BT Red Hook, LLC

SUPPLEMENTAL REMEDIAL INVESTIGATION WORK PLAN – RED HOOK 3

Site No. C224213

68 and 100 Ferris Street/242 and 300 Coffey Street

Brooklyn, New York

July 2018

SUPPLEMENTAL REMEDIAL INVESTIGATION WORK PLAN – RED HOOK 3

Site No. C224213
68 and 100 Ferris Street/
242 and 300 Coffey Street
Brooklyn, New York

Hugh Devery, Vice President
Project Manager

Andrew Korik
Principal Environmental Scientist

Prepared for:

BT Red Hook, LLC

Prepared by:

Arcadis of New York, Inc.
One Lincoln Center
110 West Fayette Street
Suite 300
Syracuse
New York 13202
Tel 315 446 9120
Fax 315 449 0017

Our Ref.:

B0038993.0001

Date:

July 2018

CONTENTS

Acronyms and Abbreviations iii

1 Introduction 1

1.1 Site Description 1

1.2 Previous Investigations 2

1.3 Overview of Work Conducted by Arcadis Through June 2018 2

1.4 Data Gaps and Supplemental Investigation Objectives 3

1.5 Summary of Available Geologic and Hydrogeologic Information 4

1.5.1 Regional Geology 4

1.5.2 Local Geology and Hydrogeology 4

2 Scope of Remedial Investigation 6

2.1 Groundwater and NAPL Gauging 6

2.2 Advancement of Soil Borings 6

2.2.1 Soil Sampling and Analyses 6

2.2.2 Screening for DNAPL and LNAPL 7

2.3 Groundwater Sampling and Analyses 7

2.4 Quality Assurance/Quality Control 7

2.5 Community Air Monitoring Program 8

2.6 Survey 8

2.7 Aquifer Testing 8

2.7.1 Slug Testing 8

2.7.2 Tidal Cycle Gauging 8

2.8 DNAPL and LNAPL Mobility, Recoverability, and Physical and Chemical Properties 9

2.8.1 NAPL-Impacted Groundwater Sampling and Analyses 9

2.8.2 Forensic Analyses 9

2.8.3 Physical Properties 9

2.8.4 DNAPL Bail-Down Testing 9

2.8.5 Bench-Scale Treatability Testing 9

2.9 Investigation Water Source 11

2.10 Waste Management 11

3 Reporting 12

4 Schedule 13

5 References 14

TABLES

Table 1 Monitoring Well Gauging Data

Table 2 Monitoring Well Construction Data

Table 3 Proposed Soil Sampling Plan

Table 4 Proposed Groundwater Sampling Plan

Table 5 Labware and Preservation

FIGURES

Figure 1 Site Location Map

Figure 2 Site Map with Block and Lot Boundaries

Figure 3 Soil Borings and Groundwater Monitoring Wells Installed by Others

Figure 4 Soil Borings Installed by Arcadis – 2017

Figure 5 Proposed DNAPL and LNAPL Delineation Boring Locations

Figure 6 Groundwater Contours – Shallow-Screened Wells

Figure 7 Groundwater Contours – Deep-Screened Wells

APPENDICES

Appendix A Boring Logs (Arcadis)

Appendix B Groundwater Results from AESI 2017 Remedial Investigation Report

Appendix C Technical Guidance Instruction Documents and Standard Operating Procedures

- Field Soil Description Procedures
- Low-Flow Groundwater Purging and Sampling Procedures
- PFAS Sampling Procedures
- Slug Testing
- Non-Aqueous Phase Liquid (NAPL) Bail-down Testing

Appendix D Project Organization

Appendix E NYSDOH Generic Community Air Monitoring Plan

ACRONYMS AND ABBREVIATIONS

AESI	Atlantic Environmental Solutions, Inc.
Arcadis	Arcadis of New York, Inc.
ASTM	ASTM International
bgs	below ground surface
DER	Division of Environmental Remediation
DNAPL	dense non-aqueous phase liquid
ELAP	Environmental Laboratory Approval Program
eV	electron volt
ISS	in-situ solidification
Langan	Langan Engineering, Environmental, Surveying and Landscape Architecture, D.P.C.
LNAPL	light non-aqueous phase liquid
NAD	North American Datum
NAPL	non-aqueous phase liquid
NAVD	North American Vertical Datum
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PFAS	per- and polyfluoroalkyl substances
Pillori	Pillori Associates, P.A.
RH3	Red Hook 3
RIWP	Remedial Investigation Work Plan
SRI	Supplemental Remedial Investigation
SVOC	semi-volatile organic compound
TAL	Target Analyte List
TGI	Technical Guidance Instructions
TIC	Tentatively Identified Compound
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound

1 INTRODUCTION

Arcadis of New York, Inc. (Arcadis) prepared this Supplemental Remedial Investigation Work Plan (RIWP) for the Red Hook 3 (RH3) Brownfield Site (New York State Department of Environmental Conservation [NYSDEC] Brownfield Site No. C224213), hereafter referred to as the "RH3 Site" or simply "RH3," located at 68 and 100 Ferris Street/242 and 300 Coffey Street in Brooklyn, New York. The RH3 Site is subject to a Brownfield Cleanup Agreement among Volunteers Red Hook Industrial Center, LLC, BT Red Hook, LLC, and NYSDEC. The scope of work for the Supplemental Remedial Investigation (SRI) described herein was developed to address data gaps identified in:

- The Remedial Investigation Report – Red Hook 3 Properties prepared by Atlantic Environmental Solutions, Inc. (AESI), dated October 31, 2017.
- Additional investigations conducted by Arcadis on behalf of BT Red Hook, LLC in June, September, and October 2017. A summary of Arcadis' findings was presented to NYSDEC during a project meeting held at the NYSDEC offices in Albany, New York, on December 12, 2017. The investigations conducted by Arcadis in 2017 will be summarized in a report to be prepared for submittal to NYSDEC after the conclusion of the currently proposed SRI.

As detailed herein, an overarching objective of the SRI is to obtain data of sufficient quantity and quality to support remedial decision-making, to develop proposed remediation extents where warranted, and to evaluate remedial alternatives.

1.1 Site Description

The RH3 Site is an approximately 9.1-acre, multi-sided and roughly "L"-shaped parcel located within a mixed industrial, commercial, and residential area in an urban setting (**Figure 1**). The RH3 Site consists of four adjoining parcels bounded to the northeast by Wolcott Street (approximately 750-foot frontage), to the southeast by Ferris Street (approximately 250-foot frontage), and to the northwest by the Buttermilk Channel (approximately 900-foot frontage) (**Figure 2**). A commercial building adjoins the RH3 Site to the south. Three buildings are located on RH3 as follows:

- A vacant, two-story, brick warehouse, constructed circa 1920 and occupying a footprint of approximately 100,000 square feet.
- A vacant, single-story, metal-sided warehouse, constructed circa 1995 and occupying 50,000 square feet.
- A single-story, masonry-sided building, most recently occupied by U.S. government offices (United States Bureau of Alcohol, Tobacco, Firearms and Explosives and United States Drug Enforcement Administration), occupying 37,000 square feet.

Areas not occupied by buildings are paved with concrete or asphalt. A steel retaining wall is located along the bulkhead along Buttermilk Channel.

1.2 Previous Investigations

Numerous previous investigations have taken place on RH3, the findings of which are summarized in the following documents:

- Phase I Environmental Site Assessment, 68 Ferris Street, Brooklyn, NY (Roux Associates, Inc., November 2007)
- Phase I Environmental Site Assessment, 212 Wolcott Street, Brooklyn, NY (Roux Associates, Inc., November 2007)
- Phase II Environmental Site Investigation Report, 212 Wolcott Street/68 Ferris Street, Brooklyn, NY (Langan Engineering and Environmental Services, Inc., P.C., April 2012)
- Preliminary Geotechnical Review, 212 Wolcott Street (aka 68 Ferris Street, Brooklyn, NY – “The Project”) (Langan Engineering and Environmental Services, Inc., P.C., April 2012)
- Phase I Environmental Site Assessment, 212 Wolcott Street and 68 Ferris Street, Brooklyn, NY (Langan Engineering and Environmental Services, Inc., P.C., May 2012)
- Phase I Environmental Site Assessment, 242/300 Coffey Street, Brooklyn, NY (Langan Engineering, Environmental, Surveying and Landscape Architecture, D.P.C. [Langan], April 2015)
- Limited Phase II Environmental Site Investigation, 242/300 Coffey Street, Brooklyn, NY (Langan, May 2015)
- Remedial Investigation Report, Red Hook 3, 68 Ferris Street (Block 573, Lot 100), 100 Ferris Street (Block 573, Lot 1), 242-300 Coffey Street (Block 595, Lot 70), NYSDEC BCP Site C224213 (AESI, October 2017)

1.3 Overview of Work Conducted by Arcadis Through June 2018

Work conducted by Arcadis in 2017 (mobilizations in June, September and October) involved real estate due-diligence activities associated with the potential lease and/or purchase of RH3 by BT Red Hook, LLC. The primary objective of the Arcadis work was further delineation and characterization of dense non-aqueous phase liquid (DNAPL) and light non-aqueous phase liquid (LNAPL) impacts. **Figure 3** shows the locations of borings and monitoring wells installed by previous consultants. **Figure 4** depicts locations of the 34 soil borings advanced by Arcadis in 2017.

Two borings installed by Arcadis were advanced to terminal depths of approximately 80 feet below ground surface (bgs) using a sonic drill rig, and 32 borings were advanced to depths of 5.6 to 55.7 feet bgs using direct-push techniques. Arcadis boring logs are presented in **Appendix A**. Tar-specific Green Optical Sensing Tool (TarGOST®) technology was used at the direct-push boring locations (denoted on **Figure 4** with “TGHP” in the location identifier). TarGOST® is a laser-induced fluorescence technology that is calibrated to detect specific DNAPL signatures associated with higher molecular weight NAPLs such as tar and creosote where polycyclic aromatic hydrocarbons (PAHs) predominate.

Visible DNAPL impacts were observed primarily beneath and proximate to the metal warehouse located on Lot 1 as shown on **Figure 5** and from boring A-RH3-B13 on the Dikeman Street sidewalk. The vertical interval of DNAPL according to boring logs generated by Arcadis and others was approximately 5 to 25 feet bgs. Soil samples were collected from selected borings in the DNAPL-impacted zone and submitted for laboratory analyses in general accordance with the previously approved RIWP (Langan 2016a – Section 3.1.2). Forensic analyses of DNAPL-impacted soil from several borings advanced by Arcadis indicated that the DNAPL resembled petroleum tar. Forensic analysis results for boring A-RH3-B13 showed a mixture of petroleum tar-like DNAPL and LNAPL resembling #4 fuel oil.

At the conclusion of the 2017 mobilization, Arcadis engaged a New York State Licensed Surveyor to establish elevations and coordinates of Arcadis borings, existing monitoring wells, and borings previously installed by Roux Associates, Inc., Langan, and AESI that could be positively identified by Arcadis in the field. The ground surface at each boring location was surveyed to the nearest 0.01 foot and referenced to North American Vertical Datum of 1988 (NAVD 88). Horizontal coordinates were established using New York Long Island State Plane Coordinates (North American Datum [NAD] 83).

The vertical and horizontal occurrence of LNAPL and DNAPL was evaluated based on information from borings advanced by Arcadis and others, as well as data from gauging of existing monitoring wells conducted by Arcadis in April 2018. **Table 1** presents the synoptic gauging data obtained on April 27, 2018. Monitoring well construction details, as provided to Arcadis by previous consultants, are presented in **Table 2**. Wells/borings with visible LNAPL/DNAPL as noted on boring logs, or measurable DNAPL encountered during well gauging in April 2018, are shown on **Figure 5**. Visible LNAPL impacts were observed only in boring A-RH3-B13 as described above. Arcadis observed 6.84 feet of DNAPL in monitoring well MW-1 during the April 27, 2018 gauging event.

The results of work conducted by Arcadis as of June 2018 will be documented with the results of the currently proposed work (see Section 3).

1.4 Data Gaps and Supplemental Investigation Objectives

The objective of the proposed work is to address data gaps so that the conceptual site model and remedial alternatives review can be completed. The following specific data objectives are proposed:

1. Evaluate the vertical and horizontal extent of DNAPL and LNAPL impacts on the RH3 Site.
2. Evaluate potential connectivity between DNAPL impacts on the adjoining Red Hook 4 property and impacts on RH3.
3. Further evaluate the extent of on-site NAPL impacts associated with open NYSDEC spill number 1500740 (April 2015).
4. Collect samples of DNAPL-impacted soil from three borings for analysis of the analytical suite specified in the approved RIWP (Langan 2016a – Section 3.1.2).
5. Collect one soil sample from the shallow fill at each proposed soil boring location for analysis of Target Analyte List (TAL) metals.

Historical map circa 1780 superimposed over current topography showing RH3 and adjoining Red Hook 4 outboard of historical low water line.

6. Collect groundwater samples from seven existing monitoring wells for analyses of per- and polyfluoroalkyl substances (PFAS) and 1,4-dioxane as requested by NYSDEC via telephone (April 17, 2018).
7. Evaluate mobility and recoverability of DNAPL.
8. Evaluate horizontal and vertical groundwater flow patterns, hydraulic conductivity, and tidal influence.
9. Obtain geotechnical data and perform a bench-scale stabilization treatability study to support the remedial alternatives review.

Proposed soil and groundwater sampling locations and rationale are presented in **Table 3**. Based on discussions with NYSDEC, Arcadis understands that free-phase DNAPL is the main driver for remediation. Concentrations of NAPL-related constituents in groundwater are generally limited to the DNAPL-impacted zone beneath and near the metal warehouse along Wolcott Street and in monitoring well LMW-2 (see groundwater analytical figures in the AESI Remedial Investigation Report dated October 2017 and included in **Appendix B**). Groundwater is generally encountered at depths of approximately 5 to 10 feet bgs.

In addition to addressing the data gaps indicated above, Arcadis will use geophysical techniques to attempt to delineate a possible oil/water separator previously noted during a utility survey on September 27, 2017. The oil/water separator is potentially located near the Wolcott Street side of the metal warehouse.

1.5 Summary of Available Geologic and Hydrogeologic Information

1.5.1 Regional Geology

The area is underlain by Hartland Formation (middle Ordovician to lower Cambrian) biotite-muscovite-quartz schist and sillimanite-plagioclase-muscovite-biotite-microcline-quartz gneissic schist (Baskerville 1994). Surficial geology in the area consists of alluvial deposits and poorly sorted glacial till varying between clay, silt-clay, and boulder-clay (Cadwell et al.1986).

1.5.2 Local Geology and Hydrogeology

RH3 is in the Red Hook section of Brooklyn at an elevation of approximately 8 feet above mean sea level. This section of Brooklyn is in an area that was historically below the water line and is currently underlain by fill (sand, silt, gravel, concrete, asphalt) that extends to approximately 10 to 15 feet bgs.

Bedrock was not encountered in borings advanced to a maximum depth of 80 feet bgs by Arcadis in 2017 and to a maximum depth of 95 feet bgs on the adjoining Red Hook 4 Site by Pillori Associates, P.A. (Pillori) in 2014. Soil borings show a surficial fill layer of 5 to 10 feet in thickness, underlain primarily by glacial sand to 80 feet bgs, with a silt and/or clay layer of 5 to 10 feet in thickness, the top of which was encountered approximately 10 to 15 feet bgs. Borings advanced by Arcadis in 2017 showed the silt/clay layer to be generally continuous with occasional gaps, with thinner, discontinuous silt/clay lenses present at greater depth at some locations. The glacial sand is generally fine to medium or medium to coarse with occasional lesser amounts of silt, clay, gravel, or cobbles.

The water table beneath RH3 occurs at approximately 5 to 10 feet bgs. Gauging data for well pairs with the deeper wells screened below the silt/clay layer indicate a potentiometric surface approximately 0.5 to 1.9 feet lower than the adjacent, shallow-screened wells (**Table 1**), suggesting a downward hydraulic gradient.

2 SCOPE OF REMEDIAL INVESTIGATION

To satisfy the investigation objectives and obtain data for the remedial alternatives review, Arcadis will implement additional subsurface investigation activities to include groundwater gauging (in progress), NAPL gauging and bail-down testing (in progress); sampling, and analyses; advancement of shallow and deep soil borings; soil sampling and analyses; NAPL characterization; and bench-scale testing of DNAPL-impacted soil.

2.1 Groundwater and NAPL Gauging

On April 27, 2018, a synoptic well gauging event was conducted to obtain depth to water measurements, depth to well bottom measurements, and depth and thickness of NAPL. LNAPL was not observed in any well; measurable DNAPL was observed in one well, MW-1, at a thickness of 6.84 feet as shown in **Table 1**. Monitoring well MW-1 is a shallow-screened well with a measured depth of 13.4 feet. Well construction details are provided in **Table 2**. Prior to ongoing bail-down testing currently being conducted by Arcadis, no previous DNAPL removal was reported based on available information. Synoptic well gauging will continue monthly through the completion of the field program proposed herein (estimated to be September 2018) and, depending on the results obtained, is anticipated to continue on a quarterly basis thereafter.

2.2 Advancement of Soil Borings

Based on visible and/or measurable NAPL as shown on **Figure 5**, a series of borings are proposed (also shown on **Figure 5**) to address *Objectives 1 through 3* identified in Section 1.4. Two deep borings are proposed to be advanced using sonic drilling techniques, and 14 direct-push delineation borings are proposed. The number and/or locations of the borings may change based on field conditions. Sonic borings will be advanced to estimated terminal depths of up to approximately 80 feet bgs. Continuous, 4-inch-diameter, 5-foot-long soil cores will be collected during soil boring installation. In accordance with Section 3.1.1 of the approved Langan RIWP (Langan 2016a), if DNAPL impacts are resting on a confining layer, casing will be installed through the confining layer to prevent vertical migration, and the sonic boring will be advanced deeper to evaluate potential impacts below the confining layer. Each sonic soil boring will be tremie-grouted to existing grade with cement-bentonite grout upon completion of drilling. Proposed direct-push borings will be advanced to terminal depths of approximately 25 feet and will be backfilled with bentonite. Direct-push soil samples will be collected in 4-foot-long acetate liners. Soil samples will be screened in the field for total volatile organic compounds (VOCs) using a photoionization detector (PID) equipped with a 10.6 electron volt (eV) lamp and characterized as described in the Field Soil Screening Technical Guidance Instructions (TGI) included in **Appendix C**.

2.2.1 Soil Sampling and Analyses

To address *Objectives 4 and 5* in Section 1.4, one DNAPL-impacted soil sample from up to three borings will be submitted to a New York State Department of Health (NYSDOH) Environmental Laboratory Approval Program (ELAP)-certified laboratory and analyzed for 6 New York Codes, Rules and Regulations (NYCRR) Part 375 list VOCs, semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), pesticides and herbicides, TAL metals (including mercury), cyanide, chromium III, and chromium VI according to the following methods:

- VOCs – United States Environmental Protection Agency (USEPA) SW-846 Method 8260C
- SVOCs – USEPA SW-846 Method 8270D
- PCBs – USEPA SW-846 Method 8082A
- Pesticides/Herbicides – USEPA SW-846 Method 8081B
- TAL Metals – USEPA SW-846 Method 6010/6020
- Mercury – USEPA SW-846 Method 7471B
- Cyanide – USEPA SW-846 Method 9014
- Chromium III and VI – USEPA SW-846 Method 7196A

Tentatively identified compounds (TICs) for VOCs and SVOCs will also be reported.

A soil sample from the fill depth interval of approximately 4 to 8 feet bgs, which was previously identified by others as having metals impacts, will be collected from each sonic and direct-push boring and be analyzed for TAL metals plus chromium III and VI. The proposed soil sampling plan is outlined in **Table 3**.

2.2.2 Screening for DNAPL and LNAPL

Soil samples suspected of containing free-phase NAPL (based on field observations) will be field screened using a hydrophobic dye (OIL-IN-SOIL™ test kit). Observations during NAPL screening and results of any NAPL screening tests conducted will be recorded in a field notebook. A photographic record will also be maintained.

2.3 Groundwater Sampling and Analyses

As directed by NYSDEC, groundwater samples will be collected from seven monitoring wells according to the proposed sampling plan presented in **Table 4** and analyzed for PFAS compounds (by USEPA SW-846 Method 537) and 1,4-dioxane (by USEPA SW-846 Method 8270) to address *Objective 6* in Section 1.4.

The selected monitoring wells will be sampled in accordance with the low-flow sampling and PFAS sampling TGI procedures included in **Appendix C**. Monitoring wells will be purged using either a peristaltic or a bladder pump (only to be used if the anticipated drawdown depth is greater than 20 feet bgs). Groundwater samples will be collected directly from the bladder pump and submitted for laboratory analysis as previously described. Wells purged using a peristaltic pump may be sampled with a bailer.

2.4 Quality Assurance/Quality Control

Consistent with the requirements of Division of Environmental Remediation (DER)-10/Technical Guidance for Site Investigation and Remediation, Section 2.3, quality assurance/quality control (QA/QC) samples will be collected in accordance with the approved Quality Assurance Project Plan (Langan 2016b). Arcadis project team roles and organization are summarized in **Appendix D**.

2.5 Community Air Monitoring Program

Consistent with Appendices 1A and 1B of DER-10 and Section 3.6.2 of the approved RIWP (Langan 2016a), community air monitoring for VOCs and particulate matter will be accomplished during ground-intrusive activities in accordance with the NYSDOH Generic Community Air Monitoring Plan (**Appendix E**). Data will be monitored in real-time, archived, and included in a report summarizing the findings of the SRI.

2.6 Survey

Following completion of borings, a surveyor licensed to practice in New York State will survey the ground surface at each new boring location to the nearest 0.01 foot, and the elevation will be determined relative to NAVD 88. Horizontal coordinates will be established using New York Long Island State Plane Coordinates (NAD 83). New boring locations will be added to existing site maps. A topographic survey showing elevation contours at 0.5-foot intervals will also be prepared.

2.7 Aquifer Testing

Aquifer characteristics will be evaluated to assist with addressing *Objectives 7 and 8* in Section 1.4.

2.7.1 Slug Testing

Slug testing will be performed at selected deep and shallow wells to estimate the hydraulic conductivity of the formation screened. Slug tests are hydraulic conductivity tests where the water level in the well is caused to change suddenly (rise or fall) and the subsequent water-level response (displacement or change from static) is measured through time. The testing methodology is presented in the TGI for Slug Testing included in **Appendix C**.

2.7.2 Tidal Cycle Gauging

Synoptic water-level gauging will be performed during and between cycles of high and low tide, and groundwater contour maps will be created to evaluate groundwater flow characteristics at different periods in the tidal cycles. Data from initial synoptic well gauging conducted on April 27, 2018 indicate that groundwater flow in the shallow-screened wells shows a bifurcating pattern, with flow toward the east-northeast on the eastern portion of the RH3 Site under the metal warehouse, and toward the Buttermilk Channel (northwest) over the northwest and western portions of RH3 (**Figure 6**). Groundwater flow in the deeper-screened wells is toward the north-northwest (**Figure 7**) based on groundwater data obtained by Arcadis on April 27, 2018.

2.8 DNAPL and LNAPL Mobility, Recoverability, and Physical and Chemical Properties

A variety of field and laboratory techniques will be employed to address *Objectives 7, 8, and 9* in Section 1.4 and therefore be able to complete the remedial alternatives review.

2.8.1 NAPL-Impacted Groundwater Sampling and Analyses

As a subset of the groundwater sampling discussed in Section 2.3, groundwater will be collected from one DNAPL-impacted well, one well with elevated dissolved VOC and SVOC impacts, and two non-impacted wells, and analyzed for geochemical parameters including nitrate, sulfate, dissolved gases, dissolved iron, and dissolved manganese as listed in **Table 4**. Labware and soil and groundwater sample preservation are summarized in **Table 5**.

2.8.2 Forensic Analyses

Up to three additional DNAPL, LNAPL, and/or NAPL-impacted soil samples may be submitted for forensic analyses of C3-C10 PIANO compounds (paraffins, isoparaffins, aromatics, naphthalene, and olefins); parent and alkylated PAH; and total petroleum hydrocarbons (TPH) with chromatograms (C8-C40 gas chromatography mass spectrometry [GC/MS] full scan).

2.8.3 Physical Properties

Additional DNAPL samples may be collected and submitted for physical properties analyses including surface tension and interfacial tension pairs, dynamic viscosity, and fluid density.

2.8.4 DNAPL Bail-Down Testing

DNAPL bail-down tests are currently in progress to evaluate DNAPL mobility and recoverability in monitoring well MW-1. Initial procedures included the removal of DNAPL to the extent practicable using a submersible pump and the placement of transducers to record DNAPL and water recovery. Negligible DNAPL recharge was observed at MW-1 after 30 days and the transducers were removed from the wells. Monthly DNAPL gauging will continue.

DNAPL removed during bail-down testing was placed in a 55-gallon drum and stored in a secure area. The DNAPL was previously profiled and is exempt from Resource Conservation and Recovery Act (RCRA) requirements based on the quantities generated. The drum will be transported by a licensed waste hauler to an approved facility for disposal.

2.8.5 Bench-Scale Treatability Testing

Arcadis will conduct a bench-scale treatability test to facilitate an evaluation of the applicability of *in-situ* solidification (ISS) remediation treatment to address soils impacted with DNAPL at RH3. DNAPL is present at depths ranging from approximately 11 to 25 feet bgs.

The treatability testing will be conducted at the Arcadis Treatability Laboratory in Durham, North Carolina. ISS of DNAPL saturated soils on the RH3 Site will be evaluated and optimized through the addition of one or more pozzolanic materials, such as Portland cement or ground-granulated blast furnace slag cement. The addition of pozzolanic admixtures will result in strength gain and hydraulic conductivity reduction within the solidified monolith, thus reducing the mobility of DNAPL and limiting leaching to surrounding groundwater.

Specifically, the objectives of the ISS treatability test are as follows:

1. Evaluate the ability of selected admixtures to achieve a targeted strength gain and reduction in hydraulic conductivity in DNAPL source areas. An unconfined compressive strength of at least 30 pounds per square inch (psi) and a maximum hydraulic conductivity of approximately 1×10^{-6} centimeters per second (or two orders of magnitude lower than the *in-situ* hydraulic conductivity) are targeted. Ultimate strength development requirements will be based on BT Red Hook, LLC’s future site use goals.
2. Investigate the performance of admixture delivery technologies, excavator bucket or auger mixing and jet grouting, for use in addressing DNAPL-impacted soils at different target treatment depths and areas at RH3.

The Arcadis Treatability Laboratory will create a series of test mixes for each of the soil samples using potable water from the RH3 Site and solidification reagents selected based on Arcadis’ extensive previous experience with ISS. The test mixes will then be cured and tested for geotechnical performance parameters at selected time intervals (e.g., unconfined compressive strength at seven and 28 days after mixing, hydraulic conductivity at 28 days). The results of performance tests for unconfined compressive strength and hydraulic conductivity will be compared between candidate mix designs to select the test mixes that effectively meet the ISS objectives.

In support of the ISS treatability study, a soil boring from each of the DNAPL impacted areas will be installed that represents the vertical profile for which ISS will be evaluated as a potential remedial alternative. Each of the soil borings should contain soils impacted with the DNAPL present at the RH3 Site. To create the depth profile, soil grab samples from each discrete 5-foot interval (5 feet to 10 feet, 10 feet to 15 feet, etc.) will be collected and placed in 1-gallon zip-lock bags. Once filled, the zip-lock bags will be placed in United States Department of Transportation rated 5-gallon metal drums. Sufficient soil volume from each 5-foot zone should be collected such that two 5-gallon drums (10 gallons of volume) are filled at each of the RH3 locations distinguished by NAPL type/depth. In addition, approximately 3 gallons of potable (municipal) water will be collected while on site and shipped to the Arcadis Treatability Laboratory for use in preparing the mix designs.

As part of this effort, baseline (untreated) soil samples will also be submitted to a geotechnical testing laboratory for the following baseline geotechnical analyses:

- Grain-size analysis (sieve and hydrometer) in accordance with ASTM International (ASTM) D422
- Specific gravity in accordance with ASTM D854
- Moisture content in accordance with ASTM D2216
- Unified Soil Classification System classification in accordance with ASTM D2487
- Organic matter and ash content in accordance with ASTM D2974
- Atterberg limits in accordance with ASTM D4318

The soil borings for this effort will be advanced and abandoned as described in Section 2.2 and surveyed as described in Section 2.6.

2.9 Investigation Water Source

Municipal potable water will be used for drilling, decontaminating drilling/sampling equipment, and grouting boreholes upon completion. A representative sample of the source will be submitted for laboratory analysis of the same analytes and in accordance with the same methods used for investigation samples. Use of any other drilling fluids or materials that could impact groundwater quality will be avoided.

2.10 Waste Management

Soil cuttings, drilling fluids, purged groundwater, recovered NAPL, decontamination fluids, and personal protective equipment will be containerized for offsite disposal.

3 REPORTING

A Supplemental Remedial Investigation Report detailing work conducted by Arcadis as of June 2018 and during the currently proposed investigation will be prepared and submitted to NYSDEC for review and approval. The report will include a discussion of analytical results, the nature and extent of impact, a site conceptual model, and recommendations supported by updated tables and figures describing the analytical data and hydrogeology. Data deliverables and validation will be in accordance with Appendix 2B of DER-10. Interim deliverables including boring logs, geologic cross sections, validated analytical data tables, and data usability summary reports will be included in monthly project status updates, as completed. A Qualitative Human Health Exposure Assessment will be submitted as a standalone report prior to submittal of the SRI Report.

4 SCHEDULE

Mobilization for the SRI will be initiated within 30 days of receipt of written approval of this Work Plan from NYSDEC. To expedite the work flow, Arcadis may request interim approval to proceed with portions of the proposed fieldwork prior to full approval of the Work Plan by NYSDEC. It is anticipated that fieldwork will be completed within six weeks following commencement of work, subject to weather and ground surface conditions.

5 REFERENCES

AESI. 2017. Remedial Investigation Report, Red Hook 3 Properties, 68 and 100 Ferris Street/242 and 300 Coffey Street, NYSDEC BCP Site C224213. October.

Baskerville, Charles A. 1994. Bedrock and Engineering Geologic Maps of New York County, Parts of Kings and Queens Counties, New York, and Parts of Bergen and Hudson Counties, New Jersey.

Cadwell, D.H. et al. 1986. Surficial Geologic Map of New York, Lower Hudson Sheet, New York State Museum – Geological Survey, Map and Chart Series #40.

Langan. 2016a. Remedial Investigation Work Plan for Red Hook 3 Properties, Site No. C224213. August.

Langan. 2016b. Quality Assurance Project Plan for Red Hook 3 Properties, Site No. C224213. August.

NYSDEC. 2010. DER-10 Technical Guidance for Site Investigation and Remediation. May 3. Available online at: http://www.dec.ny.gov/regulations/67386.html.

Pillori. 2014. Preliminary Geotechnical Engineering Investigation – RH4 62 Ferris Street. March.

TABLES

Table 1
Monitoring Well Gauging Data (4/27/2018)

Supplemental Remedial Investigation Work Plan
Red Hook 3
NYSDEC BCP Site #C224213

Well ID	PVC Elevation (ft)	DTW (ft)	Water Elevation (ft)	DTP (ft)	DNAPL or LNAPL Thickness (ft)	Measured DTB (ft)	PID (ppm)	Notes
LMW-1	9.78	8.42	1.36	NP	NP	14.71	0.0	good condition
LMW-2	9.14	8.91	0.23	NP	NP	20.8	8.91	good condition
LMW-3	8.46	7.17	1.29	NP	NP	14.75	0.5	good condition
LMW-4	7.54	6.44	1.10	NP	NP	19.17	0.0	good condition
LMW-5	9.77	9.37	0.40	NP	NP	20.45	14.6	good condition
LMW-6	11.52	12.38	-0.86	NP	NP	17.01	0.2	good condition
LMW-7S	11.20	10.23	0.97	NP	NP	17.62	0.0	good condition
LMW-7D	11.18	10.06	1.12	NP	NP	71.11	0.0	good condition
LMW-8S	11.27	10.47	0.80	NP	NP	19.55	1.9	good condition
LMW-8D	11.24	10.95	0.29	NP	NP	71.20	0.0	good condition
TMW-1	11.14	10.15	0.99	NP	NP	19.45	0.0	good condition
MW-1	8.55	6.17	2.38	6.56	**6.84**	13.4	20.6	good condition. DNAPL
MW-2	9.93	7.39	2.54	NP	NP	15.13	0.0	good condition
MW-3	6.96	5.04	1.92	NP	NP	13.1	0.0	good condition
MW-9S	9.86	7.07	2.79	NP	NP	18.12	0.0	good condition
MW-9D	9.81	8.98	0.83	NP	NP	49.54	0.0	good condition
MW-10S	7.35	6.32	1.03	NP	NP	19.76	138.9	good condition
MW-10D	7.60	NM	NM	NM	NM	NM	NM	J-Plug stuck on 4/27/2018
MW-11S	7.11	6.60	0.51	NP	NP	19.39	0.0	good condition
MW-11D	6.99	7.44	-0.45	NP	NP	51.58	0.0	good condition
MW-12S	7.10	5.52	1.58	NP	NP	8.13	0.0	good condition
MW-12D	7.13	6.74	0.39	NP	NP	49.96	0.0	good condition

Notes:
DNAPL = dense non-aqueous phase liquid (in bold)
DTB = depth to bottom of well
DTP = depth to product
DTW = depth to water
ft = feet
LNAPL = light non-aqueous phase liquid
NM = no measurement taken
NP = no product (LNAPL or DNAPL) measured
PID = photoionization detector
PPM = parts per million
PVC = polyvinyl chloride
Elevations surveyed by DPK Land Surveying, November 2017, and are in feet referenced to mean sea level.
Monitoring wells installed by others.

Table 2
Monitoring Well Construction Data

Supplemental Remedial Investigation Work Plan
Red Hook 3
NYSDEC BCP Site #C224213

Well ID	Measured Depth to Bottom of Well (ft)	Length of Screen (ft)	Depth to Top of Screen (ft)	Notes
LMW-1	14.71	17	3	
LMW-2	20.8	10	7	
LMW-3	14.75	10	5	
LMW-4	19.17	17	3	
LMW-5	20.45	17	3	
LMW-6	17.01	10	7	
LMW-7S	17.62	10	7	Screen length assumed
LMW-7D	71.11	†	†	
LMW-8S	19.55	17	3	
LMW-8D	71.20	70	50	
TMW-1	19.45	†	†	
MW-1	13.4	10	5	
MW-2	15.13	10	5	
MW-3	13.1	10	3	
MW-9S	18.12	13	12	
MW-9D	49.54	5	35	
MW-10S	19.76	15	5	
MW10D	50.54	5	35	
MW11S	19.39	17	3	
MW-11D	51.58	20	30	
MW12S	8.13	17	3	
MW-12D	49.96	20	30	

Notes:
† = not provided
ft = feet
Monitoring wells installed by others.

Table 3
Proposed Soil Sampling Plan

Supplemental Remedial Investigation Work Plan
Red Hook 3
NYSDEC BCP Site #C224213

Sample Name	Boring Name	Drilling Type	Terminal Depth	Sample Depth	Rationale	Analyses
A-RH3-B14_XX_XX	A-RH3-B14					
A-RH3-B15_XX_XX	A-RH3-B15					
A-RH3-B16_XX_XX	A-RH3-B16					
A-RH3-B17_XX_XX	A-RH3-B17					
A-RH3-B18_XX_XX	A-RH3-B18					
A-RH3-B19_XX_XX	A-RH3-B19					
A-RH3-B20_XX_XX	A-RH3-B20					
A-RH3-B21_XX_XX	A-RH3-B21	Direct Push	25 feet	4-6 feet	Evaluate metals in fill, screen for DNAPL	TAL Metals including Chromium III and VI. One sample for Part 375 VOCs, SVOCs, PCBs, Pesticides/Herbicides, TAL Metals, Chromium III and VI, Cyanide
A-RH3-B22_XX_XX	A-RH3-B22					
A-RH3-B23_XX_XX	A-RH3-B23					
A-RH3-B24_XX_XX	A-RH3-B24					
A-RH3-B25_XX_XX	A-RH3-B25					
A-RH3-B26_XX_XX	A-RH3-B26					
A-RH3-B27_XX_XX	A-RH3-B27					
A-RH3-B28_XX_XX	A-RH3-B28	Sonic	25 feet +	4-6 feet	Evaluate metals in fill	TAL Metals including Chromium III and VI
A-RH3-B28_XX_XX				10 - 25 feet	Evaluate DNAPL	Part 375 VOCs, SVOCs, PCBs, Pesticides/Herbicides, TAL Metals, Chromium III and VI, Cyanide
A-RH3-B29_XX_XX	A-RH3-B29	Sonic	25 feet +	4-6 feet	Evaluate metals in fill	TAL Metals including Chromium III and VI
A-RH3-B29_XX_XX				10 - 25 feet	Evaluate DNAPL	Part 375 VOCs, SVOCs, PCBs, Pesticides/Herbicides, TAL Metals, Chromium III and VI, Cyanide

Notes:
Part 375 = New York State Department of Environmental Conservation (NYSDEC) Title 6 of the Official Compilation of New York Codes, Rules and Regulations (NYCRR) Part 375 List
DNAPL = dense non-aqueous phase liquid
PCB = polychlorinated biphenyl
SVOC = semi-volatile organic compound
TAL = Target Analyte List
USEPA = United States Environmental Protection Agency
VOC = volatile organic compound
10. Analytical Methods:

VOCs plus tentatively identified compounds – USEPA SW-846 Method 8260C
SVOCs plus tentatively identified compounds – USEPA SW-846 Method 8270D
PCBs – USEPA SW-846 Method 8082A
Pesticides/Herbicides – USEPA SW-846 Method 8081B
TAL Metals – USEPA SW-846 Method 6010/6020
Mercury – USEPA SW-846 Method 7471B
Cyanide – USEPA SW-846 Method 9014
Chromium III and VI – USEPA SW-846 Method 7196A

Soil sample for VOC analysis will be collected using En Core or Terracore sample kits.
Field duplicates, equipment blanks, and matrix spike/matrix spike duplicates will be collected at a frequency of at least one per 20 project samples/per matrix/per 10 field days.

Table 4
Proposed Groundwater Sampling Plan

Supplemental Remedial Investigation Work Plan
Red Hook 3
NYSDEC BCP Site #C224213

Sample Name	Well Name	Sample Protocol	Well Screen Interval	Rationale	Analyses
MW-1_DATE	MW-1	Low Flow	5 to 15 feet bgs	Evaluate DNAPL-impacted water from shallow screened interval	PFAS, 1,4-Dioxane, Geochemical Parameters
LMW-8S_DATE	LMW-8S	Low Flow	7 to 20 feet bgs	Evaluate dissolved BTEX-impacted water from shallow screened interval	PFAS, 1,4-Dioxane
MW-10D_DATE	MW-10D	Low Flow	35 to 40 feet bgs	Evaluate dissolved BTEX-impacted water from deep screened interval	PFAS, 1,4-Dioxane, Geochemical Parameters
LMW-1_DATE	LMW-1	Low Flow	7 to 20 feet bgs	Evaluate non-impacted water from shallow screened interval	PFAS, 1,4-Dioxane
LMW-4_DATE	LMW-4	Low Flow	7 to 20 feet bgs	Evaluate non-impacted water from shallow screened interval	PFAS, 1,4-Dioxane, Geochemical Parameters
LMW-6_DATE	LMW-6	Low Flow	7 to 17 feet bgs	Evaluate non-impacted water from shallow screened interval	PFAS, 1,4-Dioxane, Geochemical Parameters
LMW-7S_DATE	LMW-7S	Low Flow	7 to 17 feet bgs (assumed)	Evaluate dissolved BTEX-impacted water from shallow screened interval	PFAS, 1,4-Dioxane

Notes:
Part 375 = New York State Department of Environmental Conservation (NYSDEC) Title 6 of the Official Compilation of New York Codes, Rules and Regulations (NYCRR) Part 375 List
bgs = below ground surface
BTEX = benzene, toluene, ethylbenzene, and xylenes
DNAPL = dense non-aqueous phase liquid
PFAS = per- and polyfluoroalkyl substances
USEPA = United States Environmental Protection Agency
Analytical Methods: PFAS – USEPA SW-846 Method 537; 1,4-Dioxane by USEPA Method 8270 SIM

Geochemical Parameters:

- Dissolved gases – RSK 175
- Dissolved iron – USEPA 200.7
- Dissolved manganese – USEPA 200.7
- Nitrate-Nitrogen – SM 21-22 4500 NO3 F
- Sulfate – ASTM D516-07

Groundwater samples will be collected using low-flow purging protocols.
Field duplicates, equipment blanks, and matrix spike/matrix spike duplicates will be collected at a frequency of at least one per 20 project samples/per matrix/per 10 field days.

Table 5
Labware and Preservation

Supplemental Remedial Investigation Work Plan
Red Hook 3
NYSDEC BCP Site #C224213

Glassware for Soil and Water Analysis			
Water	**Glassware**	**Quantity**	**Preservative**
8260 Standard	VOC Vial	3	Hydrochloric Acid
8270 PAH (SIM)	Amber Liter	2	None
Dissolved Gases	VOC Vial	3	Hydrochloric Acid
Iron & Manganese	250 ml Plastic	1	Nitric Acid
Nitrate	250 ml Plastic	1	None
		1	Sulfuric Acid
PFAS	250 ml Plastic	2	None
		1	Equipment Blank
Sulfate	250 ml Plastic	1	None
Soil	**Glassware**	**Quantity**	**Preservative**
8260	VOC Vial	1	Methanol
	VOC Vial	2	Sodium Bisulfate
	or	2	Deionized Water
	or	1	4 oz Amber
8081	8 oz Amber	3	None
8082			
8151			
8270			
Cyanide			
Hexavalent Chromium			
Mercury			
PFAS			
TAL 23 Metals			
TCLP Extraction			
Trivalent Chromium			

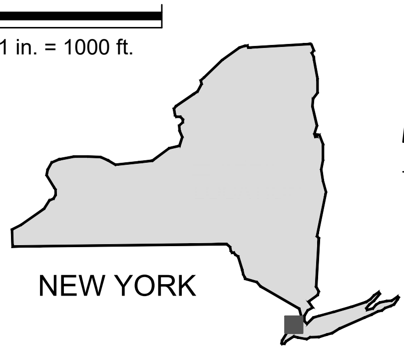
Notes:
ml = milliliter
oz = ounce
PAH = polycyclic aromatic hydrocarbon
PFAS = per- and polyfluoroalkyl substances
TAL = Target Analyte List
TCLP = Toxicity Characteristic Leaching Procedure
VOC = volatile organic compound

FIGURES

REFERENCE: BASE MAP USGS 7.5 MIN. TOPO. QUADS., JERSEY CITY, NJ-NY, 2016, AND BROOKLYN, NY, 2016

0 1000' 2000'

Approximate Scale: 1 in. = 1000 ft.



BT RED HOOK, LLC - RED HOOK 3
68 AND 100 FERRIS STREET/242 AND 300 COFFEY STREET
BROOKLYN, NEW YORK
SUPPLEMENTAL REMEDIAL INVESTIGATION WORK PLAN

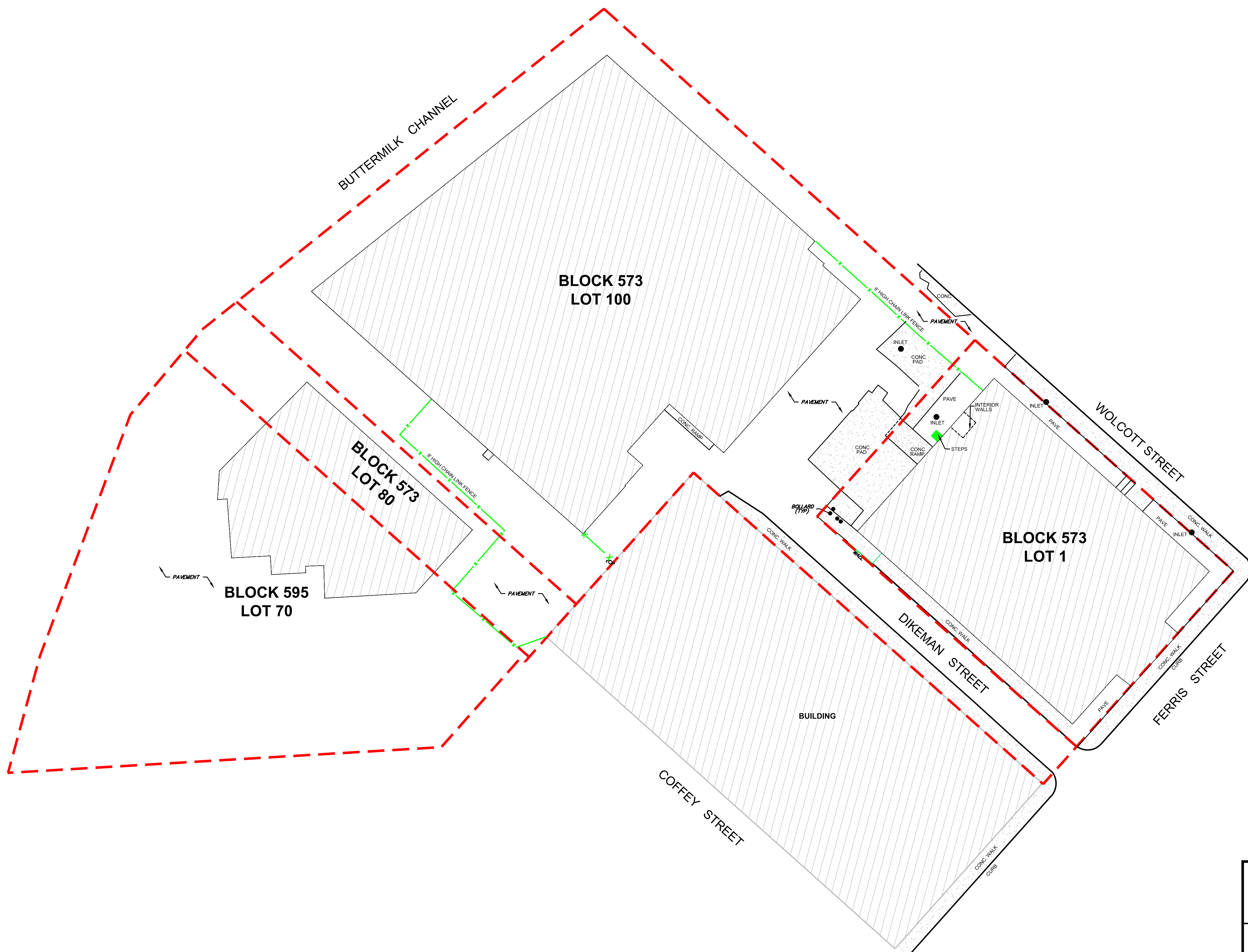
SITE LOCATION MAP

ARCADIS Design & Consultancy for natural and built assets

FIGURE
1

CITY: SYRACUSE, NY DIV/GROUP: EBC-IM/DV DB/LD: L.POSENAUER PM:(Reqd) TM: J.RODDY LYR:(Opt)ON=*;OFF=*REF*
C:\Users\DJI01061\OneDrive - ARCADIS\BIM 360 Docs\UNITED PARCEL SERVICE\Red Hook 3 Supplemental Del Inv\2018\B0038932.0002\01-DWG\Figure 1-RH3-SLM.dwg LAYOUT: 1 SAVED: 6/13/2018 5:05 PM ACADVER: 21.0S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB
PLOTTED: 6/13/2018 5:05 PM BY: JAYAPAL, DINESH KUMAR

IMAGES:
NJ_Jersey_City_20161101_TM_geo.jpg
NY_Brooklyn_20160824_TM_geo.jpg



LEGEND:

- BLOCK/LOT BOUNDARY
- FENCE
- UTILITY POLES

NOTE:

1. BASED ON "EXISTING SITE" FIGURE (AESI MARCH 2017) AND "NY CITY DEPARTMENT OF FINANCE DIGITAL TAX MAP" (AUGUST 15, 2017).

0 100' 200'

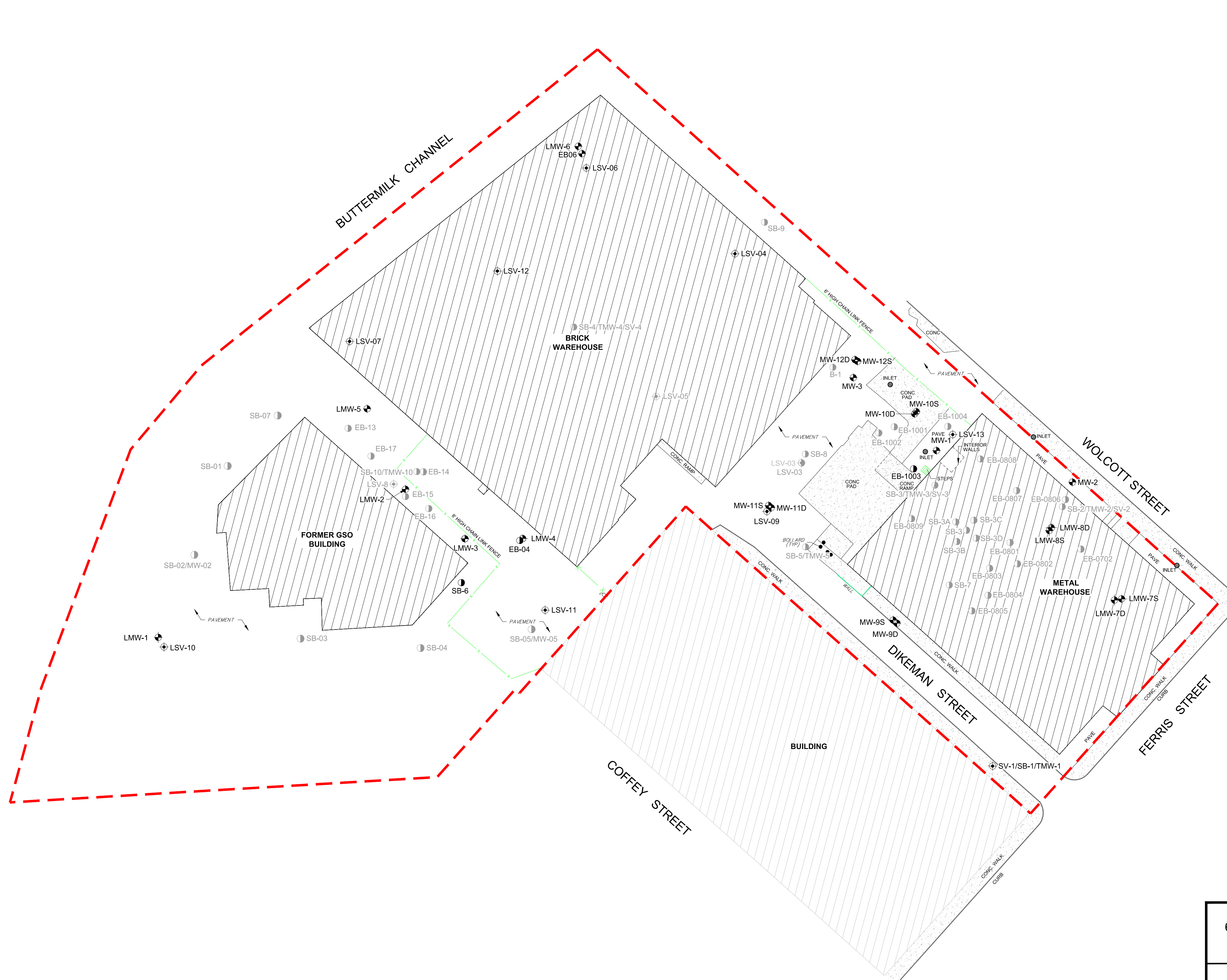
GRAPHIC SCALE

BT RED HOOK, LLC - RED HOOK 3
68 AND 100 FERRIS STREET/242 AND 300 COFFEY STREET
BROOKLYN, NEW YORK
SUPPLEMENTAL REMEDIAL INVESTIGATION WORK PLAN

SITE MAP WITH BLOCK AND LOT BOUNDARIES

ARCADIS Design & Consultancy for natural and built assets

FIGURE
2



LEGEND:

- MONITORING WELL
- SOIL BORING
- SOIL BORING (NOT SURVEYED)
- SOIL VAPOR MONITORING POINT
- SOIL VAPOR MONITORING POINT (NOT SURVEYED)
- SITE BOUNDARY
- FENCE
- UTILITY POLES

NOTES:

1. FIGURE IS BASED ON A SURVEY PREPARED BY DPK LAND SURVEYING, LLC ON 11/2/2017.
2. PROPERTY BOUNDARIES OBTAINED FROM FIGURE ENTITLED "ALTA/NSPS LAND TITLE SURVEY" (LANGAN APRIL 4, 2017).
3. BORING LOCATIONS SHOWN IN GRAY WERE NOT FIELD LOCATED OR SURVEYED BY ARCADIS AND WERE DIGITIZED FROM FIGURES PROVIDED BY AESI AND LANGAN.

