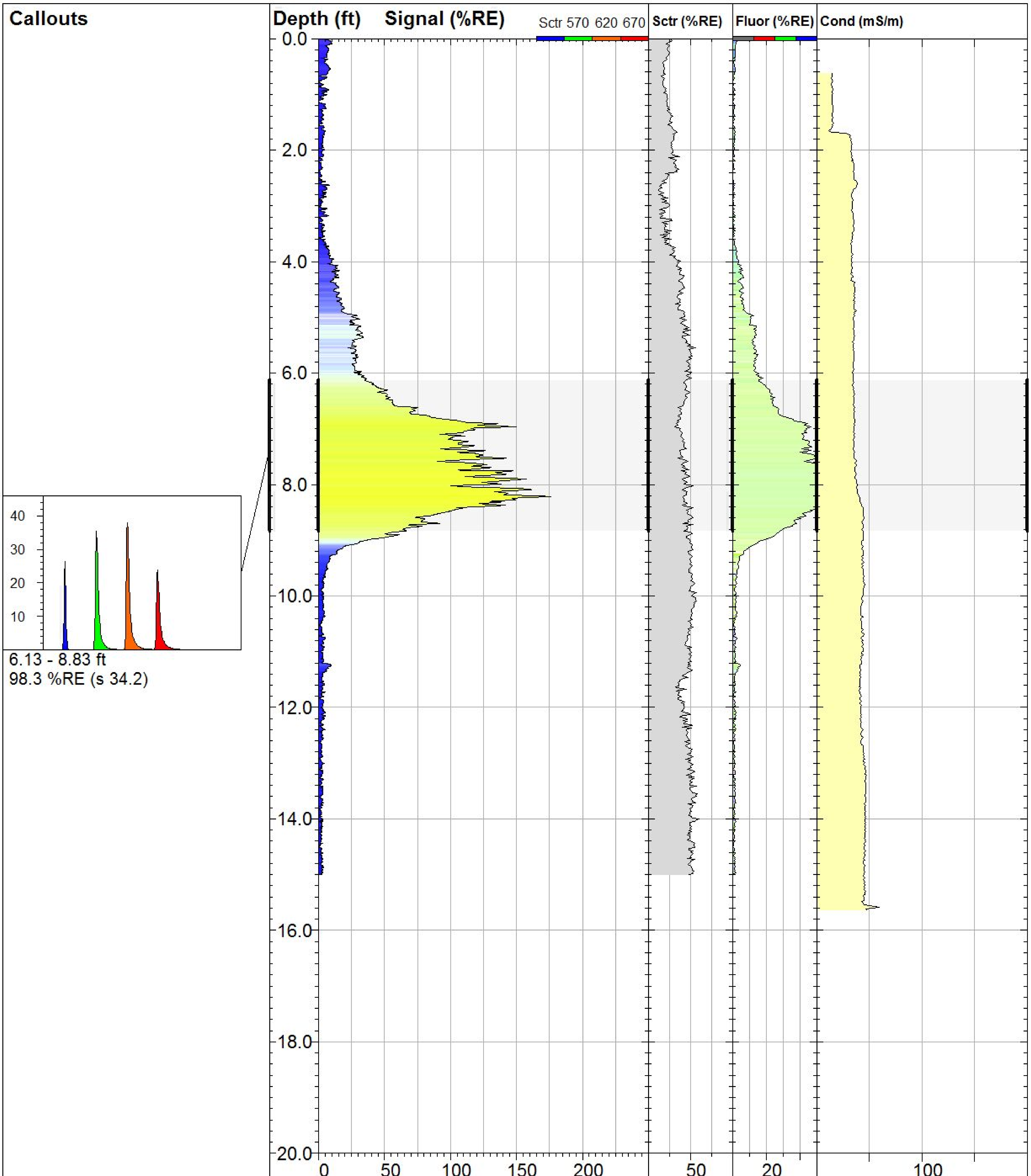

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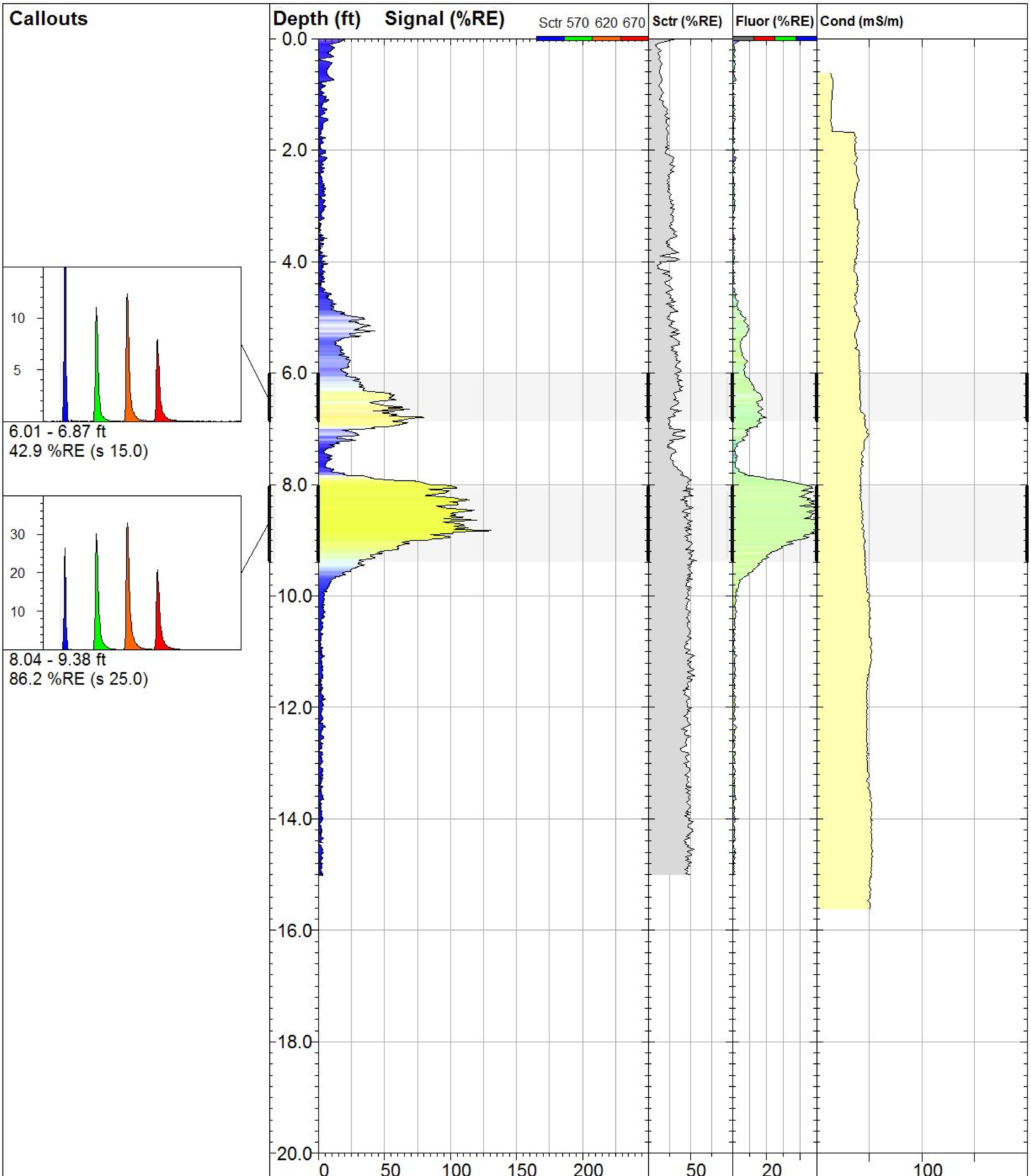
TG-03		**TarGOST® By Dakota** www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.00 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **177.6 %RE @ 8.21 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-13 17:02 CDT**



TG-04

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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.01 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **131.5 %RE @ 8.83 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-13 16:39 CDT**

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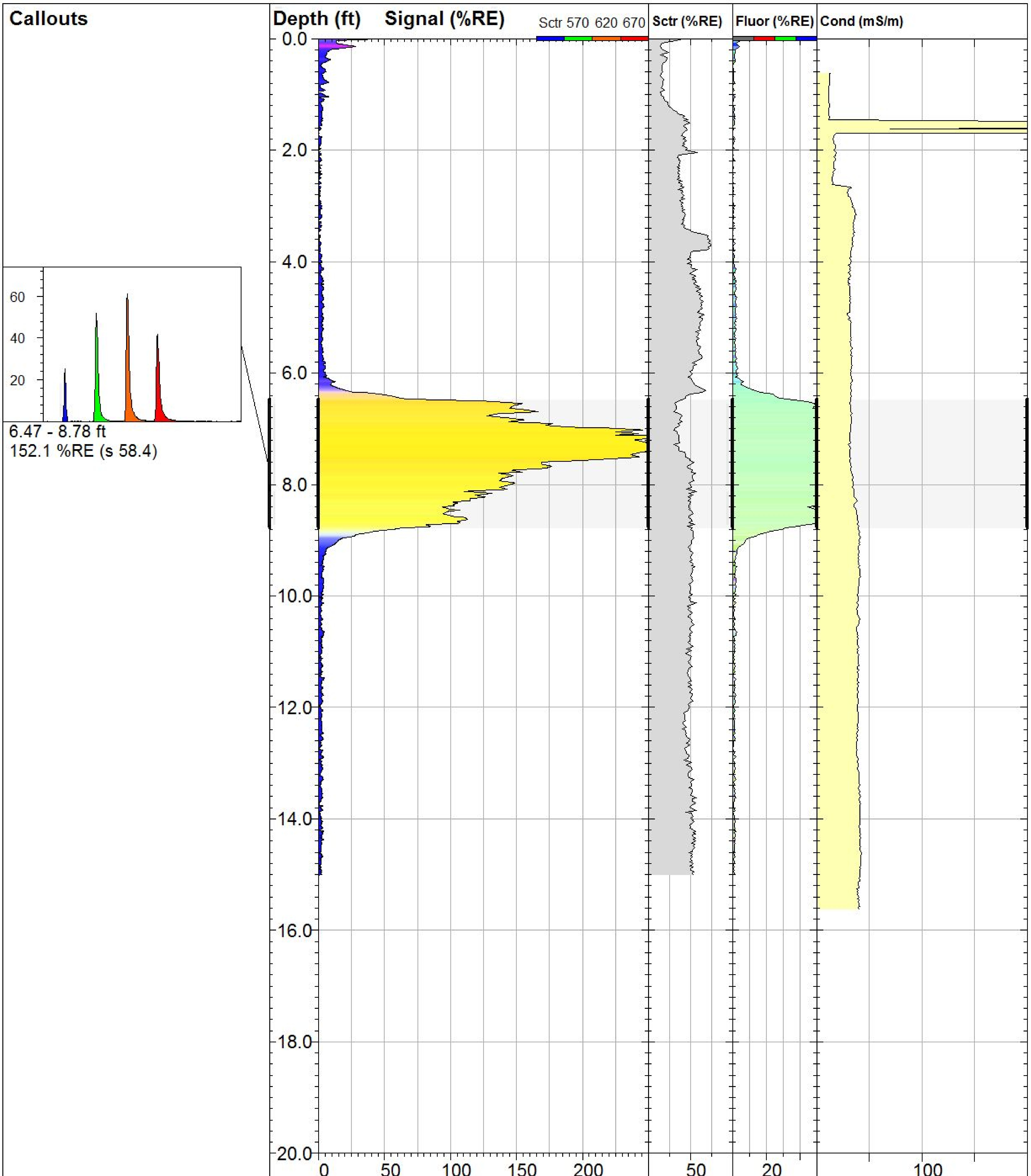

TG-05

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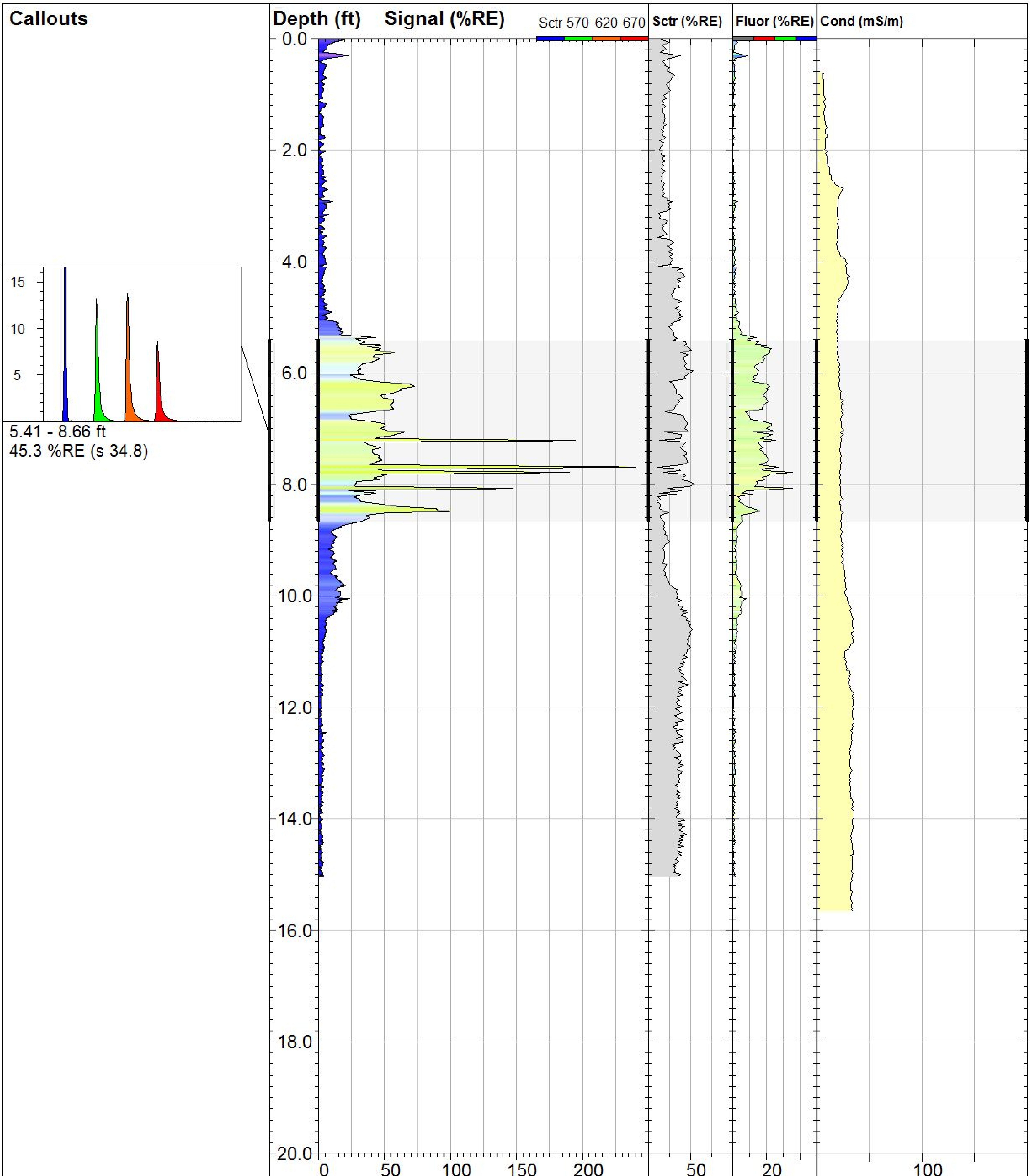
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.01 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **301.9 %RE @ 7.29 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-13 16:12 CDT**



TG-06

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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.02 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **243.0 %RE @ 7.68 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-13 15:23 CDT**

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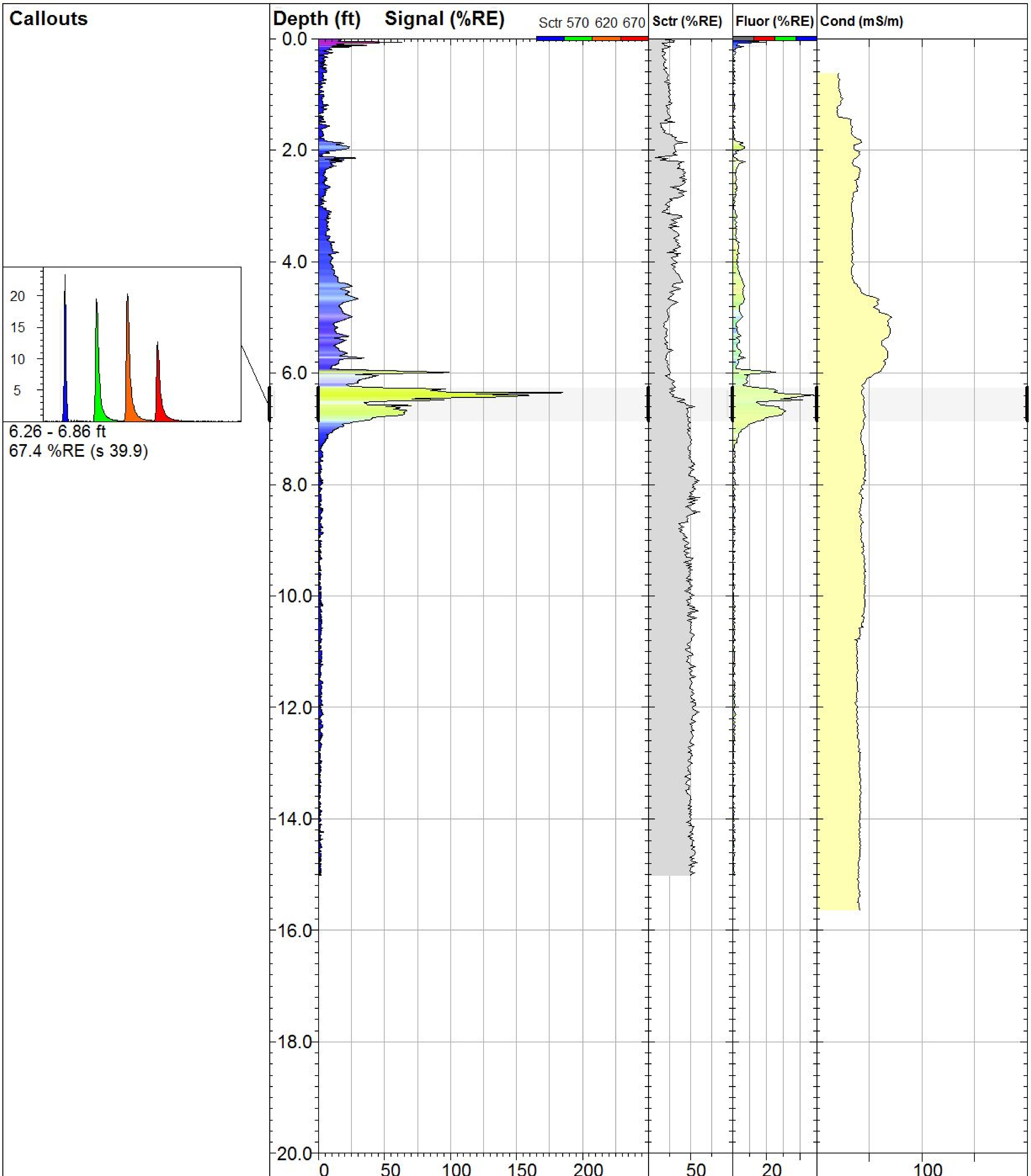

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TG-07

TarGOST® By Dakota
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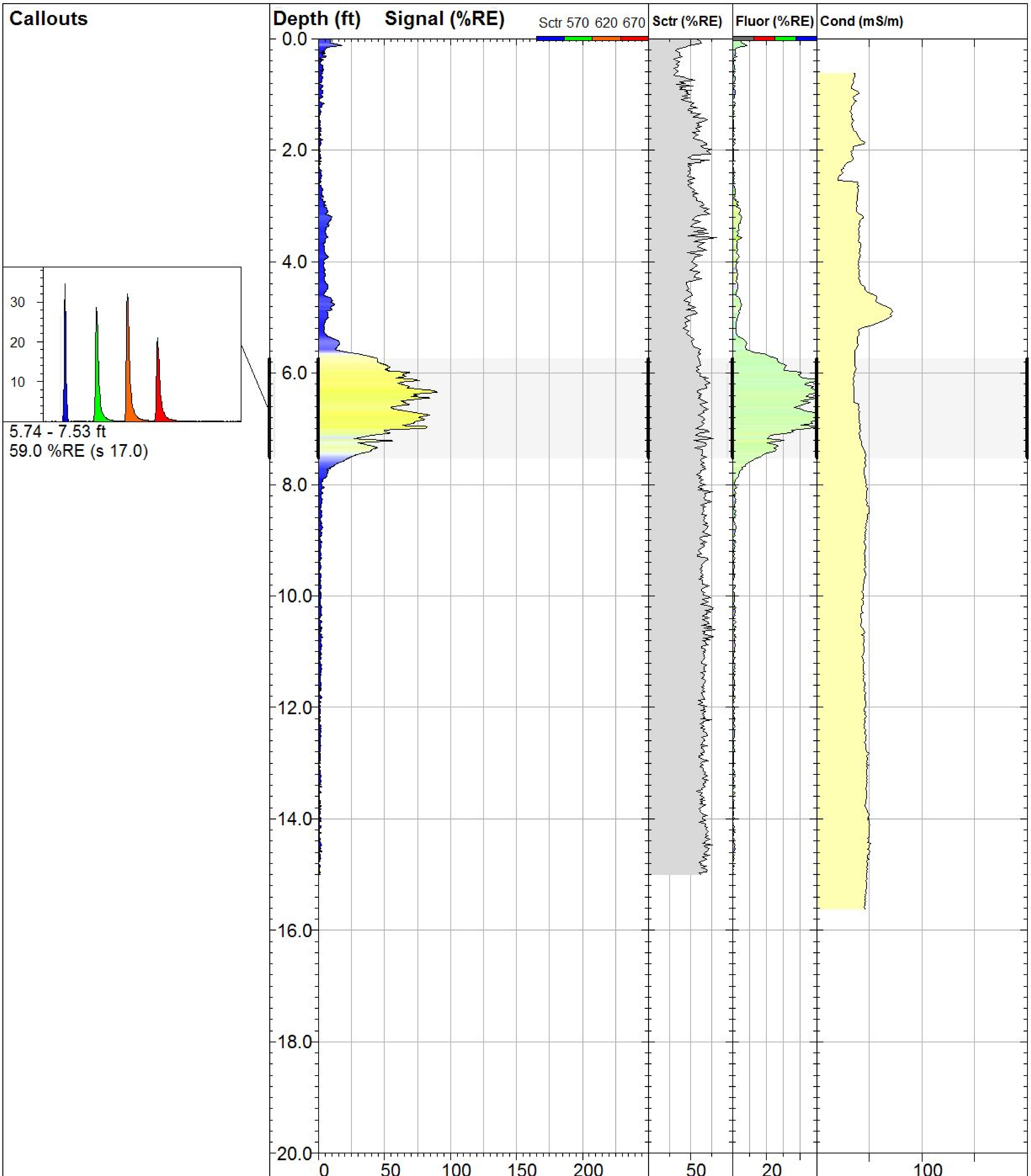
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.02 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **188.5 %RE @ 6.35 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-13 14:56 CDT**



TG-08

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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.00 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **90.0 %RE @ 6.35 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-13 14:29 CDT**

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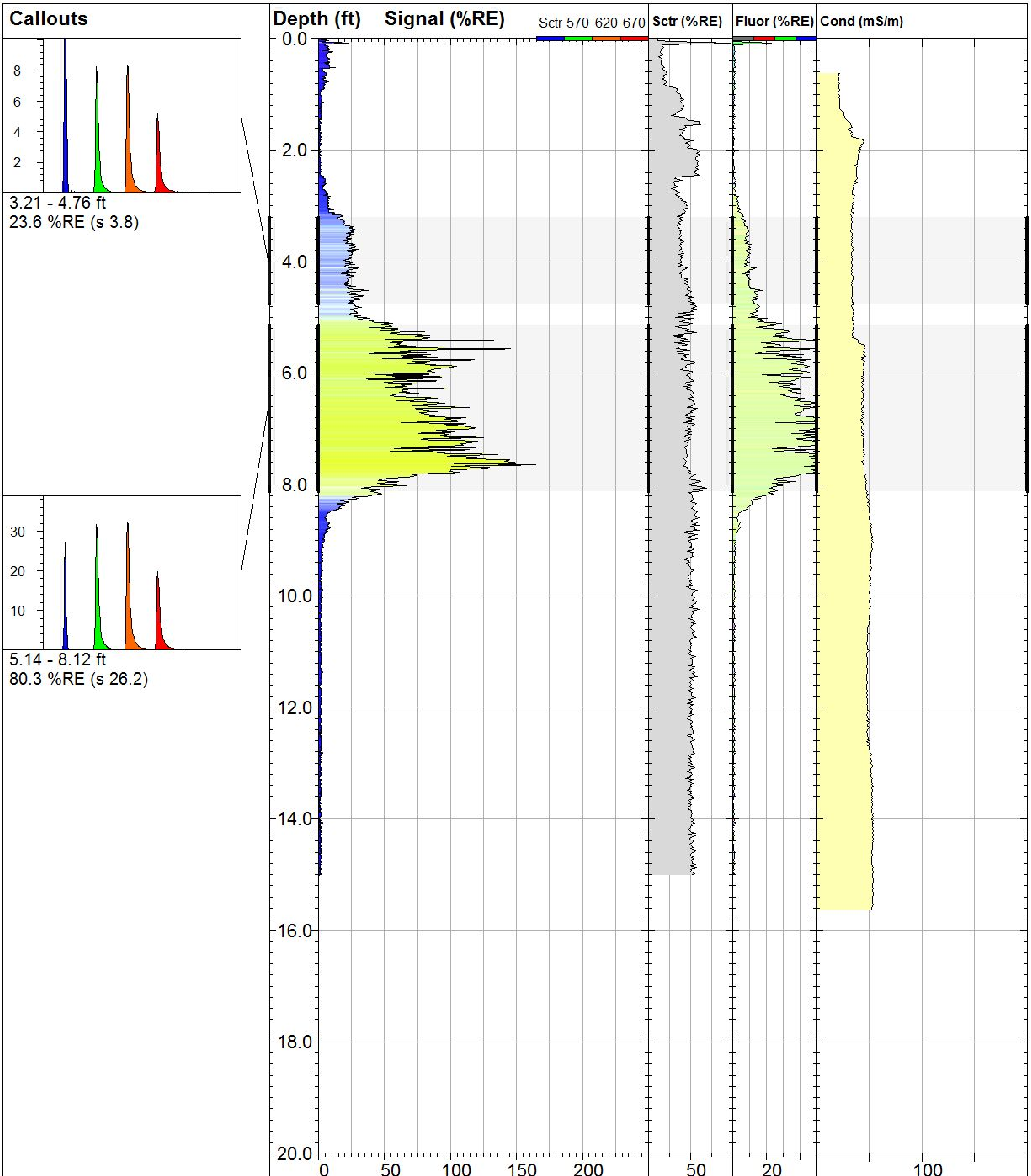

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TG-09

TarGOST® By Dakota
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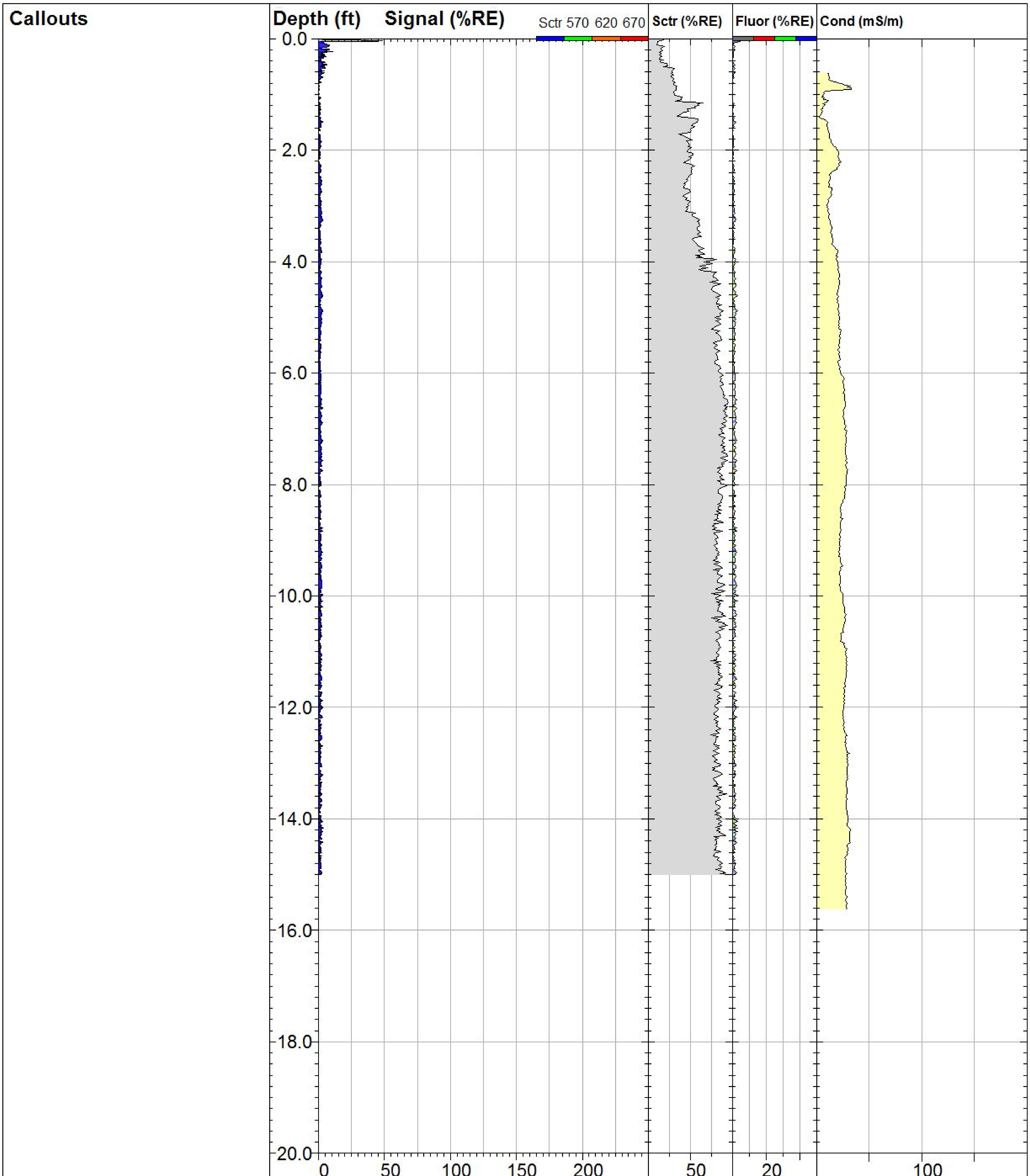
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.00 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **166.2 %RE @ 7.65 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-13 13:37 CDT**



TG-10		TarGOST® By Dakota www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.00 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **49.1 %RE @ 0.03 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-11 13:58 CDT**

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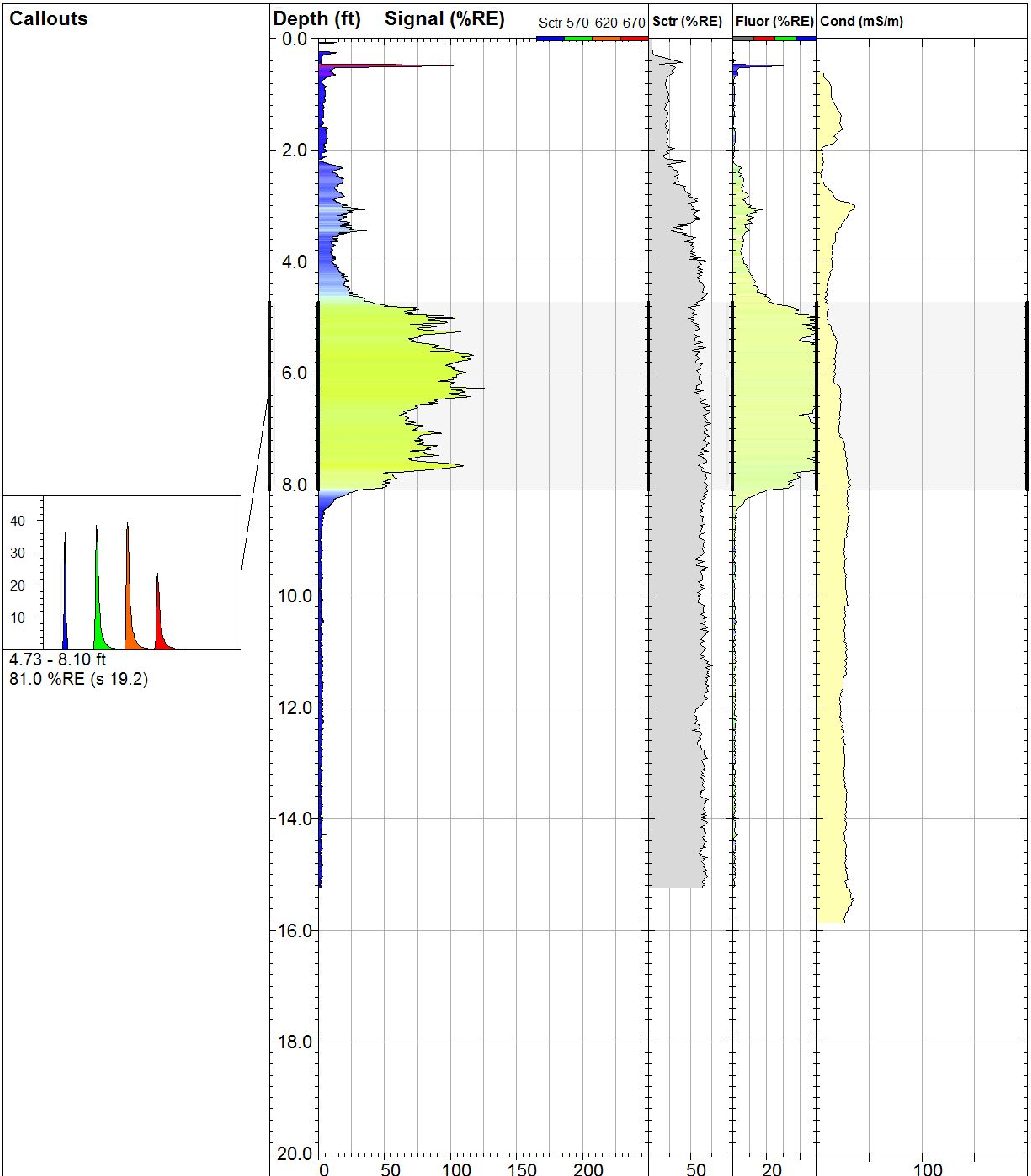

TG-11

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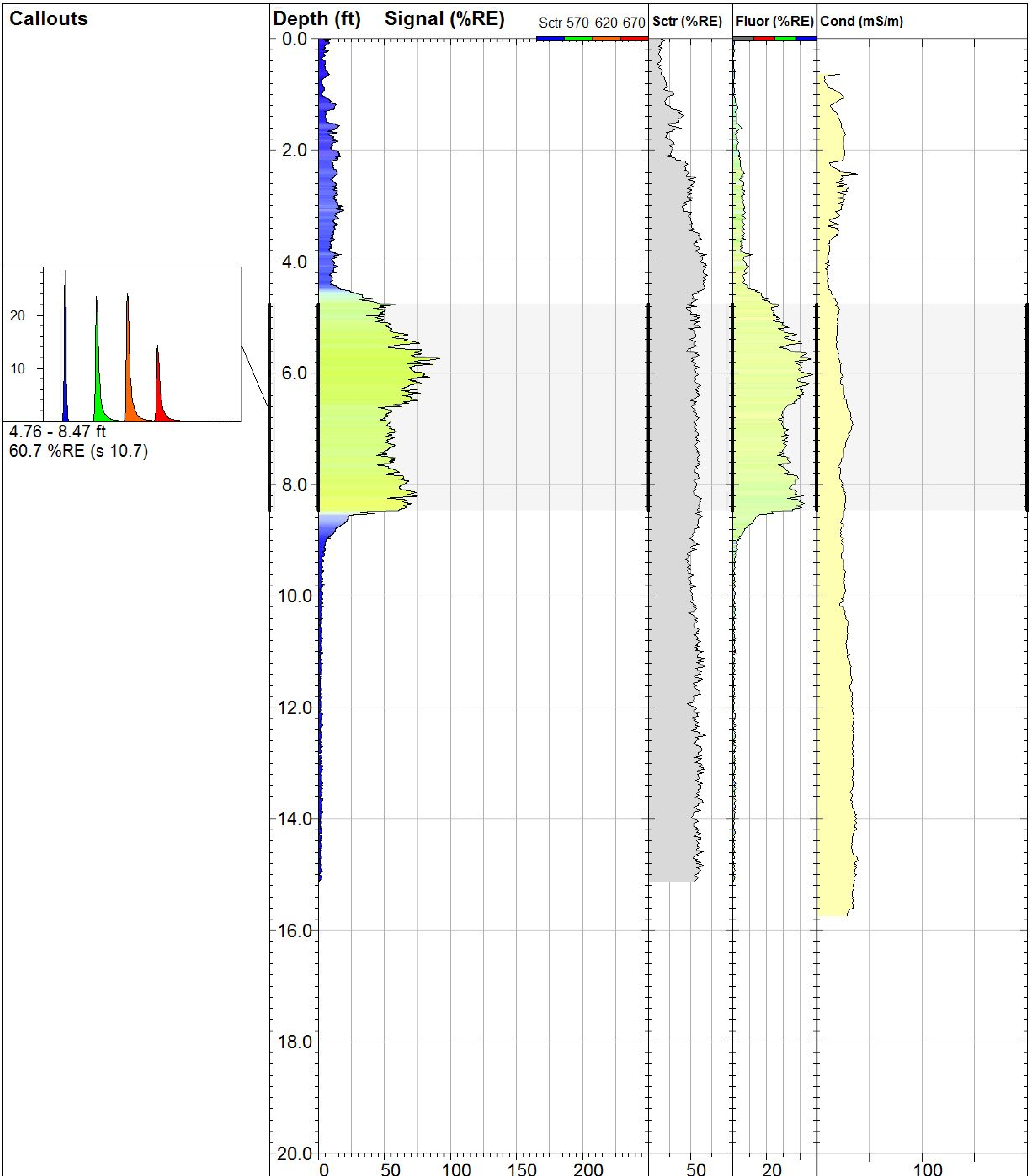
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.25 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **127.1 %RE @ 6.27 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-11 13:24 CDT**



TG-12

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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.12 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **91.8 %RE @ 5.74 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-11 12:57 CDT**

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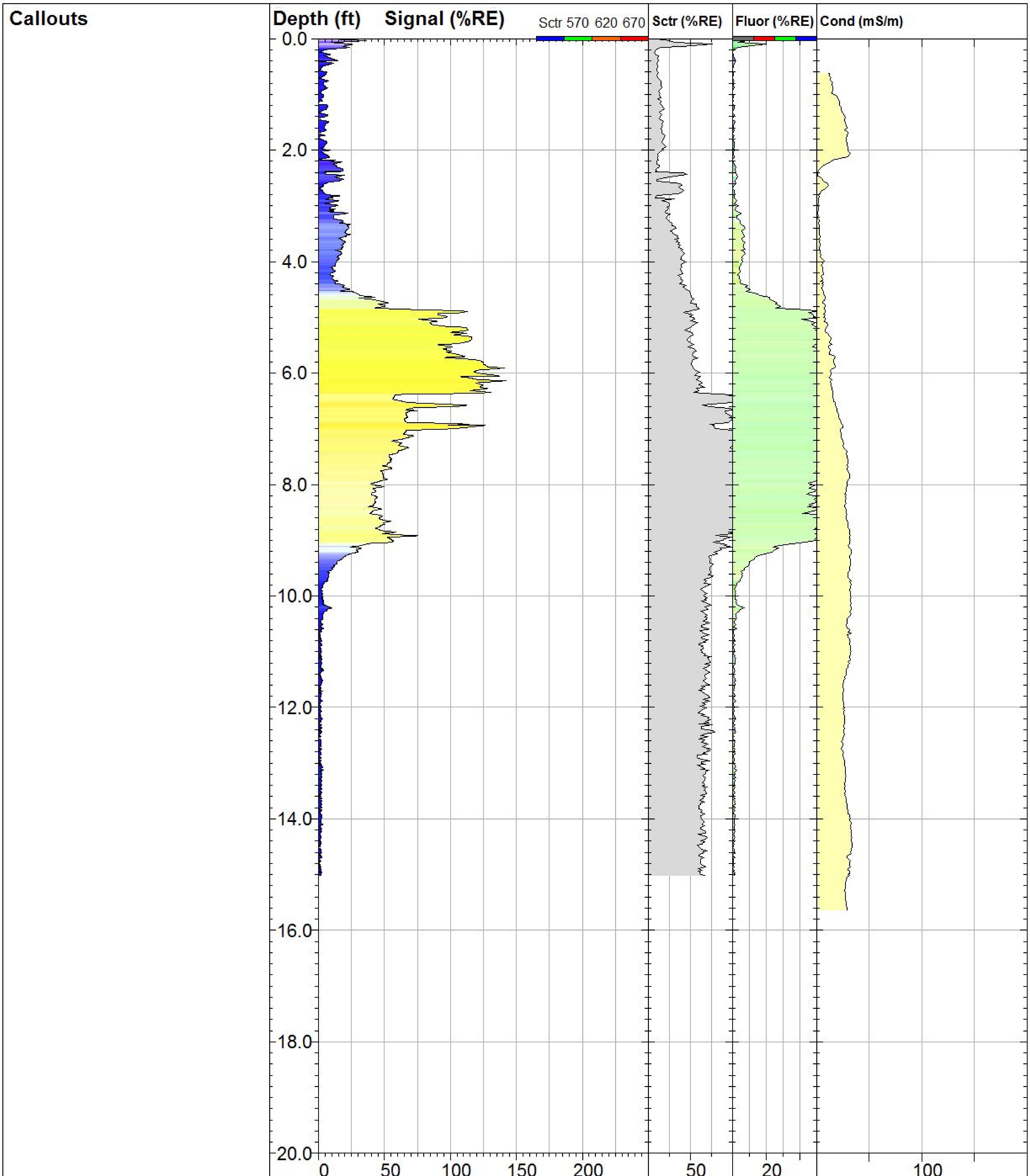

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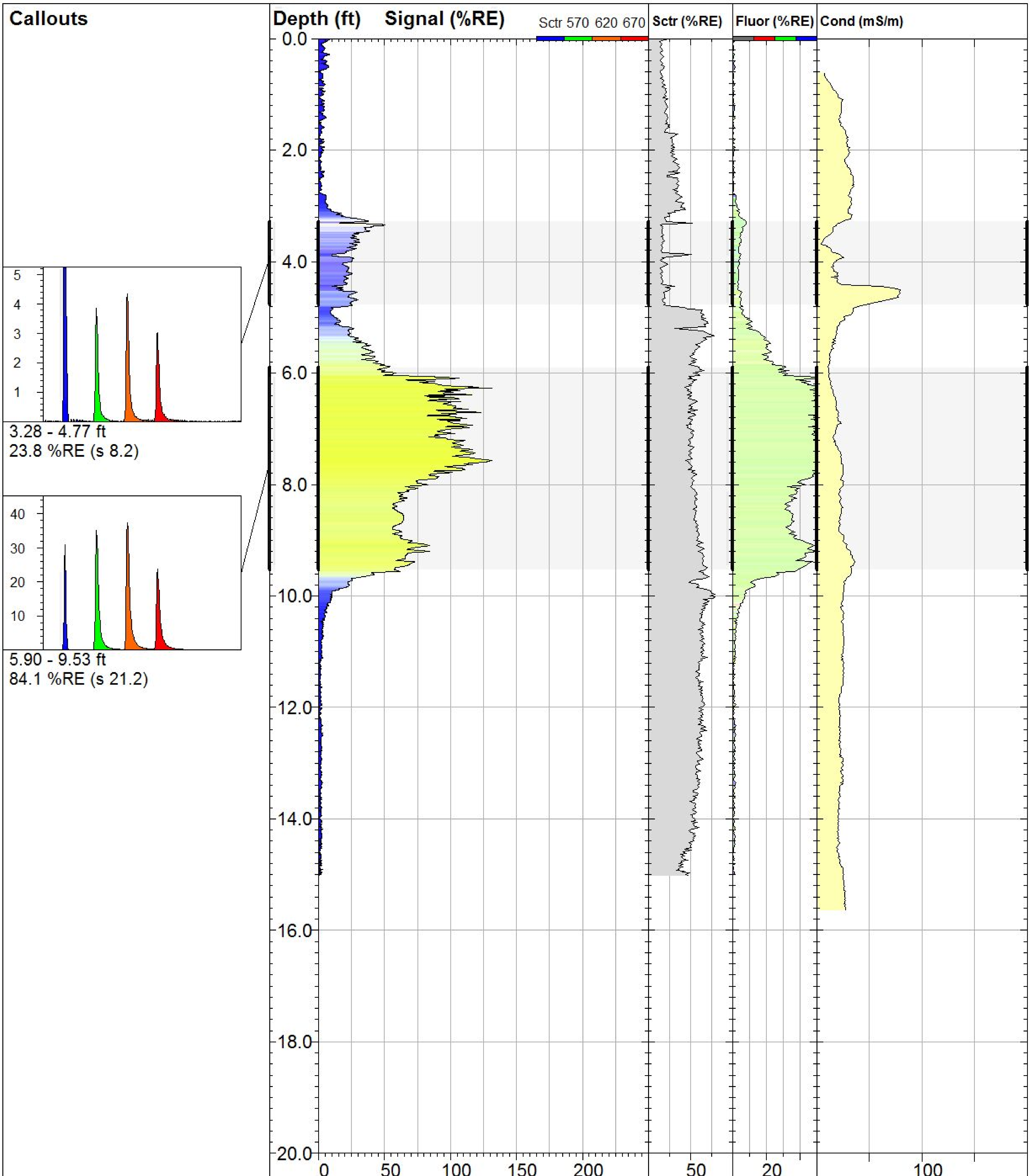
TG-13		TarGOST® By Dakota www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.01 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **142.4 %RE @ 6.14 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-11 11:30 CDT**



TG-14

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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.01 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **131.9 %RE @ 6.27 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-11 10:57 CDT**

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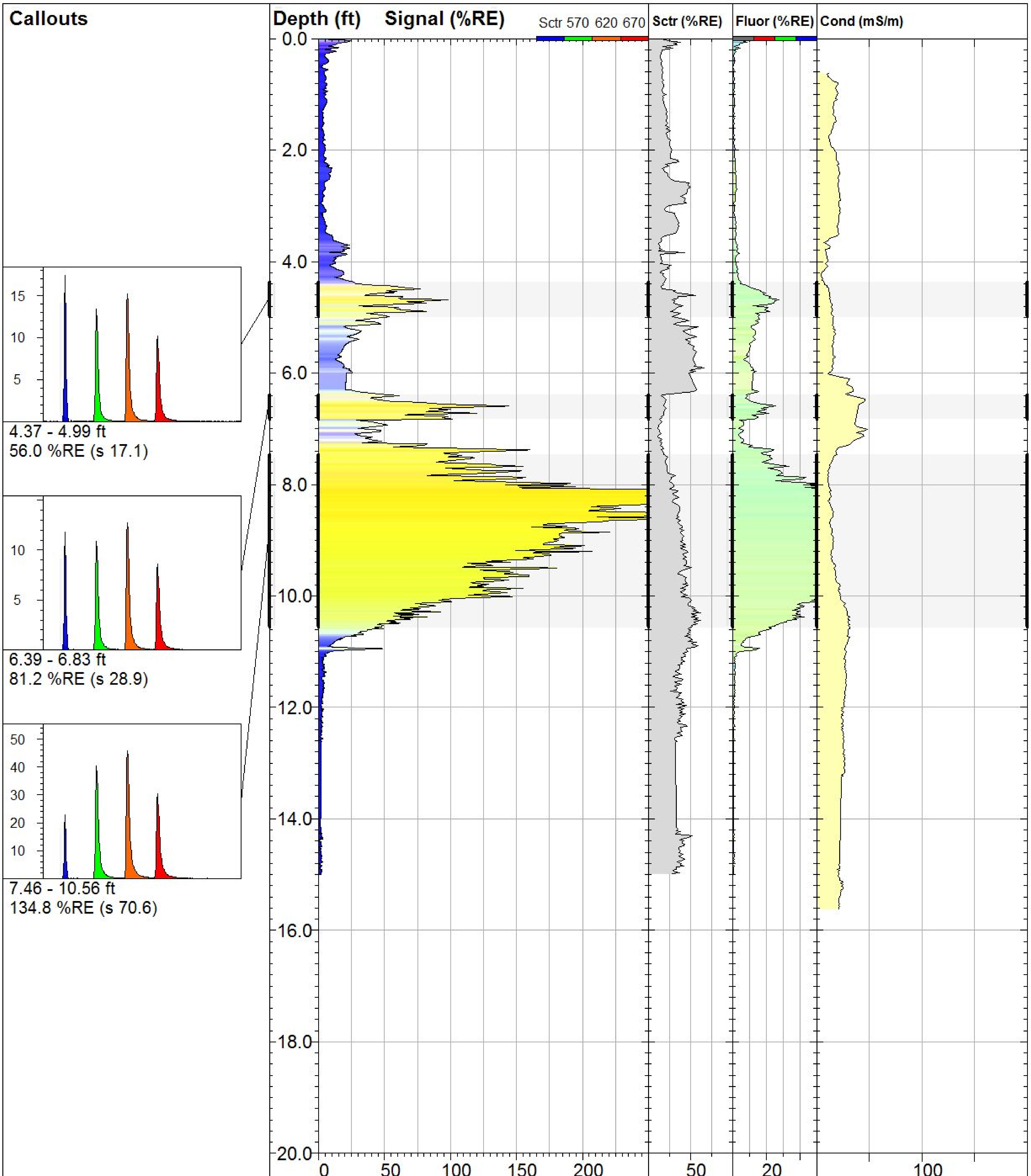

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TG-15

TarGOST® By Dakota
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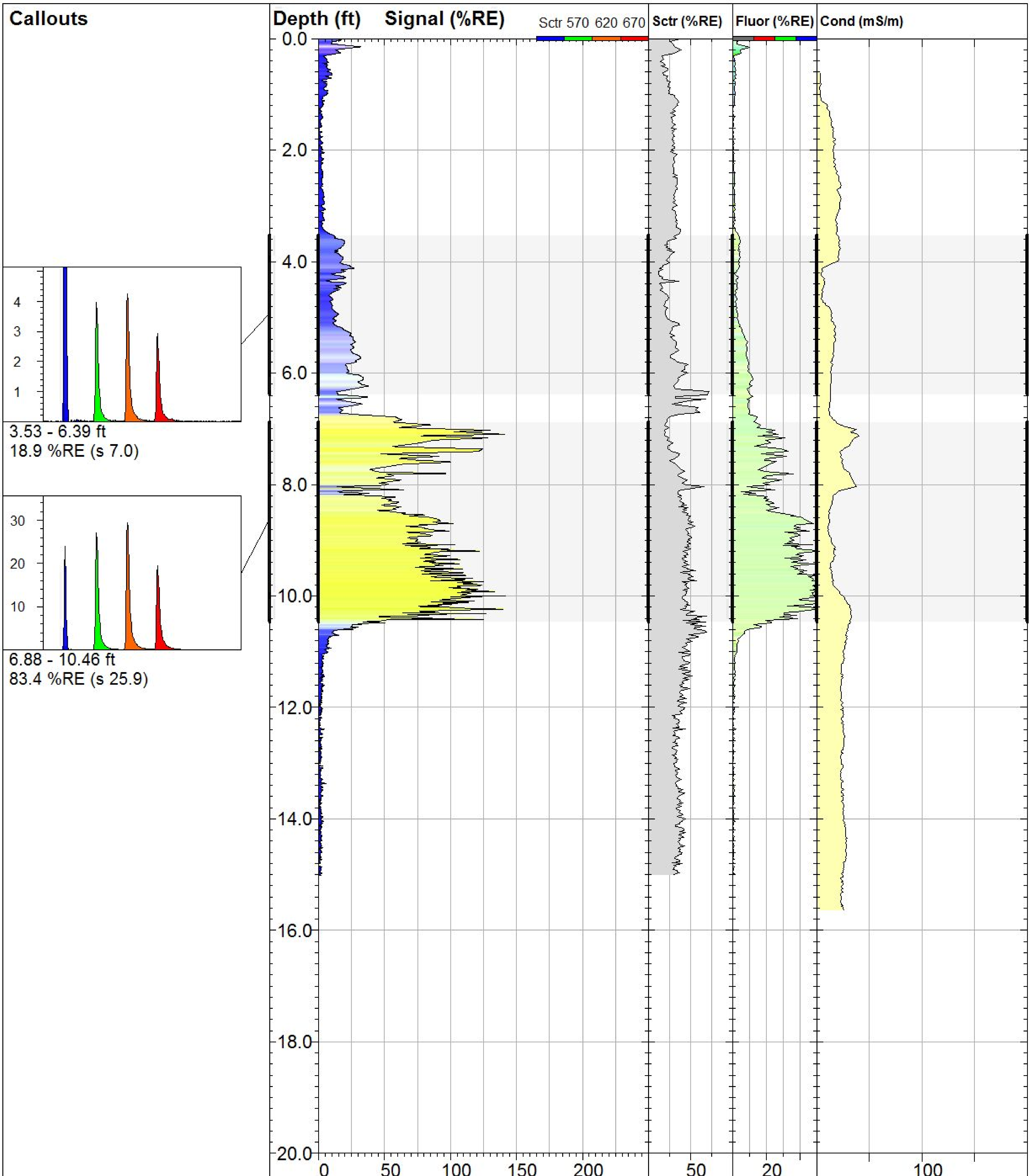
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.00 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **386.0 %RE @ 8.31 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-11 10:28 CDT**



TG-16

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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.01 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **141.9 %RE @ 10.00 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-11 09:53 CDT**

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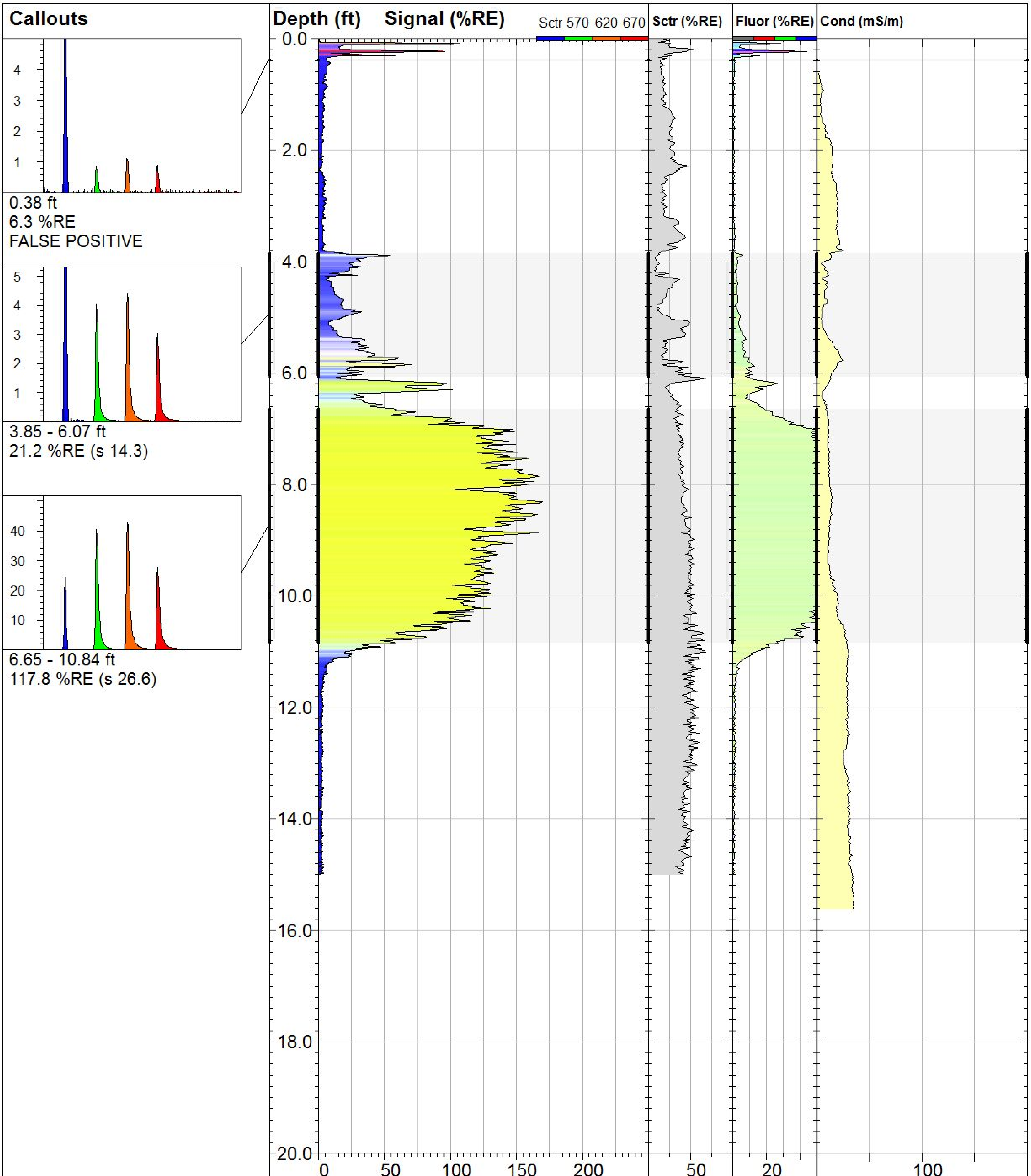

TG-17		**TarGOST® By Dakota** www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.00 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **169.5 %RE @ 8.31 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-11 09:26 CDT**

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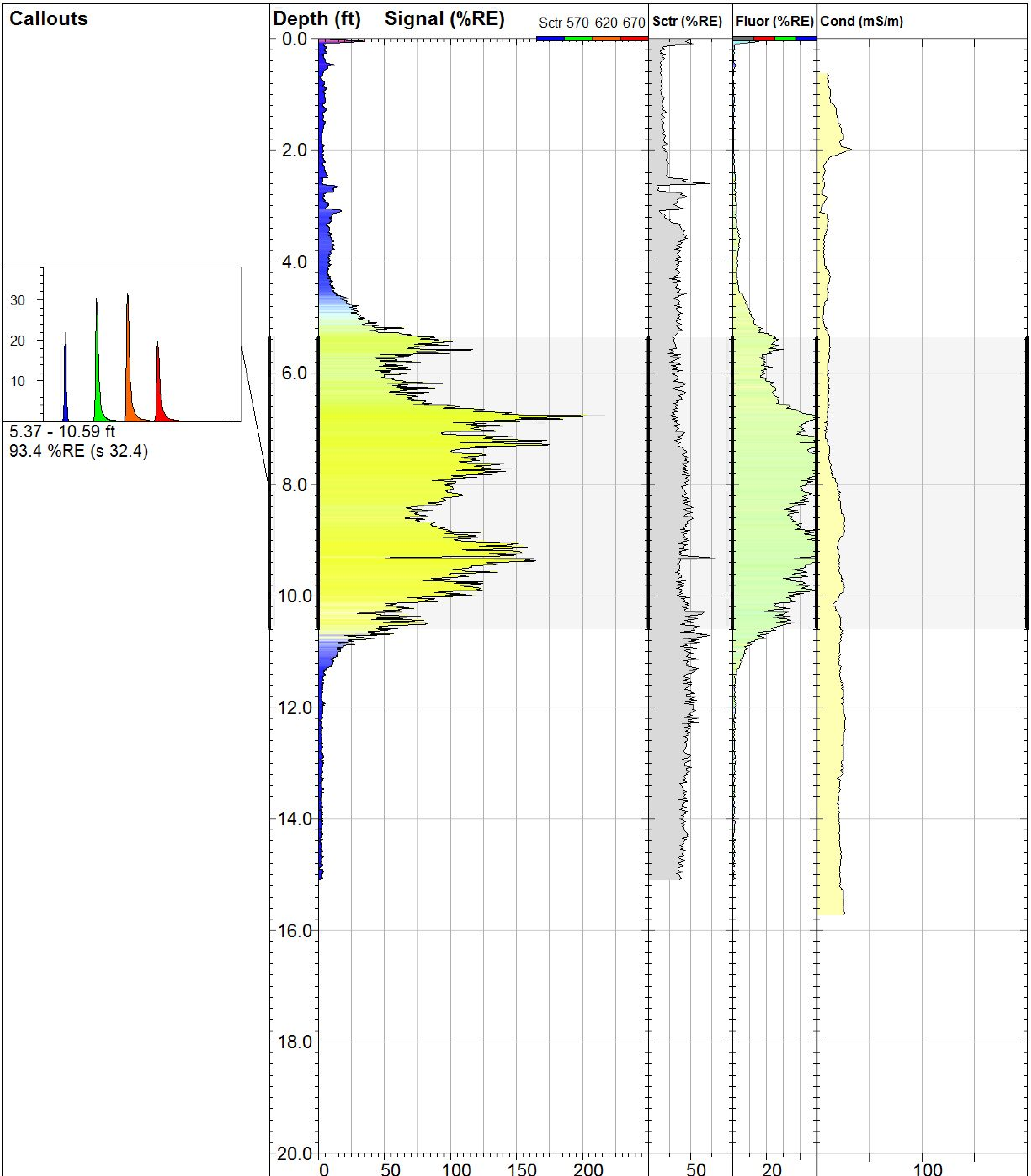