0 100' 200'

GRAPHIC SCALE

BT RED HOOK, LLC - RED HOOK 3
68 AND 100 FERRIS STREET/242 AND 300 COFFEY STREET
BROOKLYN, NEW YORK
SUPPLEMENTAL REMEDIAL INVESTIGATION WORK PLAN

SOIL BORINGS AND GROUNDWATER MONITORING WELLS INSTALLED BY OTHERS

ARCADIS Design & Consultancy for natural and built assets

FIGURE 3

LEGEND:

- ◑ SOIL BORING
- SITE BOUNDARY
- FENCE
- UTILITY POLES

NOTES:

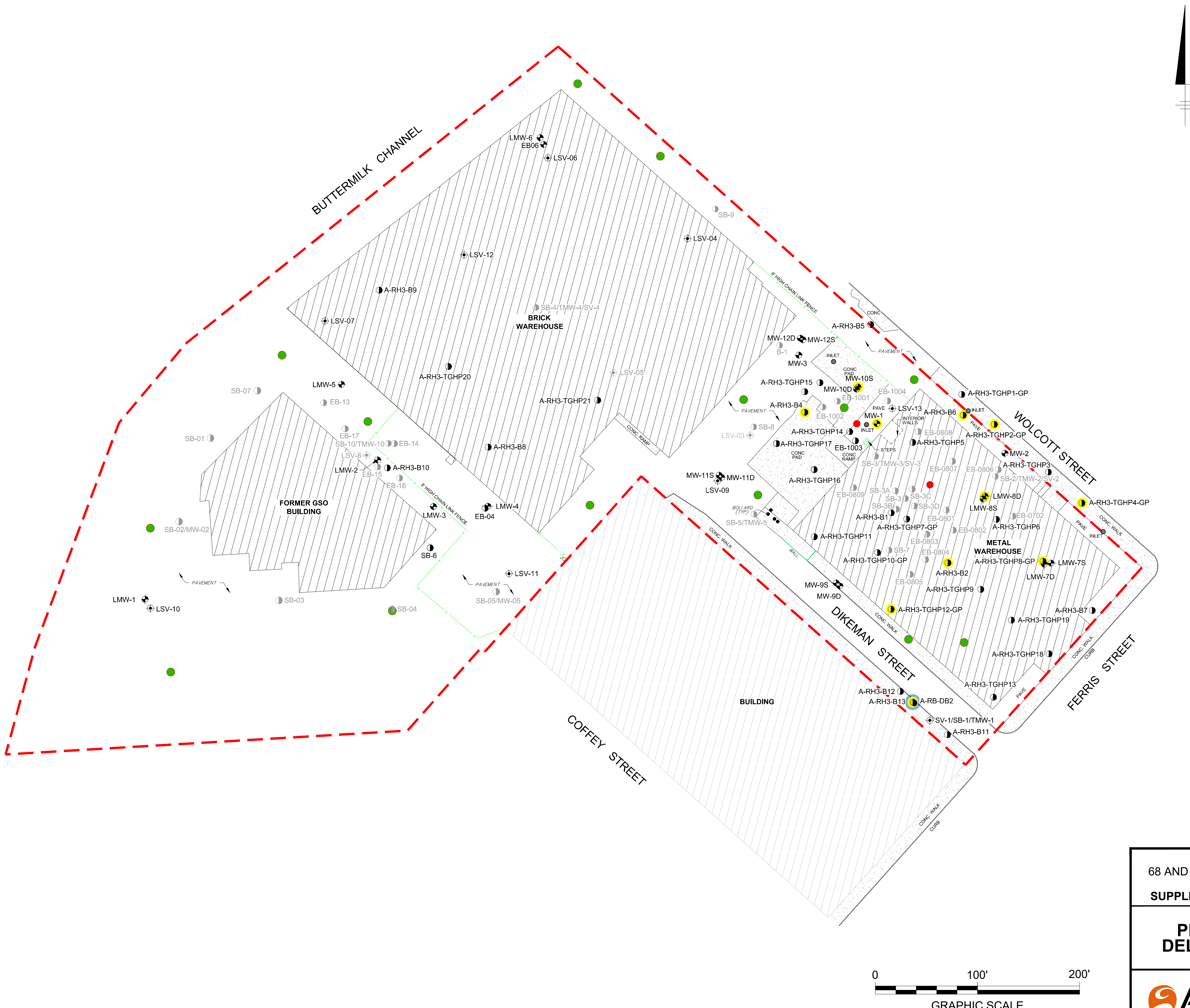
1. FIGURE IS BASED ON A SURVEY PREPARED BY DPK LAND SURVEYING, LLC ON 11/2/2017.
2. PROPERTY BOUNDARIES OBTAINED FROM FIGURE ENTITLED "ALTA/NSPS LAND TITLE SURVEY" (LANGAN APRIL 4, 2017).
3. "TGHP" INDICATES A TarGOST® LOCATION ONLY.
4. TarGOST® -TAR SPECIFIC GREEN OPTICAL SENSING TOOL.
5. "TGHP#-GP" INDICATES A GEOPROBE BORING ADVANCED IMMEDIATELY ADJACENT TO A TarGOST® LOCATION; HOWEVER, THE TarGOST® LOCATION IS NOT SHOWN. FOR EXAMPLE, A-RH3-TGHP4-GP WAS ADVANCED IMMEDIATELY ADJACENT TO TarGOST® LOCATION A-RH3-TGHP4.

BT RED HOOK, LLC - RED HOOK 3
68 AND 100 FERRIS STREET/242 AND 300 COFFEY STREET
BROOKLYN, NEW YORK
SUPPLEMENTAL REMEDIAL INVESTIGATION WORK PLAN

SOIL BORINGS INSTALLED BY ARCADIS-2017

ARCADIS Design & Consultancy for natural and built assets

FIGURE
4



LEGEND:

- MONITORING WELL
- SOIL BORING
- SOIL BORING (NOT SURVEYED)
- SOIL VAPOR MONITORING POINT
- SOIL VAPOR MONITORING POINT (NOT SURVEYED)
- SITE BOUNDARY
- FENCE
- UTILITY POLES
- PROPOSED GEOPROBE BORING (APPROXIMATELY 25 FEET MAXIMUM)
- PROPOSED DEEP SONIC BORING
- VISIBLE DNAPL NOTED IN BORING LOG OR MEASURABLE DNAPL DURING WELL GAUGING ON 4/27/2018
- VISIBLE LNAPL NOTED IN BORING LOG OR MEASURABLE LNAPL DURING WELL GAUGING ON 4/27/2018

NOTES:

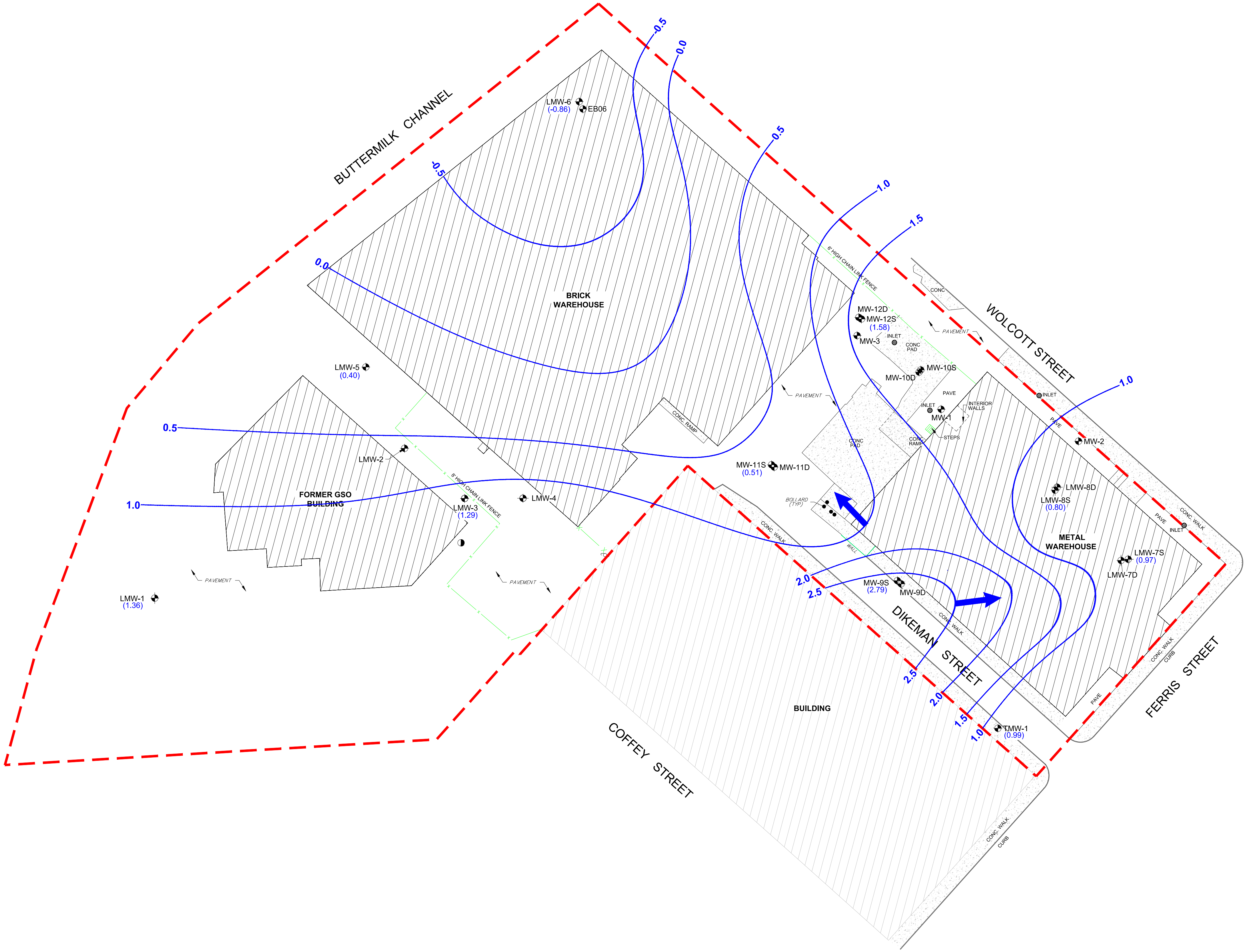
1. FIGURE IS BASED ON A SURVEY PREPARED BY DPK LAND SURVEYING, LLC ON 11/2/2017.
2. PROPERTY BOUNDARIES OBTAINED FROM FIGURE ENTITLED "ALTA/NSPS LAND TITLE SURVEY" (LANGAN APRIL 4, 2017).
3. BORING LOCATIONS SHOWN IN GRAY WERE NOT FIELD LOCATED OR SURVEYED BY ARCADIS AND WERE DIGITIZED FROM FIGURES PROVIDED BY AESI AND LANGAN.
4. "TGHP" INDICATES A TarGOST® LOCATION ONLY.
5. TarGOST® -TAR SPECIFIC GREEN OPTICAL SENSING TOOL.
6. LNAPL - LIGHT NON-AQUEOUS PHASE LIQUID.
7. DNAPL - DENSE NON-AQUEOUS PHASE LIQUID.
8. "TGHP#-GP" INDICATES A GEOPROBE BORING ADVANCED IMMEDIATELY ADJACENT TO A TarGOST® LOCATION; HOWEVER, THE TarGOST® LOCATION IS NOT SHOWN. FOR EXAMPLE, A-RH3-TGHP4-GP WAS ADVANCED IMMEDIATELY ADJACENT TO TarGOST® LOCATION A-RH3-TGHP4.
9. SOIL BORINGS AND TarGOST® LOCATIONS WITH AN "A-" PREFIX WERE ADVANCED BY ARCADIS

BT RED HOOK, LLC - RED HOOK 3
68 AND 100 FERRIS STREET/242 AND 300 COFFEY STREET
BROOKLYN, NEW YORK
SUPPLEMENTAL REMEDIAL INVESTIGATION WORK PLAN

PROPOSED DNAPL AND LNAPL DELINEATION BORING LOCATIONS

ARCADIS Design & Consultancy for natural and built assets

FIGURE
5



LEGEND:

- MONITORING WELL
- SITE BOUNDARY
- FENCE
- UTILITY POLES
- 2.5 — GROUNDWATER ELEVATION CONTOUR
- (2.79) GROUNDWATER ELEVATION (FEET ABOVE MEAN SEA LEVEL)
- GROUNDWATER FLOW DIRECTION

NOTES:

1. FIGURE IS BASED ON A SURVEY PREPARED BY DPK LAND SURVEYING, LLC ON 11/2/2017.
2. PROPERTY BOUNDARIES OBTAINED FROM FIGURE ENTITLED "ALTA/NSPS LAND TITLE SURVEY" (LANGAN APRIL 4, 2017).
3. GROUNDWATER ELEVATIONS BASED ON GAUGING DATA COLLECTED ON 4/27/2018.

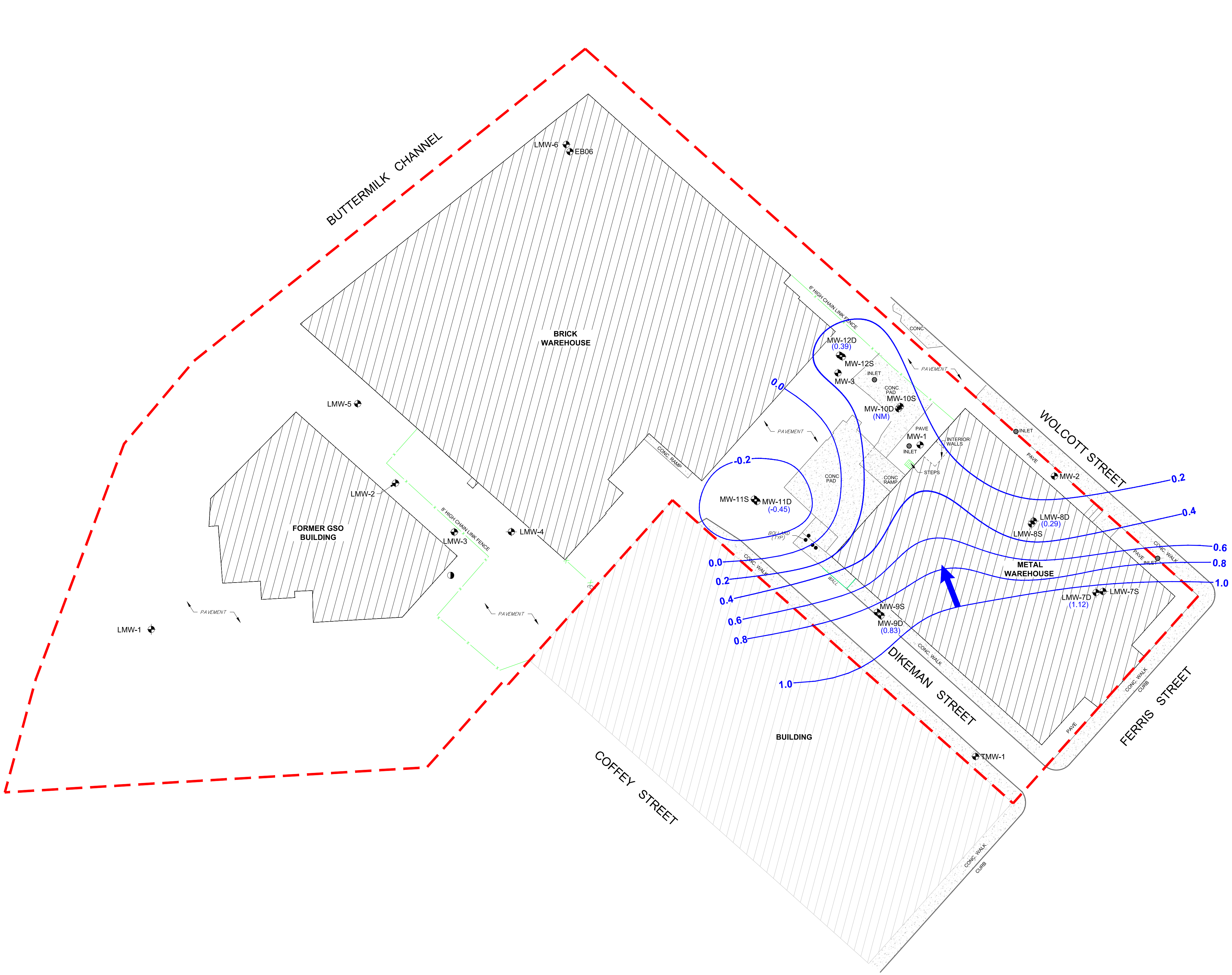
0 100' 200'
GRAPHIC SCALE

BT RED HOOK, LLC - RED HOOK 3
68 AND 100 FERRIS STREET/242 AND 300 COFFEY STREET
BROOKLYN, NEW YORK
SUPPLEMENTAL REMEDIAL INVESTIGATION WORK PLAN

GROUNDWATER CONTOURS - SHALLOW-SCREENED WELLS

ARCADIS Design & Consultancy for natural and built assets

FIGURE
6



LEGEND:

- MONITORING WELL
- SITE BOUNDARY
- FENCE
- UTILITY POLES
- 1.0 GROUNDWATER ELEVATION CONTOUR
- (1.12) GROUNDWATER ELEVATION (FEET ABOVE MEAN SEA LEVEL)
- GROUNDWATER FLOW DIRECTION

NOTES:

1. FIGURE IS BASED ON A SURVEY PREPARED BY DPK LAND SURVEYING, LLC ON 11/2/2017.
2. PROPERTY BOUNDARIES OBTAINED FROM FIGURE ENTITLED "ALTA/NSPS LAND TITLE SURVEY" (LANGAN APRIL 4, 2017).
3. GROUNDWATER ELEVATIONS BASED ON GAUGING DATA COLLECTED ON 4/27/2018.

0 100' 200'

GRAPHIC SCALE

BT RED HOOK, LLC - RED HOOK 3
68 AND 100 FERRIS STREET/242 AND 300 COFFEY STREET
BROOKLYN, NEW YORK
SUPPLEMENTAL REMEDIAL INVESTIGATION WORK PLAN

GROUNDWATER CONTOURS - DEEP-SCREENED WELLS

ARCADIS Design & Consultancy for natural and built assets

FIGURE 7

APPENDIX A

Boring Logs

Boring Logs

Date Start/Finish: 9/27/2017-9/27/2017
Drilling Company: ADT Inc.
Driller's Name: Brian Kayshack
Drilling Method: SONIC
Sampling Method: 5 feet Barrel
Rig Type: XL Max Sonic

Northing: 186588.11
Easting: 979642.18
Casing Elevation: NA

Borehole Depth: 80' bgs
Surface Elevation: 10.95

Descriptions By: David Foster

Well/Boring ID: A-RB-DB2

Client: BT Foster, LLC/UPS

Location: 202 Coffey Street, Brooklyn, New York

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Well/Boring Construction
0								Concrete Slab 6"	
		1	0-5	N/A	N/A			Hand cleared / hydrovac to 5' bgs per ARCADIS Protocol	
5		2	5-10	80%	15000	X		Brown fine to medium SAND, strong petroleum smell immediately, poorly graded,	
10		3	10-15	80%	4000			Light Brown fine to medium SAND, moist Darker brown at bottom 1.5 ft, poorly graded	Borehole pressure grounted with bentonite/ cement mix
15		4	15-20	90%	1200			Dark Brown fine to medium SAND, moist	
20									

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = Not Applicable/Available; AMSL = Above Mean Sea Level.

Analytical sample collected from 5'-10' bgs for Laboratory Analysis.

Date Start/Finish: 9/27/2017-9/27/2017
Drilling Company: ADT Inc.
Driller's Name: Brian Kayshack
Drilling Method: SONIC
Sampling Method: 5 feet Barrel
Rig Type: XL Max Sonic

Northing: 186588.11
Easting: 979642.18
Casing Elevation: NA

Borehole Depth: 80' bgs
Surface Elevation: 10.95

Descriptions By: David Foster

Well/Boring ID: **A-RB-DB2**

Client: BT Foster, LLC/UPS

Location: 202 Coffey Street, Brooklyn, New York

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Well/Boring Construction
20	660	5	20-25	90%	1300			Light Brown fine to medium SAND, moist	
25	655	6	25-30	85%	5			Light Brown fine to medium SAND, moist	
30	650	7	30-35	90%	0.6			Light Brown fine to medium SAND, moist Dark brown SILT with SAND, becoming tightly packed	Borehole pressure grounted with bentonite/ cement mix
35	645	8	35-40	100%	2.5			Dark Brown SILTY SAND SILTY, tightly packed	
40									

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = Not Applicable/Available; AMSL = Above Mean Sea Level.

Analytical sample collected from 5'-10' bgs for Laboratory Analysis.

Date Start/Finish: 9/27/2017-9/27/2017 **Drilling Company:** ADT Inc. **Driller's Name:** Brian Kayshack **Drilling Method:** SONIC **Sampling Method:** 5 feet Barrel **Rig Type:** XL Max Sonic	**Northing:** 186588.11 **Easting:** 979642.18 **Casing Elevation:** NA **Borehole Depth:** 80' bgs **Surface Elevation:** 10.95 **Descriptions By:** David Foster	**Well/Boring ID: A-RB-DB2** **Client:** BT Foster, LLC/UPS **Location:** 202 Coffey Street, Brooklyn, New York

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Well/Boring Construction
40	640	9	40-45	100%	0.0			Dark brown SILT, with some SAND,	
45	635	10	45-50	80%	0.0			Dark brown SILT, with some SAND,	
50	630	11	50-55	70%	0.0			Dark brown SILT, with some SAND,	Borehole presure grounted with bentonite/ cement mix
55	625	12	55-60	80%	0.0			Dark brown SILT, with some SAND,	
60									

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = Not Applicable/Available; AMSL = Above Mean Sea Level.

Analytical sample collected from 5'-10' bgs for Laboratory Analysis.

Date Start/Finish: 9/27/2017-9/27/2017
Drilling Company: ADT Inc.
Driller's Name: Brian Kayshack
Drilling Method: SONIC
Sampling Method: 5 feet Barrel
Rig Type: XL Max Sonic

Northing: 186588.11
Easting: 979642.18
Casing Elevation: NA

Borehole Depth: 80' bgs
Surface Elevation: 10.95

Descriptions By: David Foster

Well/Boring ID: A-RB-DB2

Client: BT Foster, LLC/UPS

Location: 202 Coffey Street, Brooklyn, New York

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	Geologic Column	Stratigraphic Description	Well/Boring Construction
60	620	13	60-65	60%	0.0			Dark brown SILT, with some SAND,	
65	615	14	65-70	60%	0.0			Dark brown SILT, with some SAND,	
70	610	15	70-75	70%	0.0			Dark brown SILT, with some SAND, very wet	Borehole pressure grounted with bentonite/ cement mix
75	605	16	75-80	60%	0.0			Dark brown SILT, with some SAND, very wet Terminate boring @ 80' bgs	
80									

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = Not Applicable/Available; AMSL = Above Mean Sea Level.

Analytical sample collected from 5'-10' bgs for Laboratory Analysis.

Date Start/Finish: 6/28/2017	**Northing:** 186774.52	**Boring ID:** **A-RH3-B1**
Drilling Company: Aquifer Drilling	**Easting:** 979620.05	**Client:** BT Red Hook, LLC - Red Hook 3
Driller's Name: Robert Allegrezza	**Surface Elevation:** 11.49' AMSL	**Location:** 68 and 100 Ferris Street/ 242 Coffey Street Brooklyn, New York
Drilling Method: Direct push	**Borehole Depth:** 20' bgs	
Sampling Method: Macrocore Liner	**Descriptions By:** Clement Papafio	
Rig Type: GeoProbe 7822		

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
0									Concrete slab.	
	10	NA	0-5	NA	NA		NA		Hand cleared to 5' bgs.	
5	5	1	5-10	4.0	4.5		SM		Light brown Silty SAND, some fine Gravel, trace red Brick and Concrete, dry. [FILL]	
10	0	2	10-12	1.0	1.1		ML		Reddish-brown SILT, some fine Gravel, trace fine to medium Sand, moist, non-plastic.	Backfilled to grade with bentonite chips
		3	12-14	1.0	19.3		CL		Brown Silty CLAY, trace fine Gravel, low plasticity, wet, coal tar-like odor.	
		4	14-15	0.5	34.5		GP		Fine to medium SAND, some fine Gravel, dry, coal tar-like odor.	
15		5	15-16	1.0	2.0		SM		Brown Silty SAND, very fine Sand seam, very loose, wet, no coal tar-like odor.	

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical sample collected at 18-20' bgs.

Client: BT Red Hook, LLC - Red Hook 3

Boring ID: **A-RH3-B1**

Site Location: 68 and 100 Ferris Street/
242 Coffey Street
Brooklyn, New York

Borehole Depth: 20' bgs

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
	-5	6	16-18	2.0	55		SM		Brown Silty fine to medium SAND, trace Gravel, strong coal tar-like odor, yellowish product staining.	Backfilled to grade with bentonite chips
20		7	18-20	2.0	466	X	SP		Dark gray medium SAND, loose, wet, very strong coal tar-like odor, yellowish-brown product. Drive shoe damaged on a boulder.	
	-10								Refusal at 20' bgs. End of boring.	
25	-15									
30	-20									
35										

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical sample collected at 18-20' bgs.

Date Start/Finish: 6/28/2017	**Northing:** 186725.47	**Boring ID:** **A-RH3-B2**
Drilling Company: Aquifer Drilling	**Easting:** 979675.55	**Client:** BT Red Hook, LLC - Red Hook 3
Driller's Name: Robert Allegrezza	**Surface Elevation:** 11.53' AMSL	**Location:** 68 and 100 Ferris Street/ 242 Coffey Street Brooklyn, New York
Drilling Method: Direct push	**Borehole Depth:** 19.5' bgs	
Sampling Method: Macrocore Liner	**Descriptions By:** Clement Papafio	
Rig Type: GeoProbe 7822		

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
0									Concrete slab.	
	10	NA	0-5	NA	NA		NA		Hand cleared to 5' bgs.	
5	5	1	5-10	3.0	2.5		GW		CONCRETE, ASPHALT, and BRICKS, some olive-gray Silty Clay. [FILL]	
10	0	2	10-12	1.5	2.7		SP		Dark gray fine to medium SAND, some Silt, loose, wet.	Backfilled to grade with bentonite chips
		3	12-14	1.5	76.4				Strong coal tar-like odor.	
		4	14-15	1.0	454				Trace yellowish-orange staining.	
15		5	15-16	1.0	89		SP		Dark gray medium SAND, some Silt, moist, strong coal tar-like odor.	

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical sample collected at 18-19.5' bgs.

Client: BT Red Hook, LLC - Red Hook 3

Boring ID: A-RH3-B2

Site Location: 68 and 100 Ferris Street/
242 Coffey Street
Brooklyn, New York

Borehole Depth: 19.5' bgs

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
	-5	6	16-18	2.0	512		SP		Some yellowish product from 16-19.5' bgs.	Backfilled to grade with bentonite chips
		7	18-20	2.0	630	X				
20	-10								Refusal at 19.5' bgs. End of boring.	
25	-15									
30	-20									
35										

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available;
AMSL = above mean sea level; PID = photoionization detector;
ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical sample collected at 18-19.5' bgs.

Date Start/Finish: 6/28/2017	**Northing:** NA	**Boring ID:** **A-RH3-B3**	
Drilling Company: Aquifer Drilling	**Easting:** NA	**Client:** BT Red Hook, LLC - Red Hook 3	
Driller's Name: Robert Allegrezza	**Surface Elevation:** NA	**Location:** 68 and 100 Ferris Street/ 242 Coffey Street Brooklyn, New York	
Drilling Method: Direct push	**Borehole Depth:** 4.5' bgs		
Sampling Method: Macrocore Liner	**Descriptions By:** Clement Papafio		
Rig Type: GeoProbe 7822			

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
0	0								Concrete slab.	
		NA	0-4.5	NA	NA		NA		Hand cleared to 4.5' bgs.	Borehole grouted to grade.
5	-5								Refusal at 4.5' bgs. End of boring.	
10	-10									
15	-15									

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Boring location was abandoned after failure to advance past 4.5' bgs.

Date Start/Finish: 6/28/2017	**Northing:** 186872.96	**Boring ID:** **A-RH3-B4**
Drilling Company: Aquifer Drilling	**Easting:** 979535.39	**Client:** BT Red Hook, LLC - Red Hook 3
Driller's Name: Robert Allegrezza	**Surface Elevation:** 7.25' AMSL	**Location:** 68 and 100 Ferris Street/ 242 Coffey Street Brooklyn, New York
Drilling Method: Direct push	**Borehole Depth:** 20' bgs	
Sampling Method: Macrocore Liner	**Descriptions By:** Clement Papafio	
Rig Type: GeoProbe 7822		

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
	10									
0									Concrete slab.	
	5	NA	0-5	NA	NA		NA		Hand cleared to 5' bgs.	
5	0	1	5-10	2.0	47	X	SM		Brown to olive Silty SAND, trace fine Gravel, very loose, wet, black staining, strong coal tar-like odor. Positive oil-in-soil test.	
10		2	10-12	2.0	13.5		SM		Dark gray Silty SAND, very soft, very loose, wet, no coal tar-like odor.	Backfilled to grade with bentonite chips
	-5	3	12-14	2.0	2.7		SP		Brown medium SAND, loose, very soft, wet. Trace Silt.	
		4	14-15	1.0	2.3		SP			
15		5	15-16	1.0	2.1		SP		Moist.	

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical sample collected at 5-10' bgs.

Client:	BT Red Hook, LLC - Red Hook 3	**Boring ID:**	**A-RH3-B4**
Site Location:	68 and 100 Ferris Street/ 242 Coffey Street Brooklyn, New York	**Borehole Depth:**	20' bgs

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
	-10	6	16-18	2.0	2.5		SP		Brown medium SAND, loose, very soft, wet.	Backfilled to grade with bentonite chips
		7	18-20	2.0	1.1					
20									End of boring at 20' bgs.	
	-15									
25										
	-20									
30										
	-25									
35										

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available;
AMSL = above mean sea level; PID = photoionization detector;
ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical sample collected at 5-10' bgs.

Date Start/Finish: 6/29/2017	**Northing:** 186958.94	**Boring ID:** **A-RH3-B5**	
Drilling Company: Aquifer Drilling	**Easting:** 979599.93	**Client:** BT Red Hook, LLC - Red Hook 3	
Driller's Name: Robert Allegrezza	**Surface Elevation:** 7.66' AMSL	**Location:** 68 and 100 Ferris Street/ 242 Coffey Street Brooklyn, New York	
Drilling Method: Direct push	**Borehole Depth:** 23' bgs		
Sampling Method: Macrocore Liner	**Descriptions By:** Clement Papafio		
Rig Type: GeoProbe 7822			

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
	10									
0	5	NA	0-5	NA	NA		NA		Hand cleared to 5' bgs.	
5		1	5-6	1.0	6		SM		Light brown medium Silty SAND, some Concrete, very loose, dry. [FILL]	
	0	2	5-10	2.0	5.5		SP		Brown medium SAND, interbedded Silt, very loose.	
		3	10-12	2.0	5.4		SP		Dark gray medium SAND, trace Silt, very loose, wet at 8' bgs.	
10		4	10-12	2.0	3.5					Backfilled to grade with bentonite chips
	-5	5	12-14	2.0	6.1					
		6	14-15	1.0	7.4				Trace Mica, fine olive Gravel and Silt, no longer saturated.	
15		7	15-16	1.0	8.4	X			Interbedded Silt, slight coal tar-like odor.	

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical sample collected at 15-16' bgs.

Client:	BT Red Hook, LLC - Red Hook 3	**Boring ID:**	**A-RH3-B5**
Site Location:	68 and 100 Ferris Street/ 242 Coffey Street Brooklyn, New York	**Borehole Depth:**	23' bgs

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
	-10	8	16-18	2.0	8.6		SP		Some Clay, trace red Brick, slight coal tar-like odor. Transitions to CLAY at 17.5' bgs.	Backfilled to grade with bentonite chips
20		9	18-20	2.0	5.6		CL		Brown Silty CLAY, medium stiff, low plasticity, no coal tar-like odor.	
		10	20-22	2.0	4.2					
	-15	11	22-23	1.0	2.9				Some fine Gravel in macrocore sampler.	
25	-20								Refusal at 23' bgs. End of boring.	
30	-25									
35										

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical sample collected at 15-16' bgs.

Date Start/Finish: 6/28/2017	**Northing:** 186870.15	**Boring ID:** A-RH3-B6
Drilling Company: Aquifer Drilling	**Easting:** 979690.61	**Client:** BT Red Hook, LLC - Red Hook 3
Driller's Name: Robert Allegrezza	**Surface Elevation:** 10.01' AMSL	**Location:** 68 and 100 Ferris Street/ 242 Coffey Street Brooklyn New York
Drilling Method: Direct push	**Borehole Depth:** 25' bgs	
Sampling Method: Macrocore Liner	**Descriptions By:** Clement Papafio	
Rig Type: GeoProbe 7822		

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
0	10	NA	0-5	NA	NA		NA		ASPHALT. Hand cleared to 5' bgs.	
5	5	1	5-10	2.0	13.8		SP		Gray to brown fine to medium SAND, some fine Gravel, trace Concrete.	Backfilled to grade with bentonite chips
10	0	2	10-12	2.0	57.5		SM		Dark gray Silty SAND, trace fine Gravel, non-plastic, wet, coal tar-like odor.	
		3	12-14	2.0	116.7		ML		Dark gray Clayey SILT, trace fine Sand, wet, coal tar-like odor, brown to yellow staining.	
		4	14-15	1.0	176.4		ML		Medium plasticity, brown staining.	
15	-5	5	15-16	0.5	106		CL		Light brown Silty CLAY, very stiff, medium plasticity, slight coal tar-like odor.	

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical sample collected at 24-25' bgs.

Client: BT Red Hook, LLC - Red Hook 3

Boring ID: **A-RH3-B6**

Site Location: 68 and 100 Ferris Street/
242 Coffey Street
Brooklyn New York

Borehole Depth: 25' bgs

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
		6	16-18	1.0	92		CL		Light brown Silty CLAY, very stiff, medium plasticity, slight coal tar-like odor.	Backfilled to grade with bentonite chips
		7	18-20	1.0	50					
20	-10	8	20-22	2.0	378				Dark gray, trace fine Sand, very soft, strong coal tar-like odor, trace yellowish-brown product.	
		9	22-24	2.0	455		SC		Dark gray Clayey fine to medium SAND, some fine Gravel, moist, strong coal tar-like odor, trace yellowish-brown product.	
		10	24-25	1.0	647	X	SP		Dark gray medium SAND, loose, wet, strong coal tar-like odor, black staining and product.	
25	-15								End of boring at 25' bgs.	
30	-20									
35	-25									

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available;
AMSL = above mean sea level; PID = photoionization detector;
ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical sample collected at 24-25' bgs.

ARCADIS Design & Consultancy for natural and built assets

Date Start/Finish:	6/28/2017	**Northing:**	186678.81
Drilling Company:	Aquifer Drilling	**Easting:**	979816.96
Driller's Name:	Todd Palomeque	**Surface Elevation:**	10.93' AMSL
Drilling Method:	Rotary Sonic	**Borehole Depth:**	80' bgs
Sampling Method:	5-feet x 3-inch core barrel	**Descriptions By:**	Levia Terrell
Rig Type:	Track-mounted Rotary Sonic		

Boring ID: A-RH3-B7

Client: BT Red Hook, LLC - Red Hook 3

Location: 68 and 100 Ferris Street/
242 Coffey Street
Brooklyn, New York

Depth (feet bgs)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Stratigraphic Description
0–5	NA	0-5	NA	0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0		NA	Concrete slab. Hand cleared to 5' bgs.
5–10	1	5-10	3.5	0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0	9-10'	SP	Reddish-brown fine SAND, moist. Wet at 8' bgs. Brown, trace fine to medium rounded to subrounded Gravel.
10–15	2	10-15	3.5	0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0		GP	Gray COBBLE, wet.
						SW	Brown fine to coarse SAND, wet. Fine to medium SAND.
15–	3	15-20	4.0	0.0, 0.0			

Soil Boring: Grouted to grade with cement/bentonite mix

Elevation (feet AMSL): 10, 5, 0, -5

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical samples collected at 9-10' bgs and 65-75' bgs.

ARCADIS Design & Consultancy for natural and built assets

Client:	BT Red Hook, LLC - Red Hook 3	**Boring ID:**	**A-RH3-B7**
Site Location:	68 and 100 Ferris Street/ 242 Coffey Street Brooklyn, New York	**Borehole Depth:**	80' bgs

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
		3	15-20	4.0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0		SW		Grayish-brown fine to coarse SAND, trace fine rounded Gravel, wet. Fine to medium SAND.	
20	-10	4	20-25	4.3	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0		SW		Fine SAND.	Grouted to grade with cement/bentonite mix
25	-15	5	25-30	4.3	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0		SW		Fine to medium SAND, faint coal tar-like odor. Fine SAND.	
30	-20	6	30-35	4.8	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0		SW			
35	-25	7	35-40	4.5	0.0 0.0		SW		Very fine SAND, trace Silt.	

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available;
AMSL = above mean sea level; PID = photoionization detector;
ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical samples collected at 9-10' bgs and 65-75' bgs.

ARCADIS Design & Consultancy for natural and built assets

Client: BT Red Hook, LLC - Red Hook 3

Boring ID: **A-RH3-B7**

Site Location: 68 and 100 Ferris Street/
242 Coffey Street
Brooklyn, New York

Borehole Depth: 80' bgs

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample
		7	35-40	4.5	0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0	
40	-30	8	40-45	4.5	0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0	
45	-35	9	45-50	4.7	0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0	
50	-40	10	50-55	5.0	0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0	
55	-45	11	55-60	4.5	0.0, 0.0	

USCS Code	Stratigraphic Description
SP	Grayish-brown fine to coarse SAND, trace fine rounded Gravel, wet. Fine to medium SAND.
ML	Brown SILT, wet.
SP	Grayish-brown fine SAND, wet.
ML	Brown SILT, wet.
SP	Brown fine SAND, wet.
SP	Grayish-brown very fine SAND, wet.

Soil Boring: Grouted to grade with cement/bentonite mix

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical samples collected at 9-10' bgs and 65-75' bgs.

Client:	BT Red Hook, LLC - Red Hook 3	**Boring ID:**	**A-RH3-B7**
Site Location:	68 and 100 Ferris Street/ 242 Coffey Street Brooklyn, New York	**Borehole Depth:**	80' bgs

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
		11	55-60	4.5	0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0		SM		Grayish-brown very fine SAND, wet.	
60	-50	12	60-65	4.7	0.0		ML		Brown Clayey SILT, low plasticity, wet.	Grouted to grade with cement/bentonite mix
					0.0, 0.0, 0.0, 0.0, 0.0		ML		Brown SILT, wet.	
					0.0, 0.0, 0.0, 0.0				Reddish-brown fine to medium SAND, trace coarse Sand, trace fine to coarse Gravel and Schist, wet.	
65	-55	13	65-70	4.8	0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0	X	SP		Reddish-brown fine to medium SAND, trace fine to coarse rounded Gravel and coarse Sand. 1-inch thick band of dark brown SAND. COBBLE at end of sampler.	
70	-60	14	70-75	3.6	0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0	X			Reddish-brown fine to medium SAND, trace coarse Sand and fine to coarse rounded Gravel, wet.	
75	-65	15	75-80	4.0	0.0, 0.0				Reddish-brown fine to coarse SAND, trace fine to coarse rounded Gravel, wet.	

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical samples collected at 9-10' bgs and 65-75' bgs.

Client:	BT Red Hook, LLC - Red Hook 3
Site Location:	68 and 100 Ferris Street/ 242 Coffey Street Brooklyn, New York
Boring ID:	**A-RH3-B7**
Borehole Depth:	80' bgs

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
		15	75-80	4.0	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0		SP		Reddish-brown fine to medium SAND, trace fine to coarse rounded Gravel and coarse Sand, wet.	Grouted to grade with cement/bentonite mix
80									End of boring at 80' bgs.	
	-70									
85										
	-75									
90										
	-80									
95										
	-85									

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical samples collected at 9-10' bgs and 65-75' bgs.

Date Start/Finish: 6/29/2017	**Northing:** 186838.81	**Boring ID:** **A-RH3-B8**	
Drilling Company: Aquifer Drilling	**Easting:** 979225.45	**Client:** BT Red Hook, LLC - Red Hook 3	
Driller's Name: Robert Allegrezza	**Surface Elevation:** 11.80' AMSL	**Location:** 68 and 100 Ferris Street/ 242 Coffey Street Brooklyn, New York	
Drilling Method: Direct push	**Borehole Depth:** 25' bgs		
Sampling Method: Macrocore Liner	**Descriptions By:** Clement Papafio		
Rig Type: GeoProbe 7822			

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
0									Concrete slab.	Backfilled to grade with bentonite chips
	10	NA	0-5	NA	NA		NA		Hand cleared to 5' bgs.	
5	5	1	5-10	2.0	190.2		SP		Gravelly medium SAND, some concrete, dry, strong creosote-like odor. [FILL]	
10	0	2	10-12	1.5	157	X	SC		Dark gray Clayey fine to medium SAND, medium plasticity, creosote-like odor. [FILL]	
		3	12-14	1.5	5.0				No creosote-like odor.	
		4	14-15	0.5	4.5					
15		5	15-16	1.0	1.7				Wet at 15' bgs.	

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical sample collected at 10-12' bgs.

Client: BT Red Hook, LLC - Red Hook 3

Boring ID: **A-RH3-B8**

Site Location: 68 and 100 Ferris Street/
242 Coffey Street
Brooklyn, New York

Borehole Depth: 25' bgs

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
	-5	6	16-18	2.0	1.6		SC		Dark gray Clayey fine to medium SAND, medium plasticity, dry, creosote-like odor. [FILL]	Backfilled to grade with bentonite chips
		7	18-20	2.0	2.5		SC		Dark gray Clayey SAND, some fine Gravel, trace red Brick and partially weathered Rock (mica), wet, no creosote-like odor.	
20		8	20-22	2.0	0.2		SP		Brown fine SAND, trace Silt, medium stiff, wet.	
	-10	9	22-24	2.0	0.6		SP		Light brown.	
		10	24-25	1.0	0.1		SP		Trace fine Gravel.	
25									End of boring at 25' bgs.	
	-15									
30										
	-20									
35										

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical sample collected at 10-12' bgs.

Date Start/Finish:	6/29/2017	**Northing:**	186992.73	**Boring ID:**	**A-RH3-B9**
Drilling Company:	Aquifer Drilling	**Easting:**	979118.59	**Client:**	BT Red Hook, LLC - Red Hook 3
Driller's Name:	Robert Allegrezza	**Surface Elevation:**	11.77' AMSL	**Location:**	68 and 100 Ferris Street/ 242 Coffey Street Brooklyn, New York
Drilling Method:	Direct push	**Borehole Depth:**	25' bgs		
Sampling Method:	Macrocore Liner	**Descriptions By:**	Clement Papafio		
Rig Type:	GeoProbe 7822				

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
0		NA	0-5	NA	NA		NA		Concrete slab.	Backfilled to grade with bentonite chips
	10								Hand cleared to 5' bgs.	
5		1	5-6	1.0	5.7		SP		Dark gray fine to coarse SAND, some fine Gravel, medium dense, dry.	
	5	2	6-8	2.0	8.6					
		3	8-10	2.0	4.2					
10	0	4	10-15	2.0	386		SC		Dark gray Clayey fine to medium Sand, interbedded Clay, high plasticity, wet, strong creosote-like odor.	
15		5	15-16	1.0	632	X			Some Clay.	

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical sample collected at 15-16' bgs.

ARCADIS Design & Consultancy for natural and built assets

Client:	BT Red Hook, LLC - Red Hook 3	**Boring ID:**	**A-RH3-B9**
Site Location:	68 and 100 Ferris Street/ 242 Coffey Street Brooklyn, New York	**Borehole Depth:**	25' bgs

Depth (feet bgs)	Elevation (feet AMSL)	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description	Soil Boring
	-5	6	16-18	2.0	17.7		SC		Dark gray CLAY, trace fine to medium Sand, soft, medium plasticity, wet, no creosote-like odor.	
		7	18-20	2.0	2.6				Dark gray Clayey SAND, loose, wet, no coal tar-like odor.	
20		8	20-22	2.0	5.0					Backfilled to grade with bentonite chips
	-10	9	22-24	2.0	5.8		SP			
		10	24-25	1.0	7.2					
25									End of boring at 25' bgs.	
	-15									
30										
	-20									
35										

ARCADIS Design & Consultancy for natural and built assets

Remarks: ags = above ground surface; bgs = below ground surface; NA = not available; AMSL = above mean sea level; PID = photoionization detector; ppm = parts per million.

The coordinate system is New York Long Island State Plane; NAD 83.

Analytical sample collected at 15-16' bgs.

Soil Boring Log

ARCADIS Design & Consultancy for natural and built assets

Boring No.: A-RH3-B10

Sheet: 1 of 1

Client Name:	BT Red Hook, LLC - Red Hook 3	Date Started:	10-16-2017
Logger:	Dave Foster		
Project Number:	B0038932.0004.0070	Date Completed:	10-16-2017
Editor:	NA		
Project Location:	Brooklyn, NY	Weather Conditions:	Sunny 80° F

Depth (feet)	Sample Interval	Blow Counts	Recovery (feet)	Sample ID	PID (ppm)	USCS Class	Description	Construction Details	Well
0-5	0-5	NA	NA				Hand cleared to 5' bgs.	Backfilled with bentonite pellets	
5-10	5-10	NA	3.5	A-RH3-B10 (9')	0.0-2.0		Fine to medium SAND, some small Gravel, damp, black/gray.		
10-11	10-11.5	NA	NA		0.0		Top 12": SAND and FILL, some small Gravel, damp, black/gray.		
11-11.5					0.0		Bottom 6": SILT, black.		
11.5-12							Refusal; End of boring at 11.5 ft bgs		

Drilling Co.:	Aquifer Drilling & Testing (ADT)	Sampling Method:	Macrocore
Driller:	Dave Moon	Sampling Interval:	Continuous
Drilling Method:	Direct Push	Water Level Start (ft. bgs.):	NA
Drilling Fluid:	None	Water Level Finish (ft. btoc.):	NA
Remarks:	ft/ '= feet; "= Inch; bgs= below ground surface; ppm= parts per million; NA= not applicable/not available. The coordinate system is New York Long Island State Plane; NAD 83. Soil sample collected from 9.0' bgs. Refusal encountered at 11.5' bgs.	Converted to Well:	☐ Yes ☒ No
		Surface Elev.:	9.25 ft NAD 1983
		North Coor:	186818.60
		East Coor:	979126.60

ARCADIS Design & Consultancy for natural and built assets

Soil Boring Log

Boring No.: A-RH3-B11

Sheet: 1 of 1

Client Name: BT Red Hook, LLC - Red Hook 3
Date Started: 10-18-2017
Logger: Dave Foster

Project Number: B0038932.0004.0070
Date Completed: 10-18-2017
Editor: NA

Project Location: Brooklyn, NY
Weather Conditions: Sunny 80° F

Depth (feet)	Sample Interval	Blow Counts	Recovery (feet)	Sample ID	PID (ppm)	USCS Class	Description	Construction Details	Well
0-5	0-5	NA	NA				Hand cleared to 5' bgs.	Backfilled with bentonite pellets	
5-10	5-10	NA	4.5		0.0		Medium SAND, some small Gravel, loose.		
10-15	10-15	NA	4.5	A-RH3-B11 (11')	0.0 0.0 0.0 0.0		Top 6": Wet, brown. Next 3": Light brown. Next 6": Stained dark brown. Bottom 39": Fine to medium SAND, wet, brown.		
15-20	15-20	NA	5		0.0		Top 30": Medium SAND, wet, brown. Bottom 30": Brown/gray.		
20-21							End of boring at 20.0 ft bgs.		

Drilling Co.: Aquifer Drilling & Testing (ADT)
Driller: Dave Moon
Drilling Method: Direct Push
Drilling Fluid: None
Remarks: ft/ '= feet; "= Inch; bgs= below ground surface; ppm= parts per million; NA= not applicable/not available. The coordinate system is New York Long Island State Plane; NAD 83. Soil sample collected from 11.0' bgs.

Sampling Method: Macrocore
Sampling Interval: Continuous
Water Level Start (ft. bgs.): NA
Water Level Finish (ft. btoc.): NA
Converted to Well: ☐ Yes ☒ No
Surface Elev.: 11.67 ft NAD 1983
North Coor: 186557.10
East Coor: 979675.00

ARCADIS Design & Consultancy for natural and built assets

Soil Boring Log

Boring No.: A-RH3-B12

Sheet: 1 of 1

Client Name: BT Red Hook, LLC - Red Hook 3
Date Started: 10-18-2017
Logger: Dave Foster

Project Number: B0038932.0004.0070
Date Completed: 10-18-2017
Editor: NA

Project Location: Brooklyn, NY
Weather Conditions: Sunny 80° F

Depth (feet)	Sample Interval	Blow Counts	Recovery (feet)	Sample ID	PID (ppm)	USCS Class	Description	Construction Details	Well
0-5	0-5	NA	NA				Hand cleared to 5' bgs.	Backfilled with bentonite pellets	
5-10	5-10	NA	5		0.0; 0.0		Top 18": Crushed Rock. Bottom 42": Medium SAND, poorly graded, moist, dark brown to gray. Wet at 9.5' bgs.		
10-15	10-15	NA	5	A-RH3-B12 (11')	0.0-0.2; 0.8		Brown to dark brown.		
15-20	15-20	NA	5		0.2-0.3; 0.3-0.5		Brown/Gray.		
20-25	20-25	NA	0				Liner stuck inside macro barrel.		
25-26							End of boring at 25.0 ft bgs.		

Drilling Co.: Aquifer Drilling & Testing (ADT)
Driller: Dave Moon
Drilling Method: Direct Push
Drilling Fluid: None
Remarks: ft/ '= feet; "= Inch; bgs= below ground surface; ppm= parts per million; NA= not applicable/not available. The coordinate system is New York Long Island State Plane; NAD 83. Soil sample collected from11.0' bgs.

Sampling Method: Macrocore
Sampling Interval: Continuous
Water Level Start (ft. bgs.): 9.5
Water Level Finish (ft. btoc.): 9.5
Converted to Well: ☐ Yes ☒ No
Surface Elev.: 10.76 ft NAD 1983
North Coor: 186599.50
East Coor: 979629.10

Soil Boring Log

Boring No.: A-RH3-B13

Sheet: 1 of 1

Client Name: BT Red Hook, LLC - Red Hook 3 | Date Started: 10-18-2017 | Logger: Dave Foster
Project Number: B0038932.0004.0070 | Date Completed: 10-18-2017 | Editor: NA
Project Location: Brooklyn, NY | Weather Conditions: Sunny 80° F

Depth (feet)	Sample Interval	Blow Counts	Recovery (feet)	Sample ID	PID (ppm)	USCS Class	Description	Construction Details	Well
0-5	0-5	NA	NA				Hand cleared to 5' bgs.	Backfilled with bentonite pellets	
5-10	5-10	NA	5		0.0-0.1		Fine to medium SAND, brown. At 9.0 ft bgs Wet.		
10-15	10-15	NA	5	A-RH3-B13 (14')	0.3-3.0 10-20 250-400		Brown/gray DNAPL at 14.5' bgs.		
15-20	15-20	NA	1		3.0-5.0				
20							End of boring at 20.0 ft bgs.		

Drilling Co.: Aquifer Drilling & Testing (ADT)
Driller: Dave Moon
Drilling Method: Direct Push
Drilling Fluid: None
Remarks: ft/ '= feet; "= Inch; bgs= below ground surface; ppm= parts per million; NA= not applicable/not available. The coordinate system is New York Long Island State Plane; NAD 83. Soil sample collected from 14.0' bgs.

Sampling Method: Macrocore
Sampling Interval: Continuous
Water Level Start (ft. bgs.): 9.0
Water Level Finish (ft. btoc.): 9.0
Converted to Well: ☐ Yes ☒ No
Surface Elev.: 10.91 ft NAD 1983
North Coor: 186589.00
East Coor: 979641.20

SOIL BORING LOG_2013 C:\USERS\RG00960\DESKTOP\GINT TEMPLATE (EXISTING) UPS RAVINDRA.GPJ ARCADIS.GDT 5/12/17

Soil Boring Log

ARCADIS Design & Consultancy for natural and built assets

Boring No.: A-RH3-TGHP1-GP

Client Name: BT Red Hook, LLC - Red Hook 3 Date Started: 10-17-2017 Logger: Dave Foster
Project Number: B0038932.0004.0070 Date Completed: 10-17-2017 Editor: NA
Project Location: Brooklyn, NY Weather Conditions: Partly Cloudy 70° F

Depth (feet)	Sample Interval	Blow Counts	Recovery (feet)	Sample ID	PID (ppm)	USCS Class	Description	Construction Details	Well
0-5	0-5	NA	NA				Hand cleared to 5' bgs.	Backfilled with bentonite pellets	
5-10	5-10	NA	2.5		80-200 60-80		Top 2": Broken rock. Next 16": Fine to medium SAND, wet, brown/stained black. Bottom 12": Some Silt.		
10-15	10-15	NA	3.5	A-RH3-TGHP1-GP (12')	760-950 40-50 15-18		Top 8": SILT, some Gravel and Sand, wet, black. Next 8": Soft. Bottom 26": Tight.		
15-20	15-20	NA	5		1.9 0.0		Top 26": SLOUGH. Bottom 34": SILT, very tight, brown.		
20-24.5	20-24.5	NA	4.5	A-RH3-TGHP1-GP (22')	100-1,100 1,000-1,100		Medium SAND, wet, brown/gray.		
24.5							Refusal; End of boring at 24.5 ft bgs.		

Drilling Co.: Aquifer Drilling & Testing (ADT)
Driller: Dave Moon
Drilling Method: Direct Push
Drilling Fluid: None
Remarks: ft/ '= feet; "= Inch; bgs= below ground surface; ppm= parts per million; NA= not applicable/not available. The coordinate system is New York Long Island State Plane; NAD 83. Soil samples collected from 12.0' and 22.0' bgs. Refusal at 24.5' bgs.