TG-18		TarGOST® By Dakota www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.09 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **217.7 %RE @ 6.77 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-11 08:50 CDT**

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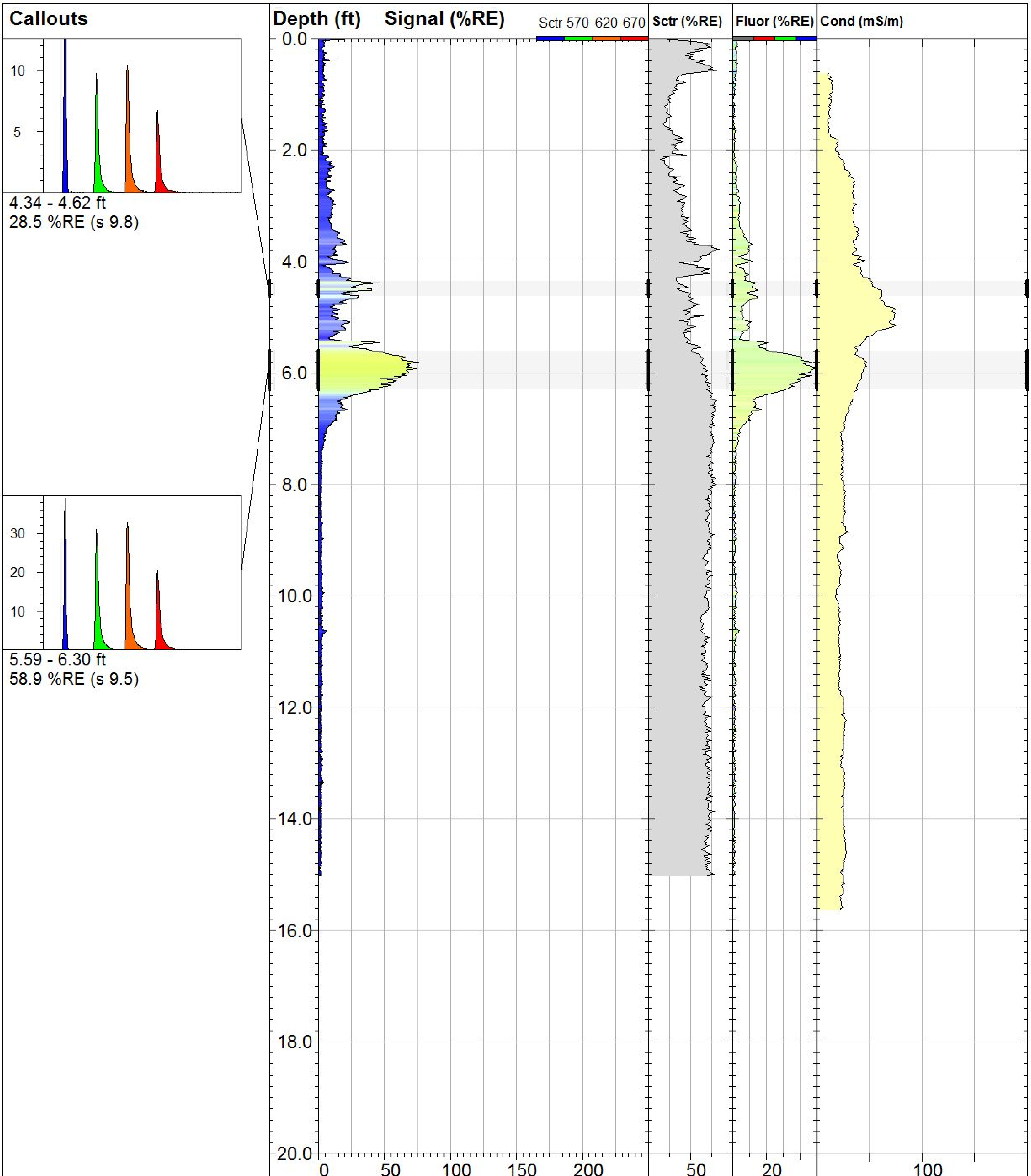
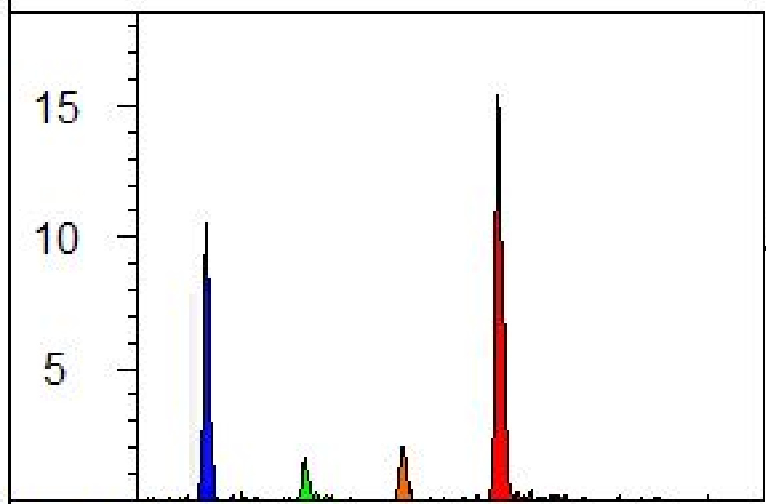


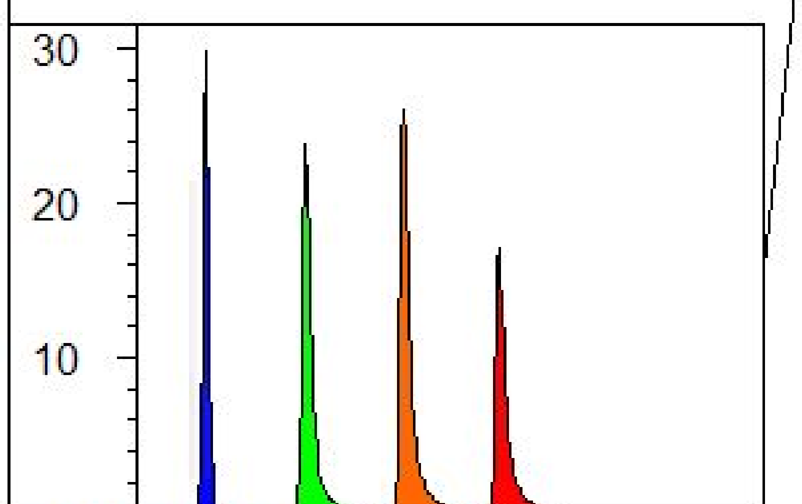
DAKOTA TECHNOLOGIES www.DakotaTechnologies.com	**TG-19**		**TarGOST® By Dakota** www.DakotaTechnologies.com
	Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.01 ft**
	Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **76.4 %RE @ 5.81 ft**
	Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-11 15:15 CDT**

Callouts

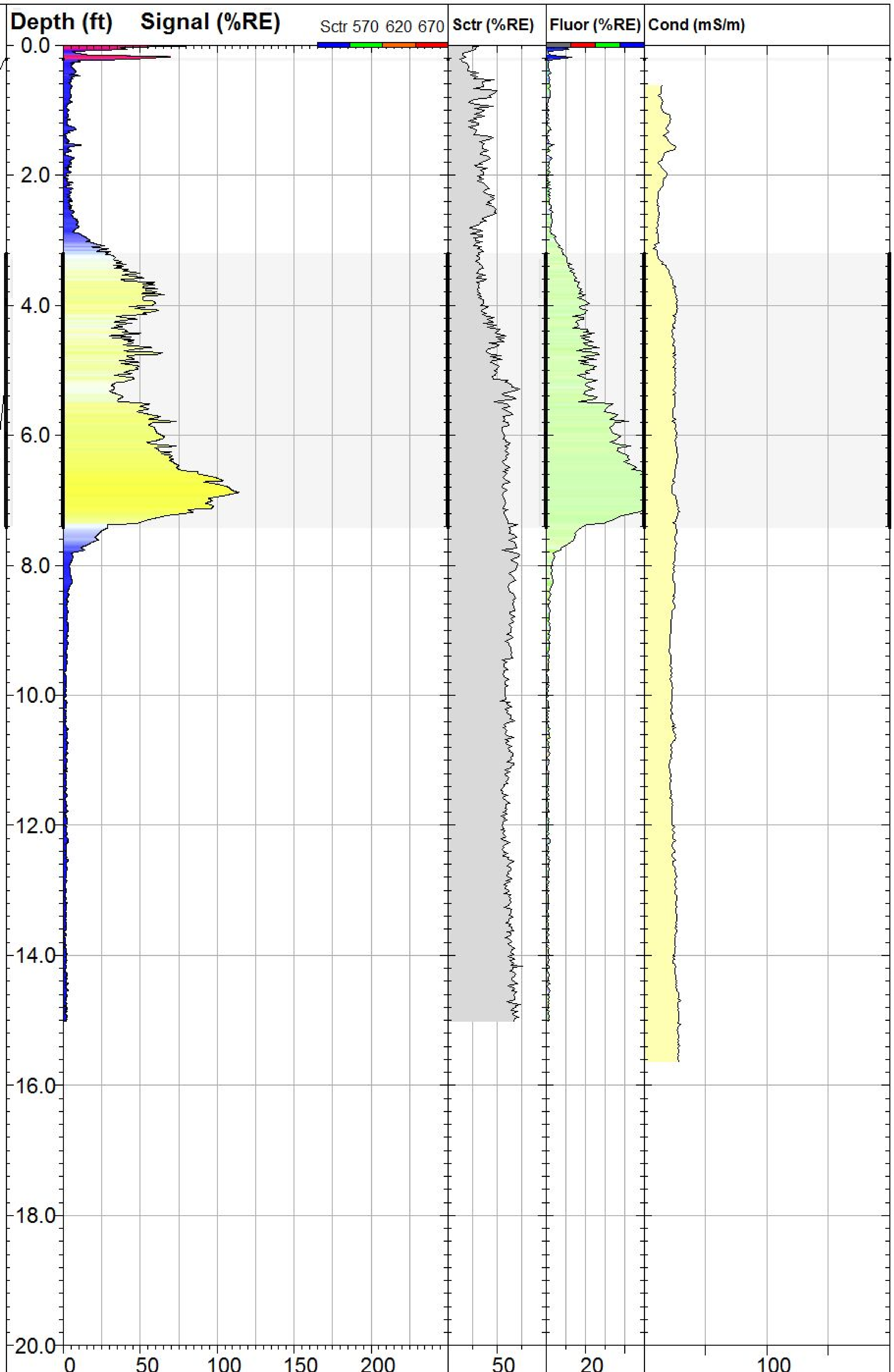


0.22 ft
43.9 %RE
FALSE POSITIVE

FALSE POSITIVE AT THE SURFACE IS LIKELY ORGANIC SWAMP MATERIAL



3.20 - 7.42 ft
55.1 %RE (s 19.0)



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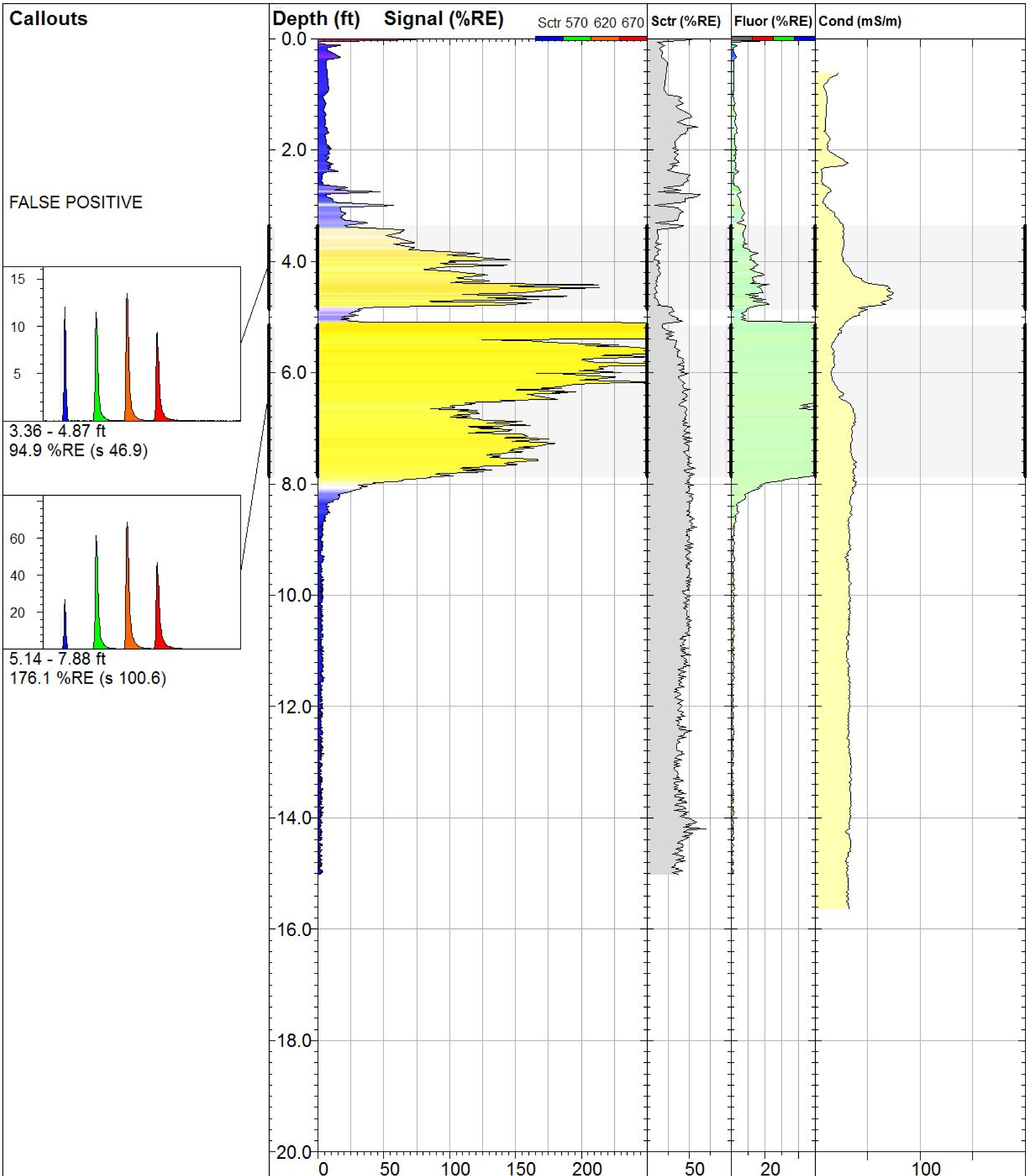
TG-20		TarGOST® By Dakota www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.01 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **114.0 %RE @ 6.88 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-11 15:52 CDT**



TG-21

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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.01 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **743.8 %RE @ 5.19 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-11 16:23 CDT**

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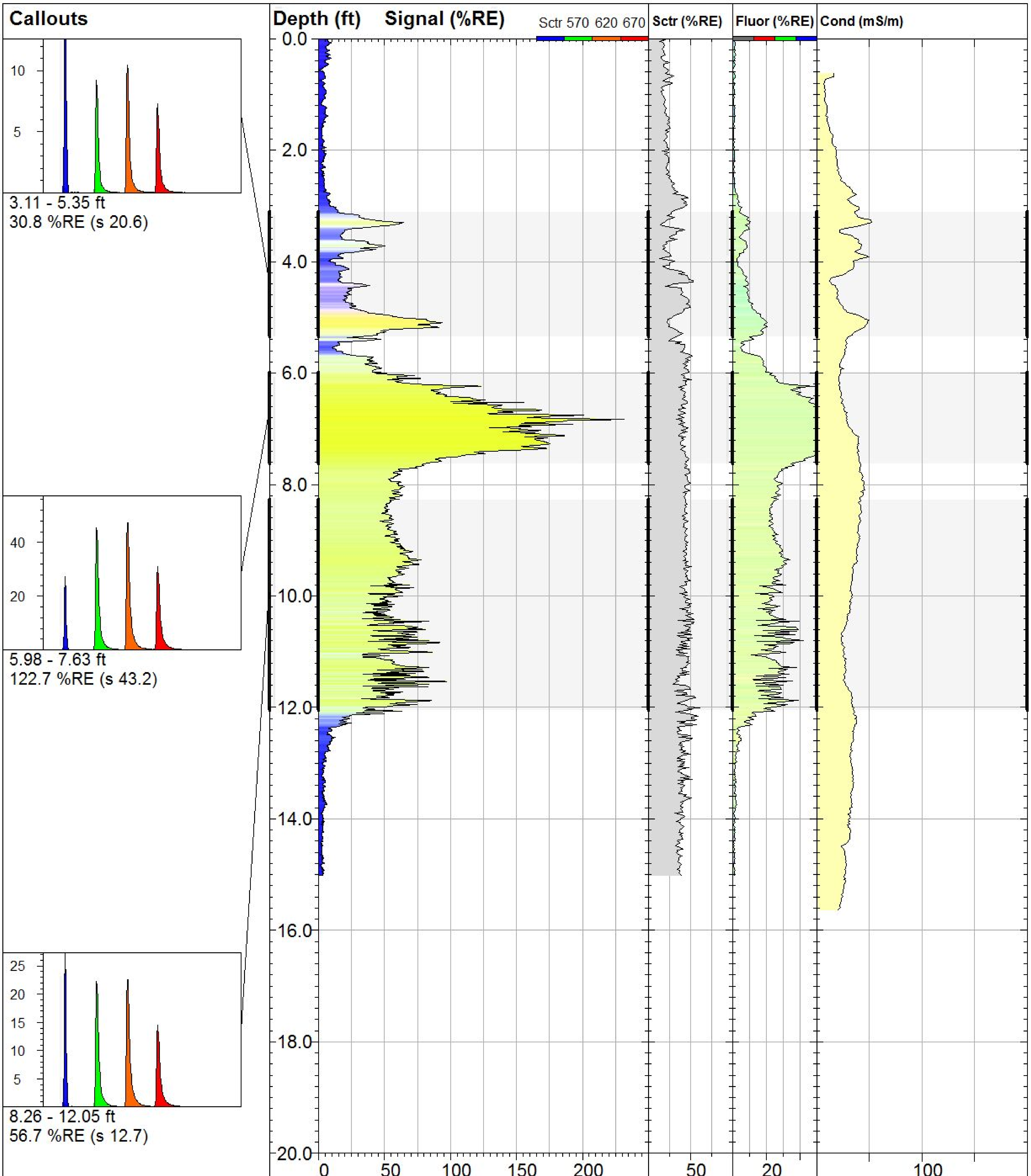

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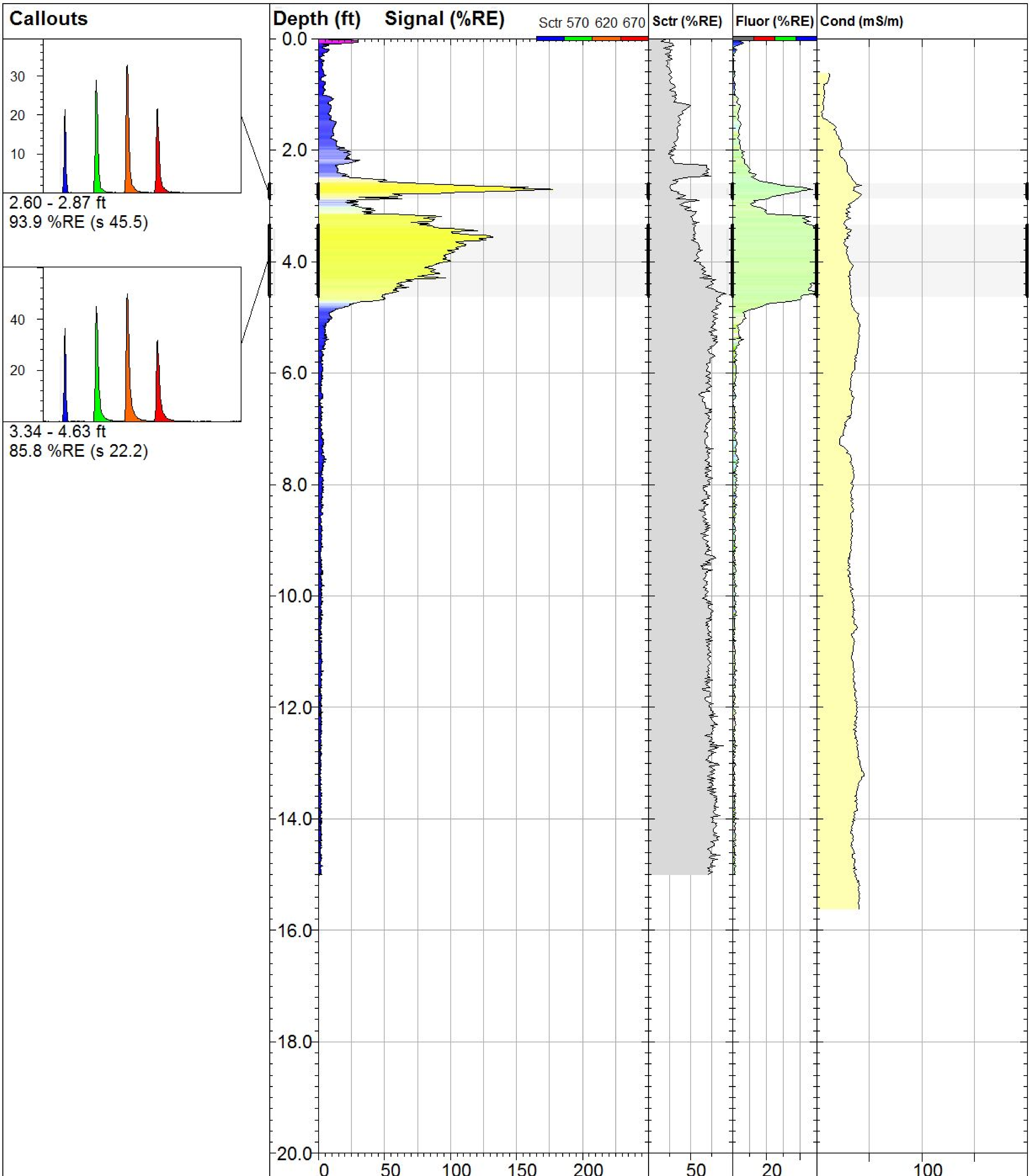
TG-22

TarGOST® By Dakota
www.DakotaTechnologies.com

Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.02 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **233.8 %RE @ 6.83 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-12 08:22 CDT**



TG-23

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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.01 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **177.8 %RE @ 2.70 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-11 14:39 CDT**

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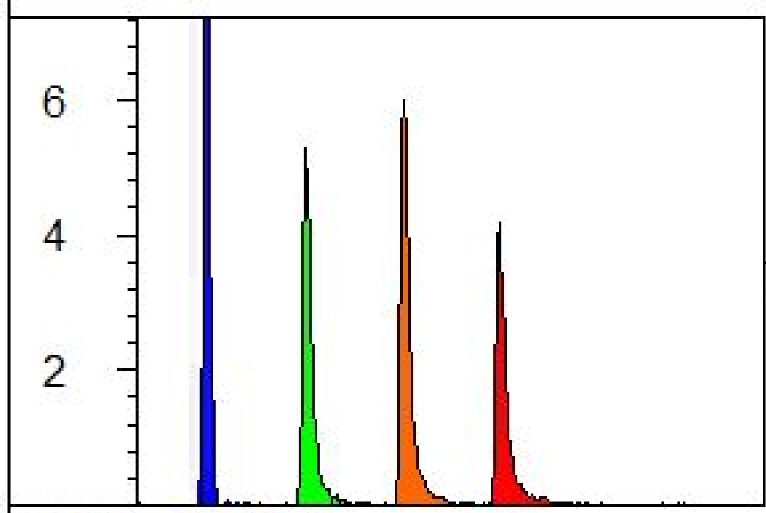
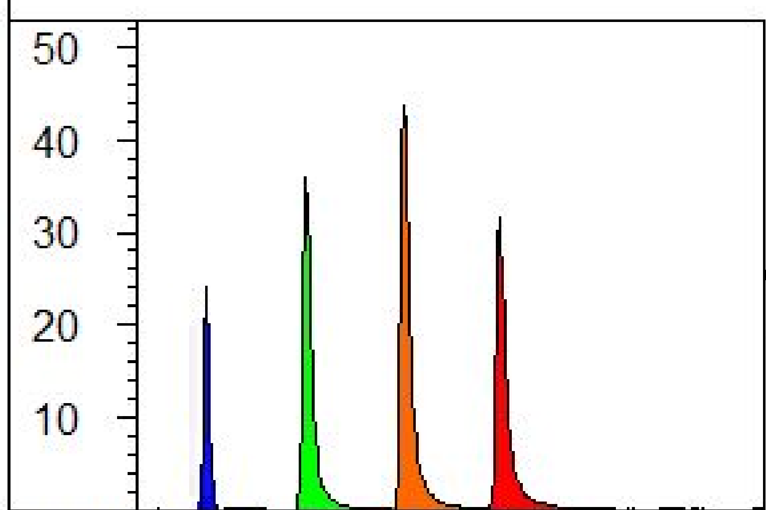
Callouts

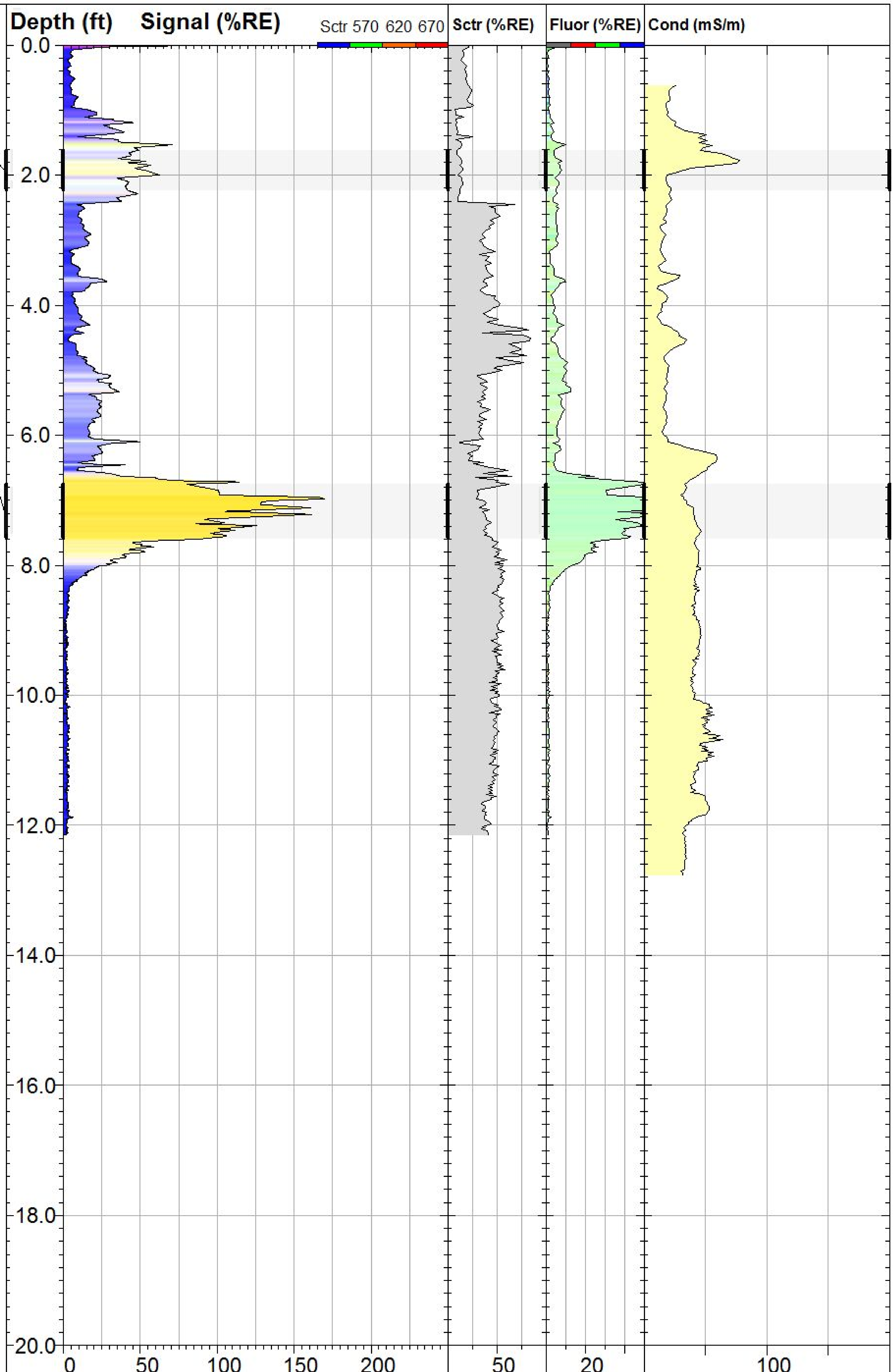


1.62 - 2.23 ft
45.1 %RE (s 7.7)



6.75 - 7.59 ft
112.1 %RE (s 25.5)

END AT 12 DUE TO INCOMING WEATHER. BORING TAKEN PAST NAPL.



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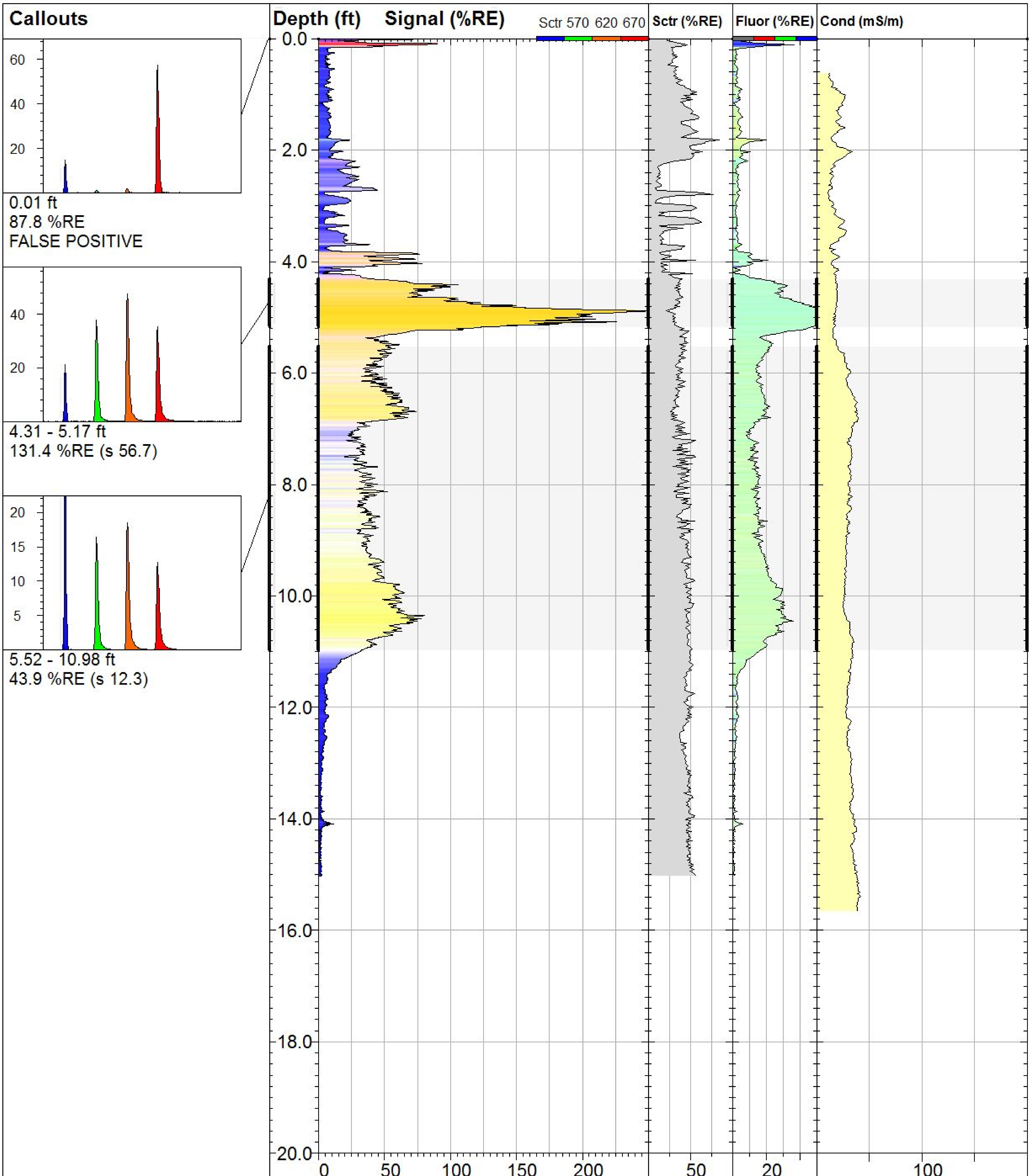
TG-24		**TarGOST® By Dakota** www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **12.15 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **169.6 %RE @ 6.98 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-12 10:19 CDT**



TG-25

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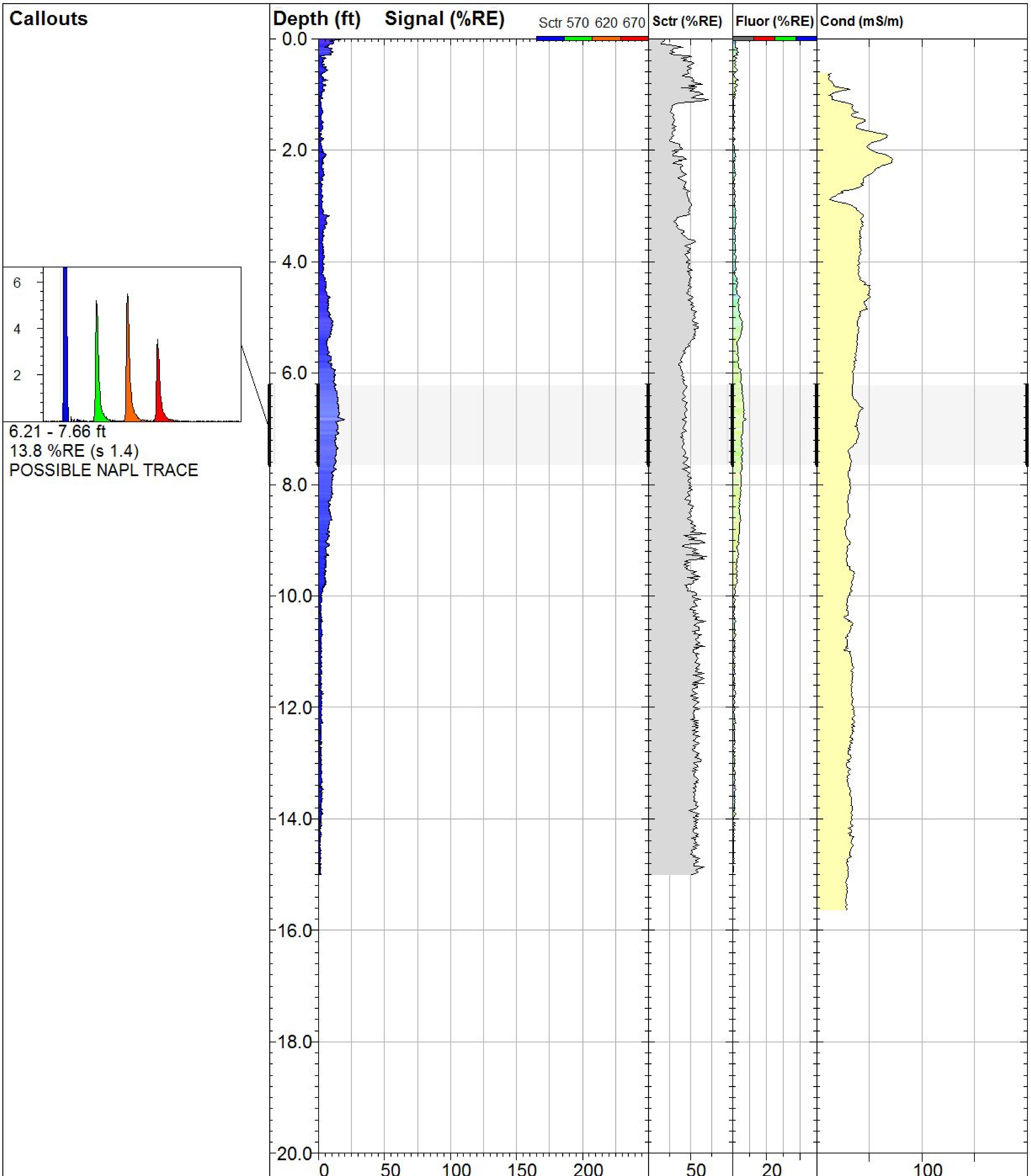
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.02 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **281.7 %RE @ 4.88 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-12 09:03 CDT**



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TG-27

TarGOST® By Dakota
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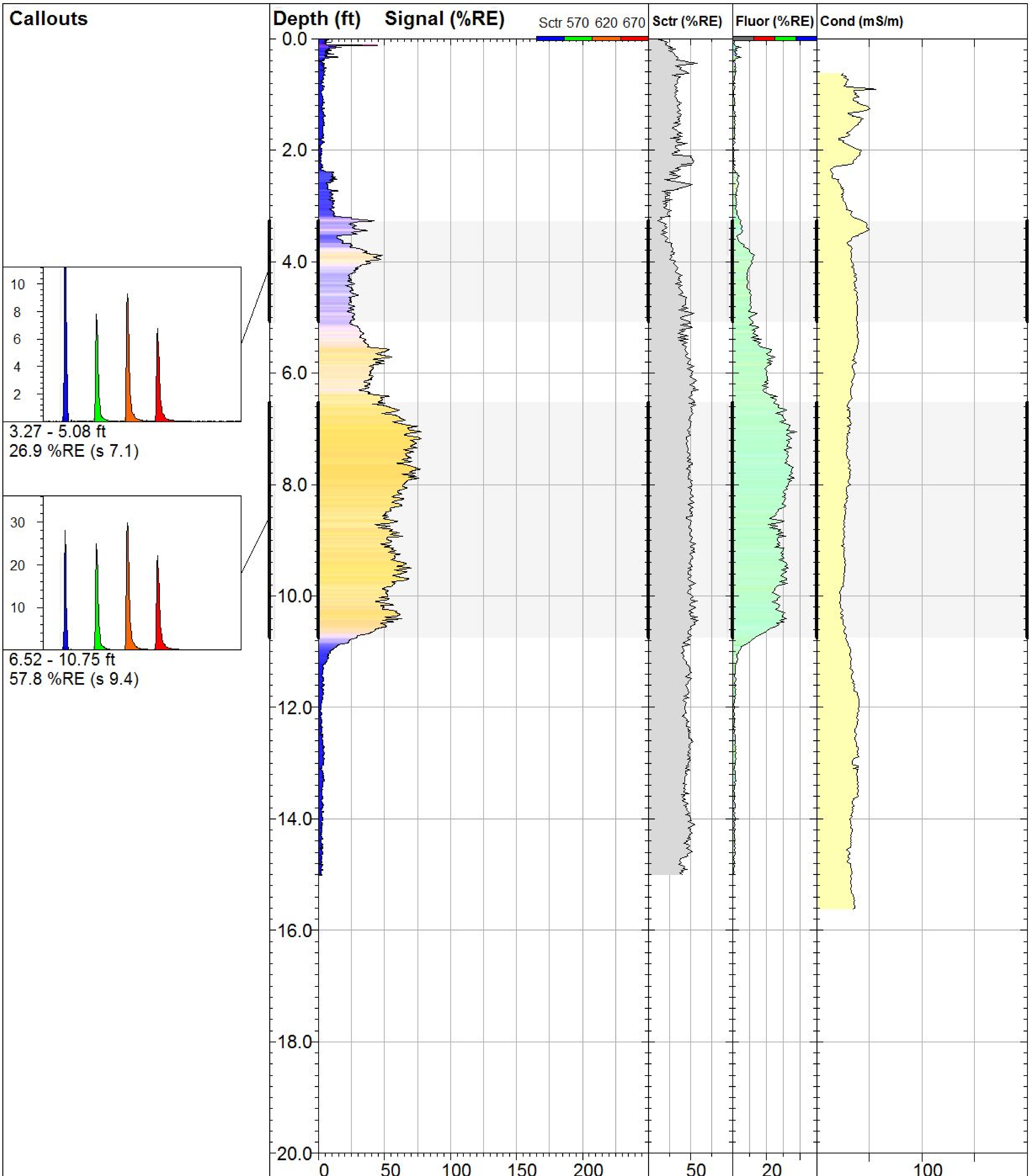
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.00 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **19.6 %RE @ 6.83 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-12 09:36 CDT**



TG-28

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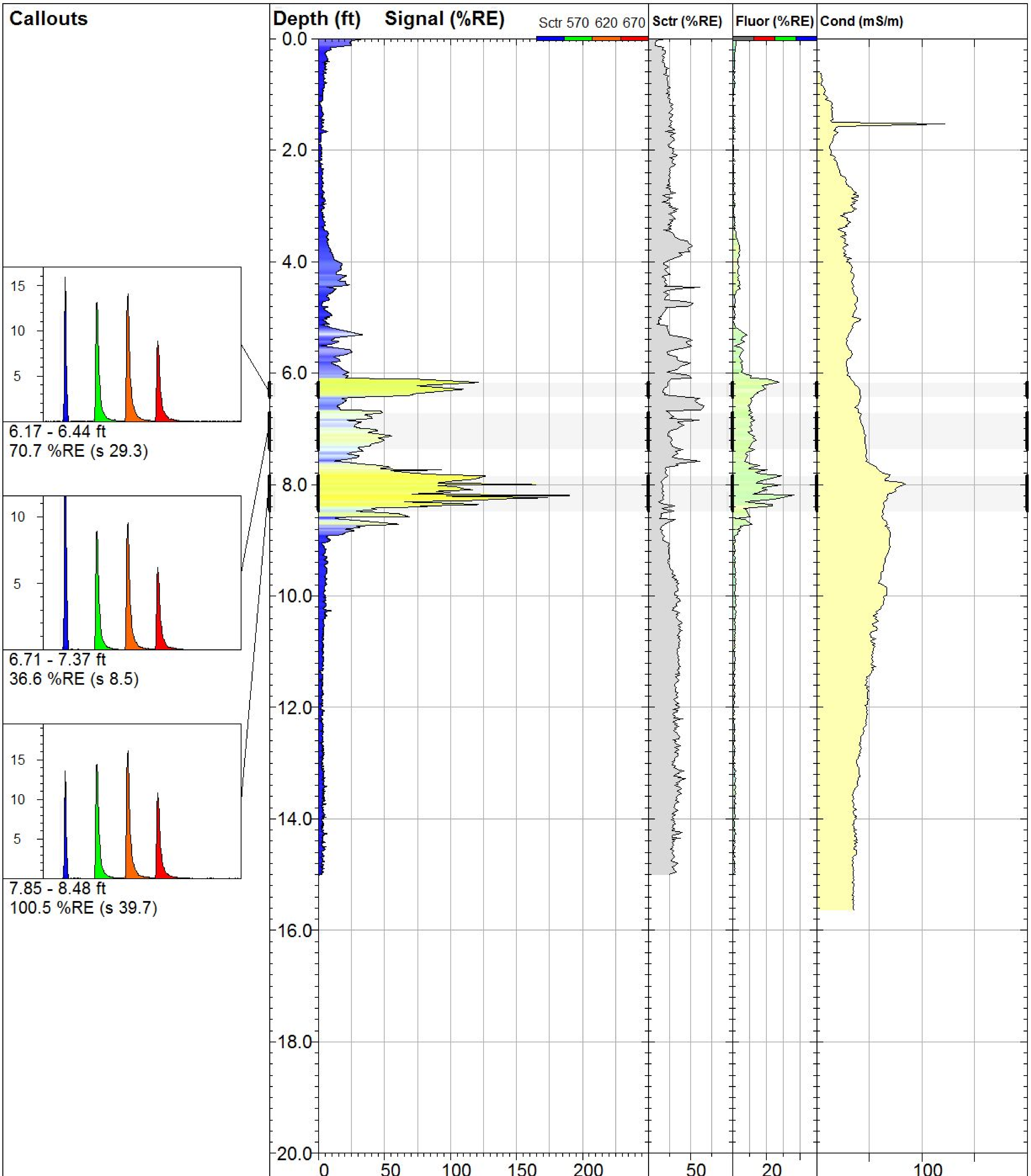
www.DakotaTechnologies.com

Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.01 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **78.0 %RE @ 7.05 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-12 14:55 CDT**



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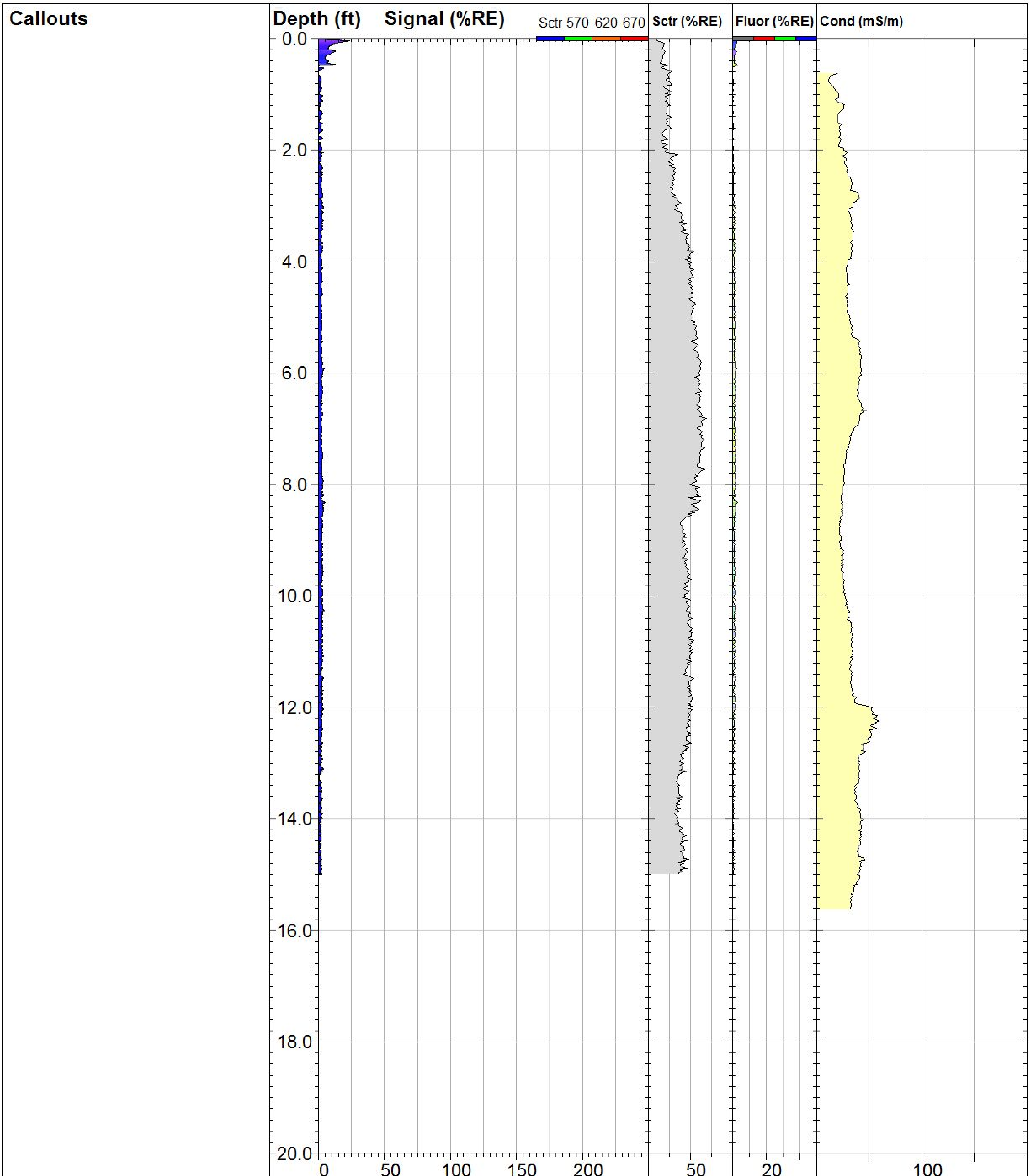
TG-29		**TarGOST® By Dakota** www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.01 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **197.6 %RE @ 8.20 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-12 14:25 CDT**



TG-30

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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.00 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **23.7 %RE @ 0.04 ft**
Operator / Unit: **SWM / TG1002**	*Elevation:* **Unavailable**	*Date & Time:* **2017-07-12 15:29 CDT**

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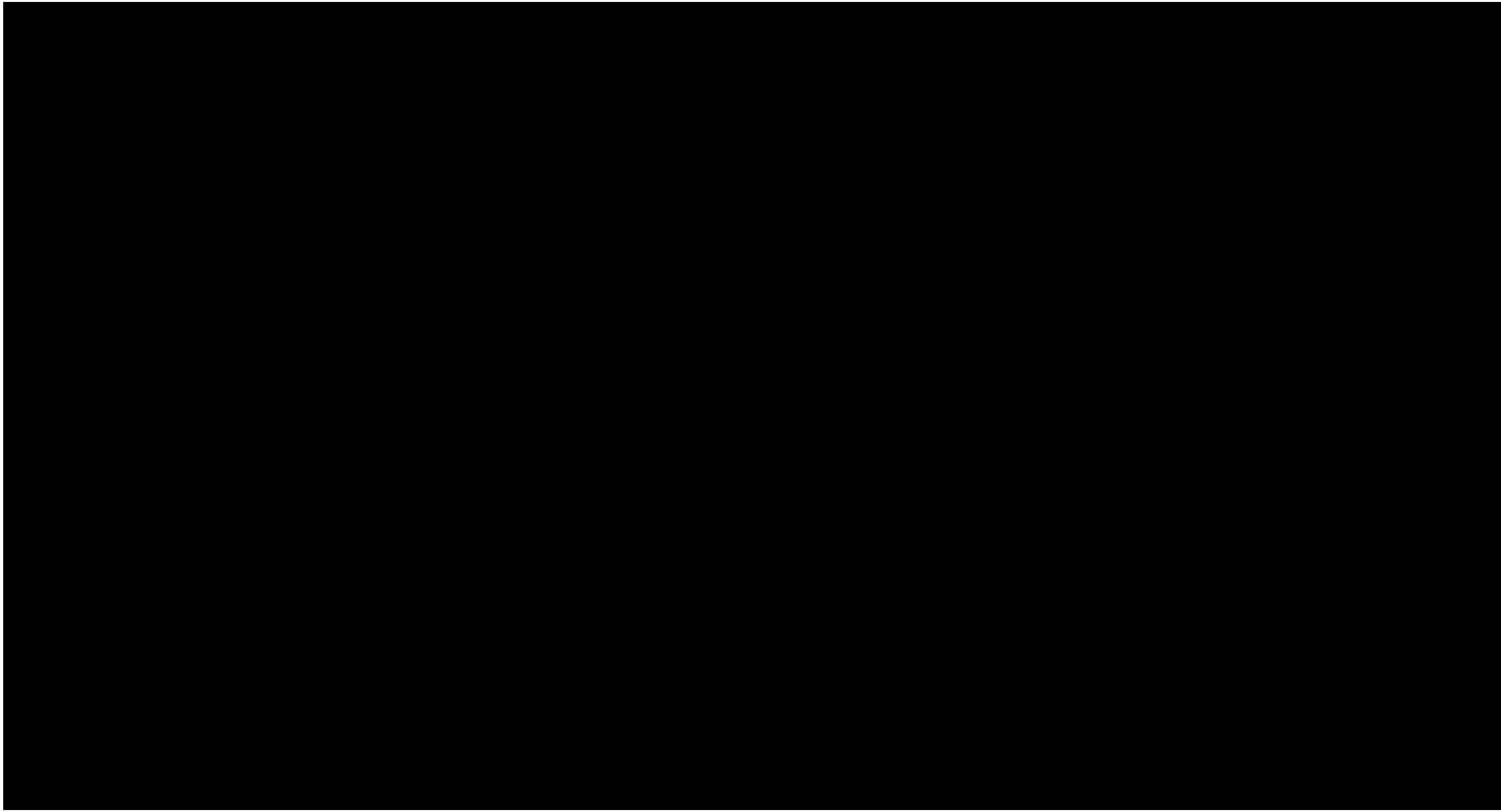
Appendix B
LIF Results

Appendix B.1
3D Model of LIF Results



Operating Layered 3D PDFs:
Toggle on/off Layers - Expand "PDF3D Scene" folder to view all available model layers

Rotate - hold down left mouse button
Zoom in/out - scroll up and down using mouse wheel
Pan - hold down right and left mouse buttons

10X VERTICAL EXAGGERATION

LEGEND

RAILROAD
SEEP LOCATIONS
HISTORICAL TANK BOTTOM
BUCKEYE PIPELINE
GAS PIPELINE (NIPSCO)
PETROLEUM PIPELINE (BP)
UNIDENTIFIED PIPELINE
UNDERLYING CLAY
NAPL THICKNESS
DITCH
SEDIMENT
AUGUST 2017 WATER ELEVATION

LASER-INDUCED FLUORESCENCE (% RE)

< 20 | 20-100 | 100-200 | 200-300 | 300-400 | 400-500 | 500-600 | >600

AUGUST 2017 WATER TABLE ELEVATION (ft)

581 | 581.5 | 582 | 582.5 | 583 | 583.5 | 584 | 584.5 | 585 | 585.5 | 586

GHD

CLINE AVENUE OIL SPILL SITE
GARY, INDIANA

LNAPL BODY DELINEATION
LASER-INDUCED FLUORESCENCE (LIF)

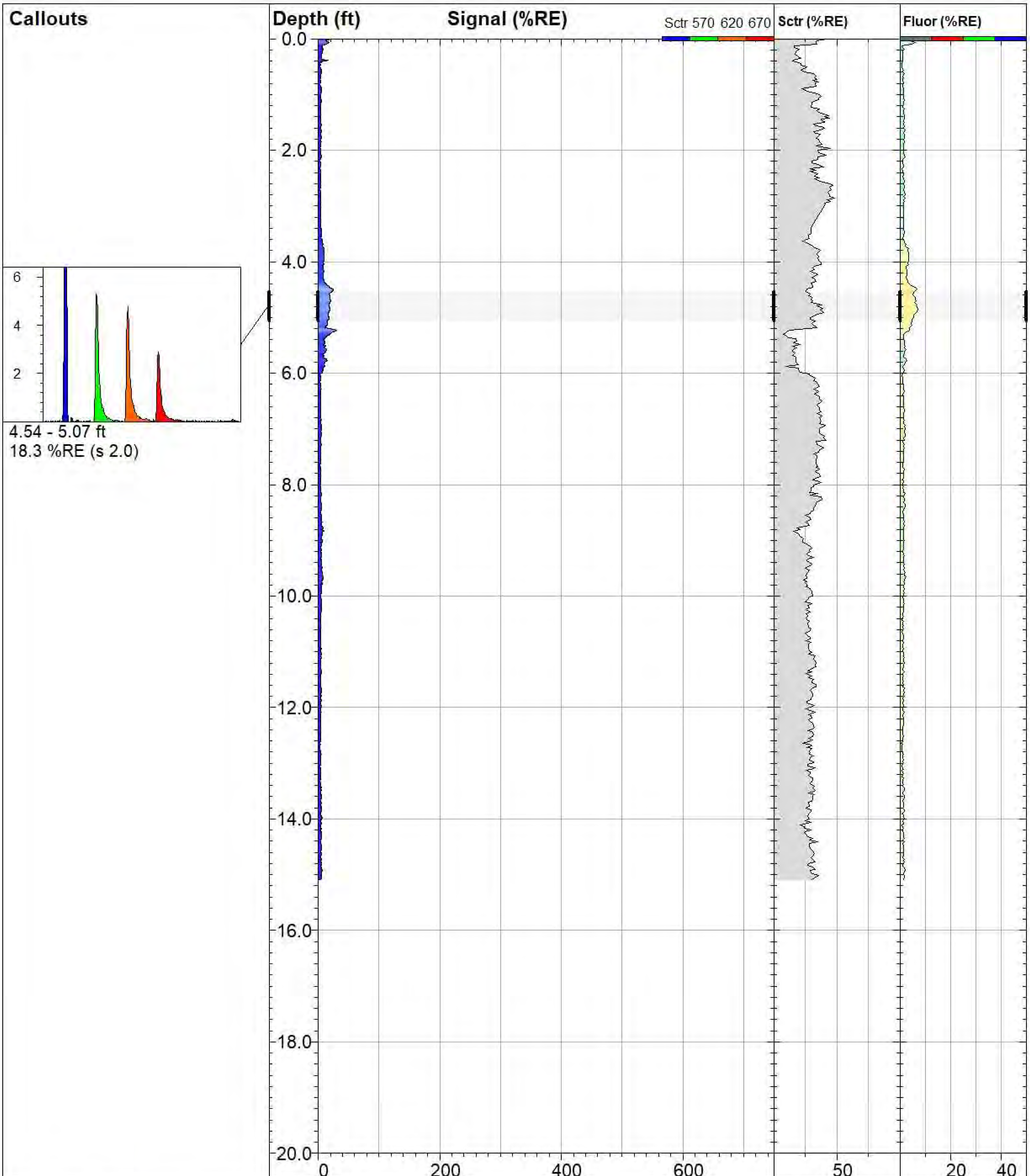
Job Number	085886-00
Date	NOV 2017

Figure 1

Z:\HEG\085886\3DV\Deliverable\PRESENTATIONS\085886-00(PRES003)3DV-WA\3DPDFs\085886-00(PRES003)3DV-WA_LNAPL_Body Delineation.PDF
created by: aflittle

651 Colby Drive Waterloo ON N2V 1C2 CANADA **T** 519 884 0510 **F** 519 725 1394 **W** www.ghd.com

Appendix B.2
LIF Results (TG-31 to TG-62)



TG-31		TarGOST® By Dakota www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.08 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **31.1 %RE @ 5.23 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-10 13:55 CDT**