Sampling Method: Macrocore
Sampling Interval: Conituous
Water Level Start (ft. bgs.): NA
Water Level Finish (ft. btoc.): NA
Converted to Well: ☐ Yes ☒ No
Surface Elev.: 9.19 ft NAD 1983
North Coor: 186890.50
East Coor: 979689.00

Boring No.: A-RH3-TGHP2-GP

Soil Boring Log

Client Name: BT Red Hook, LLC - Red Hook 3
Date Started: 10-19-2017
Logger: Dave Foster
Project Number: B0038932.0004.0070
Date Completed: 10-19-2017
Editor: NA
Project Location: Brooklyn, NY
Weather Conditions: Clear, Sunny 70° F

Depth (feet)	Sample Interval	Blow Counts	Recovery (feet)	Sample ID	PID (ppm)	USCS Class	Description	Construction Details	Well
0-5	0-5	NA	NA				Hand cleared to 5' bgs.	Backfilled with bentonite pellets	
5-10	5-10	NA	3		0.4-0.8; 50-100; 150-400		Top 6": Small GRAVEL and slough. Bottom 30": Fine to medium SAND, poorly graded, brown/gray. At 9.0 ft bgs Wet.		
10-15	10-15	NA	4.6		100-300		Medium SAND, some fine Sand, poorly graded, loose, gray. Bottom 12": Tight.		
15-20	15-20	NA	5	A-RH3-TGHP2-GP (16')	1,500; 50-200		Top 20": Fine to medium SAND, stained with dark brown DNAPL, odor. Bottom 40": SILT, very tight, brown.		
20-25	20-25	NA	5	A-RH3-TGHP2-GP (21')	500-1,000; 50-150; 500-600		Top 6": Slough; DNAPL visible. Next 24": Fine to medium SAND, wet, stained with dark brown DNAPL. Next 18": SILT, very tight, brown. Bottom 12": Medium SAND, wet, stained brown/gray.		
25-26							End of boring at 25.0 ft bgs.		

Drilling Co.: Aquifer Drilling & Testing (ADT)
Driller: Dave Moon
Drilling Method: Direct Push
Drilling Fluid: None
Remarks: ft/ '= feet; "= Inch; bgs= below ground surface; ppm= parts per million; NA= not applicable/not available. The coordinate system is New York Long Island State Plane; NAD 83. Soil samples collected from 16.0' and 21.0' bgs.

Sampling Method: Macrocore
Sampling Interval: Conituous
Water Level Start (ft. bgs.): 9.0
Water Level Finish (ft. btoc.): 9.0
Converted to Well: ☐ Yes ☒ No
Surface Elev.: 9.44
North Coor: 186861.20
East Coor: 979721.10

ARCADIS Design & Consultancy for natural and built assets

Soil Boring Log

Boring No.: A-RH3-TGHP4-GP

Sheet: 1 of 1

Client Name:	BT Red Hook, LLC - Red Hook 3	Date Started:	10-19-2017
Logger:	Dave Foster	Project Number:	B0038932.0004.0070
Date Completed:	10-19-2017	Editor:	NA
Project Location:	Brooklyn, NY	Weather Conditions:	Clear, hazy 70° F

Depth (feet)	Sample Interval	Blow Counts	Recovery (feet)	Sample ID	PID (ppm)	USCS Class	Description	Construction Details	Well
0-5	0-5	NA	NA				Hand cleared to 5' bgs.		
5-10	5-10	NA	3.6		0.4-0.6		Fine to medium SAND, poorly graded, brown. At 9.0' bgs Wet. Top 12": Soft, wet.	Backfilled with bentonite pellets	
10-15	10-15	NA	5	A-RH3-TGHP4-GP (13')	2.0-10.0; 400-600; 20-30		Next 30": Stained brown/black, odor. Bottom 18": SILT, very tight, brown; DNAPL present.		
15-20	15-20	NA	2.1		200-300		Fine to medium SAND, tight, stained brown/black.		
20-21							End of boring at 20.0 ft bgs.		

Drilling Co.:	Aquifer Drilling & Testing (ADT)	Sampling Method:	Macrocore
Driller:	Dave Moon	Sampling Interval:	Continuous
Drilling Method:	Direct Push	Water Level Start (ft. bgs.):	9.0
Drilling Fluid:	None	Water Level Finish (ft. btoc.):	9.0
Remarks:	ft/ '= feet; "= Inch; bgs= below ground surface; ppm= parts per million; NA= not applicable/not available. The coordinate system is New York Long Island State Plane; NAD 83. Soil sample collected from 13.0' bgs.	Converted to Well:	☐ Yes ☒ No
		Surface Elev.:	8.97 ft NAD 1983
		North Coor:	186784.10
		East Coor:	979806.80

Soil Boring Log

Boring No.: A-RH3-TGHP7-GP

Sheet: 1 of 1

Client Name: BT Red Hook, LLC - Red Hook 3 | Date Started: 10-20-2017 | Logger: Dave Foster

Project Number: B0038932.0004.0070 | Date Completed: 10-20-2017 | Editor: NA

Project Location: Brooklyn, NY | Weather Conditions: Sunny, Low 80° F

Depth (feet)	Sample Interval	Blow Counts	Recovery (feet)	Sample ID	PID (ppm)	USCS Class	Description	Construction Details	Well
0-5	0-5	NA	NA				Hand cleared to 5' bgs.	Backfilled with bentonite pellets	
5-10	5-10	NA	2.8		0.0		Top 3": Slough Bottom 31": Medium SAND, some Gravel, tight, wet, dark brown.		
10-15	10-15	NA	4		5.0-9.0 10-20 15-30		Top 18": SILT, some Sand and small Gravel, tight, wet, dark brown. Next 18": Brown. Bottom 12": Medium SAND, loose, dark brown.		
15-20	15-20	NA	4.5	A-RH3-TGHP7-GP (17')	20-40 70-200 50-100		Top 18": Fine to medium SAND, wet, black/brown. Next 22": Some staining on liner. Next 2": SILT. Bottom 12": Fine to medium SAND, wet, black/brown; some staining on liner.		
20-21							End of boring on 20.0 ft bgs.		

Drilling Co.: Aquifer Drilling & Testing (ADT)

Driller: Dave Moon

Drilling Method: Direct Push

Drilling Fluid: None

Remarks: ft/ '= feet; "= Inch; bgs= below ground surface; ppm= parts per million; NA= not applicable/not available. The coordinate system is New York Long Island State Plane; NAD 83. Soil sample collected from 17.0' bgs.

Sampling Method: Macrocore

Sampling Interval: Continuous

Water Level Start (ft. bgs.): NA

Water Level Finish (ft. btoc.): NA

Converted to Well: ☐ Yes ☒ No

Surface Elev.: 11.56 ft NAD 1983

North Coor: 186768.30

East Coor: 979635.20

ARCADIS Design & Consultancy for natural and built assets

Soil Boring Log

Boring No.: A-RH3-TGHP8-GP

Sheet: 1 of 1

Client Name: BT Red Hook, LLC - Red Hook 3
Date Started: 10-19-2017
Logger: Dave Foster

Project Number: B0038932.0004.0070
Date Completed: 10-19-2017
Editor: NA

Project Location: Brooklyn, NY
Weather Conditions: Sunny, Low 80° F

Depth (feet)	Sample Interval	Blow Counts	Recovery (feet)	Sample ID	PID (ppm)	USCS Class	Description	Construction Details	Well
0-5	0-5	NA	NA				Hand cleared to 5' bgs.		
5-10	5-10	NA	4.1		0.1		Top 22": Medium SAND, stained black/brown. Bottom 28": Brown.		
10-15	10-15	NA	5		0.0 0.0 0.0		Top 24": SILT, soft, wet, brown. Next 12": Medium SAND, some small Gravel, moderately tight, gray/brown. Bottom 24": SILT, tight, brown. 1" coarse sand lense at 14.5' bgs.	Backfilled with bentonite pellets	
15-20	15-20	NA	5	A-RH3-TGHP8-GP (19')			Top 24": Coarse SAND, tight, wet, gray/brown. Bottom 36": Fine to medium SAND, moderately loose, wet, black/brown; DNAPL odor.		
20-21							End of boring at 20.0 ft bgs.		

Drilling Co.: Aquifer Drilling & Testing (ADT)
Driller: Dave Moon
Drilling Method: Direct Push
Drilling Fluid: None
Remarks: ft/ '= feet; "= Inch; bgs= below ground surface; ppm= parts per million; NA= not applicable/not available. The coordinate system is New York Long Island State Plane; NAD 83. Soil sample collected from 19.0' bgs.

Sampling Method: Macrocore
Sampling Interval: Continuous
Water Level Start (ft. bgs.): 9.0
Water Level Finish (ft. btoc.): 9.0
Converted to Well: ☐ Yes ☒ No
Surface Elev.: 11.48 ft NAD 1983
North Coor: 186727.00
East Coor: 979768.80

ARCADIS Design & Consultancy for natural and built assets

Soil Boring Log

Boring No.: A-RH3-TGHP10-GP

Sheet: 1 of 1

Client Name: BT Red Hook, LLC - Red Hook 3	Date Started: 10-20-2017	Logger: Dave Foster	
Project Number: B0038932.0004.0070	Date Completed: 10-20-2017	Editor: NA	
Project Location: Brooklyn, NY		Weather Conditions: Sunny, Low 80° F	

Depth (feet)	Sample Interval	Blow Counts	Recovery (feet)	Sample ID	PID (ppm)	USCS Class	Description	Construction Details	Well
0–5	0-5	NA	NA				Hand cleared to 5' bgs.	Backfilled with bentonite pellets	
5–10	5-10	NA	5		0.0 (7); 0.0 (9)		Top 48": Fine to medium SAND and FILL, some small Gravel and cement debris. Bottom 12": Poorly graded, wet, brown.		
10–15	10-15	NA	2		0.0 (11); 0.0 (14)		Top 12": SAND, loose, light brown. Bottom 12": Some small Gravel, wet, brown.		
15–20	15-20	NA	3.5		0.0 (17); 0.0 (19)		Top 21": Fine to medium SAND, poorly graded, wet, brown. Bottom 21": SILT, tight, moist, brown.		
20–21							End of boring at 20.0' ft bgs.		

Drilling Co.: Aquifer Drilling & Testing (ADT)	Sampling Method: Macrocore
Driller: Dave Moon	Sampling Interval: Continuous
Drilling Method: Direct Push	Water Level Start (ft. bgs.): NA
Drilling Fluid: None	Water Level Finish (ft. btoc.): NA
Remarks: ft/ '= feet; "= Inch; bgs= below ground surface; ppm= parts per million; NA= not applicable/not available. The coordinate system is New York Long Island State Plane; NAD 83.	Converted to Well: ☐ Yes ☒ No
	Surface Elev.: 11.60 ft NAD 1983
	North Coor: 186735.50
	East Coor: 979606.60

ARCADIS Design & Consultancy for natural and built assets

Soil Boring Log

Boring No.: A-RH3-TGHP12-GP

Sheet: 1 of 1

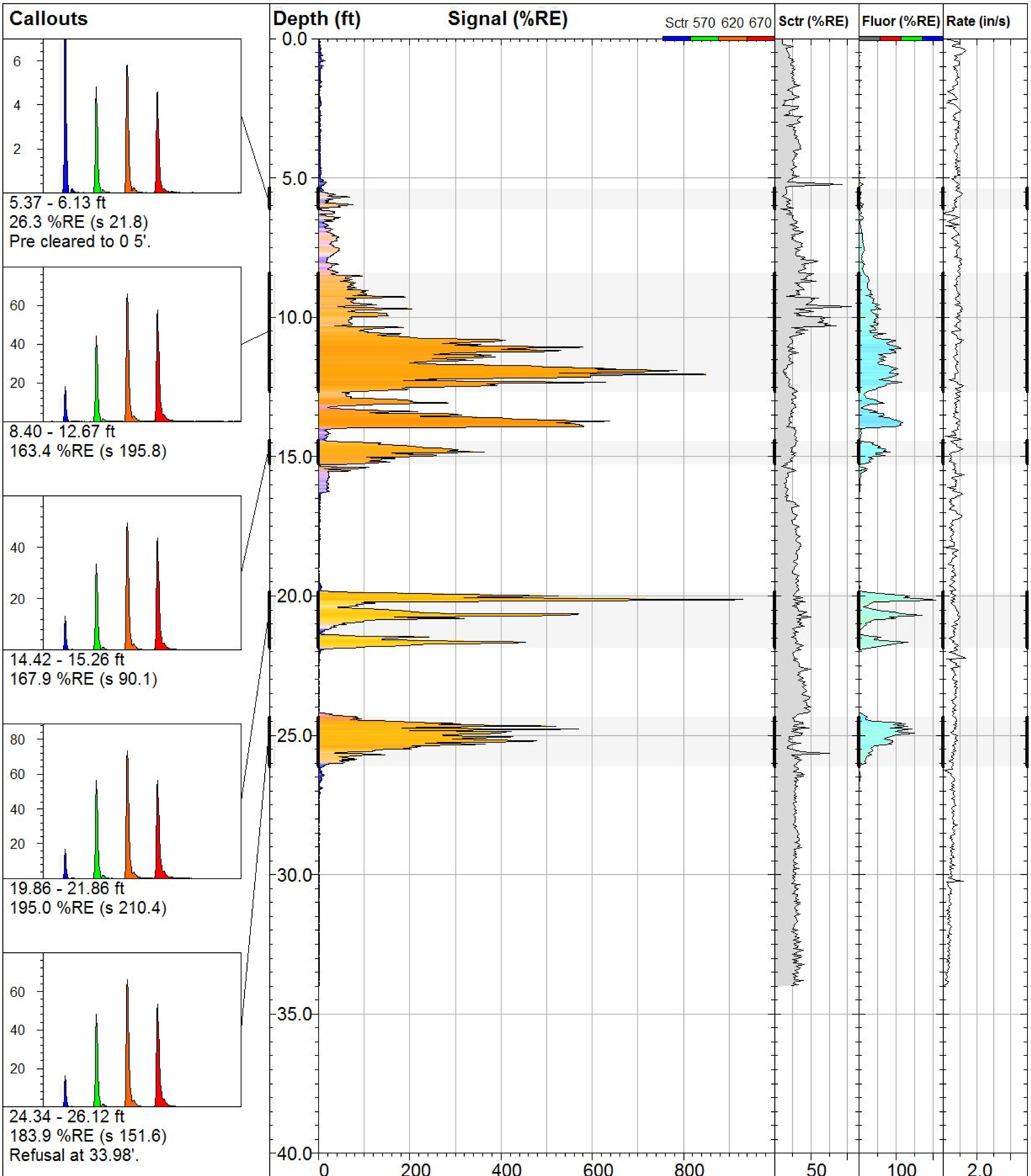
Client Name: BT Red Hook, LLC - Red Hook 3
Date Started: 10-20-2017
Logger: Dave Foster
Project Number: B0038932.0004.0070
Date Completed: 10-20-2017
Editor: NA
Project Location: Brooklyn, NY
Weather Conditions: Sunny 75° F

Depth (feet)	Sample Interval	Blow Counts	Recovery (feet)	Sample ID	PID (ppm)	USCS Class	Description	Construction Details	Well
0-5	0-5	NA	NA				Hand cleared to 5' bgs.	Backfilled with bentonite pellets	
5-10	5-10	NA	4.5		0.0		Top 18": Concrete debris, red/brown. Bottom 36": Fine to medium SAND, tight, dry, brown.		
10-15	10-15	NA	5		0.0; 0.0		Top 24": Same as above. Bottom 36": SILT, tight, moist, brown.		
15-20	15-20	NA	5	A-RH3-TGHP12-GP (19')	20-40; 400-600		Top 30": Same as above. Bottom 30": Fine to medium SAND, tight, wet, brown.		
20-25	20-25	NA	5		50-200		Poorly graded, loose to tight, brown/gray.		
25-26							End of boring at 25.0 ft bgs.		

Drilling Co.: Aquifer Drilling & Testing (ADT)
Driller: Dave Moon
Drilling Method: Direct Push
Drilling Fluid: None
Remarks: ft/ '= feet; "= Inch; bgs= below ground surface; ppm= parts per million; NA= not applicable/not available. The coordinate system is New York Long Island State Plane; NAD 83. Soil sample collected from 19.0' bgs.

Sampling Method: Macrocore
Sampling Interval: Continuous
Water Level Start (ft. bgs.): 17.5
Water Level Finish (ft. btoc.): 17.5
Converted to Well: ☐ Yes ☒ No
Surface Elev.: 11.48
North Coor: 186680.10
East Coor: 979619.90

TarGOST Logs

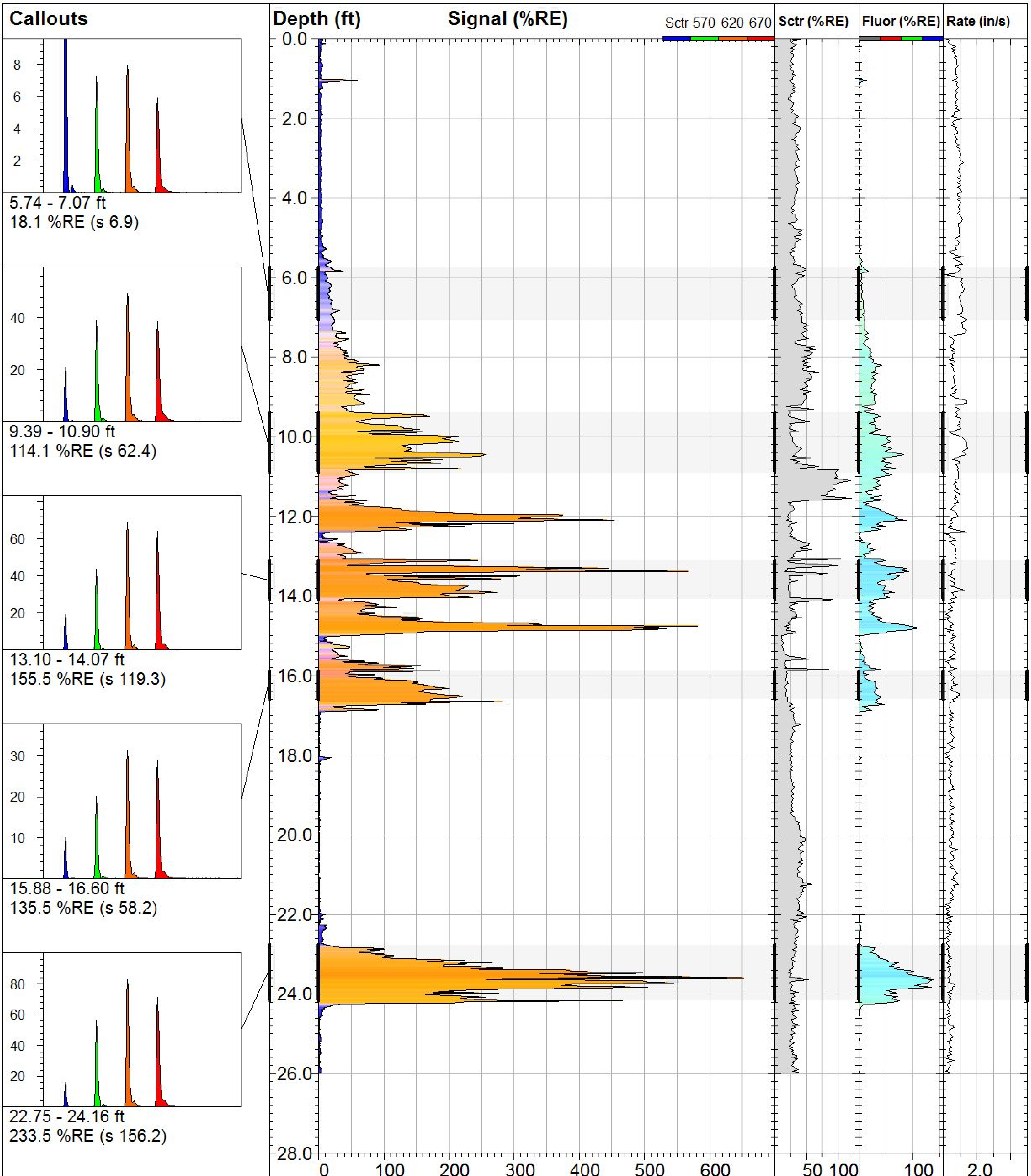


TGHP-01

TarGOST® By Dakota
www.DakotaTechnologies.com

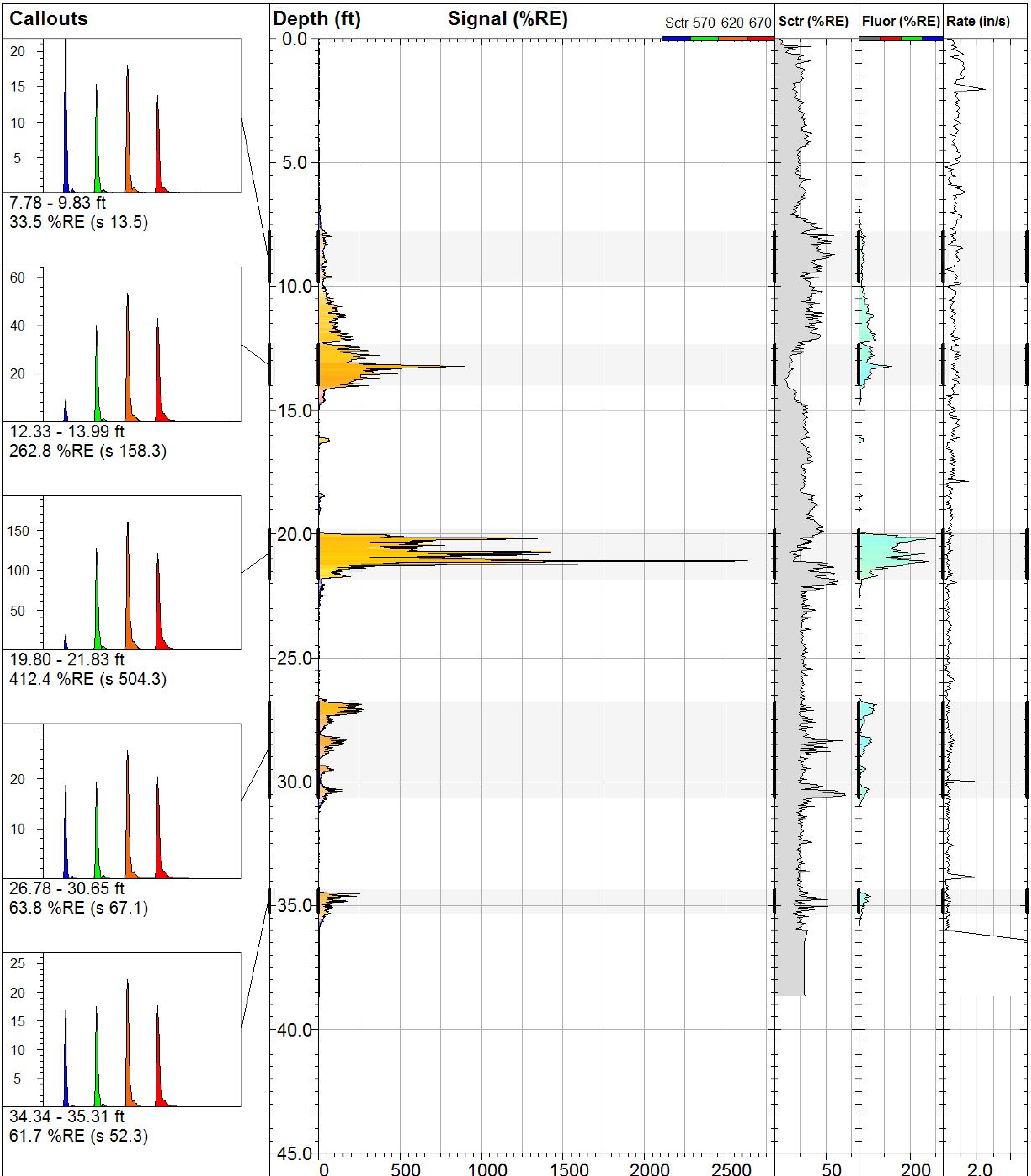
Site:	Y Coord.(Lat-N) / System:	Final depth:
Red Hook 3	**Unavailable / NA**	**33.98 ft**
Client / Job:	*X Coord.(Lng-E) / Fix:*	*Max signal:*
Arcadis /	**Unavailable / NA**	**932.8 %RE @ 20.13 ft**
Operator / Unit:	*Elevation:*	*Date & Time:*
RM / TG1005	**Unavailable**	**2017-09-28 13:46 EDT**

DAKOTA TECHNOLOGIES
www.DakotaTechnologies.com



TGHP-02		**TarGOST® By Dakota** www.DakotaTechnologies.com
Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **25.98 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **674.3 %RE @ 23.58 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-09-29 10:22 EDT**

DAKOTA TECHNOLOGIES
WWW.DAKOTATECHNOLOGIES.COM

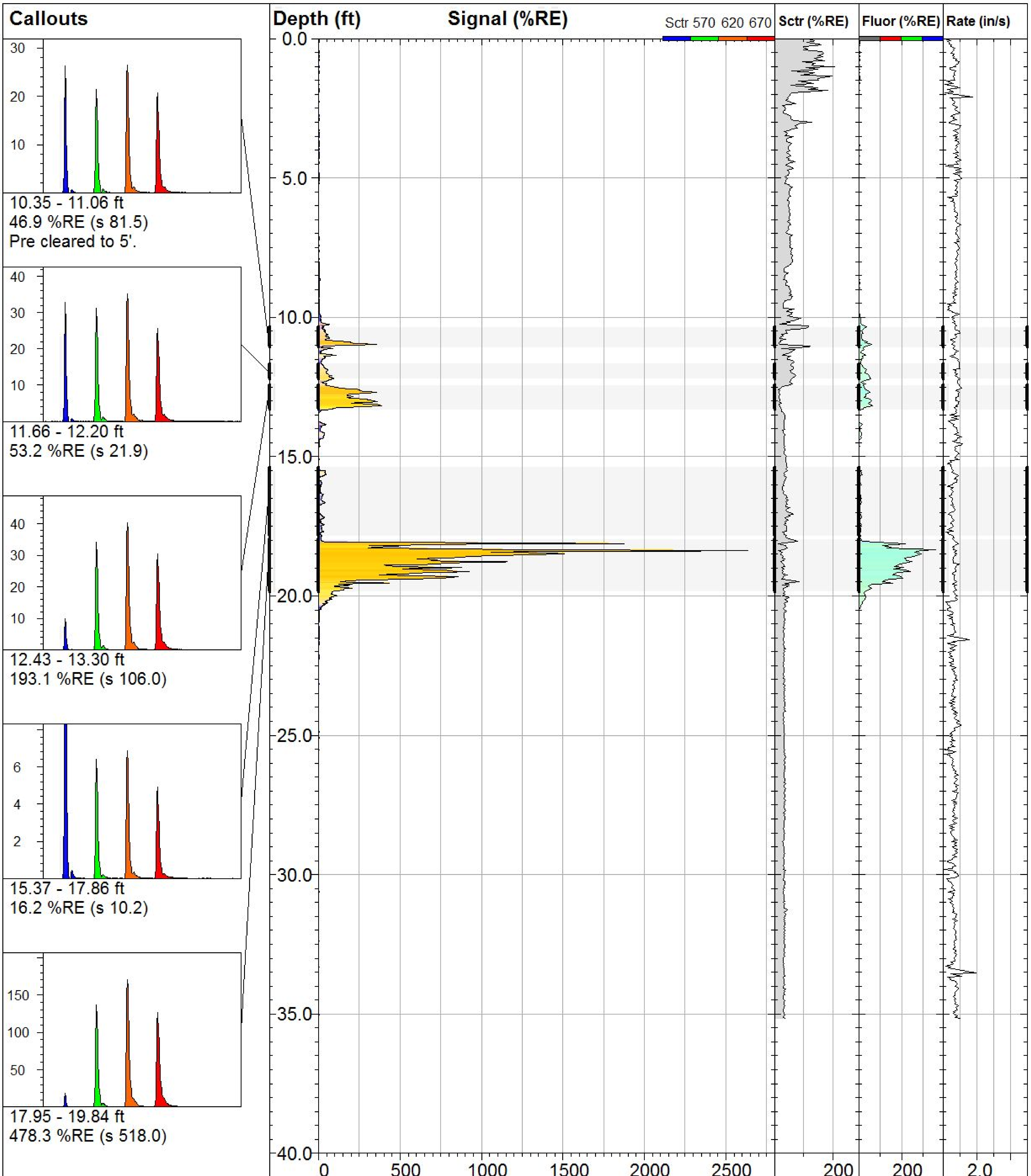


TGHP-03

TarGOST® By Dakota
www.DakotaTechnologies.com

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **38.67 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **2635.8 %RE @ 21.08 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-02 12:21 EDT**

DAKOTA TECHNOLOGIES
WWW.DAKOTATECHNOLOGIES.COM



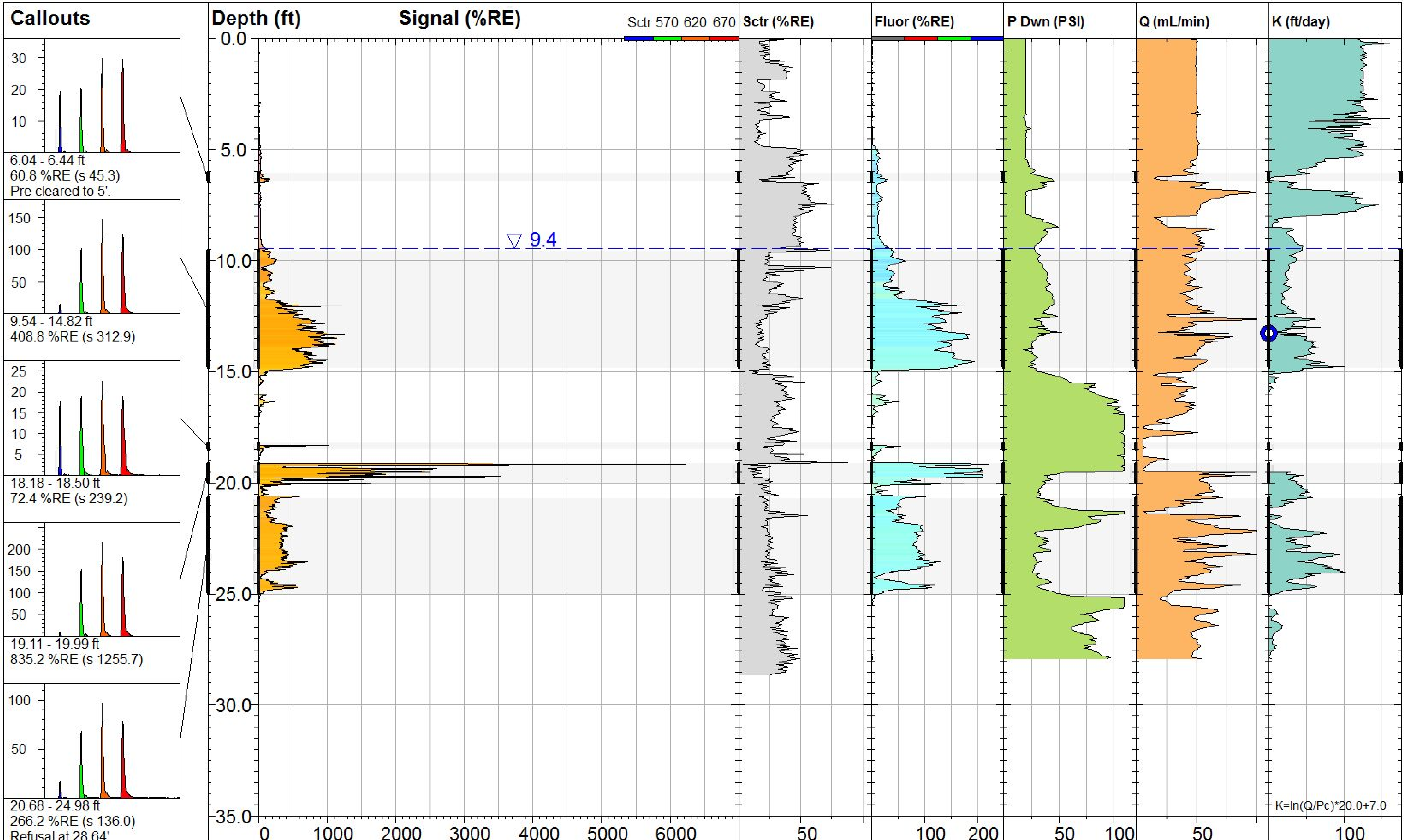
DAKOTA TECHNOLOGIES

WWW.DAKOTATECHNOLOGIES.COM

TGHP-04

TarGOST® By Dakota
www.DakotaTechnologies.com

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **35.17 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **2669.6 %RE @ 18.37 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-02 13:29 EDT**

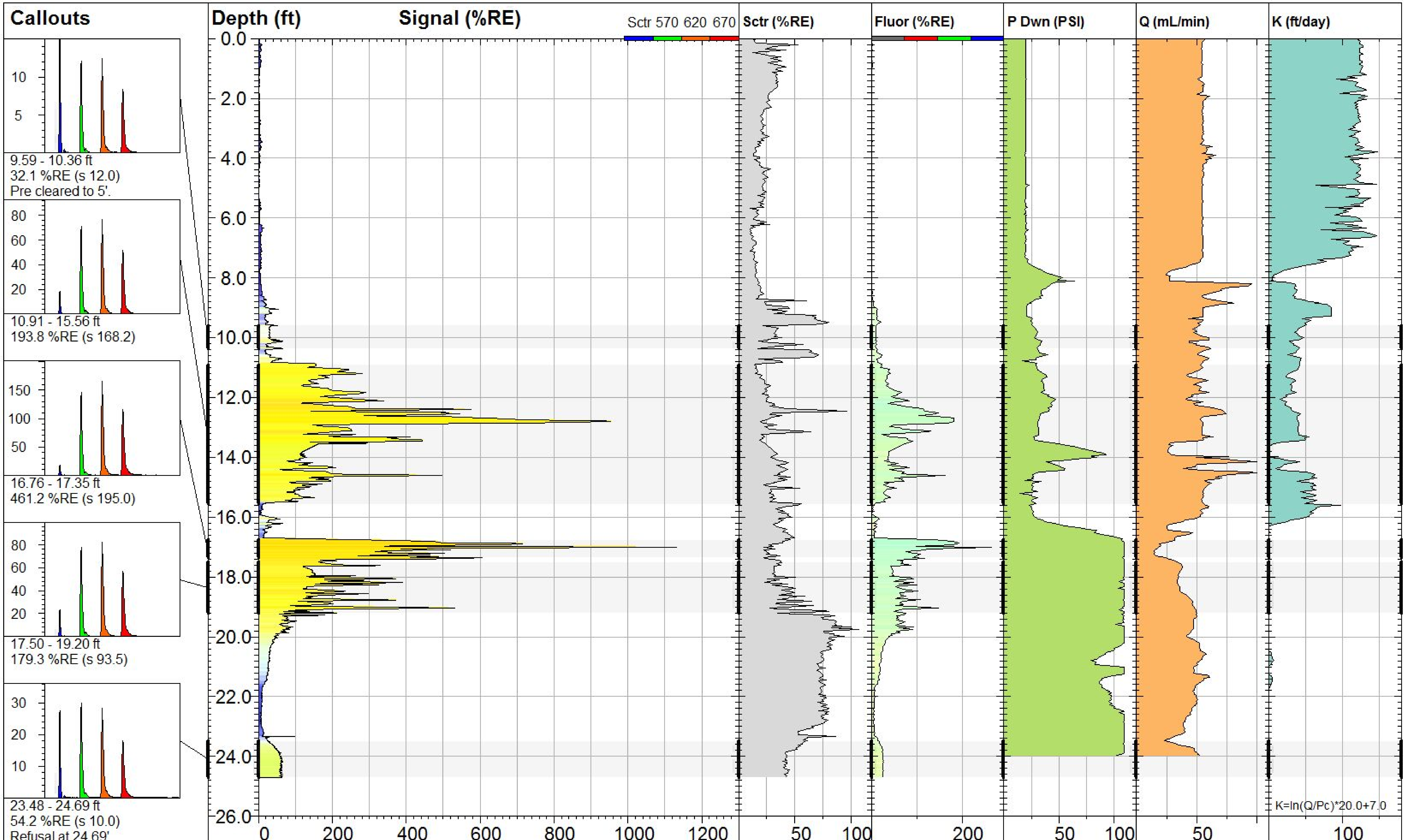


TGHP-05

TarGOST® By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
WWW.DAKOTATECHNOLOGIES.COM

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **28.64 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **6589.6 %RE @ 19.17 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-03 11:56 EDT**

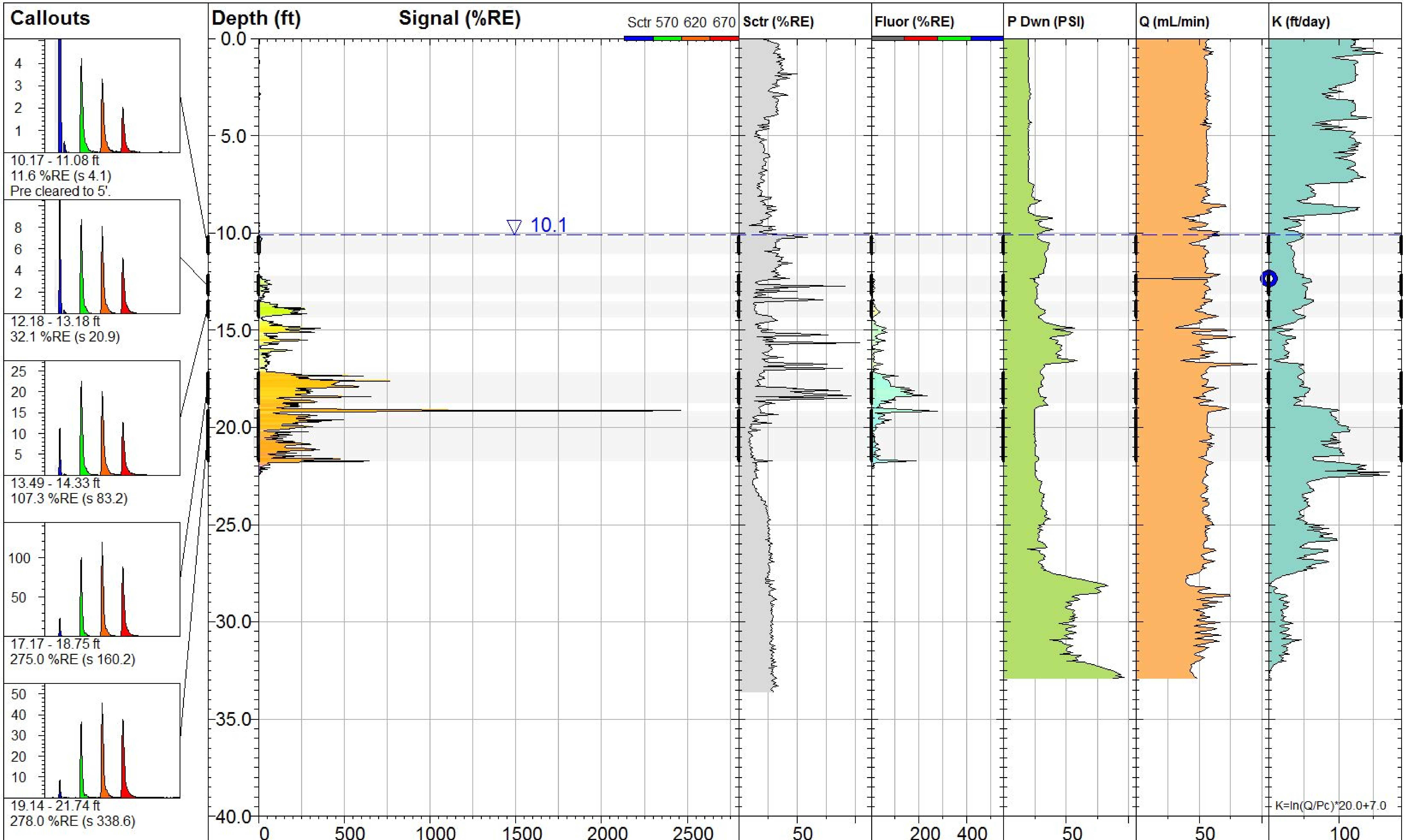


TGHP-06

TarGOST® By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
WWW.DAKOTATECHNOLOGIES.COM

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **24.69 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **1188.6 %RE @ 17.01 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-03 13:33 EDT**

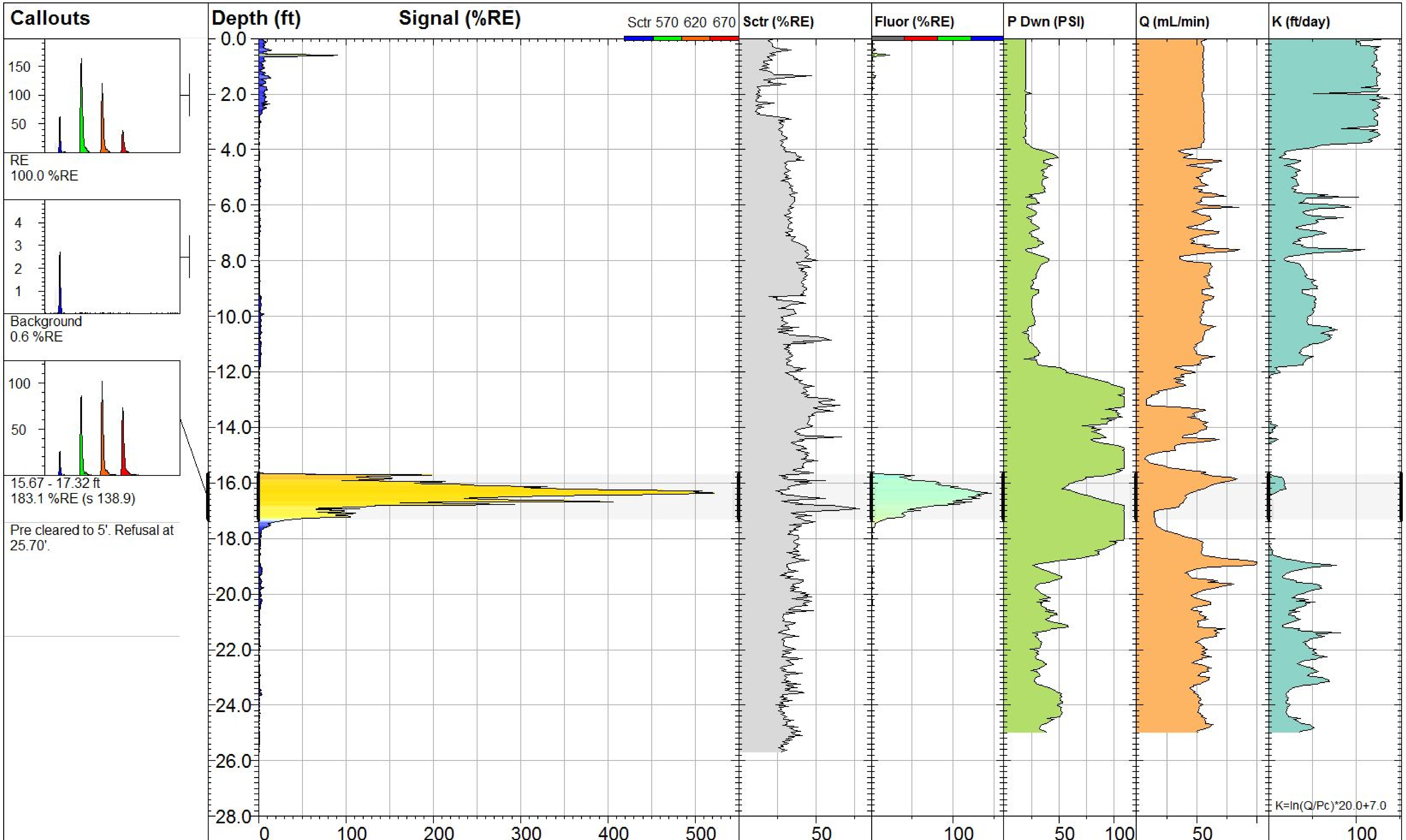


TGHP-07

TarGOST® By Dakota
www.DakotaTechnologies.com

Site: **Red Hook 3**	Y Coord.(Lat-N) / System: **Unavailable / NA**	Final depth: **33.62 ft**
Client / Job: **Arcadis /**	X Coord.(Lng-E) / Fix: **Unavailable / NA**	Max signal: **2559.0 %RE @ 19.14 ft**
Operator / Unit: **RM / TG1005**	Elevation: **Unavailable**	Date & Time: **2017-10-03 14:27 EDT**

DAKOTA TECHNOLOGIES
WWW.DAKOTATECHNOLOGIES.COM

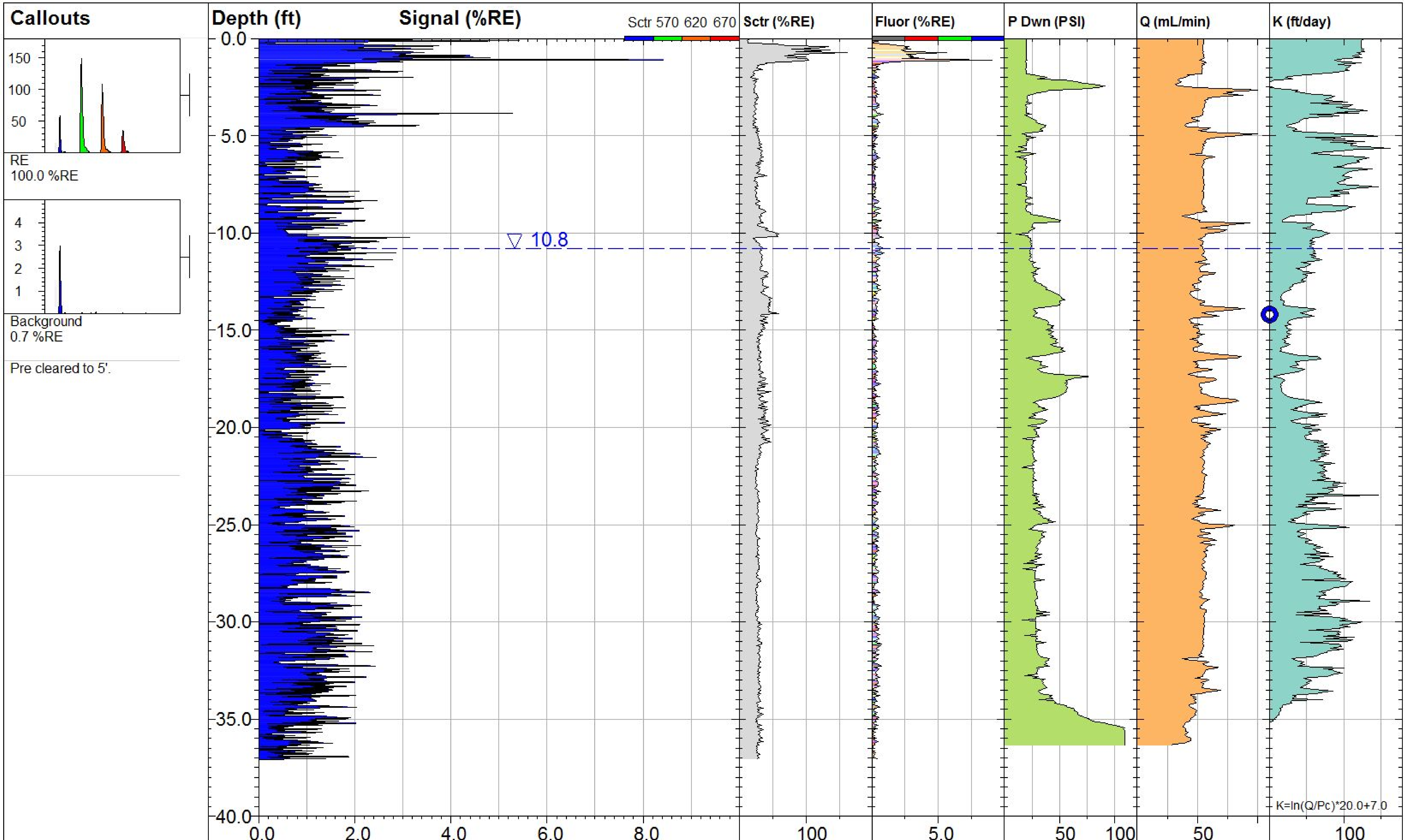


TGHP-08

TarGOST® By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
WWW.DAKOTATECHNOLOGIES.COM

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **25.70 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **522.7 %RE @ 16.37 ft**
Operator / Unit: **Rm / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-03 15:29 EDT**

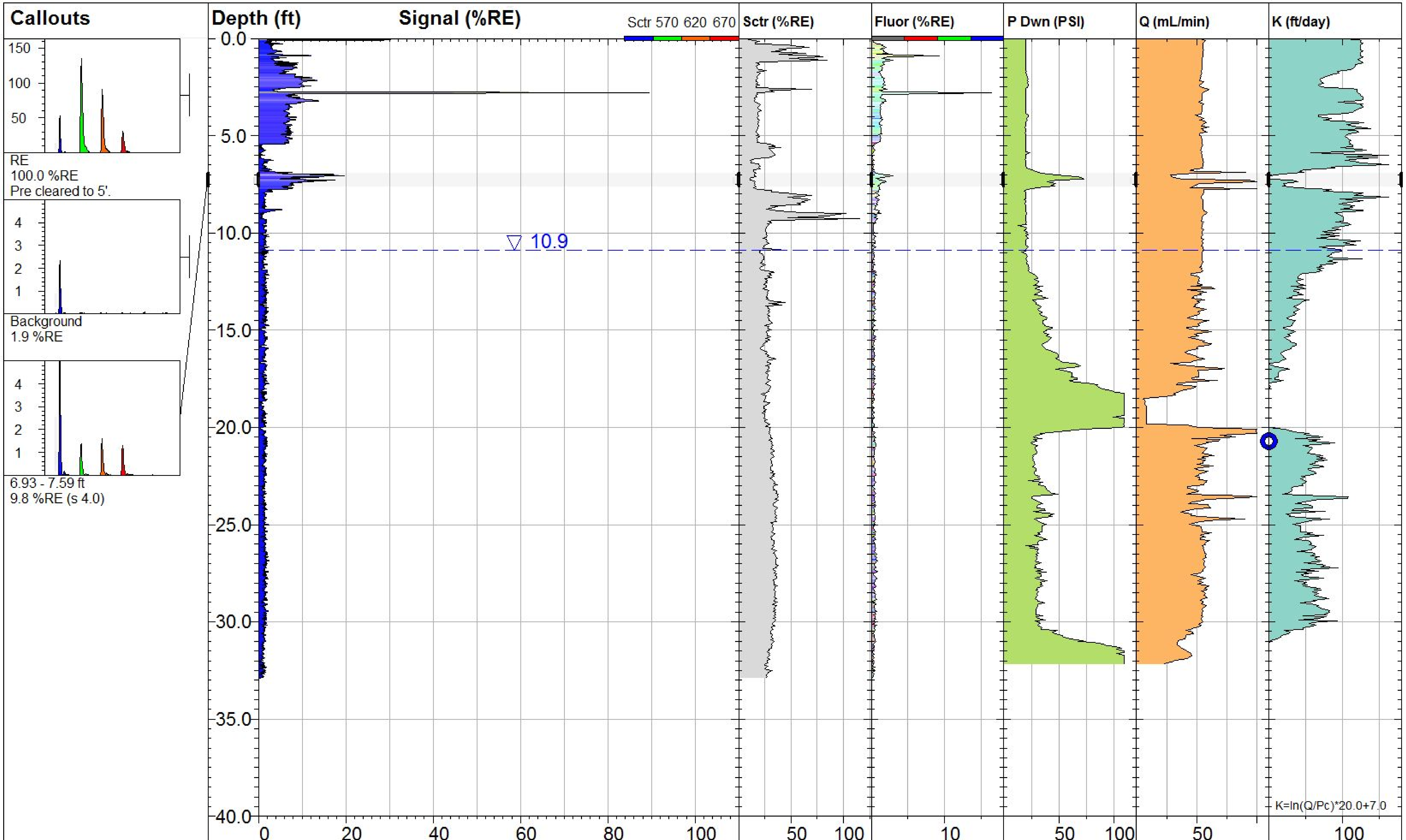


TGHP-09

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **37.06 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **8.7 %RE @ 1.10 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-04 12:52 EDT**

TarGOST® By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
WWW.DAKOTATECHNOLOGIES.COM



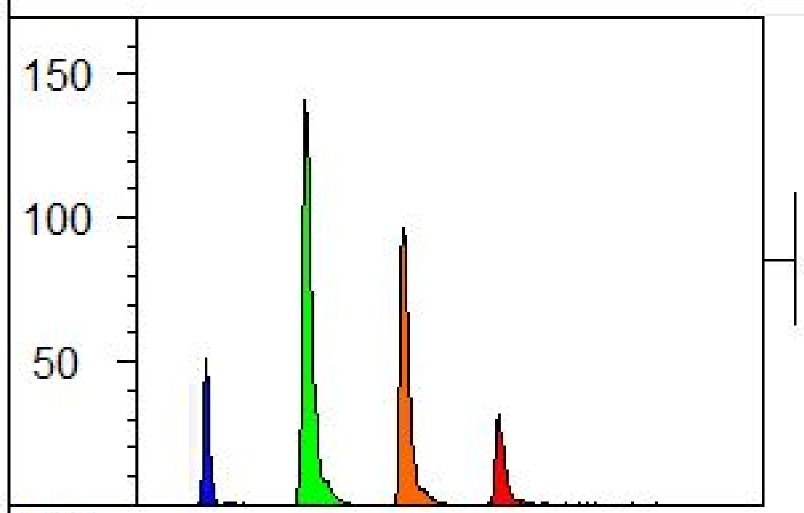
TGHP-10

TarGOST® By Dakota
www.DakotaTechnologies.com

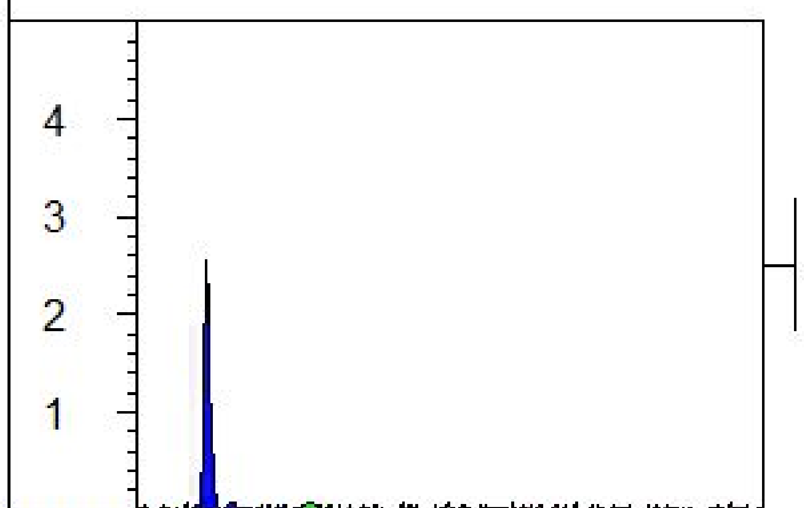
Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **32.88 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **95.7 %RE @ 2.79 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-04 11:08 EDT**

DAKOTA TECHNOLOGIES
WWW.DAKOTATECHNOLOGIES.COM

Callouts

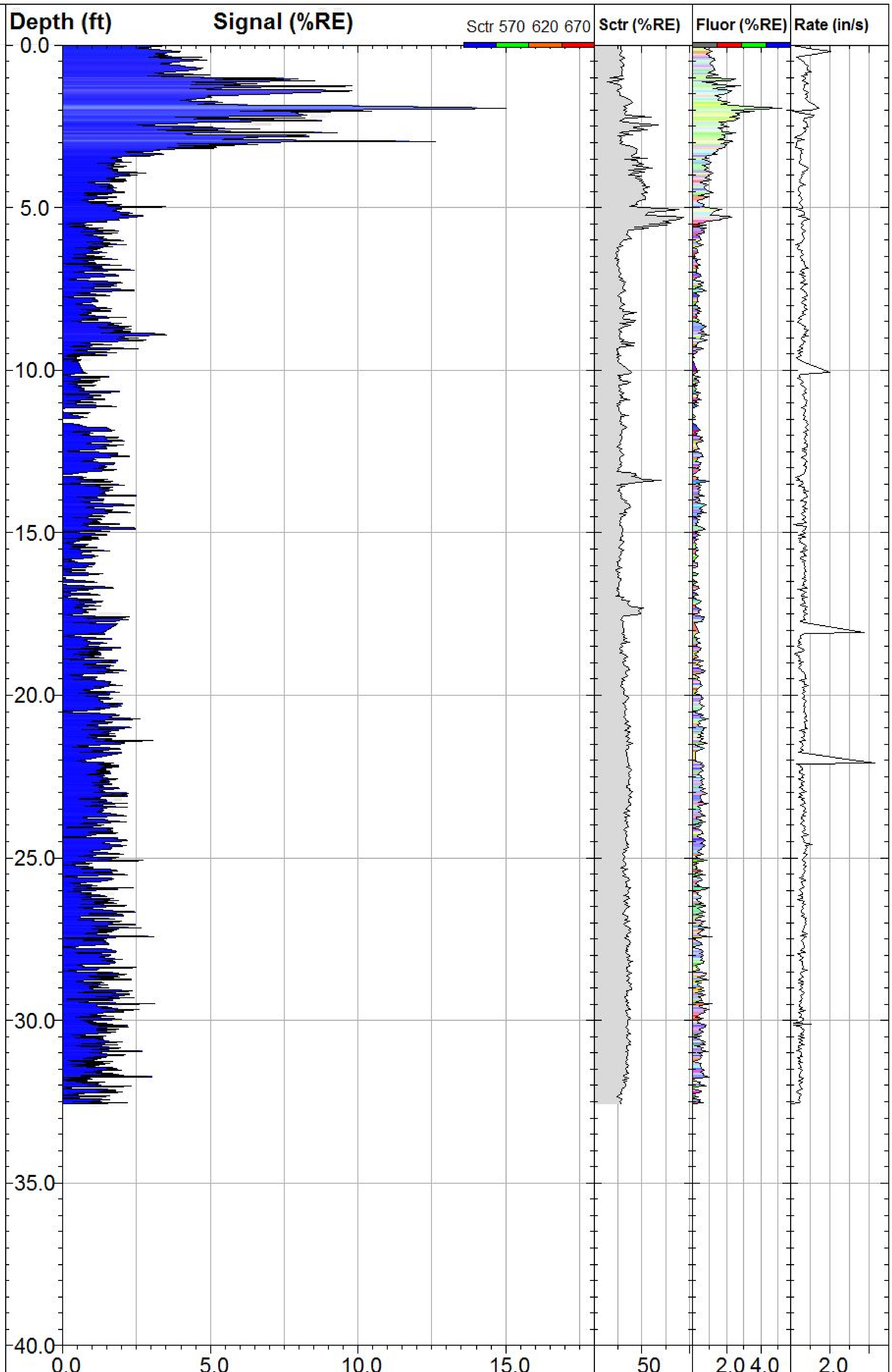


RE
100.0 %RE



Background
1.5 %RE

Pre cleared to 5'.

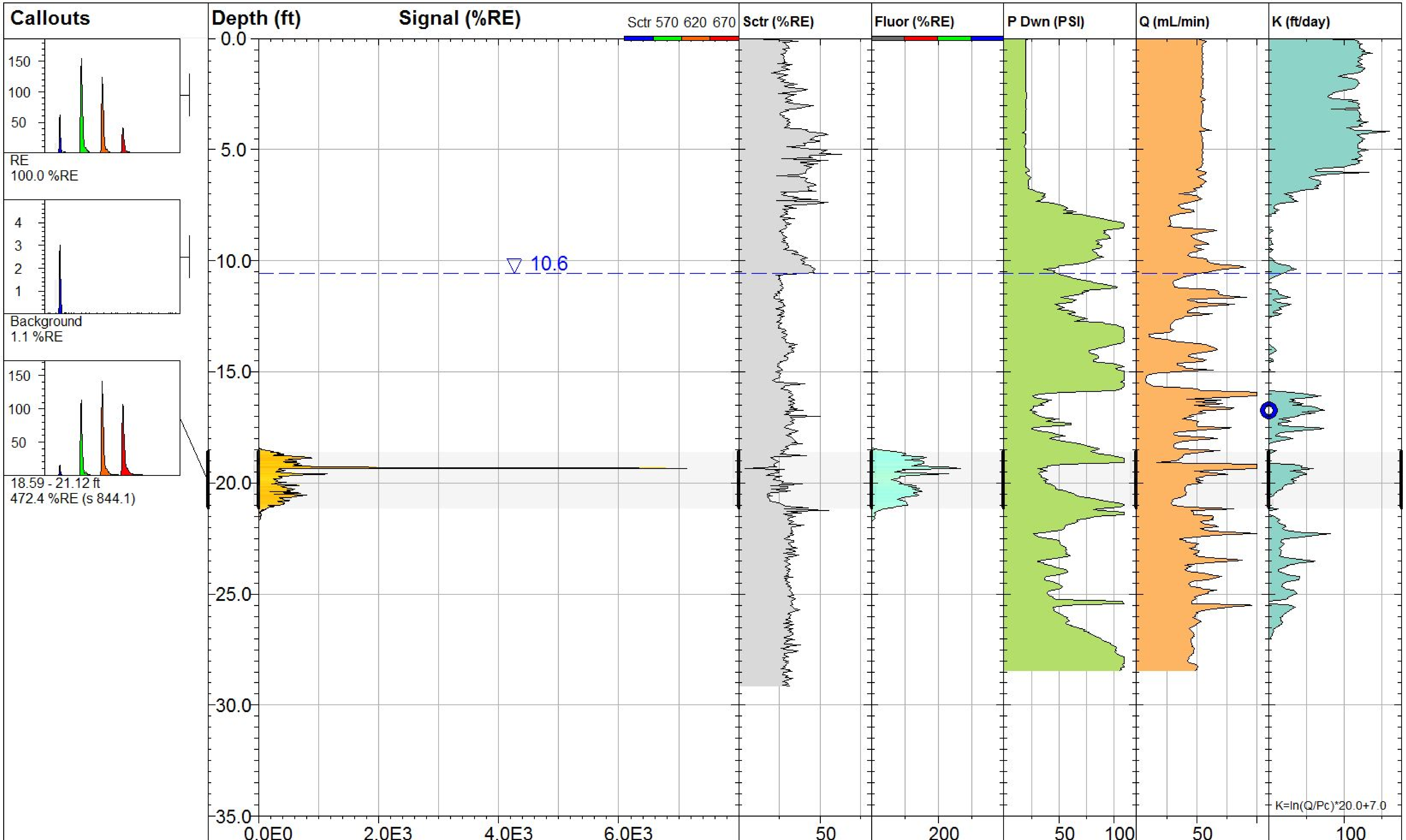


TGHP-11

TarGOST® By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
www.DakotaTechnologies.com

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **32.57 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **15.2 %RE @ 1.95 ft**
Operator / Unit: **Rm / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-04 14:52 EDT**

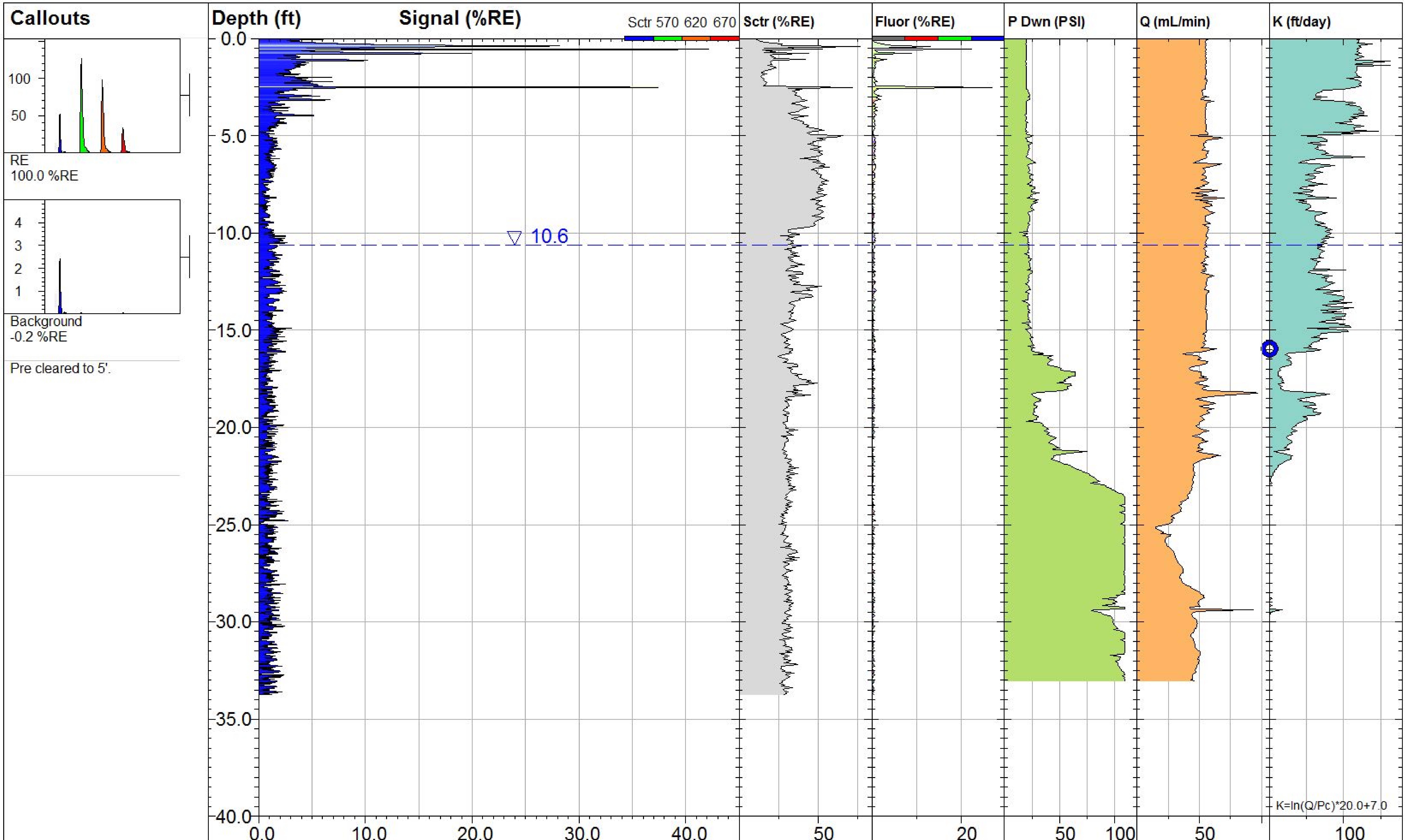


TGHP-12

TarGOST® By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
www.DakotaTechnologies.com

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **29.16 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **7498.7 %RE @ 19.34 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-05 10:06 EDT**

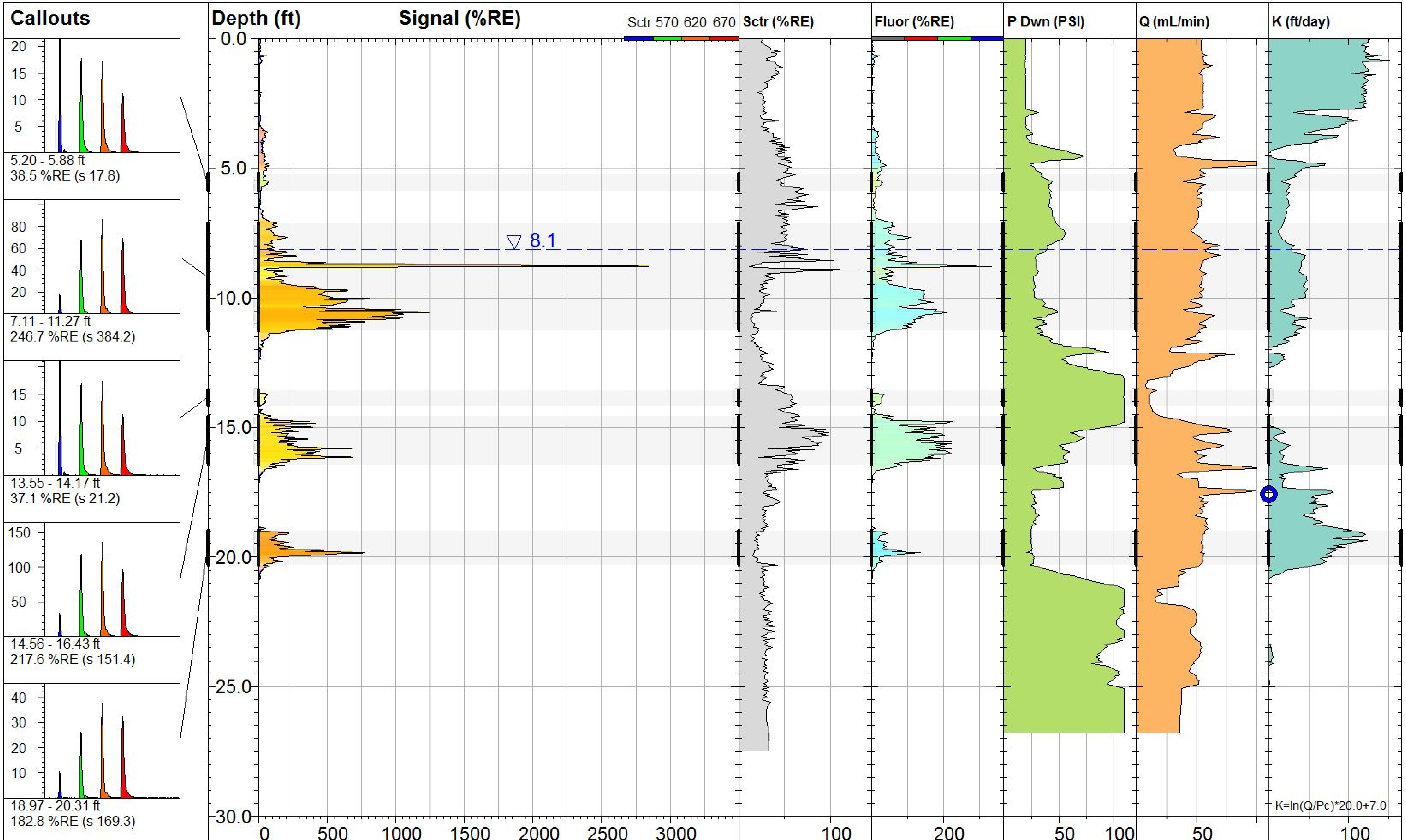


DAKOTA TECHNOLOGIES
WWW.DAKOTATECHNOLOGIES.COM

TGHP-13

TarGOST® By Dakota
www.DakotaTechnologies.com

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **33.76 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **42.3 %RE @ 0.56 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-05 11:07 EDT**

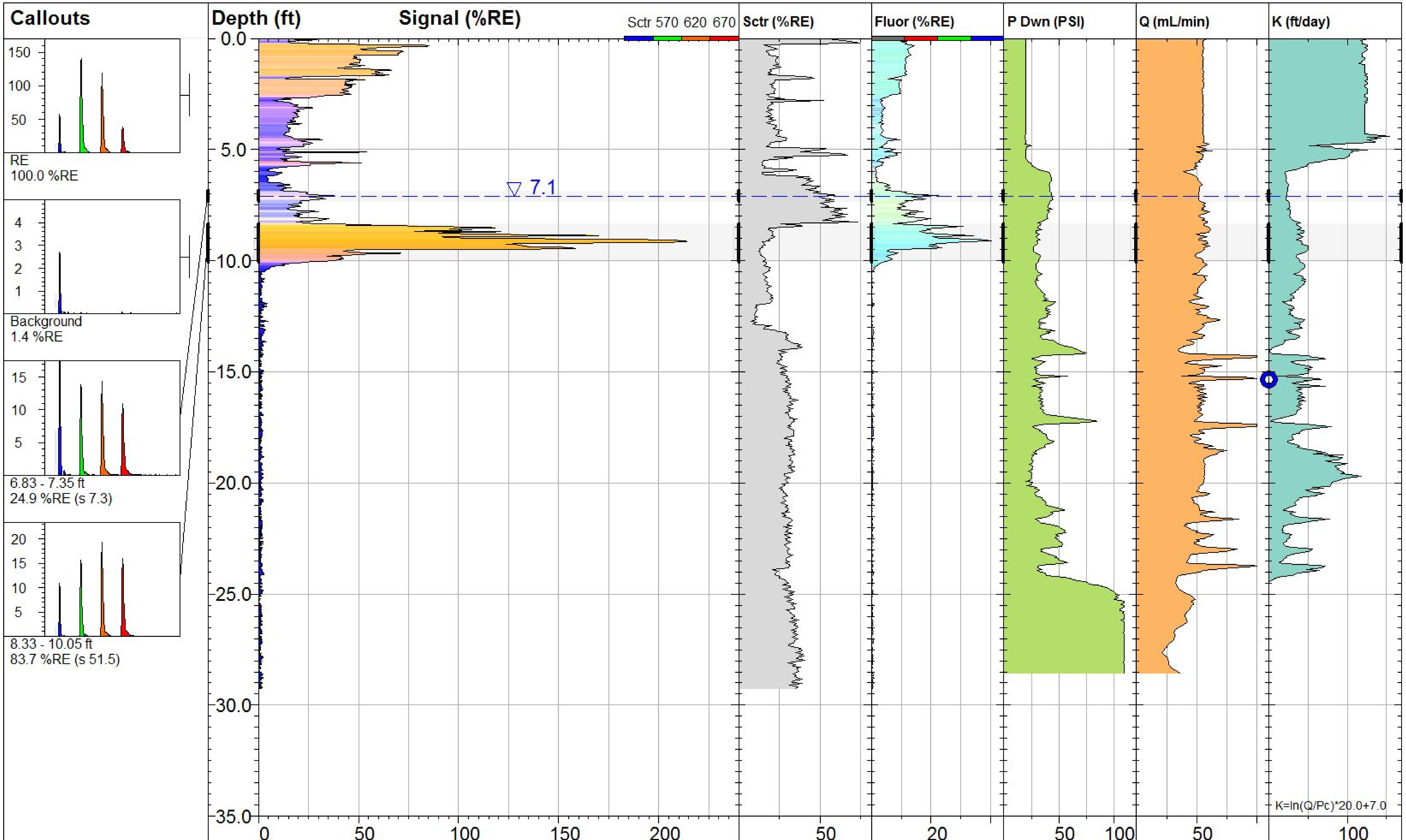


TGHP-14

TarGOST® By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
www.DakotaTechnologies.com

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **27.47 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **2868.1 %RE @ 8.78 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-05 15:18 EDT**

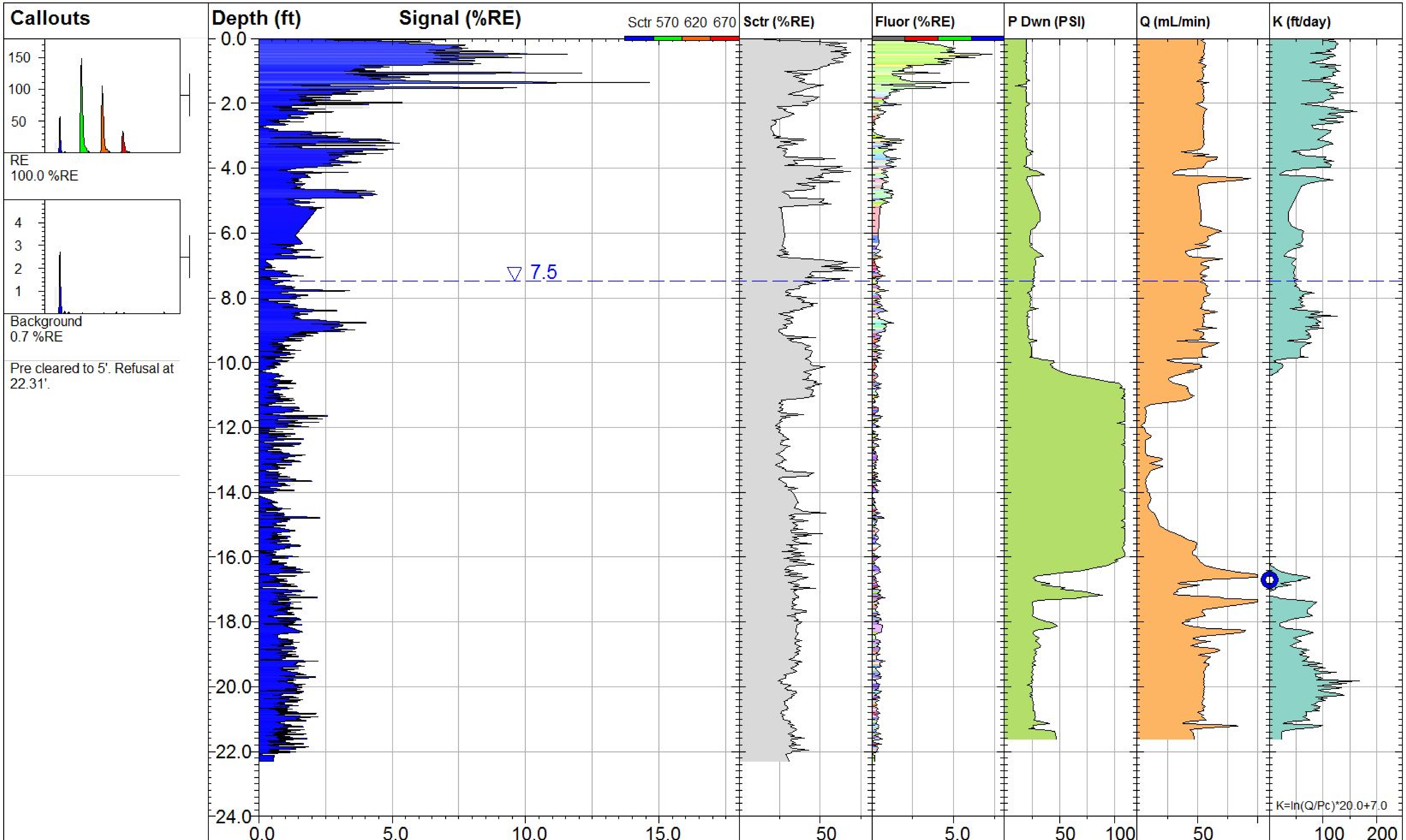


TGHP-15

TarGOST® By Dakota
www.DakotaTechnologies.com

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **29.26 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **214.2 %RE @ 9.16 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-05 16:12 EDT**

DAKOTA TECHNOLOGIES
WWW.DAKOTATECHNOLOGIES.COM

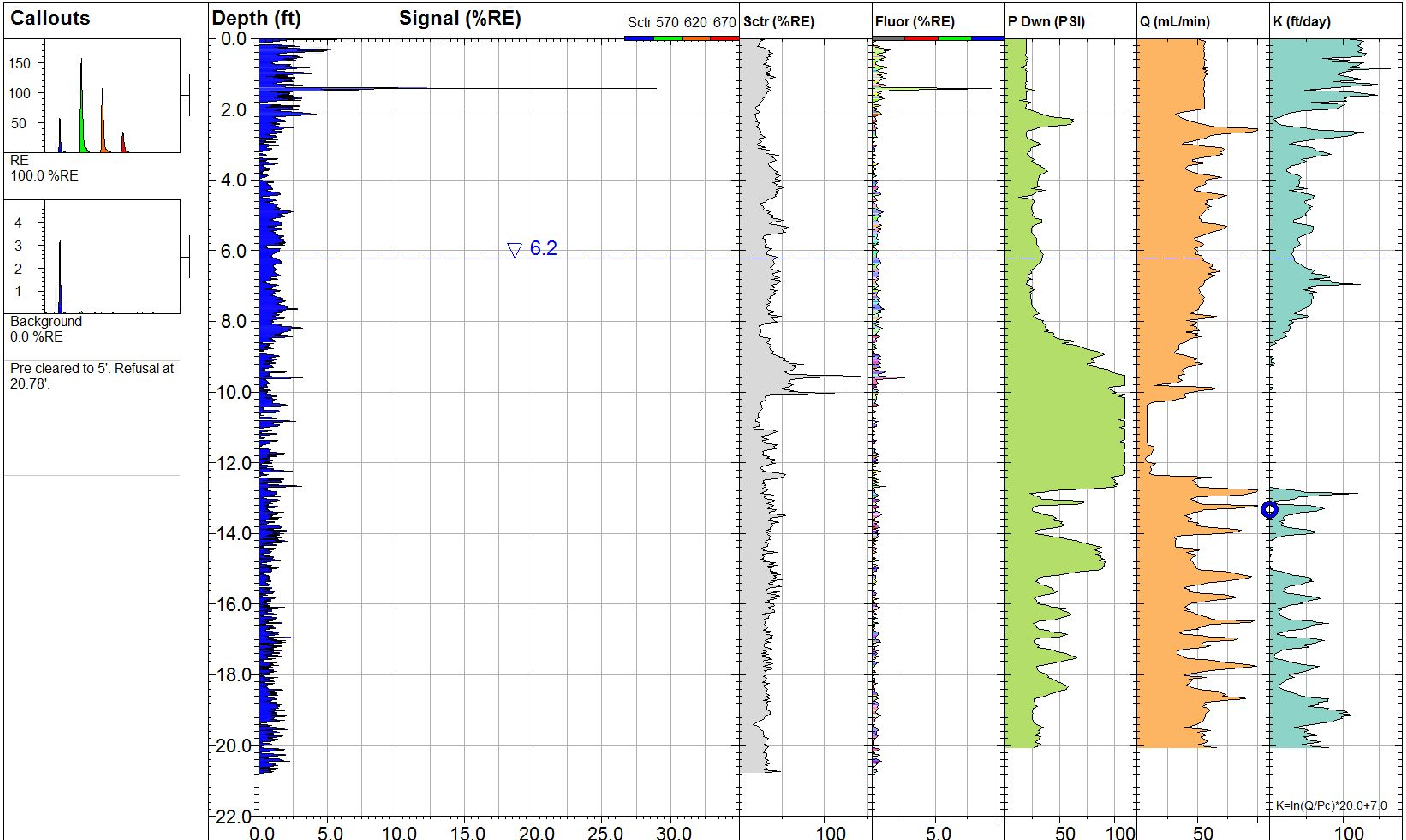


TGHP-16

TarGOST® By Dakota
www.DakotaTechnologies.com

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **22.31 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **15.0 %RE @ 1.36 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-06 08:50 EDT**

WWW.DAKOTATECHNOLOGIES.COM

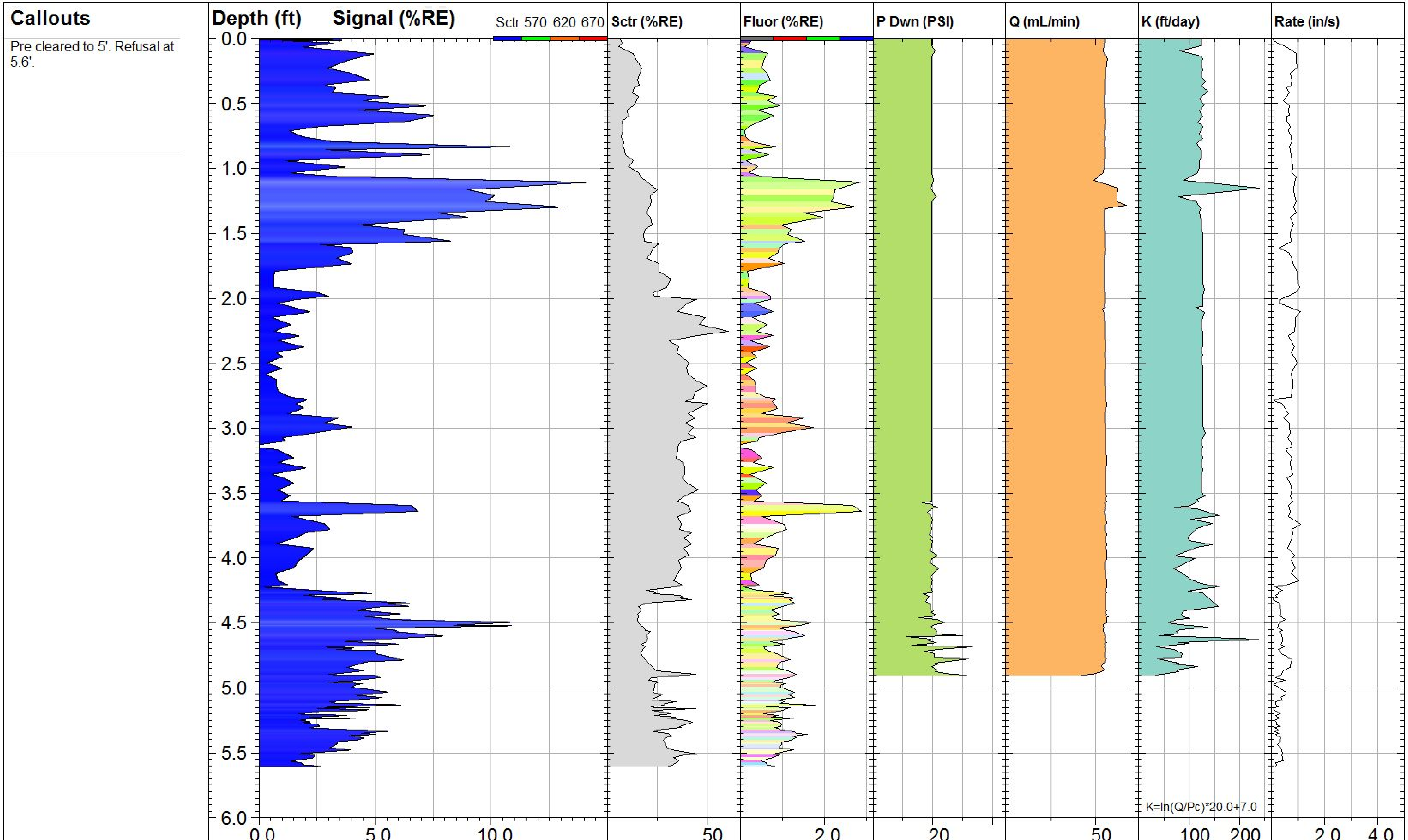


TGHP-17

TarGOST® By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
WWW.DAKOTATECHNOLOGIES.COM

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **20.78 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **29.1 %RE @ 1.42 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-06 10:01 EDT**

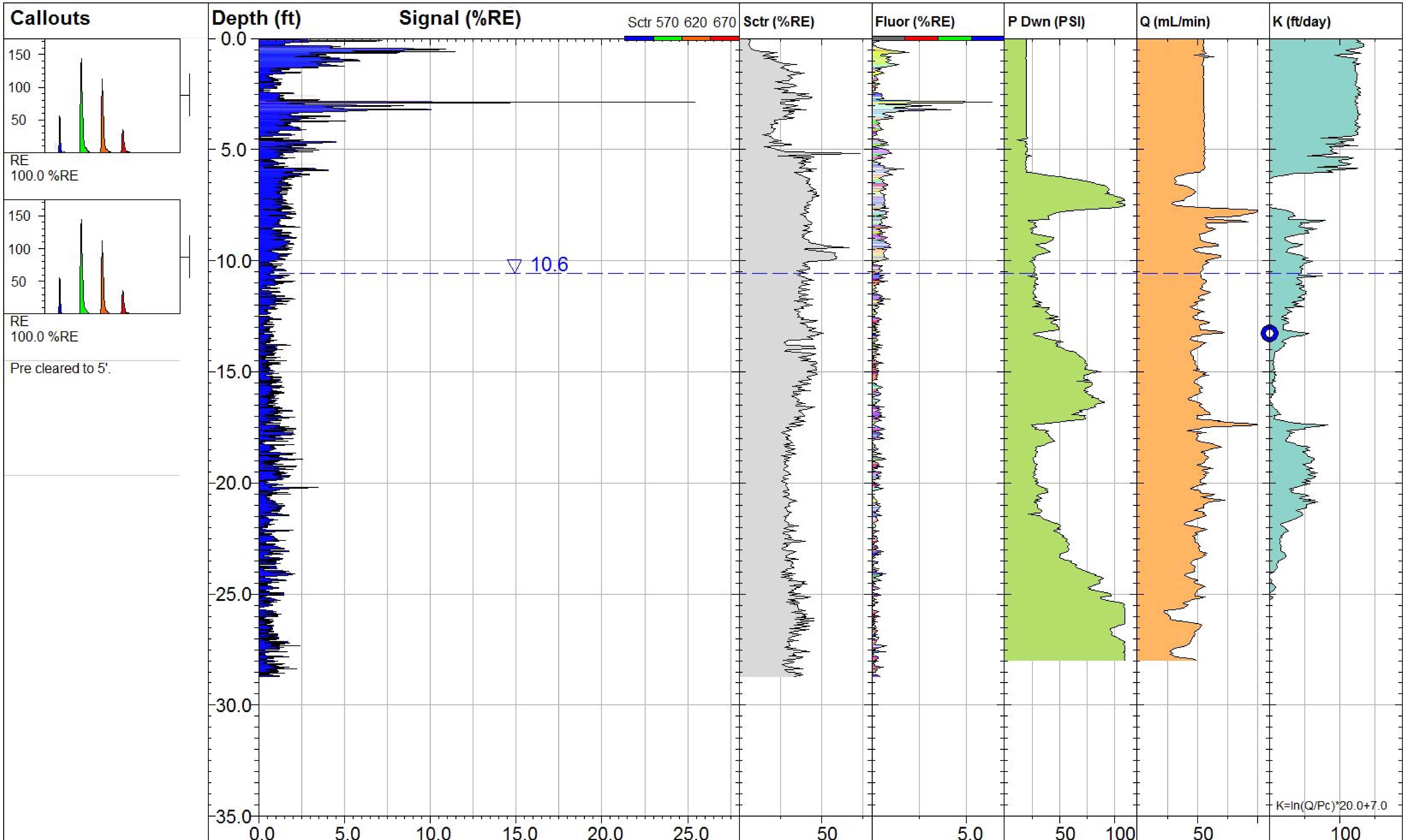


DAKOTA TECHNOLOGIES
WWW.DAKOTATECHNOLOGIES.COM

TGHP-18

TarGOST® By Dakota
www.DakotaTechnologies.com

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **5.61 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **14.2 %RE @ 1.11 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-06 11:27 EDT**

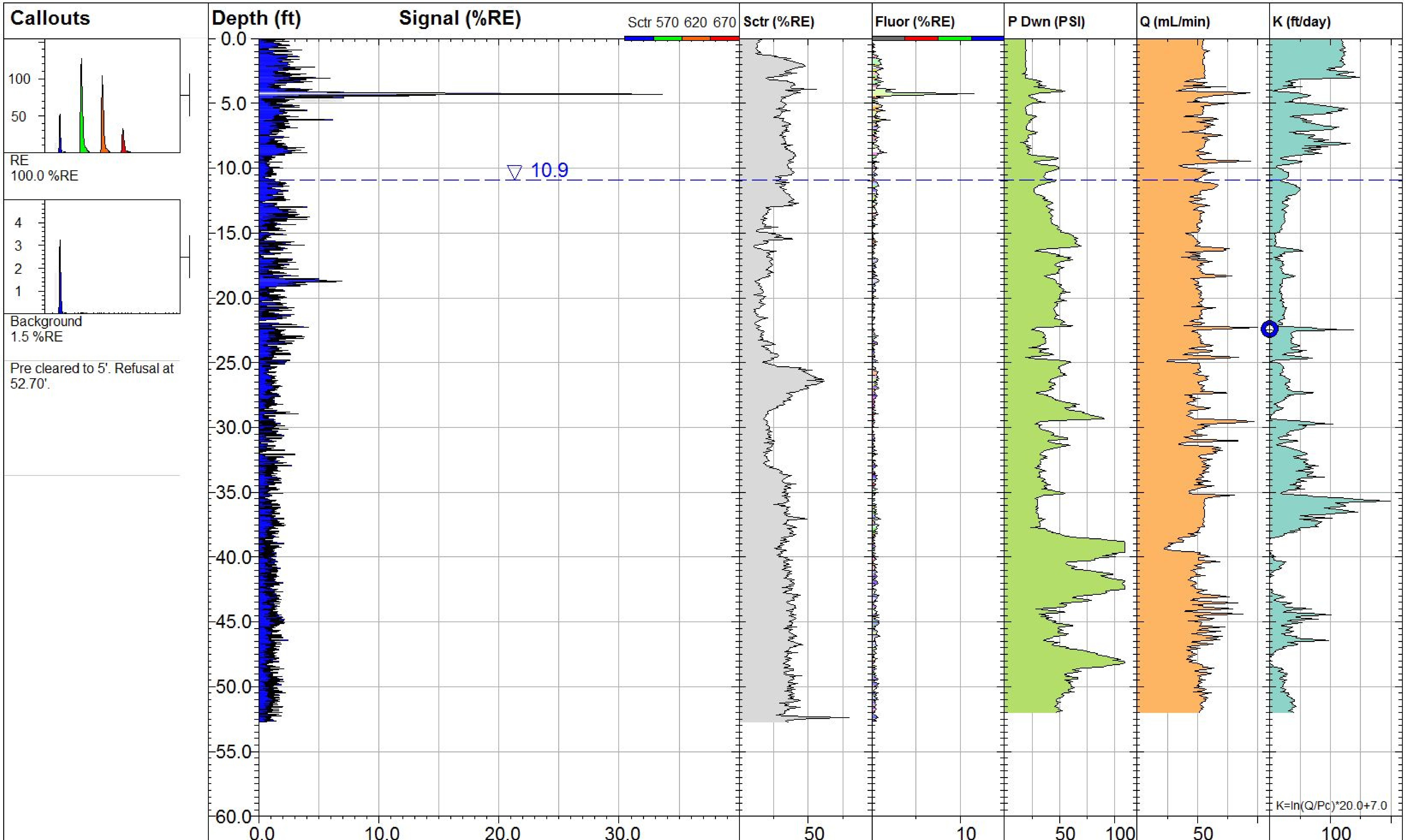


TGHP-19

TarGOST® By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
www.DakotaTechnologies.com

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **28.72 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **25.6 %RE @ 2.86 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-06 12:45 EDT**

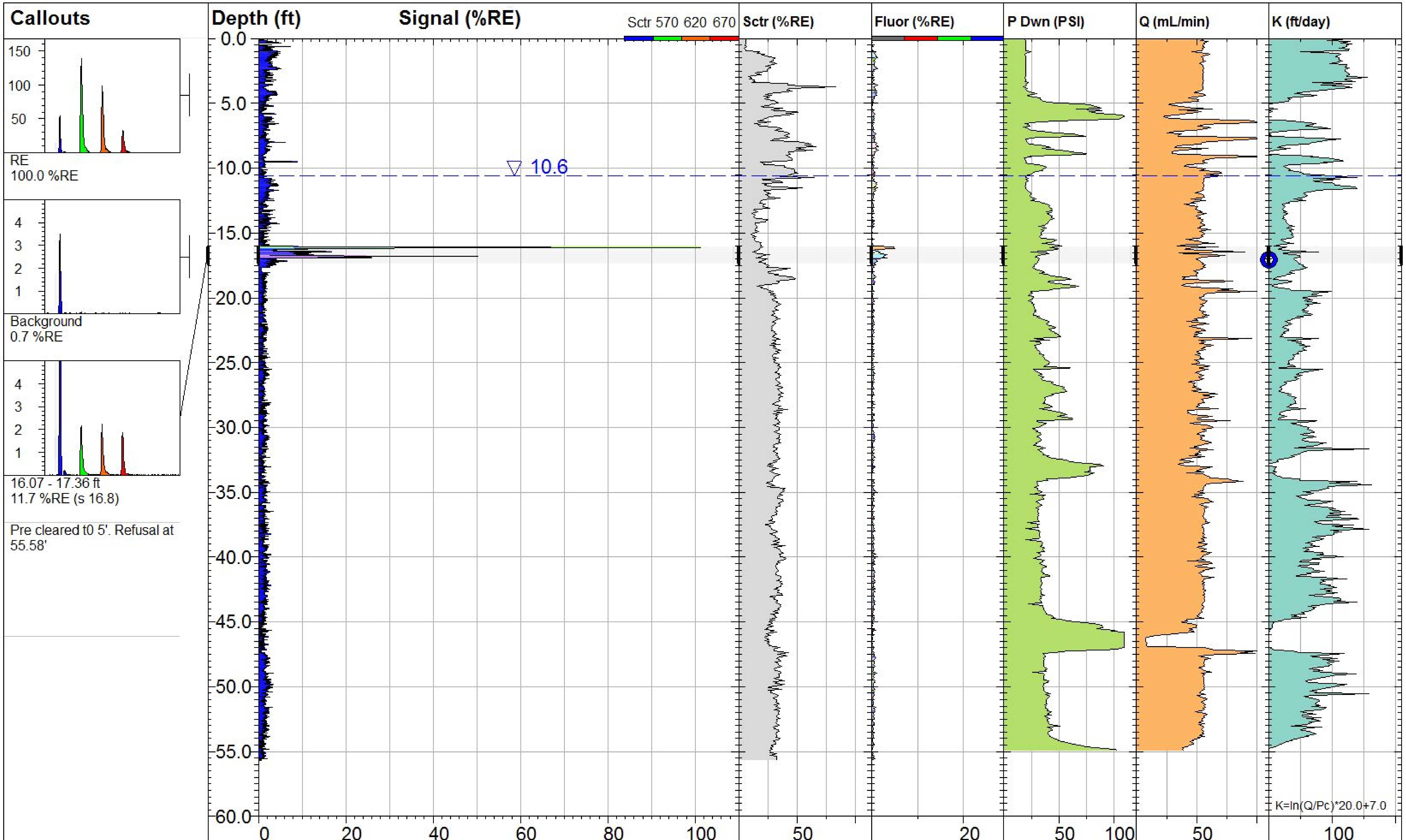


TGHP-20

TarGOST® By Dakota
www.DakotaTechnologies.com

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **52.70 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **34.1 %RE @ 4.30 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-09 14:48 EDT**

DAKOTA TECHNOLOGIES
WWW.DAKOTATECHNOLOGIES.COM



TGHP-21

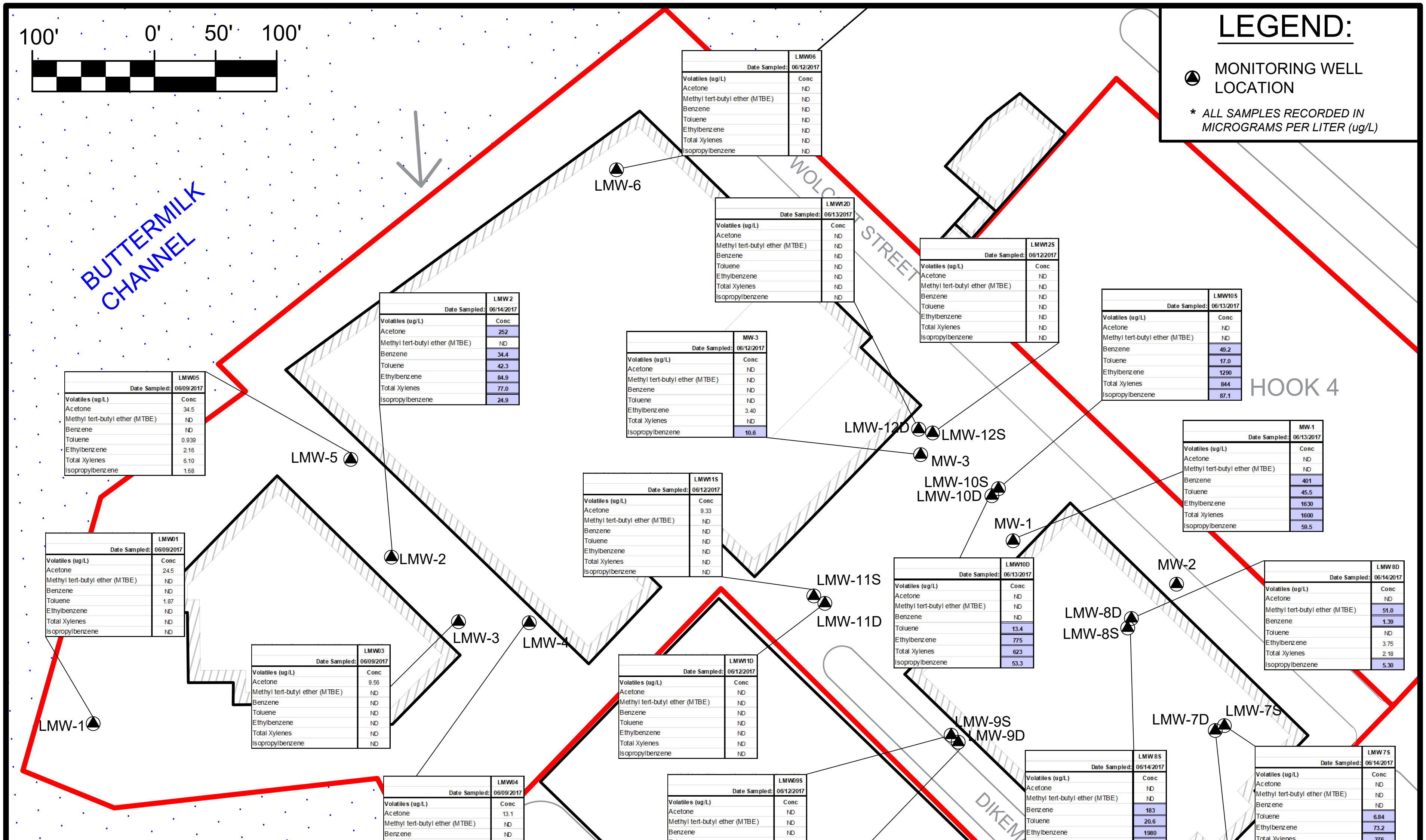
TarGOST® By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
WWW.DAKOTATECHNOLOGIES.COM

Site: **Red Hook 3**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **55.68 ft**
Client / Job: **Arcadis /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **104.9 %RE @ 16.11 ft**
Operator / Unit: **RM / TG1005**	*Elevation:* **Unavailable**	*Date & Time:* **2017-10-10 10:51 EDT**

APPENDIX B

Groundwater Results from 2017 AESI RI Report



	LMW06
Date Sampled:	06/12/2017
Volatiles (ug/L)	Conc
Acetone	ND
Methyl tert-butyl ether (MTBE)	ND
Benzene	ND
Toluene	ND
Ethylbenzene	ND
Total Xylenes	ND
Isopropylbenzene	ND

	LMW12D
Date Sampled:	06/13/2017
Volatiles (ug/L)	Conc
Acetone	ND
Methyl tert-butyl ether (MTBE)	ND
Benzene	ND
Toluene	ND
Ethylbenzene	ND
Total Xylenes	ND
Isopropylbenzene	ND

	LMW12S
Date Sampled:	06/12/2017
Volatiles (ug/L)	Conc
Acetone	ND
Methyl tert-butyl ether (MTBE)	ND
Benzene	ND
Toluene	ND
Ethylbenzene	ND
Total Xylenes	ND
Isopropylbenzene	ND

	LMW10S
Date Sampled:	06/13/2017
Volatiles (ug/L)	Conc
Acetone	ND
Methyl tert-butyl ether (MTBE)	ND
Benzene	49.2
Toluene	17.0
Ethylbenzene	1290
Total Xylenes	844
Isopropylbenzene	87.1

	LMW2
Date Sampled:	06/14/2017
Volatiles (ug/L)	Conc
Acetone	252
Methyl tert-butyl ether (MTBE)	ND
Benzene	34.4
Toluene	42.3
Ethylbenzene	84.9
Total Xylenes	77.0
Isopropylbenzene	24.9

	MW-3
Date Sampled:	06/12/2017
Volatiles (ug/L)	Conc
Acetone	ND
Methyl tert-butyl ether (MTBE)	ND
Benzene	ND
Toluene	ND
Ethylbenzene	3.40
Total Xylenes	ND
Isopropylbenzene	10.6

	LMW05
Date Sampled:	06/09/2017
Volatiles (ug/L)	Conc
Acetone	34.5
Methyl tert-butyl ether (MTBE)	ND
Benzene	ND
Toluene	0.939
Ethylbenzene	2.16
Total Xylenes	6.10
Isopropylbenzene	1.68

	MW-1
Date Sampled:	06/13/2017
Volatiles (ug/L)	Conc
Acetone	ND
Methyl tert-butyl ether (MTBE)	ND
Benzene	401
Toluene	45.5
Ethylbenzene	1630
Total Xylenes	1600
Isopropylbenzene	59.5

	LMW11S
Date Sampled:	06/12/2017
Volatiles (ug/L)	Conc
Acetone	9.33
Methyl tert-butyl ether (MTBE)	ND
Benzene	ND
Toluene	ND
Ethylbenzene	ND
Total Xylenes	ND
Isopropylbenzene	ND

	LMW01
Date Sampled:	06/09/2017
Volatiles (ug/L)	Conc
Acetone	24.5
Methyl tert-butyl ether (MTBE)	ND
Benzene	ND
Toluene	1.87
Ethylbenzene	ND
Total Xylenes	ND
Isopropylbenzene	ND

	LMW10D
Date Sampled:	06/13/2017
Volatiles (ug/L)	Conc
Acetone	ND
Methyl tert-butyl ether (MTBE)	ND
Benzene	ND
Toluene	13.4
Ethylbenzene	775
Total Xylenes	623
Isopropylbenzene	53.3

	LMW8D
Date Sampled:	06/14/2017
Volatiles (ug/L)	Conc
Acetone	ND
Methyl tert-butyl ether (MTBE)	51.0
Benzene	1.39
Toluene	ND
Ethylbenzene	3.75
Total Xylenes	2.18
Isopropylbenzene	5.30

	LMW03
Date Sampled:	06/09/2017
Volatiles (ug/L)	Conc
Acetone	9.56
Methyl tert-butyl ether (MTBE)	ND
Benzene	ND
Toluene	ND
Ethylbenzene	ND
Total Xylenes	ND
Isopropylbenzene	ND

	LMW11D
Date Sampled:	06/12/2017
Volatiles (ug/L)	Conc
Acetone	ND
Methyl tert-butyl ether (MTBE)	ND
Benzene	ND
Toluene	ND
Ethylbenzene	ND
Total Xylenes	ND
Isopropylbenzene	ND

	LMW8S
Date Sampled:	06/14/2017
Volatiles (ug/L)	Conc
Acetone	ND
Methyl tert-butyl ether (MTBE)	ND
Benzene	183
Toluene	20.6
Ethylbenzene	1980
Total Xylenes	2920
Isopropylbenzene	123

	LMW7S
Date Sampled:	06/14/2017
Volatiles (ug/L)	Conc
Acetone	ND
Methyl tert-butyl ether (MTBE)	ND
Benzene	ND
Toluene	6.84
Ethylbenzene	73.2
Total Xylenes	276
Isopropylbenzene	45.6