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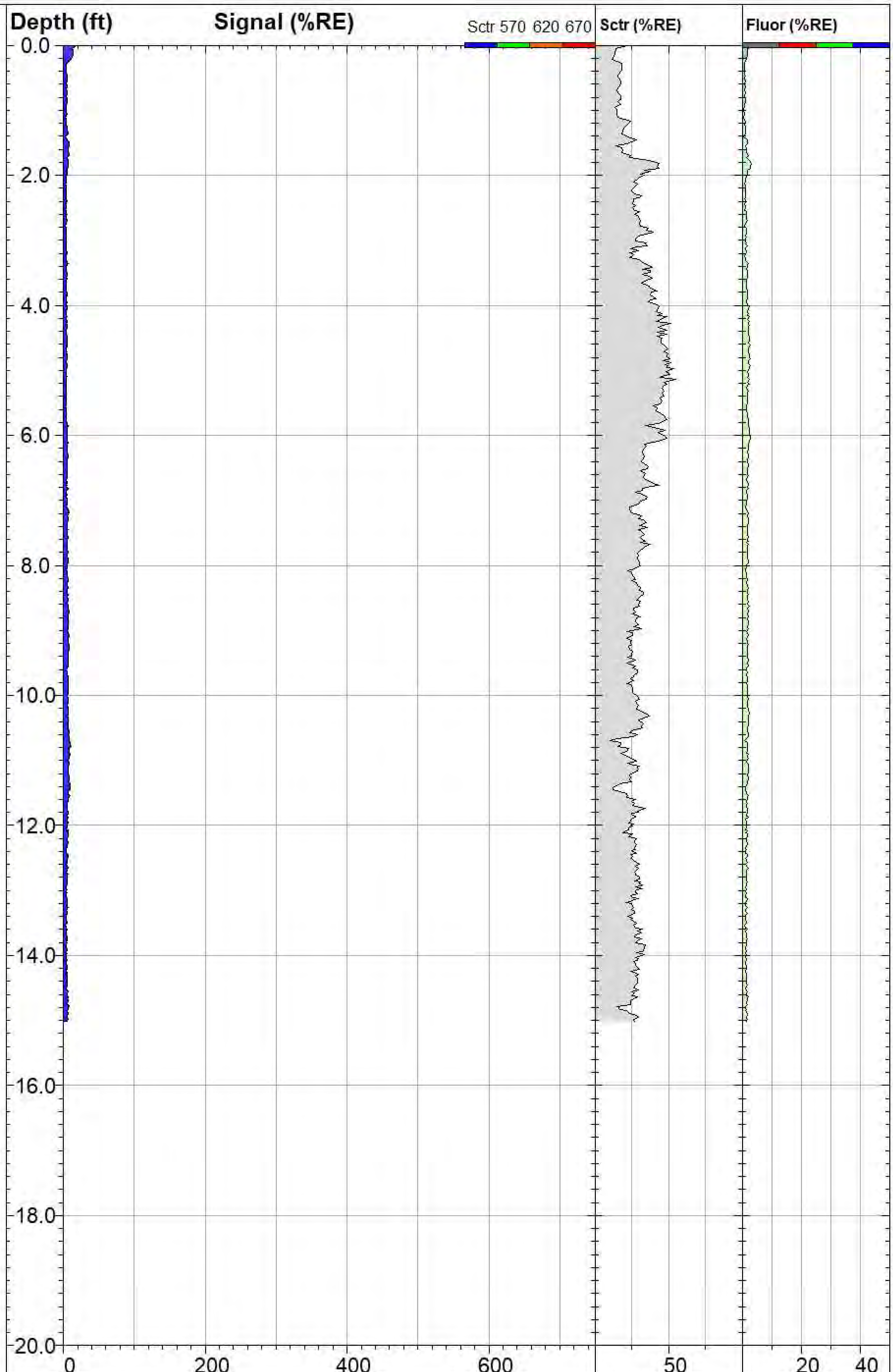
Callouts



TG-32

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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.01 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **17.8 %RE @ 0.00 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-10 13:34 CDT**

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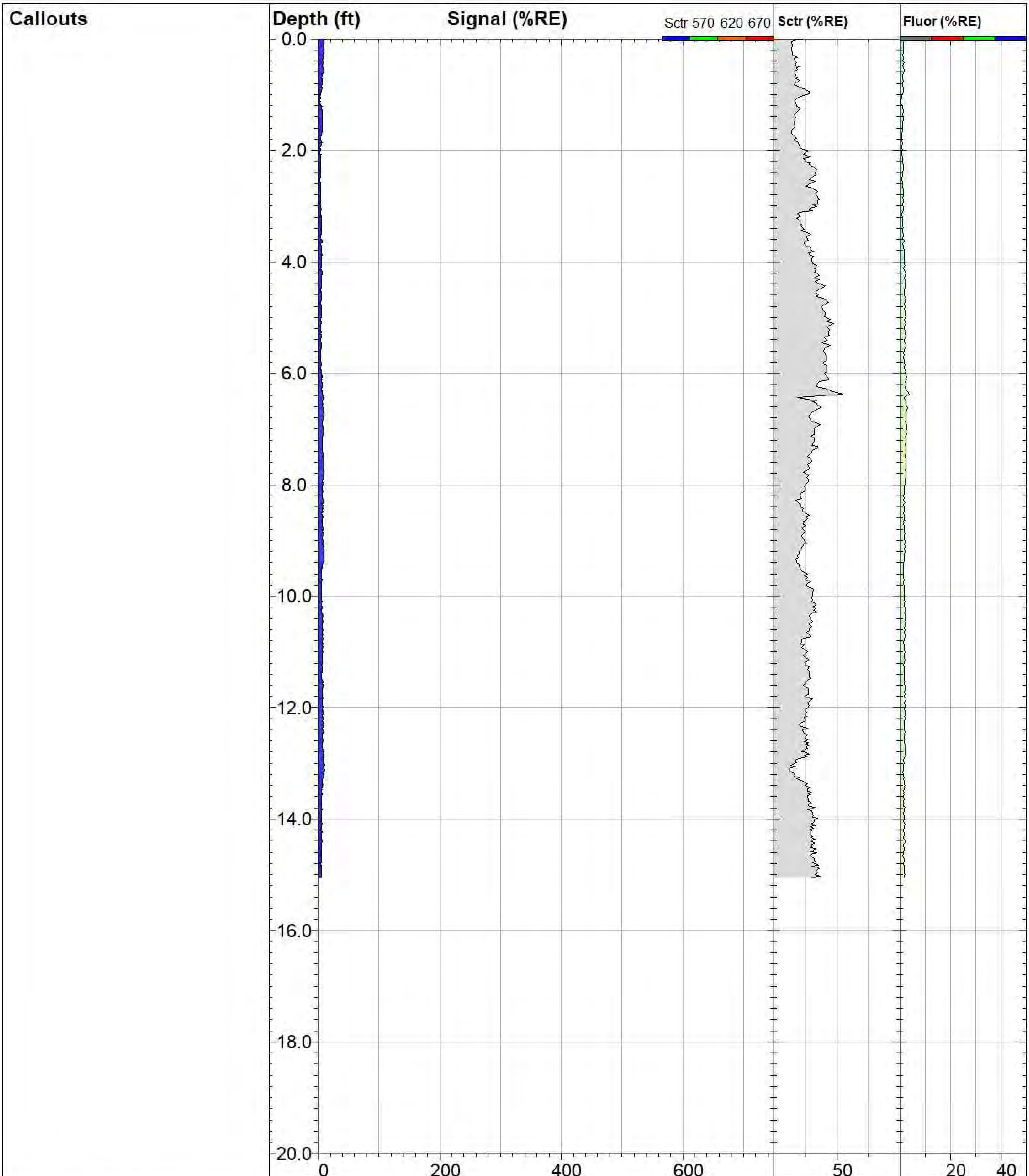

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TG-33

TarGOST® By Dakota
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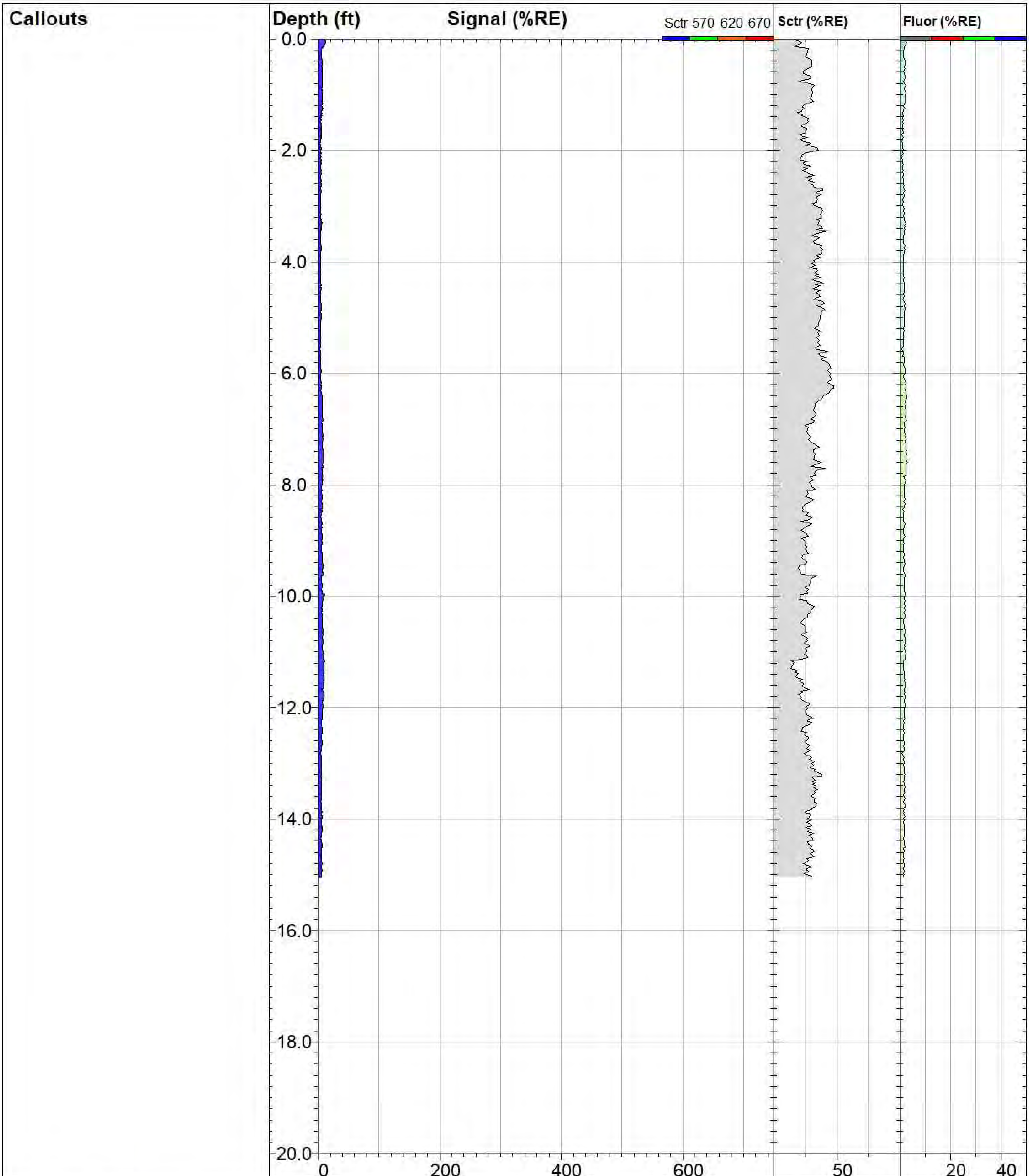
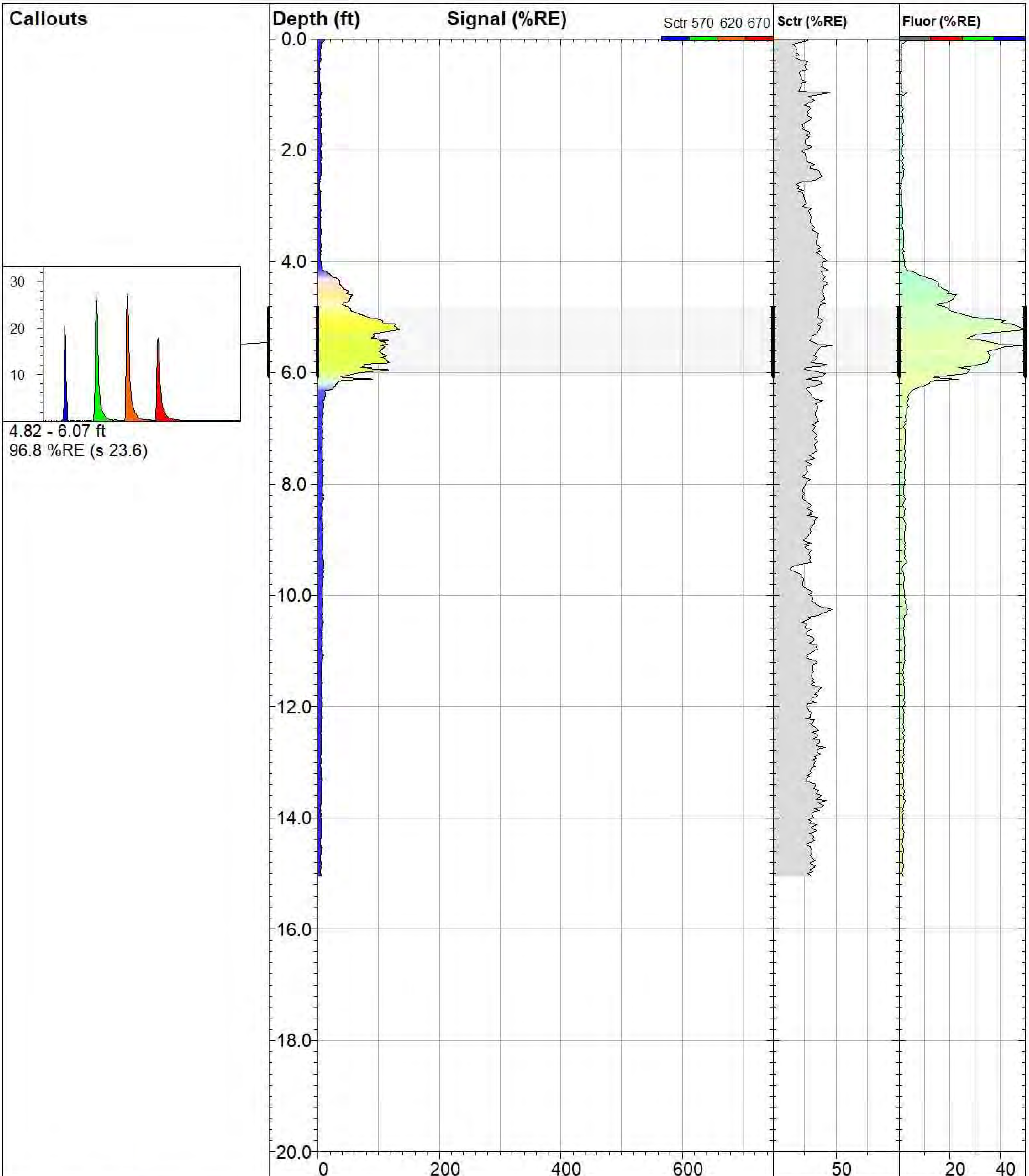
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.04 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **13.0 %RE @ 0.02 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-10 13:00 CDT**



DAKOTA TECHNOLOGIES www.DakotaTechnologies.com	TG-34		TarGOST® By Dakota www.DakotaTechnologies.com
	Site: **CLINE AVE DITCH**	Y Coord.(Lat-N) / System: **Unavailable / NA**	Final depth: **15.04 ft**
	Client / Job: **GHD / 160.17**	X Coord.(Lng-E) / Fix: **Unavailable / NA**	Max signal: **12.3 %RE @ 0.06 ft**
	Operator / Unit: **SWM / TG1004**	Elevation: **Unavailable**	Date & Time: **2017-10-10 11:31 CDT**



TG-35		**TarGOST® By Dakota** www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.05 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **134.7 %RE @ 5.23 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-10 11:07 CDT**

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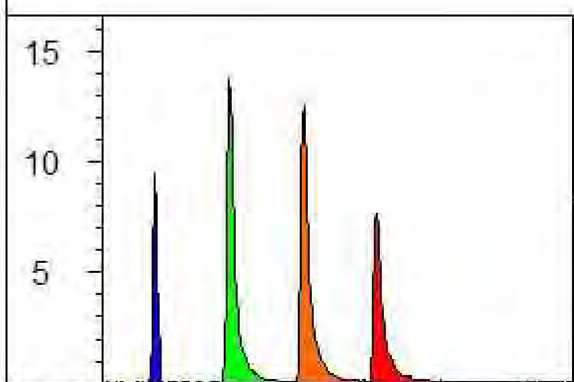
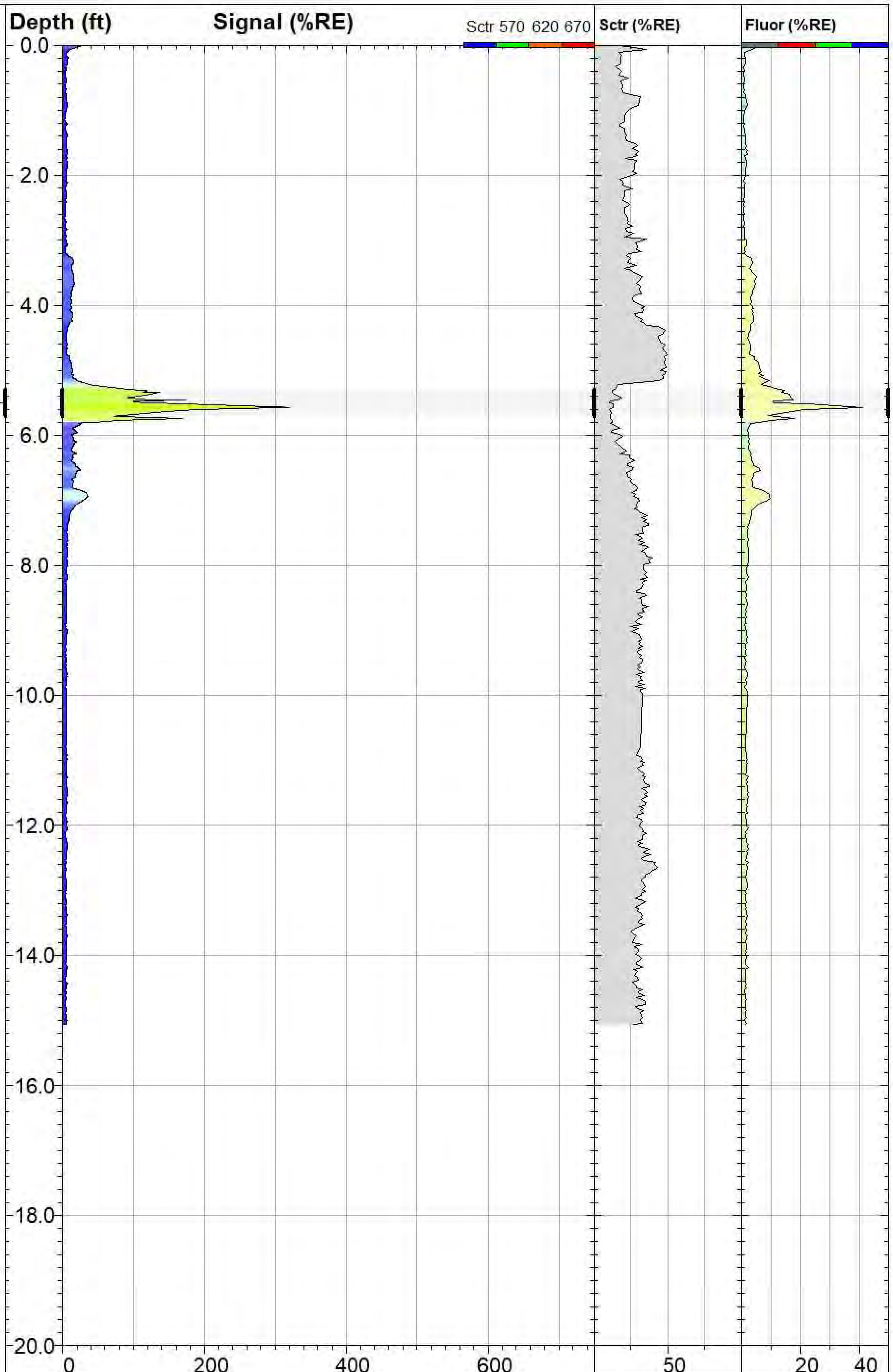
Callouts



5.29 - 5.71 ft
134.5 %RE (s 57.6)



TG-36

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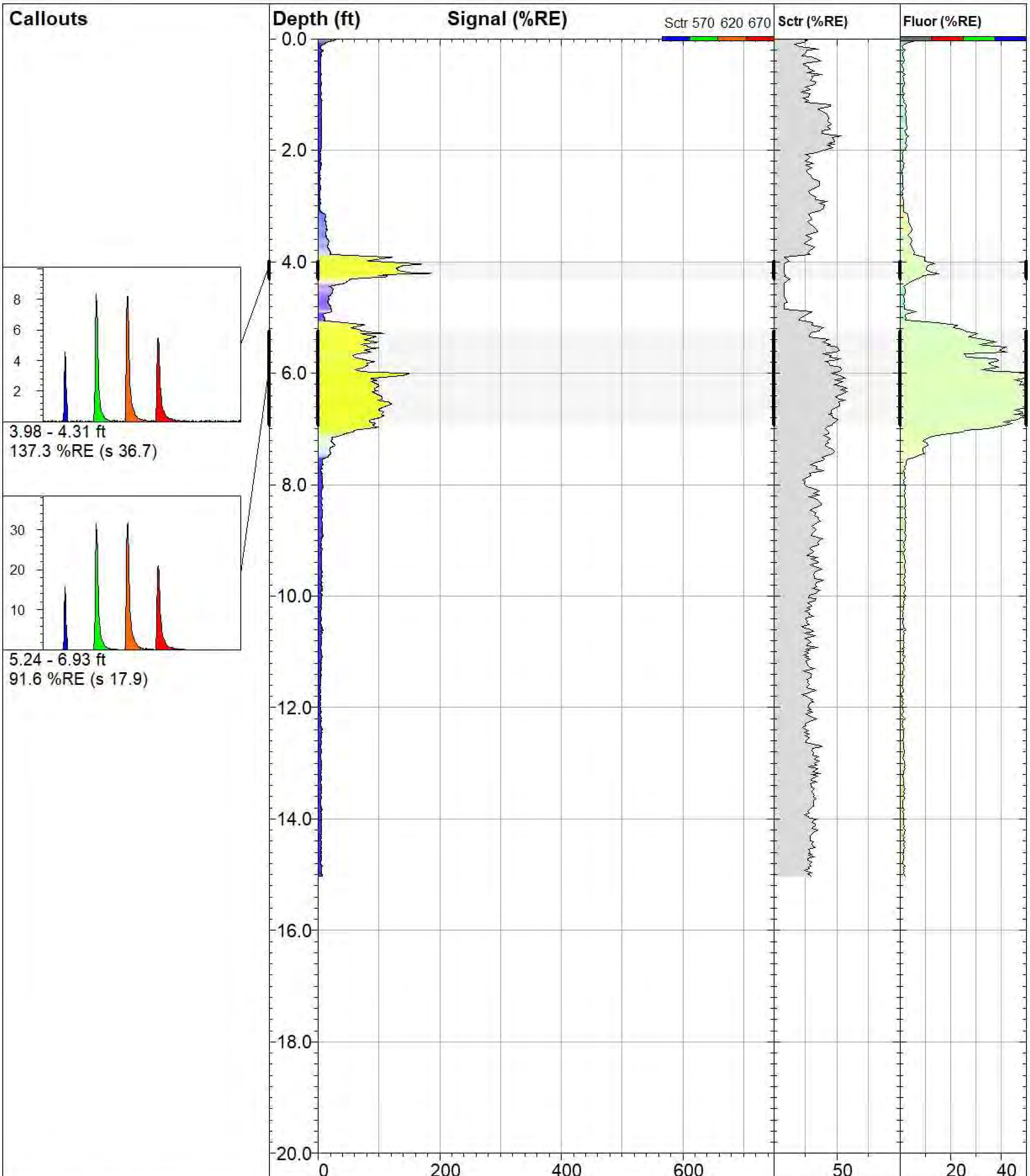
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.06 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **321.4 %RE @ 5.57 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-10 10:42 CDT**



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TG-37

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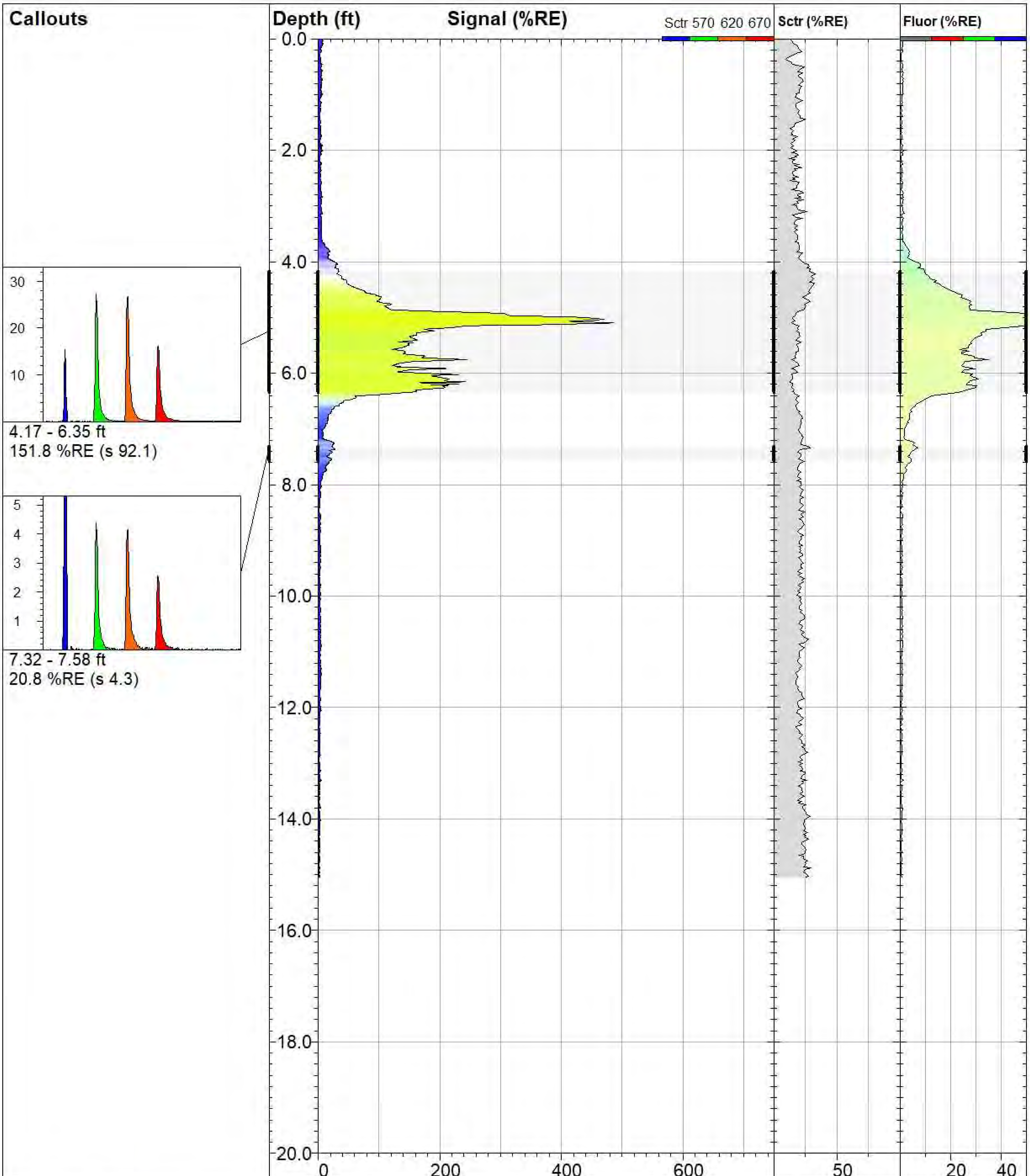
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.03 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **189.4 %RE @ 4.21 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-10 10:14 CDT**



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TG-38

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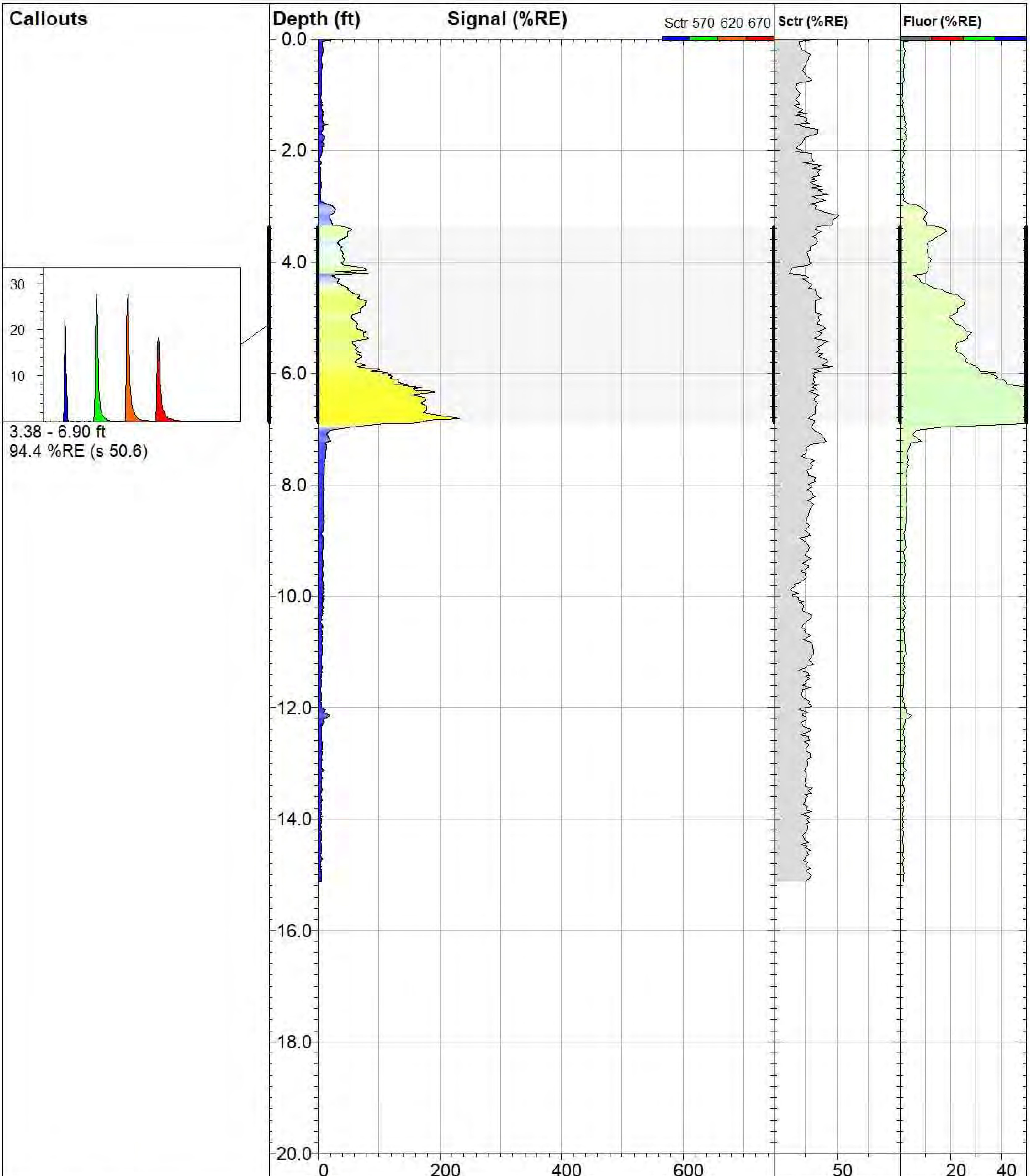
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.04 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **489.0 %RE @ 5.10 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-10 08:42 CDT**



TG-39

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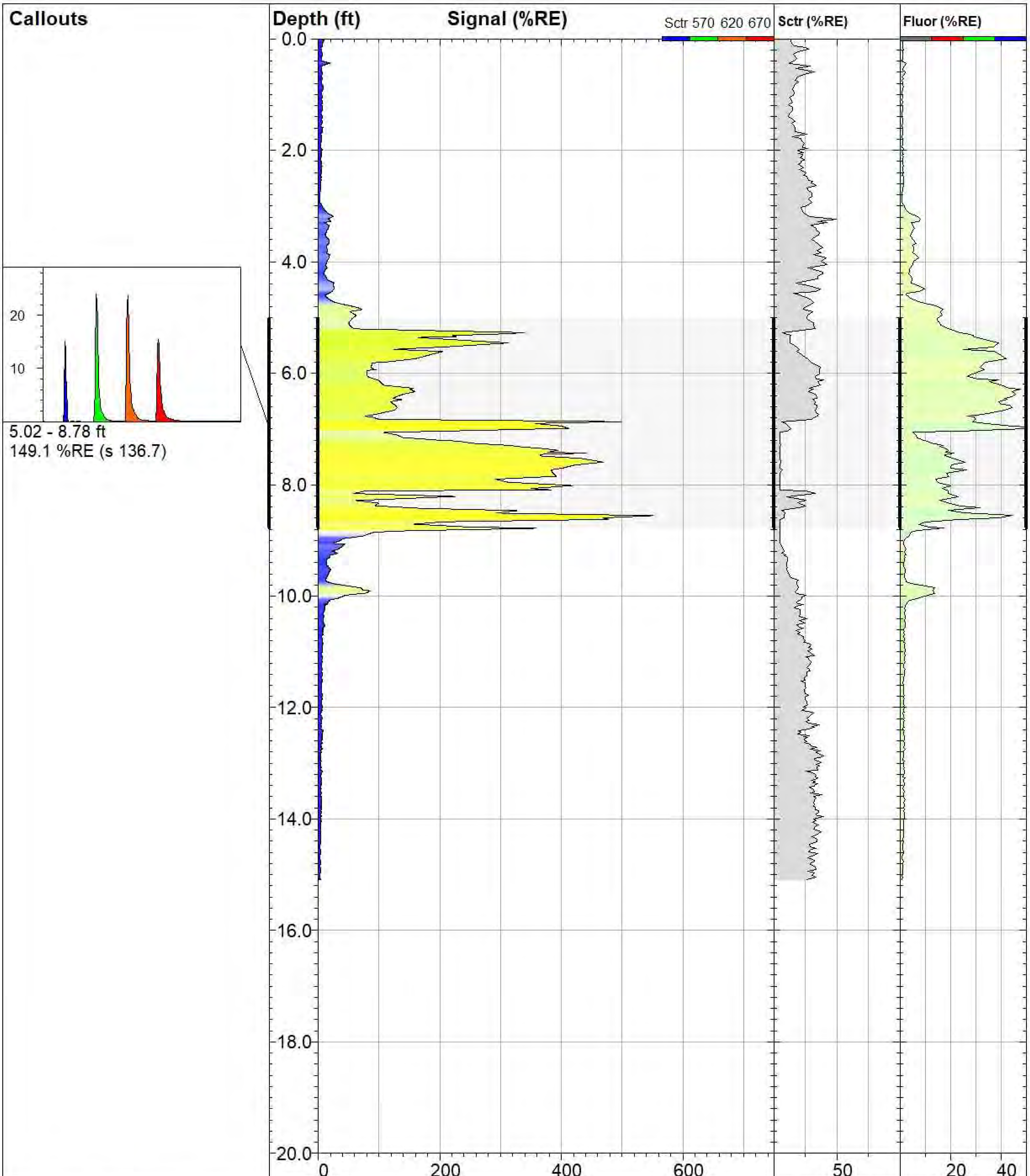
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.11 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **233.5 %RE @ 6.81 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-10 16:35 CDT**



TG-40		**TarGOST® By Dakota** www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.09 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **552.6 %RE @ 8.56 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-10 16:15 CDT**

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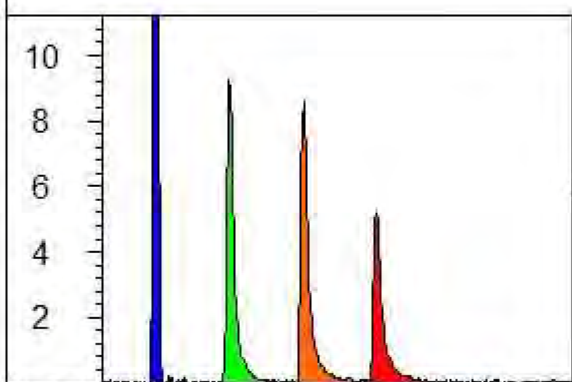
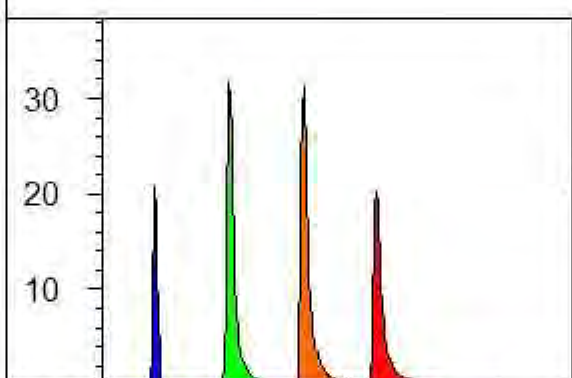
Callouts

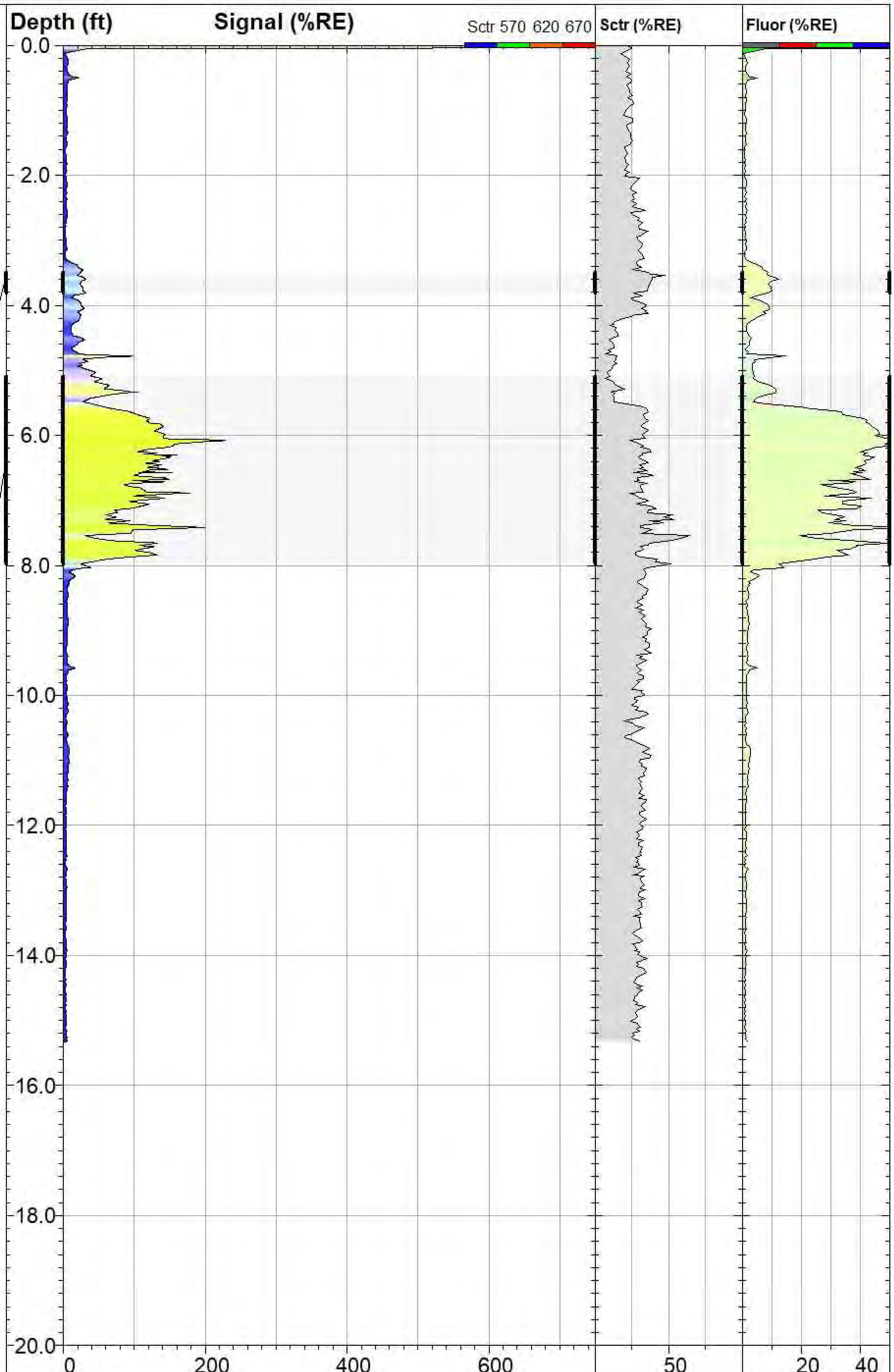
False Positive at 0.0 feet caused by fluorescent marking paint. LIF window was not completely flush with ground.



3.50 - 3.81 ft
25.7 %RE (s 4.1)



5.09 - 7.98 ft
110.1 %RE (s 41.4)



TG-41		**TarGOST® By Dakota** www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.32 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **2102.5 %RE @ 0.00 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-10 15:51 CDT**

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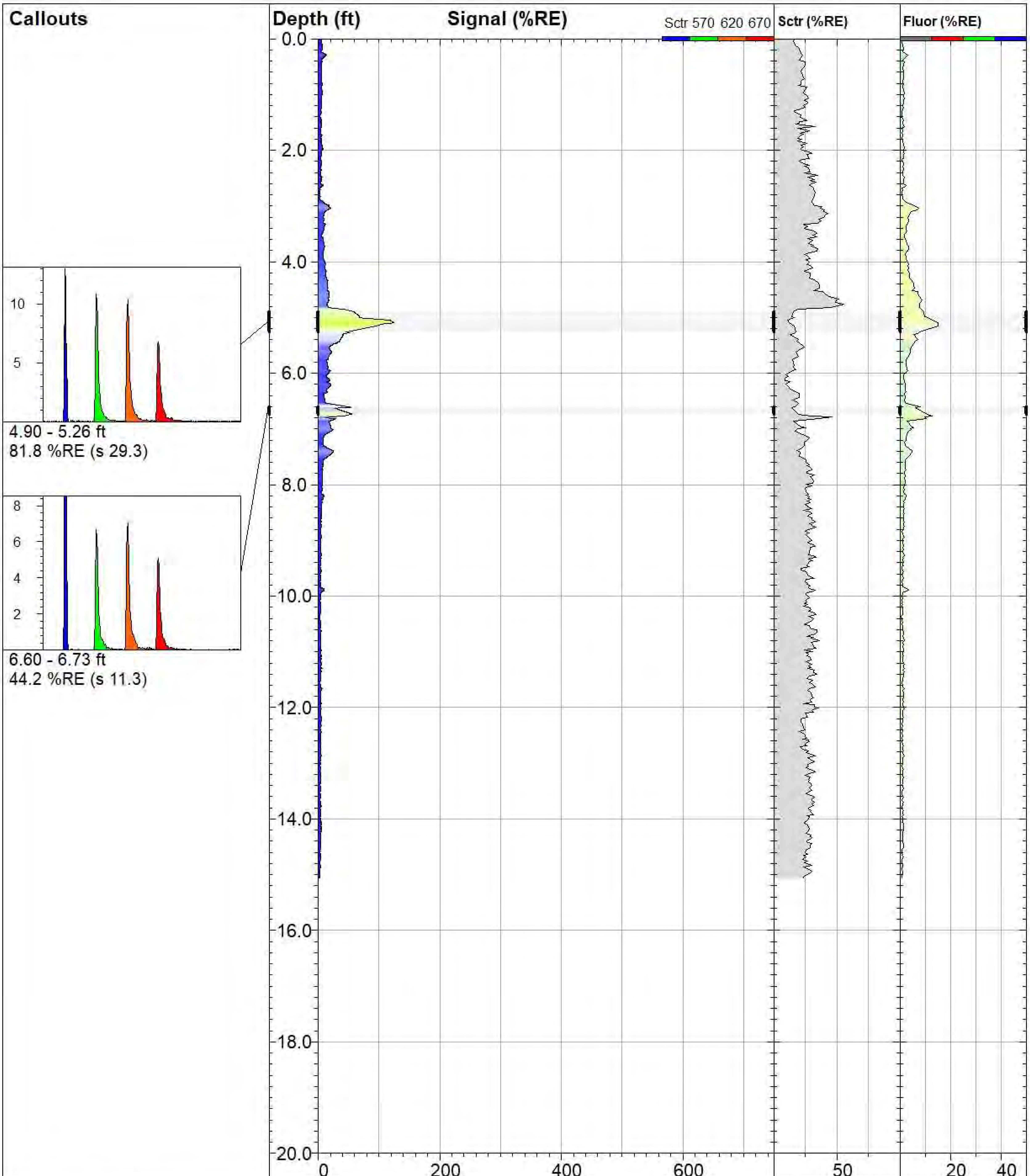

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TG-42

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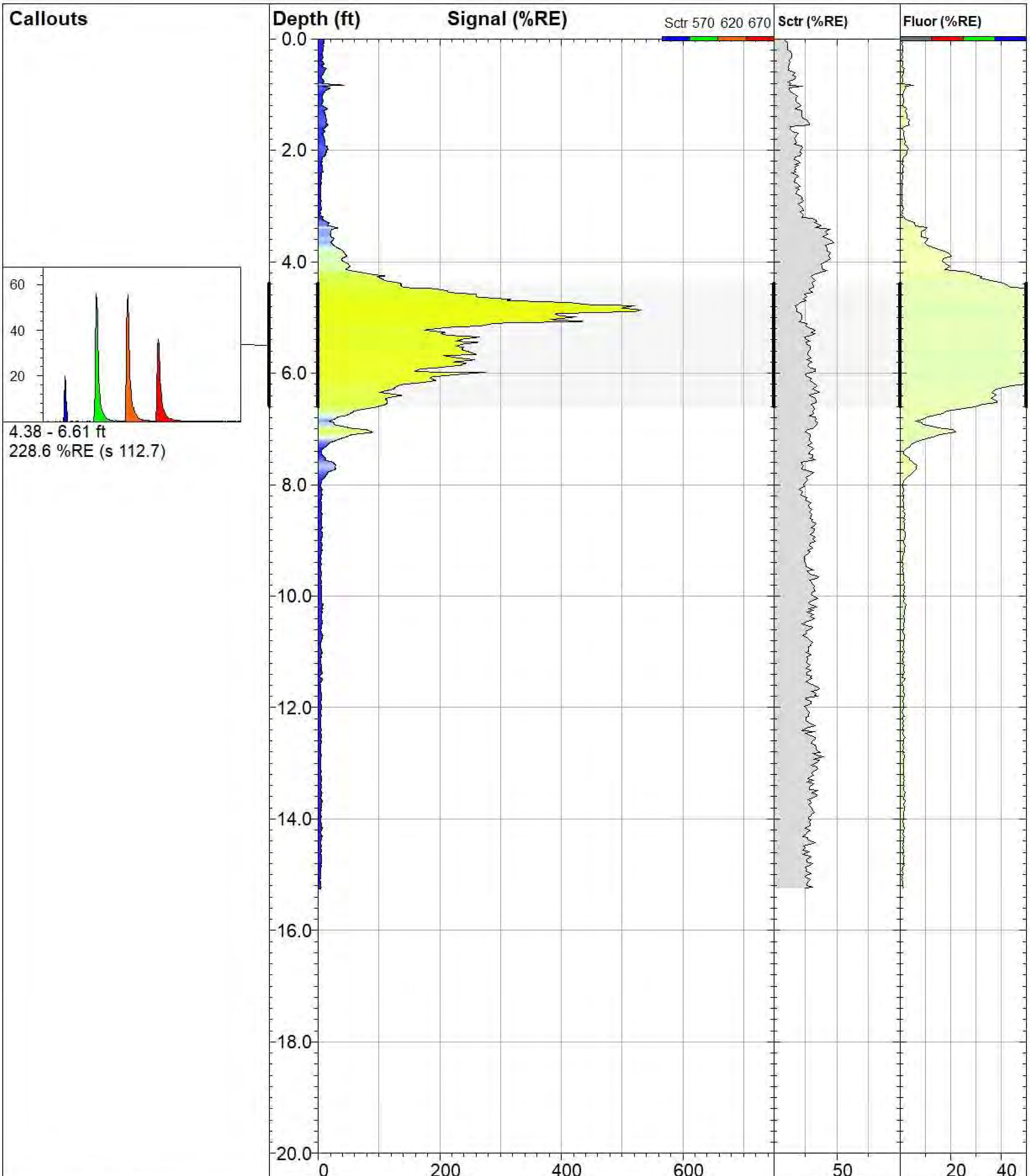
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.05 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **125.0 %RE @ 5.10 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-10 15:24 CDT**



TG-43

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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.26 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **531.9 %RE @ 4.87 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-10 15:04 CDT**

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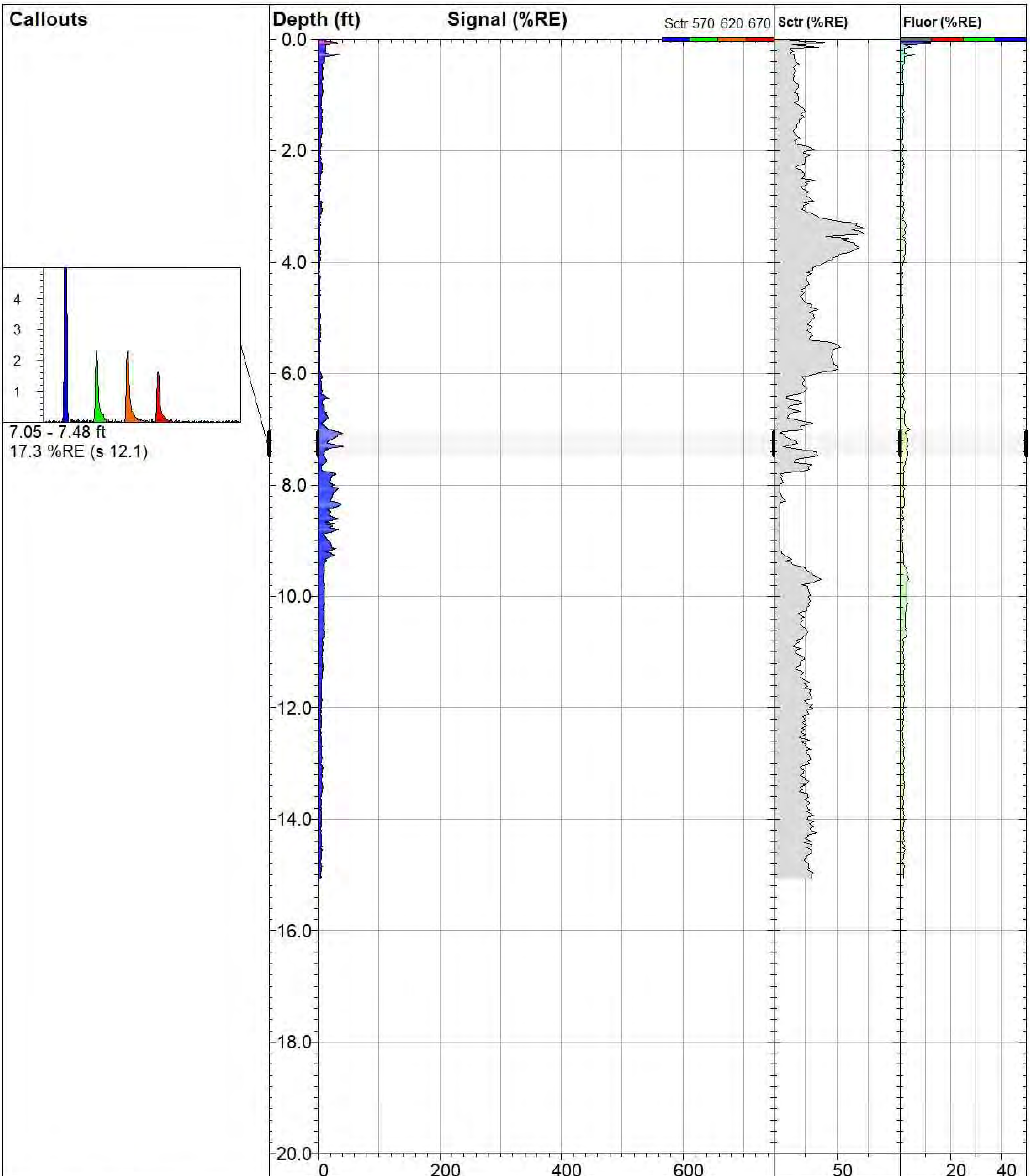

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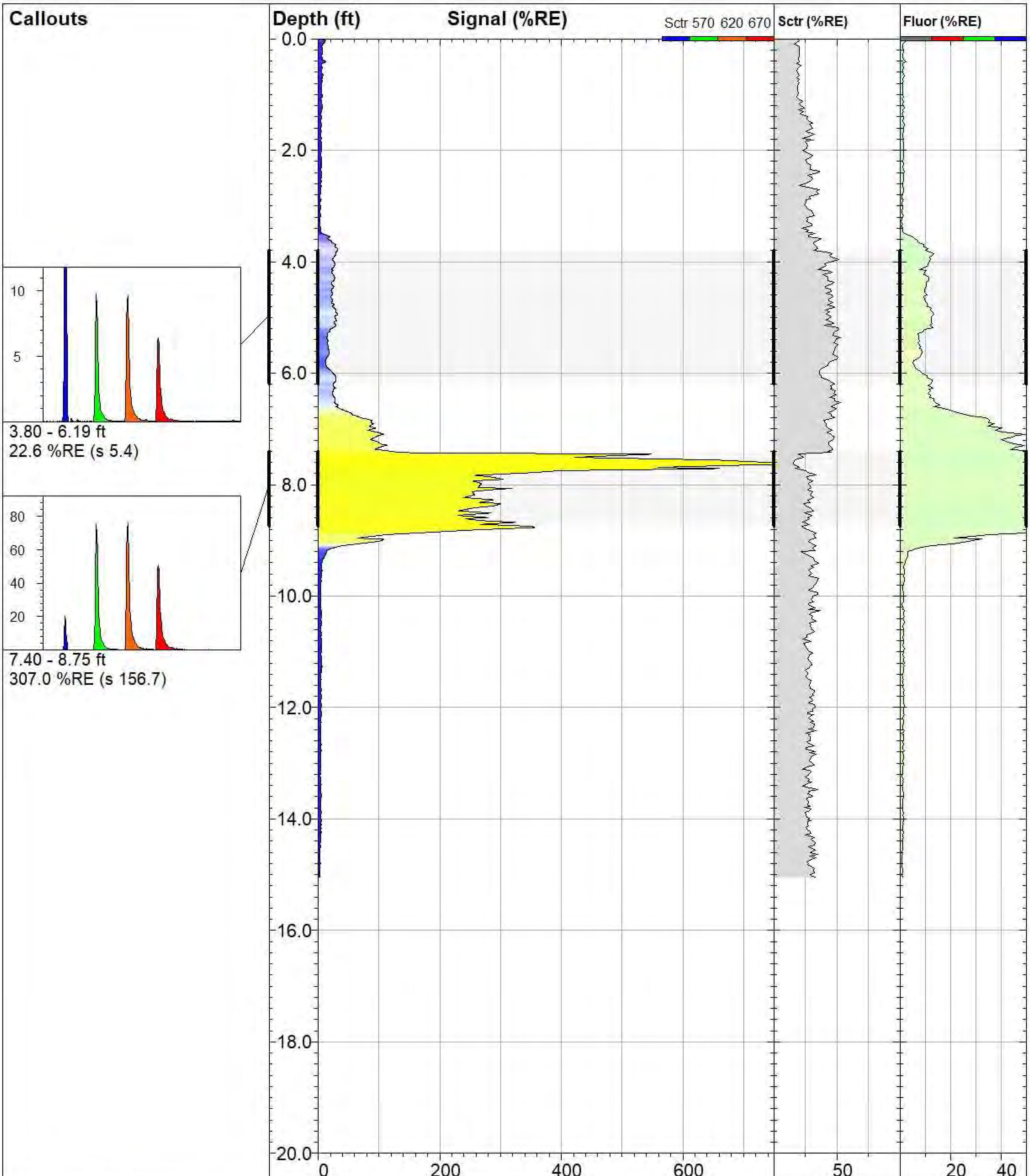
TG-44		TarGOST® By Dakota www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.07 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **41.5 %RE @ 7.31 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-10 14:43 CDT**



TG-45

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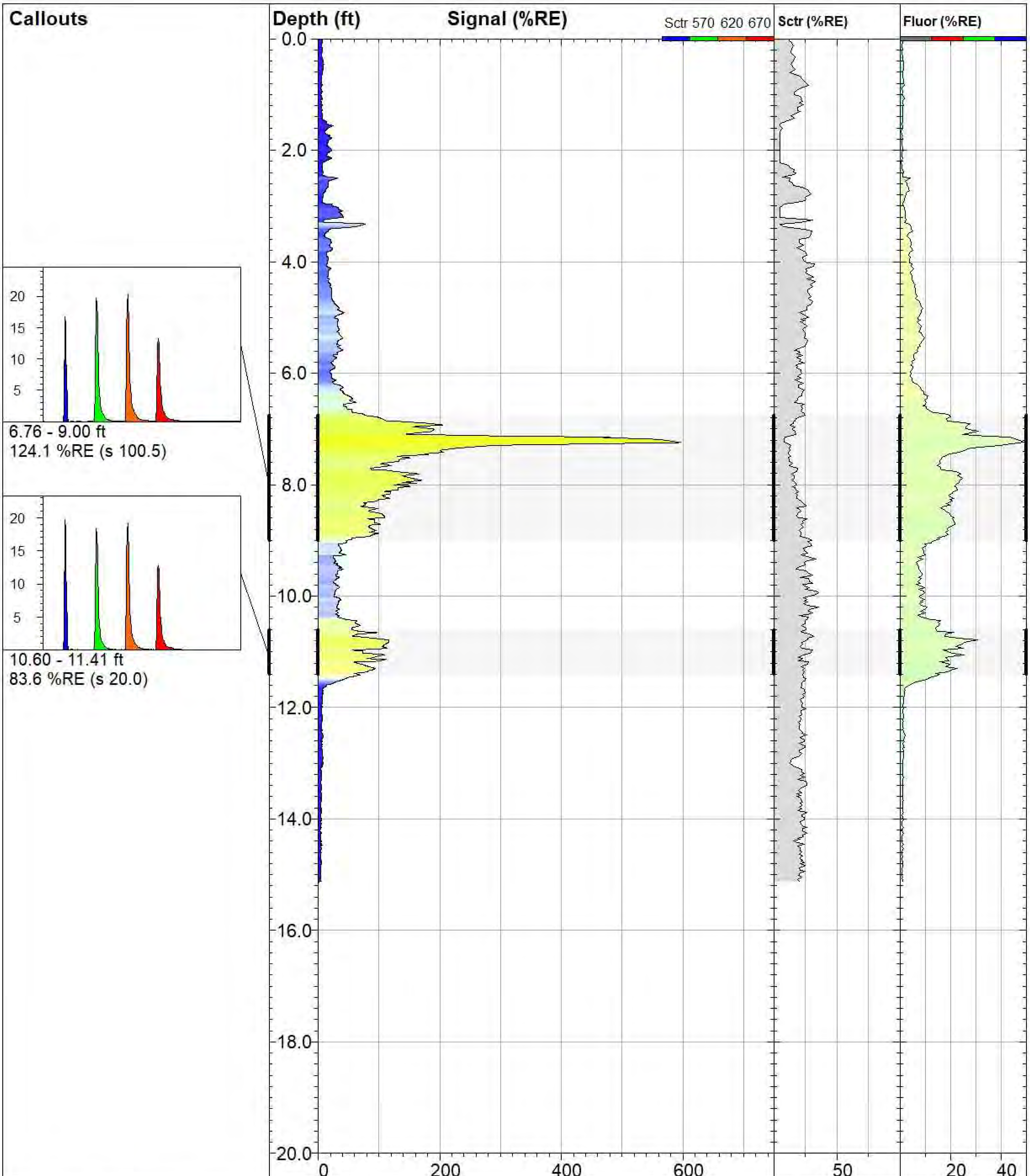
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.05 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **778.0 %RE @ 7.63 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-10 14:20 CDT**