	LMW04
Date Sampled:	06/09/2017
Volatiles (ug/L)	Conc
Acetone	13.1
Methyl tert-butyl ether (MTBE)	ND
Benzene	ND
Toluene	ND
Ethylbenzene	ND
Total Xylenes	ND
Isopropylbenzene	ND

	LMW09S
Date Sampled:	06/12/2017
Volatiles (ug/L)	Conc
Acetone	ND
Methyl tert-butyl ether (MTBE)	ND
Benzene	ND
Toluene	ND
Ethylbenzene	ND
Total Xylenes	ND
Isopropylbenzene	ND

	LMW09D
Date Sampled:	06/12/2017
Volatiles (ug/L)	Conc
Acetone	ND
Methyl tert-butyl ether (MTBE)	ND
Benzene	ND
Toluene	ND
Ethylbenzene	5.21
Total Xylenes	2.46
Isopropylbenzene	0.900

	TMW-1
Date Sampled:	06/12/2017
Volatiles (ug/L)	Conc
Acetone	ND
Methyl tert-butyl ether (MTBE)	ND
Benzene	ND
Toluene	ND
Ethylbenzene	ND
Total Xylenes	ND
Isopropylbenzene	ND

	LMW7D
Date Sampled:	06/14/2017
Volatiles (ug/L)	Conc
Acetone	11.4
Methyl tert-butyl ether (MTBE)	2.93
Benzene	56.8
Toluene	3.54
Ethylbenzene	53.5
Total Xylenes	151
Isopropylbenzene	19.0

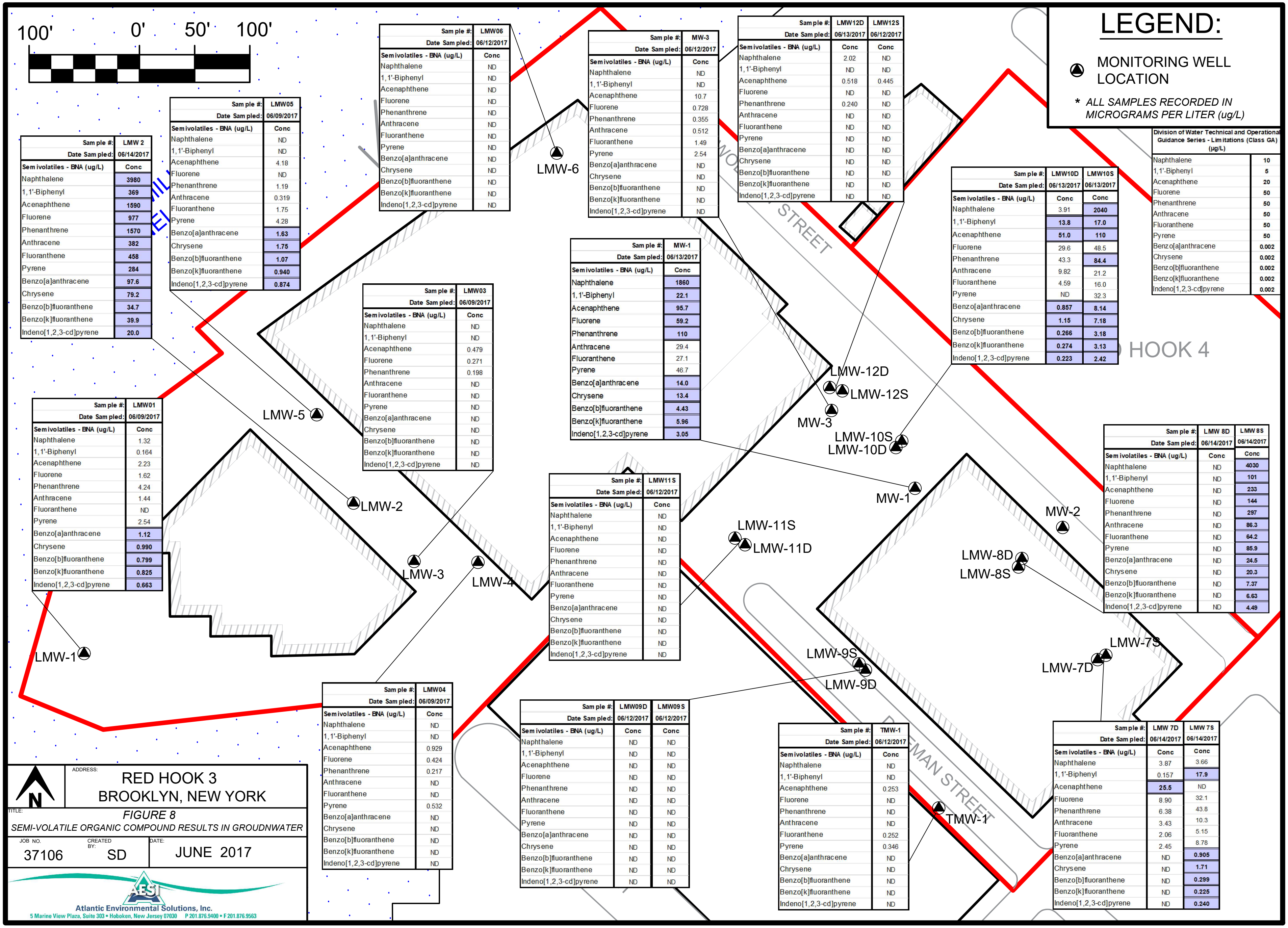
Division of Water Technical and Operational Guidance Series - Limitations (Class GA) (µg/L)	
Acetone	50
Methyl tert-butyl ether (MTBE)	10
Benzene	1
Toluene	5
Ethylbenzene	5
Total Xylenes	15
Isopropylbenzene	5

ADDRESS: RED HOOK 3
BROOKLYN, NEW YORK

TITLE: FIGURE 7
VOLATILE ORGANIC COMPOUND RESULTS IN GROUDNWATER

JOB NO.	CREATED BY:	DATE:
37106	SD	JUNE 2017

Atlantic Environmental Solutions, Inc.
5 Marine View Plaza, Suite 303 • Hoboken, New Jersey 07030 P 201.876.9400 • F 201.876.9563



LEGEND:

MONITORING WELL LOCATION

* *ALL SAMPLES RECORDED IN MICROGRAMS PER LITER (ug/L)*

Division of Water Technical and Operational Guidance Series - Limitations (Class GA) (µg/L)	
Naphthalene	10
1,1'-Biphenyl	5
Acenaphthene	20
Fluorene	50
Phenanthrene	50
Anthracene	50
Fluoranthene	50
Pyrene	50
Benzo[a]anthracene	0.002
Chrysene	0.002
Benzo[b]fluoranthene	0.002
Benzo[k]fluoranthene	0.002
Indeno[1,2,3-cd]pyrene	0.002

Sample #:	LMW 2
Date Sampled:	06/14/2017
Semivolatiles - BNA (ug/L)	Conc
Naphthalene	3980
1,1'-Biphenyl	369
Acenaphthene	1590
Fluorene	977
Phenanthrene	1570
Anthracene	382
Fluoranthene	458
Pyrene	284
Benzo[a]anthracene	97.6
Chrysene	79.2
Benzo[b]fluoranthene	34.7
Benzo[k]fluoranthene	39.9
Indeno[1,2,3-cd]pyrene	20.0

Sample #:	LMW05
Date Sampled:	06/09/2017
Semivolatiles - BNA (ug/L)	Conc
Naphthalene	ND
1,1'-Biphenyl	ND
Acenaphthene	4.18
Fluorene	ND
Phenanthrene	1.19
Anthracene	0.319
Fluoranthene	1.75
Pyrene	4.28
Benzo[a]anthracene	1.63
Chrysene	1.75
Benzo[b]fluoranthene	1.07
Benzo[k]fluoranthene	0.940
Indeno[1,2,3-cd]pyrene	0.874

Sample #:	LMW06
Date Sampled:	06/12/2017
Semivolatiles - BNA (ug/L)	Conc
Naphthalene	ND
1,1'-Biphenyl	ND
Acenaphthene	ND
Fluorene	ND
Phenanthrene	ND
Anthracene	ND
Fluoranthene	ND
Pyrene	ND
Benzo[a]anthracene	ND
Chrysene	ND
Benzo[b]fluoranthene	ND
Benzo[k]fluoranthene	ND
Indeno[1,2,3-cd]pyrene	ND

Sample #:	MW-3
Date Sampled:	06/12/2017
Semivolatiles - BNA (ug/L)	Conc
Naphthalene	ND
1,1'-Biphenyl	ND
Acenaphthene	10.7
Fluorene	0.728
Phenanthrene	0.355
Anthracene	0.512
Fluoranthene	1.49
Pyrene	2.54
Benzo[a]anthracene	ND
Chrysene	ND
Benzo[b]fluoranthene	ND
Benzo[k]fluoranthene	ND
Indeno[1,2,3-cd]pyrene	ND

Sample #:	LMW12D	LMW12S
Date Sampled:	06/13/2017	06/12/2017
Semivolatiles - BNA (ug/L)	Conc	Conc
Naphthalene	2.02	ND
1,1'-Biphenyl	ND	ND
Acenaphthene	0.518	0.445
Fluorene	ND	ND
Phenanthrene	0.240	ND
Anthracene	ND	ND
Fluoranthene	ND	ND
Pyrene	ND	ND
Benzo[a]anthracene	ND	ND
Chrysene	ND	ND
Benzo[b]fluoranthene	ND	ND
Benzo[k]fluoranthene	ND	ND
Indeno[1,2,3-cd]pyrene	ND	ND

Sample #:	LMW10D	LMW10S
Date Sampled:	06/13/2017	06/13/2017
Semivolatiles - BNA (ug/L)	Conc	Conc
Naphthalene	3.91	2040
1,1'-Biphenyl	13.8	17.0
Acenaphthene	51.0	110
Fluorene	29.6	48.5
Phenanthrene	43.3	84.4
Anthracene	9.82	21.2
Fluoranthene	4.59	16.0
Pyrene	ND	32.3
Benzo[a]anthracene	0.857	8.14
Chrysene	1.15	7.18
Benzo[b]fluoranthene	0.266	3.18
Benzo[k]fluoranthene	0.274	3.13
Indeno[1,2,3-cd]pyrene	0.223	2.42

Sample #:	LMW03
Date Sampled:	06/09/2017
Semivolatiles - BNA (ug/L)	Conc
Naphthalene	ND
1,1'-Biphenyl	ND
Acenaphthene	0.479
Fluorene	0.271
Phenanthrene	0.198
Anthracene	ND
Fluoranthene	ND
Pyrene	ND
Benzo[a]anthracene	ND
Chrysene	ND
Benzo[b]fluoranthene	ND
Benzo[k]fluoranthene	ND
Indeno[1,2,3-cd]pyrene	ND

Sample #:	MW-1
Date Sampled:	06/13/2017
Semivolatiles - BNA (ug/L)	Conc
Naphthalene	1860
1,1'-Biphenyl	22.1
Acenaphthene	95.7
Fluorene	59.2
Phenanthrene	110
Anthracene	29.4
Fluoranthene	27.1
Pyrene	46.7
Benzo[a]anthracene	14.0
Chrysene	13.4
Benzo[b]fluoranthene	4.43
Benzo[k]fluoranthene	5.96
Indeno[1,2,3-cd]pyrene	3.05

Sample #:	LMW01
Date Sampled:	06/09/2017
Semivolatiles - BNA (ug/L)	Conc
Naphthalene	1.32
1,1'-Biphenyl	0.164
Acenaphthene	2.23
Fluorene	1.62
Phenanthrene	4.24
Anthracene	1.44
Fluoranthene	ND
Pyrene	2.54
Benzo[a]anthracene	1.12
Chrysene	0.990
Benzo[b]fluoranthene	0.799
Benzo[k]fluoranthene	0.825
Indeno[1,2,3-cd]pyrene	0.663

Sample #:	LMW11S
Date Sampled:	06/12/2017
Semivolatiles - BNA (ug/L)	Conc
Naphthalene	ND
1,1'-Biphenyl	ND
Acenaphthene	ND
Fluorene	ND
Phenanthrene	ND
Anthracene	ND
Fluoranthene	ND
Pyrene	ND
Benzo[a]anthracene	ND
Chrysene	ND
Benzo[b]fluoranthene	ND
Benzo[k]fluoranthene	ND
Indeno[1,2,3-cd]pyrene	ND

Sample #:	LMW 8D	LMW 8S
Date Sampled:	06/14/2017	06/14/2017
Semivolatiles - BNA (ug/L)	Conc	Conc
Naphthalene	ND	4030
1,1'-Biphenyl	ND	101
Acenaphthene	ND	233
Fluorene	ND	144
Phenanthrene	ND	297
Anthracene	ND	86.3
Fluoranthene	ND	64.2
Pyrene	ND	85.9
Benzo[a]anthracene	ND	24.5
Chrysene	ND	20.3
Benzo[b]fluoranthene	ND	7.37
Benzo[k]fluoranthene	ND	6.63
Indeno[1,2,3-cd]pyrene	ND	4.49

Sample #:	LMW04
Date Sampled:	06/09/2017
Semivolatiles - BNA (ug/L)	Conc
Naphthalene	ND
1,1'-Biphenyl	ND
Acenaphthene	0.929
Fluorene	0.424
Phenanthrene	0.217
Anthracene	ND
Fluoranthene	ND
Pyrene	0.532
Benzo[a]anthracene	ND
Chrysene	ND
Benzo[b]fluoranthene	ND
Benzo[k]fluoranthene	ND
Indeno[1,2,3-cd]pyrene	ND

Sample #:	LMW09D	LMW09S
Date Sampled:	06/12/2017	06/12/2017
Semivolatiles - BNA (ug/L)	Conc	Conc
Naphthalene	ND	ND
1,1'-Biphenyl	ND	ND
Acenaphthene	ND	ND
Fluorene	ND	ND
Phenanthrene	ND	ND
Anthracene	ND	ND
Fluoranthene	ND	ND
Pyrene	ND	ND
Benzo[a]anthracene	ND	ND
Chrysene	ND	ND
Benzo[b]fluoranthene	ND	ND
Benzo[k]fluoranthene	ND	ND
Indeno[1,2,3-cd]pyrene	ND	ND

Sample #:	TMW-1
Date Sampled:	06/12/2017
Semivolatiles - BNA (ug/L)	Conc
Naphthalene	ND
1,1'-Biphenyl	ND
Acenaphthene	0.253
Fluorene	ND
Phenanthrene	ND
Anthracene	ND
Fluoranthene	0.252
Pyrene	0.346
Benzo[a]anthracene	ND
Chrysene	ND
Benzo[b]fluoranthene	ND
Benzo[k]fluoranthene	ND
Indeno[1,2,3-cd]pyrene	ND

Sample #:	LMW 7D	LMW 7S
Date Sampled:	06/14/2017	06/14/2017
Semivolatiles - BNA (ug/L)	Conc	Conc
Naphthalene	3.87	3.66
1,1'-Biphenyl	0.157	17.9
Acenaphthene	25.5	ND
Fluorene	8.90	32.1
Phenanthrene	6.38	43.8
Anthracene	3.43	10.3
Fluoranthene	2.06	5.15
Pyrene	2.45	8.78
Benzo[a]anthracene	ND	0.905
Chrysene	ND	1.71
Benzo[b]fluoranthene	ND	0.299
Benzo[k]fluoranthene	ND	0.225
Indeno[1,2,3-cd]pyrene	ND	0.240

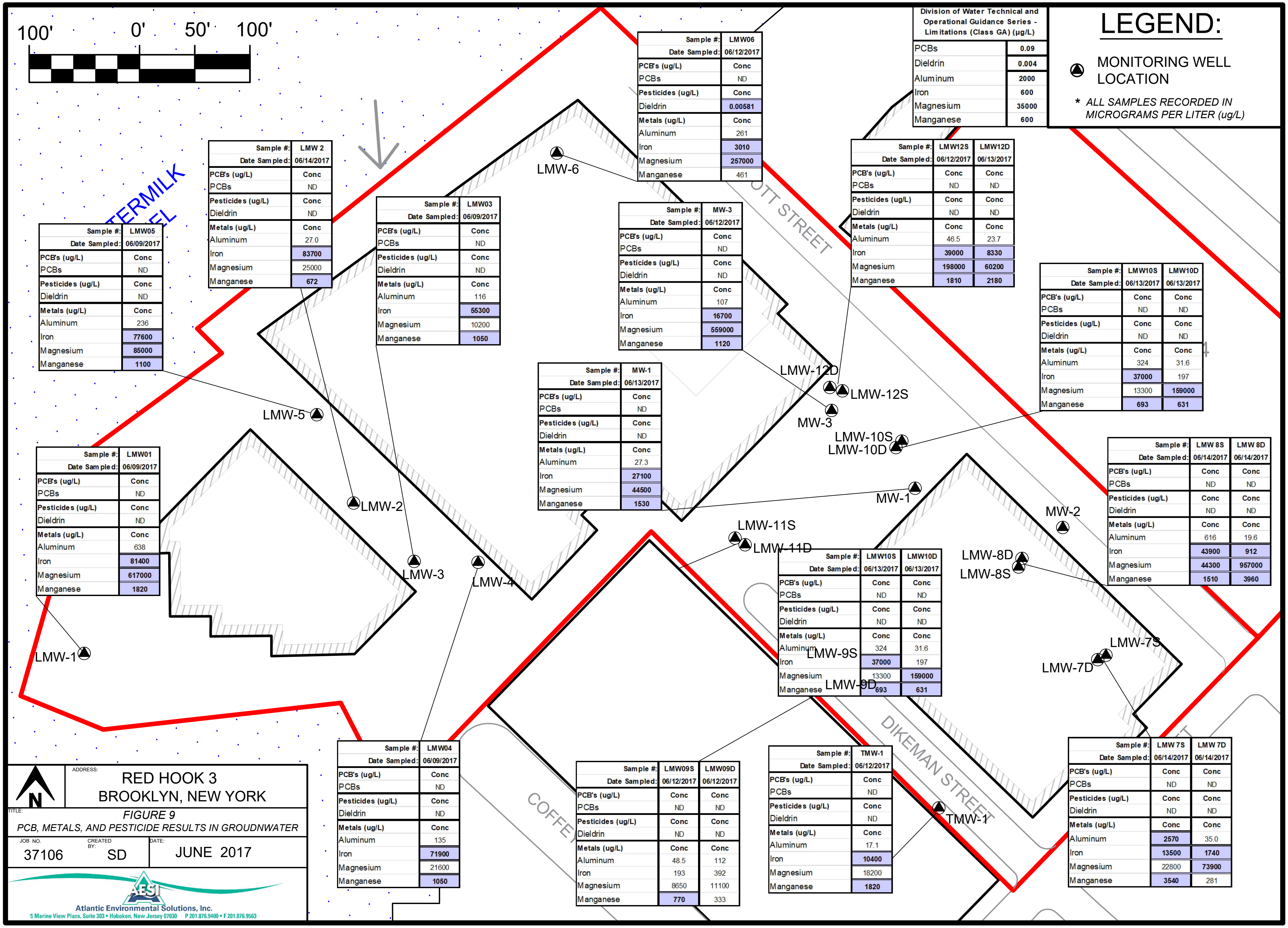
N

ADDRESS:
RED HOOK 3
BROOKLYN, NEW YORK

TITLE:
FIGURE 8
SEMI-VOLATILE ORGANIC COMPOUND RESULTS IN GROUDNWATER

JOB NO. 37106
CREATED BY: SD
DATE: JUNE 2017

Atlantic Environmental Solutions, Inc.
5 Marine View Plaza, Suite 303 • Hoboken, New Jersey 07030 P 201.876.9400 • F 201.876.9563



Division of Water Technical and Operational Guidance Series - Limitations (Class GA) (µg/L)	
PCBs	0.09
Dieldrin	0.004
Aluminum	2000
Iron	600
Magnesium	35000
Manganese	600

Sample #:	LMW06
Date Sampled:	06/12/2017
PCB's (ug/L)	Conc
PCBs	ND
Pesticides (ug/L)	Conc
Dieldrin	0.00581
Metals (ug/L)	Conc
Aluminum	261
Iron	3010
Magnesium	257000
Manganese	461

Sample #:	LMW 2
Date Sampled:	06/14/2017
PCB's (ug/L)	Conc
PCBs	ND
Pesticides (ug/L)	Conc
Dieldrin	ND
Metals (ug/L)	Conc
Aluminum	27.0
Iron	83700
Magnesium	25000
Manganese	672

Sample #:	LMW05
Date Sampled:	06/09/2017
PCB's (ug/L)	Conc
PCBs	ND
Pesticides (ug/L)	Conc
Dieldrin	ND
Metals (ug/L)	Conc
Aluminum	236
Iron	77600
Magnesium	85000
Manganese	1100

Sample #:	LMW03
Date Sampled:	06/09/2017
PCB's (ug/L)	Conc
PCBs	ND
Pesticides (ug/L)	Conc
Dieldrin	ND
Metals (ug/L)	Conc
Aluminum	116
Iron	55300
Magnesium	10200
Manganese	1050

Sample #:	MW-3
Date Sampled:	06/12/2017
PCB's (ug/L)	Conc
PCBs	ND
Pesticides (ug/L)	Conc
Dieldrin	ND
Metals (ug/L)	Conc
Aluminum	107
Iron	16700
Magnesium	559000
Manganese	1120

Sample #:	LMW12S	LMW12D
Date Sampled:	06/12/2017	06/13/2017
PCB's (ug/L)	Conc	Conc
PCBs	ND	ND
Pesticides (ug/L)	Conc	Conc
Dieldrin	ND	ND
Metals (ug/L)	Conc	Conc
Aluminum	46.5	23.7
Iron	39000	8330
Magnesium	198000	60200
Manganese	1810	2180

Sample #:	LMW10S	LMW10D
Date Sampled:	06/13/2017	06/13/2017
PCB's (ug/L)	Conc	Conc
PCBs	ND	ND
Pesticides (ug/L)	Conc	Conc
Dieldrin	ND	ND
Metals (ug/L)	Conc	Conc
Aluminum	324	31.6
Iron	37000	197
Magnesium	13300	159000
Manganese	693	631

Sample #:	MW-1
Date Sampled:	06/13/2017
PCB's (ug/L)	Conc
PCBs	ND
Pesticides (ug/L)	Conc
Dieldrin	ND
Metals (ug/L)	Conc
Aluminum	27.3
Iron	27100
Magnesium	44500
Manganese	1530

Sample #:	LMW01
Date Sampled:	06/09/2017
PCB's (ug/L)	Conc
PCBs	ND
Pesticides (ug/L)	Conc
Dieldrin	ND
Metals (ug/L)	Conc
Aluminum	638
Iron	81400
Magnesium	617000
Manganese	1820

Sample #:	LMW 8S	LMW 8D
Date Sampled:	06/14/2017	06/14/2017
PCB's (ug/L)	Conc	Conc
PCBs	ND	ND
Pesticides (ug/L)	Conc	Conc
Dieldrin	ND	ND
Metals (ug/L)	Conc	Conc
Aluminum	616	19.6
Iron	43900	912
Magnesium	44300	957000
Manganese	1510	3960

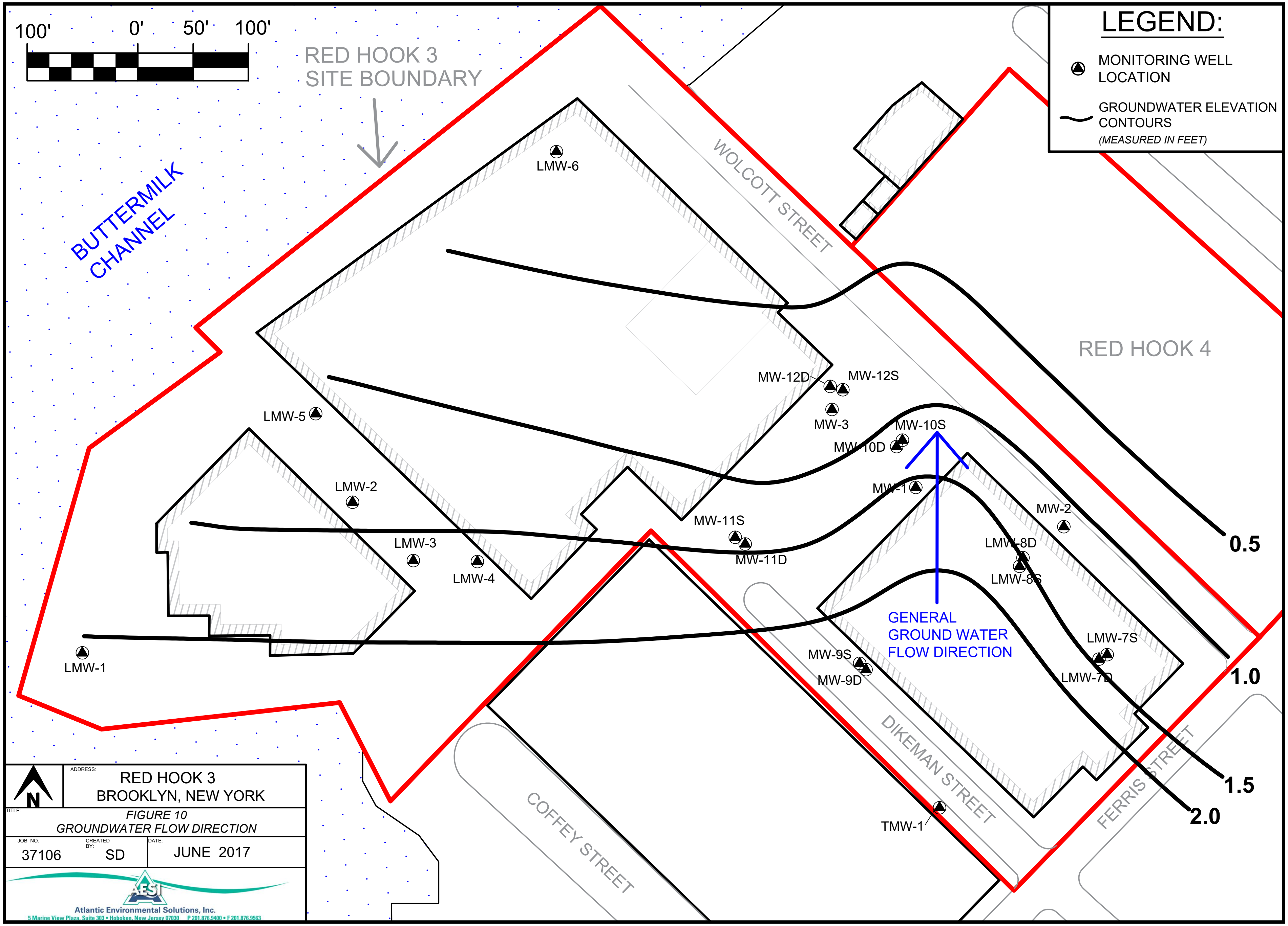
Sample #:	LMW10S	LMW10D
Date Sampled:	06/13/2017	06/13/2017
PCB's (ug/L)	Conc	Conc
PCBs	ND	ND
Pesticides (ug/L)	Conc	Conc
Dieldrin	ND	ND
Metals (ug/L)	Conc	Conc
Aluminum	324	31.6
Iron	37000	197
Magnesium	13300	159000
Manganese	693	631

Sample #:	LMW04
Date Sampled:	06/09/2017
PCB's (ug/L)	Conc
PCBs	ND
Pesticides (ug/L)	Conc
Dieldrin	ND
Metals (ug/L)	Conc
Aluminum	135
Iron	71900
Magnesium	21600
Manganese	1050

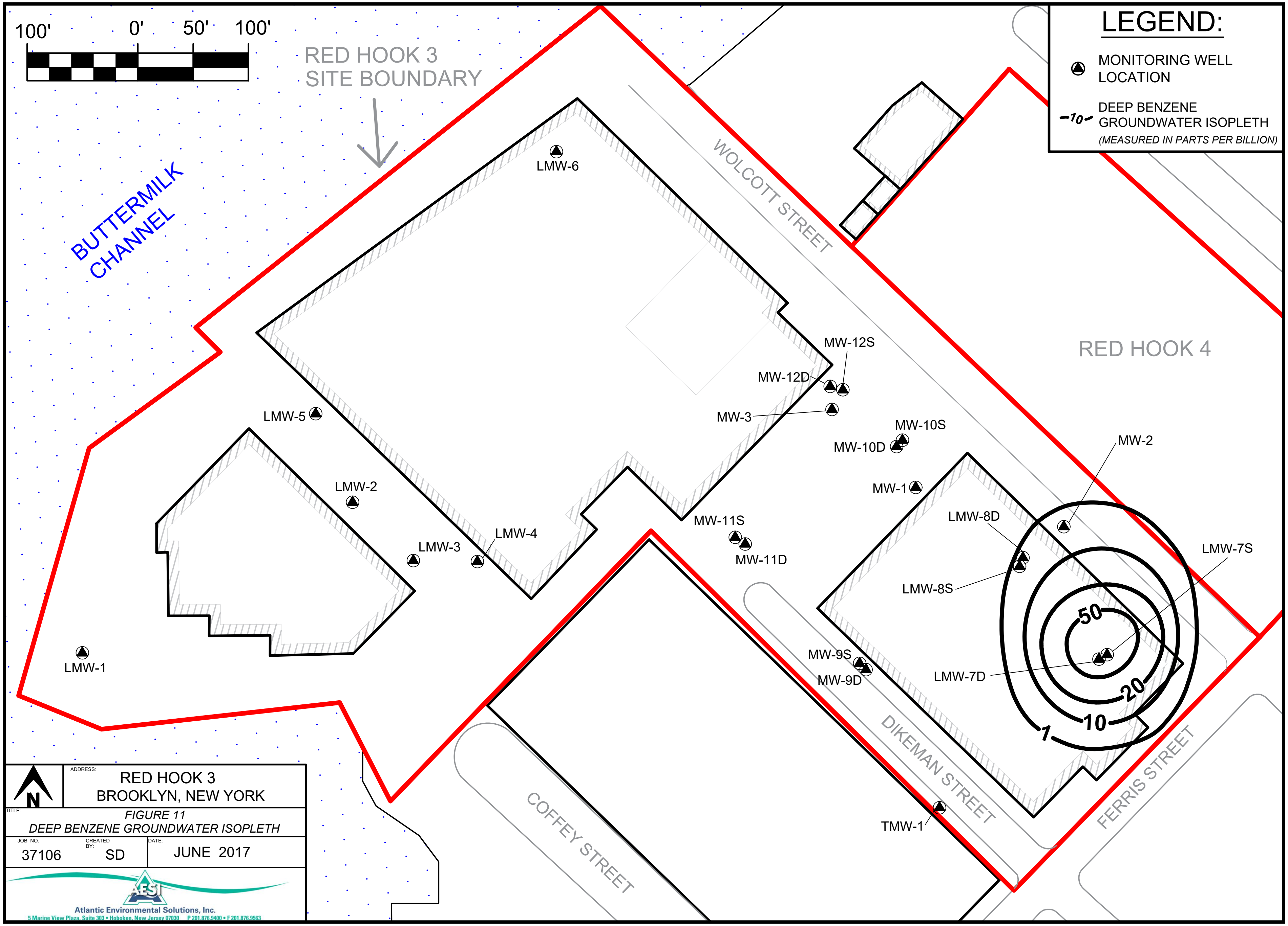
Sample #:	LMW09S	LMW09D
Date Sampled:	06/12/2017	06/12/2017
PCB's (ug/L)	Conc	Conc
PCBs	ND	ND
Pesticides (ug/L)	Conc	Conc
Dieldrin	ND	ND
Metals (ug/L)	Conc	Conc
Aluminum	48.5	112
Iron	193	392
Magnesium	8650	11100
Manganese	770	333

Sample #:	TMW-1
Date Sampled:	06/12/2017
PCB's (ug/L)	Conc
PCBs	ND
Pesticides (ug/L)	Conc
Dieldrin	ND
Metals (ug/L)	Conc
Aluminum	17.1
Iron	10400
Magnesium	18200
Manganese	1820

Sample #:	LMW 7S	LMW 7D
Date Sampled:	06/14/2017	06/14/2017
PCB's (ug/L)	Conc	Conc
PCBs	ND	ND
Pesticides (ug/L)	Conc	Conc
Dieldrin	ND	ND
Metals (ug/L)	Conc	Conc
Aluminum	2570	35.0
Iron	13500	1740
Magnesium	22800	73900
Manganese	3540	281



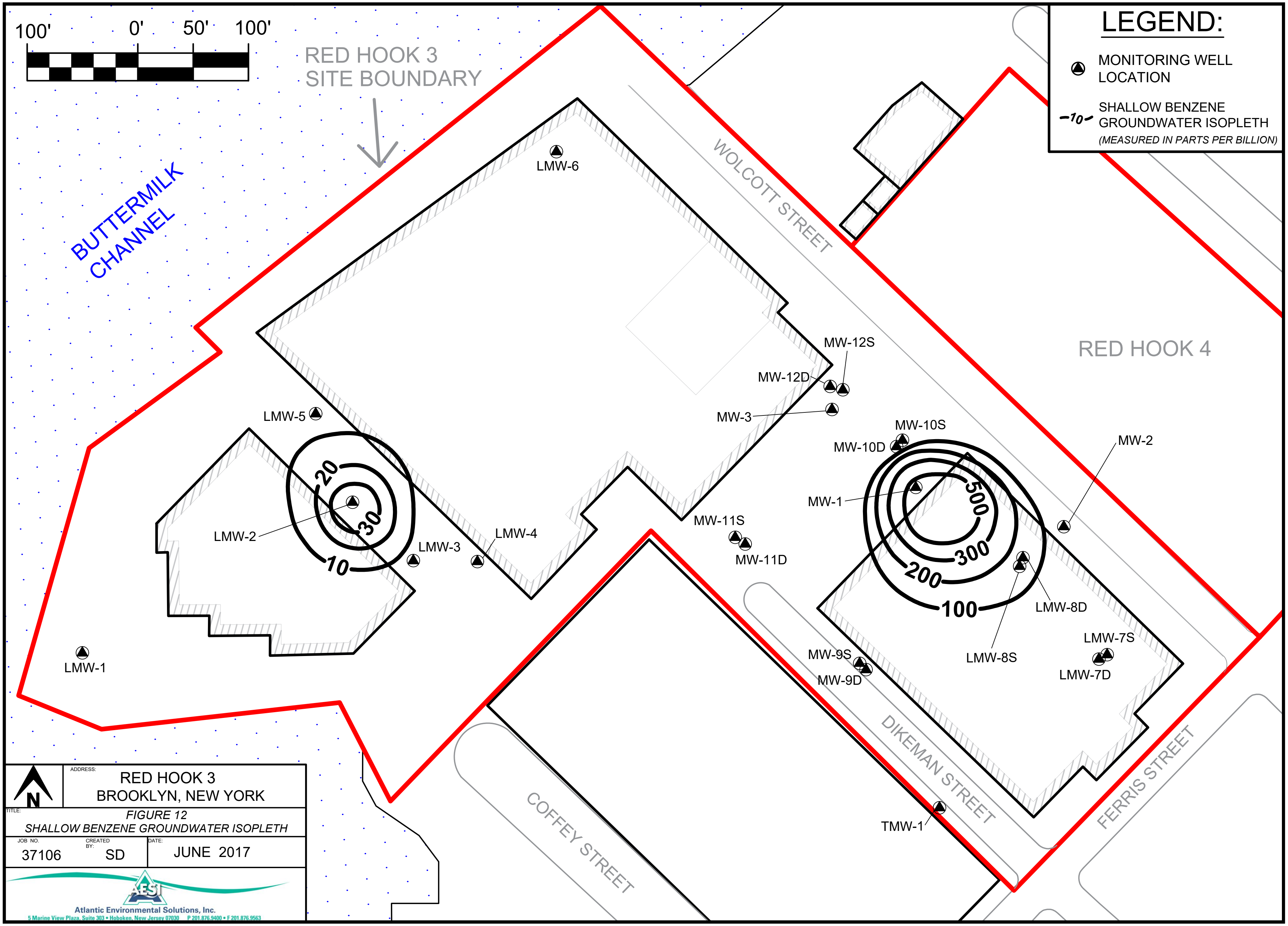
100'
0'
50'
100'
RED HOOK 3
SITE BOUNDARY
BUTTERMILK
CHANNEL
LEGEND:
MONITORING WELL
LOCATION
GROUNDWATER ELEVATION
CONTOURS
(MEASURED IN FEET)
WOLCOTT STREET
RED HOOK 4
LMW-6
LMW-5
LMW-2
LMW-3
LMW-4
LMW-1
MW-12D
MW-12S
MW-3
MW-10S
MW-10D
MW-1
MW-2
MW-11S
MW-11D
LMW-8D
LMW-8S
LMW-7S
LMW-7D
MW-9S
MW-9D
TMW-1
GENERAL
GROUND WATER
FLOW DIRECTION
0.5
1.0
1.5
2.0
DIKEMAN STREET
COFFEY STREET
FERRIS STREET
N
ADDRESS:
RED HOOK 3
BROOKLYN, NEW YORK
TITLE:
FIGURE 10
GROUNDWATER FLOW DIRECTION
JOB NO.
37106
CREATED BY:
SD
DATE:
JUNE 2017
AESI
Atlantic Environmental Solutions, Inc.

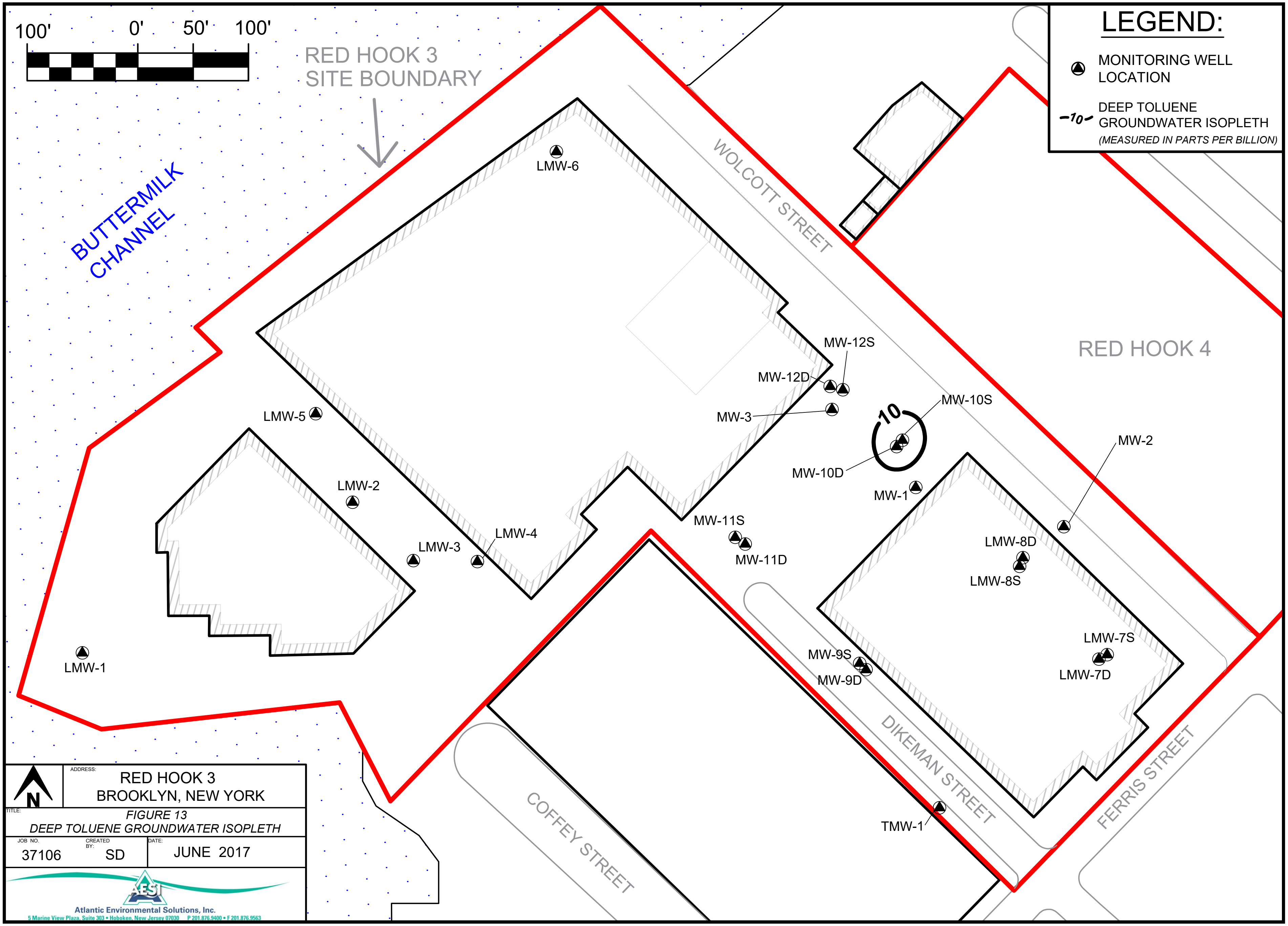


ADDRESS:	RED HOOK 3 BROOKLYN, NEW YORK
TITLE:	*FIGURE 11* *DEEP BENZENE GROUNDWATER ISOPLETH*

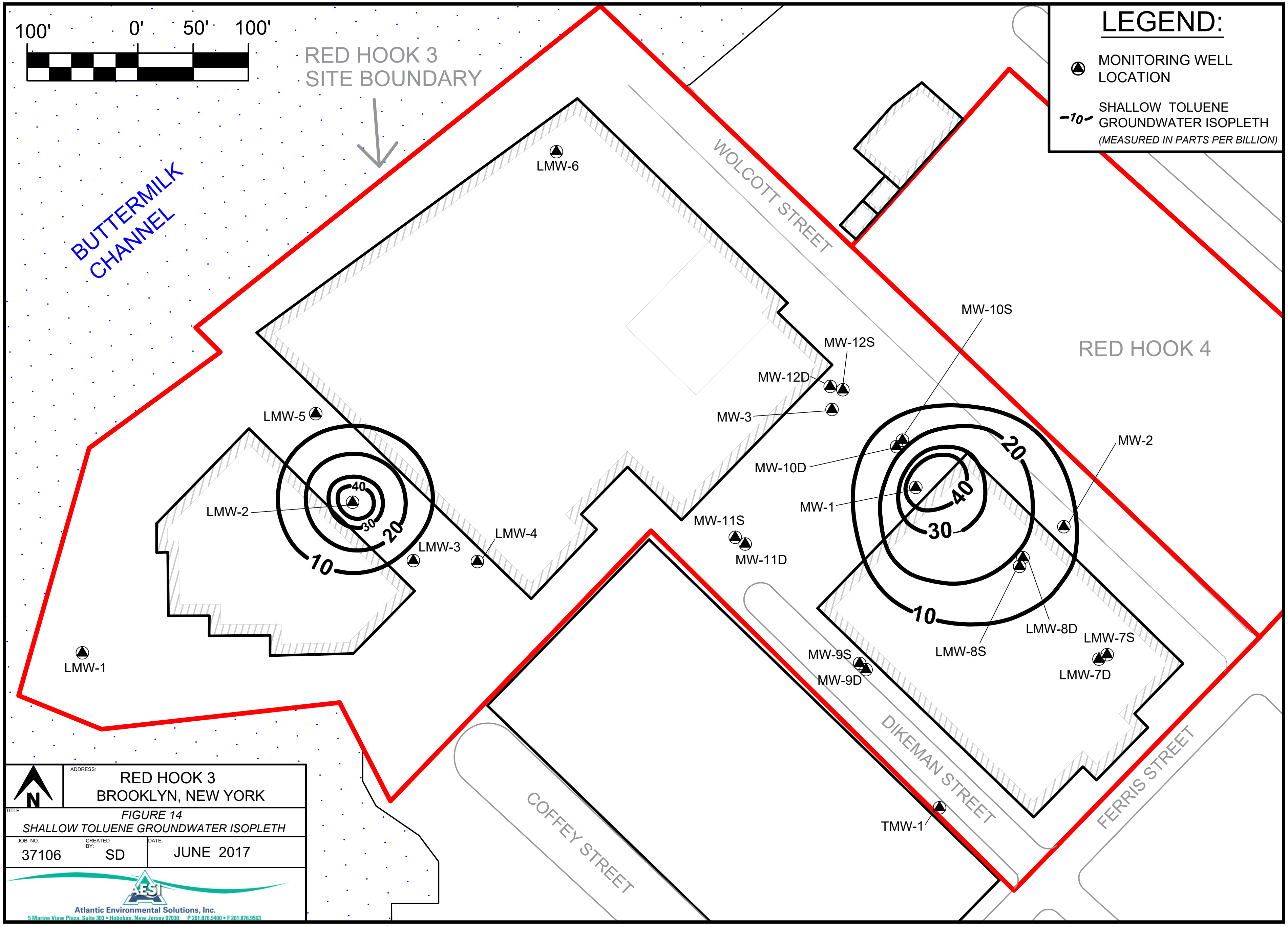
JOB NO.	CREATED BY:	DATE:
37106	SD	JUNE 2017

Atlantic Environmental Solutions, Inc.
5 Marine View Plaza, Suite 303 • Hoboken, New Jersey 07030 P 201.876.9400 • F 201.876.9563

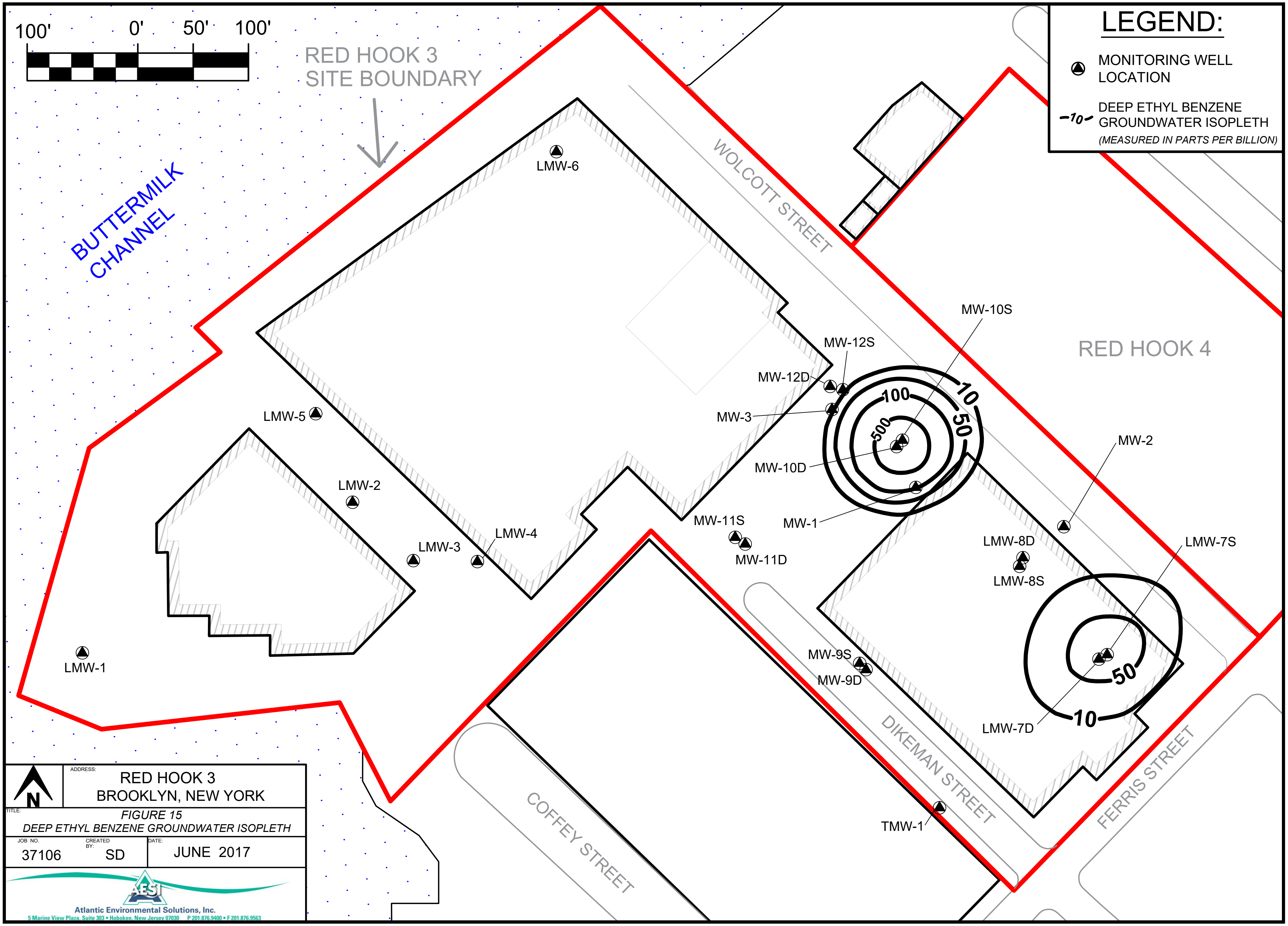

100'
0'
50'
100'
RED HOOK 3
SITE BOUNDARY
BUTTERMILK
CHANNEL
LEGEND:
MONITORING WELL LOCATION
SHALLOW BENZENE GROUNDWATER ISOPLETH
(MEASURED IN PARTS PER BILLION)
WOLCOTT STREET
RED HOOK 4
LMW-6
MW-12S
MW-12D
MW-3
LMW-5
MW-10S
MW-10D
MW-2
MW-1
500
300
200
100
20
30
10
LMW-2
LMW-3
LMW-4
MW-11S
MW-11D
LMW-8D
LMW-8S
LMW-7S
LMW-7D
MW-9S
MW-9D
LMW-1
TMW-1
DIKEMAN STREET
COFFEY STREET
FERRIS STREET
N
ADDRESS:
RED HOOK 3
BROOKLYN, NEW YORK
TITLE:
FIGURE 12
SHALLOW BENZENE GROUNDWATER ISOPLETH
JOB NO.
37106
CREATED BY:
SD
DATE:
JUNE 2017
AESI
Atlantic Environmental Solutions, Inc.



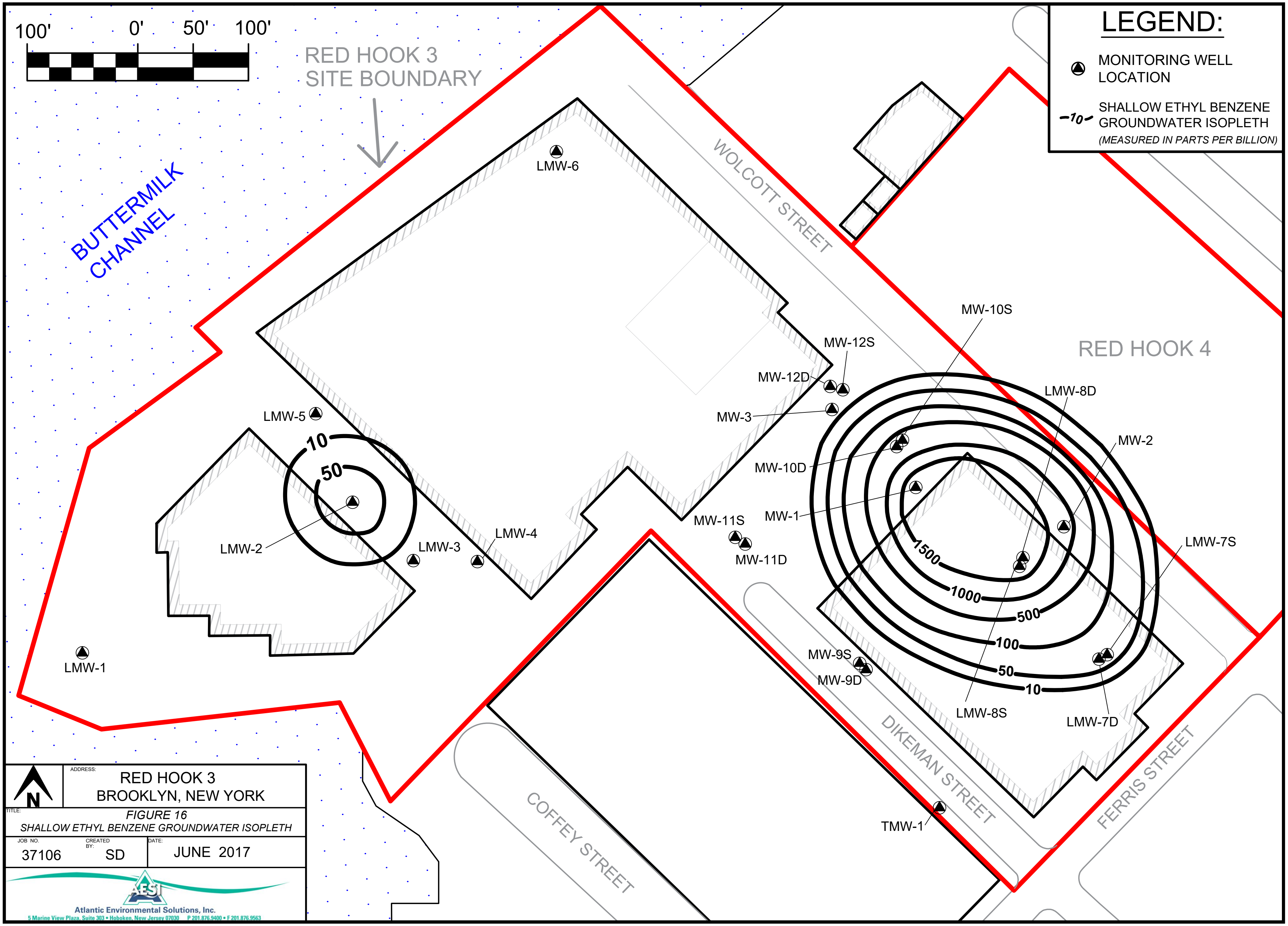
100'
0'
50'
100'
RED HOOK 3
SITE BOUNDARY
BUTTERMILK
CHANNEL
LEGEND:
MONITORING WELL
LOCATION
10
DEEP TOLUENE
GROUNDWATER ISOPLETH
(MEASURED IN PARTS PER BILLION)
WOLCOTT STREET
RED HOOK 4
DIKEMAN STREET
COFFEY STREET
FERRIS STREET
LMW-6
LMW-5
LMW-2
LMW-3
LMW-4
LMW-1
MW-12S
MW-12D
MW-3
MW-10S
MW-10D
MW-1
MW-2
MW-11S
MW-11D
LMW-8D
LMW-8S
LMW-7S
LMW-7D
MW-9S
MW-9D
TMW-1
N
ADDRESS:
RED HOOK 3
BROOKLYN, NEW YORK
TITLE:
FIGURE 13
DEEP TOLUENE GROUNDWATER ISOPLETH
JOB NO.
37106
CREATED BY:
SD
DATE:
JUNE 2017
AESI
Atlantic Environmental Solutions, Inc.