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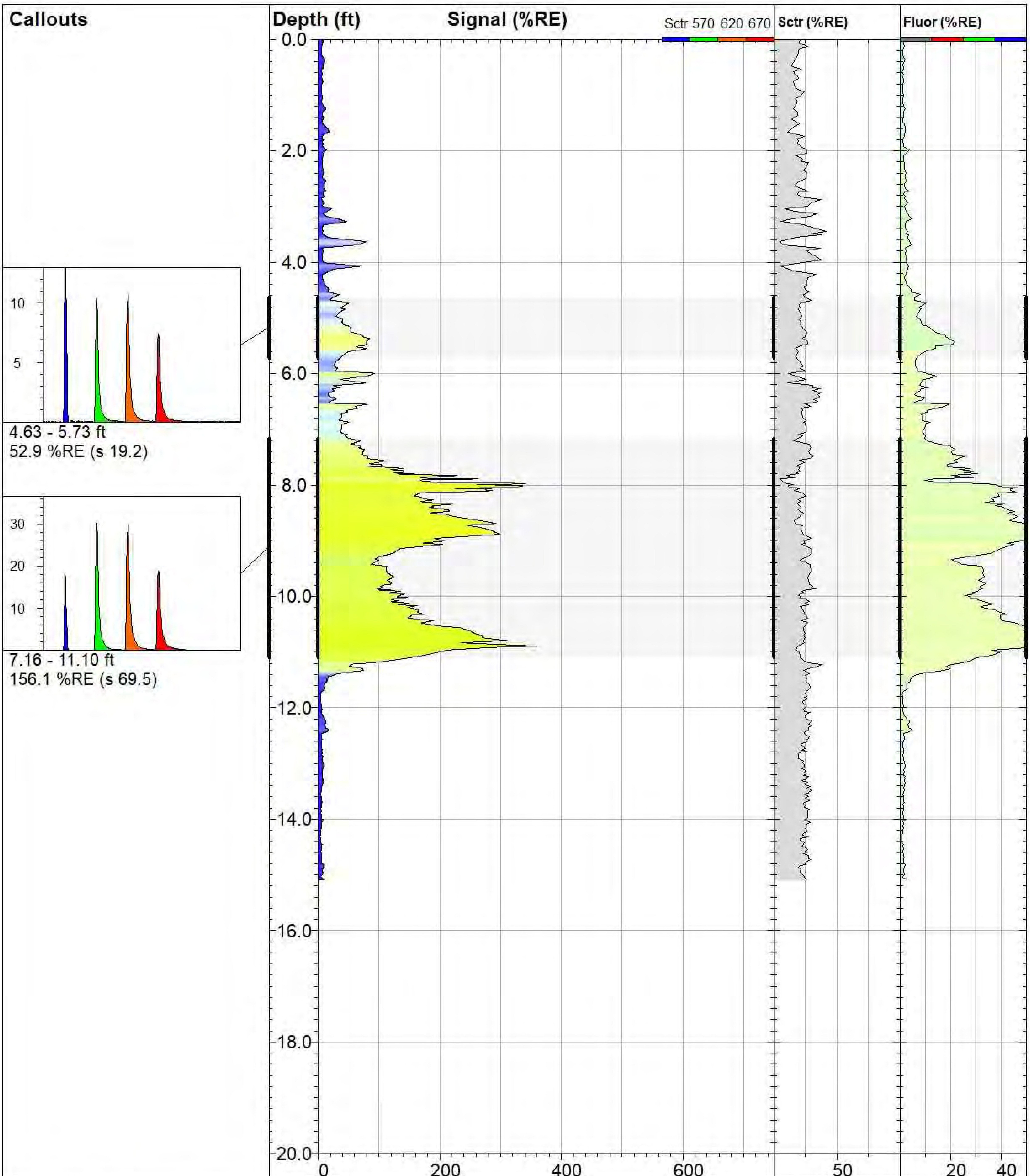
TG-46		TarGOST® By Dakota www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.13 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **597.4 %RE @ 7.24 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 11:06 CDT**



TG-47		TarGOST® By Dakota www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.09 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **360.7 %RE @ 10.89 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 10:43 CDT**

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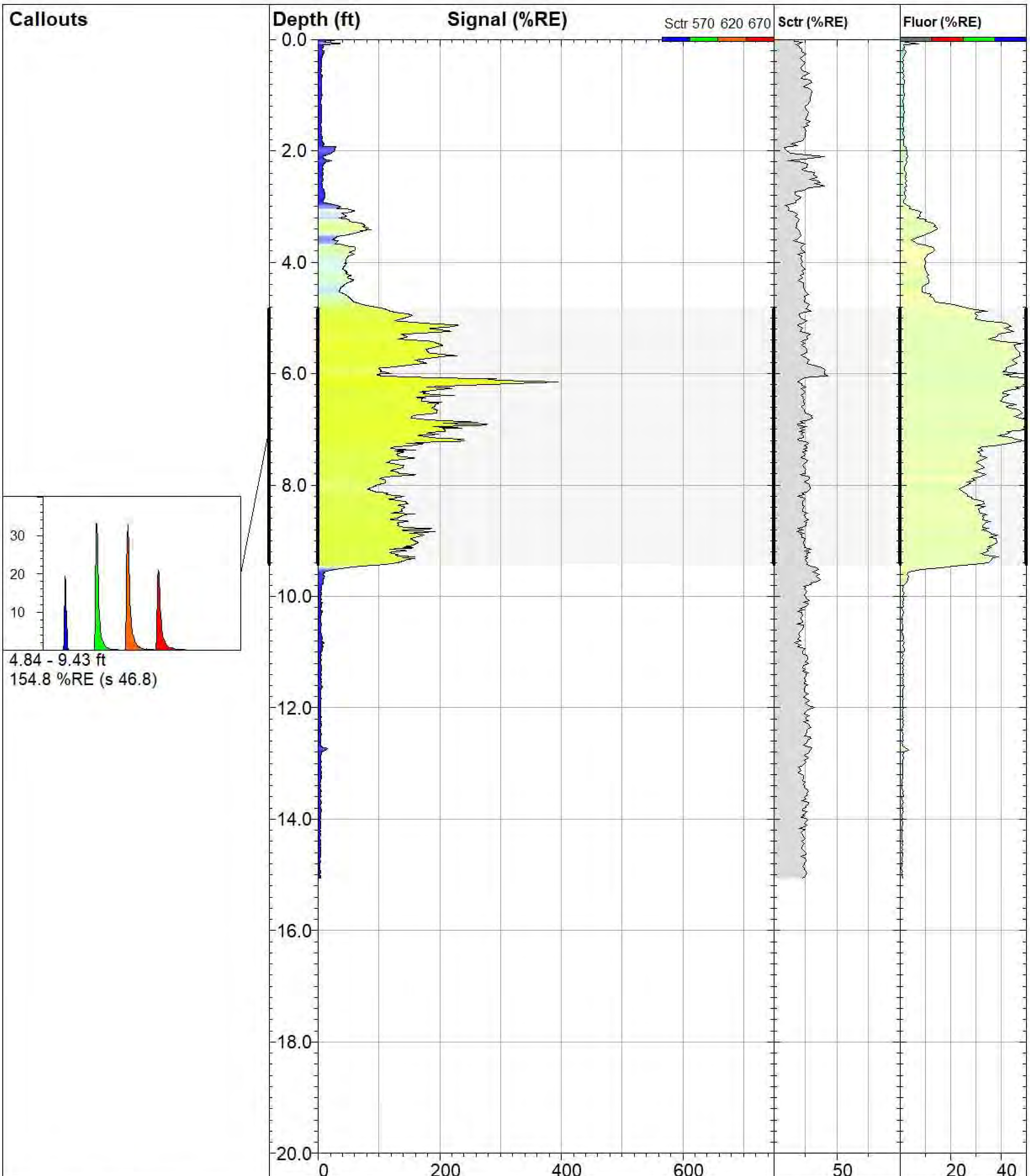

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TG-48		**TarGOST® By Dakota** www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.06 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **396.4 %RE @ 6.15 ft**
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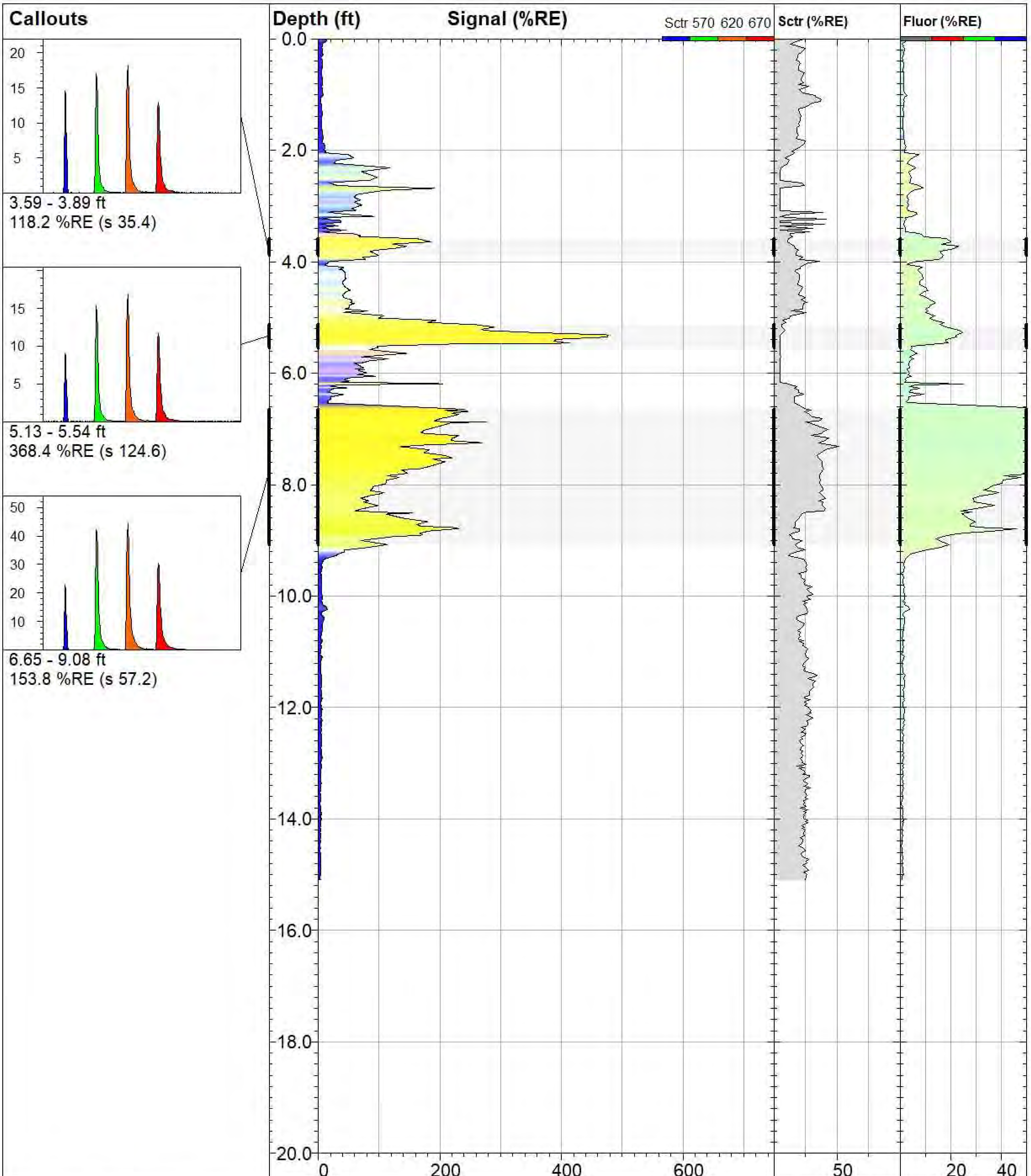

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TG-49

TarGOST® By Dakota
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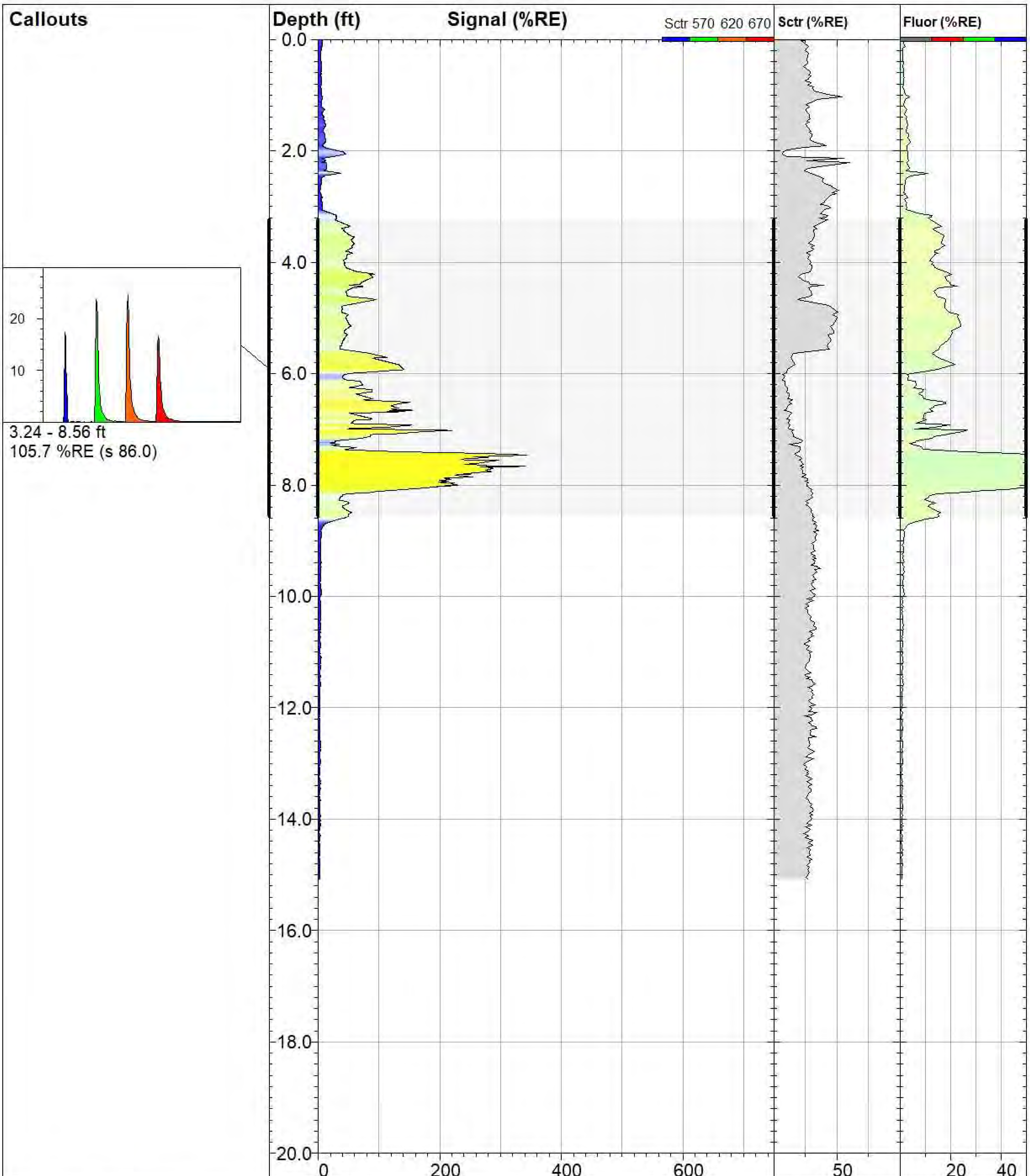
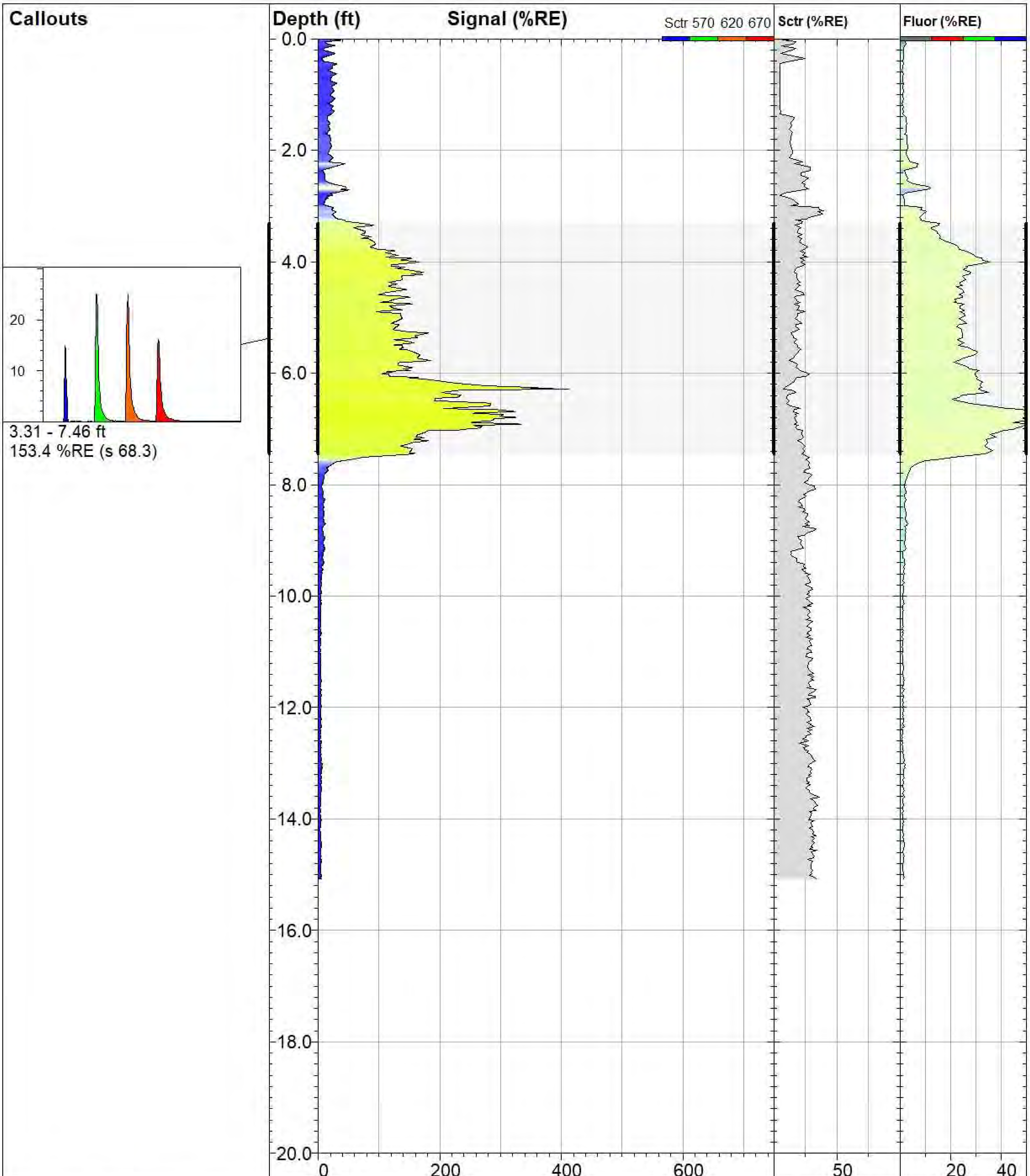
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.09 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **477.7 %RE @ 5.31 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 09:53 CDT**



DAKOTA TECHNOLOGIES www.DakotaTechnologies.com	**TG-50**		**TarGOST® By Dakota** www.DakotaTechnologies.com
	Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.08 ft**
	Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **344.1 %RE @ 7.46 ft**
	Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 09:28 CDT**



TG-51		TarGOST® By Dakota www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.07 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **415.9 %RE @ 6.29 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 09:06 CDT**

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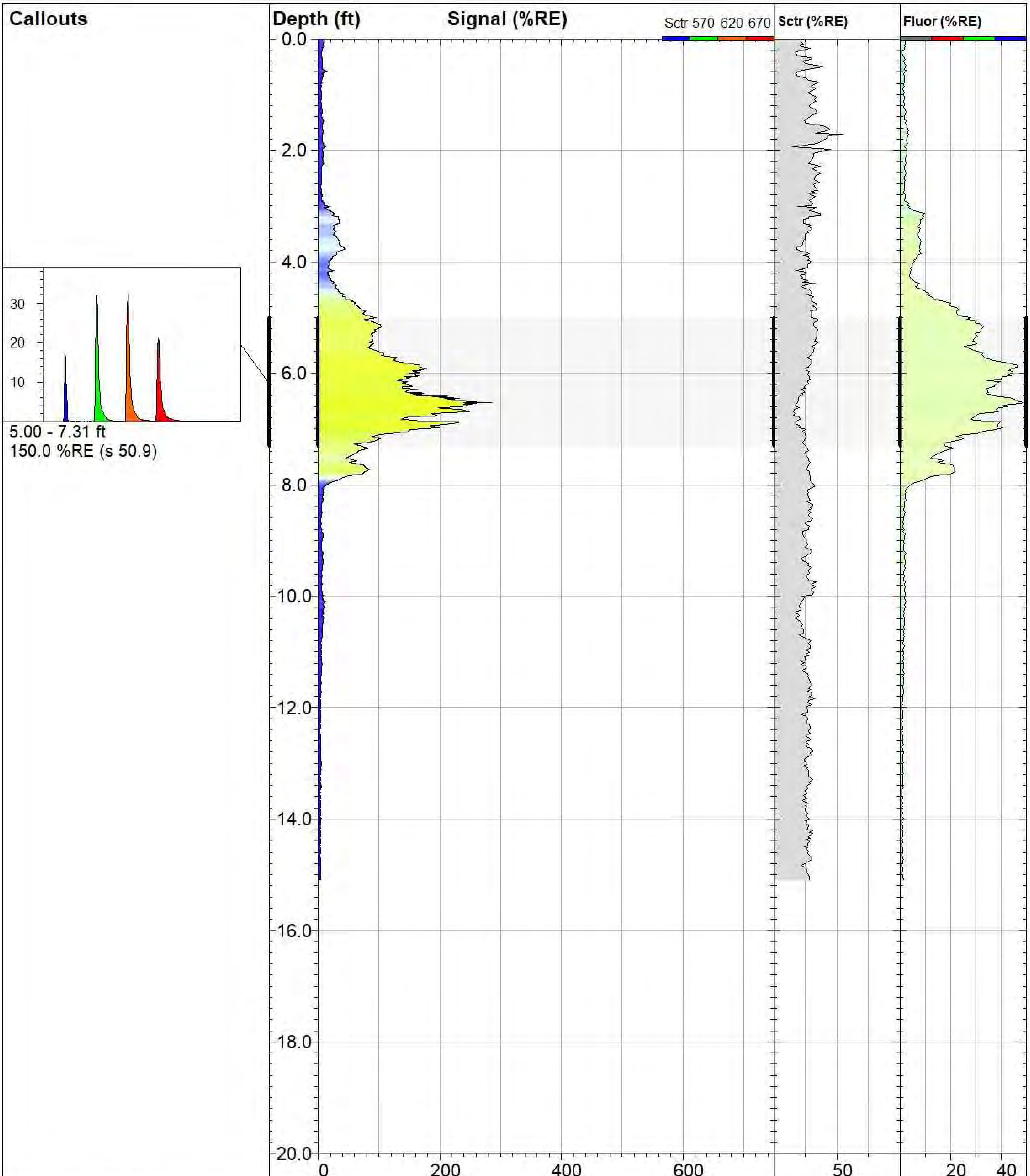

TG-52

TarGOST® By Dakota
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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.09 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **288.3 %RE @ 6.52 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 08:41 CDT**

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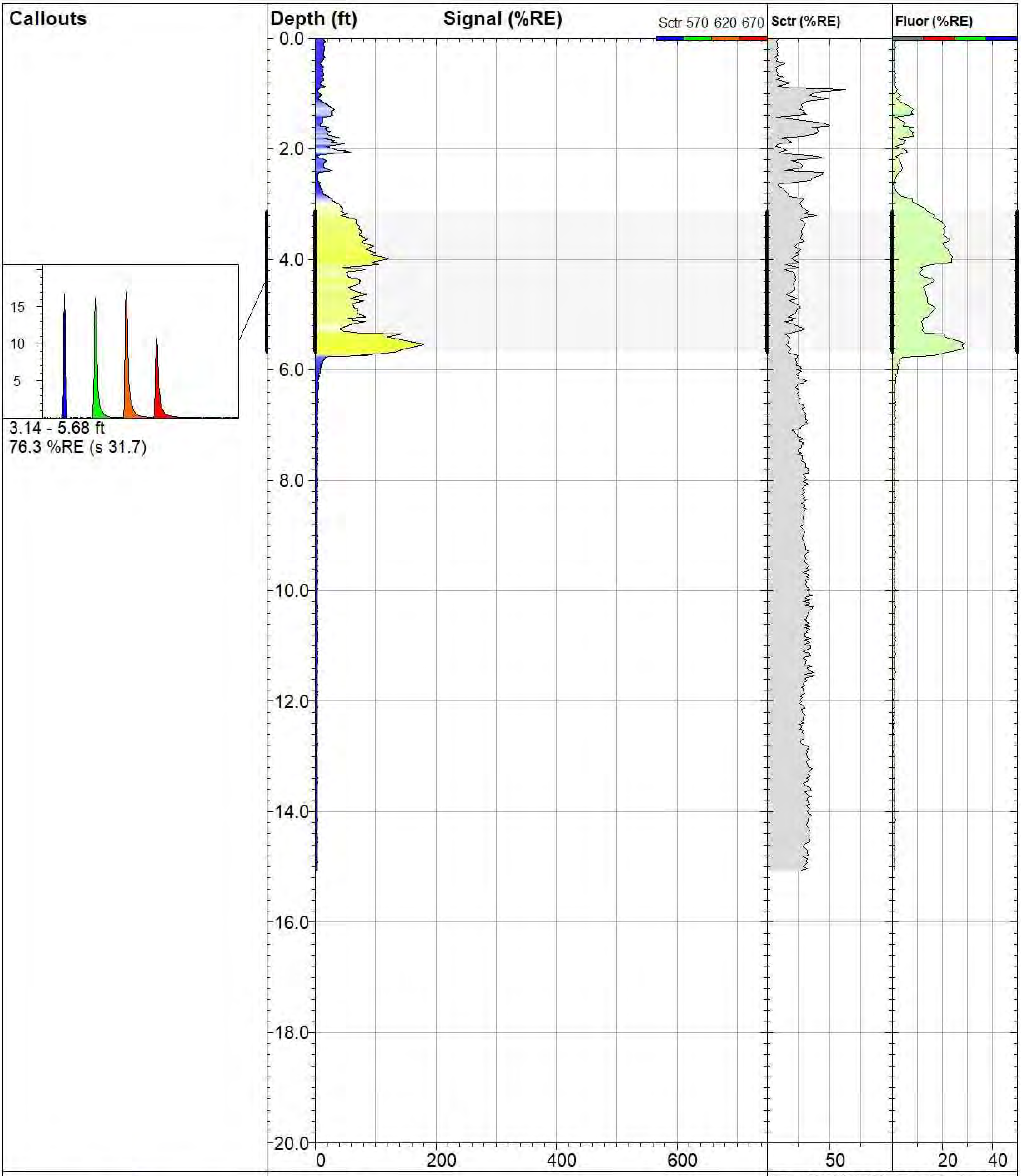

TG-53		**TarGOST® By Dakota** www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.06 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **179.3 %RE @ 5.55 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 14:26 CDT**

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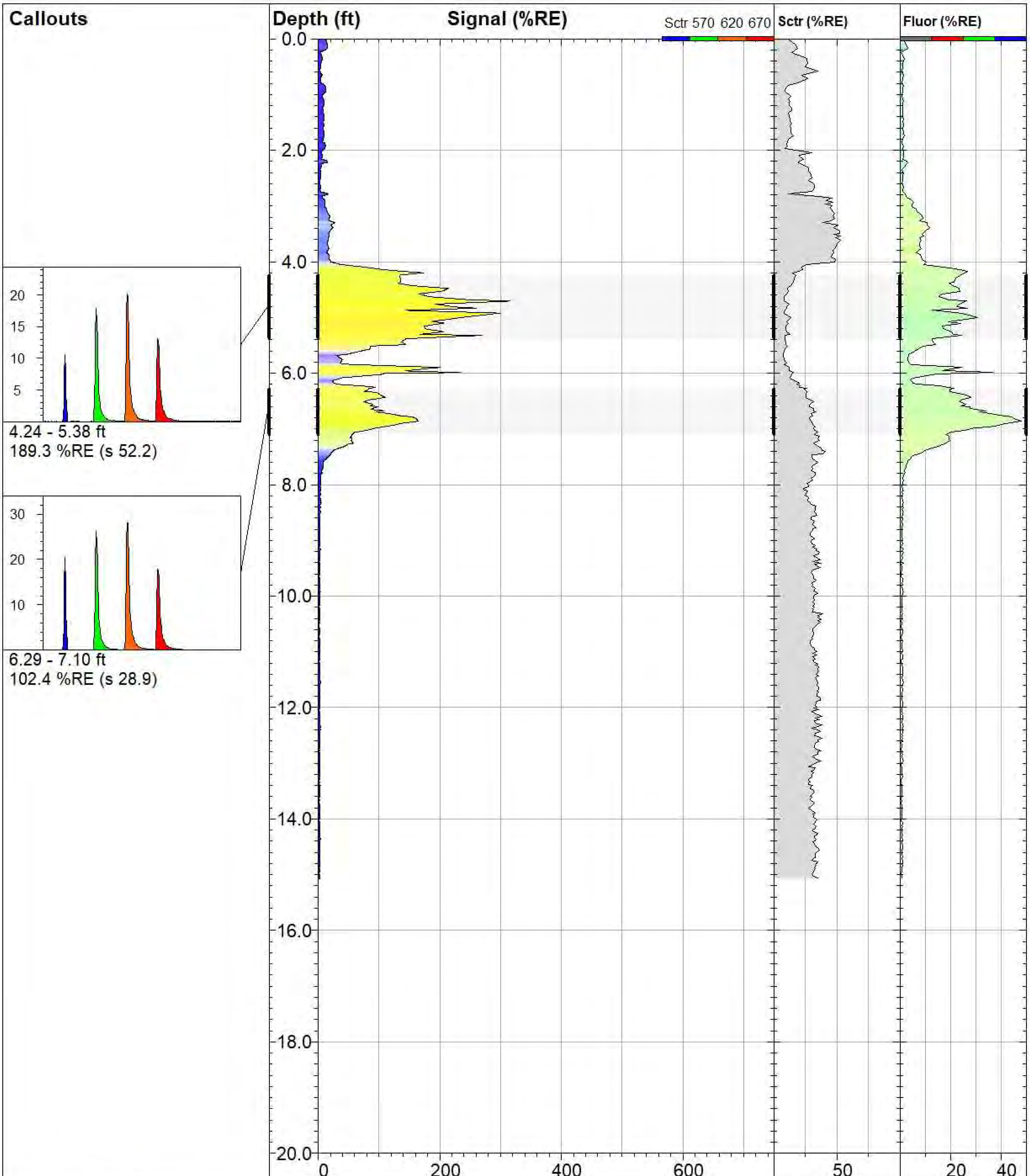

TG-54

TarGOST® By Dakota
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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.08 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **317.7 %RE @ 4.71 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 13:53 CDT**

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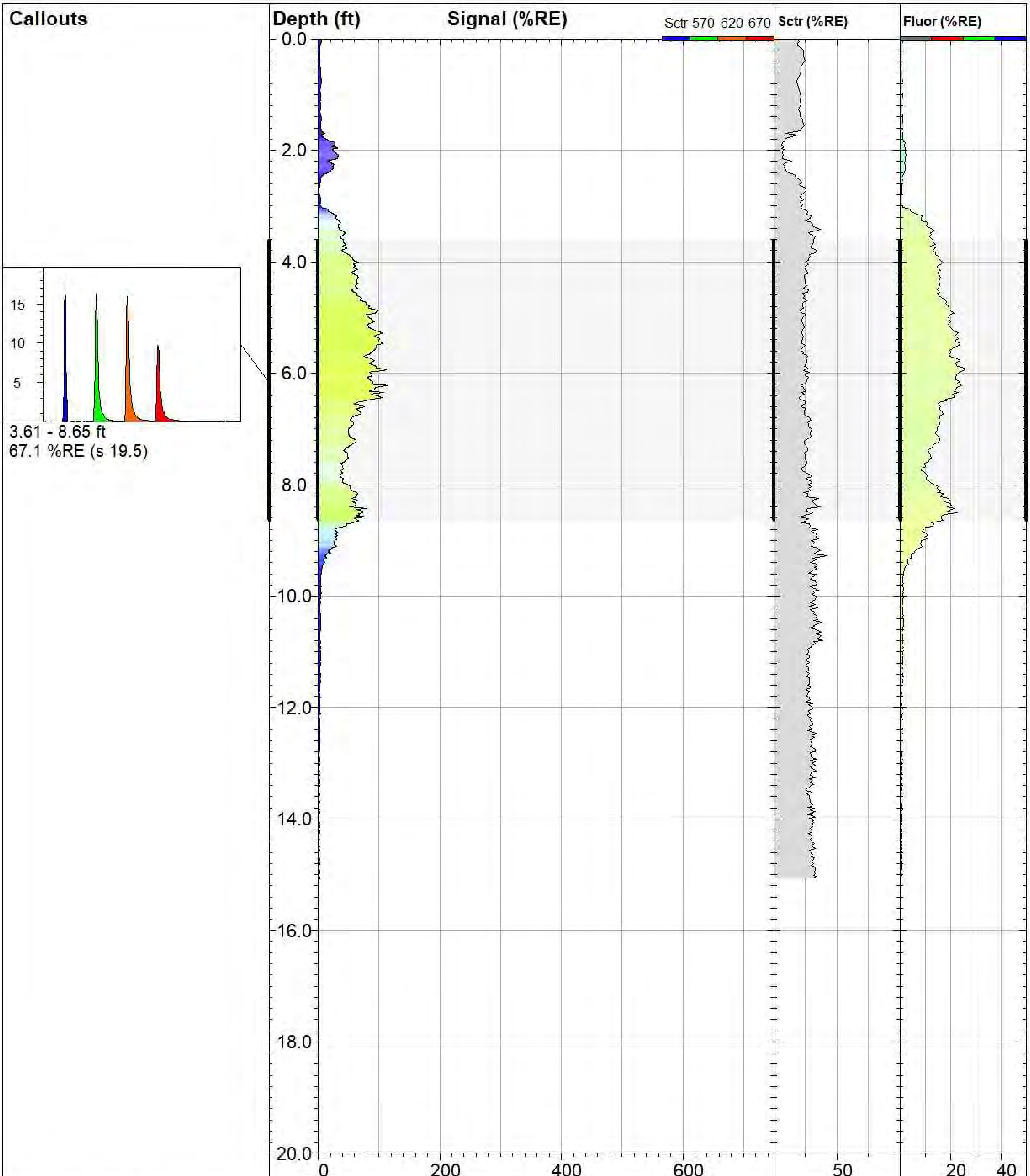

TG-55

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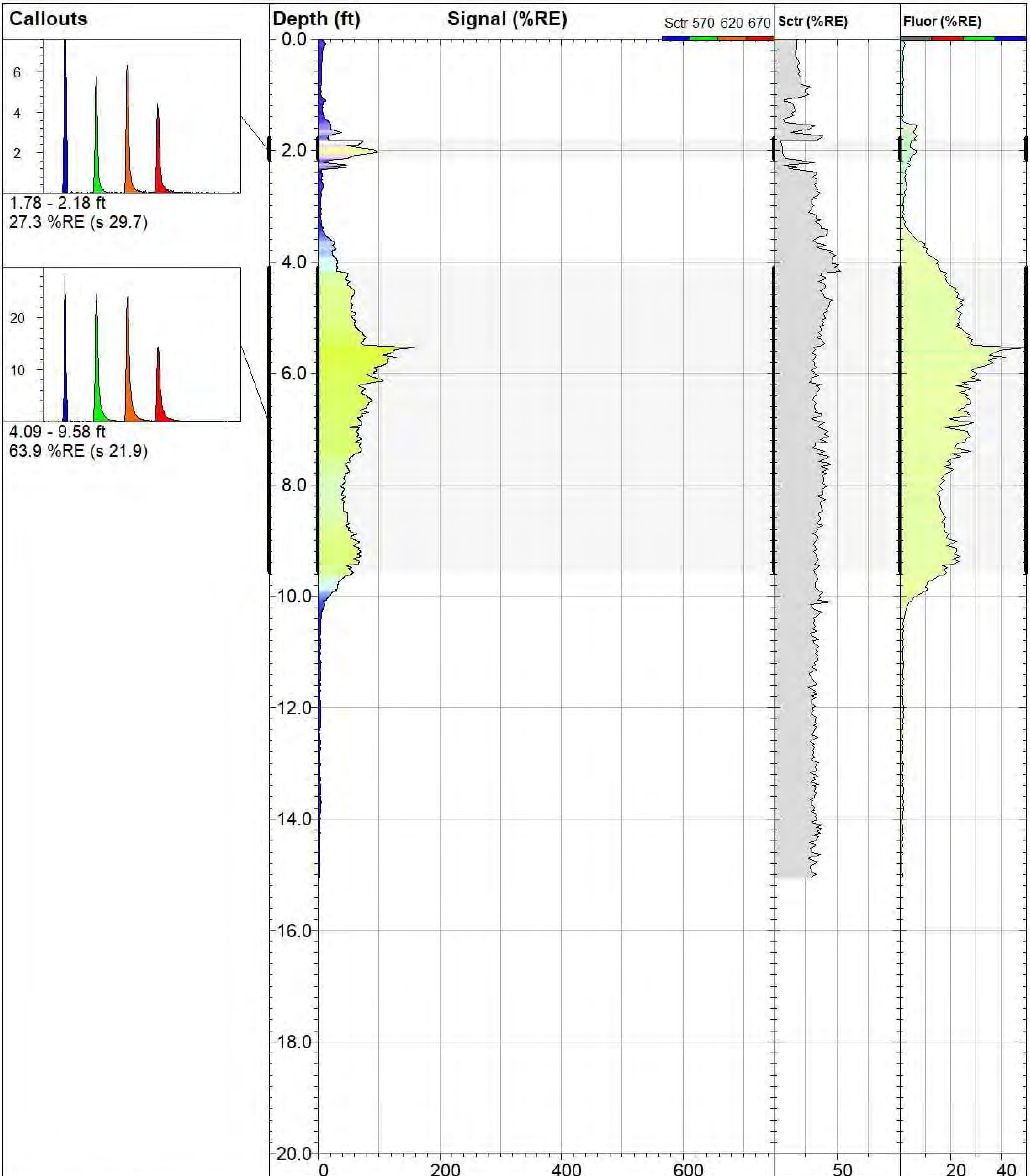
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.07 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **114.6 %RE @ 6.22 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 13:29 CDT**



TG-56

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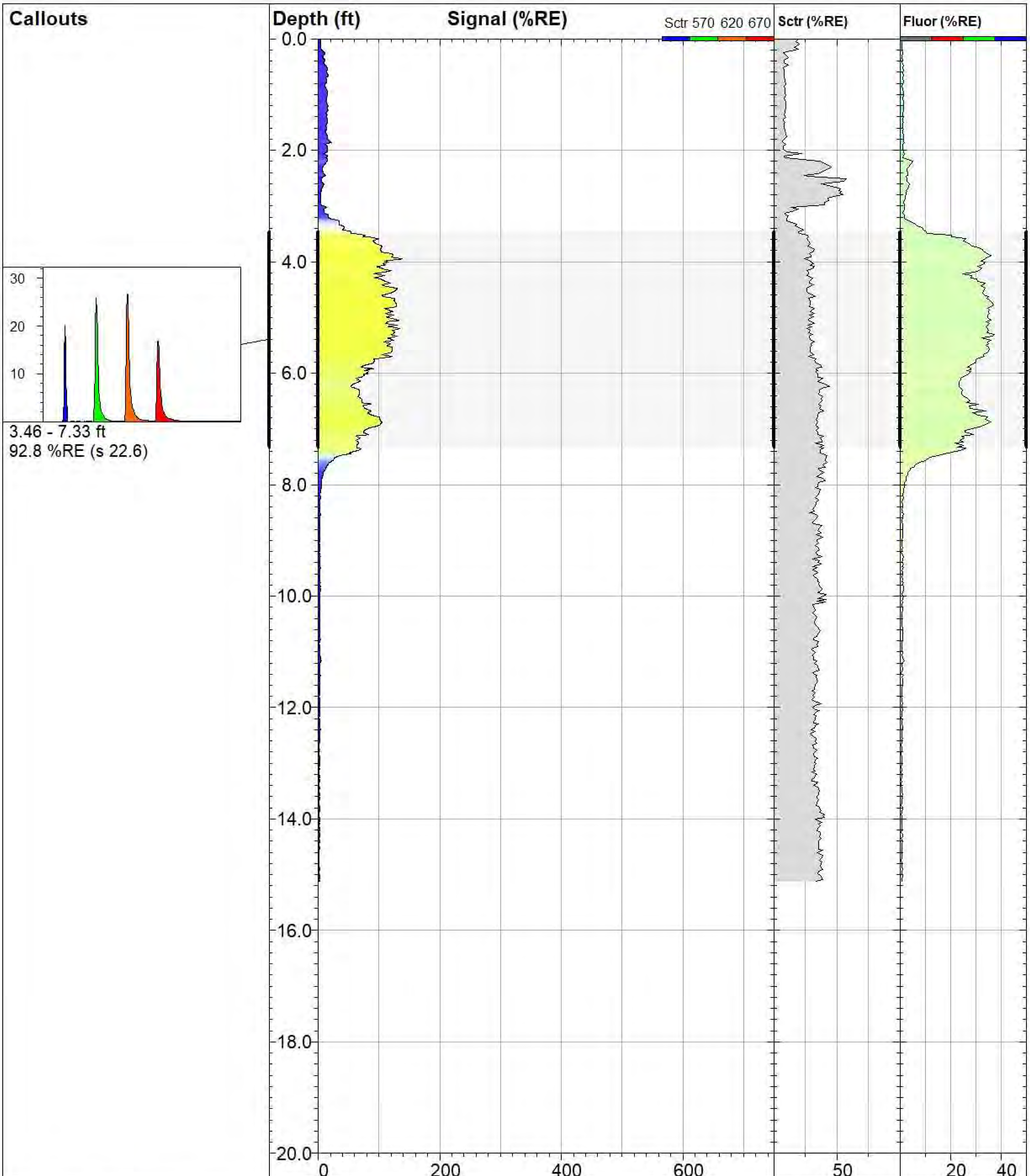
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.06 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **159.8 %RE @ 5.54 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 13:09 CDT**



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TG-57

TarGOST® By Dakota
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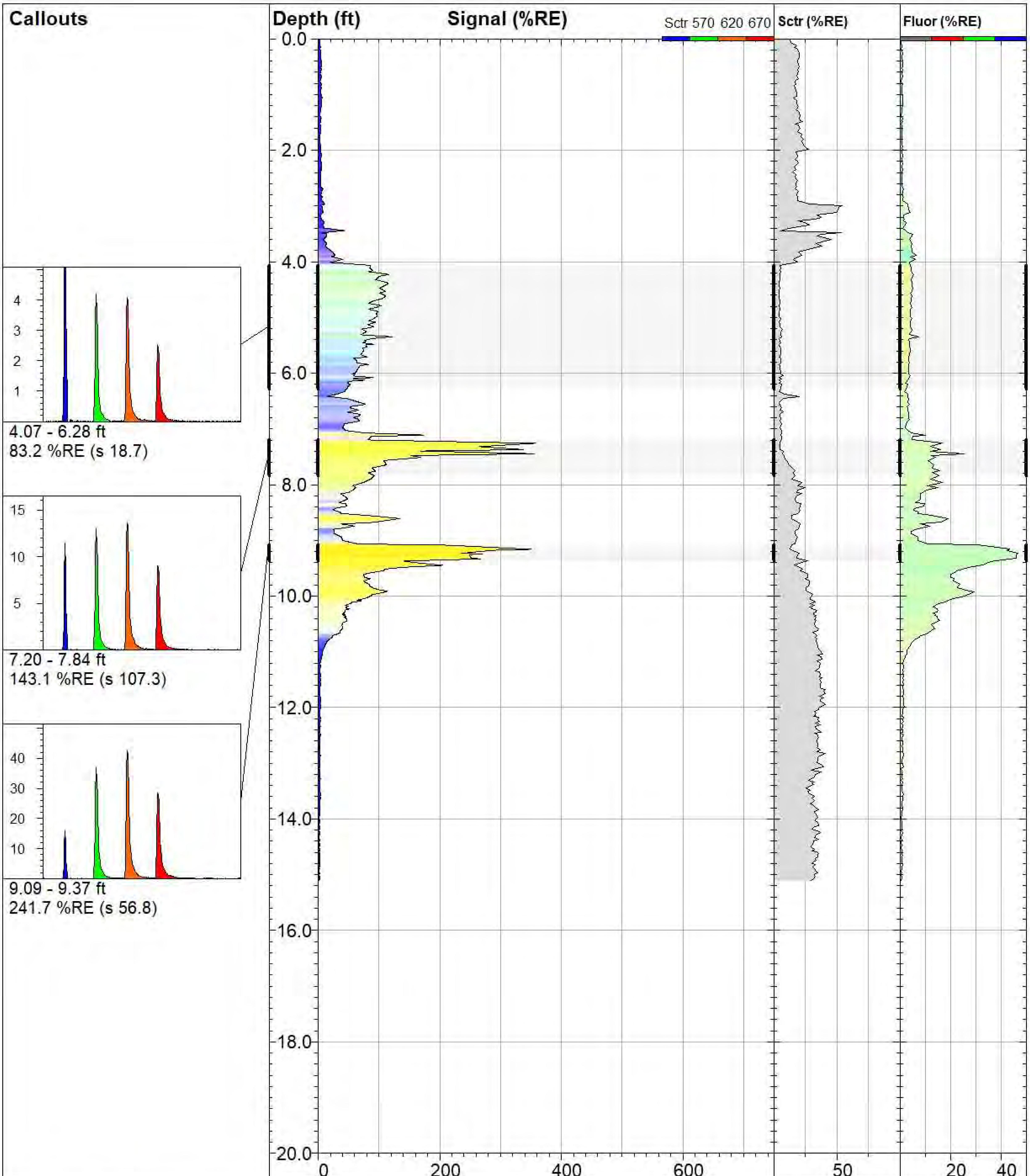
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.11 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **139.0 %RE @ 3.95 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 16:10 CDT**



TG-58

TarGOST® By Dakota
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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.10 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **358.9 %RE @ 7.26 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 15:49 CDT**

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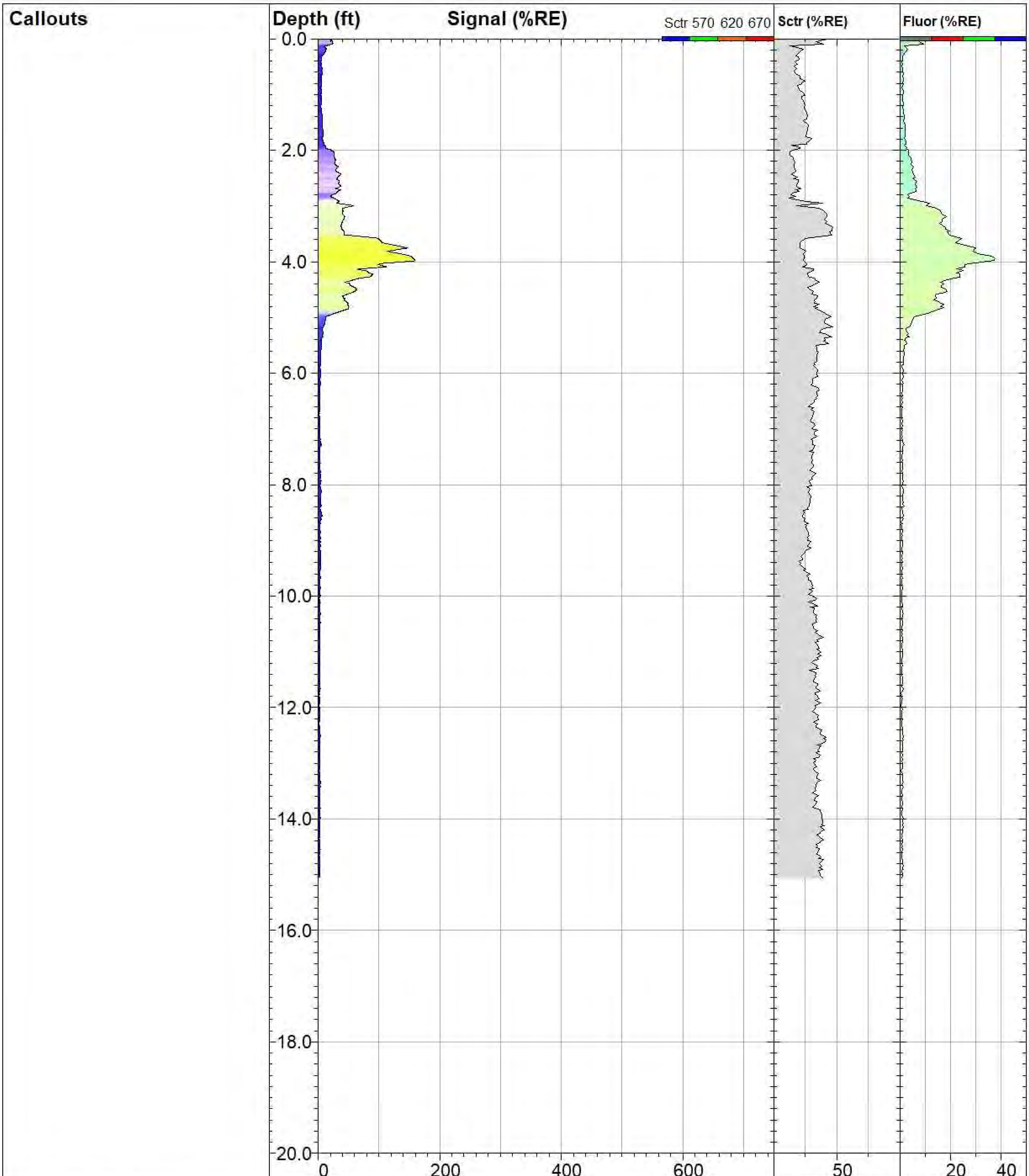

TG-59		TarGOST® By Dakota www.DakotaTechnologies.com
Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.05 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **159.6 %RE @ 3.98 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 14:52 CDT**

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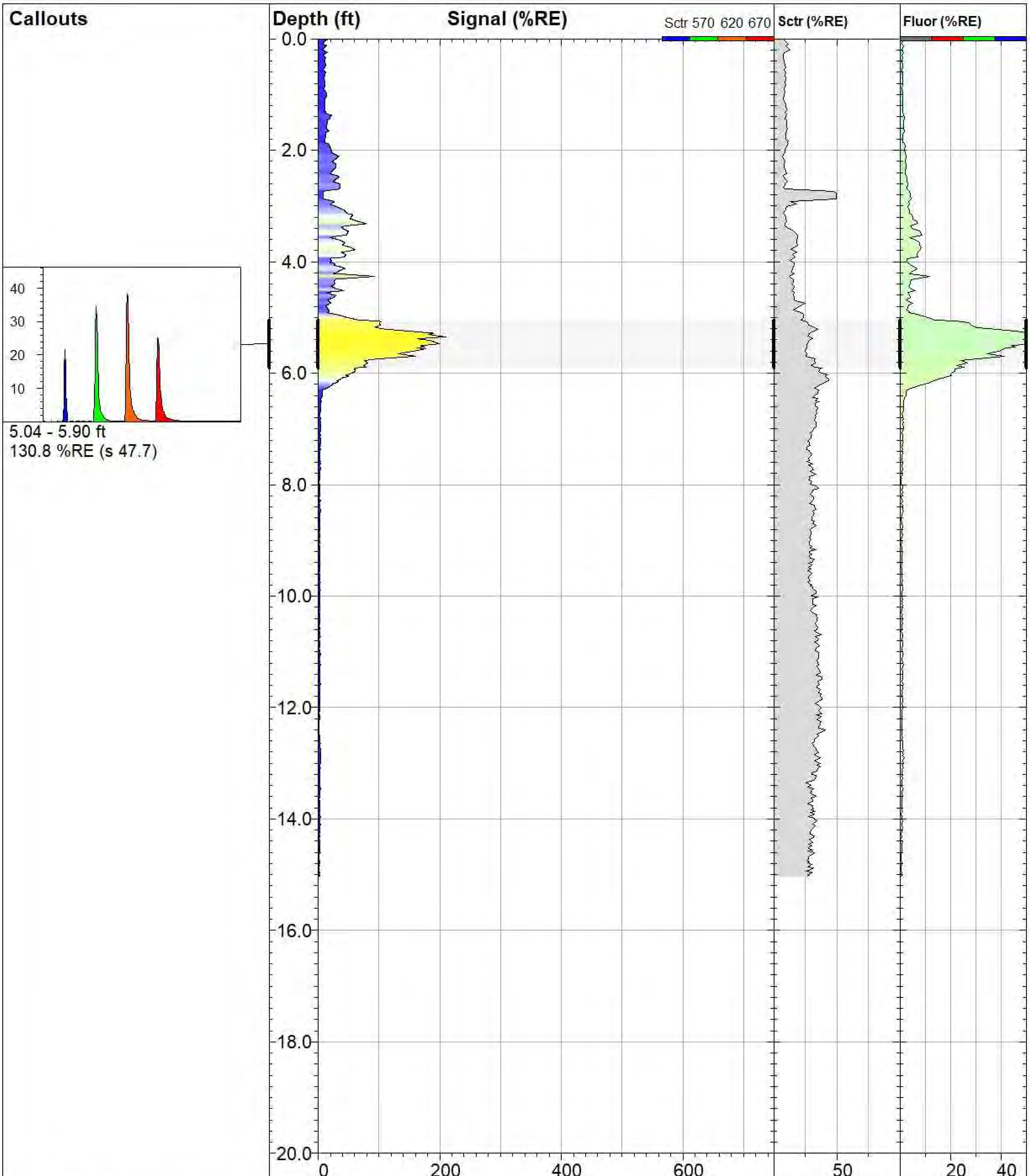

TG-60

TarGOST® By Dakota
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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.03 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **211.0 %RE @ 5.35 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 15:21 CDT**

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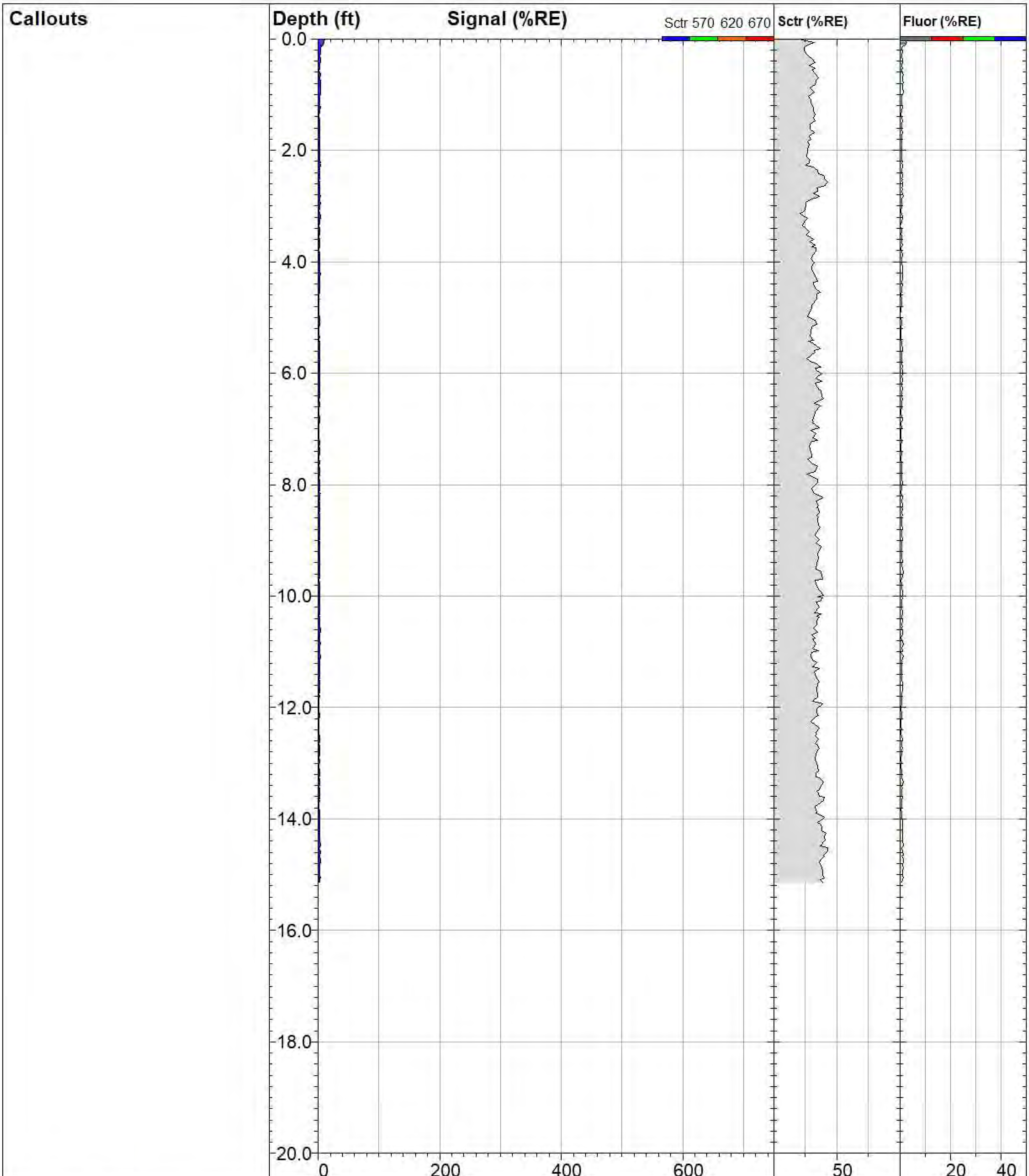

TG-61

TarGOST® By Dakota
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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.13 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **21.1 %RE @ 0.00 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 16:39 CDT**

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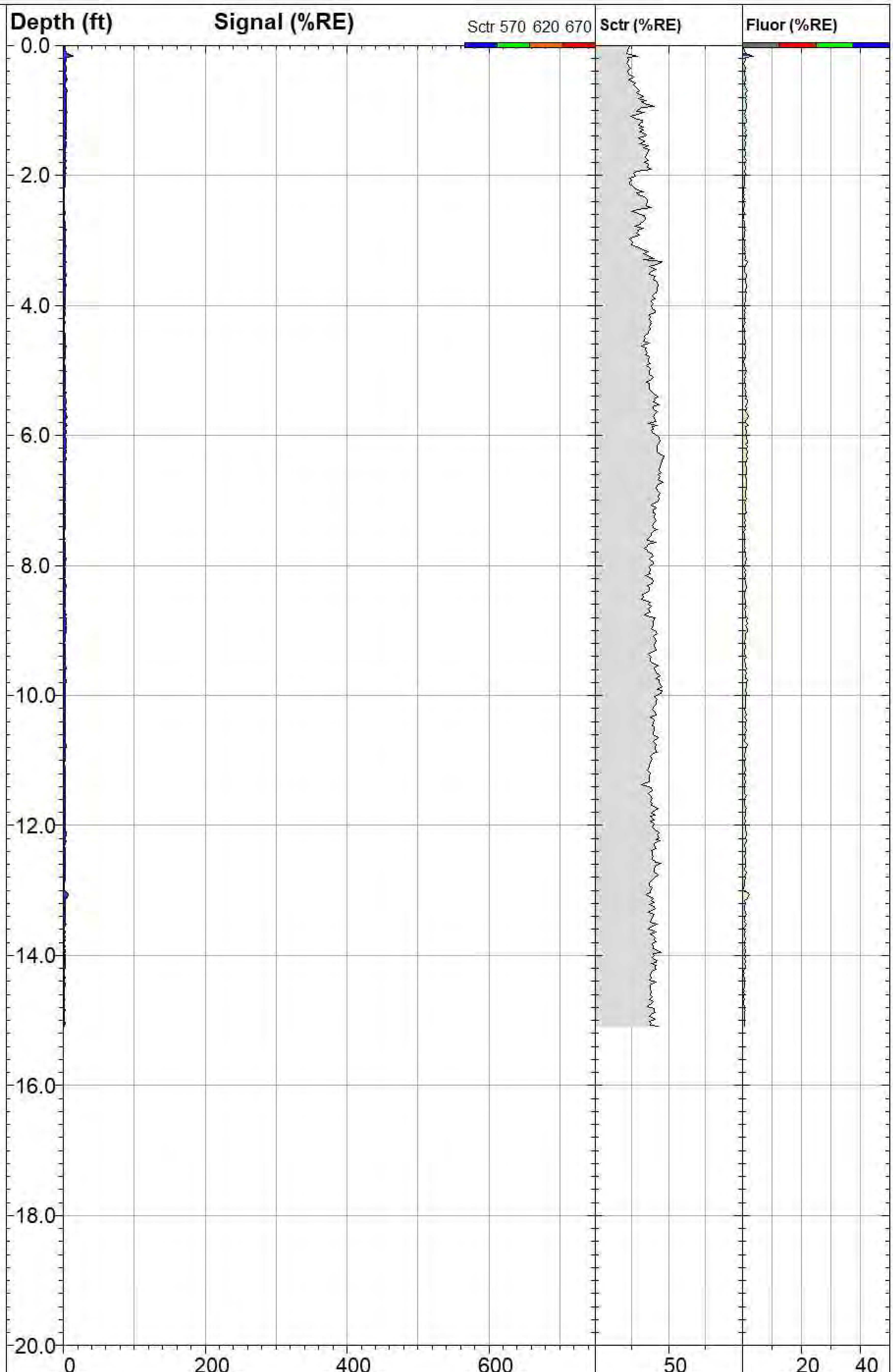
Callouts



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TG-62

TarGOST® By Dakota
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Site: **CLINE AVE DITCH**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **15.09 ft**
Client / Job: **GHD / 160.17**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **13.2 %RE @ 0.17 ft**
Operator / Unit: **SWM / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-11 17:07 CDT**

Appendix C
Dart Literature and Results

Appendix C.1
Dart Information Sheet,
“Vertical Characterization of MGP in Sediments Using Laser-Induced Fluorescence Based Passive Samplers”

Vertical Characterization of MGP NAPL in Sediments Using Laser-Induced Fluorescence Based Passive Samplers

R. St. Germain[1], T. Rudolph[1], D. Bessingpas[2]

(1) Dakota Technologies, Inc., Fargo, North Dakota, USA (2) ARCADIS, Baxter, Minnesota, USA

ABSTRACT

ARCADIS and Dakota Technologies deployed two types of in-situ NAPL screening tools in order to characterize coal tar NAPL in river sediments adjacent to a former MGP site. A Tar-specific Green Optical Screening Tool (TarGOST®) was used to log NAPL vs. depth successfully in most areas. Unfortunately, TarGOST characterization of sediments within a gas line buffer zone area was deemed too dangerous due to the direct push machinery used to advance TarGOST. As a solution, Dakota developed customized Dart™ samplers which consist of stiff rods coated with solid phase extraction (SPE) media, which attracts and sorbs PAHs. The Darts were manually installed into the upper 6 to 12 ft of sediments, left in place for 24 hours, and retrieved. Subsequent laser-induced fluorescence (LIF) analysis of the Dart's SPE media indicated the presence and relative availability of PAHs from the sediments in the buffer zone. Site-specific NAPL mixed with clean site sediments were later applied to Darts in the lab in order to improve our understanding of the in-situ Dart sampler's quantitative/qualitative behavior at this particular site.