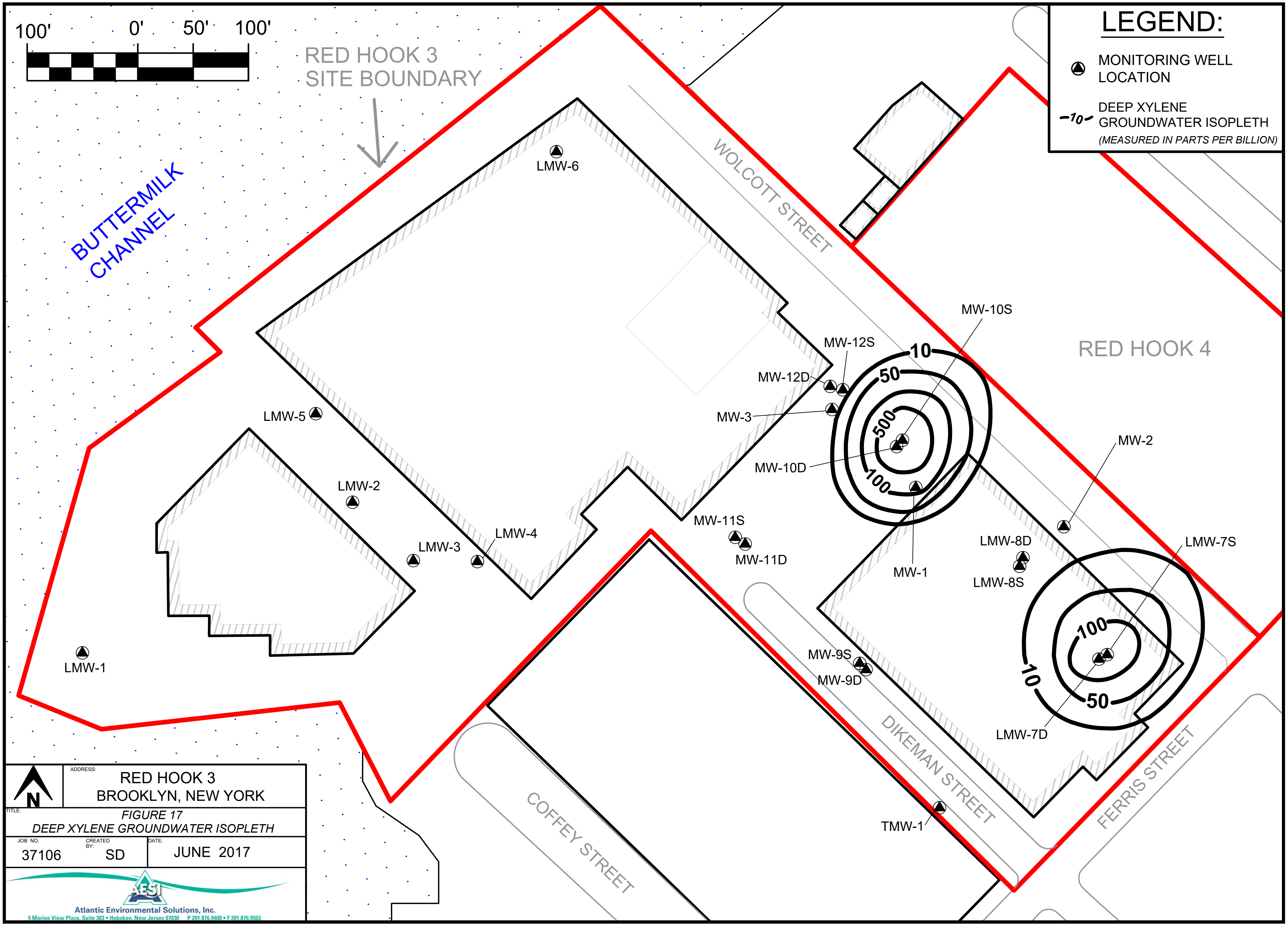


100'
0'
50'
100'
RED HOOK 3
SITE BOUNDARY
BUTTERMILK
CHANNEL
LEGEND:
MONITORING WELL
LOCATION
10
SHALLOW TOLUENE
GROUNDWATER ISOPLETH
(MEASURED IN PARTS PER BILLION)
WOLCOTT STREET
RED HOOK 4
DIKEMAN STREET
FERRIS STREET
COFFEY STREET
LMW-1
LMW-2
LMW-3
LMW-4
LMW-5
LMW-6
LMW-7S
LMW-7D
LMW-8S
LMW-8D
MW-1
MW-2
MW-3
MW-9S
MW-9D
MW-10S
MW-10D
MW-11S
MW-11D
MW-12S
MW-12D
TMW-1
10
20
30
40
N
ADDRESS:
RED HOOK 3
BROOKLYN, NEW YORK
TITLE:
FIGURE 14
SHALLOW TOLUENE GROUNDWATER ISOPLETH
JOB NO.
37106
CREATED BY:
SD
DATE:
JUNE 2017
AESI
Atlantic Environmental Solutions, Inc.

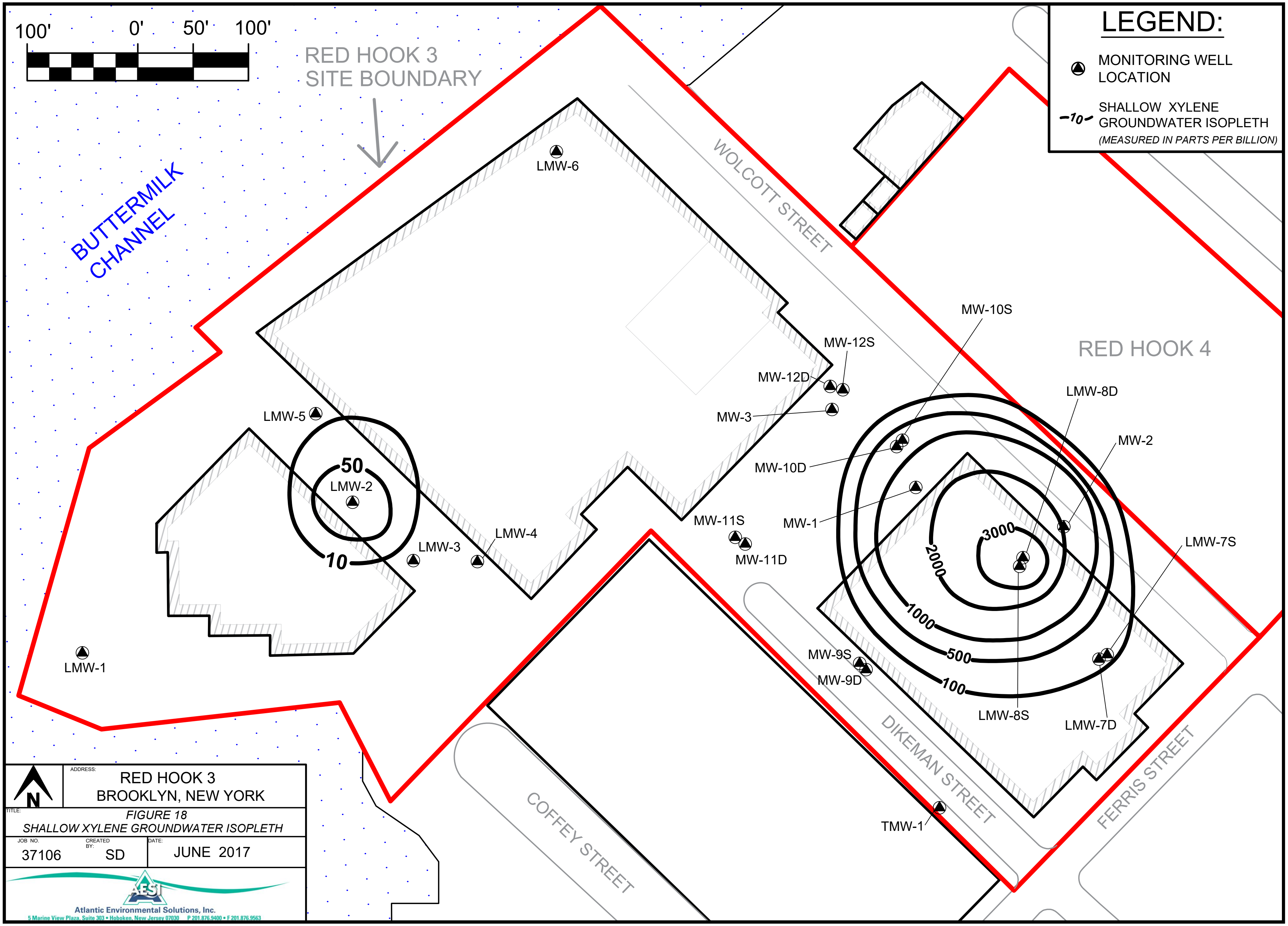


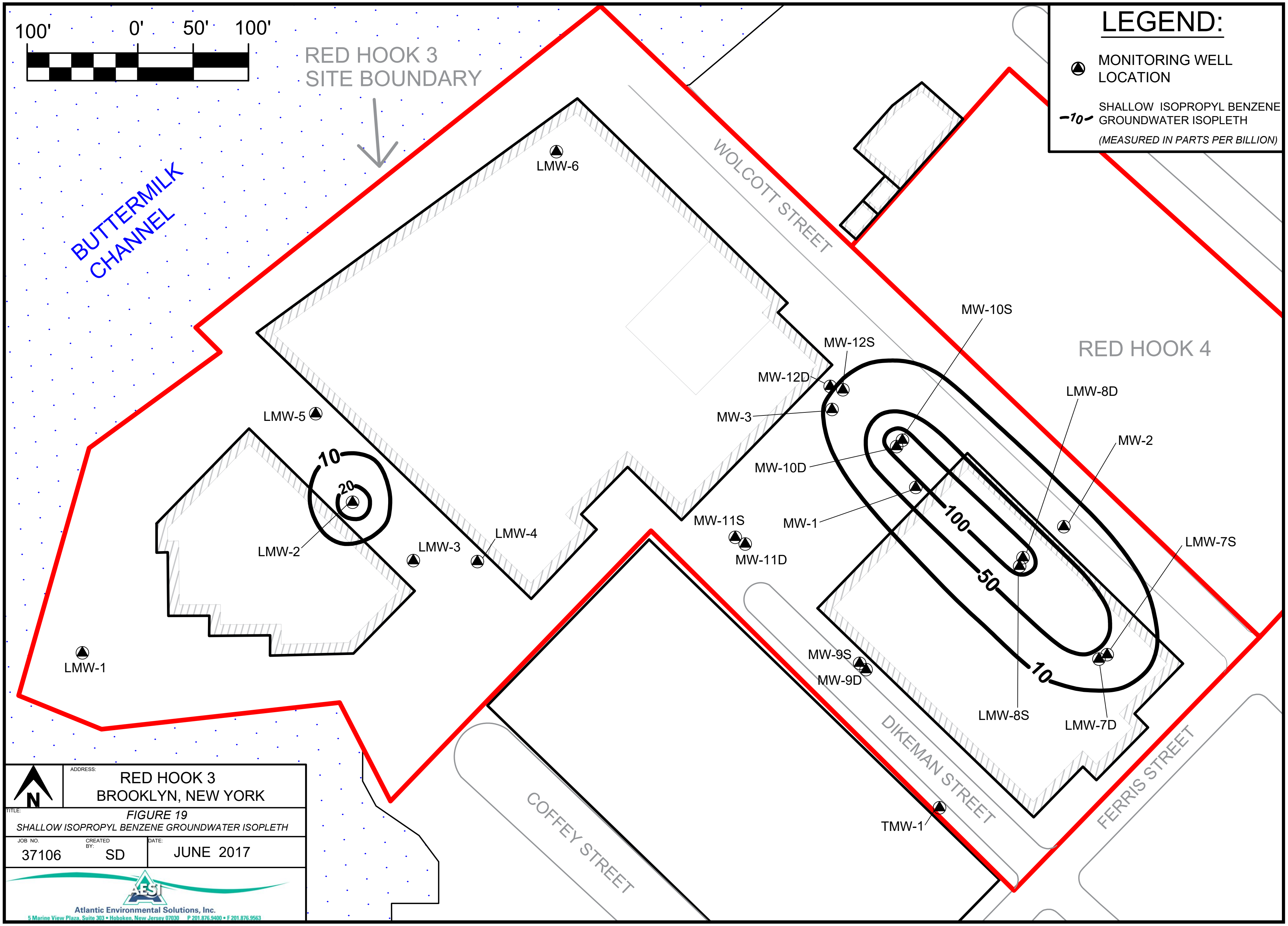
100'
0'
50'
100'
RED HOOK 3
SITE BOUNDARY
BUTTERMILK
CHANNEL
LEGEND:
MONITORING WELL LOCATION
10
DEEP ETHYL BENZENE GROUNDWATER ISOPLETH
(MEASURED IN PARTS PER BILLION)
WOLCOTT STREET
RED HOOK 4
DIKEMAN STREET
COFFEY STREET
FERRIS STREET
LMW-6
LMW-5
LMW-2
LMW-3
LMW-4
LMW-1
MW-12S
MW-12D
MW-3
MW-10S
MW-10D
MW-1
MW-11S
MW-11D
MW-2
LMW-8D
LMW-8S
LMW-7S
LMW-7D
MW-9S
MW-9D
TMW-1
500
100
50
10
N
ADDRESS:
RED HOOK 3
BROOKLYN, NEW YORK
TITLE:
FIGURE 15
DEEP ETHYL BENZENE GROUNDWATER ISOPLETH
JOB NO.
37106
CREATED BY:
SD
DATE:
JUNE 2017
Atlantic Environmental Solutions, Inc.


100'
0'
50'
100'
RED HOOK 3
SITE BOUNDARY
BUTTERMILK
CHANNEL
LEGEND:
MONITORING WELL LOCATION
SHALLOW ETHYL BENZENE GROUNDWATER ISOPLETH
(MEASURED IN PARTS PER BILLION)
WOLCOTT STREET
RED HOOK 4
DIKEMAN STREET
COFFEY STREET
FERRIS STREET
LMW-1
LMW-2
LMW-3
LMW-4
LMW-5
LMW-6
LMW-7S
LMW-7D
LMW-8S
LMW-8D
MW-1
MW-2
MW-3
MW-9S
MW-9D
MW-10S
MW-10D
MW-11S
MW-11D
MW-12S
MW-12D
TMW-1
10
50
100
500
1000
1500
N
ADDRESS:
RED HOOK 3
BROOKLYN, NEW YORK
TITLE:
FIGURE 16
SHALLOW ETHYL BENZENE GROUNDWATER ISOPLETH
JOB NO.
37106
CREATED BY:
SD
DATE:
JUNE 2017
Atlantic Environmental Solutions, Inc.



100' 0' 50' 100'
RED HOOK 3
SITE BOUNDARY
BUTTERMILK
CHANNEL
WOLCOTT STREET
DIKEMAN STREET
COFFEY STREET
FERRIS STREET
RED HOOK 4
LEGEND:
MONITORING WELL LOCATION
10
DEEP XYLENE GROUNDWATER ISOPLETH
(MEASURED IN PARTS PER BILLION)
LMW-1
LMW-2
LMW-3
LMW-4
LMW-5
LMW-6
LMW-7S
LMW-7D
LMW-8D
LMW-8S
MW-1
MW-2
MW-3
MW-9S
MW-9D
MW-10S
MW-10D
MW-11S
MW-11D
MW-12S
MW-12D
TMW-1
10
50
100
500
N
ADDRESS:
RED HOOK 3
BROOKLYN, NEW YORK
TITLE:
FIGURE 17
DEEP XYLENE GROUNDWATER ISOPLETH
JOB NO.
37106
CREATED BY:
SD
DATE:
JUNE 2017
AESI
Atlantic Environmental Solutions, Inc.
5 Marine View Plaza, Suite 303 • Hoboken, New Jersey 07030 P 201.876.9400 • F 201.876.9563


100'
0'
50'
100'
RED HOOK 3
SITE BOUNDARY
BUTTERMILK
CHANNEL
LEGEND:
MONITORING WELL
LOCATION
10
SHALLOW XYLENE
GROUNDWATER ISOPLETH
(MEASURED IN PARTS PER BILLION)
WOLCOTT STREET
RED HOOK 4
DIKEMAN STREET
COFFEY STREET
FERRIS STREET
LMW-6
LMW-5
LMW-2
LMW-3
LMW-4
LMW-1
MW-10S
MW-12S
MW-12D
MW-3
MW-10D
MW-1
MW-11S
MW-11D
LMW-8D
MW-2
LMW-7S
LMW-8S
LMW-7D
MW-9S
MW-9D
TMW-1
50
10
3000
2000
1000
500
100
N
ADDRESS:
RED HOOK 3
BROOKLYN, NEW YORK
TITLE:
FIGURE 18
SHALLOW XYLENE GROUNDWATER ISOPLETH
JOB NO.
37106
CREATED BY:
SD
DATE:
JUNE 2017
AESI
Atlantic Environmental Solutions, Inc.
5 Marine View Plaza, Suite 303 • Hoboken, New Jersey 07030 P 201.876.9400 • F 201.876.9563



100'
0'
50'
100'
RED HOOK 3
SITE BOUNDARY
BUTTERMILK
CHANNEL
LEGEND:
MONITORING WELL
LOCATION
SHALLOW ISOPROPYL BENZENE
GROUNDWATER ISOPLETH
(MEASURED IN PARTS PER BILLION)
RED HOOK 4
WOLCOTT STREET
DIKEMAN STREET
COFFEY STREET
FERRIS STREET
LMW-6
LMW-5
LMW-2
LMW-3
LMW-4
LMW-1
MW-10S
MW-12S
MW-12D
MW-3
MW-10D
MW-1
MW-11S
MW-11D
LMW-8D
MW-2
LMW-7S
MW-9S
MW-9D
LMW-8S
LMW-7D
TMW-1
10
20
100
50
10
N
ADDRESS:
RED HOOK 3
BROOKLYN, NEW YORK
TITLE:
FIGURE 19
SHALLOW ISOPROPYL BENZENE GROUNDWATER ISOPLETH
JOB NO.
37106
CREATED BY:
SD
DATE:
JUNE 2017
AESI
Atlantic Environmental Solutions, Inc.

APPENDIX C

Technical Guidance Instruction Documents and Standard Operating Procedures

Field Soil Description Procedures

TGI - SOIL DESCRIPTION

Rev: #2

Rev Date: February 16, 2018

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	May 20, 2008	17	Original SOP	Joe Quinnan Joel Hunt
1	September 2016	15	Updated to TGI	Nick Welty Patrick Curry
2	February 16, 2018	15	Updated descriptions, attachments and references in text	Nick Welty Patrick Curry

APPROVAL SIGNATURES

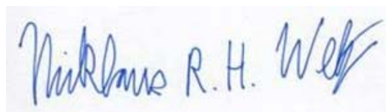
Prepared by:

June 30, 2017

Patrick Curry, PG

Date:

Technical Expert Reviewed by:



June 30, 2017

Nicklaus Welty, PG

Date:

1 INTRODUCTION

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

This Arcadis Technical Guidance Instruction (TGI) describes proper soil description procedures. This TGI should be followed for unconsolidated material unless there is an established client-required specific procedure or regulatory-required specific procedure. In cases where there is a required specific procedure, it should be followed and should be referenced and/or provided as an appendix to reports that include soil classifications and/or boring logs. When following a required non-Arcadis procedure, additional information required by this TGI should be included in field notes with client approval.

This TGI has been developed to emphasize field observation and documentation of details required to:

- make hydrostratigraphic interpretations guided by depositional environment/geologic settings;
- provide information needed to understand the distribution of constituents of concern; properly design wells, piezometers, and/or additional field investigations; and develop appropriate remedial strategies.

This TGI incorporates elements from various standard systems such as ASTM D2488-06, Unified Soil Classification System, Burmister and Wentworth. However, none of these standard systems focus specifically on contaminant hydrogeology and remedial design. Therefore, although each of these systems contain valuable guidance and information related to correct descriptions, strict application of these systems can omit information critical to our clients and the projects that we perform.

This TGI does not address details of health and safety; drilling method selection; boring log preparation; sample collection; or laboratory analysis. Refer to other Arcadis procedure, guidance, and instructional documents, the project work plans including the quality assurance project plan, sampling plan, and health and safety plan (HASP), as appropriate.

3 PERSONNEL QUALIFICATIONS

Soil descriptions should only be performed by Arcadis personnel or authorized sub-contractors with a degree in geology or a geology-related discipline. Field personnel will complete training on the Arcadis soil description TGI in the office and/or in the field under the guidance of an experienced field geologist with at least 2 years of prior experience applying the Arcadis soil description method.

4 EQUIPMENT LIST

The following equipment should be taken to the field to facilitate soil descriptions:

- field book, field forms or PDA to record soil descriptions;
- field book for supplemental notes;
- this TGI for Soil Descriptions and any project-specific procedure, guidance, and/or instructional documents (if required);
- field card showing Wentworth scale;
- Munsell® soil color chart;
- tape measure divided into tenths of a foot;
- stainless steel knife or spatula;
- hand lens;
- water squirt bottle;
- jar with lid;
- personal protective equipment (PPE), as required by the HASP; and
- digital camera

5 CAUTIONS

Drilling and drilling-related hazards including subsurface utilities are discussed in other procedure documents and site-specific HASPs and are not discussed herein.

Soil samples may contain hazardous substances that can result in exposure to persons describing soils. Routes for exposure may include dermal contact, inhalation and ingestion. Refer to the project specific HASP for guidance in these situations.

6 HEALTH AND SAFETY CONSIDERATIONS

Field activities associated with soil sampling and description will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities. Know what hazardous substances may be present in the soil and understand their hazards. Always avoid the temptation to touch soils with bare hands, detect odors by placing soils close to your nose, or tasting soils.

7 PROCEDURE

1. Select the appropriate sampling method to obtain representative samples in accordance with the selected sub-surface exploration method, e.g. split-spoon or Shelby sample for hollow-stem drilling, acetate sleeves for direct push, bagged core for sonic drilling, etc.
2. Proceed with field activities in required sequence. Although completion of soil descriptions is often not the first activity after opening sampler, identification of stratigraphic changes is often necessary to select appropriate intervals for field screening and/or selection of laboratory samples.
3. Set up boring log field sheet.
   - Drillers in both the US and Canada generally work in feet due to equipment specifications. Use the Arcadis standard boring log form (**Attachment A**).
   - The preferred boring log includes a graphic log of the principal soil component to support quick visual evaluation of grain size. The purpose of the graphic log is to quickly assess relative soil permeability. Note, for poorly sorted soils (e.g. glacial till), the principal component may not correlate to permeability of the sample. In this case, the geologist should use best judgement to graph overall soil type consistent with relative soil permeability. For example, for a dense sand/silt/clay till, the graphic log would reflect the silt/clay, rather than sand.
   - Record depths along the left-hand side at a standard scale to aid in the use of this tool. See an example completed boring log (**Attachment B**).
4. Examine each soil core (this is different than examining each sample selected for laboratory analysis), and record the following for each stratum:
   - depth interval;
   - principal component with descriptors, as appropriate;
   - amount and identification of minor component(s) with descriptors as appropriate;
   - moisture;
   - consistency/density;
   - color; and
   - additional description or comments (recorded as notes).
5. At the end of the boring, record the amount of drilling fluid used (if applicable) and the total depth logged.

The above is described more fully below.

DEPTH

To measure and record the depth below ground surface (bgs) of top and bottom of each stratum, the following information should be recorded.

1. Measured depth to the top and bottom of sampled interval. Use starting depth of sample based upon measured tool length information and the length of sample interval.
2. Length of sample recovered, not including slough (material that has fallen into hole from previous interval), expressed as fraction with length of recovered sample as numerator over length of sampled interval as denominator (e.g. 14/24 for 14 inches recovered from 24-inch sampling interval that had 2 inches of slough discarded).
3. Thickness of each stratum measured sequentially from the top of recovery to the bottom of recovery.
4. Any observations of sample condition or drilling activity that would help identify whether there was loss from the top of the sampling interval, loss from the bottom of the sampling interval, or compression of the sampling interval. Examples: 14/24, gravel in nose of spoon; or 10/18 bottom 6 inches of spoon empty.

DETERMINATION OF COMPONENTS

Obtain a representative sample of soil from a single stratum. If multiple strata are present in a single sample interval, each stratum should be described separately. More specifically, if the sample is from a 2-foot long split-spoon where strata of coarse sand, fine sand and clay are present, then the resultant description should be of the three individual strata unless a combined description can clearly describe the interbedded nature of the three strata. Example: Fine Sand with interbedded lenses of Silt and Clay, ranging between 1 and 3 inches thick.

Identify principal component and express volume estimates for minor components on logs using the following standard modifiers.

Modifier	Percent of Total Sample (by volume)
and	36 - 50
some	21 - 35
little	10 - 20
trace	<10

Determination of components is based on using the Udden-Wentworth particle size classification (see below) and measurement of the average grain size diameter. Each size grade or class differs from the next larger grade or class by a constant ratio of ½. Due to visual limitations, the finer classifications of Wentworth's scale cannot be distinguished in the field and the subgroups are not included. Visual determinations in the field should be made carefully by comparing the sample to the Soil Description Field Guide (**Attachment C**) that shows Udden-Wentworth scale or by measuring with a ruler. Use of field sieves is encouraged to assist in estimating percentage of coarse grain sizes. Settling test or wash method (Appendix X4 of ASTM D2488) is encouraged for determining presence and estimating percentage of clay and silt. Note that "gravel" is not an Udden-Wentworth size class.

Udden-Wenworth Scale Modified Arcadis, 2008			
Size Class	Millimeters	Inches	Standard Sieve #
Boulder	256 – 4096	10.08+	
Large cobble	128 - 256	5.04 -10.08	
Small cobble	64 - 128	2.52 – 5.04	
Very large pebble	32 – 64	0.16 - 2.52	
Large pebble	16 – 32	0.63 – 1.26	
Medium pebble	8 – 16	0.31 – 0.63	
Small pebble	4 – 8	0.16 – 0.31	No. 5 +
Granule	2 – 4	0.08 – 0.16	No.5 – No.10
Very coarse sand	1 -2	0.04 – 0.08	No.10 – No.18
Coarse sand	½ - 1	0.02 – 0.04	No.18 - No.35
Medium sand	¼ - ½	0.01 – 0.02	No.35 - No.60
Fine sand	1/8 -¼	0.005 – 0.1	No.60 - No.120
Very fine sand	1/16 – 1/8	0.002 – 0.005	No. 120 – No. 230
Silt (subgroups not included)	1/256 – 1/16	0.0002 – 0.002	Not applicable (analyze by pipette or hydrometer)
Clay (subgroups not included	1/2048 – 1/256	.00002 – 0.0002	

Identify components as follows. Remove particles greater than very large pebbles (64-mm diameter) from the soil sample. Record the volume estimate of the greater than very large pebbles. Examine the sample fraction of very large pebbles and smaller particles and estimate the volume percentage of the pebbles, granules, sand, silt and clay. Use the jar method, visual method, and/or wash method (Appendix X4 of ASTM D2488) to estimate the volume percentages of each category.

Determination of actual dry weight of each Udden-Wentworth fraction requires laboratory grain-size analysis using sieve sizes corresponding to Udden-Wentworth fractions and is highly recommended to determine grain-size distributions for each hydrostratigraphic unit.

Lab or field sieve analysis is advisable to characterize the variability and facies trends within each hydrostratigraphic unit. Field sieve-analysis can be performed on selected samples to estimate dry weight fraction of each category using ASTM D2488 Standard Practice for Classification of Soils for Engineering Purposes as guidance, but replace required sieve sizes with the following Udden-Wentworth set: U.S. Standard sieve mesh sizes 6; 12; 20; 40; 70; 140; and 270 to retain pebbles; granules; very coarse sand; coarse sand; medium sand; fine sand; and very fine sand, respectively.

PRINCIPAL COMPONENT

The principal component is the size fraction or range of size fractions containing the majority of the volume. Examples: the principal component in a sample that contained 55% pebbles would be "Pebbles"; or the principal component in a sample that was 20% fine sand, 30% medium sand and 25% coarse sand would be "Sand, fine to coarse" or for a sample that was 40% silt and 45% clay the principal component would be "Clay and Silt". Shade the boxes on the graphic log (**Attachment A**) up to and including the box with the principal component. The purpose of the graphical log is to provide a relative estimate of permeability. As noted above, for poorly sorted soils such as glacial till, the principal component may not correlate to permeability of the sample. In this case, the geologist should use best judgement to graph overall soil type consistent with relative soil permeability.

Include appropriate descriptors with the principal component. These descriptors vary for different particle sizes as follows.

Angularity – Describe the angularity for very coarse sand and larger particles in accordance with the table below (ASTM D-2488-06). Figures showing examples of angularity are available in ASTM D-2488-06 and the Arcadis Soil Description Field Guide.

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces.
Sub-angular	Particles are similar to angular description but have rounded edges.
Sub-rounded	Particles have nearly plane sides but have well-rounded corners and edges.
Rounded	Particles have smoothly curved sides and no edges.

Plasticity – Describe the plasticity for silt and clay based on observations made during the following test method (ASTM D-2488-06).

- As in the dilatancy test below, select enough material to mold into a ball about ½ inch (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.
- Shape the test specimen into an elongated pat and roll by hand on a smooth surface or between the palms into a thread about 1/8 inch (3 mm) in diameter. If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation. Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about 1/8 inch. The thread will crumble when the soil is near the plastic limit.

Description	Criteria
Non-plastic	A 1/8-inch (3 mm) thread cannot be rolled at any water content.
Low	The thread can barely be rolled, and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

Dilatancy – Describe the dilatancy for silt and silt-sand mixtures using the following field test method (ASTM D-2488-06).

- From the specimen select enough material to mold into a ball about ½ inch (12 mm) in diameter. Mold the material adding water if necessary, until it has a soft, but not sticky, consistency.
- Smooth the ball in the palm of one hand with a small spatula.
- Shake horizontally, striking the side of the hand vigorously with the other hand several times.
- Note the reaction of water appearing on the surface of the soil.
- Squeeze the sample by closing the hand or pinching the soil between the fingers, and not the reaction as none, slow, or rapid in accordance with the table below. The reaction is the speed with which water appears while shaking and disappears while squeezing.

Description	Criteria
None	No visible change in the specimen.
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing.
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing.

Note that silt and silt-sand mixtures will be non-plastic and display dilatancy. Clay mixtures will have some degree of plasticity but do not typically react to dilatancy testing. Therefore, the tests outlined above can be used to differentiate between silt dominated and clay dominated soils.

MINOR COMPONENT(S)

The minor component(s) are the size fraction(s) containing less than 50% volume. Example: the identified components are estimated to be 60% medium sand to granules, 25% silt and clay; 15 % pebbles – there are two identified minor components: silt and clay; and pebbles.

Include a standard modifier to indicate percentage of minor components (see Table on Page 6) and the same descriptors that would be used for a principal component. Plasticity should be provided as a descriptor for clay and clay mixtures. Dilatancy should be provided for silt and silt mixtures. Angularity should be provided as a descriptor for pebbles and coarse sand. For the example above, the minor constituents with modifiers could be: some silt and clay, low plasticity; little medium to large pebbles, sub-round.

SORTING

Sorting is the opposite of grading, which is a commonly used term in the USCS or ASTM methods to describe the uniformity of the particle size distribution in a sample. Well-sorted samples are poorly graded and poorly sorted samples are well graded. Arcadis prefers the use of sorting for particle size distributions and grading to describe particle size distribution trends in the vertical profile of a sample or hydrostratigraphic unit because of the relationship between sorting and the energy of the depositional process. For soils with sand-sized or larger particles, sorting should be determined as follows:

Well sorted – the range of particle sizes is limited (e.g. the sample is comprised of predominantly one or two grain sizes).

Poorly sorted – a wide range of particle sizes are present.

You can also use sieve analysis to estimate sorting from a sedimentological perspective; sorting is the statistical equivalent of standard deviation. Smaller standard deviations correspond to higher degree of sorting (see Remediation Hydraulics, 2008).

MOISTURE

Moisture content should be described for every sample since increases or decreases in water content is critical information. Moisture should be described in accordance with the table below (percentages should not be used unless determined in the laboratory).

Description	Criteria
Dry	Absence of moisture, dry to touch, dusty.
Moist	Damp but no visible water.
Wet (Saturated)	Visible free water, soil is usually below the water table.

CONSISTENCY or DENSITY

This can be determined by standard penetration test (SPT) blow counts (ASTM D-1586) or field tests in accordance with the tables below. When drilling with hollow-stem augers and split-spoon sampling, the SPT blow counts and N-value is used to estimate density. The N-value is the blows per foot for the 6” to 18” interval. Example: for 24-inch spoon, recorded blows per 6-inch interval are: 4/6/9/22. Since the second interval is 6” to12”, the third interval is 12” to 18”, the N value is 6+9, or 15. Fifty blow counts for less than 6 inches is considered refusal. In recent years, more common drilling methods include rotary-sonic or direct push. When blow counts are not available, density is determined using a thumb test. Note however, the thumb test only applies to fine-grained soils.

Fine-grained soil – Consistency

Description	Criteria
Very soft	N-value < 2 or easily penetrated several inches by thumb.
Soft	N-value 2-4 or easily penetrated one inch by thumb.
Medium stiff	N-value 9-15 or indented about ¼ inch by thumb with great effort.
Very stiff	N-value 16-30 or readily indented by thumb nail.
Hard	N-value > than 30 or indented by thumbnail with difficulty

Coarse-grained soil – Density

Description	Criteria
Very loose	N-value 1- 4
Loose	N-value 5-10
Medium dense	N-value 11-30
Dense	N-value 31- 50
Very dense	N-value >50

COLOR

Color should be described using simple basic terminology and modifiers based on the Munsell system. Munsell alpha-numeric codes are required for all samples. If the sample contains layers or patches of varying colors this should be noted and all representative colors should be described. The colors should be described for moist samples. If the sample is dry it should be wetted prior to comparing the sample to the Munsell chart.

ADDITIONAL COMMENTS (NOTES)

Additional comments should be made where observed and should be presented as notes with reference to a specific depth interval(s) to which they apply. Some of the significant information that may be observed includes the following.

- Odor - You should not make an effort to smell samples by placing near your nose since this can result in unnecessary exposure to hazardous materials. However, odors should be noted if they are detected during the normal sampling procedures. Odors should be based upon descriptors such as those used in NIOSH “Pocket Guide to Chemical Hazards”, e.g. “pungent” or “sweet” and should not indicate specific chemicals such as “phenol-like” odor or “BTEX” odor.
- Structure
- Bedding planes (laminated, banded, geologic contacts).
- Presence of roots, root holes, organic material, man-made materials, minerals, etc.
- Mineralogy
- Cementation
- NAPL presence/characteristics, including sheen (based on client-specific guidance).
- Reaction with HCl - typically only used for special soil conditions, such as caliche environments.
- Origin, if known (Lacustrine; Fill; etc.).

EXAMPLE DESCRIPTIONS

51.4 to 54.0’ CLAY, some silt, medium to high plasticity; trace small to large pebbles, sub-round to sub-angular up to 2” diameter; moist, stiff, dark grayish brown (10 YR 4/2) NOTE: Lacustrine; laminated 0.1 to 0.2” thick, laminations brownish yellow (10 YR 4/3).

32.5 to 38.0' SAND, medium to very coarse, sub-round to sub-angular; little granule and pebble, trace silt; poorly sorted, wet, grayish brown (10 YR 5/2).

Unlike the first example where a density of cohesive soils could be estimated, this rotary-sonic sand and pebble sample was disturbed during drilling (due to vibrations in a loose sand and pebble matrix) so no density description could be provided. Neither sample had noticeable odor so odor comments were not included.

The standard generic description order is presented below.

- Depth
- Principal Components
  - Angularity for very coarse sand and larger particles
  - Plasticity for silt and clay
  - Dilatancy for silt and silt-sand mixtures
- Minor Components
- Sorting
- Moisture
- Consistency or Density
- Color
- Additional Comments

8 WASTE MANAGEMENT

Project-specific requirements should be identified and followed. The following procedures, or similar waste management procedures are generally required.

Water generated during cleaning procedures will be collected and contained onsite in appropriate containers for future analysis and appropriate disposal. PPE (such as gloves, disposable clothing, and other disposable equipment) resulting from personnel cleaning procedures and soil sampling/handling activities will be placed in plastic bags. These bags will be transferred into appropriately labeled 55-gallon drums or a covered roll-off box for appropriate disposal.

Soil materials will be placed in sealed 55-gallon steel drums or covered roll-off boxes and stored in a secured area. Once full, the material will be analyzed to determine the appropriate disposal method.

9 DATA RECORDING AND MANAGEMENT

Upon collection of soil samples, the soil sample should be logged on a standard boring log and/or in the field log book depending on Data Quality Objectives (DQOs) for the task/project. The preferred standard boring log is presented below and is included as **Attachment A**.

The general scheme for soil logging entries is presented above; however, depending on task/project DQOs, specific logging entries that are not applicable to task/project goals may be omitted at the project manager's discretion. In any case, use of a consistent logging procedure is required.

Completed logs and/or logbook will be maintained in the task/project field records file. Digital photographs of typical soil types observed at the site and any unusual features should be obtained whenever possible. All photographs should include a ruler or common object for scale. Photo location, depth and orientation must be recorded in the daily log or log book and a label showing this information in the photo is useful.

10 QUALITY ASSURANCE

Soil descriptions should be completed only by appropriately trained personnel. Descriptions should be reviewed by an experienced field geologist for content, format and consistency. Edited boring logs should be reviewed by the original author to assure that content has not changed.

11 REFERENCES

Arcadis Soil Description Field Guide, 2008.

Munsell® Color Chart – available from Forestry Suppliers, Inc.- Item 77341 "Munsell® Color Soil Color Charts.

Field Gauge Card that Shows Udden-Wentworth scale – available from Forestry Suppliers, Inc. – Item 77332 "Sand Grain Sizing Folder."

ASTM D-1586, Test Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM D-2488-00, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

United States Bureau of Reclamation. Engineering Geology Field Manual. United States Department of Interior, Bureau of Reclamation. http://www.usbr.gov/pmts/geology/fieldmap.htm.

Petrology of Sedimentary Rocks, Robert L. Folk, 1980, p. 1-48.

NIOSH Pocket Guide to Chemical Hazards.

Remediation Hydraulics, Fred C. Payne, Joseph A. Quinnan, and Scott T. Potter, 2008, p 59-63.

ATTACHMENT A

Arcadis Standard Soil Boring Log Form

SOIL BORING LOG

Boring/Well ________ Project ________ Page ___ of ___

Site Location ________ Drilling Started ________

Total Depth Drilled ________ Feet Hole Diameter ________ inches Drilling Completed ________

Type of Sample or Coring Device ________ Length and Diameter of Coring Device ________ Sampling Interval ________ feet

Drilling Method ________ Drilling Fluid Used ________

Drilling Contractor ________ Driller ________

Prepared By ________ Helper ________

Core Recovery (feet)	PID Reading (ppm)	Sample Depth (ft bgs)	MUD		SAND					GRAVEL				**Udden-Wentworth Description:** principal components, (angularity, plasticity, dilatency); minor components, (angularity, plasticity, dilatency); sorting, moisture content, consistency/density, color, additional comments
			clay	silt	very fine	fine	medium	coarse	very coarse	granular	pebble	cobble	boulder	

ARCADIS Design & Consultancy for natural and built assets

SOIL BORING LOG (CONT'D)

Boring/Well ____________________ Prepared By ______________________________ Page ____ of ____

			MUD		SAND					GRAVEL				
Core Recovery (feet)	PID Reading (ppm)	Sample Depth (ft bgs)	clay	silt	very fine	fine	medium	coarse	very coarse	granular	pebble	cobble	boulder	Udden-Wentworth Description: principal components, (angularity, plasticity, dilatency); minor components, (angularity, plasticity, dilatency); sorting, moisture content, consistency/density, color, addtl. Comments

ATTACHMENT B

Example of Completed Arcadis Soil Boring Log

ARCADIS Design & Consultancy for natural and built assets

SOIL BORING LOG

Boring/Well SB-01 Project Example Page 1 of 1

Site Location Anytown, North America

Drilling Started 6/26/17

Total Depth Drilled 20 Feet Hole Diameter 4.5 inches Drilling Completed 6/26/17

Type of Sample or Coring Device Continuous Length and Diameter of Coring Device 5', 2.25" macrocore Sampling Interval 5 feet

Drilling Method Geoprobe Drilling Fluid Used NA

Drilling Contractor Fibertec Driller Ryan Brown

Prepared By A. DeGrandis Helper Grant Berger

Core Recovery (feet)	PID Reading (ppm)	Sample Depth (ft bgs)	MUD: clay	MUD: silt	SAND: very fine	SAND: fine	SAND: medium	SAND: coarse	SAND: very coarse	GRAVEL: granular	GRAVEL: pebble	GRAVEL: cobble	GRAVEL: boulder	Udden-Wentworth Description: principal components, (angularity, plasticity, dilatency); minor components, (angularity, plasticity, dilatency); sorting, moisture content, consistency/density, color, additional comments
	0.3	1	X	X	X	X	X							(0.0-4.0) SAND, fine to medium, sub-rounded;
	0.1	2	X	X	X	X	X							little granules to small pebbles, sub-rounded
60"	0.0	3	X	X	X	X	X							to sub-angular; trace silt; poorly sorted, dry
(HA)	0.0	4	X	X	X	X	X							to moist, dark grayish brown (10YR 4/2).
	1.4	5	X	X										NOTE: Ablation till.
	1.7	6	X	X										
	0.9	7	X	X										(4.0-10.0) SILT, non-plastic, rapid dilatancy;
52"	1.2	8	X	X										dry to moist, soft to medium stiff,
	0.6	9	X	X										gray (10YR 5/1).
	0.2	10	X	X										
	0.0	11	X	X	X	X								(10.0-15.5) SAND, fine, sub-rounded; trace
	0.0	12	X	X	X	X								silt; well sorted, moist to wet, pale
60"	0.1	13	X	X	X	X								brown (10YR 6/3).
	0.0	14	X	X	X	X								
	0.0	15	X	X	X	X								NOTE: Wet at 12.0'
	0.2	16	x	x	x	x								
	0.0	17	X											(15.5-20.0) CLAY, high plasticity, no dilatancy;
58"	0.0	18	X											little silt; moist, soft to medium stiff,
	0.0	19	X											light gray (10YR 7/1) to dark gray (10YR 4/1).
	0.0	20	X											NOTE: Lacustrine, minor 0.1-0.25" lamination.
														End of boring - 20.0'

ATTACHMENT C

Arcadis Soil Description Field Guide

ON THE ORIGINAL DRAWING.
USE TO VERIFY FIGURE
REPRODUCTION SCALE

SOIL DESCRIPTION FIELD GUIDE (JUNE 30, 2017; REV. 2.0)

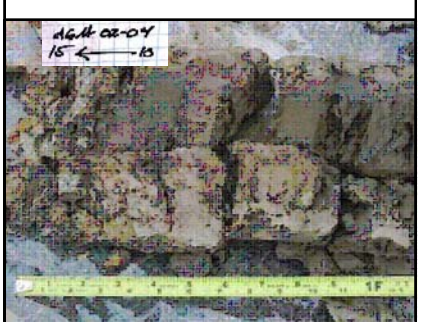
ARCADIS Design & Consultancy for natural and built assets

FINE-GRAINED SOILS

Description	Criteria
	Descriptor - Plasticity
Nonplastic	A 1/8-inch (3mm) thread cannot be rolled at any moisture content.
Low	Thread can barely be rolled, and lump cannot be formed when drier than plastic limit.
Medium	Takes considerable time and rolling to reach plastic limit. Thread cannot be rolled after reaching plastic limit. Lump crumbles when drier than plastic limit.
High	Thread is easy to roll and quickly reaches plastic limit. Thread can be rerolled several times after reaching plastic limit. Lump can be formed without crumbling when drier than plastic limit.
	Descriptor - Dilatancy
No Dilatancy	No visible change when shaken or squeezed.
Slow	Water appears slowly on the surface of soil during shaking and does not disappear or disappears slowly when squeezed.
Rapid	Water appears quickly on surface of soil during shaking and disappears quickly when squeezed.
Minor Components with Descriptors	
	Moisture
Dry	Absence of moisture, dry to touch, dusty.
Moist	Damp but no visible water.
Wet	Visible free water; soil is usually below the water table. (Saturated)
	Consistency
Very soft	N-value < 2 or easily penetrated several inches by thumb.
Soft	N-value 2-4 or easily penetrated 1 inch by thumb.
Medium stiff	N-value 5-8 or indented about 1/2 inch by thumb with great effort.
Stiff	N-value 9-15 or indented about 1/4 inch by thumb with great effort.
Very stiff	N-value 16-30 or readily indented by thumb nail.
Hard	N-value > than 30 or indented by thumbnail with difficulty.
Color using Munsell	
Geologic Origin (if known)	
Other	

EXAMPLE OF SOIL DESCRIPTION AND PHOTO

10-15 feet CLAY, medium to high plasticity; trace silt; trace small to very large pebbles, subround to subangular up to 2" diameter; moist, stiff, dark grayish brown (10YR 4/2). NOTE: Lacustrine; laminated 0.1 to 0.2" thick, laminations brownish yellow (10YR 4/3).



DESCRIPTION ORDER

Depth Interval
Principal Components with Descriptors
Minor Components with Descriptors
Sorting
Field Moisture Condition
Density/Consistency
Color using Munsell
Geologic Origin (if known)
Other descriptions as NOTES:
- Odor
- Stratigraphy
- Structure
- Sphericity
- Cementation
- Reaction to acid

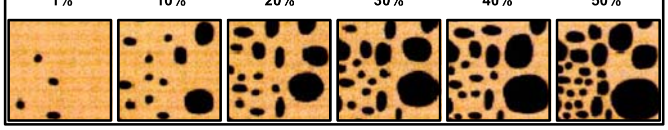
MINOR COMPONENTS % MODIFIERS

Modifier	Percent of Total Sample (by volume)
and	36 - 50
some	21 - 35
little	10 - 20
trace	<10

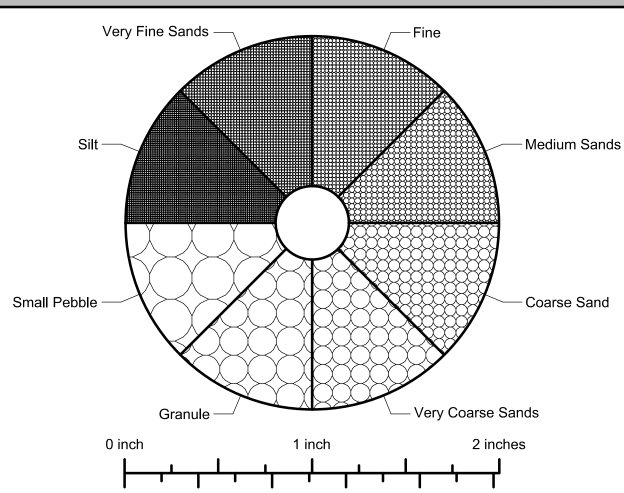
UDDEN-WENTWORTH SCALE

Fraction	Sieve Size	Grain Size	Approximate Scale
Boulder		256 - 4096 mm	Larger than volleyball
Large Cobble		128 - 256 mm	Softball to volleyball
Small Cobble		64 - 128 mm	Pool ball to softball
Very Large Pebble		32 - 64 mm	Pinball to pool ball
Large Pebble		16 - 32 mm	Dime size to pinball
Medium Pebble		8 - 16 mm	Pencil eraser to dime size
Small Pebble	No. 5+	4 - 8 mm	Pea size to pencil eraser
Granule	No. 10 - 5	2 - 4 mm	Rock salt to pea size
Very Coarse Sand	No. 18 - 10	1 - 2 mm	See field gauge card
Coarse Sand	No. 35 -18	0.5 - 1 mm	See field gauge card
Medium Sand	No. 60 - 35	0.25 - 0.5 mm	See field gauge card
Fine Sand	No. 120 - 60	0.125 - 0.25 mm	See field gauge card
Very Fine Sand	No. 230 - 120	0.0625 - 0.125 mm	See field gauge card
Silt and Clay. See SOP for description of fines	Not Applicable	<0.0625 mm	Analyze by pipette or hydrometer

PARTICLE PERCENT COMPOSITION ESTIMATION



GRAPH FOR DETERMINING SIZE OF PARTICLES



FOR COARSE-GRAINED SOILS

Description	Criteria
	Descriptor - Angularity
Angular	Particles have sharp edges and relatively planar sides withunpolished surfaces.
Subangular	Particles are similar to angular but have rounded edges.
Subround	Particles have nearly planar sides but have well-roundedcorners and edges.
Round	Particles have smoothly curved sides and no edges.
Minor Components with Descriptors	
	Sorting Cu= d60/d10
Well Sorted	Near uniform grain-size distribution Cu= 1 to 3.
Poorly Sorted	Wide range of grain size Cu= 4 to 6.
	Moisture
Dry	Absence of moisture, dry to touch, dusty.
Moist	Damp but no visible water.
Wet	Visible free water; soil is usually below the water table. (Saturated)
	Density
Very loose	N-value 1 - 4
Loose	N-value 5 - 10
Medium Dense	N-value 11 - 30
Dense	N-value 31 - 50
Very dense	N-value >50
Color using Munsell	
Geologic Origin (if known)	
Other	
	Cementation
Weak Cementation	Crumbles or breaks with handling or little finger pressure.
Moderate Cementation	Crumbles or breaks with considerable finger pressure.
Strong Cementation	Will not crumble with finger pressure.
	Reaction with Dilute HCl Solution (10%)
No Reaction	No visible reaction.
Weak Reaction	Some reaction, with bubbles forming slowly.
Strong Reaction	Violent reaction, with bubbles forming immediately.

EXAMPLE OF SOIL DESCRIPTION AND PHOTO

10 -15 feet SAND, medium to very coarse; little granules to medium pebbles, subround to subangular; trace silt; poorly sorted, wet, grayish brown (10YR5/2).

ON THE ORIGINAL DRAWING, USE TO VERIFY FIGURE REPRODUCTION SCALE

SOIL DESCRIPTION FIELD GUIDE (JUNE 30, 2017; REV. 2.0)

ARCADIS Design & Consultancy for natural and built assets

10 inches · 9 inches · 8 inches · 7 inches · 6 inches · 5 inches · 4 inches · 3 inches · 2 inches · 1 inch · 1/10in

0 mm · 10 mm · 20 mm · 30 mm · 40 mm · 50 mm · 60 mm · 70 mm · 80 mm · 90 mm · 100 mm · 110 mm · 120 mm · 130 mm · 140 mm · 150 mm · 160 mm · 170 mm · 180 mm · 190 mm · 200 mm · 210 mm · 220 mm · 230 mm · 240 mm · 250 mm

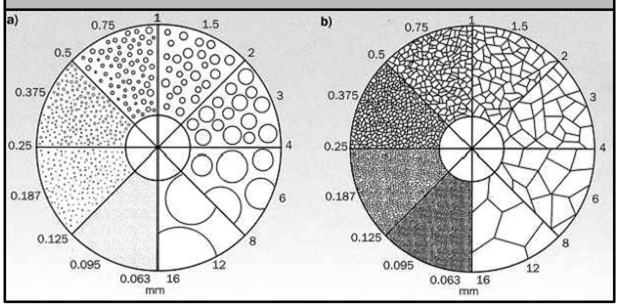
VARIATIONS IN SOIL STRATIGRAPHY

Term	Thickness of Configuration
Parting	0 - to 1/16-inch thickness.
Seam	1/16 - to 1/2-inch thickness.
Layer	1/2 - to 12-inch thickness.
Stratum	> 12-inch thickness.
Pocket	Small erratic deposit, usually less than 1 foot in size.
Varved Clay	Alternating seams or layers of sand, silt, and clay (laminated).
Occasional	≤ 1 foot thick.
Frequent	> 1 foot thick.

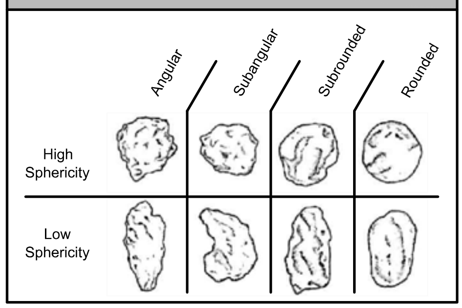
SOIL STRUCTURE DESCRIPTIONS

Term	Description
Homogeneous	Same color and appearance throughout.
Laminated	Alternating layers < 1/4 inch thick.
Stratified	Alternating layers ≥ 1/4 inch thick.
Lensed	Inclusions of small pockets of different materials, such as lenses of sand scattered through a mass of clay; note thickness.
Blocky	Cohesive soil can be broken down into small angular lumps, which resist further breakdown.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided	Fracture planes appear to be polished or glossy, sometimes striated.

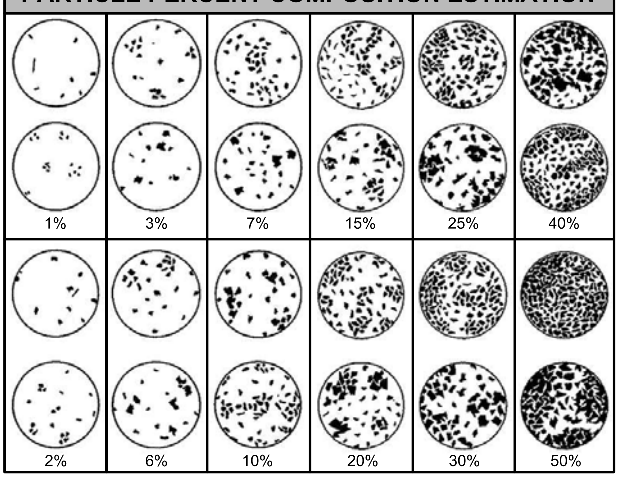
GRAPH FOR DETERMINING SIZE OF PARTICLES



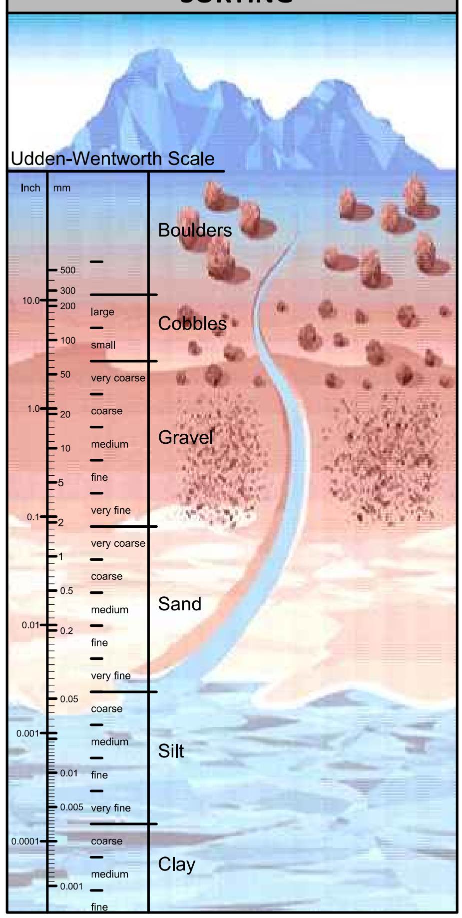
ANGULARITY CHART



PARTICLE PERCENT COMPOSITION ESTIMATION



SORTING



SETTLING TABLE (SILT/CLAY)

Diameter of Particle (mm)	<0.625	<0.031	<0.016	<0.008	<0.004	<0.002	<0.0005
Depth of Withdrawal (cm)	10	10	10	10	5	5	3
Time of Withdrawal	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec
Temperature (Celsius)							
20	00:00:29	00:01:55	00:07:40	00:30:40	00:61:19	04:05:00	37:21:00
21	00:00:28	00:01:52	00:07:29	00:29:58	00:59:50	04:00:00	
22	00:00:27	00:01:50	00:07:18	00:29:13	00:58:22	03:54:00	
23	00:00:27	00:01:47	00:07:08	00:28:34	00:57:05	03:48:00	
24	00:00:26	00:01:45	00:06:58	00:27:52	00:55:41	03:43:00	33:56:00
25	00:00:25	00:01:42	00:06:48	00:27:14	00:54:25	03:38:00	
26	00:00:25	00:01:40	00:06:39	00:26:38	00:53:12	03:33:00	
27	00:00:24	00:01:38	00:06:31	00:26:02	00:52:02	03:28:00	
28	00:00:24	00:01:35	00:06:22	00:25:28	00:50:52	03:24:00	31:00:00
29	00:00:23	00:01:33	00:06:13	00:24:53	00:49:42	03:10:00	
30	00:00:23	00:01:31	00:06:06	00:24:22	00:48:42	03:05:00	

Low Flow Groundwater Purging and Sampling Procedures

LOW-FLOW GROUNDWATER PURGING AND SAMPLING PROCEDURES FOR MONITORING WELLS

Rev. #: 5

Rev Date: 12/30/2016

TGI VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by

APPROVAL SIGNATURES

Prepared by: Ryan McKinney Date: 12/30/2016

Reviewed by: Eric Killenbeck (Technical Expert) Date: ________________

I. SCOPE AND APPLICATION

Groundwater samples are collected from monitoring wells to evaluate groundwater quality. The protocol presented in this Technical Guidance Instruction (TGI) describes the procedures recommended to purge monitoring wells and collect groundwater samples. This protocol has been developed in accordance with the United States Environmental Protection Agency (USEPA) Region I Low Stress (Low-Flow) Purging and Sampling Procedures for the Collection of Groundwater Samples from Monitoring Wells (EQASOP-GW001; January 19, 2010). Both filtered and unfiltered groundwater samples may be collected using this low-flow sampling method. Filtered samples should be obtained using a 0.45-micron disposable filter. Project teams should determine the last time the wells were developed and if additional development might be necessary. Groundwater samples should not be collected within 1 week following well development.

II. PERSONNEL QUALIFICATIONS

Arcadis personnel providing assistance to groundwater sample collection and associated activities should have a minimum of 6 months of related experience or an advanced degree in environmental sciences, engineering, hydrogeology, or geology. The supervisor of the groundwater sampling team should have at least 1 year of previous supervised groundwater sampling experience. Prior to mobilizing to the field, the groundwater sampling team should review and be thoroughly familiar with relevant site-specific documents including but not limited to the site work plan, field sampling plan, Quality Assurance Project Plan (QAPP), Health and Safety Plan (HASP), historical information, and site relevant documents.
Additionally, the groundwater sampling team should review and be thoroughly familiar with documentation provided by equipment manufacturers for all equipment that will be used in the field prior to mobilization.

III. EQUIPMENT LIST

Specific to this activity, the following materials (or equivalent) should be available:

- Health and safety documents and equipment (as identified in the site HASP)
- Site Plan, well construction records, prior groundwater sampling records (if available)
- Sampling pump, which may consist of one or more of the following:
  - Submersible pump (e.g., Grundfos Redi-Flo 2)
  - Peristaltic pump (e.g., ISCO Model 150)
  - Bladder pump (e.g., Marschalk System 1, QED Micropurge, Geotech)
- Appropriate controller and power source for pump:
  - Submersible and peristaltic pumps require electric power from either a generator or a deep cell battery.
  - Submersible pumps such as Grundfos require a pump controller to run the pump.

- Bladder pumps require a pump controller and a gas source (e.g., air compressor or compressed N_2 or CO_2 gas cylinders).

- Teflon® tubing or Teflon®-lined polyethylene tubing of an appropriate size for the pump being used. For peristaltic pumps, dedicated Tygon® tubing (or other type as specified by the manufacturer) should also be used through the pump apparatus. When collecting samples for perflourinated compounds (PFCs), Teflon® components or tubing should not be used. Teflon® components or tubing may not be necessary when sampling for metals and/or inorganics.
- Water-level probe (e.g., Solinist Model 101)
- Water-quality (temperature/pH/specific conductivity/oxidation reduction potential [ORP]/turbidity/dissolved oxygen) meter and flow-through measurement cell. Several brands may be used, including:

  - YSI 6-Series Multi-Parameter Instrument
  - Horiba U-22 Multi-Parameter Instrument
  - Hydrolab Series 3 or Series 4a Multiprobe and Display
- Supplemental turbidity meter (e.g., Horiba U-10, Hach 2100P, LaMotte 2020). Turbidity measurements collected with multi-parameter meters have sometimes been shown to be unreliable due to fouling of the optic lens of the turbidity meter within the flow-through cell. A supplemental turbidity meter should be used to verify turbidity data during purging if such fouling is suspected. An in-line tee and valve should allow for collection of water for turbidity measurements before the pump discharge enters the flow-through cell. Note that industry improvements may eliminate the need for these supplemental measurements in the future.
- Appropriate water sample containers (supplied by the laboratory)
- Appropriate blanks (trip blank supplied by the laboratory)
- 0.45-micron disposable filters (if field filtering is required)
- Cleaning equipment
- Groundwater sampling log (attached) or bound field logbook.

Note that, in the future, the client may acquire different makes/models of some of this equipment if the listed makes/models are no longer available, or as a result of general upgrades or additional equipment acquisitions. Note the specific make/model of the equipment used during a sampling event on the groundwater sampling log. The maintenance requirements for the above equipment generally involve decontamination or periodic cleaning, battery charging, and proper storage, as specified by the manufacturer. For operational difficulties, the equipment should be serviced by a qualified technician.

IV. CAUTIONS

Different USEPA regions and/or state regulatory agencies may stipulate deviations from this document. It is the responsibility of the Project Manager or Technical manager to be fully aware of the requirements from the applicable regulatory framework.

If heavy precipitation occurs, and no cover over the sampling area and monitoring well can be erected, sampling may be discontinued until adequate cover is provided. Rain water could contaminate groundwater samples. Do not use permanent marker or felt-tipped pens for labels on sample container or sample coolers; use indelible ink. Permanent markers could introduce volatile constituents into the samples. It may be necessary to field filter some parameters (e.g., metals) prior to collection, depending on preservation, analytical method, and project quality objectives. Store and/or stage empty and full sample containers and coolers out of direct sunlight. To mitigate potential cross-contamination, groundwater samples are to be collected in a pre-determined order from least impacted to impacted based on previous analytical data. If no analytical data are available, collect samples in order of upgradient, then furthest downgradient to source area locations. Be careful not to overtighten lids with Teflon® liners or septa (e.g., 40 mL vials). Overtightening can cause the glass to shatter or impair the integrity of the Teflon® seal.

V. HEALTH AND SAFETY CONSIDERATIONS

Review all site-specific and procedural hazards as they are provided in the HASP, and review Job Safety Analysis (JSA) documents in the field each day prior to beginning work. Generators and cord and plug equipment should employ an overcurrent protection device such as an integrated ground fault circuit interrupter (GFCI) cord. Grundfos pump controllers will not run properly with a GFCI, so the power source should be equipped with other overcurrent protection means.

VI. PROCEDURE

Groundwater should be purged from the wells using an appropriate pump. If the depth to water is below the sampling range of a peristaltic pump (approximately 25 feet), submersible pumps or bladder pumps should be used provided that the well is constructed with a casing diameter greater than or equal to 2 inches (the minimum well diameter capable of accommodating such pumps). Bladder pumps are preferred over peristaltic and submersible pumps if sampling of volatile organic compounds (VOCs) is required to prevent volatilization. For smaller diameter wells, where the depth to water is below the sampling range of a peristaltic pump, alternative sampling methods (i.e., bailing or small diameter bladder pumps) should be used to purge and sample the groundwater. Purge water should be collected and containerized according to the direction of the project team.

1. Calibrate field instruments according to manufacturer procedures for calibration and document.

2. Open the well cover while standing upwind of the well. Remove the well cap and place it on the plastic sheeting. Insert the photoionization detector (PID) probe approximately 4 to 6 inches into the casing or the well headspace and cover it with a gloved hand. Record the PID reading in the field log. Perform air monitoring in the breathing zone according to the HASP and/or JSA. Measure the initial depth to groundwater prior to placing the pumps.
3. Prepare and install the pump in the well: For submersible and non-dedicated bladder pumps, decontaminate the pump according to site decontamination procedures. Non-dedicated bladder pumps will require a new bladder and attachment of an air line, sample discharge line, and safety cable prior to placement in the well. Attach the air line tubing to the air port on the top of the bladder pump. Attach the sample discharge tubing to the water port on the top of the bladder pump. Take care not to reverse the air and discharge tubing lines during bladder pump setup, as this could result in bladder failure or rupture.

   Attach and secure a safety cable to the eyebolt on the top of bladder pump (if present, depending on pump model used). Slowly lower the pump, safety cable, tubing, and electrical lines into the well to a depth corresponding to the approximate center of the saturated screen section of the well. Avoid twisting and tangling of safety cable, tubing, and electrical lines while lowering the pump into the well; twisted and tangled lines could result in the pump becoming stuck in the well casing. Also, make sure to keep tubing and lines from touching the ground or other surfaces while introducing them into the well, as this could lead to well contamination. If a peristaltic pump is being used, slowly lower the sampling tubing into the well to a depth corresponding to the approximate center of the saturated screen section of the well. The pump intake or sampling tube must be kept at least 2 feet above the bottom of the well to prevent mobilization of any sediment present in the bottom of the well.

   4. If using a bladder pump, connect the air line to the pump controller output port. The pump controller should then be connected to a supply line from an air compressor or compressed gas cylinder using an appropriate regulator and air hose. Tighten the regulator connector onto the gas cylinder (if used) to prevent leaks. Teflon® tape may be used on the threads of the cylinder to provide a tighter seal. Once the air compressor or gas cylinder is connected to the pump controller, turn on the compressor or open the valve on the cylinder to begin the gas flow. Turn on the pump controller power if an on/off switch is present, and verify that all batteries are charged and fully operating before beginning to pump.

   5. Connect the pump discharge water line to the bottom inlet port on the flow-through cell connected to the water quality meter.

   6. Measure the water level again with the pump in the well before starting the pump to ensure that it has stabilized. Start pumping the well at 200 to 500 milliliters (mL) per minute (or at lower site-specific rate if specified). Adjust the pump rate to cause little or no water level drawdown in the well (less than 0.3 foot below the initial static depth to water measurement), and the water level should stabilize; however, this is not always possible. The water level should be monitored every 3 to 5 minutes (or as appropriate, lower flow rates may require longer time between readings) during pumping if the well diameter is of sufficient size to

allow such monitoring. Do not break pump suction or cause entrainment of air in the sample. Record pumping rate adjustments and depths to water. If necessary, reduce pumping rates to the minimum capabilities of the pump to avoid pumping the well dry and/or to stabilize indicator parameters. Maintain a steady flow rate to the extent practicable. Review groundwater sampling records from previous sampling events (if available) prior to mobilization to estimate the optimum pumping rate and anticipated drawdown for the well in order to more efficiently reach a stabilized pumping condition. If the recharge rate of the well is very low, use alternative purging techniques, which will vary based on the well construction and screen position. For wells screened across the water table, the well may be pumped dry and sampling can commence as soon as the volume in the well has recovered sufficiently to permit collection of samples. For wells screened entirely below the water table, the well can be pumped until a stabilized level (which may be greater than the maximum displacement goal of 0.3 foot) is maintained, and monitoring for stabilization of field indicator parameters can commence. If a lower stabilization level cannot be maintained, the well may be pumped until the drawdown is at a level slightly higher than top of the well screen. Sampling may commence after one well volume has been removed and the well has recovered sufficiently to permit collection of samples. During purging, monitor the field indicator parameters (e.g., turbidity, temperature, specific conductance, pH, ORP, and dissolved oxygen [DO]) every 3 to 5 minutes (or after each volume of the flow-through cell has been purged). Measure field indicator parameters using a flow-through analytical cell or a clean container such as a glass beaker. Record field indicator parameters on the groundwater sampling log. The well is considered stabilized and ready for sample collection when turbidity values remain within 10% (or within 1 nephelometric turbidity unit [NTU] if the turbidity reading is less than 10 NTU), the specific conductance and temperature values remain within 3%, ORP readings remain within ± 10 mV, DO values remain within 10%, and pH remains within 0.1 unit for three consecutive readings collected at 3- to 5-minute intervals (or other appropriate interval, alternate stabilization goals may exist in different geographic regions, consult the site-specific Work Plan for stabilization criteria). If the field indicator parameters do not stabilize within 1 hour of the start of purging, but the groundwater turbidity is below the goal of 50 NTU and the values for all other parameters are within 10%, the well can be sampled. If the parameters have stabilized but the turbidity is not in the range of the 50 NTU goal, the pump flow rate may be decreased to a minimum rate of 100 mL/min to reduce turbidity levels as low as possible. DO is extremely susceptible to various external influences (including temperature or the presence of bubbles on the DO meter); care should be taken to minimize the agitation or other disturbance of water within the flow-through cell while collecting these measurements. If air bubbles are present on the DO probe or in the discharge tubing, remove them before taking a measurement. If DO values are not within acceptable range for the temperature of groundwater (Attachment 1), then again check for and remove air bubbles on the probe before re-measuring. If the DO value is 0.00 or less, then the meter should be serviced and re-calibrated. If the DO values are above possible results, then the meter should be serviced and re-calibrated.

During extreme weather conditions, stabilization of field indicator parameters may be difficult to attain. Modifications to the sampling procedures to alleviate these conditions (e.g., measuring the water temperature in the well adjacent to the pump intake) should be documented in the field notes. If other field conditions preclude stabilization of certain parameter, an explanation of why the parameters did not stabilize should also be documented in the field logbook.

7. Complete the sample label(s) and cover the label(s) with clear packing tape to secure the label onto the container.

8. After the indicator parameters have stabilized, collect groundwater samples by diverting flow out of the unfiltered discharge tubing into the appropriate labeled sample container. If a flow-through analytical cell is being used to measure field parameters, the flow-through cell should be disconnected after stabilization of the field indicator parameters and prior to groundwater sample collection. Under no circumstances should analytical samples be collected from the discharge of the flow-through cell. When the container is full, tightly screw on the cap. Samples should be collected in the following order: VOCs, total organic carbon (TOC), semi-volatile organic compounds (SVOCs), metals and cyanide, and others (or other order as defined in the site-specific Work Plan).

9. If sampling for total and filtered metals and/or polychlorinated biphenyls (PCBs), a filtered and unfiltered sample should be collected. Install an in-line, disposable 0.45-micron particle filter on the discharge tubing after the appropriate unfiltered groundwater sample has been collected. Continue to run the pump until an initial volume of “flush” water has been run through the filter in accordance with the manufacturer’s directions (generally 100 to 300 mL). Collect the filtered groundwater sample by diverting flow out of the filter into the appropriately labeled sample container. When the container is full, tightly screw on the cap.

10. Secure with packing material and store at 4°C in an insulated transport container provided by the laboratory.

11. Record on the groundwater sampling log or bound field logbook the time at which sampling procedures were completed, any pertinent observations of the sample (e.g., physical appearance and the presence or lack of odors or sheens), and the values of the stabilized field indicator parameters as measured during the final reading during purging (Attachment 2 – Example Sampling Log).

12. Turn off the pump and air compressor or close the gas cylinder valve if using a bladder pump setup. Slowly remove the pump, tubing, lines, and safety cable from the well. Do not allow the tubing or lines to touch the ground or any other surfaces which could contaminate them.

13. If tubing is to be dedicated to a well, it should be folded to a length that will allow the well to be capped and also facilitate retrieval of the tubing during later sampling events. A length of rope or string should be used to tie the tubing to the well cap. Alternatively, if tubing and safety line are to be saved and reused for sampling the well at a later date, they may be coiled neatly and placed in a clean plastic bag that is clearly labeled with the well ID. Make sure the bag is tightly sealed before placing it in storage.

14. Secure the well and properly dispose of personal protective equipment (PPE) and disposable equipment.

15. Complete the procedures for packaging, shipping, and handling with the associated chain of custody.

16. Complete decontamination for flow-through analytical cell and submersible or bladder pump, as appropriate.
17. At the end of the day, perform calibration check of field instruments.

VII. WASTE MANAGEMENT

Materials generated during groundwater sampling activities, including disposable equipment, should be placed in appropriate containers. Containerized waste should be disposed of by the client consistent with the procedures identified in the HASP.

VIII. DATA RECORDING AND MANAGEMENT

Initial field logs and chain-of-custody records should be transmitted to the Arcadis Project Manager at the end of each day unless otherwise directed. The groundwater team leader retains copies of the groundwater sampling logs.

IX. QUALITY ASSURANCE

In addition to the quality control samples to be collected in accordance with this TGI, the following quality control procedures should be observed in the field:

- Collect samples from monitoring wells, in order of increasing concentration, to the extent known based on review of historical site information if available.
- Equipment blanks should include the pump and tubing (if using disposable tubing) or the pump only (if using tubing dedicated to each well).
- Collect equipment blanks after wells with higher concentrations (if known) have been sampled.
- Operate all monitoring instrumentation in accordance with manufacturer's instructions and calibration procedures. Calibrate instruments at the beginning of each day and verify the calibration at the end of each day. Record all calibration activities in the field notebook.
- Clean all groundwater sampling equipment prior to use in the first well and after each subsequent well following procedures for equipment decontamination.

X. REFERENCES

United States Environmental Protection Agency (USEPA). 1986. RCRA Groundwater Monitoring Technical Enforcement Guidance Document (September 1986).

USEPA Region II. 1998. *Ground Water Sampling Procedure Low Stress (Low Flow) Purging and Sampling*.

USEPA. 1991. Handbook Groundwater, Volume II Methodology, Office of Research and Development, Washington, DC. USEPN62S, /6-90/016b (July, 1991).

U.S. Geological Survey (USGS). 1977. National Handbook of Recommended Methods for Water-Data Acquisition: USGS Office of Water Data Coordination. Reston, Virginia.

PFAS Sampling Procedures

Design & Consultancy for natural and built assets

TGI - POLY- AND PERFLUORINATED ALKYL SUBSTANCES (PFAS) FIELD SAMPLING GUIDANCE

Rev #: 0

Rev Date: April 27, 2017

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	April 27, 2017	All	Initial Release	Erica Kalve Erika Houtz Sue Tauro

APPROVAL SIGNATURES

Prepared by:		04/26/2017
	Erika F. Houtz, PhD Environmental Engineer and PFAS Analytical Lead	Date:
Technical Expert Reviewed by:		04/27/2017
	Erica Kalve, PG-CA Emerging Contaminants Focus Group Leader	Date:

1 INTRODUCTION

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to any and all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, state-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

The purpose of this Technical Guidance Instructions (TGI) is to provide guidance on field sampling to be used for poly-and perfluorinated alkyl substances (PFAS). This protocol was adapted from various sources including Arcadis Australia, Transport Canada, and the U.S Army Corp of Engineers (USACE) Omaha.

Given the extremely low detection limits associated with PFAS analysis and the many potential sources of trace levels of PFAS, field personnel are advised to err on the side of caution by strictly following these protocols, frequently replacing nitrile gloves, and rinsing field equipment to help mitigate the potential for false detections of PFAS. Other specific items related to field sampling for PFAS are discussed in the sections below.

This TGI applies to all Arcadis and subcontractor personnel involved in field sampling for PFAS.

3 PERSONNEL QUALIFICATIONS

3.1 Sampling Personnel

Field personnel must have current health and safety training, including 40-hour HAZWOPER training, site supervisor training, and site-specific training, as needed. In addition, field personnel will be versed in the other relevant SOPs (e.g., low flow sampling) and will possess the skills and experience necessary to successfully complete the desired field work. The site Health and Safety Plan (HASP) and other documents will identify any other training requirements such as site-specific safety training or access control requirements.

3.2 Laboratories

These laboratories may be used to analyze environmental media for PFAS:

- United States: Test America, SGS, Vista, ALS, RTI, and Eurofins
- Canada: Axys-SGS and Maxxam Laboratories

Other laboratories may be used if they are accredited for PFAS analysis.

4 EQUIPMENT LIST

The following equipment and materials must be available for sampling:

- Site plan of sampling locations, relevant work plan (or equivalent), and this TGI;
- Appropriate health and safety equipment, as specified in the site HASP;
- Dedicated plastic sheeting (preferably high-density polyethylene [HDPE]) or other clean surface to prevent sample contact with the ground;
- Conductivity/temperature/pH meter;
- Dissolved oxygen meter, oxidation reduction potential meter, and turbidity meter;
- Depth to water meter;
- If using low-flow groundwater sampling techniques, peristaltic pump (groundwater sampling)/bladder pump (with PFAS free bladder/ HDPE bladder), flow through cell, and accompanying HDPE and silicone tubing;
- Hydrasleeves, if using Hydrasleeves for groundwater sampling;
- Metal trowel for soil samples; specialized soil/sediment sampling equipment as required;
- Brushes for scrubbing sampling equipment;
- Pens, pencils, and/or Sharpies for writing;
- Clipboards, field binders, and field note pages that are not waterproof;

- Labeled sample bottles:
  - Water: HDPE bottles fitted with polypropylene screw cap only; some types of PFAS samples (primarily drinking water) may require preservative, which will be indicated by the laboratory conducting the analysis. The laboratory will specify the sample bottle volume.
  - Soil and sediment: HDPE bottles fitted with polypropylene screw cap only; no preservatives. The laboratory will specify the sample bottle volume.
- If high concentrations of PFAS related to class B firefighting foams are expected, bring ‘shaker test' vials;
- Ziploc® bags to hold ice and samples;
- Appropriate blanks (field reagent blanks supplied by the laboratory);
- Appropriate transport bottles (coolers) with ice and appropriate labeling, no blue ice;
- Deionized water for initial decontamination rinsing;
- “PFAS-free” water provided by the laboratory for final decontamination rinsing;
- Methanol, if readily available; especially important for soil sampling;
- Alconox or Liquinox®;
- Packing and shipping materials;
- Groundwater Sampling Log; and
- Chain-of-Custody (COC) Forms.

5 CAUTIONS

5.1 Food Packaging

Some food packaging may be treated with PFAS-containing chemicals to prevent permeation of oil and water in the food outside of the packaging. To avoid potential food packaging-related PFAS contact:

- Do not bring any food outside of the field vehicles onsite and eat snacks and meals offsite.
- Wash hands after eating.
- Remove any field garments or outer layers prior to eating. Do not put them back on until done eating and hands are washed.

5.2 Field Gear

5.2.1 Clothing

Many types of clothing are treated with PFAS for stain and water resistance, in particular outdoor performance wear under brand names such as Gore-Tex®. To avoid potential clothing-related PFAS contact:

- Do not wear any outdoor performance wear that is water or stain resistant, or appears to be. Err on the side of caution.
- Wear pre-laundered (multiple washings, i.e. 6+) clothing that is not stain resistant or water proof.
- Natural fabrics such as cotton are preferred. Synthetic fabrics may also be acceptable if there is no indication on the label that the fabric is water and stain resistant.
- Most importantly, avoid contacting your clothing with sampling equipment, bottles, and samples.

5.2.2 Personal Protective Equipment

Safety Footwear

Some safety footwear has been treated to provide a degree of waterproofing and increased durability, and may represent a source of trace PFAS. For the health and safety of field personnel, footwear must be protected at all times to avoid potential PFAS contamination. To do this:

- Do not touch your safety footwear in the immediate vicinity of the sampling port (i.e., within 10 meters [m]).
- Do not allow gloves used for sampling to come in contact with safety footwear.

Nitrile Gloves

- Wear disposable nitrile gloves at all times. Don a new pair of nitrile gloves **<u>before</u>** the following activities at each sample location:
- Decontamination of re-usable sampling equipment;
- Contact with sample bottles or "PFAS-free" water bottles;
- Insertion of anything into the sample ports (e.g., HDPE tubing); and
- Handling of any quality assurance/quality control (QA/QC) samples including field blanks and equipment blanks.

Don a new pair of nitrile gloves <u>after</u> the following activities:

- Handling of any non-dedicated sampling equipment;
- Contact with contaminated surfaces; or

- When judged necessary by field personnel.

5.3 Personal Hygiene

- Shower at night.
- Do not use personal care products after showering such as lotions, makeup, and perfumes, UNLESS medically necessary.
- Use sunscreen and insect repellent ONLY if necessary for health and safety. If they are necessary, apply sunscreen and repellant prior to initiating field sampling. If sunscreen and/or repellant need to be reapplied, ensure a safe distance away from the sampling locations and equipment (i.e., more than 10 m away). Wash hands after application.

5.4 Visitors

Visitors to the site are asked to remain at least 10 m from sampling areas.

5.5 Rain Events

Special care should be taken when rain is falling at the project site:

- Do not perform field sampling when rain fall is persistent at a consistent rate that saturates the ground (i.e., formation of puddles) because rain gear is not permitted while sampling. Intermittent showers or fog are acceptable conditions to proceed. If rain showers occur; field gear must be removed from the monitoring well location until the rain subsides.
- If project timelines are tight, consider the use of a gazebo tent that can be erected over the top of the monitoring well to provide shelter from the rain. The canopy material is possibly a PFAS-treated surface and should be managed as such; therefore, wear gloves when moving the tent, change them immediately after moving the tent, and avoid further contact with the tent until all sampling activities have been finished and the team is ready to move on to the next site.

6 HEALTH AND SAFETY CONSIDERATIONS

- The ability to safely access the surface water sampling locations must be verified before sampling.
- Field activities must be performed in accordance with the site HASP, a copy of which will be present onsite during such activities.
- Safety hazards associated with sampling surface water include fast-moving water, deep water, and steep slopes close to sampling sites. Use extreme caution when approaching sampling sites.
- If thunder or lighting is present, discontinue sampling and take cover until 30 minutes have passed after the last occurrence of thunder or lighting.
- Use caution when removing well caps as well may be under pressure, cap can dislodge forcefully and cause injury.

7 PROCEDURE

7.1 Field Equipment Cleaning

Field sampling equipment will require cleaning between uses. For groundwater sampling, between uses, decontaminate the flow-through cell and any non-dedicated equipment (i.e., interface probe of depth to water meter) that comes into contact with well water. Trowels and other materials used to sample soil samples will also require decontamination.

After donning a new pair of nitrile gloves:

- Rinse sampling equipment with Alconox or Liquinox® cleaning solution; Scrub equipment with a plastic brush if needed;
- Rinse two times with distilled water or deionized water;
- Rinse one time with "PFAS-free" water or once with methanol, if it is available, and once with "PFAS-free" water; methanol is especially useful for decontaminating soil sampling equipment; and
- Collect all rinsate in a sealed pail for disposal. Do not reuse decontamination solutions between sampling locations.

Clean all field equipment used at locations that are suspected of containing class B firefighting foam (i.e., those that foam during shaking or are known to be near a class B firefighting foam source zone) using each of the above steps repeated twice.

7.2 Borehole/Monitoring Well Development

If a drill rig is being used to drill for soil cores or to install monitoring wells, wear clean nitrile gloves before collecting <u>each</u> continuous soil sample. Additional requirements include the following:

- Verify in writing with the manufacturer that single-use liners used to collect each sample are made of a material that does not contain PFAS;
- Collect soil samples in laboratory-supplied HDPE bottles.
- Store the sample bottles in coolers and keep at a temperature of 0 to 6ºC until transported to the laboratory.

7.2.1 Well Condition Survey/ Water Level Monitoring

Using equipment that has been thoroughly decontaminated according to the procedures in Section 7.1, conduct the well condition surveys and water level monitoring:

- Conduct monitoring well inspections and record water levels.
- Use an interface probe to evaluate presence/absence of non-aqueous phase liquid (NAPL).
- Measure the depth to water from the top of the polyvinyl chloride (PVC) riser and the total depth of the well.

- Record information in the field notes.

7.2.2 Monitoring Well Development and Purging

Follow these requirements for monitoring well development and purging:

- Do not use Teflon™ tubing for purging or sample collection. HDPE tubing is acceptable.
- Do not re-use materials between wells. Upon completion of use, remove all disposable materials (such as HDPE and/or silicone tubing) and place in heavy duty garbage bags for disposal.
- During development of the well, create sufficient energy to agitate the water column and create flow reversals in the well screen, filter pack and formation to loosen fine-grained materials and draw them into the well. The pumping or bailing action should then draw all drilling fluids and fine-grained material out of the borehole and adjacent formation and then out of the well. Review the Arcadis Monitoring Well Development guidance (Arcadis 2010) for more detailed information.
- Follow the low-flow purge and sampling techniques per the U.S. Protection Agency's (EPA's) guidance document titled *Low Stress (Low Flow) purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells (2010) and ASTM's standard titled Standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations* (2002). Also, available for review is the Arcadis Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells (Arcadis 2011).
- To purge the well, if using HDPE tubing and a peristaltic pump, insert the end of the tubing to the approximate depth of the midpoint of the screened section of the monitoring wells. Measure the length of HDPE tubing to be inserted into each monitoring well and pre-cut it to approximate lengths (such as the previously measured arm span of a field technician) to avoid contact with any materials other than the monitoring well and peristaltic pump. Flow rates should be as low as can be reasonably achieved. Collect and appropriately dispose of purge water.
- Silicone tubing should direct the purge water through a flow-through cell for field parameter measurements of pH, conductivity, temperature, dissolved oxygen, and turbidity. Calibrate the instrument in the field prior to use. Decontaminate the instrument and flow-through cell at each monitoring well location before purging.
- Record field parameters in intervals (generally of 3-minute duration) to ensure purge water has cycled through the flow-through cell. Sample the wells after field parameter measurements indicate stabilization, which allows collection of representative formation water (generally acceptable standards are three consecutive pH readings to within ±0.1 units, and three consecutive conductivity, temperature and dissolved oxygen measurements to within 3%). Turbidity must be monitored, but does not need to be used as a stabilization indicator of purge completion. Record field parameter measurements at each well. Drawdown should be monitored throughout the purge.
- If wells are suspected to be dewatering throughout the purge (i.e., reduced flow rate/difficulty pumping water or bubbles begin to come through the flow through cell), turn off the pump and allow the water level to recover for ½ hour, followed by sample collection. Document these activities in the field notes.

7.3 Sample Collection

Different laboratories may supply sample collection bottles of varying sizes depending on the type of media to be sampled.

7.3.1 Sample Containers

- Collect samples in HDPE bottles fitted with an unlined (no Teflon™), polypropylene screw cap.
- Complete bottle labels after the caps have been placed back on each bottle.
- Do not use glass bottles due to potential loss of analyte through adsorption. This is particularly important for aqueous samples.

7.3.2 Soil Sampling

Before Sample Collection

- Place plastic sheeting (preferably HDPE) adjacent to the sample port for use as a clean work area, if conditions allow. Otherwise, prevent sampling equipment from contacting the ground or other surface that could compromise sample integrity.
- Trowels or drilling equipment that will come into contact with a sample should be decontaminated prior to sample collection, preferably with methanol;
- Don a new set of nitrile gloves. Do not use gloved hands to subsequently handle papers, pens, clothes, etc., before collecting samples.
- Use the HDPE bottles that are supplied by the laboratory. Make sure that the caps remain on the bottle until immediately prior to sample collection.

During Sample Collection

- Collect soil samples using a clean stainless steel trowel or with single-use PFAS-free liners;
- Place soil samples in labeled HDPE bottles supplied by the laboratory.
- Collect any necessary duplicates/co-located samples and matrix spikes – verify with laboratory whether they need to be collected in separate sample bottles.
- Note the time on the sample label.

After Sample Collection

- Place soil sample bottles in a sealed Ziploc© bag (optional).
- Record the label information and time of sampling in the field notes.
- Place soil sample bottles in coolers that are durable in transportation and keep the temperature between 0 and 6ºC until transported to the laboratory. **Do not use blue ice.**

7.3.3 Groundwater Sampling

Before Sample Collection

- Place plastic sheeting (preferably HDPE) adjacent to the sample port for use as a clean work area, if conditions allow. Otherwise, prevent sampling equipment from contacting the ground or other surface that could compromise sample integrity.
- Don a new set of nitrile gloves. Do not use gloved hands to subsequently handle papers, pens, clothes, etc., before collecting samples.
- Use the labeled HDPE bottles that are supplied by the laboratory. Make sure that the caps remain on the bottle until immediately prior to sample collection.
- Measure depth to water and field parameters. Turbidity and the physical appearance of the purged water should be noted on the Groundwater Sampling Log.

During Sample Collection

- Start groundwater sample collection upon stabilization of field parameters.
- If low-flow groundwater sampling techniques are being used, disconnect the silicone tubing from the flow-through cell, enabling collection of groundwater samples prior to passing through the cell.
- Hydrasleeves are also considered acceptable for sampling of PFAS in groundwater – consult the project manager to determine which technique should be used. In general, low flow sampling is preferable.
- Collect groundwater samples (to the neck of the bottle, some headspace is acceptable) from the dedicated sampling ports at the center of the well screen. While collecting the sample, make sure the bottle cap remains in the other hand of the sampler, until replaced on the bottle.
- To mitigate cross contamination, collect groundwater samples in a pre-determined order from least impacted to greater impacted based on previous analytical data or knowledge about past activities at the site. If no analytical data are available, samples are to be collected in the following order:
  1. First sample the upgradient well(s).
  2. Next, sample the well located furthest downgradient of the interpreted or known source.
  3. The remaining wells should be progressively sampled in order from downgradient to upgradient, such that the wells closest to the interpreted or known source are sampled last.
- NOTE: If high concentrations of PFAS related to class B firefighting foams are expected in a groundwater sample, collect and shake a small portion of the sample (~10 to 25 mL) on site. If foaming is noted within the sample, document the foaming when samples are submitted for analysis; the 'shaker test' vial can then be disposed. This shaker test provides information about how each of the samples should be handled analytically.
- After collecting the sample, tightly screw on the polypropylene cap (snug, but not too tight). This will minimize leaking or cross contamination of the sample. Most PFAS, including all analytes measured by USEPA Method 537, are not volatile at environmental pH.

- Note the time on the sample label.
- Collect any necessary duplicates and matrix spikes. As the laboratory should be analyzing the entire aqueous sample rather than sub-sampling, separate bottles will be required for these samples.
- Do not rinse PFAS sample bottles during sampling. Do not filter samples.

After Sample Collection

- Place groundwater sample bottles in a sealed Ziploc© bag (optional).
- Record the label information and time of sampling in the field notes and COC. Note ‘shake test’ results if appropriate.
- Place groundwater samples in coolers that are durable in transportation and keep the temperature between 0 and 6ºC until transported to the laboratory. **Do not use blue ice. Store PFAS samples in a separate cooler from other types of samples.**
- Treat all disposable sampling materials as single use and dispose of them appropriately after sampling at each monitoring well.

7.3.4 Sediment Sampling

Before Sample Collection

- Place plastic sheeting (preferably HDPE) adjacent to the sample port for use as a clean work area, if conditions allow. Otherwise, prevent sampling equipment from contacting the ground or other surface that could compromise sample integrity.
- Don a new set of nitrile gloves. Do not use gloved hands to subsequently handle papers, pens, clothes, etc., before collecting samples.
- Use the HDPE bottles that are supplied by the laboratory. Make sure that the caps remain on the bottle until immediately prior to sample collection.

During Sample Collection

- Where surface water samples and sediment samples are collected at the same location, collect surface water samples first to minimize siltation.
- Collect sediment samples either manually using a stainless-steel trowel or using a petite ponar grab sampler, depending on field conditions at each sampling location during sampling program.
- Collect sediment samples from the upper 10 cm of sediment.
- For a sample to be acceptable overlying, low turbidity water must be present.
- Decant the overlying water and use a stainless-steel trowel to collect only the upper 5 centimeters (cm) of sediment.

- Collect sediment samples directly into laboratory-supplied bottles that are suitable in both material and size.
- Do not overfill the sample bottle.
- Make sure that the sample does not contain vegetation, that the sediment is undisturbed, and that the sampler shows no signs of winnowing or leaking.
- Make sure bottle caps remain in the gloved hand of the sampler until sampling is complete and caps are replaced on the bottle.
- Collect any necessary duplicates and matrix spikes.

After Sample Collection

- Place sample bottles in a sealed Ziploc© bag (optional).
- Record the label information and time of sampling in the field notes.
- Place samples in coolers that are durable in transportation and keep the temperature between 0 and 6ºC until transported to the laboratory. **Do not use blue ice. Store PFAS samples in a separate cooler from other types of samples.**
- Measure surface water pH, conductivity, temperature, and total dissolved solids (TDS) at each location **after** both surface water and sediment sampling is completed.

7.3.5 Surface Water Sampling

Before Sample Collection

- Place plastic sheeting (preferably HDPE) adjacent to the sample port for use as a clean work area, if conditions allow. Otherwise, prevent sampling equipment from contacting the ground or other surface that could compromise sample integrity.
- Don a new set of nitrile gloves. Do not use gloved hands to subsequently handle papers, pens, clothes, etc., before collecting samples.
- Use the HDPE bottles that are supplied by the laboratory. Make sure that the caps remain on the bottle until immediately prior to sample collection.

During Sample Collection

- Avoid sampling the surface.
- Where surface water samples and sediment samples are collected at the same location, collect surface water samples first to minimize siltation.
- Collect surface water samples directly into laboratory-supplied bottles; wide-mouth bottles may be preferable to narrow mouth bottles for ease of surface water collection.

- Collect any necessary duplicates and matrix spikes. As the laboratory should be analyzing the entire aqueous sample rather than sub-sampling, separate bottles will be required for these samples.
- Make sure bottle caps remain in the gloved hand of the sampler until sampling is complete and caps are replaced on the bottle.

After Sample Collection

- Place sample bottles in a sealed Ziploc© bag (optional).
- Record the label information and time of sampling in the field notes.
- Place samples in coolers that are durable in transportation and keep the temperature between 0 and 6ºC until transported to the laboratory. **Do not use blue ice. Store PFAS samples in a separate cooler from other types of samples.**
- Measure surface water pH, conductivity, temperature, and TDS at each location **after** both surface water and sediment sampling.

7.4 Shipping

- If samples cannot be shipped the same day as collected, arrange an appropriate means of keeping the samples cool overnight and maintain the temperature between 0 and 10°C for the first 48 hours after collection, and then between 0 and 6°C thereafter.
- Store samples in appropriate transport bottles (coolers) with ice (Ziploc© bags for use as ice containers) with appropriate labeling. **Do not use blue ice. Store PFAS samples in a separate cooler from other types of samples.**
- Complete the appropriate procedures for COC, handling, packing, and shipping.
- Fill out and check COC Forms against the labels on the sample bottles progressively after each sample is collected.
- Place all disposable sampling materials (such as plastic sheeting, and health and safety equipment) in appropriate containers.
- Ship samples via courier service with priority overnight delivery. Tracking numbers for all shipments should be provided and recorded after they have been sent out to ensure their timely delivery.
- Do not ship samples via Fed Ex for Saturday delivery.

8 WASTE MANAGEMENT

All rinsate should be collected in a sealed pail for disposal. Drill cuttings and purge water will be managed as specified in the Field Sampling Plan (FSP) or Work Plan, and according to state and/or federal requirements. PPE and decontaminated fluids will be contained separately and staged at the sampling location. Containers must be labeled at the time of collection. Labels will include date, location(s), site name, city, state, and description of matrix contained (e.g., soil, groundwater, PPE). General guidelines for investigation derived waste (IDW) handling and storage are set forth in a separate IDW guidance document (Arcadis 2009).

Typical waste characterization procedures include collection of a composite sample of the drill cutting material and a composite sample of the purge water for laboratory analysis. Samples are typically analyzed for disposal toxicity characteristic leaching procedure (TCLP) analysis for metals and VOCs. For PFAS, a simple leach test with neutral pH water may be more indicative of actual risk. Additionally, generators of waste are required to include analysis of other constituents that are reasonably believed to be present including (in this case) PFAS.

Emerging contaminants pose a unique challenge for disposal because acceptance of such waste will be based on the local facility and their permit restrictions. Project teams will be required to identify appropriate facilities based on the facility's legal ability to accept the waste and the team should confirm that the facility is meeting the regulatory requirements for accepting waste containing PFAS. In general, facilities that provide solidification and/or incineration will be likely to meet the necessary requirements to accept PFAS-containing waste. The facility will then provide the definitive laboratory analysis requirements needed to meet their permit requirements for waste classification.

9 DATA RECORDING AND MANAGEMENT

9.1 Field Notes

Waterproof field books must not be used for field notes. Instead, field notes should be on loose paper on Masonite, plastic, or aluminum clip boards. Other requirements for field notes include:

- Pens, pencils, and Sharpies may be used.
- Keep field notes and writing implements away from samples and sampling materials.
- One person should conduct sampling while another records field notes.
- Do not write on sampling bottles unless they are closed.

9.2 Other Project Documentation

- Complete Groundwater Sampling Logs.
- Make sure COC Forms are properly completed. Verify which PFAS analytes (e.g., just PFOS and PFOA, some or all of the 537 list, etc.) are required for analysis and note on the COC.

10 QUALITY ASSURANCE

Refer to quality control requirements for the project to ensure that appropriate quality assurance and quality control (QA/QC) samples are collected. When collecting QA/QC samples, the same guidelines apply as when collecting regular samples – specifically that:

- Samples should be collected in laboratory-supplied HDPE bottles;

- Bottle caps must remain in the hand of the sampler until replaced on the bottle;
- Labels must be completed after the caps have been placed back on each bottle; and
- Samples must be stored in appropriate transport bottles (coolers) with ice (Ziploc© bags for use as ice containers) with appropriate labeling. **Do not use blue ice. Store PFAS samples in a separate cooler from other types of samples.**

10.1 Equipment Blanks (if relevant)

QA/QC sampling typically includes daily collection of equipment blanks using the laboratory-supplied "PFAS-free" water. For peristaltic pump tubing, laboratory supplied "PFAS-free" water should be poured into a clean HDPE sample bottle and then pumped through new HDPE tubing using the peristaltic pump (with new silicone tubing).

10.2 Field Duplicates

QA/QC sampling typically includes the collection of one field duplicate for every 10 or 20 samples collected. Each duplicate sample will be collected immediately after the initial sample of which it is a duplicate into a separate laboratory-provided sample bottle. Do not indicate to the laboratory which sample the duplicate replicates, i.e. it should be given a blind reference on the COC and sample name such as "duplicate".

10.3 Field Blanks

QA/QC sampling for PFAS typically includes the submission of one laboratory supplied reagent field blank per day. The reagent field blank sample is brought to the site in a laboratory-supplied sample bottle. Field staff transfer the laboratory-supplied reagent blank to an empty sample bottle. This reagent field blank should be placed in the same cooler as the other PFAS samples.

10.4 Matrix Spikes (optional in some cases)

QA/QC sampling includes submitting a sample to be used as a matrix spike if the project requires it. If a separate sample bottle is required, an additional sample will be collected immediately after the initial sample of which it is a duplicate into a separate laboratory-supplied sample bottle.

10.5 Laboratory Analytical QA/QC

- Internal laboratory QA/QC should consist of one laboratory blank and one laboratory control sample (or blank spike) per batch of samples, and additional QA/QCs as indicated by the laboratory QAQC procedures. Isotope dilution should be used for quantification with isotope-labeled surrogate standards, as available.
- For groundwater and surface water samples, extract the entire groundwater and surface water sample and at least two sampling bottle solvent rinsates for analysis to increase sample accuracy. Avoid sub-sampling an aliquot of the sample bottle.

- Soil samples should be analyzed in their entirety or thoroughly homogenized before extraction and analysis.
- As part of the internal QA/QC, relative percent difference (RPD) should be calculated between samples and corresponding field or laboratory duplicates. The laboratory quality assurance portion of the laboratory certificates should be reviewed to verify that all calculations/recoveries were within acceptable limits as established by the laboratory method.
- In January 2017, the U.S. Department of Defense (DOD) and U.S. Department of Energy (DOE) Quality Systems Manual (QSM) 5.1 was finalized and introduced laboratory guidance for the measurement of PFAS in matrices other than drinking water. This guidance is not a detailed procedural method such as an EPA method, but it does recommend best practices around the analysis of PFAS. Laboratories are not required to comply with QSM 5.1 until 2019, although the recommendations around PFAS analysis are similar to what most laboratories are already implementing. Arcadis recommends that any request for PFAS analysis in groundwater or soil should specifically reference the need to comply with Table B-15 in the QSM 5.1.

11 REFERENCES

Arcadis Australia. 2017. Soil and Concrete Sampling for PFAS. April.

Arcadis. 2010. Monitoring Well Development, Rev. #2.2. March 22.

Arcadis. 2009. Investigation-Derived Waste Handling and Storage, Rev. #2. March 6.

Arcadis. 2011. Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells, Rev. #4. February 2.

ASTM. 2002. ASTM D6771-02 - Standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations (Withdrawn 2011). Available at: https://www.astm.org/Standards/D6771.htm.

U.S. Army Corps of Engineers – Omaha District. 2016. Chemistry Requirements – PFAS.

U.S. Department of Defense (DoD). 2017. Consolidated Quality Systems Manual (QSM) for Environmental Laboratories, Version 5.1. In conjunction with the U.S. Department of Energy. January.

U.S. Environmental Protection Agency. 2009. USEPA Method 537: Determination of Selected Perfluorinated Alkyl Acids in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS), version 1.1, September. National Exposure Research Laboratory, Office of Research and Development.

U.S. Environmental Protection Agency. 2010. Low Stress (Low Flow) purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells. Available at: https://www.epa.gov/quality/low-stress-low-flow-purging-and-sampling-procedure-collection-groundwater-samples-monitoring.

Transport Canada. February 2016, Per-and Polyfluorinated Alkyl Substances (PFAS) Field Sampling Guidance.

Slug Testing

TECHNICAL GUIDANCE INSTRUCTIONS FOR SLUG TESTING

Rev: 4

Rev Date: March 2015

TGI VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by

APPROVAL SIGNATURES

Prepared by:	Everett H. Fortner III (Trey) Aaron Kempf	Date:	March 5, 2015
Reviewed by:	Marc Killingstad	Date:	March 5, 2015

ABOUT THIS TGI

This Technical Guidance Instruction for Slug Testing is intended as general guidance for testing design that applies to all forms of slug testing. Guidance for the specific slug testing method selected based on this overall guidance is attached in four separate documents. The four detailed methods of slug testing covered include:

A TGI: Solid Slug Testing

B TGI: Water Slug (Inflow) Testing

C TGI: Baildown Testing

D TGI: Pneumatic Slug Testing

Each of these attachments should be used in conjunction with this general guidance. For more information or questions, please contact the TKI technical lead for Aquifer Testing.

1 SCOPE AND APPLICATION

The objective of this Technical Guidance Instruction (TGI) is to establish uniform procedures for slug testing to estimate the hydraulic conductivity of the groundwater zone near a well. A slug test is completed by "instantaneously" inducing an artificial change in hydraulic head and measuring the rate of the groundwater return to equilibrium (static) conditions. This guidance document provides detailed information on test methodology, planning, and application. Field forms and procedures for conducting tests using solid slugs, inflow (water slug), baildown, and pneumatic testing methods are attached. Also attached is a parts list and as-built drawing for the pneumatic testing manifold.

Please note that the data analysis portion of slug testing is not covered in this guidance.

It is strongly advised that, prior to conducting any aquifer testing, the project team contact the Technical Knowledge and Innovation (TKI) Aquifer Testing Focus Group to receive specific technical guidance regarding the design, execution, and analysis phases of the proposed testing.

Slug tests are used as an economic, simple, and rapid way to obtain data needed to estimate near-well hydraulic conductivity (Butler 1998). The advantages of slug testing over other testing methods (e.g. pumping tests) is that they are relatively easy and inexpensive to implement and generate little to no investigation-derived waste. These advantages allow for several tests to be completed at a site over a relatively short period of time, which provides a better understanding of the spatial distribution of hydraulic conductivity both horizontally and vertically across the groundwater zone(s) (i.e., aquifer heterogeneity). However, slug tests should not be viewed as a replacement for the larger scale estimates of hydraulic conductivity derived from multi-well pumping tests (Kruseman and de Ridder 1994). The shorter time frame and limited stress on the groundwater zone from slug tests provides a smaller scale (near-well) hydraulic conductivity estimate than pumping tests. Due to this localized scale of slug testing, the effects of the well filter pack, well development, and well skin are more significant than during pumping tests, and have the potential to limit water-level change during testing. Wells that are insufficiently developed can adversely affect the results of the slug test and generally lead to a lower hydraulic conductivity estimate than other conventional methods. Therefore, careful consideration should be given prior testing wells that are expected to have skin damage and where the development history is unknown. Varying the direction and magnitude of the stress and inducing a relatively large, measurable head change can facilitate determination of skin effects and increase the probability that the selected test response is a result of groundwater zone hydraulics and not the well construction hydraulics (Butler 1998).

Slug Test Design

The initial step during the planning stage should consist of determining whether or not slug tests will provide adequate aquifer characterization to meet the specific project objectives. For example, slug testing may be useful in mapping relative changes in hydraulic conductivity (heterogeneities) or used to calibrate high resolution hydraulic testing results provided by direct-push tools. However, slug testing is not an appropriate testing method to obtain aquifer storage estimates. In addition, slug testing may not be appropriate for testing of bedrock, particularly when there is incomplete understanding of the fracture network. A pumping test, packer test, or open borehole test may be more appropriate in bedrock. However, weathered bedrock zones can often be considered hydraulically equivalent to a porous medium and, therefore, slug testing may be appropriate.

The design phase includes several elements as outlined below. Please note, there may be exceptions, as design specifications need to be tailored to the conceptual site model (CSM) and project objectives.