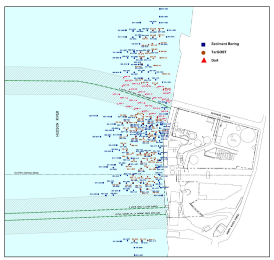

FIGURE 1. Site map showing utility corridor of concern along with TarGOST and Dart locations (Dart locations in red).

Dart Samplers: How they function and how they're analyzed

The Dart samplers are basically fiberglass rods covered with a non-fluorescent SPE media, similar to that used in solid-phase micro-extraction (SPME) analytical methods. With a Kow ranging from 3 to 6, the hydrophobic PAHs prefer to be in NAPL (or similar organic material). The Dart's organic SPE cladding has a high affinity for PAHs, which they sorb into readily. The PAHs contained in MGP NAPL (coal tar) fluoresce poorly under ultra-violet excitation. But those same PAHs, having transferred into "solid solution" in the Dart's SPE cladding, fluoresce much more intensely. This fluorescence can be sensitively analyzed along the entire length of the Dart with LIF, resulting in a log of the PAH concentration along the Dart's length. The LIF log represents the PAH exposure that occurred while the Dart was exposed to the sediment column.

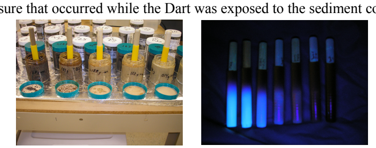

FIGURE 2. A visual demonstration of how Darts glow in response to various concentrations of MGP NAPL on Fisher Scientific sea sand.

Visual observations with a handheld lamp, while "handy" and intuitive, do not generate the sensitive and quantitative digitized readings that laser-induced fluoresce systems such as UVOST can provide. In order to "read" the sorbed PAHs' fluorescence along the Darts entire length and circumference, a lathe-like device is used to rotate the Dart while the UVOST system logs a detailed reading of the PAH fluorescence vs. "depth".

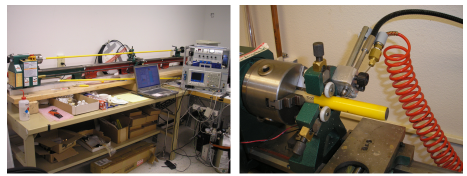

FIGURE 3. Dart logging system including lathe-based reader and UVOST system – full system (left) and close-up of optics system (right).

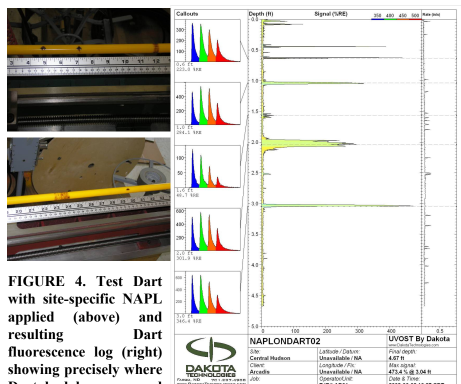

FIGURE 4. Test Dart with site-specific NAPL applied (above) and resulting Dart fluorescence log (right) showing precisely where Dart had been exposed to NAPL.

Field Deployment

The Dart samplers are inserted into the sediments and left in place for 24 hours to allow PAHs to transfer into the SPE cladding. Buoys were used to pre-mark the Dart locations and divers placed the Darts into the sediment by hand, on occasion using a small customized drive hammer to achieve full penetration. Short lengths of floating cord attached to each Dart allowed the divers to find the Darts 24 hours later and retrieve them. After retrieval, the Darts were wrapped in aluminum foil and taken to shore for UVOST analysis. Analysis of each Dart takes about 30 minutes.

FIGURE 5. Plastic wrapped Darts ready for installation (upper left), diver with Dart and drive tool (upper middle), retrieved Dart ready for reading (upper right), and dive boat in buffer zone (bottom).

Analysis Results

Each Dart was scanned on-site with UVOST LIF. Since the PAHs are now "locked into" the SPE cladding and don't require icing, the Darts could have been shipped to Dakota for reading. A variety of responses were observed. Examples logs from the 28 Dart locations are shown below in Figure 6. Notice that most of the logs show a foot or so of clean sediment near the surface. The "spiky" appearance is due to smearing, streaking, or "hot spots" on one side of the Dart, but not the other.

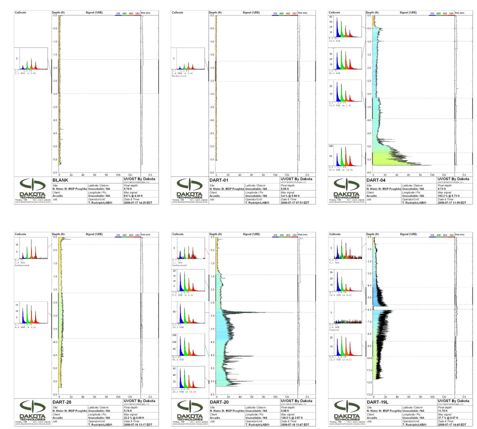

FIGURE 6. Variety of logs generated from the 28 Darts deployed in the buffer zone (utility corridor).

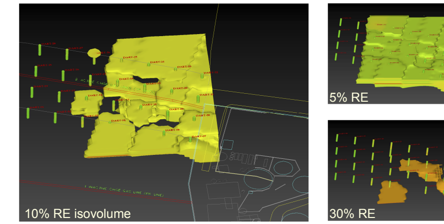

FIGURE 7. 3D visualization of the fluorescence response of the Darts. The fluorescence scaled with PAHs transferred to the SPE of the Darts.

Lab Results

Laboratory experiments were conducted using site sediment (a fine dark highly organic sediment) and Fisher Scientific brand sea sand to mimic two extremes of soil types. Site NAPL from a nearby well was spiked onto the two soil types. Test Darts were exposed to these sediments for 24 hours and analyzed with UVOST. The samples were also tested with TarGOST for comparison. See Figure 2 for basic approach.

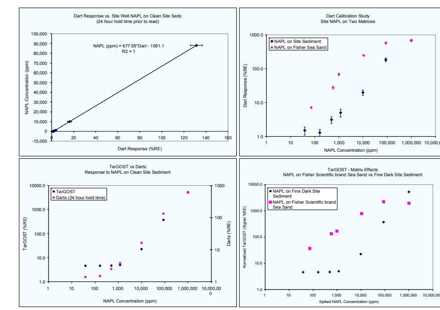

FIGURE 8. Dart and TarGOST response to site-specific NAPL on fine dark organic sediment and Fisher Scientific sea sand.

Conclusions

The use of Dart samplers to delineate the extent of PAH impacted sediments within the gas line buffer zone area was successful. Like TarGOST, the Darts responded monotonically to NAPL concentration as desired. Just as TarGOST responds to PAHs (NAPL) "available" to the sapphire window, Darts respond to PAHs "available" for direct contact with the SPE cladding. Soil matrix effects influence both TarGOST and Darts, similar to how soil type influences a visual core examination by a geologist. The Dart samplers, like TarGOST, are affected by sediment type and have improving limits of detection with increasing porosity (grain size) and decreasing organic content. Determination of an exact %RE threshold that is equivalent to a "NAPL present" visual assessment was difficult because the presence of NAPL at low concentrations is difficult to define or quantify. Site-specific calibration was useful for rigorously quantifying the Dart's in-situ performance and to provide confidence regarding interpretation of the LIF logs generated during the Dart survey.

Appendix C.2
LIF-Dart Paper,
“Laser-Induced Fluorescence Coupled with Solid-Phase Microextraction for In Situ Determination of PAHs in Sediment Pore Water”

Laser-Induced Fluorescence Coupled with Solid-Phase Microextraction for In Situ Determination of PAHs in Sediment Pore Water

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Energy and Environmental Research Center, Campus Box 9018, University of North Dakota, Grand Forks, North Dakota 58202, Dakota Technologies, Inc., 2201A 12th Street North, Fargo, North Dakota 58102, and ENSR Corporation, Inc., 1001 West Seneca Street, Suite 204, Ithaca, New York 14850

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In situ sampling with solid-phase microextraction (SPME) was coupled with laser-induced fluorescence (LIF) in an effort to develop a simple field-portable method to determine total dissolved PAH (polycyclic aromatic hydrocarbon) concentrations in sediment pore water. Glass fiber rods with a 50 μm coating of optically clear polydimethylsiloxane (PDMS) were inserted directly into sediment/water slurries. After 1−140 h (typically 18 h), the coated rods were recovered, rinsed with water, and their LIF response was measured with excitation wavelength (308 nm) and emission wavelengths (350−500 nm) chosen to monitor 2- to 6-ring PAHs. SPME-LIF response was independent of sediment sample size, as is required for equilibrium sampling methods to be used in situ in the field. Potential interferences from high and variable background fluorescence from dissolved organic matter were eliminated by the use of the nonpolar PDMS sorbent. The detection limit in pore water was ca. 2 ng/mL (as total PAH-34), which corresponds to ca. 0.2 EPA PAH toxic units. Good quantitative agreement ($r^2 = 0.96$) for total PAH-34 pore water concentrations with conventional GC/MS determinations was obtained for 33 surface sediments collected from former manufactured gas plant (MGP) and related sites. Quantitative agreement between SPME-LIF and GC/MS total PAH-34 concentrations was also good for 11 sediment cores ($r^2 = 0.87$), but the predominance of 2-ring PAHs (compared to the other sites) resulted in a lower relative SPME-LIF response compared to the surface sediment samples. The method is very simple to perform, and should be directly applicable to field surveys.

Introduction

Several investigators have demonstrated that using sediment concentrations and conventional organic carbon/water partitioning coefficients (K_{OC}) can over-predict pore water concentrations of hydrophobic organic pollutants such as polycyclic aromatic hydrocarbons (PAHs) by up to three orders of magnitude, most likely because of the presence of several types of “black” or “soot” carbon (BC) in sediments that tightly bind PAHs (*1−5*). Therefore, investigations into the bioavailability of PAHs and related hydrophobic organics in sediments have increasingly focused on measuring pore water concentrations, rather than attempting to predict pore water concentrations based on sediment concentrations (*6−11*). Pore water concentrations are usually measured either by direct exposure of a nondepletive sorbent into the sediment/water slurry (*8−11*), or by separating the pore water and determining the dissolved PAH concentrations after solvent extraction or by using solid-phase microextraction (SPME) (*6, 12*).

In addition to the increasing recognition that direct pore water measurements are needed to predict the bioavailability of sediment PAHs, it is becoming apparent that the conventional parent PAHs measured by EPA method 8270 (PAH-16) are not sufficient to represent potential PAH biological effects (*7, 13*). For example, the PAH-16 only accounts for ca. 40% of the total PAH concentrations in coal tars from manufactured gas plant (MGP) sources, and only ca. 1% of the total PAH concentrations in a petroleum crude oil (*14*). In recognition of this fact, the U.S. EPA has proposed measuring a more inclusive range of 18 parent and 16 groups of alkyl PAHs (PAH-34) in sediments and sediment pore water (*13*). Although laboratory methods to measure pore water PAH-34 concentrations have been developed (*12*), there is a strong desire on the part of site managers and regulatory personnel to determine pore water PAH concentrations on site with in situ samplers, both to reduce the time and cost of site surveys and to minimize alterations to the samples that may occur during sample collection, shipping, and laboratory analysis.

Several groups have used a nondepletive in situ solid-phase microextraction (SPME) approach to determine dissolved PAH pore water concentrations. Sorbents such as polydimethylsiloxane (PDMS) or polyoxymethylene (POM) are inserted directly into sediment/water slurries and typically left for weeks to come to equilibrium (*8−11*). The partitioning of PAHs to such sorbents is controlled primarily by each PAH’s octanol/water partitioning coefficient (K_{OW}), and is therefore thought to mimic partitioning of PAHs between sediment pore water and biological lipids. Such sorbents are typically retrieved from the sediment, returned to the laboratory, and solvent extracted to determine PAH concentrations by conventional chromatographic methods. Therefore, these methods tend to retain many of the time and cost disadvantages of collecting sediment samples and shipping them to the laboratory for pore water analysis.

There have also been several attempts to directly measure PAH concentrations in water using laser-induced fluorescence (LIF). Unfortunately, the success of LIF to determine PAH concentrations has been limited by background spectral interferences from natural dissolved organic matter (DOM) (*15−19*). Time-resolved fluorescence has been used to reduce background DOM emission, but approaches typically measure only a limited number of parent PAHs (*15−19*). An alternate approach would be to separate the PAHs from the DOM prior to LIF with the use of a nonpolar solvent such as hexane (*20*), but this requires separation of the sediment and pore water, and is not practical in the field. However, since DOM is polar and has high water solubility, nonpolar sorbents used for in situ pore water sampling (e.g., PDMS) should largely exclude DOM, while collecting the nonpolar

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PAHs. Therefore, the goal of our present study is to combine the ability of in situ SPME methods to determine pore water PAH concentrations with the sorbents' ability to exclude polar DOM in an effort to allow LIF determination of sediment pore water PAH-34 concentrations. SPME rods were selected that had low intrinsic fluorescence background and rapidly approached equilibrium with the pore water. Four emission wavelengths associated with 2- to 6-ring PAHs were monitored and the emission intensities were compared to pore water and sediment concentrations of the PAH-34, and the total PAH "toxic units" (TUs) were calculated using the EPA hydrocarbon narcosis model (*13*).

Experimental Procedures

Sediment Collection and Characterization. Sediment collection procedures and analytical methods have been described in detail in earlier reports (*4, 12, 14*). In brief, sediments were collected using a Ponar grab sampler or, for the subsurface samples (Site D), using 3-in. Vibracores. Sediment/water slurry samples were field sieved through a 4-mm screen, briefly mixed, transferred to new glass jars with Teflon-lined lids, and immediately placed on ice. This procedure resulted in sediment/water slurries with approximately 40−70% water content. Samples were shipped overnight to the laboratory, and stored in the dark at ca. 4 °C until used. Because of concerns about possible changes in pore water PAH concentrations during storage, GC/MS and SPME-LIF analyses were typically performed within one week of each other, and all sediments were analyzed less than 28 days after collection. TOC and BC were determined by elemental analysis (C, H, N) after acidification with HCl to remove inorganic carbonates. Samples for BC were prepared by oxidation under air at 375 °C for 24 h in a gas chromatographic oven (*22*).

Sediment and pore water PAH-34 concentrations were determined in quadruplicate using GC/MS as previously described (*12, 14*). Sediment extracts were prepared using 18-h Soxhlet extractions. Pore water samples were prepared using centrifugation followed by flocculation (*12*), and concentrations were determined using commercially available SPME fibers (7 μm PDMS coating, Supelco, Bellefonte, PA) specifically designed for thermal desorption into a gas chromatograph's injection port. Both methods used 2- to 6-ring perdeuterated PAHs as analytical internal standards. Pore water TUs were calculated using octanol−water coefficients (K_{OW}) as specified by the U.S. EPA (*13*).

SPME-LIF Determinations. The SPME sorbent used for the in situ studies was prepared by stripping the nylon buffer from an optical fiber supplied by Fiberguide Industries, Inc. (Stirling, NJ) with hot propylene glycol for approximately 2 min. The remaining PDMS cladding (50 μm film thickness, 600 μm core diameter) was found to have the lowest LIF response of any of the various PDMS materials tested. (Note: It is important not to confuse the SPME fibers used for GC/MS analysis of the flocculated pore water samples described above, and the SPME rods made from optical fibers used for direct insertion into the sediments followed by LIF determinations.) Each rod was cut into 2-cm lengths, rinsed with water, and stored in reverse osmosis purified water (previously determined to be clean of fluorescence via direct measurement with LIF).

SPME sorptions of the PAHs in sediment/water slurries were performed directly in the 250-mL jars used to ship the samples to the laboratory from the field. The rod was simply inserted into the center of the sediment/water slurry and the samples were kept in the dark during the exposure times. No steps were taken to prepare the field samples prior to inserting the cleaned SPME rod. In an effort to best mimic use of the rods in the field (e.g., inserting the rod into the top 10 cm of sediment, or the biologically active zone), no mixing was used. After the selected exposure time, the rod was removed from the sediment, particles were removed with a brief spray of clean water, and the PAH content was analyzed by LIF.

LIF was performed using an Ultra-Violet Optical Screening Tool (UVOST) manufactured by Dakota Technologies, Inc. (Fargo, ND). The sorbent rod was placed in a holder at 90 degrees to collinear excitation and emission optics, located approximately 5 mm from the surface of the rod. This orientation provided an optical interrogation zone approximately 3 mm long at the center of the rod's length, which allowed the sorbent rod to be handled at the ends without disturbing or contaminating the section of the rod interrogated by LIF. Excitation was achieved with 5 ns (full width at half-maximum) pulses from a XeCl excimer laser. Since the goal of this method is to monitor the total alkyl and parent PAHs, excitation was performed at 308 nm in order to excite 2- to 6-ring PAHs, and to avoid fluorescence from monocyclic aromatics such as benzene and toluene. Emission wavelengths were monitored at 350, 400, 450, and 500 nm in order to monitor emission from 2- to 6-ring PAHs, as has previously been demonstrated in soil and sediment samples (*21*). Calibration was based on a reference emitter (RE) response from a standard solution of 2- to 6-ring PAHs diluted in acetone.

Data Analysis. Data from all four sites were evaluated using Minitab 14 (Minitab, Inc.). The GC/MS pore water concentrations and SPME-LIF intensities were evaluated for normality using the Ryan−Joiner test for data in original and log-transformed units. Data determined to be neither normal nor log-normally distributed were transformed using ranks. Correlations between measurements were determined using either the Pearson product moment (normal data) or Spearman rank correlation (non-normal data). Principal component analysis (PCA) was used to identify which variables explained the largest percentage of the variance in the GC/MS pore water concentrations of 2- through 6-ring PAHs and LIF emission intensities at 350, 400, 450, and 500 nm. PCA was calculated from the correlation matrix.

Results and Discussion

Sediment Characteristics and PAH Concentrations. General characteristics of the MGP sediments used in this study are given in Table 1. (Relative distributions of each of the PAH-34 parent and alkyl groups are shown in Figure S1 in the Supporting Information.) Sites A, B, and C involved MGP surface sediments, and show PAH ring-size distributions that are typical of the vast majority of the 230 sediments that we have analyzed for sediment and pore water PAH-34 (*4, 7*). Site D was also from an MGP location, but samples consisted of subsurface cores collected from depths greater than 1 ft. below the sediment surface. Site D was included in this study because it showed the highest relative concentrations of low molecular weight PAHs of any of the 14 MGP and aluminum smelter sites analyzed to date. Lastly, Site E included surface sediments from an aluminum smelting site that historically used coal tar pitch in its manufacturing processes. Site E was selected because it represented the highest relative concentrations of high molecular weight PAHs from the sites studied to date. For the 58 sediments used in the present study, PAH-34 concentrations ranged from typical background concentrations of a few μg/g to impacted sediments as high as 1100 μg/g PAH-34. Total organic carbon (TOC) ranged from 0.14 to 5.3 wt%, and BC ranged from 0.06 to 2.1% (Table 1). Sediment textures ranged from coarse sand to fine silt and clay. Twenty of the 58 sediments had NAPL (nonaqueous phase liquid) observed in the field during sample collection, and confirmed in the laboratory. However, no attempt was made to remove NAPL droplets prior to SPME-LIF analysis, since no such alteration of the sediments would be possible in an in situ field approach.

TABLE 1. Summary of Sediment and Pore Water Characteristics

	minimum	maximum	median
bulk sediment[a]			
total PAH-34 (μg/g)			
Sites A, B, C ($n = 22$)	9	768	166
Site D ($n = 11$)	46	1057	184
Site E ($n = 10$)	57	902	135
2- and 3-ring PAHs/total PAH-34, %[b]			
Sites A, B, C	37	65	51
Site D	68	96	90
Site E	8	19	13
total organic carbon (TOC)[c]	0.14	5.3	1.2
black carbon (BC)[c]	0.06	2.1	0.47
fraction (BC/TOC)[c]	0.11	0.88	0.37
sediment pore water			
total PAH-34 (ng/mL)			
Sites A, B, C	2	501	16
Site D	56	1429	597
Site E	1	27	2

[a] Sediment PAH concentrations are on a dry weight basis. [b] The sum concentration of all 2- and 3-ring PAHs divided by the total PAH-34 concentration. [c] All sites.

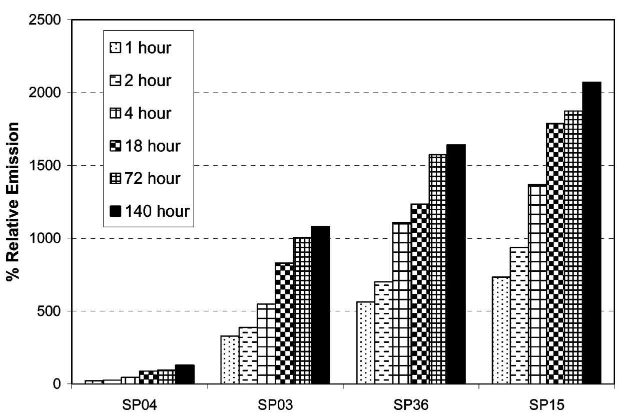

FIGURE 1. SPME-LIF response for sorbent rods exposed to sediments for different times. Sediment characteristics ranged from 0.6 to 2.0 wt.% total organic carbon, 2.5 to 11 mg/L dissolved organic carbon, and 0.6 to 44 pore water PAH-34 TUs.

Effect of Exposure Time on LIF Response. The effect of the SPME exposure time to the sediment/water slurry samples on the SPME-LIF response is shown in Figure 1. Even under the static (no mixing) conditions used to mimic in situ sampling, sorption occurs fairly rapidly. For example, after only 1 h the SPME-LIF signals were ca. 30% of the values attained after 140 h of exposure, and after 18 h the response averaged 77 ± 7% of the values attained after 140 h. Since 18 h represents a reasonable time frame for deploying and retrieving multiple in situ SPME devices in the field, the 18 h exposure time was chosen for subsequent studies unless otherwise noted. It should also be noted that useful survey data can be achieved with quite short exposure times. For example, with the eight sediments used in the time studies (including those in Figure 1), the linear correlation between the SPME-LIF responses obtained after 1 h compared to the responses at either 18 or 140 h was very strong ($r^2 = 0.96$). These results indicate that useful site mapping survey data could be obtained during field studies on hour time frames, which would allow near real-time adaptive management of field sampling and analysis plans.

Effect of Sediment Volume on LIF Response. For the SPME approach to apply in the field, the concentrations of PAHs sorbed into the rod coating must be independent of sample size; i.e., a rod placed in the sediment in the lake or river should have the same PAH concentrations and the same fluorescence response as a rod placed in a small jar of the same sediment. In essence, this is the same as saying the SPME extraction must be nondepletive to the exposed sediment/pore water slurry PAH concentrations, as is required for other equilibrium-based in situ methods (*8*−*11*). To test if this sample size independence (i.e., nondepletive) requirement was met, the four sediments that were used for the time study in Figure 1 were exposed to 7 and 250 mL sediment/water slurry samples for 18 and 48 h (*23*). After 18 h the fluorescence signal in the 7 mL samples averaged 96 ± 11% of the signal in the 250 mL samples, and after 48 h the signals from the 7 mL samples averaged 98 ± 6% of those for the 250 mL samples (Figure S2 in the Supporting Information). These results demonstrate that there is no dependence on sample size that can be measured compared to the method reproducibility (which has an RSD of ca. 8% based on the LIF response of five rods placed in the same sediment sample for 18 h). Therefore, a rod exposed to sediment in the field will accurately reflect the pore water PAHs in a small sample taken from the same location, and vice-versa.

Background and Detection Limit. The goal of this method was to attain a detection limit for PAHs corresponding to one TU (or lower) as defined by the EPA narcosis model (*13*), a value which corresponds to a total PAH-34 water concentration of ca. 10 ng/mL for a sediment that has a typical distribution of PAHs from an MGP site. With the LIF system, the fluorescence response does not limit sensitivity; rather the major limitation to achieving low detection limits is the background fluorescence from the PDMS sorbent material. The material chosen for this study was the PDMS found to have the lowest background of those tested. Since alkyl 2- and 3-ring PAHs contribute the highest pore water concentrations and generally account for the most TUs of the PAH-34 list (*7*), it would be desirable to prepare solutions containing "standard" alkylated isomeric clusters for calibration and determining detection limits. However, no standards of the alkylated isomeric clusters exist, and their production from pure compounds is not possible because of the several hundreds of isomers present in PAH-contaminated materials from both petrogenic and pyrogenic sources (*14*). Therefore, the SPME-LIF method detection limit was estimated by comparing SPME-LIF response to the concentrations measured by the pore water PAH-34 GC/MS method (*12*) on several sediment samples that had low pore water concentrations. With the preparation described above, the PDMS on the rod selected for this study showed background signals at ca. 10% relative emission (on the scale shown in Figure 1). Based on a 3:1 signal-to-noise ratio, the SPME-LIF method currently has a detection limit for total PAH-34 in pore water of ca. 2 ng/mL, which corresponds to ca. 0.2 TUs. Since these values are below typical urban background levels in sediments (*7*), the method is sufficiently sensitive to use at industrial and urban sites. However, obtaining PDMS material that has a lower background signal would further reduce the method detection limit, since the LIF signal is still reasonably intense at this background level.

Fluorescence from dissolved organic matter (DOM) has been a major obstacle to direct fluorescence determinations of PAHs in water (*15*−*19*), but does not appear to affect the SPME-LIF approach since DOM is too polar to preferentially sorb into (or onto) the nonpolar PDMS. For example, a rod soaked for 18 h in a solution of 9 mg/mL Suwannee River

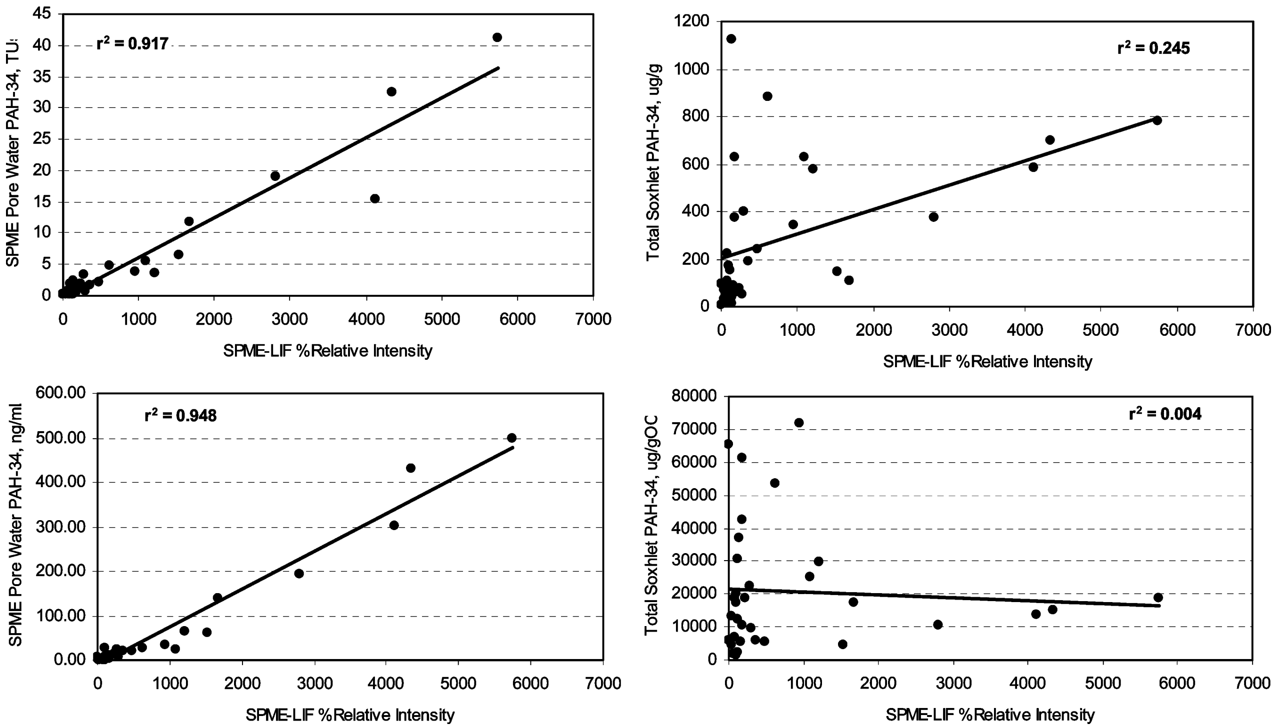

FIGURE 2. Comparison of SPME-LIF response with total pore water PAH-34 TUs (top left), total PAH-34 pore water concentrations (bottom left), total sediment PAH-34 concentrations (top right), and total sediment PAH-34 concentration on an organic carbon basis (bottom right) for the 33 surface sediments from sites A, B, C, and E.

fulvic acid in water showed no detectable change in LIF response from a duplicate rod soaked in clean water, even though the fulvic acid water solution showed an LIF response several times the rod background response (Supporting Information Figure S3). Similarly, water samples equilibrated for 24 h (1:3 wt. to wt. ratio in water) with manure, peat moss, and a 13 wt. % TOC agricultural soil showed no increase in SPME-LIF response compared to clean water, further demonstrating that the SPME sorbent efficiently excludes background fluorescence from natural organic matter.

Potential effects of DOM were also investigated by measuring the SPME-LIF response of 15 clean background sediments that were collected in unimpacted areas from the same 5 sites (in addition to the 43 sediments used in the remainder of this study) that had total PAH-34 pore water concentrations (as measured by the GC/MS method) less than 1 ng/mL, and less than 0.05 TUs. After the 18-h exposure of the SPME rod to the sediment/slurry mix, the only cleaning step was a brief rinse with clean water. For all of these samples, no significant fluorescence above the rod background was observed. The lack of SPME-LIF response in these uncontaminated sediments also demonstrates that colloids which may stick to the rod surface do not cause a detectable change in the LIF signal.

SPME-LIF Response Compared to Laboratory PAH-34 GC/MS Analyses. A comparison of the 18 h SPME-LIF signals with the total sediment and total pore water PAH-34 concentrations, and with the total PAH TUs calculated from the EPA's narcosis model (*13*), was initially performed on a site-by-site basis. These plots showed general agreement for the surface sediments from sites A, B, C, and E, but significant deviations for the subsurface cores from site D (as discussed below). Therefore, subsequent data analysis was performed with the combined data from surface sediments (sites A, B, C, and E), but with the data from the subsurface cores (site D) handled separately unless otherwise noted. It should also be noted that the EPA's hydrocarbon narcosis model (*13*) predicts mortality to *Hyalella azteca* when PAH-34 water concentrations are high enough to contribute 1 TU (equivalent to 2.2 μmol/g lipid), so the important range for accuracy of the SPME-LIF method might initially be considered ca. $<$1 to 3 TUs. However, a recent study of 97 PAH-impacted field sediments demonstrated that no mortality occurs below 5 TUs, and that the important range for distinguishing toxic versus nontoxic samples is from ca. 5 to 30 TUs (*7*). A similar result was obtained by a separate study using pure fluoranthene under controlled laboratory conditions (*24*). Therefore, evaluation of SPME-LIF in subsequent discussions focuses on PAH-34 concentrations contributing ca. 5 to 30 TUs.

Figure 2 shows the linear correlations between the SPME-LIF response and the pore water TUs, total dissolved pore water concentrations, and the total sediment concentrations for the PAH-34 from sites A, B, C, and E (33 surface sediments). For both total pore water TUs and PAH-34 concentrations, the Pearson correlation is quite good ($r^2 = 0.92$ and 0.95, respectively). However, the correlation between the total sediment concentrations and the SPME-LIF signal is low ($r^2 = 0.245$), as is the correlation with sediment concentrations expressed on an organic carbon (OC) basis ($r^2 = 0.004$). This poor correlation with the sediment concentrations is expected, since the sorbent coating approaches equilibrium with the pore water fraction, and it is known that pore water PAH concentrations can not be accurately estimated using literature K_{OC} values and sediment PAH concentrations for MGP and other historically contaminated sediments (*1*−*5*).

Since several of the 33 sediments shown in Figure 2 had PAH-34 concentrations and SPME-LIF intensities that were neither normal nor log-normally distributed, a Spearman rank correlation was also done, and yielded similar results. For the pore water TUs, PAH-34 concentrations, and sediment concentrations, the Spearman rank correlation coefficients were 0.83, 0.73, and 0.40, respectively (Supporting Information Figure S4).

Effect of PAH Molecular Weight Distribution. As noted above, sediments from sites A, B, and C have PAH molecular weight distributions that are typical of the vast majority of 230 sediments we have analyzed from 16 MGP and related sites. However, different PAH distributions are likely to be encountered from some locations, and it is important to understand the effect of PAH distribution on the SPME-LIF response. As shown in Table 1 and Supporting Information Figure S1, the sediments from site D had a much higher proportion of low molecular weight PAHs than is typical for surface sediments from MGP sites, as might be expected since the sediments from site D were obtained from cores collected below the sediment surface and had therefore been subjected to less weathering than the surface sediments from sites A, B, and C. Thus, while naphthalene and alkyl naphthalenes normally account for ca. 10% of the total PAH-34 sediment concentrations, they account for ca. 40% for site D sediments. In contrast, sediments at Site E consisted of higher molecular weight PAHs, and only ca. 2% of the sediment PAHs consist of naphthalene and alkyl naphthalenes, as might be expected since the major source of PAHs at Site E was coal tar pitch, which consists of higher molecular weight PAHs than typical MGP tars. However, as shown in Figure 2, the pore water PAH data from Site E do correlate with those from sites A, B, and C despite the differences in molecular weight distribution.

For the subsurface core samples from site D, even though the correlation of SPME-LIF response with total pore water TUs and total pore water PAH-34 remains quite good (r^2 = 0.74 and 0.87, respectively), the SPME-LIF response is significantly lower as evidenced by the slopes of the least-squares regression lines. The slope of the total pore water PAH-34 concentrations versus LIF response (Supporting Information Figure S5) is 9-fold steeper for site D than for sites A, B, C, and E. Similarly, the slope of the total pore water TUs is 4-fold higher for site D. That is, to get the same SPME-LIF signal for the subsurface core samples from site D as for the other more typical surface sediment samples from the other four sites shown in Figure 2, the pore water must have 9 times the total dissolved PAH concentrations, or 4 times higher TUs.

These results demonstrate that, as might be expected, some knowledge about the molecular weight distribution of PAHs at a particular site will be needed to verify any quantitative determinations of pore water PAH-34 concentrations or TUs based on SPME-LIF response at different sites.

Effect of Monitoring Wavelength. As described above, the LIF emission wavelengths were chosen at 350, 400, 450, and 500 nm to monitor all 2- to 6-ring PAHs with similar sensitivities (*19, 20*). Based on standard fluorescence spectra of standard pure PAHs, the emission wavelength at 350 nm primarily focuses on 2-ring PAHs, while the higher wavelengths monitor increasing higher molecular weight PAHs. However, real-world MGP samples have hundreds to thousands of individual parents and alkyl isomers (*14*), as well as heteroatom-containing aromatics including (but not limited to) 2- to 4-ring furans, thiophenes, and pyroles. Therefore, principal component analysis (PCA) was used to evaluate the emission wavelength relationship to the relative percentage of 2- to 6-ring PAHs for the complex mixture of alkyl and parent PAHs found at these sites. The first two principal components (PCs) accounted for 81% of the total variance in emission wavelength and PAH ring size. A loading plot of the first two PCs shows that 2- and 3-ring PAHs are tightly associated with 350 and 400 nm emissions, while the higher molecular weight PAHs are associated with the longer emission wavelengths, which verifies the expectations based on pure compound emission spectra (Figure 3).

Since (as discussed above), the 2- and 3-ring PAHs dominate pore water PAH concentrations and related TUs, we investigated the use of only 350 or 350 and 400 nm

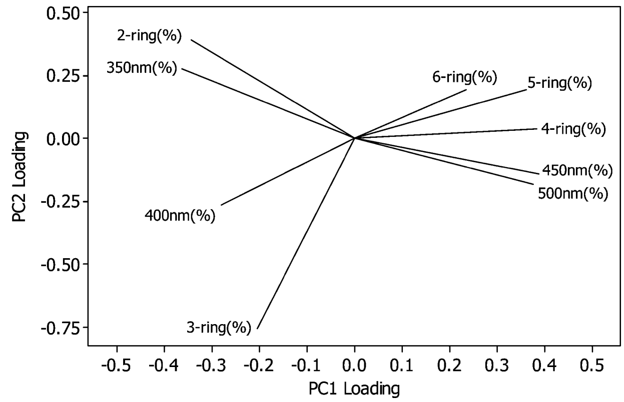

FIGURE 3. Relationship of LIF emission wavelength to PAH ring size for the 43 sediments (all sites) based on principal component analysis.

emission signals. Interestingly, the differences in SPME-LIF response previously shown by the subsurface core samples from site D are reduced compared to the other four sites when only the 350 nm emission is monitored as shown in Supporting Information Figure S6 (the plot from the sum of 350 and 400 nm looks similar). Linear correlation coefficients (r^2) for the five combined sites are 0.72 for the total pore water PAH-34 concentration, but increase to 0.81 for the pore water TUs. Similarly, the Spearman rank correlations are 0.81 for the pore water PAH-34 concentrations, and 0.88 for the pore water TUs.

While stronger quantitative correlations would be desirable, the 350 nm data clearly suggest that SPME-LIF should be useful for screening MGP and related sites for pore water PAHs, without the need for prior knowledge of the PAH distribution. The results of combining the four emission wavelength data (as in Figure 1) demonstrate that reasonable quantitative data can be obtained with the technique, as long as the PAH distribution at the site is not highly unusual for an MGP site. The results also demonstrate that the SPME-LIF approach can be used to obtain semiquantitative results with exposure times as short as 1 h, which could greatly aid field real-time adaptive management of sample location selections and analytical programs. Since nearly one-half (20 of 43) of the impacted sediments had NAPL phases present (including samples with high and low PAH-34 concentrations), the good correlation with dissolved pore water concentrations shows that the SPME-LIF procedure is not greatly affected by the presence of a NAPL phase, as is desirable for any field applications of the method.

The SPME-LIF approach may best be used on-site to rapidly map the relative PAH pore water concentrations, and those results could be used to select sampling areas for more complete testing such as pore water PAH-34 by GC/MS and biological toxicity studies. The coated rods are inexpensive and the LIF measurement requires only a few minutes per sample using instrumentation similar to that already routinely deployed in field studies. In addition, no solvents or other hazardous materials are needed to perform SPME-LIF in the field.

Acknowledgments

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Supporting Information Available

This material is available free of charge via the Internet at http://pubs.acs.org.

Literature Cited

(1) Jonker, M. T. O.; Koelmans, A. A. Sorption of polycyclic aromatic hydrocarbons and polychlorinated biphenyls to soot and soot-like materials in the aqueous environment: Mechanistic considerations. *Environ. Sci. Technol.* **2002**, *36*, 3725–3734.

(2) Cornelissen, G.; Gustafsson, O.; Bucheli, T. D.; Jonker, M. T. O.; Koelmans, A. A.; van Noort, P. C. M. Extensive sorption of organic compounds to black carbon, coal, and kerogen in sediments and soils: mechanisms and consequences for distribution, bioaccumulation, and biodegradation. *Environ. Sci. Technol.* **2005**, *39*, 6881–6895.

(3) Khalil, M. F.; Ghosh, U.; Kreitinger, J. P. Role of weathered coal tar pitch in the partitioning of polycyclic aromatic hydrocarbons in manufactured gas plant site sediments. *Environ. Sci. Technol.* **2006**, *40*, 5681–5687.

(4) Hawthorne, S. B.; Grabanski, C. B.; Miller, D. J. Measured partitioning coefficients for parent and alkyl polycyclic aromatic hydrocarbons in 114 historically contaminated sediments: Part 1. K_{OC} values. *Environ. Toxicol. Chem.* **2006**, *25*, 2901–2911.

(5) Lohmann, R.; MacFarlane, J. K.; Gschwend, P. M. Importance of black carbon to sorption of native PAHs, PCBs, and PCDDs in Boston and New York harbor sediments. *Environ. Sci. Technol.* **2005**, *39*, 141–148.

(6) Xu, Y.; Spurlock, F.; Wang, Z.; Gan, J. Comparison of five methods for measuring sediment toxicity of hydrophobic contaminants. *Environ. Sci. Technol.* **2007**, *41*, 8394–8399.

(7) Hawthorne, S. B.; Azzolina, N. A.; Neuhauser, E. F.; Kreitinger, J. P. Predicting bioavailability of sediment polycyclic aromatic hydrocarbons to *Hyalella azteca* using equilibrium partitioning, supercritical fluid extraction, and pore water concentrations. *Environ. Sci. Technol.* **2007**, *41*, 6297–6304.

(8) Cornelissen, G.; Pettersen, Ar.; Broman, D.; Mayer, P.; Breedveld, G. D. Field testing of equilibrium passive samplers to determine freely dissolved native polycyclic aromatic hydrocarbon concentrations. *Environ. Toxicol. Chem.* **2008**, *27* (3), 499–508.

(9) Hunter, W.; Xu, Y.; Spurlock, F.; Gan, J. Using disposable polydimethylsiloxane fibers to assess the bioavailability of permethrin in sediment. *Environ. Toxicol. Chem.* **2008**, *27* (3), 568–575.

(10) Jonker, M. T. O.; Van Der Heijden, S. A.; Kreitinger, S.; Hawthorne, S. B. Predicting PAH bioaccumulation and toxicity in earthworms exposed to manufactured gas plant soils with solid-phase microextraction. *Environ. Sci. Technol.* **2007**, *41*, 7472–7478.

(11) Styrishave, B.; Mortensen, M.; Krogh, P. H.; Andersen, O.; Jensen, J. Solid-phase microextraction (SPME) as a tool to predict the bioavailability and toxicity of pyrene to the springtail, *Folsomia candida*, under various soil conditions. *Environ. Sci. Technol.* **2008**, *42*, 1332–1336.

(12) Hawthorne, S. B.; Grabanski, C. B.; Miller, D. J.; Kreitinger, J. P. Solid-phase microextraction measurement of parent and alkyl polycyclic aromatic hydrocarbons in milliliter sediment pore water samples and determination of K_{DOC} values. *Environ. Sci. Technol.* **2005**, *39*, 2795–2803.

(13) U.S. Environmental Protection Agency. *Procedures for the derivation of ESBs for the protection of benthic organisms: PAH mixtures*; EPA/600/R-02/013; Office of Research and Development: Washington, DC, 2003.

(14) Hawthorne, S. B.; Miller, D. J.; Kreitinger, J. P. Measurement of 'total' PAH concentrations and toxic units used for estimating risk to benthic invertebrates at manufactured gas plant sites. *Environ. Toxicol. Chem.* **2006**, *25*, 287–296.

(15) Kuo, D. T. F.; Adams, R. G.; Rudnick, S. M.; Chen, R. F.; Gschwend, P. M. Investigating desorption of native pyrene from sediment on minute- to month-timescales by time-gated fluorescence spectroscopy. *Environ. Sci. Technol.* **2007**, *41* (22), 7752–7758.

(16) Nahorniak, M. L.; Booksh, K. S. Excitation-emission matrix fluorescence spectroscopy in conjunction with multiway analysis for PAH detection in complex matrices. *Analyst* **2006**, *131*, 1308–1315.

(17) Valero-Navarro, A.; Fernández-Sánchez, J. F.; Medina-Castillo, A. L.; Fernández-Ibáñez, F.; Segura-Carretero, A.; Ibáñez, J. M.; Fernández-Gutiérrez, A. A rapid, sensitive screening test for polycyclic aromatic hydrocarbons applied to Antarctic water. *Chemosphere* **2007**, *67*, 903–910.

(18) Rudnik, S. M.; Chen, R. F. Laser-induced fluorescence of pyrene and other polycyclic aromatic hydrocarbons (PAH) in seawater. *Talanta* **1998**, *47*, 907–919.

(19) Kotzick, R.; Niessner, R. Application of time-resolved, laser-induced and fiber-optically guided fluorescence for monitoring of a PAH-contaminated remediation site. *Fresenius J. Anal. Chem.* **1996**, *354*, 72–76.

(20) Owen, C. J.; Axler, R. P.; Nordman, D. R.; Schubauer-Berigan, M.; Lodge, K. B.; Shubauer-Berigan, J. P. Screening for PAHs by fluorescence spectroscopy: a comparison of calibrations. *Chemosphere* **1995**, *31*, 3345–3356.

(21) Grundl, T. J.; Aldstadt, J. H.; Harb, J. G.; St. Germain, R. W.; Schweitzer, R. C. Demonstration of a method for the direct determination of polycyclic aromatic hydrocarbons in submerged sediments. *Environ. Sci. Technol.* **2003**, *37*, 1189–1197.

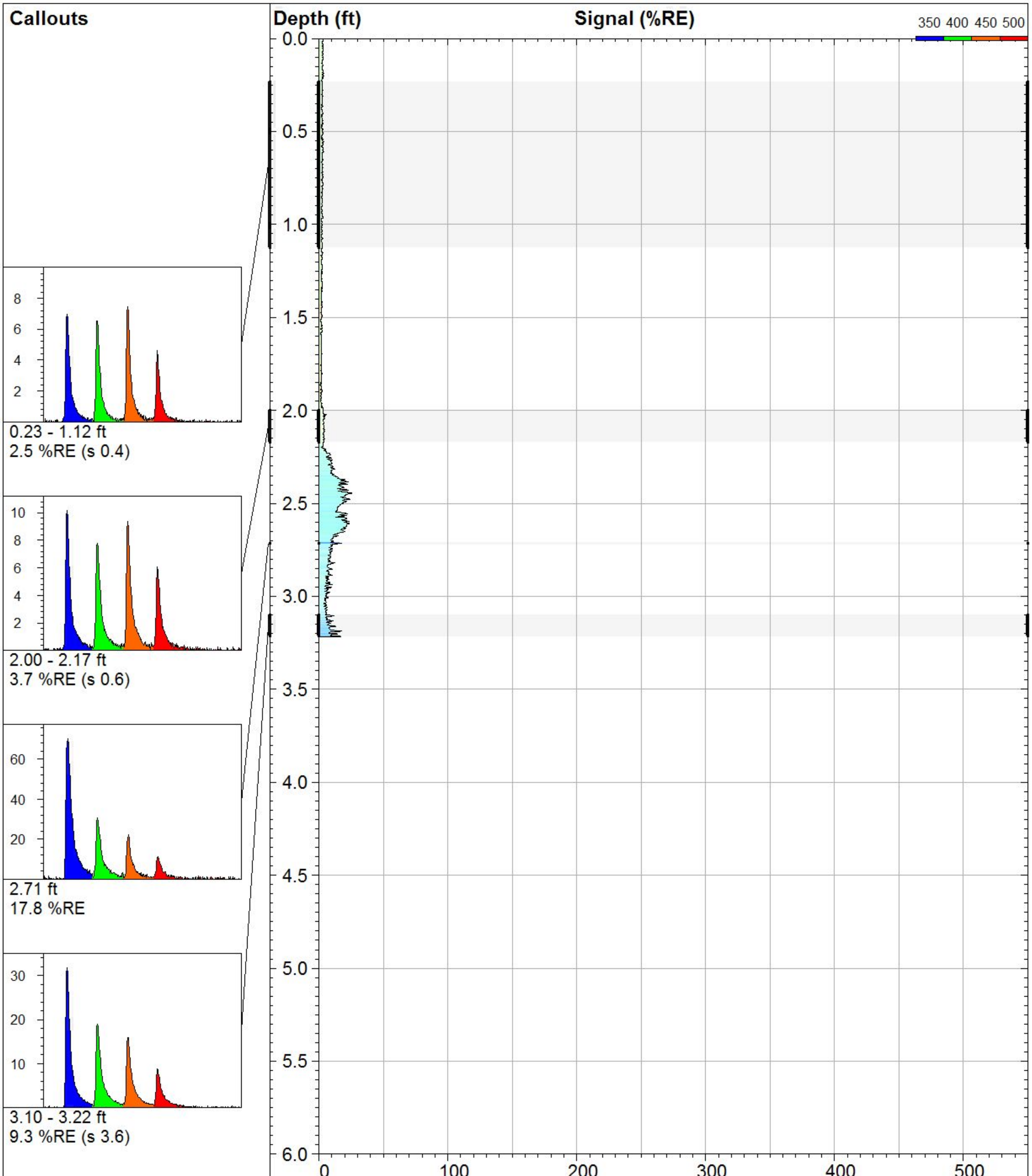
(22) Gustafsson, O.; Haghseta, F.; Chan, C.; MacFarlane, J.; Gschwend, P. M. Quantification of the dilute sedimentary soot phase: Implications for PAH speciation and bioavailability. *Environ. Sci. Technol.* **1997**, *31*, 203–209.

(23) Mayer, P.; Tolls, J.; Hermens, J.; Mackay, D. Equilibrium sampling devices. *Environ. Sci. Technol.* **2003**, *37*, 185A–191A.

(24) Schuler, L. J.; Landrum, P. F.; Lydy, M. Comparative toxicity of fluoranthene and pentachlorobenzene to three freshwater invertebrates. *Environ. Toxicol. Chem.* **2006**, *25*, 985–994.

ES8011673

Appendix C.3
Dart Results – East Side of Cline Avenue Ditch



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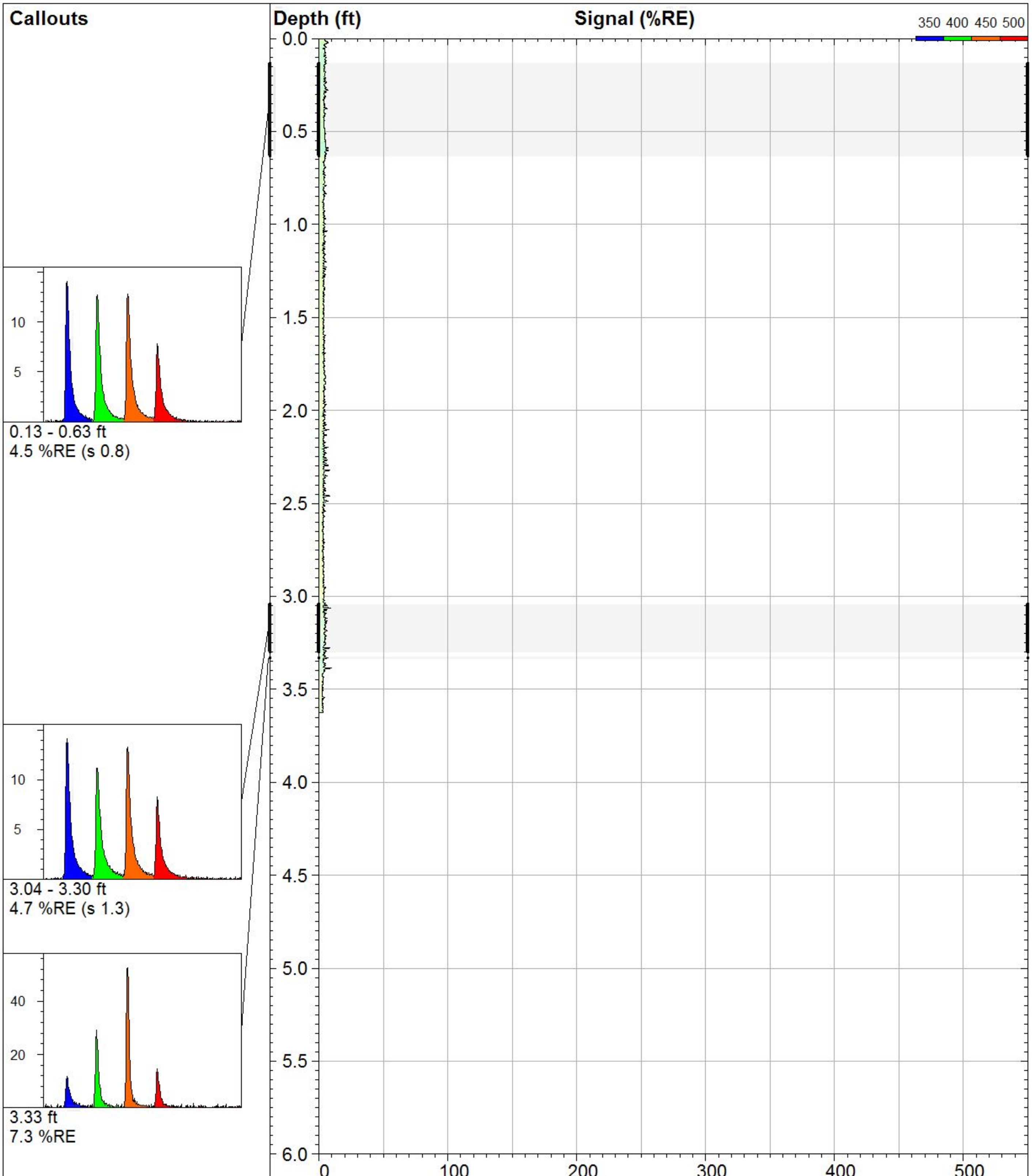
Dart-01		**Darts By Dakota** www.DakotaTechnologies.com
Site: **Cline Ave Ditch**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **3.22 ft**
Client / Job: **GHD /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **25.5 %RE @ 2.45 ft**
Operator / Unit: **S.Adamek / UVOST01**	*Elevation:* **Unavailable**	*Date & Time:* **2017-09-21 14:51 CDT**



Dart-02		**Darts By Dakota** www.DakotaTechnologies.com
Site: **Cline Ave Ditch**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **3.63 ft**
Client / Job: **GHD /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **9.8 %RE @ 3.39 ft**
Operator / Unit: **S.Adamek / UVOST01**	*Elevation:* **Unavailable**	*Date & Time:* **2017-09-21 15:05 CDT**

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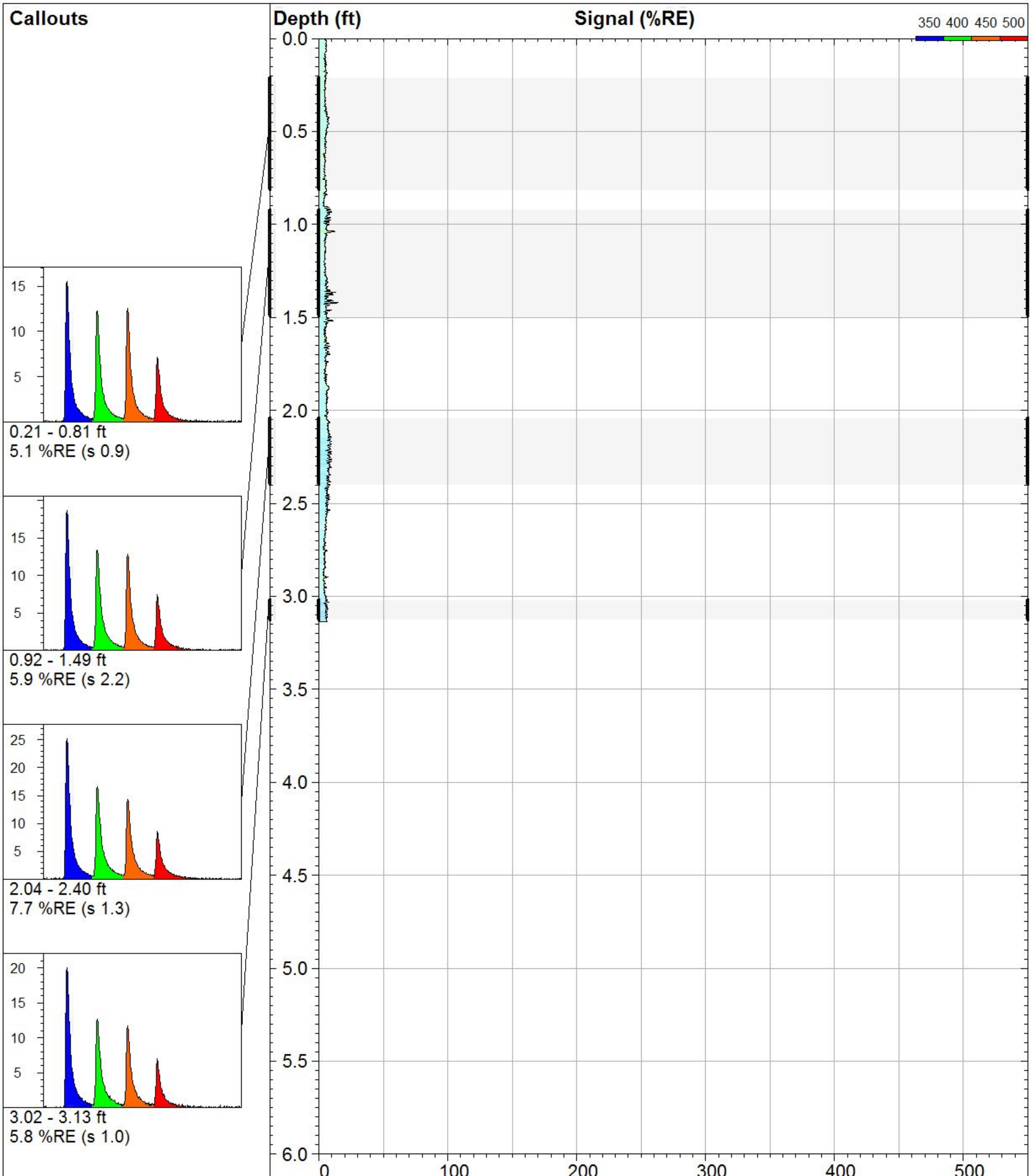

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Dart-03

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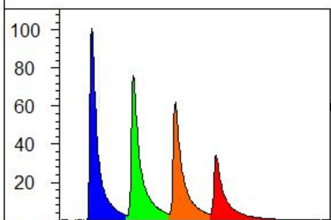
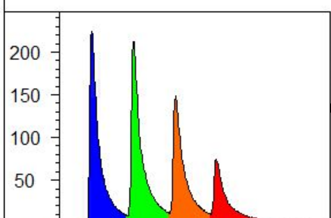
Site: **Cline Ave Ditch**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **3.14 ft**
Client / Job: **GHD /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **15.4 %RE @ 1.42 ft**
Operator / Unit: **S.Adamek / UVOST01**	*Elevation:* **Unavailable**	*Date & Time:* **2017-09-21 15:21 CDT**

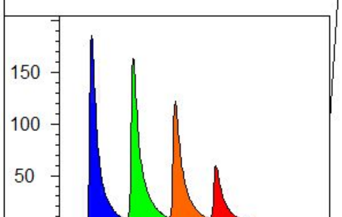
Callouts



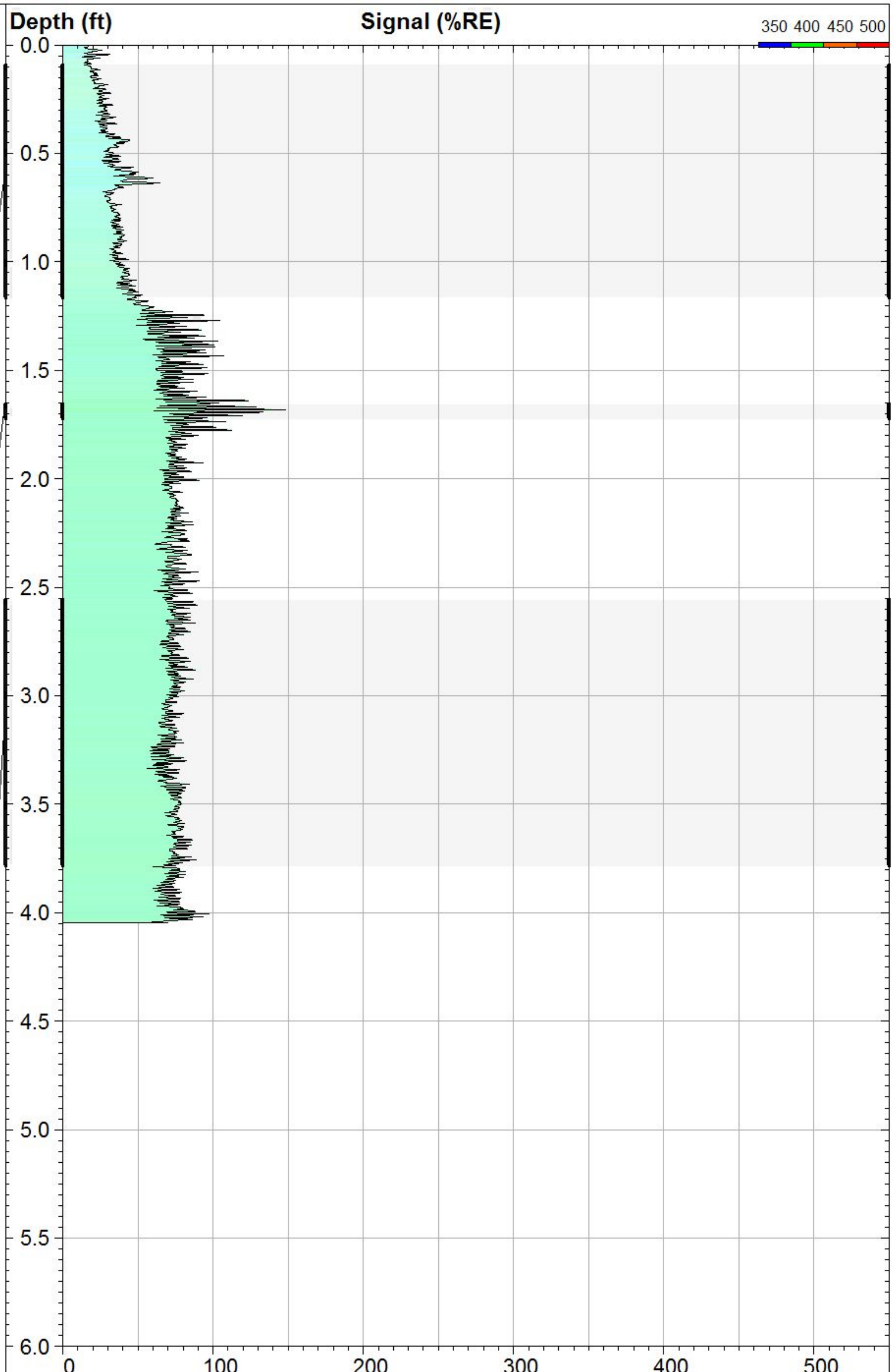
0.09 - 1.16 ft
33.9 %RE (s 8.4)



1.66 - 1.72 ft
93.9 %RE (s 31.0)



2.56 - 3.78 ft
73.4 %RE (s 6.3)



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Dart-04

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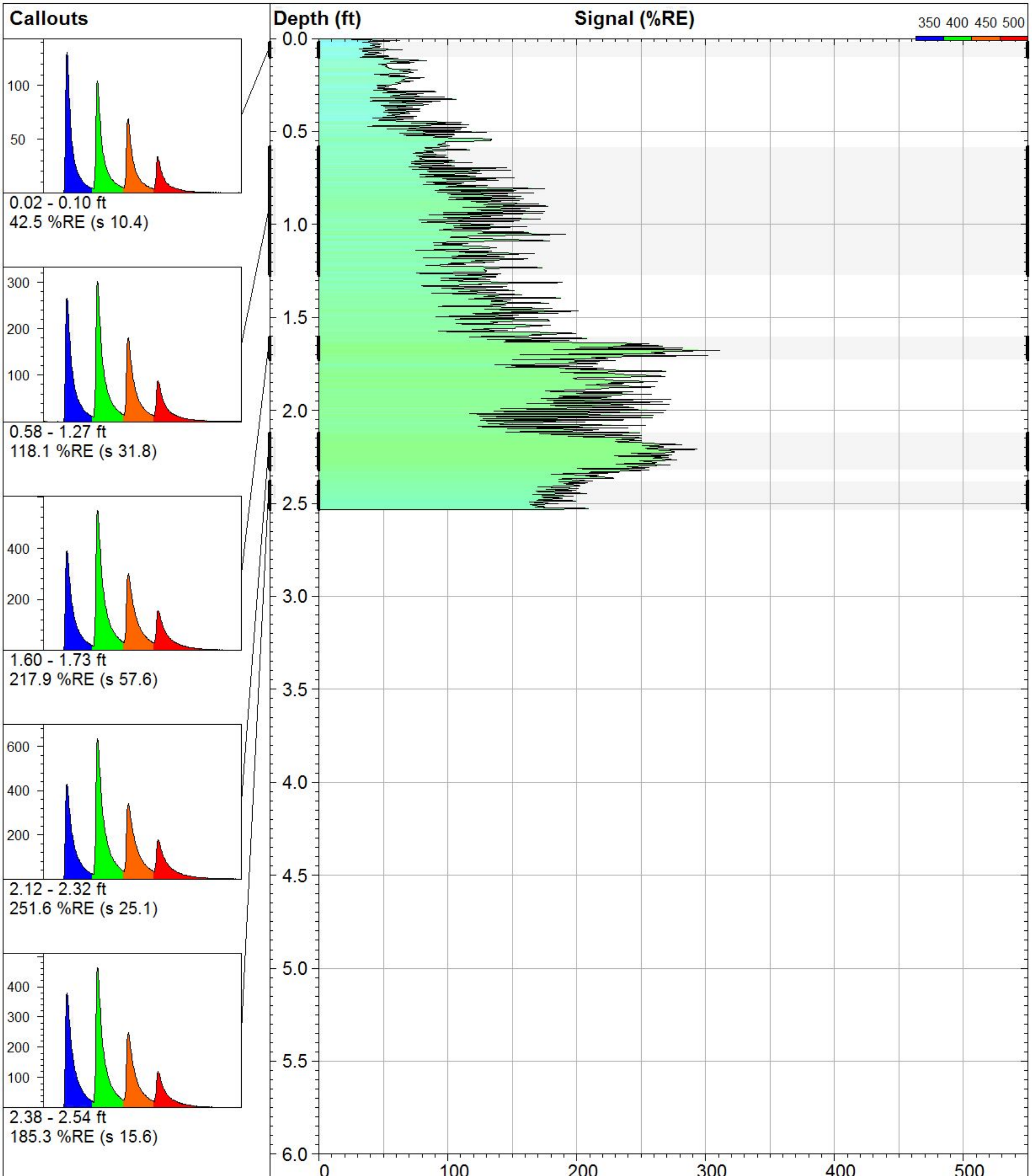
Site: **Cline Ave Ditch**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **4.05 ft**
Client / Job: **GHD /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **151.3 %RE @ 1.68 ft**
Operator / Unit: **S.Adamek / UVOST01**	*Elevation:* **Unavailable**	*Date & Time:* **2017-09-21 15:35 CDT**



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Dart-05

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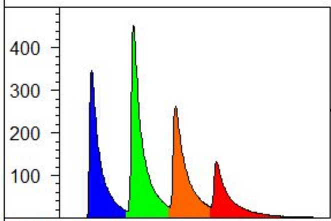
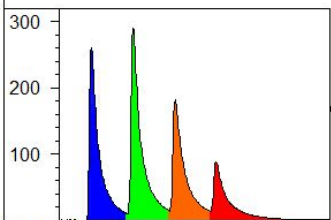
Site: **Cline Ave Ditch**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **2.54 ft**
Client / Job: **GHD /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **312.0 %RE @ 1.68 ft**
Operator / Unit: **S.Adamek / UVOST01**	*Elevation:* **Unavailable**	*Date & Time:* **2017-09-21 15:52 CDT**

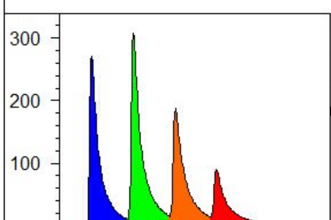
Callouts



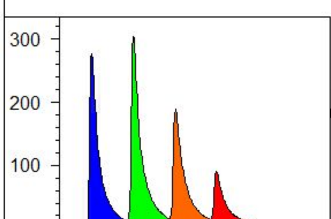
0.01 - 0.35 ft
213.5 %RE (s 86.7)



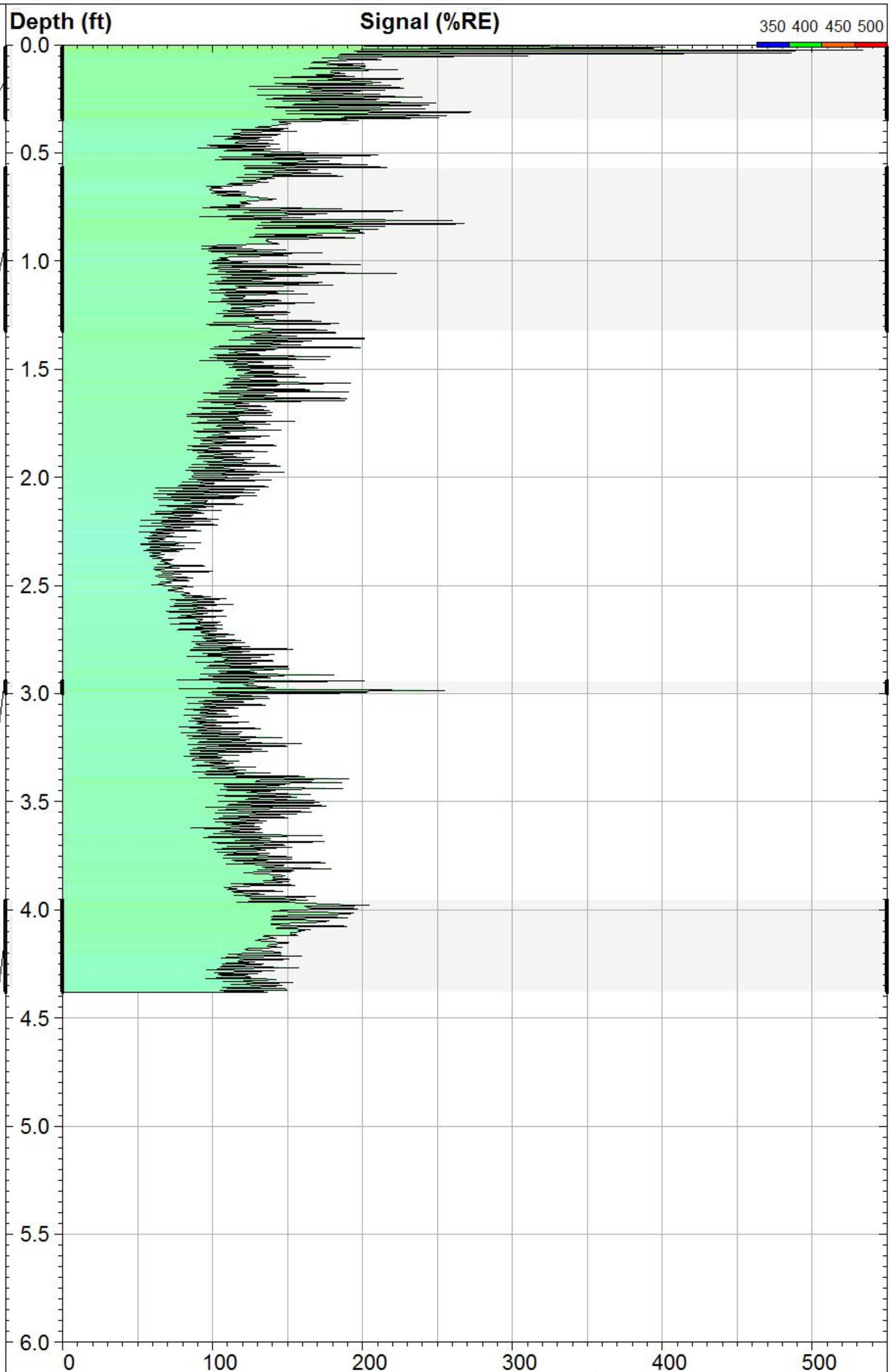
0.57 - 1.32 ft
134.4 %RE (s 36.5)



2.94 - 3.00 ft
142.6 %RE (s 57.3)



3.96 - 4.38 ft
141.0 %RE (s 24.8)



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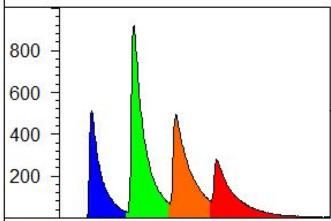
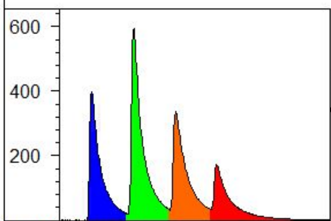
Dart-15		**Darts By Dakota** www.DakotaTechnologies.com
Site: **Cline Ave Ditch**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **4.38 ft**
Client / Job: **GHD /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **545.8 %RE @ 0.03 ft**
Operator / Unit: **S.Adamek / UVOST01**	*Elevation:* **Unavailable**	*Date & Time:* **2017-09-22 11:02 CDT**

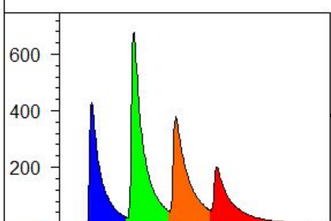
Callouts



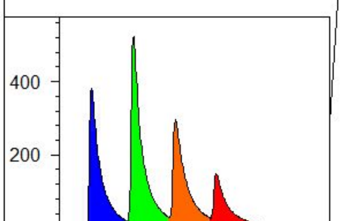
0.06 - 0.48 ft
440.5 %RE (s 149.3)



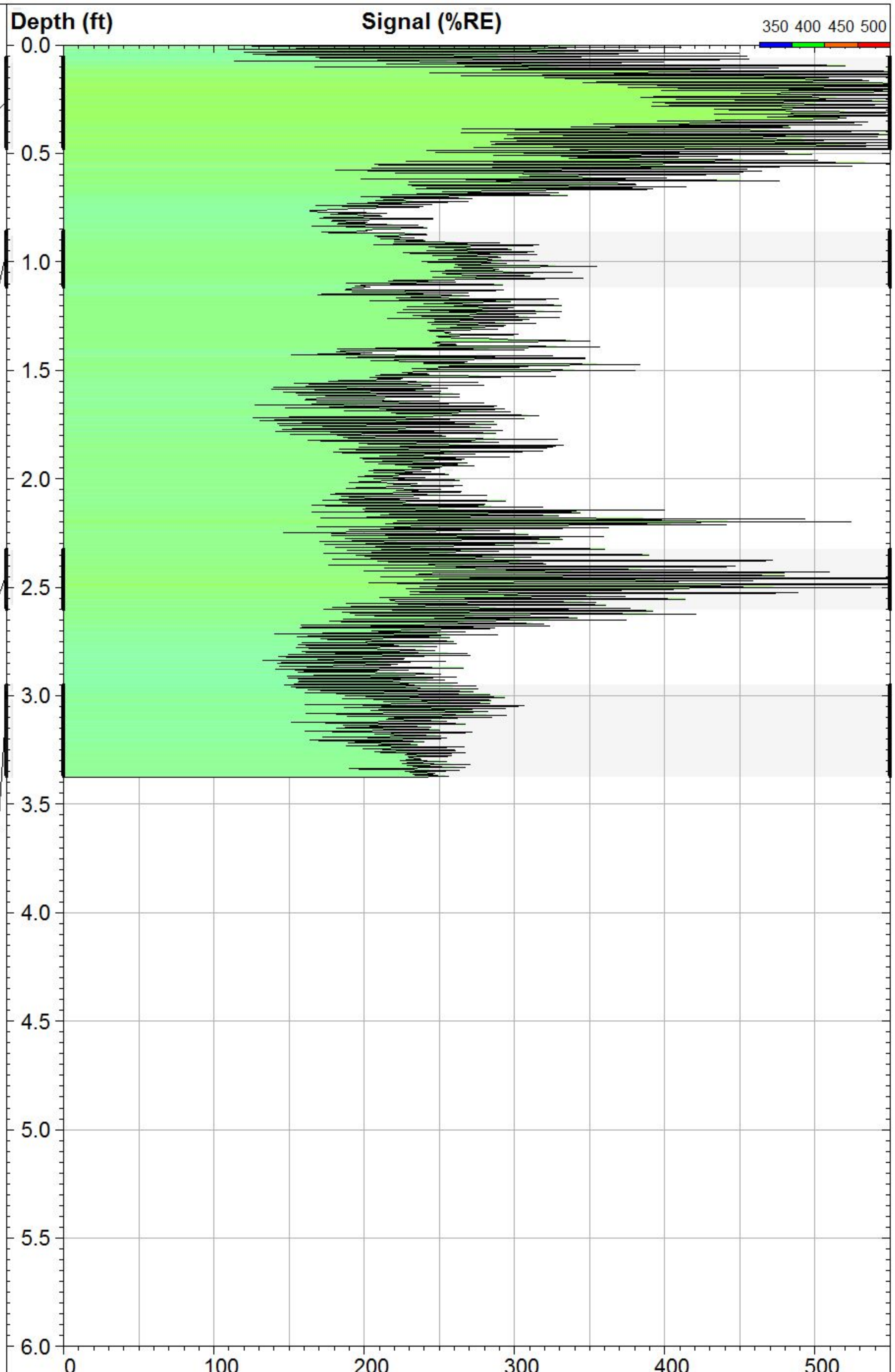
0.86 - 1.12 ft
259.0 %RE (s 44.7)



2.32 - 2.60 ft
308.0 %RE (s 123.4)



2.95 - 3.37 ft
230.4 %RE (s 42.1)



Dart-14

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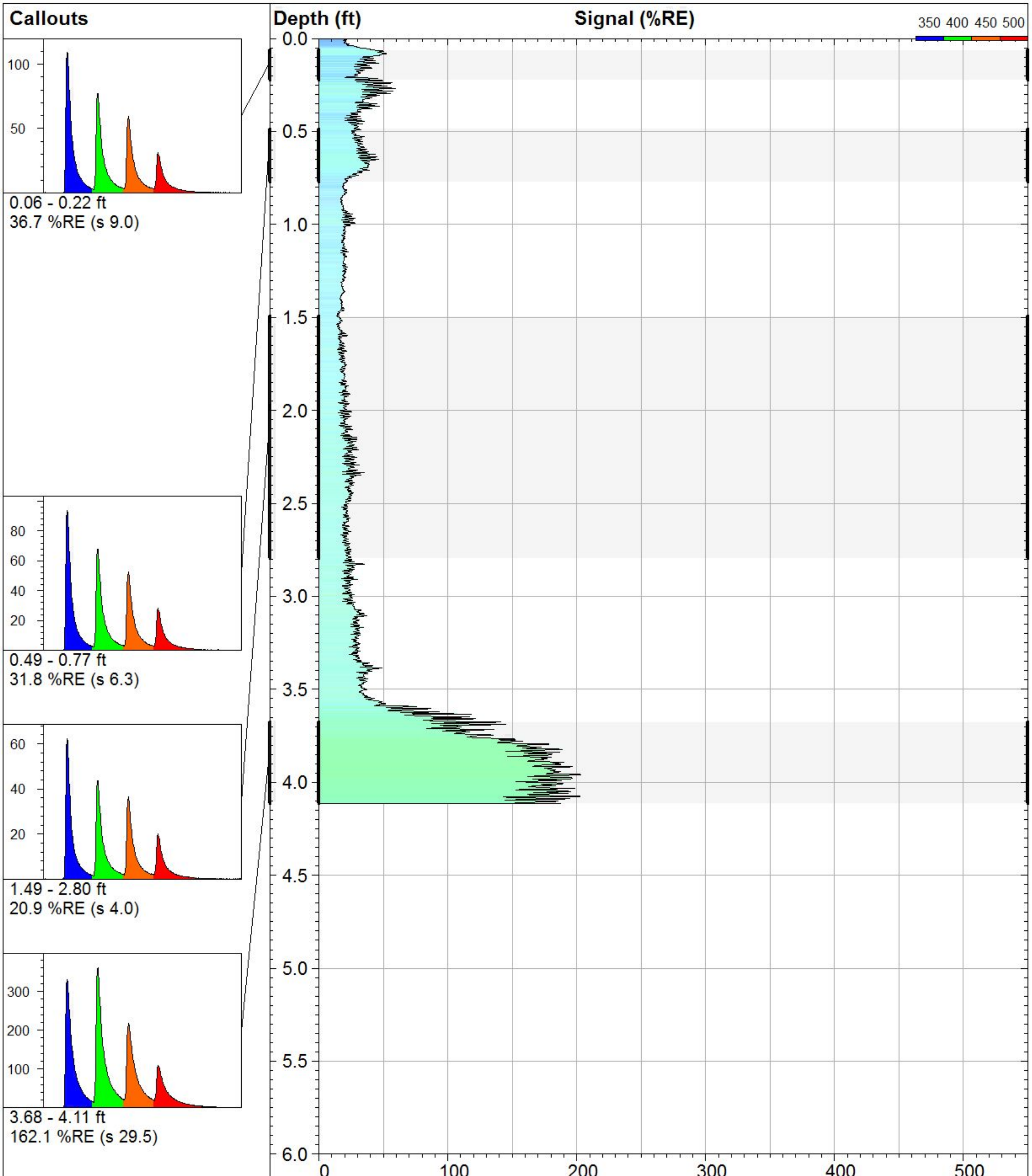
Site: **Cline Ave Ditch**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **3.37 ft**
Client / Job: **GHD /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **711.0 %RE @ 0.19 ft**
Operator / Unit: **S.Adamek / UVOST01**	*Elevation:* **Unavailable**	*Date & Time:* **2017-09-22 10:46 CDT**



Dart-13

Darts By Dakota
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Site: **Cline Ave Ditch**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **4.11 ft**
Client / Job: **GHD /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **205.8 %RE @ 4.08 ft**
Operator / Unit: **S.Adamek / UVOST01**	*Elevation:* **Unavailable**	*Date & Time:* **2017-09-22 10:30 CDT**

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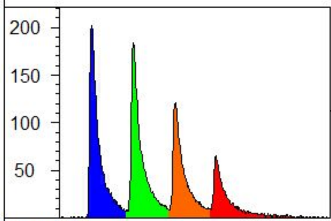
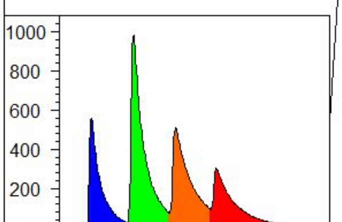
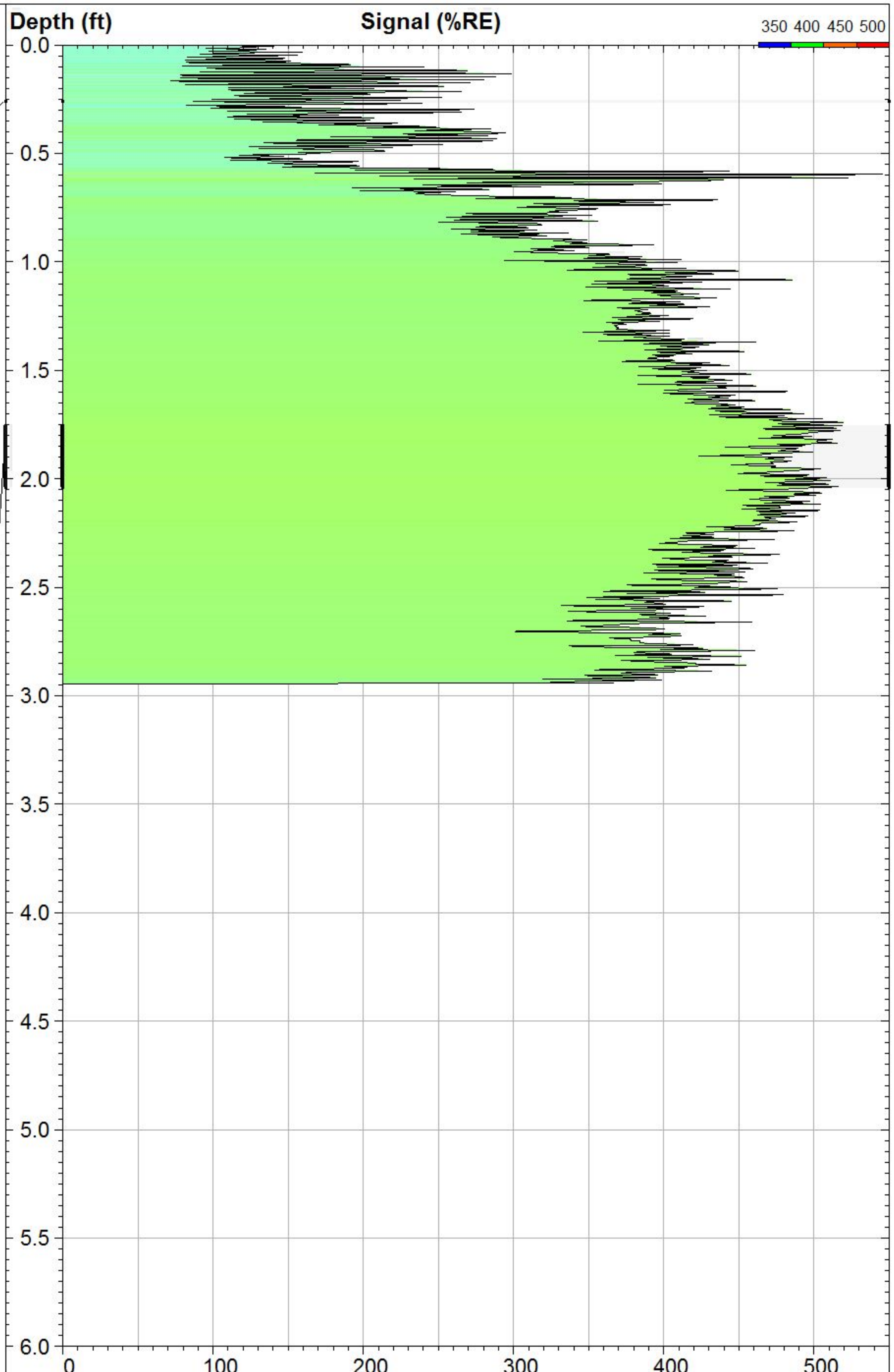
Callouts



0.26 ft
84.6 %RE



1.75 - 2.04 ft
484.3 %RE (s 22.4)



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Dart-12

Darts By Dakota
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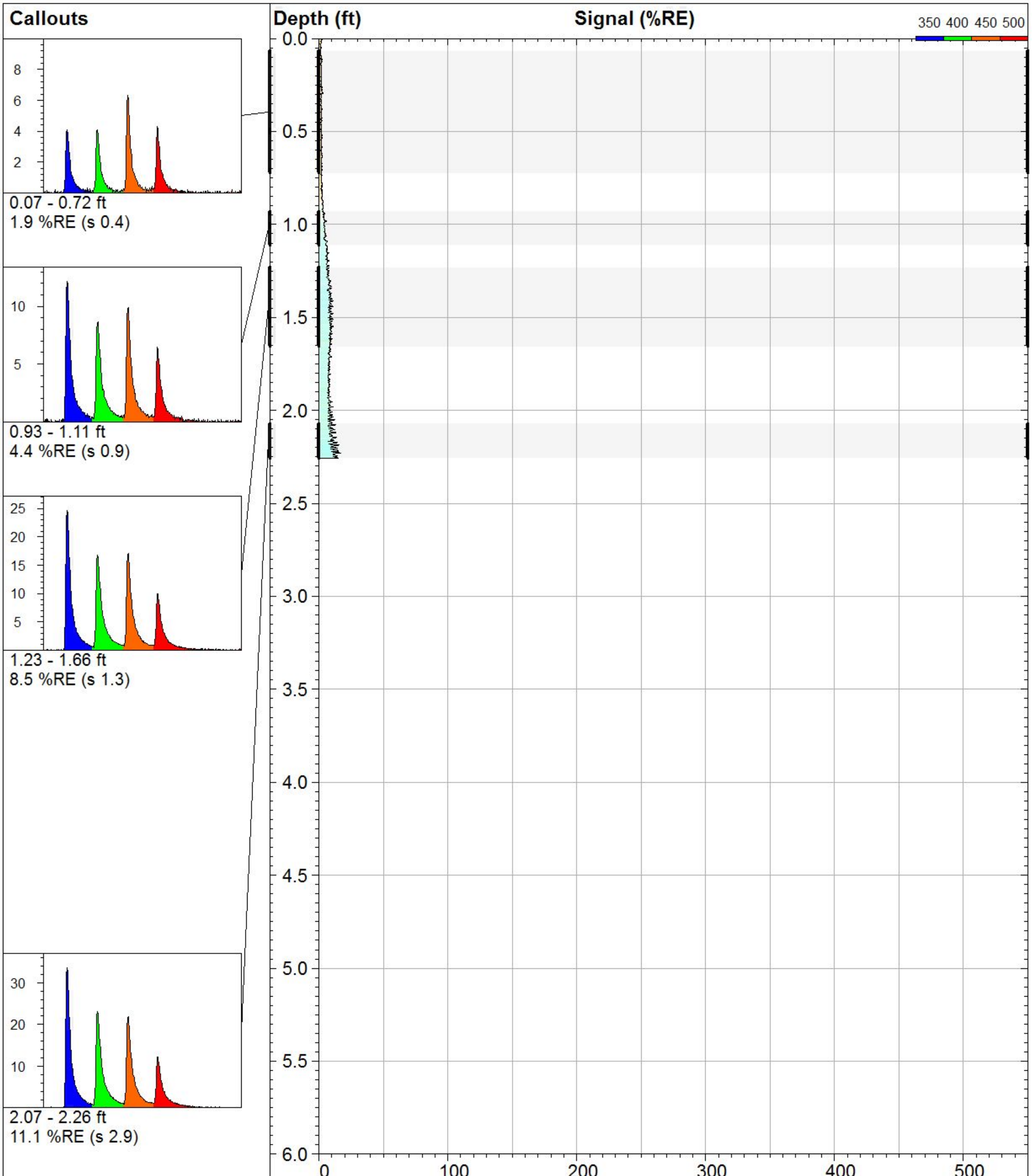
Site: **Cline Ave Ditch**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **2.94 ft**
Client / Job: **GHD /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **546.2 %RE @ 0.60 ft**
Operator / Unit: **S.Adamek / UVOST01**	*Elevation:* **Unavailable**	*Date & Time:* **2017-09-22 10:16 CDT**

Appendix C.4
Dart Results – West Side of Cline Avenue Ditch



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Dart-07

Darts By Dakota
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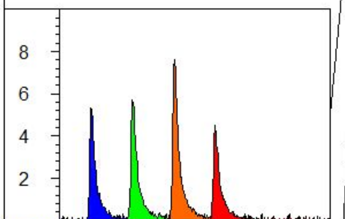
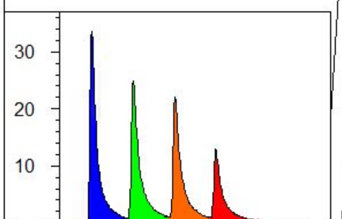
Site:	*Y Coord.(Lat-N) / System:*	*Final depth:*
Cline Ave Ditch	**Unavailable / NA**	**2.26 ft**
Client / Job:	*X Coord.(Lng-E) / Fix:*	*Max signal:*
GHD /	**Unavailable / NA**	**17.4 %RE @ 2.23 ft**
Operator / Unit:	*Elevation:*	*Date & Time:*
S.Adamek / UVOST01	**Unavailable**	**2017-09-21 16:21 CDT**

Callouts

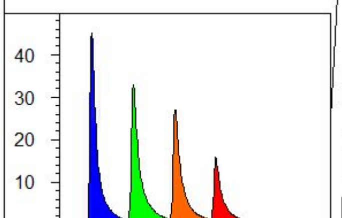
Bottom 2" was foldered over and not read



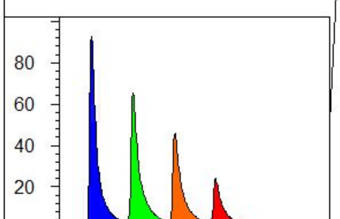
0.03 - 0.24 ft
2.4 %RE (s 0.6)



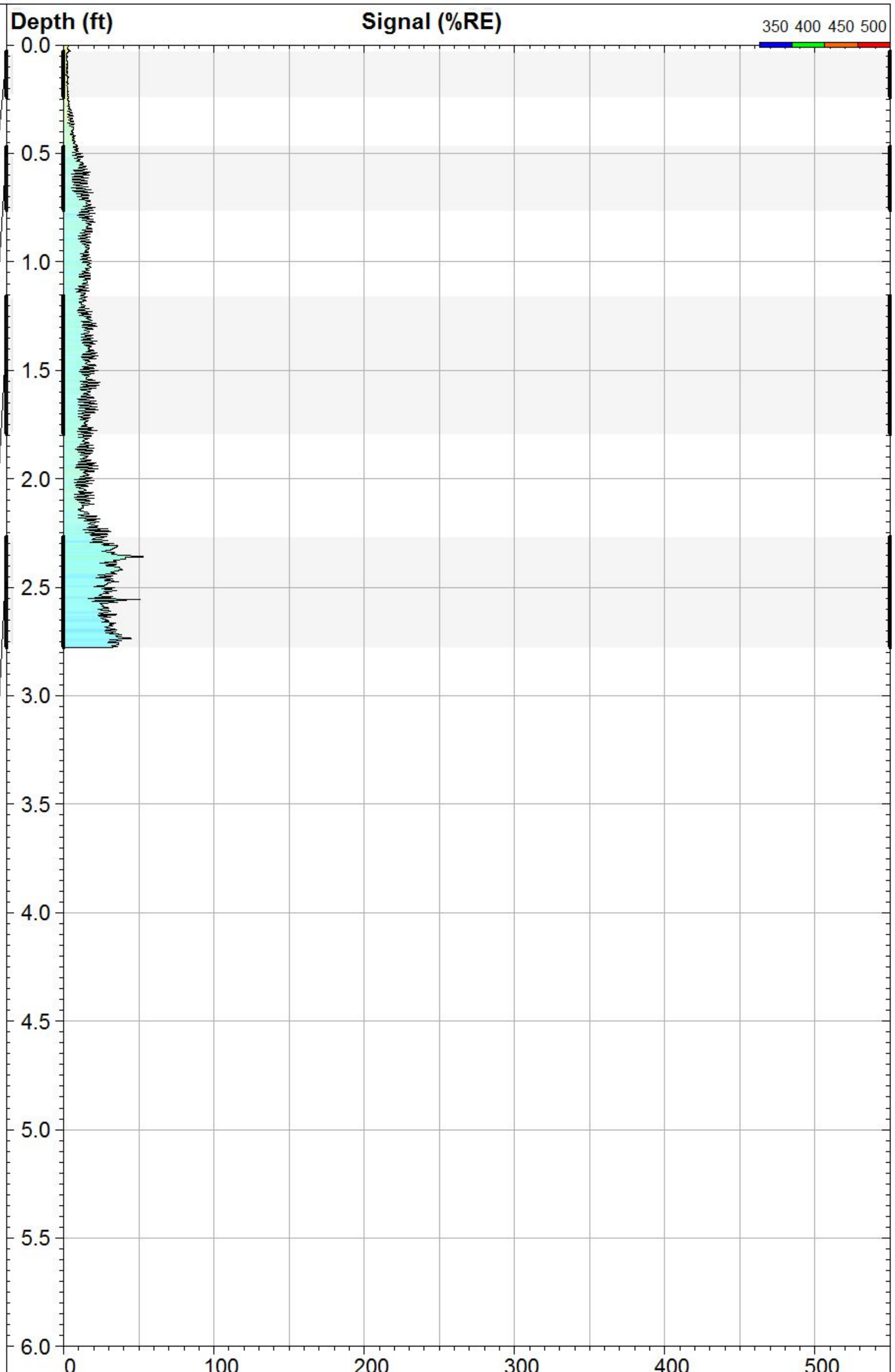
0.47 - 0.76 ft
11.9 %RE (s 4.9)



1.16 - 1.80 ft
15.5 %RE (s 4.7)



2.27 - 2.78 ft
30.9 %RE (s 6.8)



Dart-06

Darts By Dakota
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Site: **Cline Ave Ditch**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **2.78 ft**
Client / Job: **GHD /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **53.7 %RE @ 2.36 ft**
Operator / Unit: **S.Adamek / UVOST01**	*Elevation:* **Unavailable**	*Date & Time:* **2017-09-21 16:07 CDT**

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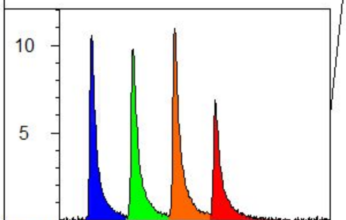
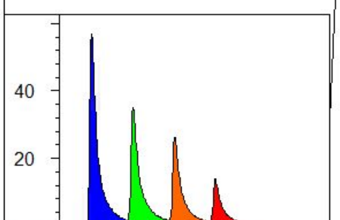
Callouts

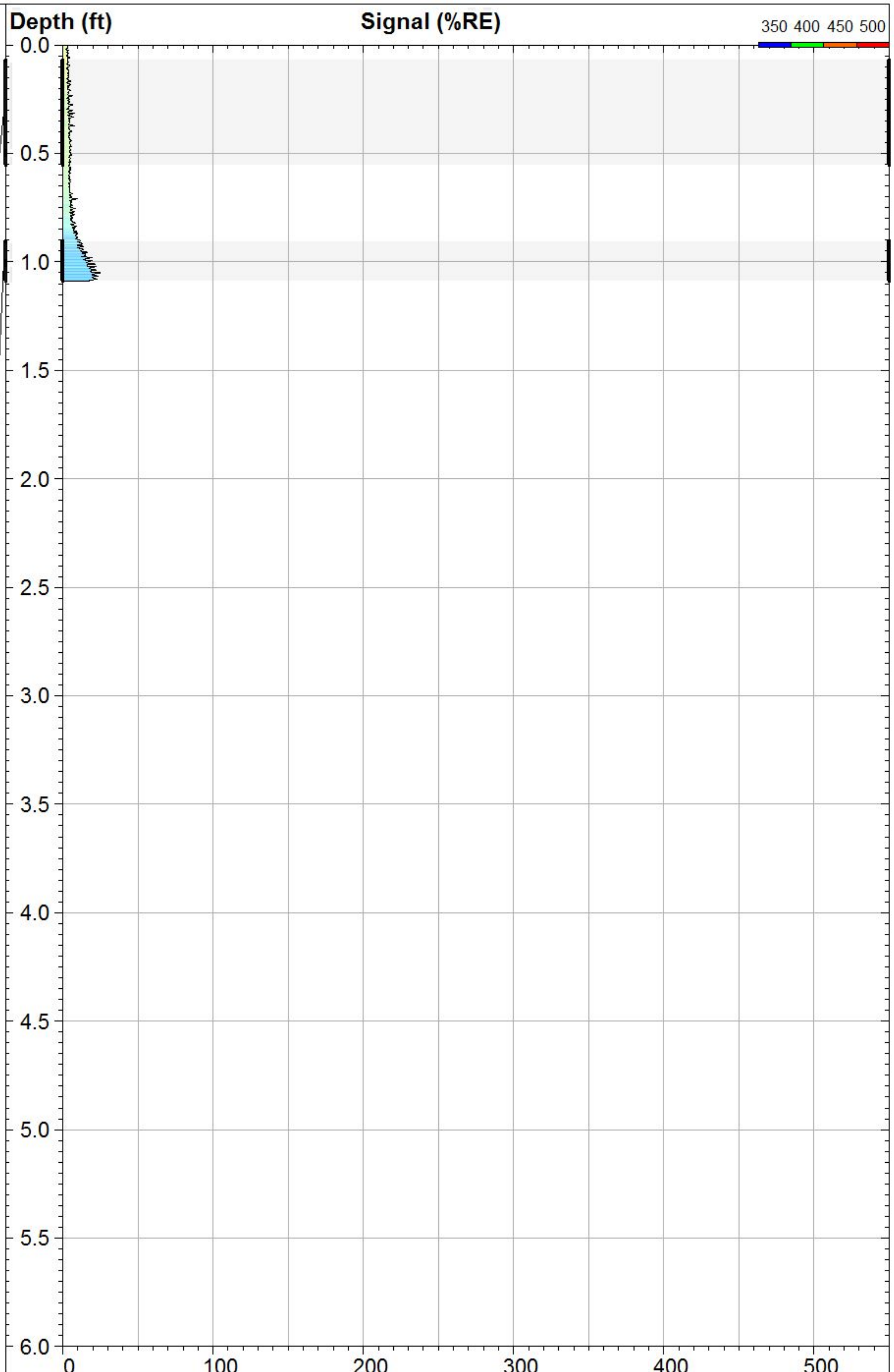
Tore up some bottom 6"



0.07 - 0.55 ft
4.2 %RE (s 1.1)



0.90 - 1.09 ft
16.6 %RE (s 4.0)



Dart-08

Darts By Dakota
www.DakotaTechnologies.com

Site: **Cline Ave Ditch**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **1.09 ft**
Client / Job: **GHD /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **25.0 %RE @ 1.05 ft**
Operator / Unit: **S.Adamek / UVOST01**	*Elevation:* **Unavailable**	*Date & Time:* **2017-09-21 16:31 CDT**

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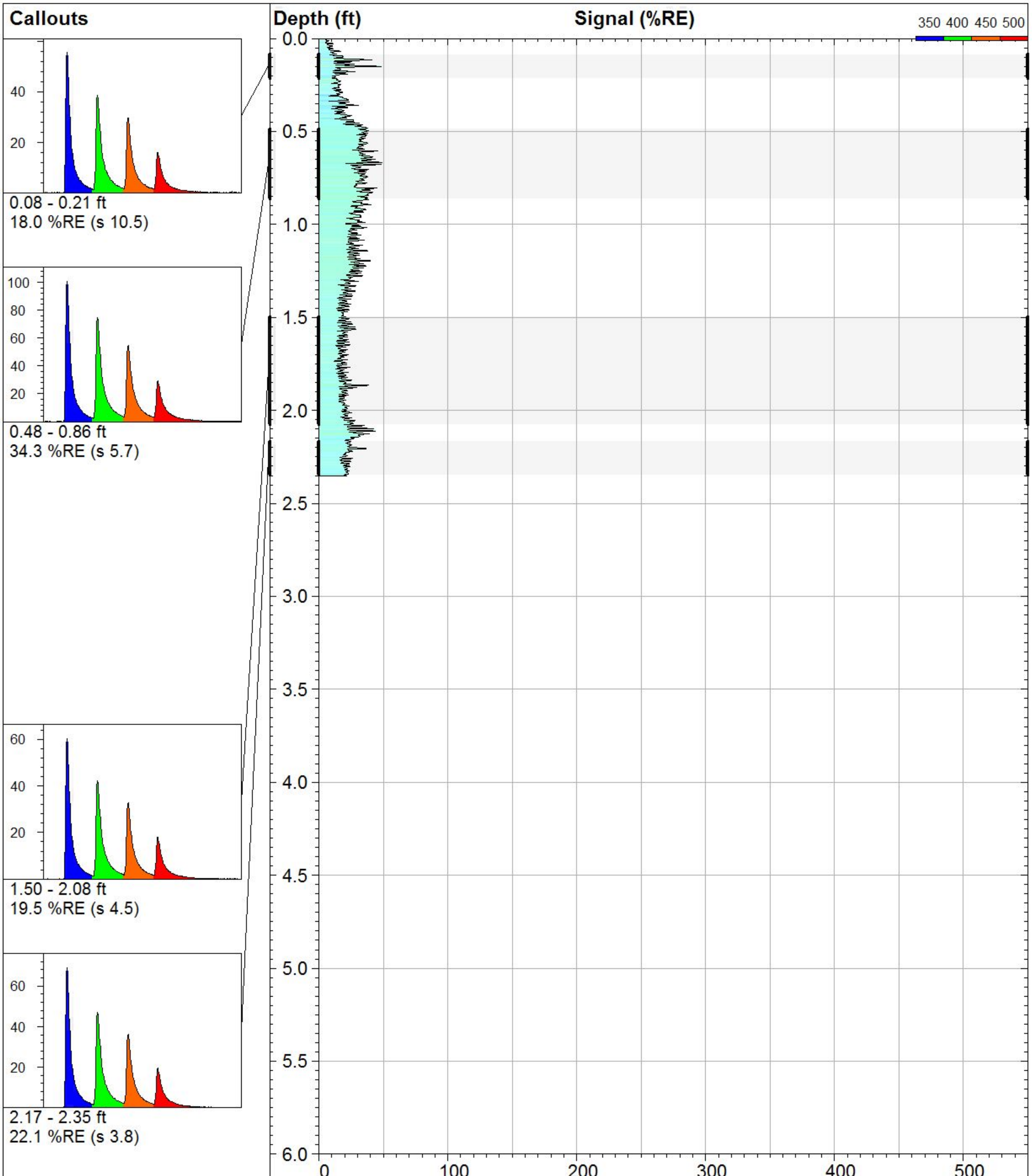

Dart-09		Darts By Dakota www.DakotaTechnologies.com
Site: **Cline Ave Ditch**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **2.35 ft**
Client / Job: **GHD /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **50.3 %RE @ 0.67 ft**
Operator / Unit: **S.Adamek / UVOST01**	*Elevation:* **Unavailable**	*Date & Time:* **2017-09-21 16:40 CDT**

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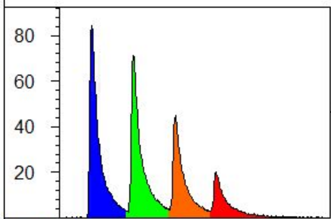
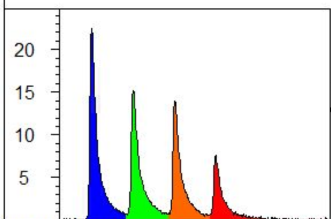
Callouts

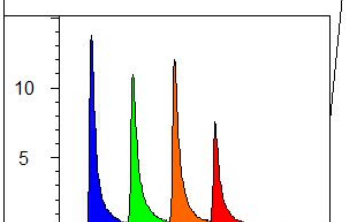


0.35 - 0.37 ft
31.1 %RE (s 40.6)

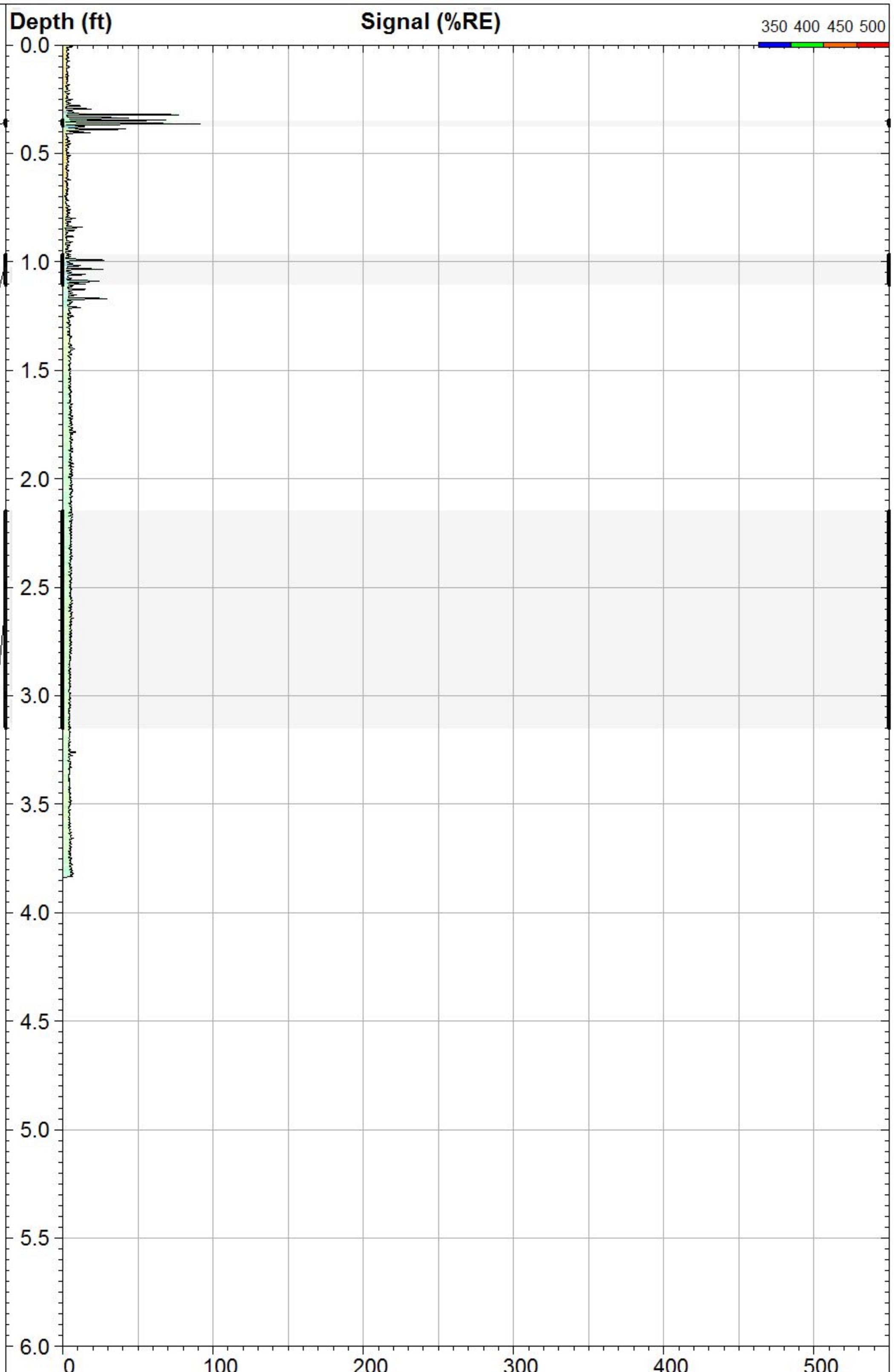


0.97 - 1.11 ft
7.2 %RE (s 7.8)

6" to 24" cuts in Dart material



2.15 - 3.15 ft
5.0 %RE (s 0.7)



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Dart-10

Darts By Dakota
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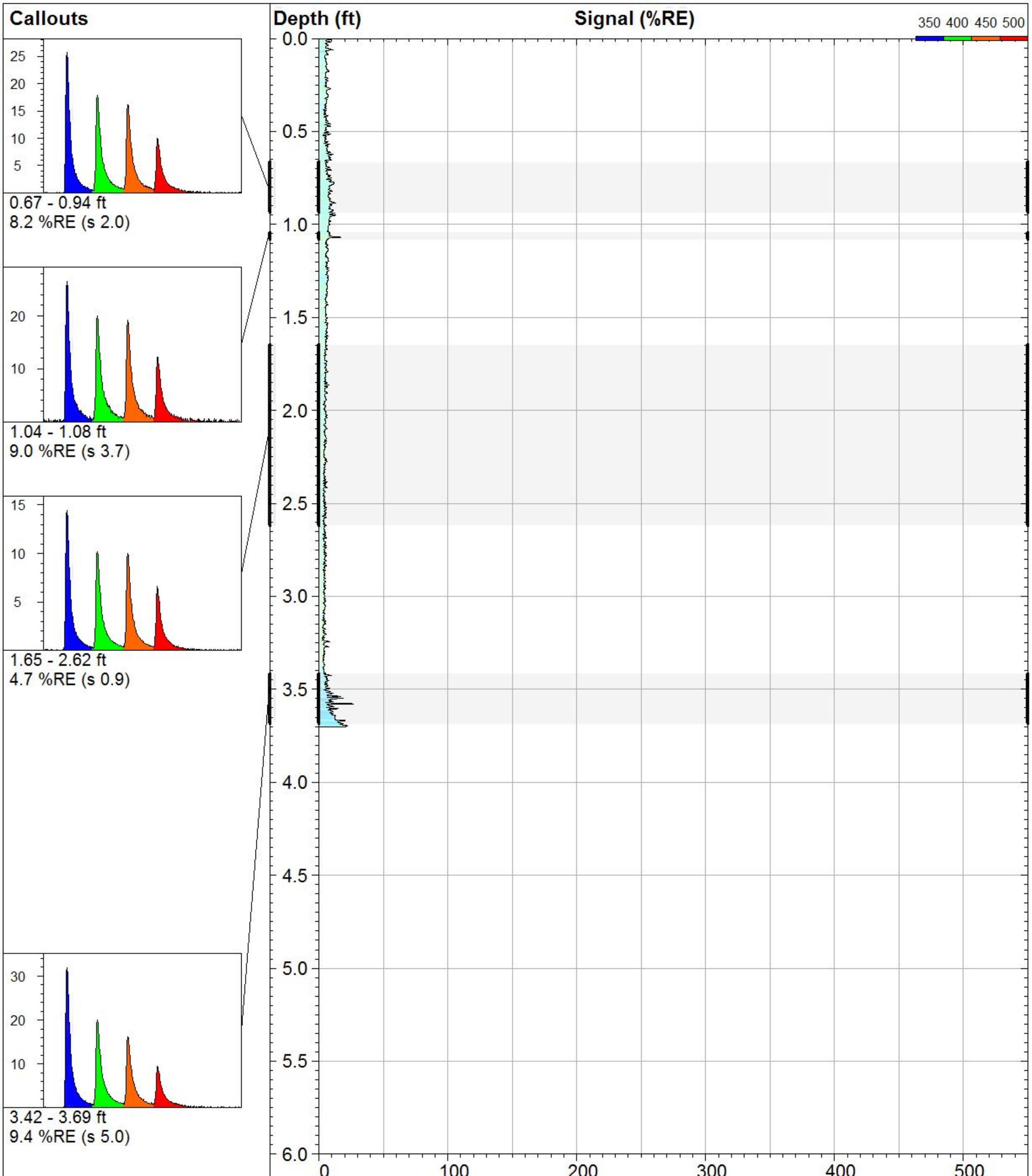
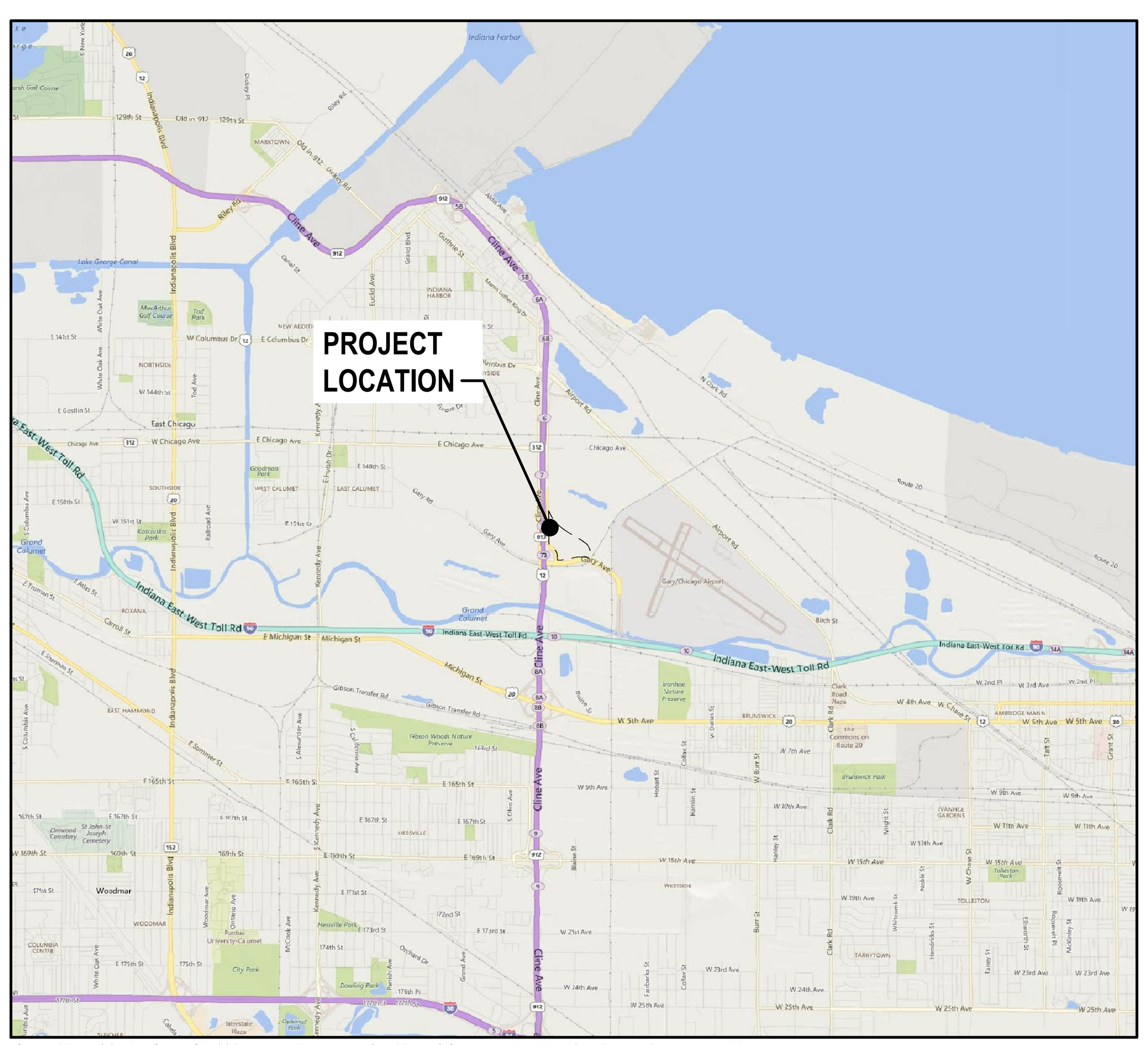
Site:	*Y Coord.(Lat-N) / System:*	*Final depth:*
Cline Ave Ditch	**Unavailable / NA**	**3.84 ft**
Client / Job:	*X Coord.(Lng-E) / Fix:*	*Max signal:*
GHD /	**Unavailable / NA**	**94.1 %RE @ 0.36 ft**
Operator / Unit:	*Elevation:*	*Date & Time:*
S.Adamek / UVOST01	**Unavailable**	**2017-09-21 16:59 CDT**



DAKOTA TECHNOLOGIES Fargo, ND 701.237.4908 www.DakotaTechnologies.com	**Dart-11**		**Darts By Dakota** www.DakotaTechnologies.com
	Site: **Cline Ave Ditch**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **3.70 ft**
	Client / Job: **GHD /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **27.2 %RE @ 3.58 ft**
	Operator / Unit: **S.Adamek / UVOST01**	*Elevation:* **Unavailable**	*Date & Time:* **2017-09-21 17:18 CDT**

Appendix D
DRAFT 90% Design Package

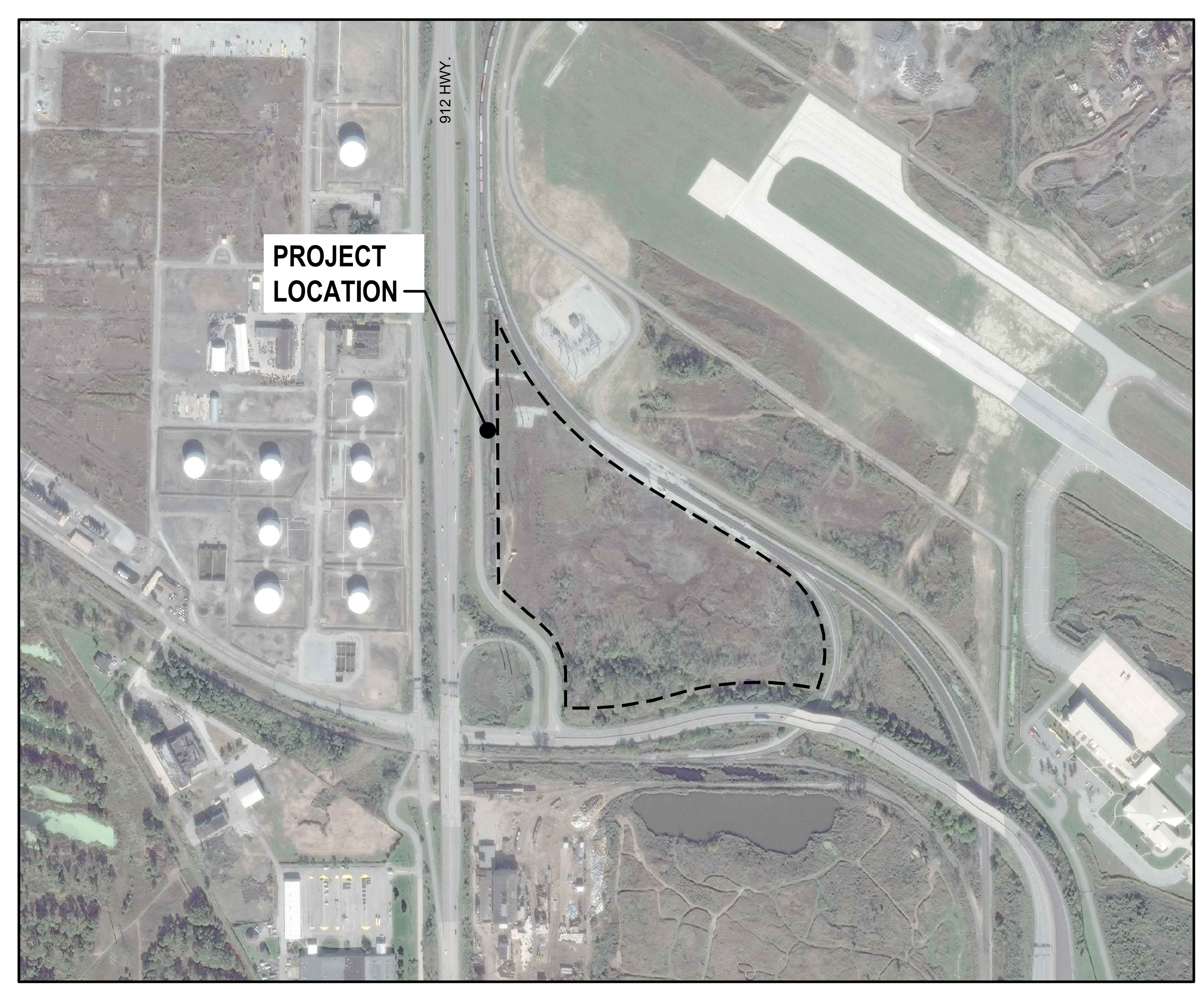
DITCH REMEDIATION
CLINE AVENUE
OIL SPILL SITE
GARY, INDIANA
90% DESIGN
MARCH 17, 2020
11198545



Source: Microsoft Product Screen Shot(s) Reprinted with permission from Microsoft Corporation, Acquisition Date [unknown], Accessed: 2019

AREA MAP

0 2500 5000 ft



AERIAL IMAGE BY TERRASERVER, 0.5m RESOLUTION, 2016-10-23.