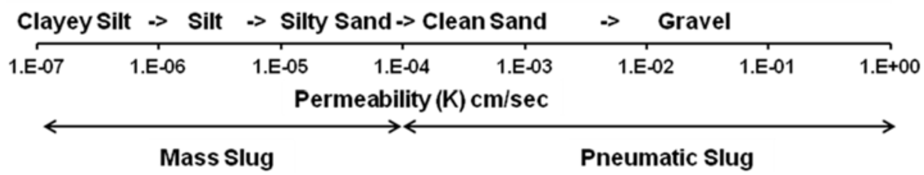
1. Review of the CSM and site data. This should include a review of boring logs (key elements – lithology and drilling method utilized), well construction details, well development logs, cross-sections, constituent plume information, hydrostratigraphic zones, previous estimates of hydraulic conductivity, and regional estimates from published sources. Special attention should be given to well screen intervals in order to ensure that the tests are conducted in the targeted groundwater zone. If a well is screened across multiple hydrostratigraphic zones, uncertainty associated with estimated hydraulic conductivity values for a given zone is introduced. However, there are exceptions if the permeability of the zones that are crossed by the well screen differ significantly.
2. Review of regulatory program rules or guidance to ensure proper compliance with the criteria outlined in the regulatory documents. In most cases, slug testing using pneumatic or solid slug methods will not require permitting; however, use of in-flow procedures, although unexpected, may require a permit (e.g., Underground Injection Control [UIC] permit).
3. Compile detailed information for each proposed test well:
    a. Well construction information
        i. Well casing/screen diameters and lengths
        ii. Screen type (material and slot design) and slot size
        iii. Total depth – reviewing the measurement of the test well total depth aids in development assessment. If the total depth has decreased substantially since installation, sediment buildup may be occurring and redevelopment should be completed before testing
        iv. Filter pack construction (thickness and material)
    b. Historical and current groundwater levels – this will aid in the determination of the appropriate slug test type (e.g., is the screen submerged)
    c. Well development record – testing improperly developed wells will result in anomalous results
    d. Recent well sampling logs – historic sampling data will provide information on the potential yield of the well and groundwater quality (turbidity)
4. Determine appropriate testing method(s): In light of the information researched in items 1 through 3, slug test method(s) should be selected based on the groundwater zone information and data needs for proper analysis:

    - Solid Slug – used for rising and falling head tests in wells of adequate water column length with fully or partially submerged screens. If screen is partially submerged (i.e., intersects the groundwater table), then a rising head test is the most appropriate test method. Adequate length of water column would allow for placement of transducer at least 1 foot below the anticipated submersion depth of the slug or length of water column to accommodate the just the slug when using manual measurements.

    - Inflow – used for falling head tests where the water column is too small to accommodate typical slug test equipment or applied as part of development procedures.

    - Baildown – used for rising head tests.

- Pneumatic – used for rising head tests with fully submerged well screens. The well is pressurized to depress the water-level and then allowed to equilibrate. The recovery to static conditions is measured after the pressure is released.
- Aquifer information: The initial hypotheses of the groundwater zone characteristics and permeability based on either previous testing, qualitative information (boring logs), or other studies in the area is also an important consideration when determining the testing methodology. The chart below depicts of test type to be applied in relation to permeability for guidance.



Note: For instance, if boring logs indicate the groundwater zone is predominantly sand and/or gravel and groundwater sampling logs indicate good well yield, then a hypothesis may be made that the formation may have has a relatively high permeability. Therefore, if the well screens are fully submerged, pneumatic slug testing would be appropriate.

- Additional data needs: Additional data may be required or appropriate in order to determine the most appropriate test method (Butler 1998) and to understand external influences on the test. This includes duplicate testing, rising and/or falling head tests, multiple tests with varying initial displacements, and background data to assess background water level trends. Generally, three tests per well is recommended with two duplicate tests at the same displacement and one with double the original displacement. Special cases with expected external influences that induce water level changes (tidal, atmospheric or pumping) may require determination of pre-test water level trends. Arrange to have nearby active pumping wells shut down for at least 48 hours prior to testing or constant rate extraction during testing, if applicable and possible. Finally, testing should not be completed during periods of significant precipitation.

5. Data acquisition: To ensure high resolution data acquisition, data-logging pressure transducers should be used to collect water level data. Change in head measurements should be collected at a frequency of 0.5 second or less for high permeability groundwater zones (e.g., gravels and sands). A lower frequency can be selected for lower permeability groundwater zones (e.g., fine sands, silts, and clays). Ideally, frequencies should be in the seconds range depending on the permeability and the length of the test. To optimize data collection and test quality decisions, the transducer can be used in real-time viewing. Manual water-level measurements should also be collected to verify and back-up the electronic data collected using pressure transducers. For low permeability formations with fully submerged well screens, manual data acquisition may be appropriate (i.e., where groundwater recovery occurs at a rate slow enough such that frequent data collection is not required).

2 PERSONNEL QUALIFICATIONS

Field personnel performing the testing should have the following qualifications:

- Sufficient "hands-on" experience necessary to successfully complete the slug test field work. Training requirements for conducting slug tests include reviewing this guidance and other applicable documents and instrument calibration.
- Demonstrated familiarity with the electronic data logging equipment.
- Completed current health and safety training in accordance with the project health and safety plan (e.g., 40-hour Hazardous Waste Operations training and site-specific training, as appropriate)

Additional Information – Key Considerations

- Pressure Transducers/Data Loggers
  - Ensure that all rental instruments and tapes have been calibrated.
  - Small-diameter pressure transducers (typically 0.5 to 0.75 in) are available that cover a range of pressures. Install the pressure transducer at a reasonable distance below the targeted drawdown estimated for the well to prevent noise. Do not install the transducer closer than 6 inches from the base of the well to eliminate the possibility of fouling the transducer with debris/mud accumulated at the bottom of the well. To prevent pressure transducer malfunction or damage, do not submerge pressure transducers in excess of the operating range, and do not insert objects in the sensor opening unless directed by the manufacturer.
  - For vented pressure transducers/data loggers, test functionality with a field test of readings using a bucket or barrel filled with water. Submerge pressure transducer, accurately measure the water head above the pressure transducer, and compare the measurement to the reading.
  - Non-vented transducers, which record a combined pressure of barometric and the water column above the pressure transducer, can be tested in the same fashion as the vented pressure transducer (outlined above). The water column above the pressure transducer can be checked by subtracting out current atmospheric pressure.
  - In general, when testing the pressure transducers, check the pressure transducer response to changing heads by raising the pressure transducer a certain distance, observing the change in head, and then measuring the distance manually. Additionally, water level meters should be in good working condition and calibrated to true depth and ensuring that there are no breaks or splices in the cable.
  - Pressure transducers should be set in the well at least 10 minutes prior to testing to allow to the transducer to thermally equilibrate with groundwater and ensure that the pressure transducer cable will not stretch during testing.
  - Logarithmic or head-change settings should not be used to log data, only linear.

  - Prior to testing, secure pressure transducer cables at the wellhead to prevent movement that would affect measurements. Mark a reference point on the down-hole transducer cable or securing line and check regularly to detect slippage.

- Data Management
  - Data management is crucial to prevent any loss. Use caution not to overwrite any previously recorded files and remember, data backup is always necessary. A job loss would occur if data would be accidently lost. Always back up data on a laptop computer and a flash drive and keep at different spots (e.g., back pack and glove compartment) to reduce the risk of data loss (e.g., computer failure).
- Slug Volume
  - Solid slugs should be calibrated to determine their accurate volume(s) for theoretical displacement. In most cases, rental slugs offer economic and data quality benefits over field-built slugs.
  - When completing baildown or inflow testing, purge or injected volume should be measured accurately.
- Initial Displacement and Recovery
  - When performing slug tests, the general rule of thumb for initial displacement is between 1 and 6 feet and/or generally less than 25% of the effective screen length.
  - Water levels should be recorded to within 80% to 95% recovery. In addition, duplicate tests should be completed only after the first test has recovered by at least 95%.
- Investigative-Derived Waste (IDW)
  - Containerize all purged water as specified in the project plans. Discharge water should be disposed of according to all applicable laws, regulations, and project guidelines. Contact the governing agencies to determine which restrictions apply. Arcadis should not be responsible for signing manifests and should not "take possession" of purged water.
- Equipment Care
  - Keep sensitive electronic equipment away from devices that generate significant magnetic fields. For example, do not place pressure transducers near electric power generators or electric pump motors. Likewise, radio signals may cause pressure transducers or computers to malfunction.
- Decontamination
  - Make sure all equipment that enters the test well (slug, water-level meter, pressure transducer) is decontaminated before use. If testing multiple wells, start with the least contaminated and progress to the most contaminated.
- Non-Aqueous Phase Liquids (NAPL)
  - Slug tests should not be conducted in wells where Non-Aqueous Phase Liquids are present. Consult TKI Aquifer Testing Focus Group lead for guidance.

3 HEALTH AND SAFETY CONSIDERATIONS

The site-specific HASP will be used to ensure that the tests are conducted in a safe manner, and should include a Job Safety Analysis (JSA). The following specific health and safety issues should be considered when conducting slug tests:

- Appropriate PPE with minimum of Level D should be worn to avoid contact with site chemicals of concern during slug test.
- Well covers should be carefully removed to avoid potential contact with insects or animals. Well caps should be vented or tethered to avoid potential eye injury in case of gas buildup in the well.
- Pressurization or vacuum hazards associated with pneumatic slug testing should be considered during test planning and implementation.

4 WASTE MANAGEMENT

Rinse water, PPE, and other waste materials generated during equipment decontamination should be placed in appropriate containers and labeled. Containerized waste should be disposed of, consistent with appropriate waste management procedures for investigation-derived waste.

5 DATA RECORDING AND MANAGEMENT

Field personnel will complete a Slug Test Field Log form for each test. As previously noted, it is generally recommended to conduct three tests per well (the original displacement, a duplicate, and double original displacement); therefore, one field log should be completed for each test. It is strongly recommended that data be copied to a flash drive and transmitted to the project team as soon as possible to ensure no data loss. Field equipment calibration, decontamination activities, and waste management activities should be recorded in the field logbook.

6 QUALITY ASSURANCE

Review data collected during field testing to determine reasonableness/quality given site-specific conditions. Again, this can also be completed using the transducer in real-time viewing mode as the test progresses. Compare the theoretical head displacement calculated from the slug volume or pressure to the observed displacement. If the data are questionable, the field equipment should be checked to confirm proper working order and the test may be repeated, if possible. Consult with the project hydrogeologist to work through issues encountered in the field and to help determine test validity.

Any issues that may affect the data should be recorded in the field logbook for consideration by the project hydrogeologist.

7 REFERENCES

Butler, J.J., Jr., 1998. The Design, Performance, and Analysis of Slug Tests, Lewis Publishers, New York, 252p.

Kruseman, G.P. and N.A. de Ridder, 1994. Analysis and Evaluation of Pumping Test Data (2nd ed.), Publication 47, Intern. Inst. for Land Reclamation and Improvement, Wageningen, The Netherlands, 370p.

ATTACHMENT A

TGI: Solid Slug Testing

Design & Consultancy for natural and built assets

Slug Testing TGI Attachment A

TECHNICAL GUIDANCE INSTRUCTIONS FOR SOLID SLUG TESTING

Rev: 4

Rev Date: March 2015

TGI VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by

APPROVAL SIGNATURES

Prepared by: ______________________________ Date: March 5, 2015

Everett H. Fortner III (Trey) Aaron Kempf

Reviewed by: ______________________________ Date: March 5, 2015

Marc Killingstad

1 SCOPE AND APPLICATION

The use of a solid slug allows for both falling- and rising-head slug tests to be completed. Solid slug(s) of a known volume are inserted and removed from the water column in a well in a near-instantaneous manner. The water level response is observed using a data-logging pressure transducer with manual measurement backup or using just a manual water level meter for slow recovering wells with fully submerged screens.

2 EQUIPMENT LIST

The following materials should be available, as required, during slug testing using a solid slug:

1. Job safety analysis and site Health and Safety Plan
2. Related project-specific requirements and plans
3. Personal protective equipment, as required by the site Health and Safety Plan
4. Solid slug(s) of known volume
5. Pressure transducer and barologger
6. Pressure transducer software
7. Laptop computer and/or data transfer device
8. Rope or cables (for deep wells) (chemical resistant, low stretch is optimal)
9. Water level meter
10. Measuring tape
11. Spring-loaded clamps and zip ties
12. Decontamination equipment
13. Slug test field form
14. Field notebook
15. Waterproof marker.

3 PROCEDURE

1. Decontaminate all down-well equipment: pressure transducer and cable, slug(s), rope or cable, water level meter in accordance with project specific requirements. In general, wells should be tested from least contaminated to more contaminated, if possible or applicable.
2. Measure depth to water and well total depth. Determine the water column length.
    a. Multiple depth to waters should be measured and any trends should be noted.
    b. The "static" depth to water should be representative of the water level after the well equalizes with atmosphere.
3. Review the well construction log to determine screened interval and confirm depth to bottom. If discrepancies exist, consult with project hydrogeologist.
4. Program the pressure transducer to record water levels at the following suggested frequencies. Note that the lithologic descriptions and datalogger memory should be used to select the highest measurement frequency possible.

   a. In hydrologic settings where high hydraulic conductivity is expected, water levels should be measured at 0.5-second intervals or the highest frequency available. This measurement frequency should be selected for gravels and sands.
   b. In hydrologic settings where low hydraulic conductivity is expected, water levels should be measured at 1- to 2-second intervals. This measurement frequency should be selected for silts and clays.
5. If applicable, program the barologger to record barometric pressure. The barologger should be placed in the headspace of an adjacent well, or on grade, adjacent to the well being tested.
6. Install the pressure transducer deep enough within the water column to not interfere with the testing equipment. Ideally the transducer should be 5 to 10 feet lower than the maximum depth of the slug testing equipment not closer than 6 inches above the well bottom. Remember to use measurements and not the well bottom as silt can clog the pressure transducer. Clamp the pressure transducer cable to the well casing or other static object.
7. View the measured water level in real time on the laptop computer. Wait for the water levels to stabilize. Note that the temperature of the pressure transducer should be permitted to equilibrate to groundwater temperatures to ensure accurate water-level measurements.
8. Re-measure the depth to water.
9. Measure the slug and rope assembly length and mark the rope at a length as follows:

   Rope Mark #1 = Depth to Potentiometric Surface from TOC

   Rope Mark #2 = Depth to Potentiometric Surface from TOC + Length of Slug + Safety Factor (Safety Factor = 10% of the Length of Slug)

   When deployed, Rope Mark #2 should be at the well top of casing, and the slug should be totally submerged. If insufficient water column is available to cover the slug assembly top, note the theoretical length of the slug to be inserted into the water column. Upon removal, measure the wet slug length.

10. Slowly insert the slug assembly into the well and stop just above the potentiometric surface Rope Mark #1.
11. With slack in the rope and the slug being suspended above the water column, place the Rope Mark #2 at the top of casing. Clamp the non-slug end of the rope to a static object.
12. Quickly drop the slug into the water column.
13. Observe the water level response on the laptop computer and/or measure depth to water, being careful not to interfere with the pressure transducer cable. Several manual depth to water measurements should be made throughout the test (typically 2 to 3 in the first minute, one reading a minute for the next 5 to 10 minutes, and every 2 to 5 minutes thereafter). If the water level meter is used as the primary measurement technique, the measurement frequency should be increased as practicable.
14. Allow sufficient time for water level to recover to static level. If completing one test (just a falling head test or just a rising head test), then 80% recovery is sufficient. Duplicate tests are highly recommended, and the next test should be completed after the first test has recovered to greater than 95%. A third test at a displacement of twice the initial is recommended.

15. Quickly remove the slug assembly from the water column. The slug assembly should be left in the well above the static water level in order to limit pressure cable disturbance until the testing is complete and the water levels have equilibrated to the target level.
16. Repeat both the falling- and rising-head slug tests for data reproducibility by repeating steps 12 and 13, if applicable. If possible, complete a third test with a slug or combination of slugs that equates to twice the volume as the original.
17. Save all data files to the laptop, backup on flash drive or by emailing, and finalize any field notes.
18. Review the data collected to determine the reasonableness of the preliminary results and compare the pressure transducer results to the water level meter results. The observation of apparently anomalous results should be discussed with senior project staff prior to additional testing or leaving the field site. The water level record for each test should show static conditions, the insertion or removal of the slug(s), and the water level response. Make notes on the field form and notebook concerning any irregularities.
19. Decontaminate all down-well equipment in accordance with project plans.

ATTACHMENT B

TGI: Water Slug (Inflow) Testing

Slug Testing TGI Attachment B

TECHNICAL GUIDANCE INSTRUCTIONS FOR WATER SLUG (INFLOW) TESTING

Rev: 4

Rev Date: March 2015

TGI VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by

APPROVAL SIGNATURES

Prepared by: ______________________________ Date: March 5, 2015

Everett H. Fortner III (Trey) Aaron Kempf

Reviewed by: ______________________________ Date: March 5, 2015

Marc Killingstad

1 SCOPE AND APPLICATION

A known volume of potable water (slug) may be used to complete falling-head slug tests. Water of a known volume is poured into a well in a near-instantaneous manner. The water level response is observed using a pressure transducer. Slug tests using a water slug are most appropriate for fully submerged well screen (i.e. water table above the well screen top), and where a relatively slow response is anticipated. These constraints limit the probability of slug water entering the filter pack and vadose zone, thereby ensuring slug insertion to be near instantaneous relative to the observed response. This type of test is sometimes used to evaluate well development by performing a slug test before and after well development.

Consult with local regulatory requirements concerning underground injections. The injection volume and injectate are typically innocuous enough that a permit-by-rule authorization is granted in lieu of an underground injection control permit.

2 EQUIPMENT LIST

The following materials should be available during slug testing using a water slug:

- Job safety analysis and site Health and Safety Plan
- Related project-specific requirements and plans
- Personal protective equipment, as required by the site Health and Safety Plan
- Potable water (do not use distilled water, as it is not conductive and will not work with electronic water level meters)
- Pressure transducer and cable
- Pressure transducer software
- Laptop computer and/or data transfer device
- Graduated cylinder or similar measuring device
- Funnel with large neck and opening (wide mouth)
- Water level meter
- Spring-loaded clamp and zip ties
- Decontamination equipment
- Slug test field form
- Field notebook.

3 PROCEDURE

1. Decontaminate all down-well equipment: pressure transducer, pressure transducer cable, and water level meter in accordance with project specific requirements. In general, wells should be tested from least contaminated to more contaminated, if possible or applicable.
2. Measure depth to water and well total depth. Determine the water column length.
    a. Multiple depth to waters should be measured and any trends should be noted.
    b. The "static" depth to water should be representative of the water level after the well equalizes with atmosphere.
3. Review the well construction log to determine screened interval and confirm depth to bottom. If discrepancies exist, consult with project hydrogeologist.
4. Program the pressure transducer to record water levels at the following suggested frequencies. Note that the lithologic descriptions and datalogger memory should be used to select the highest measurement frequency possible.
    a. In hydrologic settings where high hydraulic conductivity is expected, water levels should be measured at 0.5-second intervals, or the highest frequency available. This measurement frequency should be selected for gravels and sands.
    b. In hydrologic settings where low hydraulic conductivity is expected, water levels should be measured at 1 to 2 second intervals. This measurement frequency should be selected for silts and clays.
5. If applicable, program the barologger to record barometric pressure. The barologger should be placed in the headspace of an adjacent well, or on grade, adjacent to the well being tested.
6. Install the pressure transducer deep enough within the water column to not interfere with the testing equipment. Ideally, the transducer should be 5 to 10 feet lower than the maximum depth of the slug testing equipment, not closer than 6 inches above the well bottom. Remember to use measurements and not the well bottom, as silt can clog the pressure transducer. Clamp the pressure transducer cable to the well casing or other static object.
7. View the measured water level in real time on the laptop computer. Wait for the water levels to stabilize. Note that the temperature of the pressure transducer should be permitted to equilibrate to groundwater temperatures to ensure accurate water-level measurements.
8. Determine the volume of the water slug. A general guideline is that initial displacements are generally between 1 and 3 feet, but should depend on the anticipated response (i.e., larger initial displacements should be chosen for formations with high hydraulic conductivity, smaller initial displacements can be used for formations with low hydraulic conductivity).

Slug Volume (gal)	Slug Volume (mL)	Casing Diameter (in)	Theoretical Initial Displacement (ft)
0.25	946	2	1.56
0.5	1893	2	3.13
1	3785	2	6.25
0.5	1893	4	0.77

Slug Volume (gal)	Slug Volume (mL)	Casing Diameter (in)	Theoretical Initial Displacement (ft)
1	3785	4	1.54
2	7570	4	3.08
1	3785	6	0.68
2	7570	6	1.36
3	11355	6	2.04

Notes:
gal = gallons (U.S.)
mL = milliliters
in = inches
ft = feet

9. Measure the slug volume and place in a container that is easy to quickly pour from. Note the measured volume.
10. Insert the wide mouth funnel into the well casing.
11. Quickly pour the slug through the funnel and into the well. Note the approximate time required to insert the slug.
12. Observe the water level response on the laptop computer or use water level meter.
13. Measure depth to water, being careful not to interfere with the pressure transducer cable. Several manual depth to water measurements should be made throughout the test.
14. Allow sufficient time for water level to recover to static level. If completing one test, then 80% recovery is sufficient. Duplicate tests are highly recommended, and the next test should be completed after the first test has recovered to greater than 95%. A third test at a displacement of twice the initial is recommended.
15. Repeat steps 9 through 14.
16. Save all data files to the laptop, backup to flash drive, and finalize any field notes.
17. Review the data collected to determine the reasonableness of the preliminary results. The observation of apparently anomalous results should be discussed with senior project staff prior to additional testing or leaving the field site. The water level record for each test should show static conditions, the insertion or removal of the slug(s), and the water level response. Make notes on the field form and notebook concerning any irregularities.
18. Decontaminate all down-well equipment in accordance with project plans.

ATTACHMENT C

TGI: Baildown Testing

Slug Testing TGI Attachment C

TECHNICAL GUIDANCE INSTRUCTIONS FOR BAILDOWN TESTING

Rev: 4

Rev Date: March 2015

TGI VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by

APPROVAL SIGNATURES

Prepared by: ______________________________ Date: March 5, 2015

Everett H. Fortner III (Trey) Aaron Kempf

Reviewed by: ______________________________ Date: March 5, 2015

Marc Killingstad

1 SCOPE AND APPLICATION

A bailer is used to remove a volume of water (slug) to complete rising-head tests. A bailer removes water from a well in a near-instantaneous manner. The water level response is observed using a pressure transducer.

2 EQUIPMENT LIST

The following materials should be available during slug testing using a water slug:

- Job safety analysis and site Health and Safety Plan
- Related project-specific requirements and plans
- Personal protective equipment, as required by the site Health and Safety Plan
- Bailers of known size/capacity
- Pressure transducer and cable
- Graduated cylinder or similar measuring device
- Pressure transducer software
- Laptop computer and/or data transfer device
- Rope or cables (for deep wells) (chemical resistant, low stretch is optimal)
- Water level meter
- Measuring tape
- Spring-loaded clamps and zip ties
- Decontamination equipment
- Slug test field forms
- Field notebook
- Waterproof marker.

3 PROCEDURE

1. Select a bailer according to a target initial displacement using the table below. A general guideline is that initial displacements are between 1 and 3 feet, but should depend on the anticipated response (i.e., larger initial displacements should be chosen for formations with high hydraulic conductivity, smaller initial displacements can be used for formations with low hydraulic conductivity).

Bailer Volume (gal)	Bailer Volume (mL)	Casing Diameter (in)	Theoretical Initial Displacement (ft)
0.25	946	2	1.56
0.5	1893	2	3.13
1	3785	2	6.25
0.5	1893	4	0.77
1	3785	4	1.54
2	7570	4	3.08
1	3785	6	0.68
2	7570	6	1.36
3	11355	6	2.04

Notes:
gal = gallons, U.S. liquid
ml = milliliters
in = inches
ft = feet

2. Decontaminate all down-well equipment: pressure transducer and cable, slug(s), rope or cable, water level meter in accordance with project-specific requirements. In general, wells should be tested from least contaminated to more contaminated, if possible or applicable.
3. Measure depth to water and well total depth. Determine the water column length.
   a. Multiple depth to waters should be measured and any trends should be noted.
   b. The "static" depth to water should be representative of the water level after the well equalizes with atmosphere.
4. Measure depth to water and well total depth. Total depth should be taken using a weighted tag line. Determine the water column length.
5. Review the well construction log to determine screened interval and confirm depth to bottom. If discrepancies exist, consult with project hydrogeologist.
6. Program the pressure transducer to record water levels at the following suggested frequencies. Note that the lithologic descriptions and datalogger memory should be used to select the highest measurement frequency possible.
   a. In hydrologic settings where high hydraulic conductivity is expected, water levels should be measured at 0.5-second intervals, or the highest frequency available. This measurement frequency should be selected for gravels and sands.
   b. In hydrologic settings where low hydraulic conductivity is expected, water levels should be measured at 1- to 2-second intervals. This measurement frequency should be selected for silts and clays.
7. If applicable, program the barologger to record barometric pressure. The barologger should be placed in the headspace of an adjacent well, or on grade, adjacent to the well being tested.

8. Install the pressure transducer deep enough within the water column to not interfere with the testing equipment. Ideally, the transducer should be 5 to 10 feet lower than the maximum depth of the slug testing equipment not closer than 6 inches above the well bottom. Remember to use measurements and not the well bottom, as silt can clog the pressure transducer. Clamp the pressure transducer cable to the well casing or other static object.
9. View the measured water level in real time on the laptop computer. Wait for the water levels to stabilize. Note that the temperature of the pressure transducer should be permitted to equilibrate to groundwater temperatures to ensure accurate water-level measurements.
10. Measure the bailer and rope assembly length and mark the rope at a length as follows:

    Rope Mark #1 = Depth to Potentiometric Surface from TOC

    Rope Mark #2 = Depth to Potentiometric Surface from TOC + Length of Bailer + Safety Factor (Safety Factor = 10% of the Length of Slug)

    When deployed, Rope Mark #2 should ensure that the bailer is fully submerged. If a sufficient water column is not available to obtain a full bailer, measure the volume removed upon removal.

11. Slowly insert the bailer into the well and stop just above the potentiometric surface Rope Mark #1.
12. With slack in the rope and the bailer being suspended above the water column, lower the bailer and place the Rope Mark #2 at the top of casing. Clamp the non-bailer end of the rope to a static object to keep in place.
13. Wait for water level to equilibrate using response from the laptop computer, and/or data transfer device, or from water level meter.
14. Quickly remove the bailer from the water column and carefully pull it to surface. Pour the removed water into an empty bucket.
15. Observe the water level response on the laptop computer and/or measure depth to water, being careful not to interfere with the pressure transducer cable. Several manual depth to water measurements should be made throughout the test.
16. Allow sufficient time for water level to recover to static level. If completing one test, then 80% recovery is sufficient. Duplicate tests are highly recommended, and the next test should be completed after the first test has recovered to greater than 95%. A third test at a displacement of twice the initial is recommended.
17. Measure the volume of water removed by the bailer that was poured into the empty bucket using a graduated cylinder.
18. Repeat rising-head slug tests for data reproducibility. If possible, complete a third test with a bailer or multiple bailers connected in series that equates to twice the volume as the original.
19. Save all data files, backup on flash drive, and finalize any field notes.
20. Review the data collected to determine the reasonableness of the preliminary results. The observation of apparently anomalous results should be discussed with senior project staff prior to additional testing or leaving the field site. The water level record for each test should show static conditions, the insertion or removal of the slug(s), and the water level response. Make notes on the field form and notebook concerning any irregularities.
21. Decontaminate all down-well equipment.

ATTACHMENT D

TGI: Pneumatic Slug Testing

Slug Testing TGI Attachment D

TECHNICAL GUIDANCE INSTRUCTIONS FOR PNEUMATIC SLUG TESTING

Rev: 4

Rev Date: March 2015

TGI VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by

APPROVAL SIGNATURES

Prepared by: ______________________ Date: March 5, 2015

Everett H. Fortner III (Trey) Aaron Kempf

Reviewed by: ______________________ Date: March 5, 2015

Marc Killingstad

1 SCOPE AND APPLICATION

Pneumatic slug tests are conducted by sealing the well head and applying air pressure to depress the water level. As air pressure is increased in the well, the water level falls until the water pressure and the air pressure return to equilibrium. After the water level is stable, air is released from the sealed well head by opening an air release valve. The water level recovery (i.e., rising head) typically produces very high quality data with little interference. A pressure transducer is used to monitor and record the change of the water level in the well during the pneumatic slug test.

2 EQUIPMENT LIST

The following materials should be available during slug testing using a water slug:

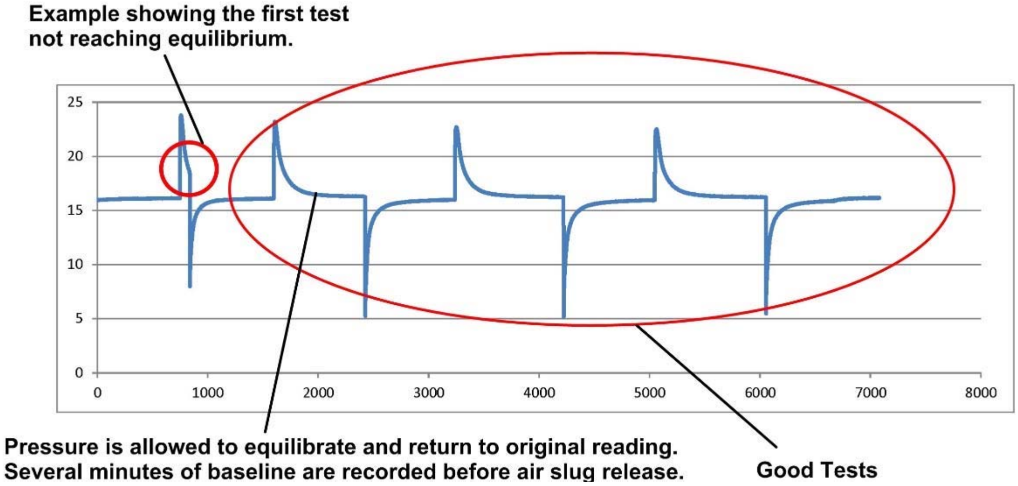
- Job safety analysis and site Health and Safety Plan
- Related project-specific requirements and plans
- Personal protective equipment, as required by the site Health and Safety Plan
- Pneumatic slug test manifold (see attached Figure 1 for suggested configuration)
- Pressure transducer and cable
- Pressure transducer software
- Air pressurization source (compressed or pump) and appropriate hoses
- Leak prevention supplies (Teflon pipe sealant, plumbers putty or similar product)
- Laptop computer and/or data transfer device
- Water level meter
- Measuring tape
- Decontamination equipment
- Slug test field forms
- Field notebook
- Waterproof marker.

3 PROCEDURE

1. Decontaminate all down-well equipment: pressure transducer, cable, and water level meter in accordance with project-specific requirements. In general, wells should be tested from least contaminated to more contaminated, if possible or applicable.
2. Measure depth to water and well total depth. Determine the water column length.
    a. Multiple depth to waters should be measured and any trends should be noted.
    b. The "static" depth to water should be representative of the water level after the well equalizes with atmosphere.

3. Review the well construction log to determine screened interval and confirm depth to bottom. If discrepancies exist, consult with project hydrogeologist.
4. Attach the pneumatic slug test manifold onto the top of the well casing. Tighten the rubber connector to ensure an airtight seal.
5. If applicable, program the barologger to record barometric pressure. The barologger should be placed in the headspace of an adjacent well, or on grade, adjacent to the well being tested.
6. Program the pressure transducer to record water levels at the following suggested frequencies. Note that the lithologic descriptions and datalogger memory should be used to select the highest measurement frequency possible.
    a. In hydrologic settings where high hydraulic conductivity is expected, water levels should be measured at 0.5-second intervals, or the highest frequency available. This measurement frequency should be selected for gravels and sands.
    b. In hydrologic settings where low hydraulic conductivity is expected, water levels should be measured at 1- to 2-second intervals. This measurement frequency should be selected for silts and clays.
7. Install the pressure transducer deep enough within the water column to not interfere with the testing equipment. Ideally, the transducer should be 5 to 10 feet lower than the maximum depth of the slug testing equipment not closer than 6 inches above the well bottom. Remember to use measurements and not the well bottom as silt can clog the pressure transducer. Clamp the pressure transducer cable to the well casing or other static object.
8. View the measured water level in real time on the laptop computer. Wait for the water levels to stabilize. Note that the temperature of the pressure transducer should be permitted to equilibrate to groundwater temperatures to ensure accurate water-level measurements.
9. Re-measure the depth to water
10. Close the air release valve.
11. Close the inlet air valve with the pressure regulator closed.
12. Verify that the incoming pressure is less than safe operating pressure of the manifold pressure regulator (<10 psi is necessary) before attaching air hose (not applicable for hand pump).
13. Attach air hose and open regulator to verify incoming pressure (not applicable for hand pump).
14. Close regulator and open the inlet air valve.
15. Slowly open the pressure regulator to pressurize well head and depress water level a sufficient distance without lowering the head below the top of the well screen (2.31 feet of water is equal to 1 psi). Keep to the rule of thumb of 1 to 3 feet displacement and follow best practices with two duplicate tests and a third test with double the displacement. Larger displacements may be appropriate for high conductivity formations. Begin with a low pressure and gradually increase the pressure in order to obtain the desired displacement. DO NOT OVER PRESSURIZE THE WELL (do not exceed ~2 psi). If using a hand pump, pressurize the well head with pump with regulator open.
16. Close the regulator and leak check the system with leak detection fluid and fix any leaks. If the leak is very slow, or down the well, the regulator may be used to maintain a constant pressure head.
17. Check the pressure transducer response and air pressure to verify system is stable. This may take a period of time, as the pressure transducer is equalizing to both the pressurized atmosphere in the well and the displaced water column (see below figure). Stabilization is

reached once the reported pressure returns to near the original pressure. If it is stable proceed to the next step, if not check the seals.



18. Record a baseline pressure for a minimum of 3 minutes. Record data on the field form.
19. Close inlet valve and quickly open the release valve to initiate the test.
20. Allow sufficient time for water level to recover to static level. If completing one test (just a falling head test or just a rising head test), then 80% recovery is sufficient. Duplicate tests are highly recommended, and the next test should be completed after the first test has recovered to greater than 95%. A third test at a displacement of twice the initial is recommended.
21. Save all data files to the laptop, backup on flash drive or by emailing, and finalize any field notes.
22. Review the data collected to determine the reasonableness of the preliminary results. The observation of apparently anomalous results should be discussed with senior project staff prior to proceeding. The water level record for each test should show static conditions, pressurization of the well column, and the recovery response. Make notes on the field form and notebook concerning any irregularities.
23. Decontaminate all down-well equipment.

Non-Aqueous Phase Liquid (NAPL) Bail-Down Testing

MEMO

To:
Arcadis Field Team

Copies:
Hugh Devery

From:
Andrew Korik
Christopher Spooner

Arcadis of New York, Inc.
One Lincoln Center
110 West Fayette Street
Suite 300
Syracuse
New York 13202
Tel 315 446 9120
Fax 315 449 0017

Date:
April 25, 2018

Arcadis Project No.:
B0038994.0001

Subject:
Red Hook 3 and Red Hook 4 Dense Non-Aqueous Phase Liquid Baildown Testing Procedure

---

PURPOSE

The following procedure outlines the steps to be taken to perform rising-head dense non-aqueous phase liquid (DNAPL) baildown tests to qualitatively evaluate DNAPL recoverability at two well locations (MW-10D and MW-14) at the Red Hook 4 site. Testing results will be utilized to evaluate DNAPL mobility in the subsurface. These procedures can also be used to evaluate light non-aqueous phase liquid (LNAPL). This procedure should be used in conjunction with the Site HASP and JSAs.

CONTACTS

Arcadis PIC/PM: Hugh Devery

Arcadis APM: Andy Korik – 315.671.9323

Arcadis Field Support: Ray Stevenson – 860.533.9917

Arcadis TKI – Andy Pennington – office: 312-229-5464; cell: 312-371-4509

ACTION ITEMS

Daily

- Health and Safety Tailgate Meeting
- Task-specific JSAs must be dirtied in field
- Monitor with 4-gas meter Testing Procedure

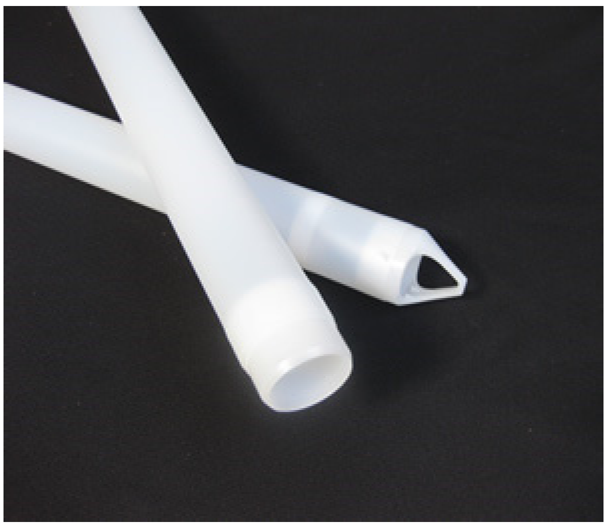
Before onsite work, check transducer function and get familiar with the software used to start and stop the sensors and download the data.

Specific procedures for conducting DNAPL baildown tests are presented below:

1. Identify site, well number, date, and time in the field logbook along with other appropriate DNAPL baildown testing information.
2. Place clean plastic sheeting and several oil absorbent pads on the ground next to the well.
3. Unlock and open the monitoring well cover while standing upwind from the well.
4. Conduct breathing zone air monitoring in accordance with the HASP and record the PID reading in the field logbook.
5. Gauge depth to water, depth to product, and depth to bottom. Use the measured DNAPL thickness and the well diameter to calculate and record the initial DNAPL volume in the well.
6. Set transducers to record readings at one-minute intervals. Set transducers to take simultaneous readings (both transducers) by synchronizing start time. It's ok to start recording readings before the transducers are in the well.
    a. Measure and cut twine to set the DNAPL transducer at bottom of well and to set the water transducer at level where it won't encounter DNAPL (e.g., 2 feet above static DNAPL elevation). If water level decreases significantly during test initiation, you may need to collect depth to water readings with interface probe until water reaches transducer. Both transducers can be hung on one piece of twine to reduce tangling.
    b. Use failsafe method to attach transducers so they won't be lost in well – e.g., tying to the hole on the bottom of the monitoring well plug:

    c. Set up the barometric transducer at nearby outdoor location that is exposed to air and shaded (e.g., hang inside a traffic cone next to a building).
    d. Get transducers ready to put down the well – logging data, attached to well cap at correct lengths – but don't put them down the well yet.
7. Slowly lower the pump or tubing into the well until it touches bottom, and then raise it up slightly (e.g., 1 inch). Set up the tubing to discharge to buckets. Put a small ball valve on the end, or near the end, of the tubing to help regulate flow and prevent backflow, like this:

8. Evacuate DNAPL from the well by pumping it into plastic buckets. Minimize water production.
9. Removal of DNAPL will be considered complete when water appears in the pump stream with little DNAPL content. Turn the pump off and close the discharge valve on the tubing. Gently remove the pump or tubing from the well to minimize agitation of the water column. Keep the valve closed until the pump is out of the well casing, so that fluid in the pump and tubing doesn’t back-flow into the well. Drain the liquid from the pump and tubing into the bucket. Place the pump and tubing on the plastic sheeting until it can be decontaminated.
10. If pumping the NAPL is not feasible (lots of water is produced, or no flow is observed) use bailers to remove NAPL. Let the bailer sink to the bottom of the well and then slowly retrieve it up through the water column. Use bailers with a wide mouth opening (like the Eon superbailers below) or make a wide-mouth bailer by cutting two smaller ones apart (see attached PDF).



STX01P0116082214
400.pdf

11. Record the time at which DNAPL removal is complete.
12. As soon as the pump is removed from the well, gauge the DNAPL level and groundwater level in the well. Then immediately insert the pressure transducers in the well to their pre-determined depths. Record the time that transducers are at their final depths.
13. Record the volumes removed of DNAPL and groundwater on the Baildown Test Log. If a DNAPL/water emulsion formed during fluid recovery, allow time for DNAPL/water separation and make note of the observed emulsification.
14. At some point after the first hour of recovery, pull both transducers and download the readings to confirm that they are reading properly. Be sure to restart the logging if it’s stopped for downloading.
15. Periodically gauge the well manually (e.g., once every 4 hours after the test starts) to see how DNAPL recovery is progressing. Transducers may need to be removed for these measurements. Note the time of gauging and then carefully reinstall the transducers. Take care not to tangle the twine suspending the transducers; check and untangle if necessary. Fluid levels should be monitored in the well until (ideally) 80 percent recovery of initial DNAPL thickness is achieved. This may take several days or more; keep in touch with the project team to discuss recovery rates and monitoring schedule.

16. Place all DNAPL and groundwater collected during the test into an appropriate container for proper waste management.
17. Decontaminate the oil-water level indicator and pump.

Equipment

Rental

- Interface probe
- PID
- Stainless steel monsoon pump
- Monsoon pump tubing (relatively small diameter, with matching hose barb for pump)
- Pump controller
- Pump battery
- Two transducers per test well (Minidiver or similar, rated to ~90 ft; don't get models that are rated for very large depths, as accuracy decreases)
- Barometric transducer

Field Room

- Nitrile gloves
- Buckets w/ lids
- Backup interface probe (check battery)
- Decon supplies (for interface probe and transducers)
- Garbage bags
- Oil absorbent pads
- Bailers (as backup)

Misc.

- Stop-valve for tubing (to prevent backflow)
- Plastic sheeting
- Stopwatch/watch
- Drums
- Drum wrench

Paperwork

- HASP
- JSAs
- Field book
- DNAPL forms

PPE

- Level D
- Fire Retardant Suit
- No jewelry

APPENDIX D

Project Organization

APPENDIX D – PROJECT ORGANIZATION

Personnel	Investigation Role	Contact Information
Moniqua Williams BT Red Hook, LLC	BCP Volunteer	Phone: (470) 658-5642 Email: moniquawilliams@ups.com
Hugh Devery, Arcadis	Project Manager	Phone: 678.488.5792 Email: hugh.devery@arcadis.com
Terry W. Young, P.E., Arcadis	Project Engineer-of-Record	Phone: 315.671.9478 Email: terry.young2@arcadis.com
Andrew Korik, P.G., Arcadis	Assistant Project Manager	Phone: 315.671.9323 Email: andrew.korik@arcadis.com
Denise Dixon., Arcadis	Assistant Project Manager	Phone: 770.384.6660 Email: denise.dixon@arcadis.com
Greg Mason, Arcadis	Project Health and Safety Officer	Phone: 859.253.9036 Email: greg.mason@arcadis.com
David Cornell, Arcadis	Field Team Lead and Safety Officer	Phone: 315.671.9379 Email: david.cornell@arcadis.com
Ray Stevenson, Arcadis	Quality Assurance Manager	Phone: 860.533.9917 Email: ray.stevenson@arcadis.com
Jeffrey Davin, Arcadis	Data Validator/Quality Assurance Officer	Phone: 315.671.9468 Email: jeffrey.davin@arcadis.com
Shawn Miller, ADT	Drilling Contractor	Phone: 516.616.6026 Email: smiller@aquiferdrilling.com
Theresa Ferrentino, Con-Test Analytical Laboratory	Laboratory Contractor for 2018	Phone: 413.525.2332 Email: tferrentino@contestlabs.com

APPENDIX E

Generic Community Air Monitoring Plan

Appendix 1A
New York State Department of Health
Generic Community Air Monitoring Plan

Overview

A Community Air Monitoring Plan (CAMP) requires real-time monitoring for volatile organic compounds (VOCs) and particulates (i.e., dust) at the downwind perimeter of each designated work area when certain activities are in progress at contaminated sites. The CAMP is not intended for use in establishing action levels for worker respiratory protection. Rather, its intent is to provide a measure of protection for the downwind community (i.e., off-site receptors including residences and businesses and on-site workers not directly involved with the subject work activities) from potential airborne contaminant releases as a direct result of investigative and remedial work activities. The action levels specified herein require increased monitoring, corrective actions to abate emissions, and/or work shutdown. Additionally, the CAMP helps to confirm that work activities did not spread contamination off-site through the air.

The generic CAMP presented below will be sufficient to cover many, if not most, sites. Specific requirements should be reviewed for each situation in consultation with NYSDOH to ensure proper applicability. In some cases, a separate site-specific CAMP or supplement may be required. Depending upon the nature of contamination, chemical- specific monitoring with appropriately-sensitive methods may be required. Depending upon the proximity of potentially exposed individuals, more stringent monitoring or response levels than those presented below may be required. Special requirements will be necessary for work within 20 feet of potentially exposed individuals or structures and for indoor work with co-located residences or facilities. These requirements should be determined in consultation with NYSDOH.

Reliance on the CAMP should not preclude simple, common-sense measures to keep VOCs, dust, and odors at a minimum around the work areas.

Community Air Monitoring Plan

Depending upon the nature of known or potential contaminants at each site, real-time air monitoring for VOCs and/or particulate levels at the perimeter of the exclusion zone or work area will be necessary. Most sites will involve VOC and particulate monitoring; sites known to be contaminated with heavy metals alone may only require particulate monitoring. If radiological contamination is a concern, additional monitoring requirements may be necessary per consultation with appropriate DEC/NYSDOH staff.

Continuous monitoring will be required for all ground intrusive activities and during the demolition of contaminated or potentially contaminated structures. Ground intrusive activities include, but are not limited to, soil/waste excavation and handling, test pitting or trenching, and the installation of soil borings or monitoring wells.

Periodic monitoring for VOCs will be required during non-intrusive activities such as the collection of soil and sediment samples or the collection of groundwater samples from existing monitoring wells. "Periodic" monitoring during sample collection might reasonably consist of taking a reading upon arrival at a sample location, monitoring while opening a well cap or overturning soil, monitoring during well baling/purging, and taking a reading prior to leaving a sample location. In some instances, depending upon the proximity of potentially exposed individuals, continuous monitoring may be required during sampling activities. Examples of such situations include groundwater sampling at wells on the curb of a busy urban street, in the midst of a public park, or adjacent to a school or residence.

<u>VOC Monitoring, Response Levels, and Actions</u>

Volatile organic compounds (VOCs) must be monitored at the downwind perimeter of the immediate work area (i.e., the exclusion zone) on a continuous basis or as otherwise specified. Upwind concentrations should be measured at the start of each workday and periodically thereafter to establish background conditions, particularly if wind direction changes. The monitoring work should be performed using equipment appropriate to measure the types of contaminants known or suspected to be present. The equipment should be calibrated at least daily for the contaminant(s) of concern or for an appropriate surrogate. The equipment should be capable of calculating 15-minute running average concentrations, which will be compared to the levels specified below.

1. If the ambient air concentration of total organic vapors at the downwind perimeter of the work area or exclusion zone exceeds 5 parts per million (ppm) above background for the 15-minute average, work activities must be temporarily halted and monitoring continued. If the total organic vapor level readily decreases (per instantaneous readings) below 5 ppm over background, work activities can resume with continued monitoring.

2. If total organic vapor levels at the downwind perimeter of the work area or exclusion zone persist at levels in excess of 5 ppm over background but less than 25 ppm, work activities must be halted, the source of vapors identified, corrective actions taken to abate emissions, and monitoring continued. After these steps, work activities can resume provided that the total organic vapor level 200 feet downwind of the exclusion zone or half the distance to the nearest potential receptor or residential/commercial structure, whichever is less - but in no case less than 20 feet, is below 5 ppm over background for the 15-minute average.

3. If the organic vapor level is above 25 ppm at the perimeter of the work area, activities must be shutdown.

4. All 15-minute readings must be recorded and be available for State (DEC and NYSDOH) personnel to review. Instantaneous readings, if any, used for decision purposes should also be recorded.

<u>Particulate Monitoring, Response Levels, and Actions</u>

Particulate concentrations should be monitored continuously at the upwind and downwind perimeters of the exclusion zone at temporary particulate monitoring stations. The particulate monitoring should be performed using real-time monitoring equipment capable of measuring particulate matter less than 10 micrometers in size (PM-10) and capable of integrating over a period of 15 minutes (or less) for comparison to the airborne particulate action level. The equipment must be equipped with an audible alarm to indicate exceedance of the action level. In addition, fugitive dust migration should be visually assessed during all work activities.

1. If the downwind PM-10 particulate level is 100 micrograms per cubic meter (mcg/m^3) greater than background (upwind perimeter) for the 15-minute period or if airborne dust is observed leaving the work area, then dust suppression techniques must be employed. Work may continue with dust suppression techniques provided that downwind PM-10 particulate levels do not exceed 150 mcg/m^3 above the upwind level and provided that no visible dust is migrating from the work area.

2. If, after implementation of dust suppression techniques, downwind PM-10 particulate levels are greater than 150 mcg/m^3 above the upwind level, work must be stopped and a re-evaluation of activities initiated. Work can resume provided that dust suppression measures and other controls are successful in reducing the downwind PM-10 particulate concentration to within 150 mcg/m^3 of the upwind level and in preventing visible dust migration.

3. All readings must be recorded and be available for State (DEC and NYSDOH) and County Health personnel to review.

December 2009

Appendix 1B
Fugitive Dust and Particulate Monitoring

A program for suppressing fugitive dust and particulate matter monitoring at hazardous waste sites is a responsibility on the remedial party performing the work. These procedures must be incorporated into appropriate intrusive work plans. The following fugitive dust suppression and particulate monitoring program should be employed at sites during construction and other intrusive activities which warrant its use:

1. Reasonable fugitive dust suppression techniques must be employed during all site activities which may generate fugitive dust.

2. Particulate monitoring must be employed during the handling of waste or contaminated soil or when activities on site may generate fugitive dust from exposed waste or contaminated soil. Remedial activities may also include the excavation, grading, or placement of clean fill. These control measures should not be considered necessary for these activities.

3. Particulate monitoring must be performed using real-time particulate monitors and shall monitor particulate matter less than ten microns (PM10) with the following minimum performance standards:

(a) Objects to be measured: Dust, mists or aerosols;
(b) Measurement Ranges: 0.001 to 400 mg/m3 (1 to 400,000 :ug/m3);
(c) Precision (2-sigma) at constant temperature: +/- 10 :g/m3 for one second averaging; and +/- 1.5 g/m3 for sixty second averaging;
(d) Accuracy: +/- 5% of reading +/- precision (Referred to gravimetric calibration with SAE fine test dust (mmd= 2 to 3 :m, g= 2.5, as aerosolized);
(e) Resolution: 0.1% of reading or 1g/m3, whichever is larger;
(f) Particle Size Range of Maximum Response: 0.1-10;
(g) Total Number of Data Points in Memory: 10,000;
(h) Logged Data: Each data point with average concentration, time/date and data point number
(i) Run Summary: overall average, maximum concentrations, time/date of maximum, total number of logged points, start time/date, total elapsed time (run duration), STEL concentration and time/date occurrence, averaging (logging) period, calibration factor, and tag number;
(j) Alarm Averaging Time (user selectable): real-time (1-60 seconds) or STEL (15 minutes), alarms required;
(k) Operating Time: 48 hours (fully charged NiCd battery); continuously with charger;
(l) Operating Temperature: -10 to 50^{o} C (14 to 122^{o} F);
(m) Particulate levels will be monitored upwind and immediately downwind at the working site and integrated over a period not to exceed 15 minutes.

4. In order to ensure the validity of the fugitive dust measurements performed, there must be appropriate Quality Assurance/Quality Control (QA/QC). It is the responsibility of the remedial party to adequately supplement QA/QC Plans to include the following critical features: periodic instrument calibration, operator training, daily instrument performance (span) checks, and a record keeping plan.

5. The action level will be established at 150 ug/m3 (15 minutes average). While conservative,

this short-term interval will provide a real-time assessment of on-site air quality to assure both health and safety. If particulate levels are detected in excess of 150 ug/m3, the upwind background level must be confirmed immediately. If the working site particulate measurement is greater than 100 ug/m3 above the background level, additional dust suppression techniques must be implemented to reduce the generation of fugitive dust and corrective action taken to protect site personnel and reduce the potential for contaminant migration. Corrective measures may include increasing the level of personal protection for on-site personnel and implementing additional dust suppression techniques (see paragraph 7). Should the action level of 150 ug/m3 continue to be exceeded work must stop and DER must be notified as provided in the site design or remedial work plan. The notification shall include a description of the control measures implemented to prevent further exceedances.

6. It must be recognized that the generation of dust from waste or contaminated soil that migrates off-site, has the potential for transporting contaminants off-site. There may be situations when dust is being generated and leaving the site and the monitoring equipment does not measure PM10 at or above the action level. Since this situation has the potential to allow for the migration of contaminants off-site, it is unacceptable. While it is not practical to quantify total suspended particulates on a real-time basis, it is appropriate to rely on visual observation. If dust is observed leaving the working site, additional dust suppression techniques must be employed. Activities that have a high dusting potential--such as solidification and treatment involving materials like kiln dust and lime--will require the need for special measures to be considered.

7. The following techniques have been shown to be effective for the controlling of the generation and migration of dust during construction activities:

(a) Applying water on haul roads;
(b) Wetting equipment and excavation faces;
(c) Spraying water on buckets during excavation and dumping;
(d) Hauling materials in properly tarped or watertight containers;
(e) Restricting vehicle speeds to 10 mph;
(f) Covering excavated areas and material after excavation activity ceases; and
(g) Reducing the excavation size and/or number of excavations.

Experience has shown that the chance of exceeding the 150ug/m3 action level is remote when the above-mentioned techniques are used. When techniques involving water application are used, care must be taken not to use excess water, which can result in unacceptably wet conditions. Using atomizing sprays will prevent overly wet conditions, conserve water, and provide an effective means of suppressing the fugitive dust.

8. The evaluation of weather conditions is necessary for proper fugitive dust control. When extreme wind conditions make dust control ineffective, as a last resort remedial actions may need to be suspended. There may be situations that require fugitive dust suppression and particulate monitoring requirements with action levels more stringent than those provided above. Under some circumstances, the contaminant concentration and/or toxicity may require additional monitoring to protect site personnel and the public. Additional integrated sampling and chemical analysis of the dust may also be in order. This must be evaluated when a health and safety plan is developed and when appropriate suppression and monitoring requirements are established for protection of health and the environment.