LOCATION MAP

0 300 600 ft

DRAWING INDEX

DRAWING NUMBER	FILE NUMBER	DATE	TITLE
G-01	11198545(RPT001)GN-WA001	FEBRUARY 2020	COVER SHEET
C-01	11198545(RPT001)CI-WA001	FEBRUARY 2020	EXISTING CONDITIONS PLAN AND PROFILE
C-02	11198545(RPT001)CI-WA001	FEBRUARY 2020	EXISTING CONDITIONS TRANSECTS
C-03	11198545(RPT001)CI-WA002	FEBRUARY 2020	SITE WORKS, PROPOSED STORM SEWER INSTALLATION WITHIN DITCH PLAN AND PROFILE
C-04	11198545(RPT001)CI-WA003	FEBRUARY 2020	FINAL GRADING PLAN
C-05	11198545(RPT001)CI-WA004	FEBRUARY 2020	PROPOSED STORM SEWER INSTALLATION WITHIN DITCH CROSS SECTION
C-06	11198545(RPT001)CI-WA005	FEBRUARY 2020	PROPOSED STORM SEWER INSTALLATION WITHIN DITCH DETAILS
S-01	11198545(RPT001)ST-WA001	FEBRUARY 2020	STRUCTURAL NOTES
S-02	11198545(RPT001)ST-WA002	FEBRUARY 2020	PROPOSED STORM SEWER INSTALLATION WITHIN DITCH DETAILS (SHEET 1 OF 3)
S-03	11198545(RPT001)ST-WA003	FEBRUARY 2020	PROPOSED STORM SEWER INSTALLATION WITHIN DITCH DETAILS (SHEET 2 OF 3)
S-04	11198545(RPT001)ST-WA004	FEBRUARY 2020	PROPOSED STORM SEWER INSTALLATION WITHIN DITCH DETAILS (SHEET 3 OF 3)

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Client
CLINE AVENUE OIL SPILL SITE GARY INDIANA

Project

No.	Issue	Drawn	Approved	Date
2	90% DESIGN (WITH SUBMISSION OF FFS)	CJ	MT	MAR 17, 2020
1	60% REVIEW	MJ	MT	AUG 6, 2019

Drawn	MJ	Designer	AW/RH
Drafting Check	JC	Design Check	JC
Project Manager	MT	Date	Mar 16, 2020
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Project No. 11198545

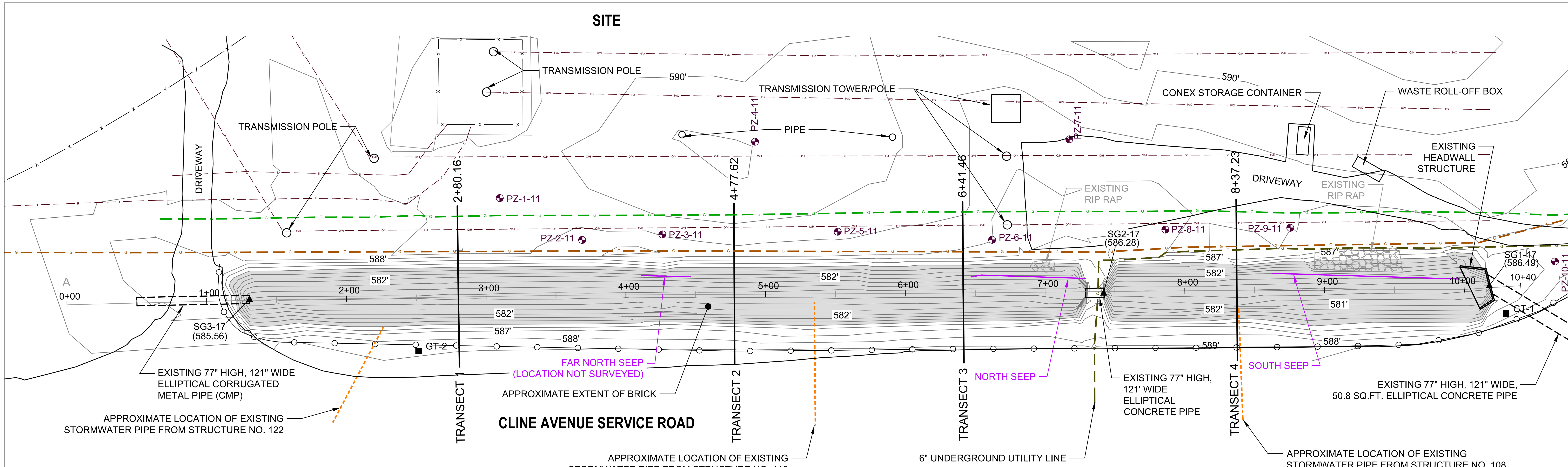
Title
COVER SHEET

Sheet No.
G-01

Sheet 1 of 11

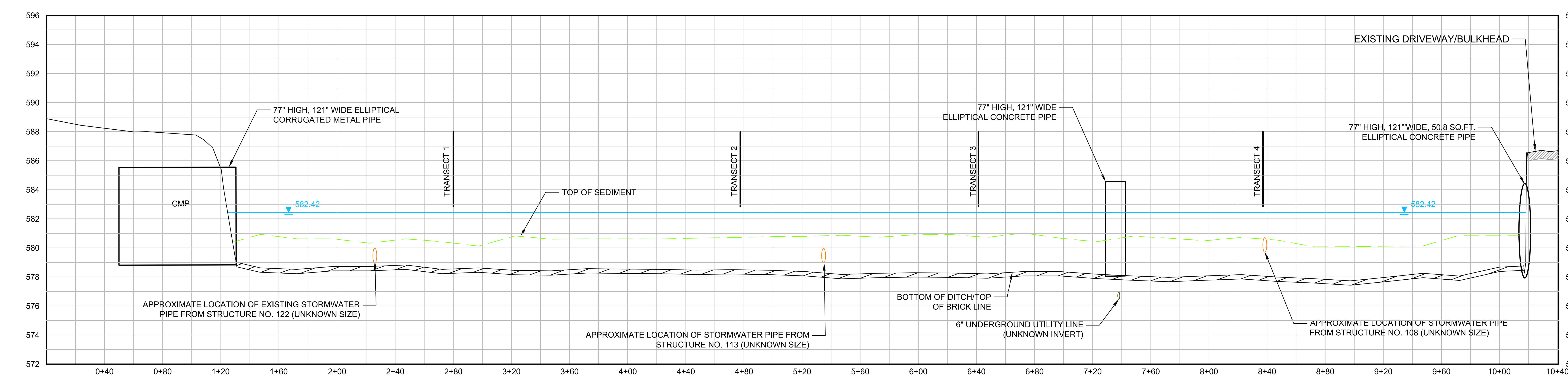
Plot Date: 17 March 2020 - 10:05 AM Plotted By: Bruce Pletz CAD File: N:\CA\Waterloo\Projects\662\11198545\Digital_Design\Figures\RPT001\11198545(RPT001)GN-WA001.DWG

SITE



LEGEND

SEEP LOCATION (SURVEYED JUNE 2, 2017)
PZ-1-11 PIEZOMETER LOCATION (SURVEYED JUNE 2, 2017)
(586.28) SG2-17 STAFF GAUGE LOCATION (REFERENCE ELEVATION) (SURVEYED JUNE 2, 2017, NAVD88)
GUARDRAIL
SURVEYED UNDERGROUND ELECTRICAL LINE
SURVEYED OVERHEAD WIRE
SURVEYED NIPSCO UNDERGROUND UTILITY LINE
SURVEYED BP UNDERGROUND UTILITY LINE
SURVEYED BUCKEYE UTILITY LINE



LEGEND

WATER ELEVATION (JANUARY 2020)
SURVEYED TOP OF SEDIMENT

PROFILE A
SCALES:
1"=50' HORIZONTAL
1"=5' VERTICAL
10X VERTICAL EXAGGERATION

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0 20 40 ft

Client
CLINE AVENUE OIL SPILL SITE
GARY INDIANA

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Drawn	MJ	Designer	AW/RH
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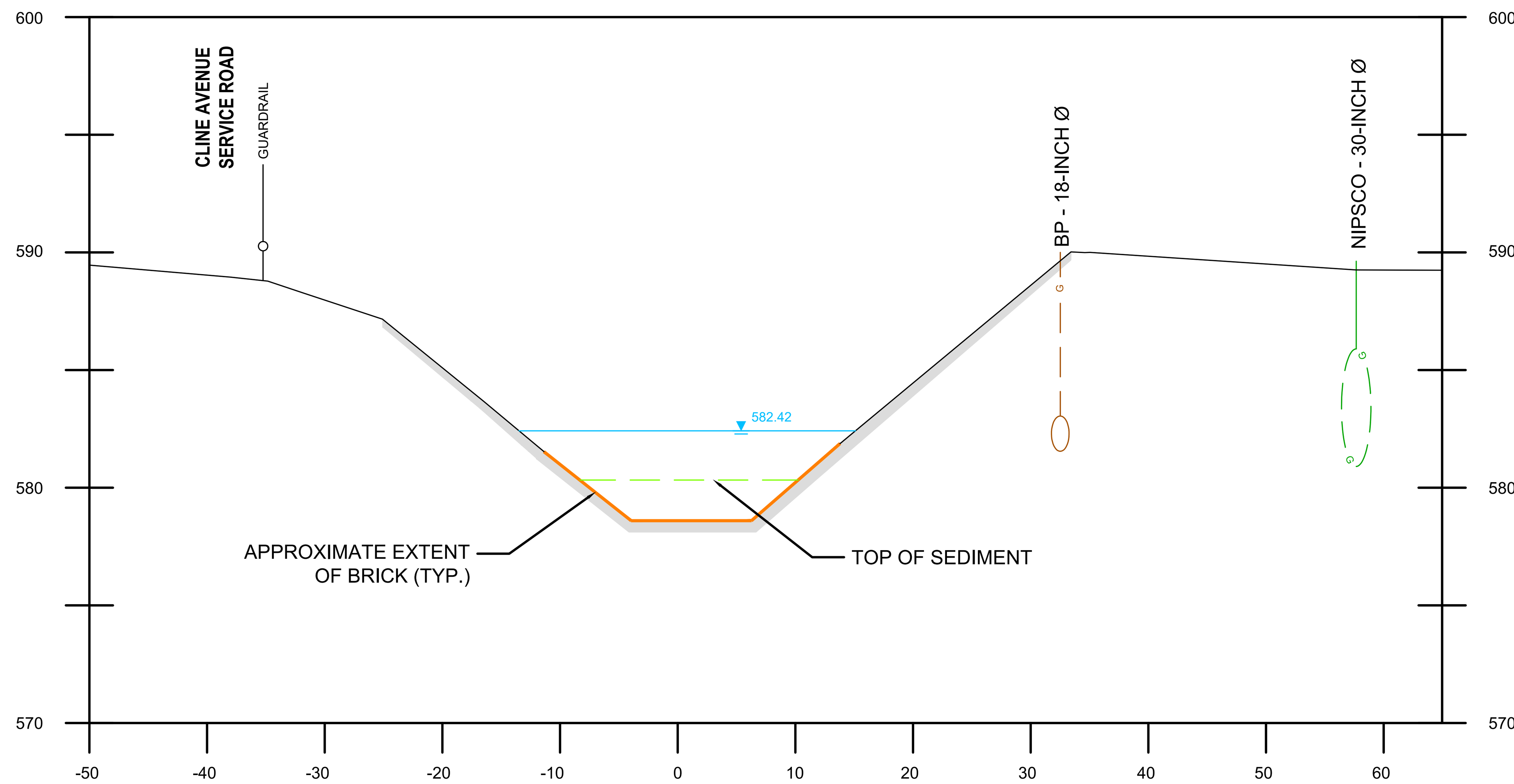
Project No. 11198545

Title
EXISTING CONDITIONS PLAN AND PROFILE

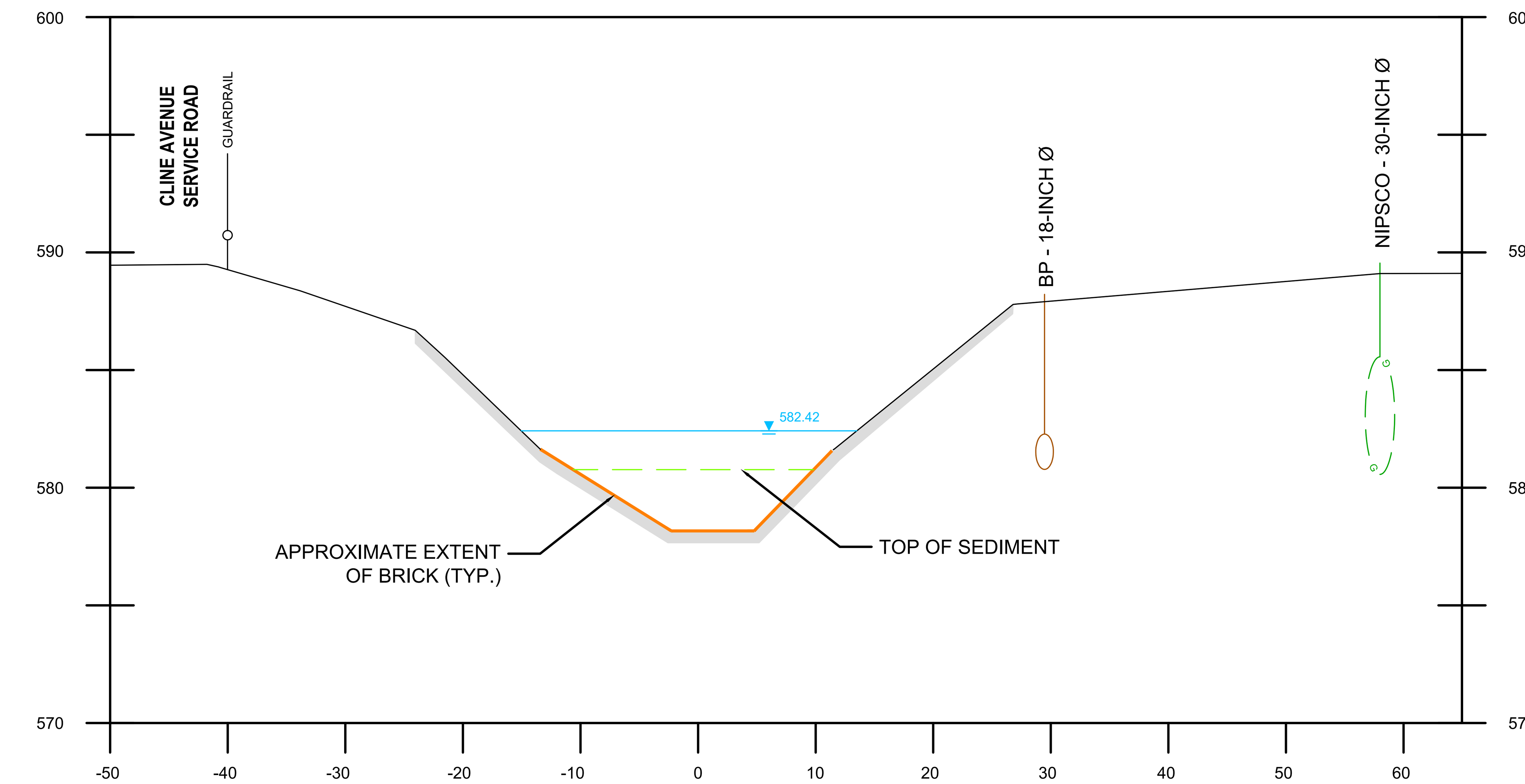
Sheet No.
C-01

Sheet 2 of 11

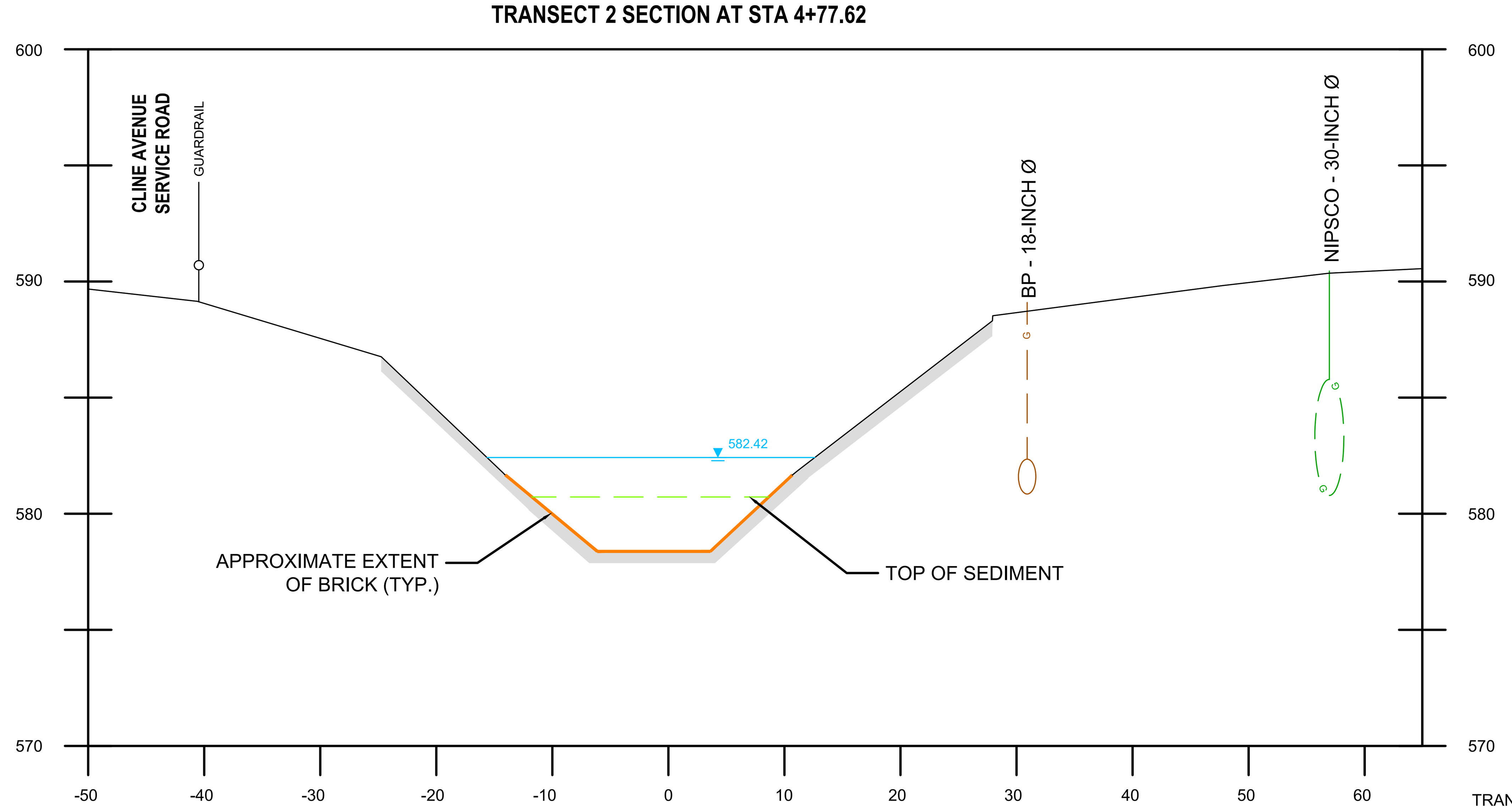
TRANSECT 1 SECTION AT STA 2+80.16



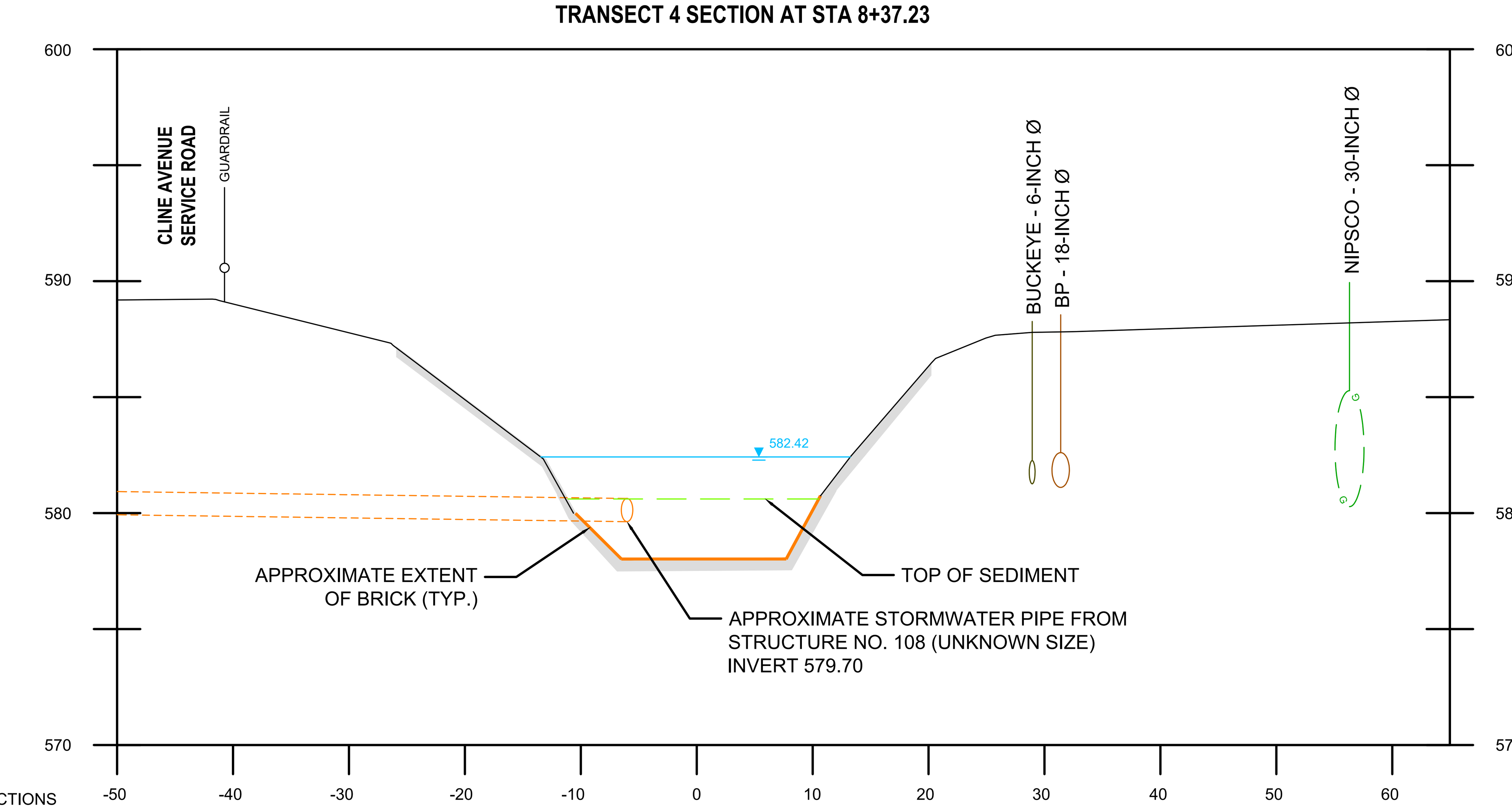
TRANSECT 3 SECTION AT STA 6+41.46



TRANSECT 2 SECTION AT STA 4+77.62



TRANSECT 4 SECTION AT STA 8+37.23



TRANSECT SECTIONS
SCALES:
1"=10' HORIZONTAL
1"=5' VERTICAL
2x VERTICAL EXAGGERATION

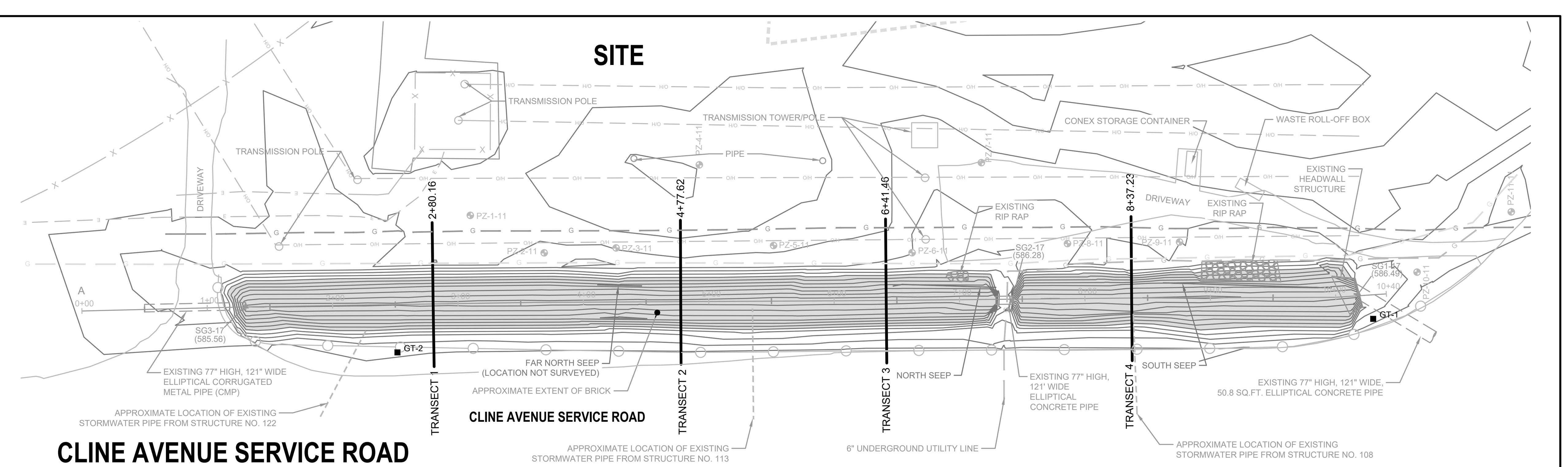
LEGEND

WATER ELEVATION (JANUARY 2020)
NOTE: WATER LEVEL RANGE IN DITCH FLUCTUATES APPROXIMATELY 1FT FROM 581.5 TO 582.5.

TOP OF SEDIMENT

LEGEND

SEEP LOCATION (SURVEYED JUNE 2, 2017)
PZ-1-11 PIEZOMETER LOCATION (SURVEYED JUNE 2, 2017)
(586.28) SG2-17 STAFF GAUGE LOCATION (REFERENCE ELEVATION) (SURVEYED JUNE 2, 2017, NAVD88)
SURVEYED UNDERGROUND ELECTRICAL LINE
SURVEYED OVERHEAD WIRE
SURVEYED NIPSCO UNDERGROUND UTILITY LINE
SURVEYED BP UNDERGROUND UTILITY LINE
SURVEYED BUCKEYE UTILITY LINE



KEY MAP
TRANSECT LOCATIONS

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0 20 40 ft

Client
CLINE AVENUE OIL SPILL SITE
GARY INDIANA

Project

No.	Issue	Drawn	Approved	Date
2	90% DESIGN (WITH SUBMISSION OF FFS)	CJ	MT	MAR 17, 2020
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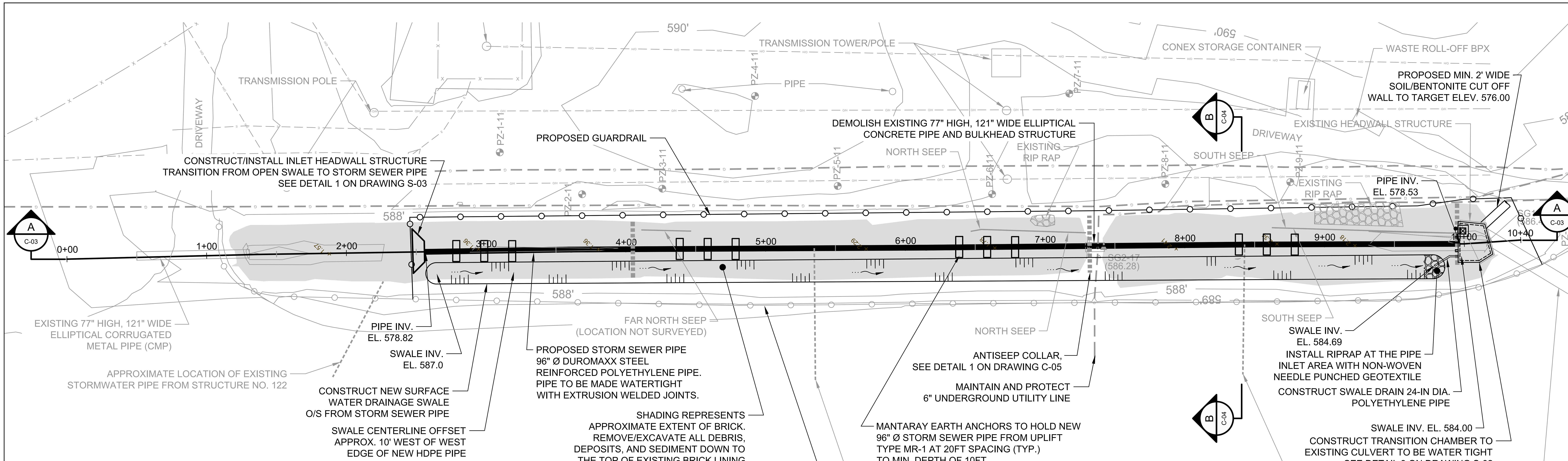
Project No. 11198545

Title
EXISTING CONDITIONS
TRANSECTS

Sheet No.
C-02

Sheet 3 of 11

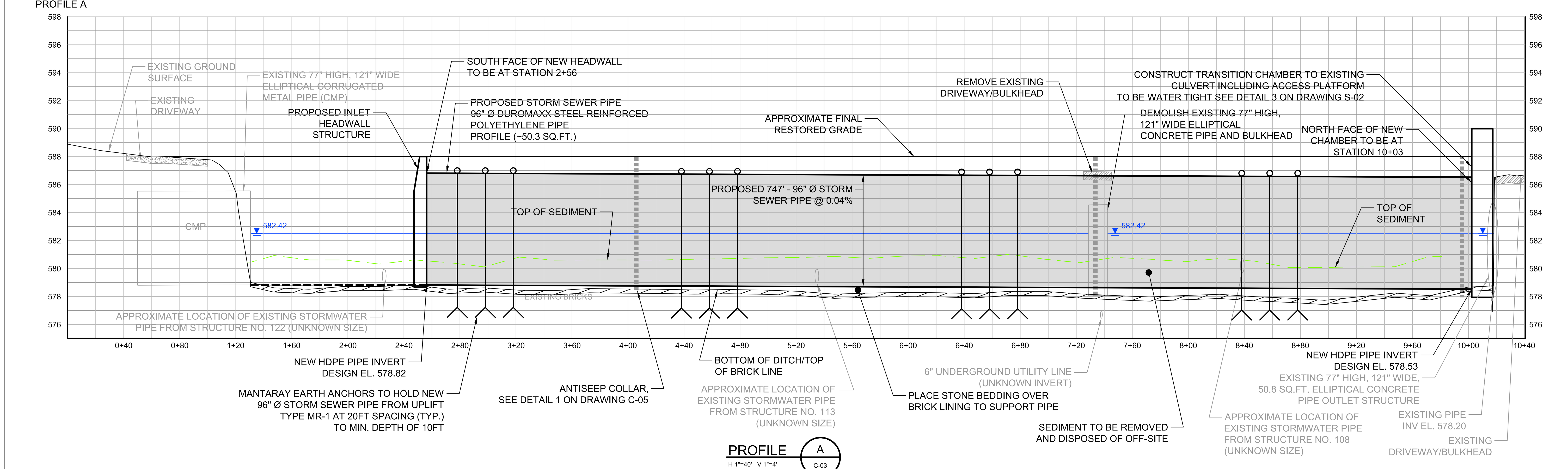
Plot Date: 17 March 2020 - 12:17 AM Plotted By: Chris Johnson CAD File: \\ghdnet\ghd\CA\Waterloo\Projects\662\11198545\Digital_Design\Figures\RPT001\11198545(RPT001)CI-WA001.DWG



CONSTRUCTION NOTES:

1. CONTRACTOR TO VERIFY ALL LOCATIONS AND GRADES PRIOR TO CONSTRUCTION AND REPORT ANY DISCREPANCIES TO ENGINEER.
2. EXISTING CONNECTIONS TO THE SWALE AND UTILITY CROSSINGS TO BE VERIFIED IN THE FIELD.
3. SEDIMENT ABOVE BRICK, THAT LINES THE SWALE, TO BE REMOVED AND DISPOSED OF OFF SITE (DISPOSAL FACILITY TO BE DETERMINED).
4. BRICK THAT LINES THE SWALE TO REMAIN IN PLACE. SEWER TO BE INSTALLED ON BEDDING ON TOP OF BRICK THAT LINES THE SWALE.
5. DITCH TO BE DEWATERED TO ALLOW FOR CONSTRUCTION IN DRY CONDITIONS.
   (a) ISOLATE SECTION OF SWALE AND BYPASS FLOW.
   (b) COLLECT INFILTRATION WATER FROM WORK ZONE, TREAT, AND DISCHARGE. TREATMENT PROCESS TO BE DETERMINED. ASSUME SOLIDS REMOVAL.
   (c) WATER IN THE SWALE IS TYPICALLY STAGNANT, EXCEPT DURING PRECIPITATION EVENTS. CONTRACTOR MAY NEED TO TEMPORARILY PLUG EXISTING UPGRADIENT AND DOWNGRADIENT CULVERTS TO DEWATER.
6. STORM SEWER PIPE SIZED TO MATCH EXISTING DOWNSTREAM OPENING (APPROX. 50.8 SQ.FT.).
7. WORK WILL NEED TO BE COORDINATED WITH THE UTILITY COMPANIES AND INDOT. CONTRACTOR TO FOLLOW APPLICABLE INDOT AND UTILITY COMPANY CONSTRUCTION REQUIREMENTS.

PROFILE A



PROFILE A (C-03)
H 1"=40' V 1"=4'

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Client
CLINE AVENUE OIL SPILL SITE
GARY INDIANA

Project

No.	Issue	Drawn	Approved	Date
2	90% DESIGN (WITH SUBMISSION OF FFS)	CJ	MT	MAR 17, 2020
1	60% REVIEW	MJ	MT	AUG 6, 2019

Drawn	MJ	Designer	AW/RH
Drafting Check	JC	Design Check	JC
Project Manager	MT	Date	Mar 16, 2020
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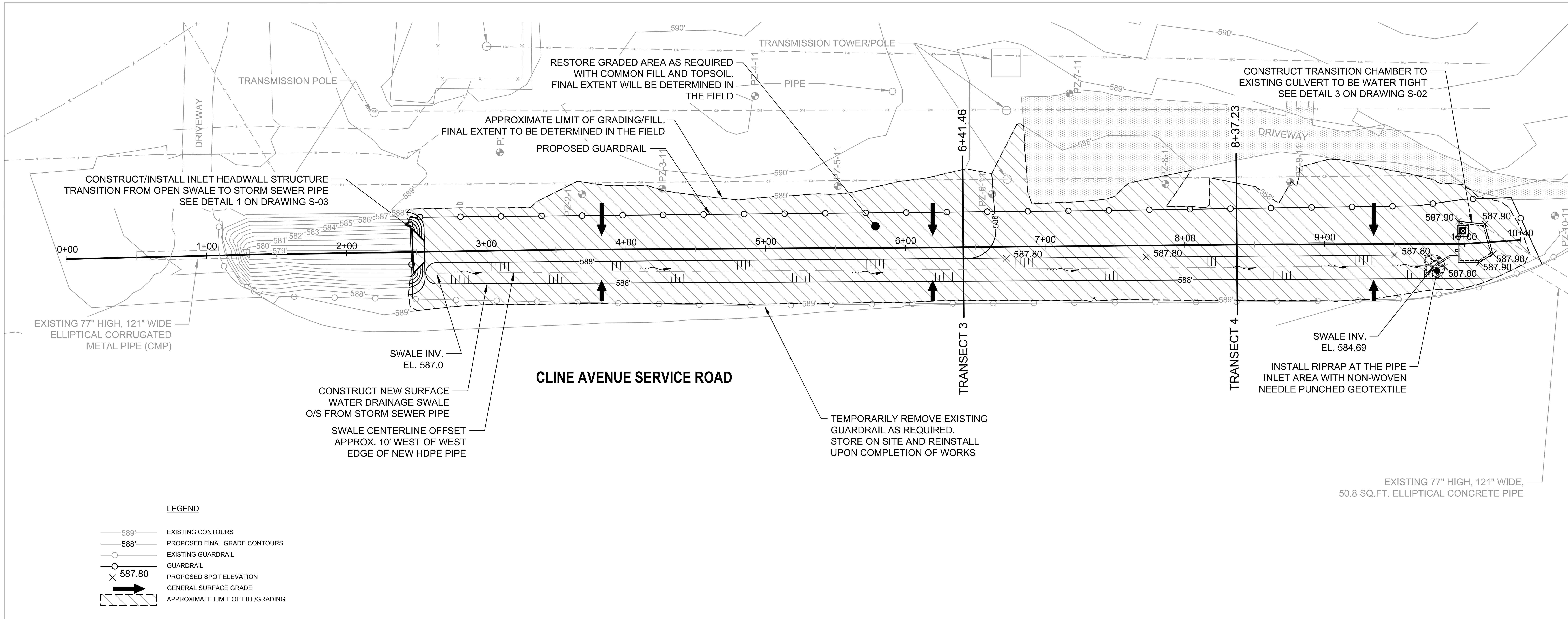
Project No. 11198545

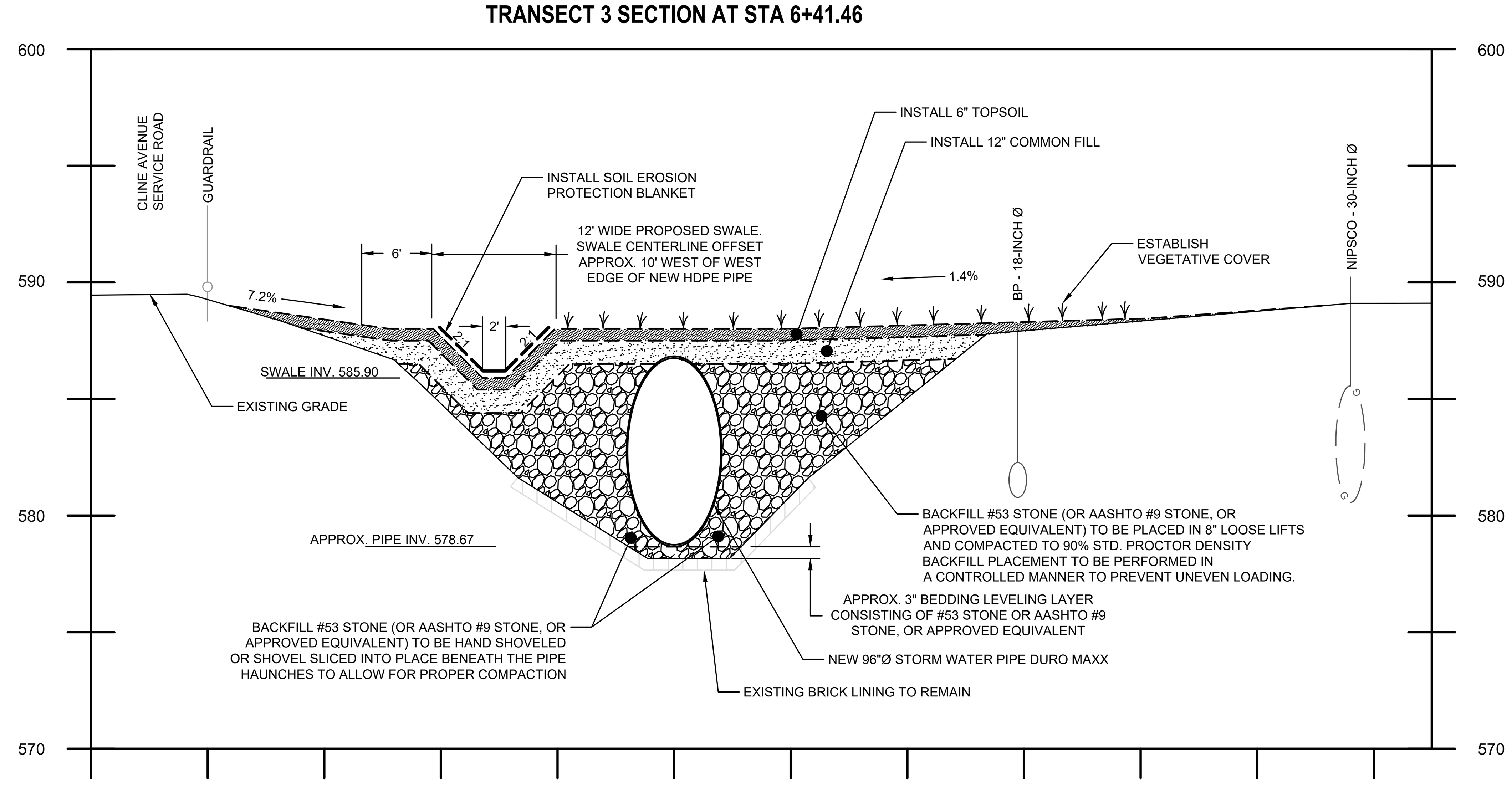
Title
SITE WORKS
PROPOSED STORM SEWER
INSTALLATION WITHIN DITCH
PLAN AND PROFILE

Sheet No.
C-03

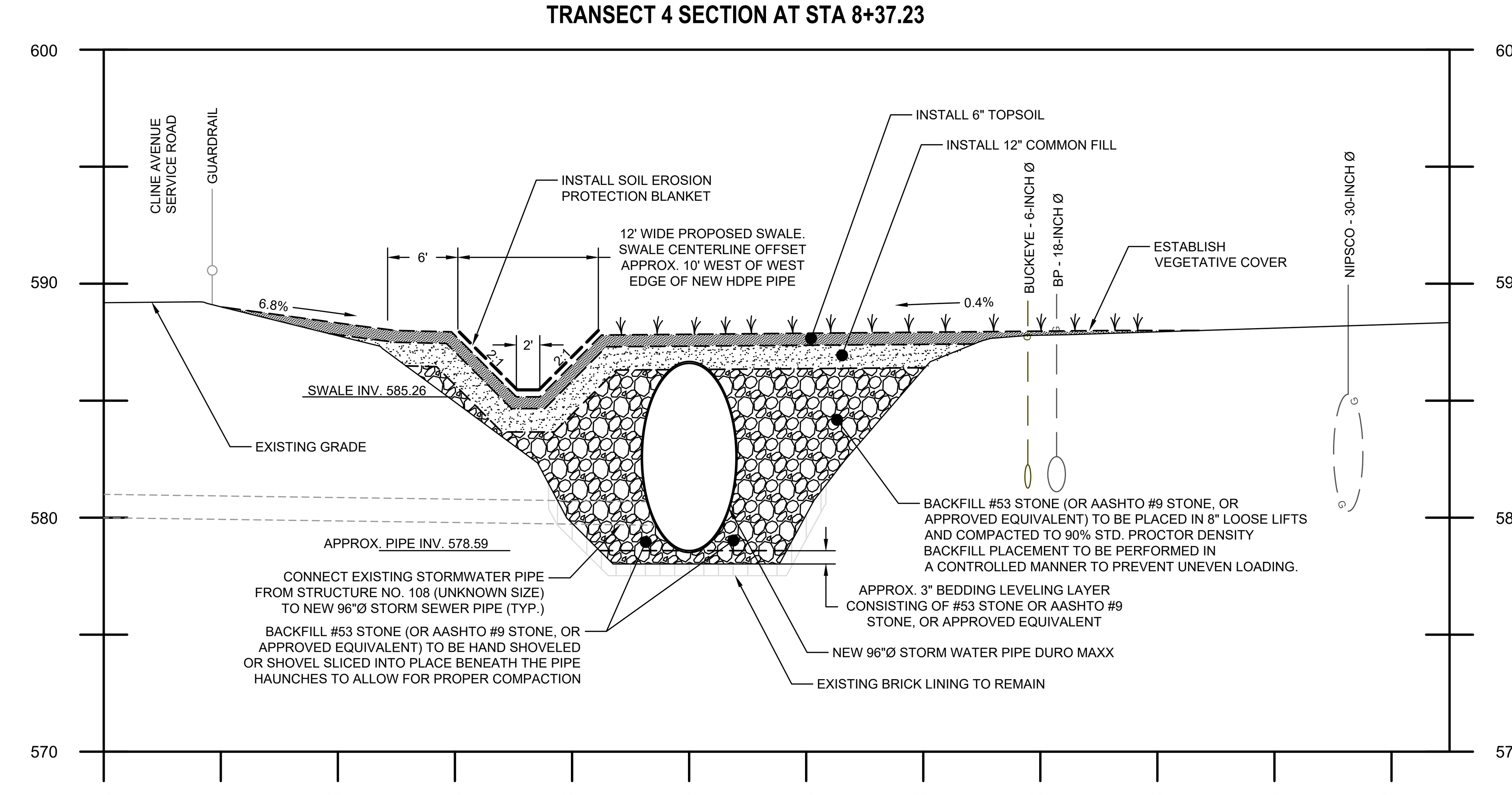
Plot Date: 17 March 2020 - 12:17 AM Plotted By: Chris Johnson CAD File: \\ghdnet\ghd\CA\Waterloo\Projects\662\11198545\Digital_Design\Figures\RPT001\11198545(RPT001)CI-WA002.DWG



TRANSECT 3 SECTION AT STA 6+41.46



TRANSECT 4 SECTION AT STA 8+37.23



TRANSECT SECTIONS
SCALES:
1"=10' HORIZONTAL
1"=5' VERTICAL
2x VERTICAL EXAGGERATION

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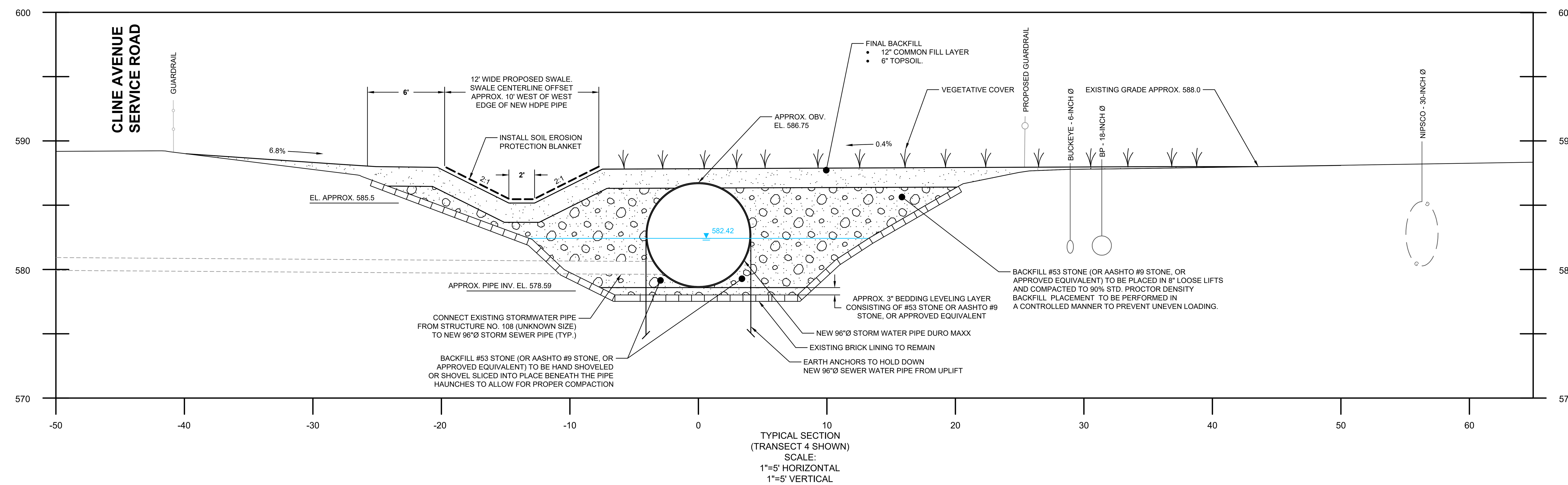
Project No. 11198545

Title
FINAL GRADING PLAN

Sheet No.
C-04

Sheet 5 of 11



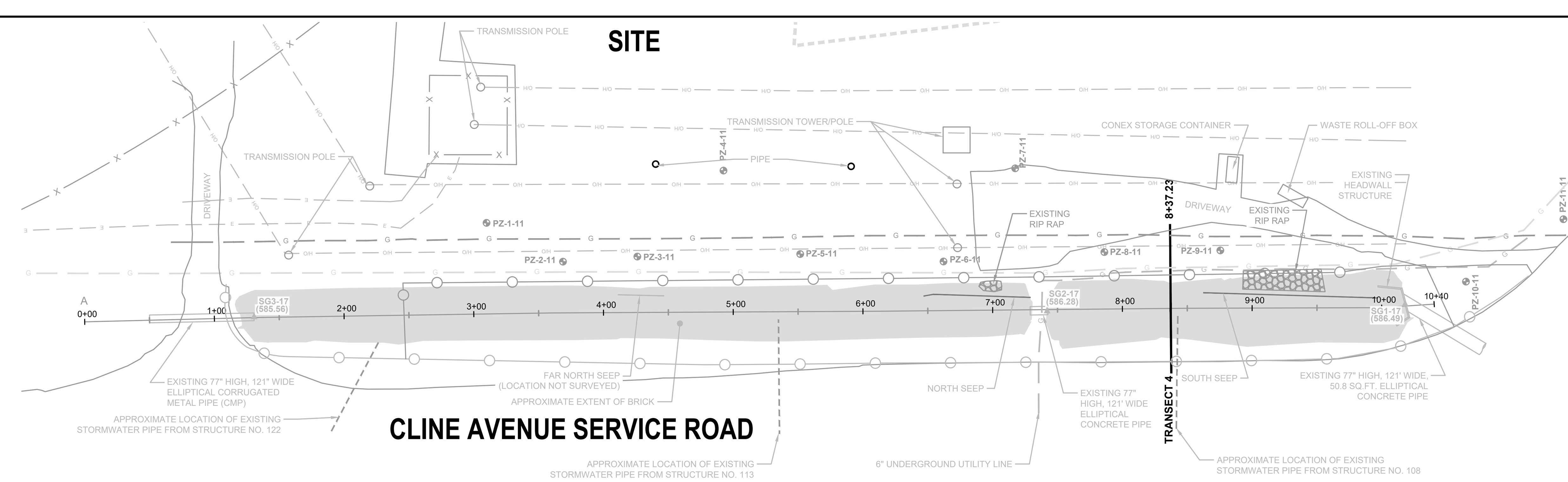
TYPICAL SECTION
(TRANSECT 4 SHOWN)
SCALE:
1"=5' HORIZONTAL
1"=5' VERTICAL

LEGEND

- WATER ELEVATION (JANUARY 2020)
  NOTE: WATER LEVEL RANGE IN DITCH FLUCTUATES APPROXIMATELY 1FT FROM 581.5 TO 582.5.
- TOP OF SEDIMENT

LEGEND

- SEEP LOCATION (SURVEYED JUNE 2, 2017)
- PZ-1-11 — PIEZOMETER LOCATION (SURVEYED JUNE 2, 2017)
- (586.28) SG2-17 — STAFF GAUGE LOCATION (REFERENCE ELEVATION) (SURVEYED JUNE 2, 2017, NAVD88)
- GUARDRAIL
- SURVEYED UNDERGROUND ELECTRICAL LINE
- SURVEYED OVERHEAD WIRE
- SURVEYED NIPSCO UNDERGROUND UTILITY LINE
- SURVEYED BP UNDERGROUND UTILITY LINE
- SURVEYED BUCKEYE UTILITY LINE



KEY MAP
SECTION LOCATION

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0 40 80 ft

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CLINE AVENUE OIL SPILL SITE GARY INDIANA

Project

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Drawn	MJ	Designer	AW/RH
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Project No. 11198545

Title
PROPOSED STORM SEWER INSTALLATION WITHIN DITCH CROSS SECTION

Sheet No.
C-05

Sheet 6 of 11

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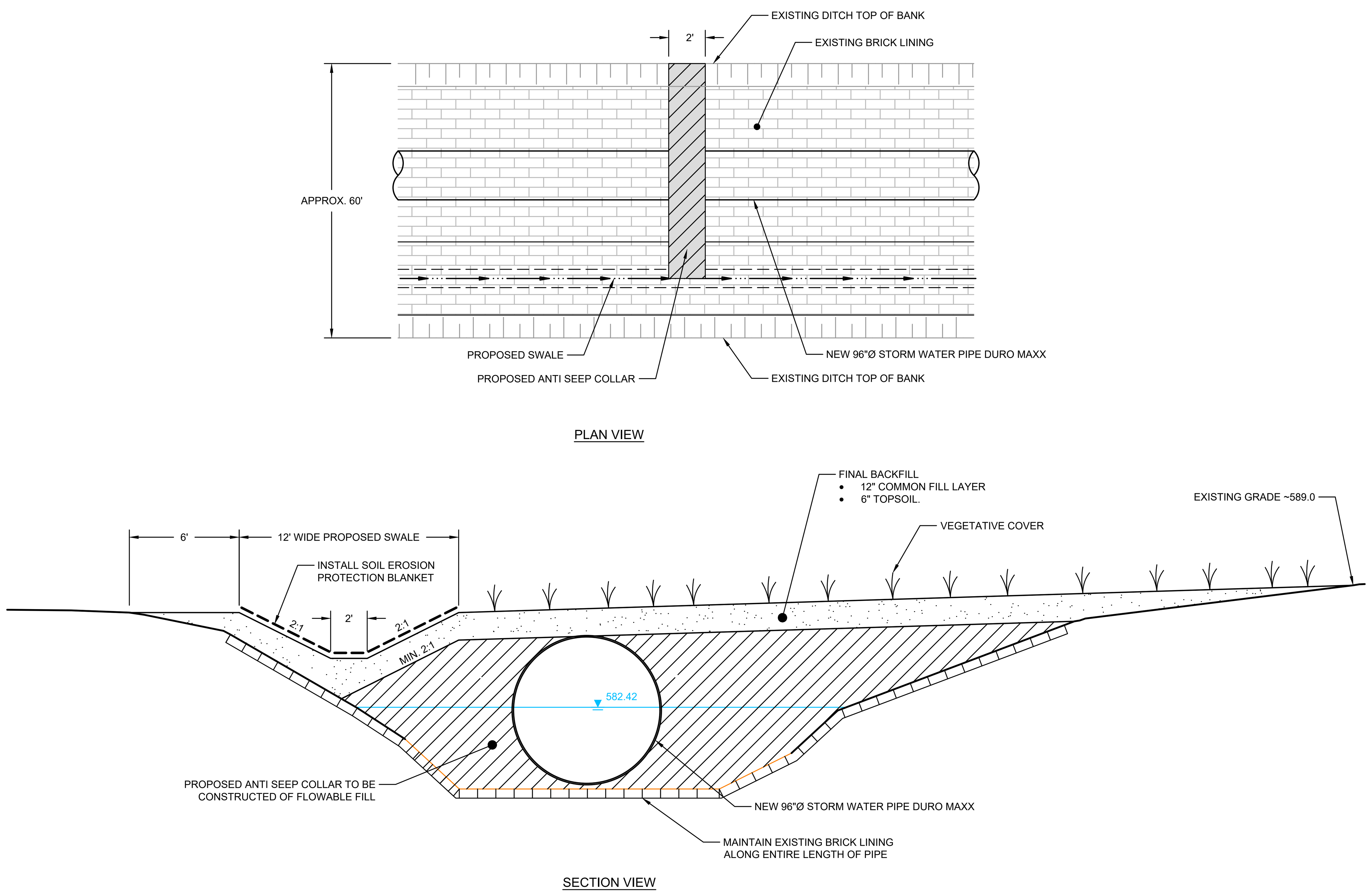

DETAIL 1 ANTI SEEP COLLAR
NTS

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1	60% REVIEW	MJ	MT	AUG 6, 2019

Drawn MJ	Designer AW/RH
Drafting Check JC	Design Check JC
Project Manager MT	Date Mar 17, 2020
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Project No. 11198545

Title
PROPOSED STORM SEWER INSTALLATION WITHIN DITCH DETAILS

Sheet No.
C-06

Sheet 7 of 11

GENERAL

1. ALL WORK SHALL COMPLY WITH LATEST REVISION AND/OR VERSION OF ALL CODES AND REFERENCE STANDARDS, THE WORKPLACE HEALTH AND SAFETY BOARD AND BEST TRADE PRACTICES. WORK SHALL COMPLY WITH FEDERAL AND STATE REGULATIONS AND WITH APPLICABLE ACI SPECIFICATIONS.
2. STRUCTURAL DESIGN COMPLIES WITH THE MINIMUM REQUIREMENTS OF ASCE 7 AND ACI 318.
3. LOCATE ALL BURIED AND ABOVE SERVICES PRIOR TO EXCAVATION. THE CONTRACTOR SHALL BE RESPONSIBLE FOR ALL TEMPORARY BRACING, SHORING AND DEWATERING NECESSARY TO UNDERTAKE THE WORK.
4. READ THESE DRAWINGS IN CONJUNCTION WITH ALL RELATED DRAWINGS AND CONTRACT DOCUMENTS.
5. THE CONTRACTOR SHALL CHECK AND VERIFY ALL CONDITIONS AND MEASUREMENTS AT THE SITE AND REPORT TO THE ENGINEER ANY DISCREPANCIES OR UNSATISFACTORY CONDITIONS WHICH MAY ADVERSELY AFFECT THE PROPER COMPLETION OF THE JOB BEFORE PROCEEDING WITH THE WORK.
6. DO NOT SCALE DRAWINGS.
7. DESIGN LIVE LOADS FOR EACH PORTION OF THE STRUCTURE ARE AS INDICATED ON THE DRAWINGS. DO NOT EXCEED THESE LOADS DURING CONSTRUCTION.
8. DESIGN LOADS INDICATED ARE UNFACTORED UNLESS NOTED OTHERWISE.
9. REFERENCE ELEVATIONS SHOWN CORRESPOND TO ACTUAL GEODETIC ELEVATIONS IN FEET.
10. ALL DIMENSIONS ON DRAWINGS ARE IN INCHES UNLESS NOTED OTHERWISE.
11. APPROVED SHALL MEAN APPROVED IN WRITING BY THE ENGINEER OF RECORD.
12. DELIVER, HANDLE AND STORE MATERIALS TO AVOID DAMAGE IN ANY MANNER.
13. MAINTAIN A SET OF DRAWINGS ON SITE & UPDATE WEEKLY WITH CONSTRUCTION RECORD INFORMATION.

FOUNDATION AND BACKFILL:

1. PREPARE FOUNDATION SUBGRADE IN ACCORDANCE WITH THE GEOTECHNICAL REPORT PREPARED BY GHD DATED FEBRUARY 25, 2020 (REF NO. 11198545).
2. FOOTINGS SHALL BE CONSTRUCTED ON NATIVE SAND OR NON-FROST SUSCEPTIBLE GRANULAR FILL (INDOT NO. 53) COMPACTED ACCORDING TO GEOTECHNICAL RECOMMENDATION.
3. BACKFILL SHALL BE FREE DRAINING GRANULAR MATERIAL AS RECOMMENDED IN THE GEOTECHNICAL REPORT. BACKFILL TO BE PLACED IN MAXIMUM 8" LOOSE LIFTS AND COMPACTED TO A MINIMUM OF 98% SPMDD.
4. A QUALIFIED GEOTECHNICAL ENGINEER SHALL FIELD VERIFY THAT THE NATIVE MATERIAL PROVIDES THE MINIMUM ALLOWABLE BEARING CAPACITY OF 4,000 PSF AND THE FILL HAS BEEN COMPACTED TO THE SATISFACTORY LEVEL.
5. PROTECT BEARING SURFACES FROM FREEZING BEFORE AND AFTER FOOTINGS ARE POURED.

DESIGN LOADS:

1. BACKFILL PROPERTIES:
   UNIT WEIGHT = 120 lb/ft3
   ka = 0.31
   ko = 0.47
   kp = 3.25
2. LIVE LOAD ON CHAMBER COVER = 100 PSF
3. SNOW LOAD = 25 PSF

STRUCTURAL AND MISC. STEEL AND ANCHOR NOTES:

1. STRUCTURAL STEEL SHAPES SHALL CONFORM TO ASTM A992 GRADE 50.
2. STEEL GRATING TO CONFORM TO ASTM A 1011/A 1011M COMMERCIAL STEEL (TYPE 2).
3. ALL STEEL COMPONENTS, U.N.O., SHALL BE HOT DIP GALVANIZED AFTER FABRICATION, IN ACCORDANCE TO ASTM A123/A123M.
4. ANCHOR RODS SHALL BE STAINLESS STEEL HAS RODS, MEETING THE REQUIREMENTS OF ASTM F593 (CONDITION CW). ANCHOR RODS SHALL BE BONDED USING HILTI HY-200 ADHESIVE SYSTEM, OR APPROVED EQUIVALENT.
5. FASTENERS SHALL BE MINIMUM 3/4 INCH DIAMETER GALVANIZED BOLTS CONFORMING TO ASTM A325 SPECIFICATIONS UNLESS NOTED OTHERWISE. GALVANIZING SHALL BE IN ACCORDANCE TO ASTM A153/A153M.

CAST-IN-PLACE CONCRETE NOTES:

1. CONCRETE DESIGN IN ACCORDANCE WITH ACI 318. WHERE CONCRETE MATERIALS AND/OR CONSTRUCTION DETAILS ARE NOT SPECIFIED, FOLLOW THE LATEST APPLICABLE ACI SPECIFICATIONS AND STANDARDS.
2. MINIMUM CONCRETE COMPRESSIVE STRENGTH SHALL BE 4,000 PSI (F3 EXPOSURE) AT 28 DAYS.
3. REINFORCING STEEL SHALL BE NEW DEFORMED BARS CONFORMING TO ASTM A615, GRADE 60 SPECIFICATIONS. ALL REINFORCING MATERIAL IS TO BE FREE OF DIRT, LOOSE RUST, SCALE, OIL, PAINT OR OTHER COATINGS.
4. BARS AND SPLICES AND EMBEDMENT LENGTHS ARE TO BE IN ACCORDANCE WITH ACI 318.
5. REINFORCING IS TO BE DETAILED IN ACCORDANCE WITH ACI SP 66 - ACI DETAILING MANUAL.
6. ALL REINFORCING BARS SHALL BE SUPPORTED IN THE FORMS AND SPACED WITH STANDARD ACCESSORIES.
7. CONCRETE FORMS SHALL HAVE SUFFICIENT STRENGTH AND RIGIDITY TO WITHSTAND THE NECESSARY PRESSURE, TAMPING AND VIBRATION WITHOUT DEFLECTION FROM THE PRESCRIBED LINES. THEY SHALL BE MORTAR-TIGHT AND CONSTRUCTED SO THAT THEY CAN BE REMOVED WITHOUT HAMMERING OR PRYING AGAINST THE CONCRETE. THE INSIDE OF THE FORMS SHALL BE OILED WITH NON-STAINING MINERAL OIL OR THOROUGHLY WETTED BEFORE CONCRETE IS PLACED.
8. METAL TIES OR ANCHORAGES SHALL BE FULL DIMENSION. NOMINAL SIZE WALL TIES ARE NOT PERMITTED. WALL TIE ENDS MUST BE BROKEN OFF AND PATCHED WITH AN APPROVED MATERIAL. PATCHING IS REQUIRED ON BOTH THE INSIDE AND OUTSIDE OF CONCRETE STRUCTURES.
9. ALL CONCRETE FOR WALLS SHALL BE CONSOLIDATED WITH INTERNAL TYPE MECHANICAL VIBRATORS. CONCRETE SHALL BE PLACED IN HORIZONTAL LIFTS NOT GREATER THAN 20 INCHES. CONCRETE SHALL NOT HAVE A VERTICAL DROP GREATER THAN 5 FEET.
10. CONCRETE SHALL NOT BE PLACED WHEN THE DAILY MINIMUM ATMOSPHERIC TEMPERATURE IS LESS THAN 40 DEGREE F UNLESS FACILITIES ARE PROVIDED TO ENSURE ADEQUATE PROTECTION OF THE CONCRETE. THE CONCRETE SHALL BE PROTECTED FROM FREEZING FOR A MINIMUM OF 7 DAYS OR THE CONCRETE SHALL BE KEPT AT A TEMPERATURE AT OR ABOVE 55 DEGREE F FOR A MINIMUM OF 3 DAYS.
11. UNLESS NOTED OTHERWISE ON DRAWINGS, THE MIN. CLEAR DISTANCE BETWEEN REINFORCING STEEL AND SURFACE OF CONCRETE SHALL BE AS FOLLOWS:
    WALLS : 2" TO EXT. FACE
    FOOTINGS : 3" TO BOTTOM FACE CAST AGAINST EARTH, 2" TO TOP FACE.
12. CONCRETE PROTECTION IN ALL CASES SHALL BE AT LEAST 1.5 TIMES THE BAR DIAMETER.
13. NO CUTTING OR DRILLING IN HARDENED CONCRETE IS PERMITTED WITHOUT WRITTEN AUTHORIZATION FROM THE ENGINEER.
14. PROVIDE 3/4" CHAMFER EDGE ON ALL EXPOSED CONCRETE CORNERS.
15. DO NOT PLACE UNBALANCED BACKFILL LOADS ON WALLS UNTIL THE CONCRETE HAS ACHIEVED THE 28-DAY DESIGN STRENGTH.
16. ALL REINFORCING STEEL TO BE INSPECTED BY THE ENGINEER BEFORE POURING CONCRETE.
17. DO NOT DRIVE CONSTRUCTION VEHICLES WITHIN 10'-0" FROM THE FACE OF THE WALLS (ON FILL SIDE), USE LIGHT COMPACTION EQUIPMENT ADJACENT TO THE WALL.
18. CONTRACTOR SHALL SUBMIT A COPY OF ALL SHOP DRAWINGS PRIOR TO STARTING ANY WORK.
19. CLEAN (WATER JETTING OR ANY OTHER APPROVED METHOD) AND APPLY APPROVED BONDING AGENT ON EXISTING CONCRETE WALL AND SLAB SURFACES PRIOR TO POURING NEW CONCRETE AGAINST EXISTING CONCRETE.
20. ROUGHEN EXISTING SLAB SURFACES PRIOR TO POURING NEW CONCRETE TOPPING.
21. SEAL ENTIRE CONCRETE STRUCTURE INTERIOR WITH APPROVED EPOXY / POLYUREA WATER PROOFING COATING.

STEEL DECK

1. DECK STEEL SHALL CONFORM TO ASTM A653/A6M3M WITH MINIMUM YIELD STRENGTH OF 33 ksi (230 MPa). PROFILE FOR COMPOSITE DECKING SHALL BE CANAM P-2432 WITH METALLIC COATING ZF075 OR APPROVED EQUIVALENT.
2. DESIGN, FABRICATE AND INSTALL STEEL DECK TO AISI S100 AND STEEL DECK INSTITUTE (SDI) UNLESS NOTED OTHERWISE ON DRAWINGS.
3. INSTALL DECKING CONTINUOUS OVER MINIMUM THREE SPANS UNLESS NOTED OTHERWISE ON DRAWINGS.
4. FASTEN DECK TO SUPPORTING STEEL AT EVERY FLUTES WITH POWER DRIVEN PIN, SELF DRILLING SCREWS OR WELDS IN ACCORDANCE WITH DRAWINGS. FASTEN SIDE LAPS WITH #12-14 SELF DRILLING SCREWS @ 12" O.C. UNLESS NOTED OTHERWISE ON DRAWINGS. USE GALVANIZED FASTENERS FOR EXTERIOR AREAS.

EXISTING STRUCTURE

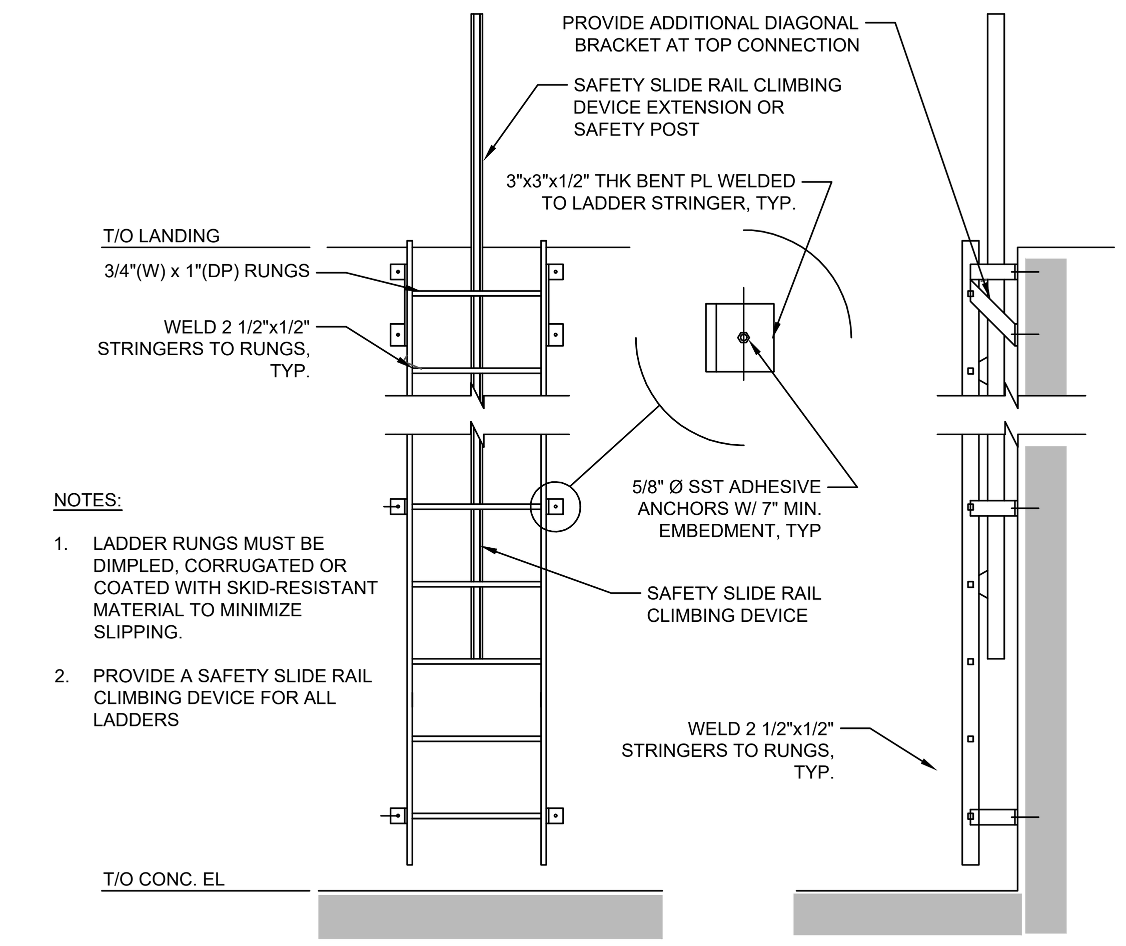
1. ELEVATIONS AND DIMENSIONS FOR EXISTING STRUCTURES SHOWN ON THESE DRAWINGS ARE BASED ON AVAILABLE INFORMATION. AFTER EXCAVATION BUT BEFORE FORMING AND PLACING OF REINFORCEMENT, THE CONTRACTOR SHALL ENSURE THAT ALL ELEVATIONS AND DIMENSIONS SHOWN ON THE DRAWINGS RELATED TO THE EXISTING STRUCTURE ARE ACCURATE AND NOTIFY THE ENGINEER IMMEDIATELY OF ANY DISCREPANCIES OR CONFLICTS.
2. THE CONTRACTOR SHALL PROTECT EXISTING FACILITIES, STRUCTURES AND UTILITY LINES FROM ALL DAMAGE.
3. INVESTIGATE THE EXISTING STRUCTURE TO DETERMINE ACTUAL FIELD CONDITIONS AND TAKE FIELD DIMENSIONS.
4. MAKE GOOD ALL EXISTING WORK DISTURBED BY EXCAVATION, SHORING OPERATIONS AND OTHER CONSTRUCTION PROCEDURES..

CONCRETE WALL PIPE PENETRATION

1. REFER TO PIPE MANUFACTURER FOR PIPE END CONNECTION TO CONCRETE WALLS. CONNECTIONS MUST BE WATERTIGHT. FILL GAPS WITH NON-SHRINKING GROUT C/W 2 BEADS OF $\frac{1}{4}$" THICK CONTINUOUS, ANNULAR, FIELD APPLIED, HYDROPHYLIC CAULK (LEAKMASTER LV-1 OR APPROVED EQUAL) PER PIPE MANUFACTURER'S RECOMMENDATION.

ABBREVIATIONS

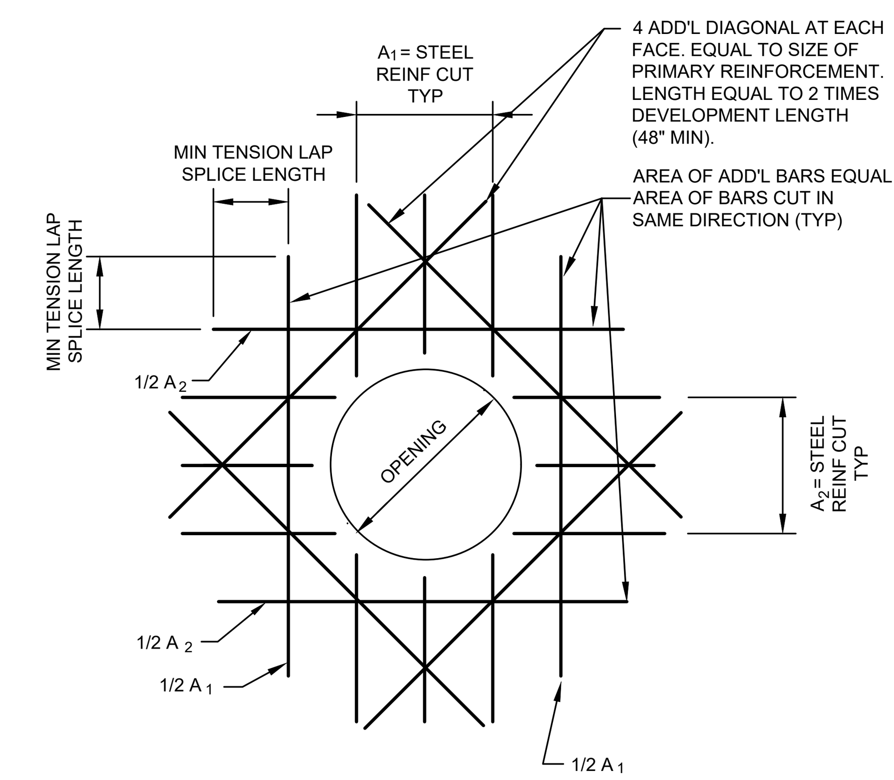
ADD'L	ADDITIONAL
CONC.	CONCRETE
C/W	COMPLETE WITH
DN	DOWN
EF	EACH FACE
EQ	EQUAL
EW	EACH WAY
EX	EXISTING
EXT	EXTERIOR
ID	INSIDE DIAMETER
GA	GALVANIZED
INV	INVERT
FIN	FINISHED
MAX	MAXIMUM
MIN	MINIMUM
O/C	ON CENTRE
OD	OUTSIDE DIAMETER
PL	PLATE
PR	PROPOSED
RAD	RADIUS
REINF.	REINFORCEMENT
REQ'D	REQUIRED
ST.	STEEL
T&B	TOP AND BOTTOM
THK	THICK
T.O.	TOP OF
TYP	TYPICAL
U.N.O.	UNLESS NOTED OTHERWISE
U/S	UNDER SIDE
W/	WITH



NOTES:

1. LADDER RUNGS MUST BE DIMPLED, CORRUGATED OR COATED WITH SKID-RESISTANT MATERIAL TO MINIMIZE SLIPPING.
2. PROVIDE A SAFETY SLIDE RAIL CLIMBING DEVICE FOR ALL LADDERS

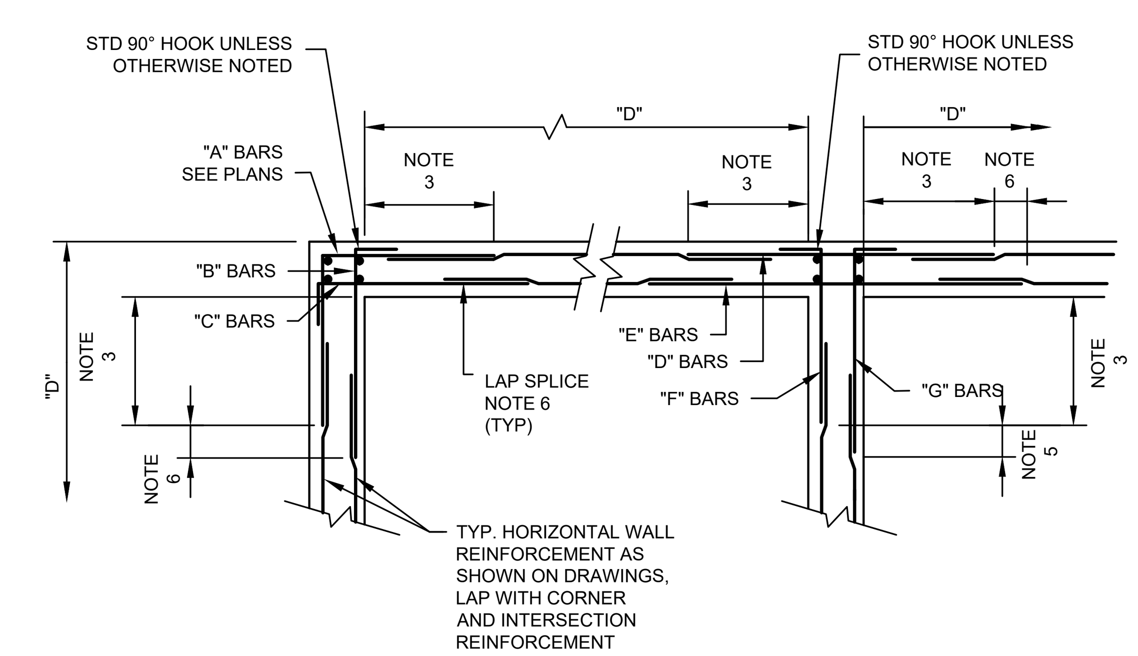
FIXED LADDER



NOTES:

1. TYPICAL FOR ALL OPENINGS IN WALLS AND SLABS UNLESS INDICATED OTHERWISE ON PLANS.
2. FOR PIPE SLEEVE REQUIREMENTS AND DETAILS SEE MECHANICAL DRAWING. DO NOT WELD REINFORCEMENT TO PIPE SLEEVES AND INSERTS.
3. FOR SMALL DIAMETER PIPE OPENINGS WHICH DO NOT REQUIRE CUTTING OF THE REINFORCEMENT AND ARE >3"Ø SUPPLY 4 DIAGONAL BARS AS SHOWN IN DETAIL (SEE ALSO NOTE 5 FOR BAR LOCATIONS)
4. AREA OF ADDITIONAL BARS PER EACH SIDE OF OPENING EQUALS 1/2 AREA OF BARS CUT IN SAME DIRECTION.
5. ADDITIONAL BARS TO BE PLACED:
   a) AT CENTERLINE OF WALLS OR SLABS WHERE ONE LAYER OF REINFORCEMENT IS PROVIDED.
   b) AT EACH FACE OF WALLS OR SLABS WHERE TWO LAYERS OF REINFORCEMENT ARE REQUIRED.
6. INCREASE SIZE OF ADDITIONAL BARS AS NEEDED TO FIT WITHIN A DISTANCE OF 2X WALL/SLAB THICKNESS FROM OPENING. PROVIDE 2" MIN CLEAR DISTANCE BETWEEN BARS

CONCRETE OPENING REINFORCEMENT



DOUBLE MAT CORNER AND INTERSECTION REINFORCEMENT

NOTES:

1. TYPICAL HORIZONTAL WALL CORNER AND INTERSECTION REINFORCEMENT LAYOUT IS SHOWN TO AVOID CONGESTION AND PERMIT PROPER PLACEMENT. FOR SIZE AND SPACING SEE PLANS.
2. WHERE THE CORNER OR INTERSECTION REINFORCEMENT SIZE AND SPACING IS NOT SHOWN, NOTED OR TABULATED ON THE DRAWINGS THE SIZE AND SPACING SHALL BE THE SAME AS THE WALL HORIZONTAL REINFORCEMENT SHOWN ON THE WALL SECTIONS OR AS NOTED FOR THE REINFORCEMENT BETWEEN THE CORNERS OR INTERSECTION.
3. FOR WALLS WHERE D IS LESS THAN THE HEIGHT OF THE WALL, UNLESS OTHERWISE SHOWN ON THE DRAWINGS, THE LENGTH INDICATED AS "NOTE 3" SHALL BE D/4, EXCEPT THAT IN NO CASE SHALL IT BE LESS THAN 2 FEET.
4. FOR CASES WHERE D ≥ THE HEIGHT OF THE WALL, CORNER AND INTERSECTION WALLS MAY USE CONTINUOUS STANDARD HOOKED BARS OR THE SPLICE BAR METHOD WITHOUT THE NEED TO SHIFT THE LAP AS NOTED IN 3. ABOVE, UNLESS OTHERWISE SHOWN ON THE DRAWINGS.
5. D = LENGTH OF WALL PARALLEL TO THE BAR LENGTH IN QUESTION.
6. EXCEPT WHERE OTHERWISE SHOWN ON THE DRAWINGS, THE LENGTH INDICATED AS "NOTE 6" SHALL BE EQUAL TO ONE TENSION LAP SPLICE LENGTH AS REQUIRED BY THE GENERAL STRUCTURAL NOTES. USE THE LAP SPLICE LENGTH AS REQUIRED FOR THE SMALLER OF THE TWO REINFORCEMENT BARS BEING SPLICED.
7. UNLESS OTHERWISE NOTED, "B" AND "C" BARS ARE THE SAME SIZE AND SPACING AND, "F" AND "G" BARS ARE THE SAME SIZE AND SPACING.

CONCRETE WALL REINFORCEMENT

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CLINE AVENUE OIL SPILL SITE
GARY INDIANA

Project

No.	Issue	Drawn	Approved	Date
1	90% DESIGN (WITH	AL	MT	MAR 17, 2020
	SUBMISSION OF FFS)			

Drawn **A. LeGAULT**	Designer **M. MIR**
Drafting Check **-**	Design Check **-**
Project Manager **MT**	Date **Mar 16, 2020**
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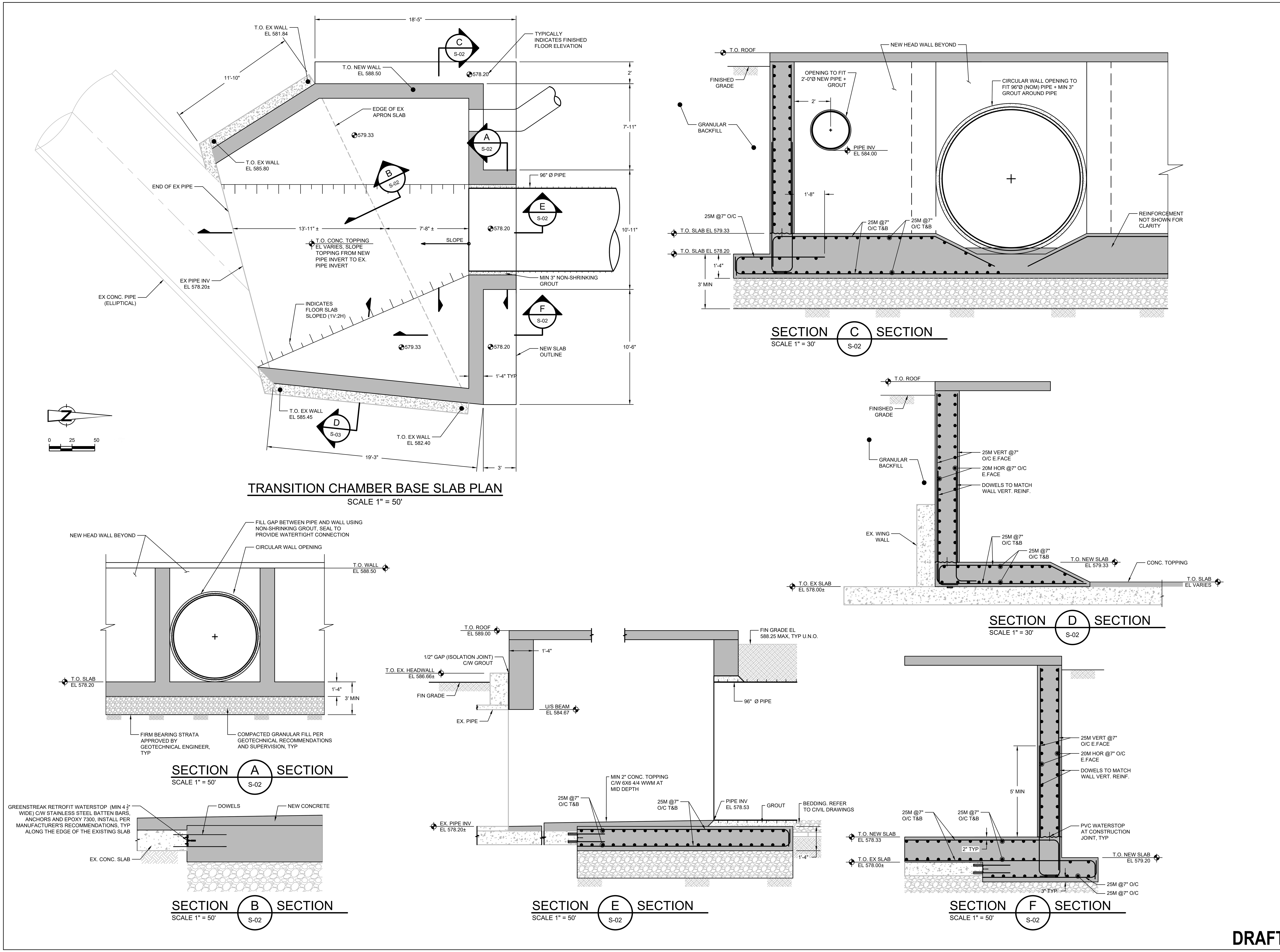
Project No. **11198545**

Title
STRUCTURAL NOTES

Sheet No.
S-01

Plot Date: 17 March 2020 - 10:01 AM Plotted By: Bruce Pletz CAD File: N:\CA\Waterloo\Projects\662\11198545\Digital_Design\Figures\RPT001\11198545(RPT001)ST-WA001.DWG



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Drawn	A. LeGAULT	Designer	M. MIR
Drafting Check	JC	Design Check	JC
Project Manager	MT	Date	Mar 16, 2020
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Project No. 11198545

Title

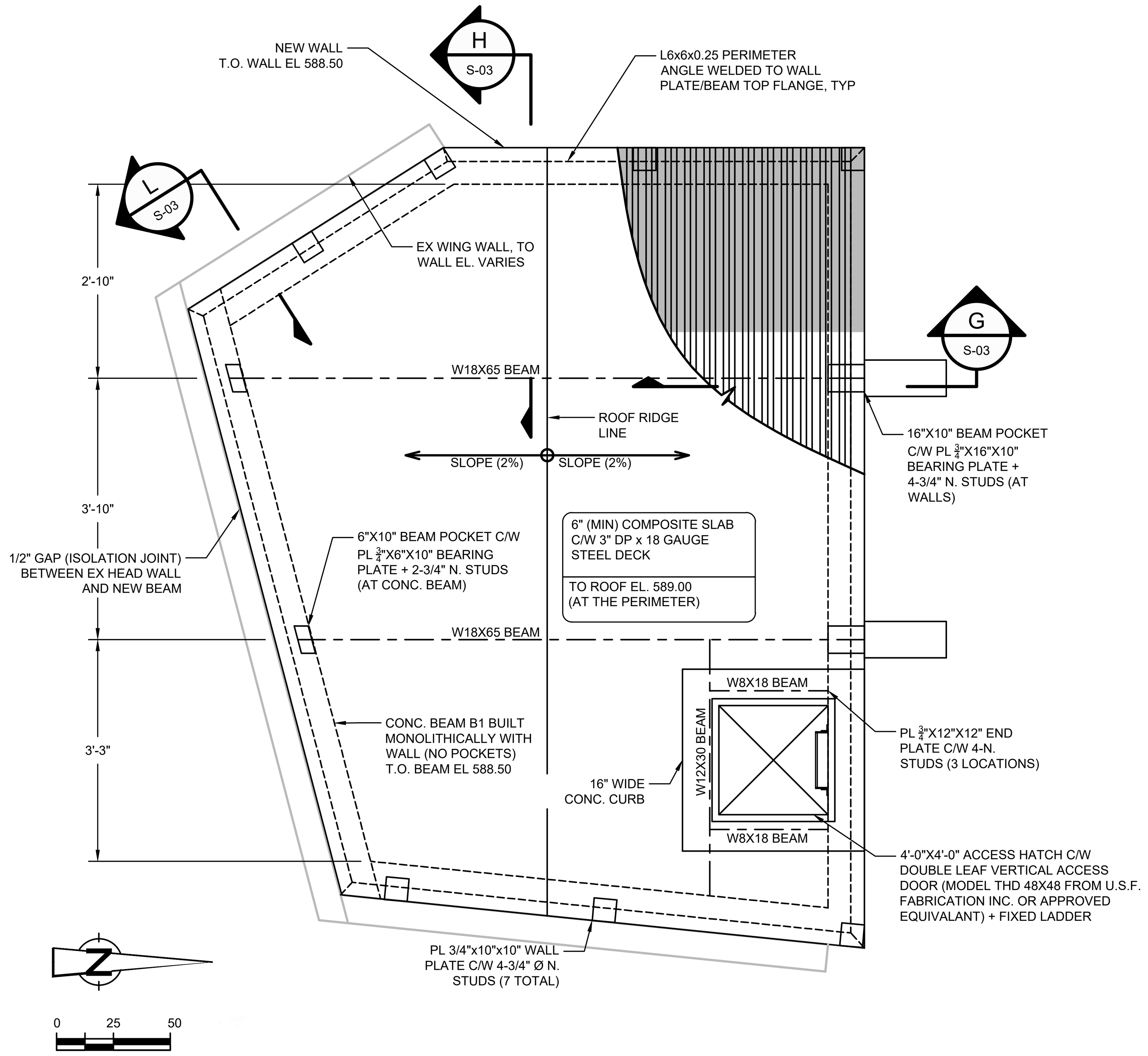
PROPOSED STORM SEWER INSTALLATION WITHIN DITCH DETAILS (SHEET 1 OF 3)

Sheet No.

S-02

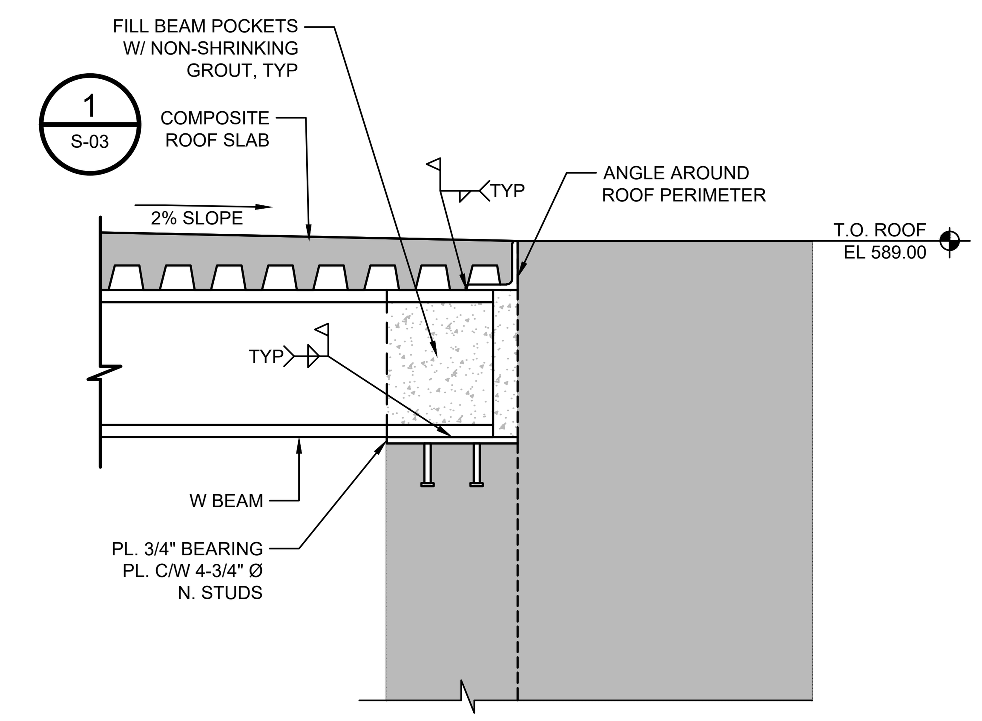
Sheet 9 of 11

Plot Date: 17 March 2020 - 9:49 AM Plotted By: Bruce Pletz CAD File: N:\CA\Waterloo\Projects\662\11198545\Digital_Design\Figures\RPT001\11198545(RPT001)ST-WA002.DWG



TRANSITION CHAMBER COVER F FRAMING PLAN

SCALE 1" = 50'



SECTION G SECTION S-03

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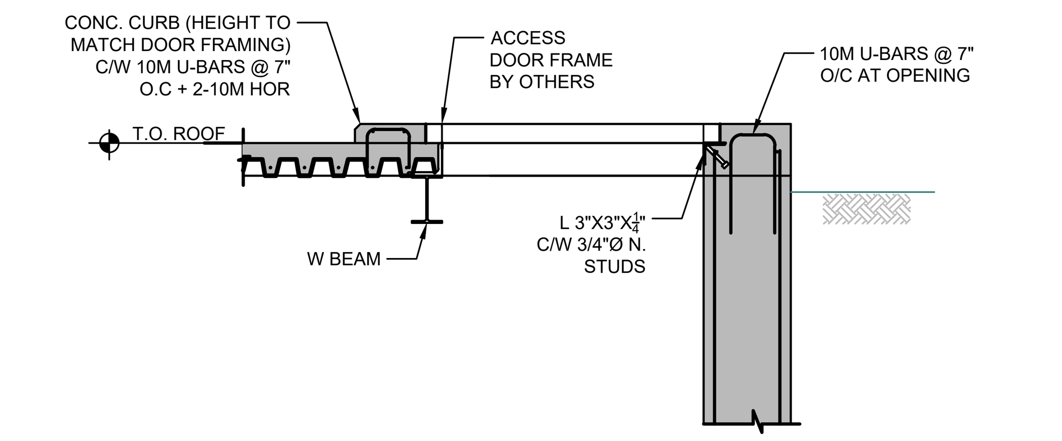

SECTION I SECTION S-03

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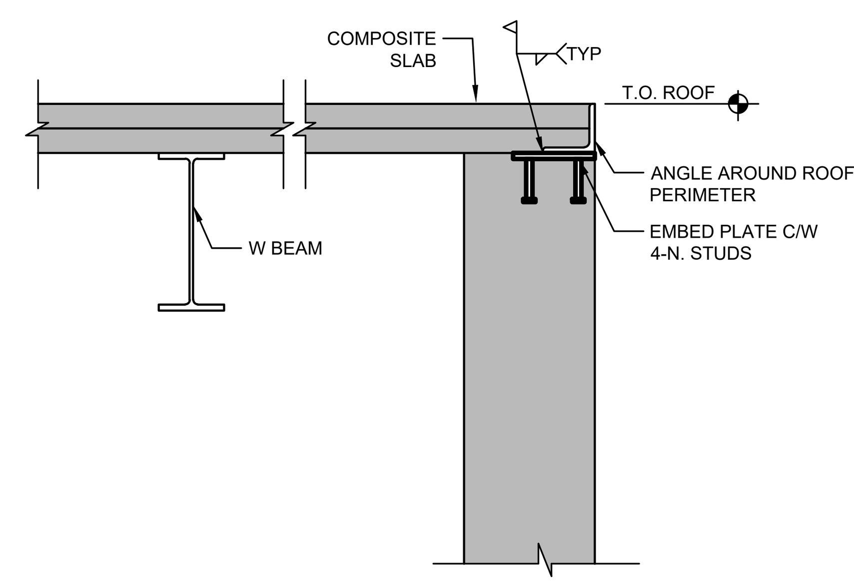

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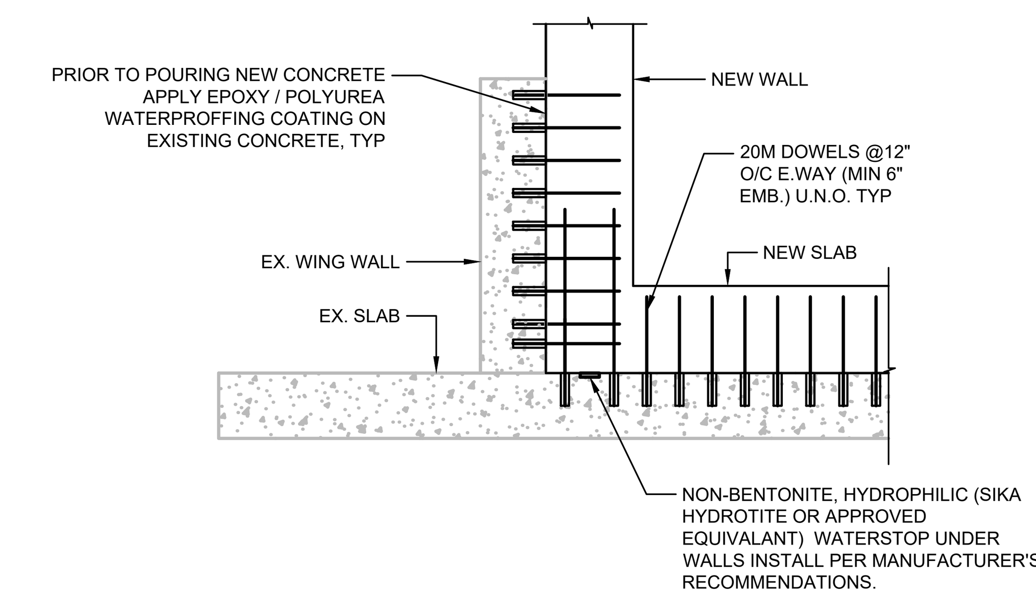

TYPICAL NEW-TO-EXISTING DOWELS

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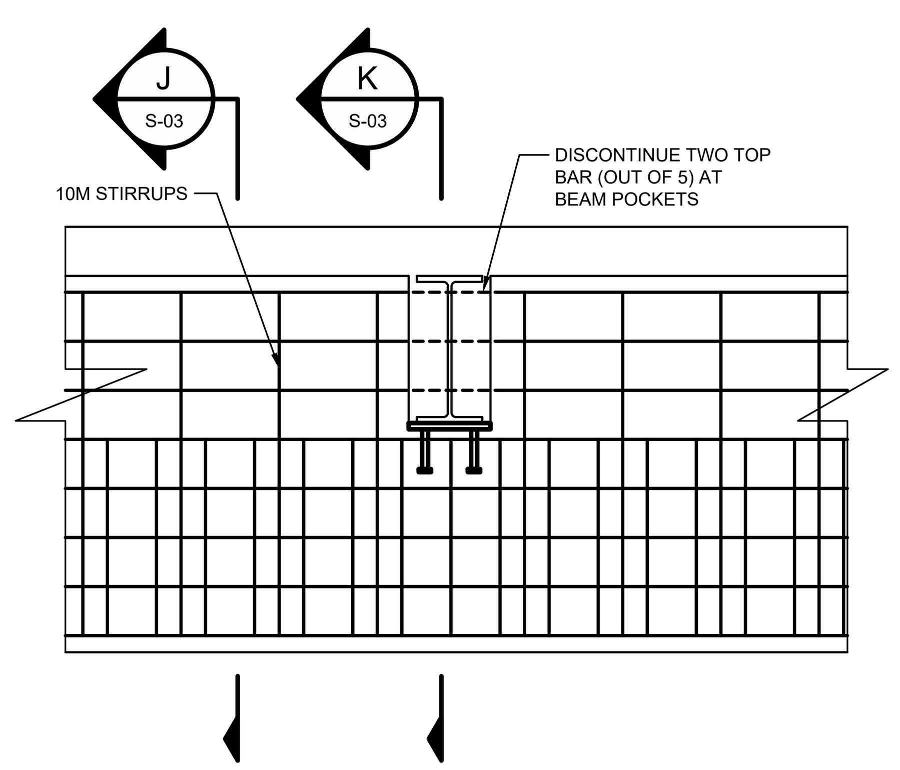

CONCRETE BEAM B1 ELEVATION

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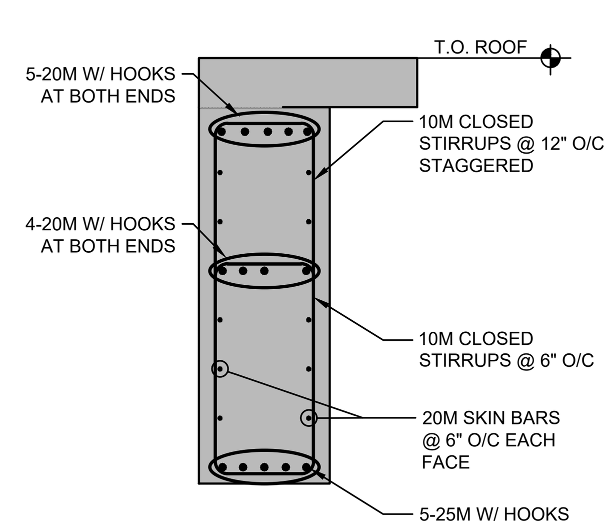

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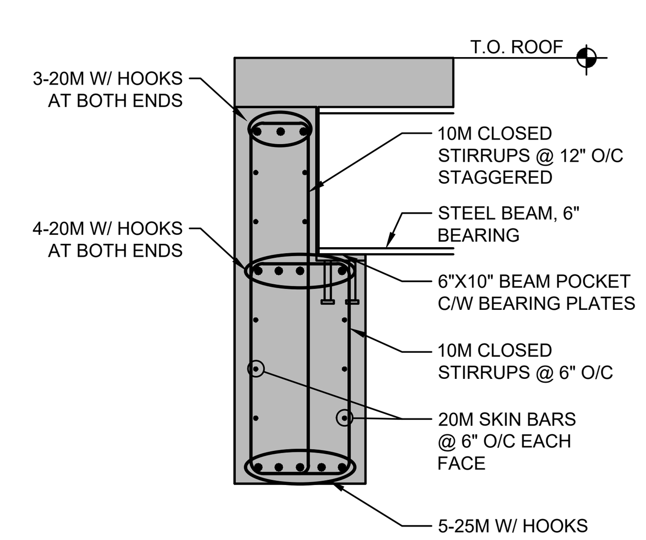

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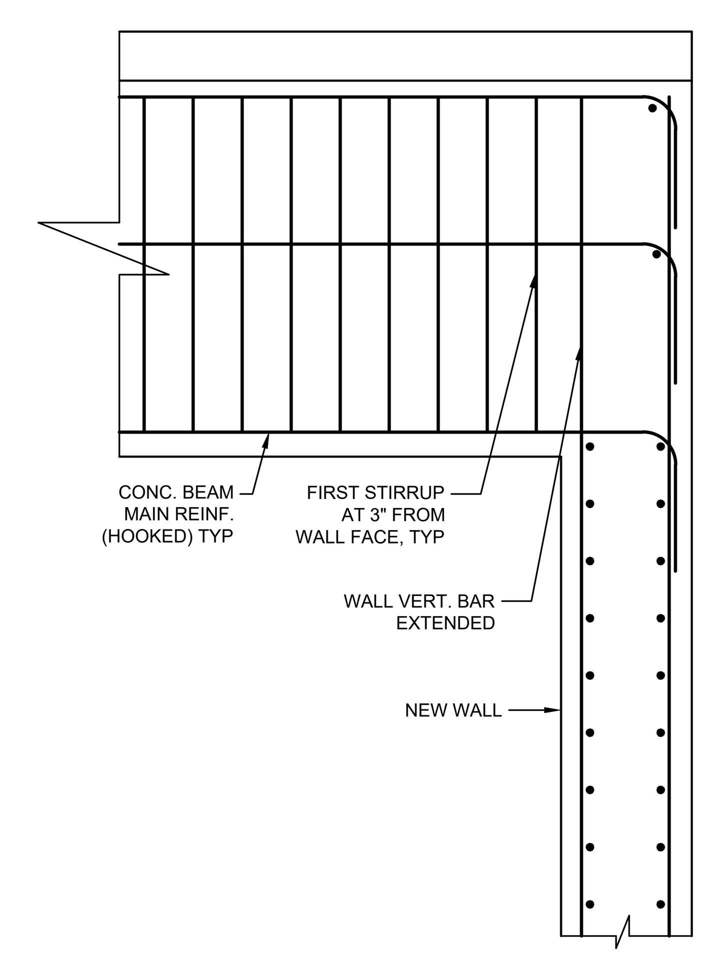

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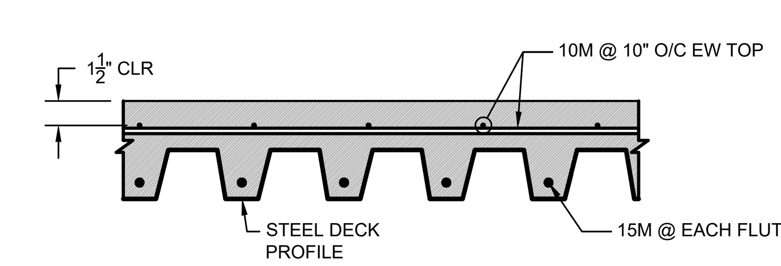

DETAIL 1 COMPOSITE ROOF SLAB S-03

SCALE 1" = 10'

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Client

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Project

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1	90% DESIGN (WITH SUBMISSION OF FFS)	AL	MT	MAR 17, 2020

Drawn	A. LeGAULT	Designer	M. MIR
Drafting Check	JC	Design Check	JC
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PROPOSED STORM SEWER INSTALLATION WITHIN DITCH DETAILS (SHEET 2 OF 3)

Sheet No.

S-03

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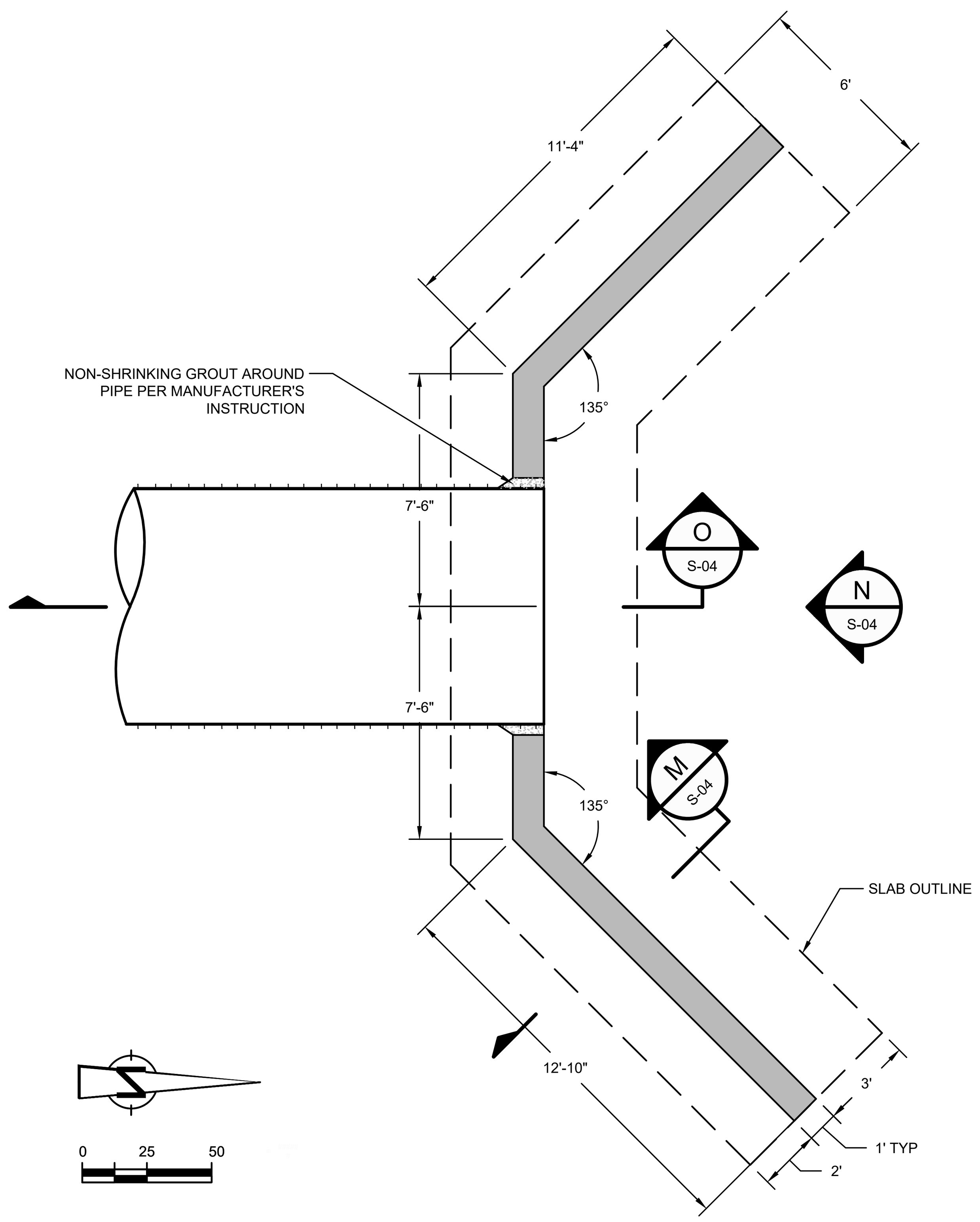
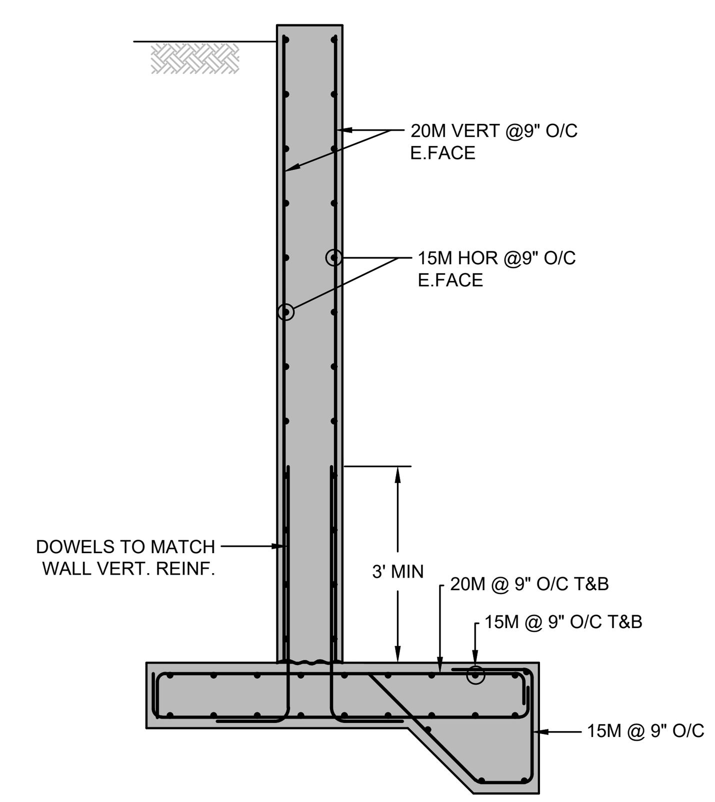


INLET HEADWALL PLAN

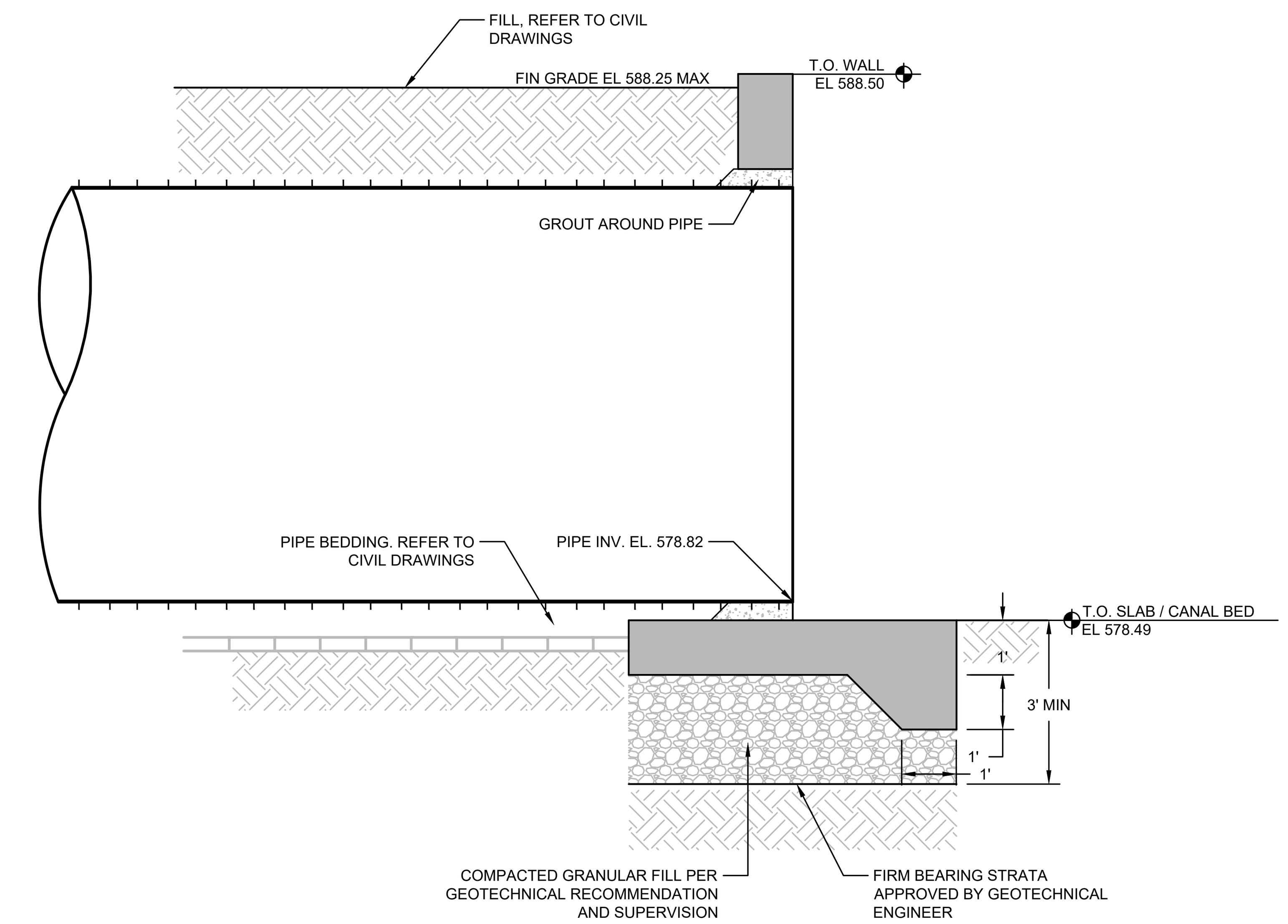
SCALE 1" = 50'



SECTION M SECTION

SCALE 1" = 30'

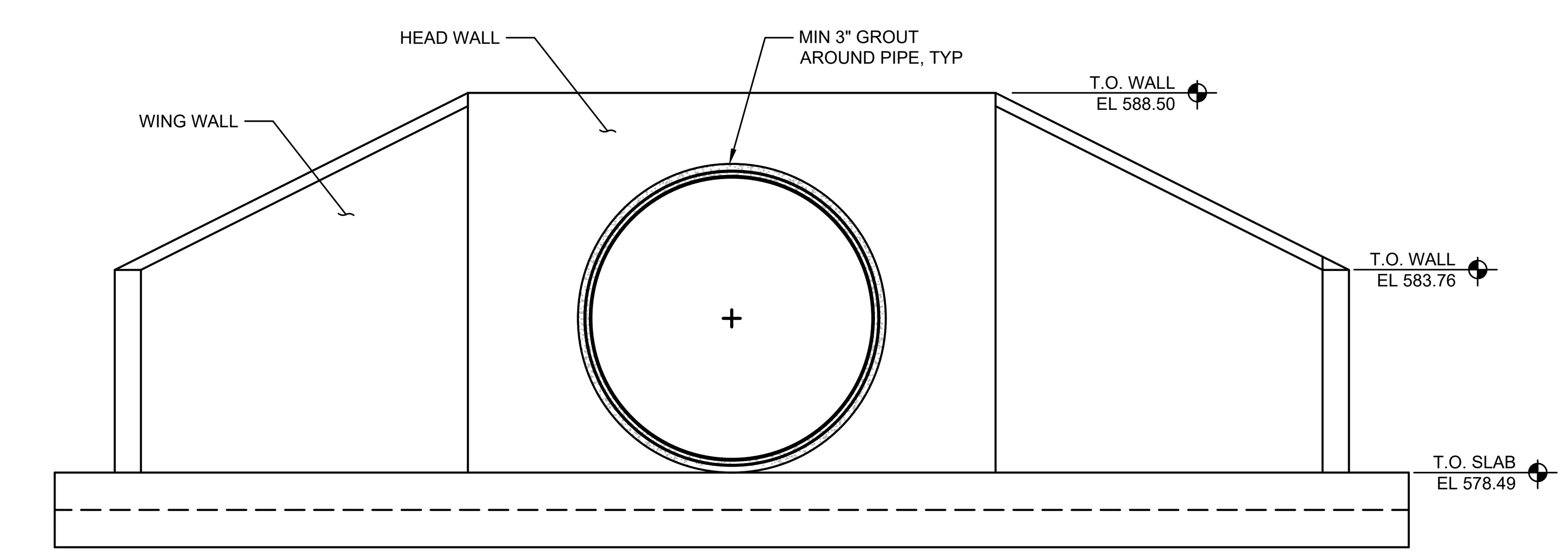
S-04



SECTION O SECTION

SCALE 1" = 30'

S-04



ELEVATION N SECTION

SCALE 1" = 50'

S-04

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1	90% DESIGN (WITH SUBMISSION OF FFS)	AL	MT	MAR 17, 2020

Drawn A. LeGAULT | Designer M. MIR

Drafting Check JC | Design Check JC

Project Manager MT | Date Mar 16, 2020

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Project No. 11198545

Title

PROPOSED STORM SEWER INSTALLATION WITHIN DITCH DETAILS (SHEET 3 OF 3)

Sheet No.

S-04

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