ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE

and

DOMINION TRANSMISSION, INC.
SUPPLY HEADER PROJECT

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APPENDIX A

Site-Specific Plan for the Gateway Horizontal Directional Drill

Prepared for

Dominion Transmission, Inc.
P.O. Box 2450
Clarksburg, West Virginia 26302

GEOTECHNICAL SITE INVESTIGATION REPORT

for

ATLANTIC COAST PIPELINE – HORIZONTAL DIRECTIONALLY DRILLED CROSSING

Route 58, Segment AP3-071
Virginia

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3/10/2017

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1. INTRODUCTION

This report was prepared by Geosyntec Consultants, Inc. (Geosyntec) for Dominion Transmission, Inc. (Dominion) to present the results of the geotechnical site investigation for the proposed horizontal directionally drilled (HDD) crossing beneath the Route 58 as part of Segment AP3-071 of the Atlantic Coast Pipeline (ACP) Project. The Route 58 Crossing is located in Nansemond County, Virginia on pipeline AP-3 at Mile Post 071 (Figure 1).

This report provides descriptions of the geotechnical drilling and sampling procedures, description of the subsurface conditions encountered, and the results of geotechnical laboratory testing on selected representative samples of the subsurface materials.

The work presented in this report was performed at the request of Dominion under Contract/Purchase Order 70291181, and it is in accordance with our proposal "HDD Boring Services for the Atlantic Coast Pipeline Project" submitted on 29 June 2015.

The recommendations provided in this report are based on data collected from a limited number of samples at the locations described herein. The materials are typical of a riverine environment and should not be considered to be homogenous or consistent across the planned alignment. This data should only be considered generally indicative of conditions that may be encountered along the alignment.

1.1 Project Background

Dominion is proposing to construct the ACP, which will comprise five segments totaling approximately 550-mile in length, of natural gas transmission pipeline system extending generally southward from Harrison County, West Virginia to Robeson County, Virginia. Near the Virginia/Virginia state line a branch will extend generally eastward from Franklin, Virginia to Chesapeake, Virginia. The segments are identified as follows with reference to the 2 March 2016 Revision 10 Route:

- Segment AP-1: 42 inch pipe from Mile Post (MP) 0.0 in Harrison County West Virginia south across the West Virginia/Virginia State Line to MP 300 on the Virginia/Virginia State Line;
- Segment AP-3: 36 inch pipe from MP 0.0 (vicinity of AP-1 MP 300) on the Virginia/Virginia State Line south to MP 182.95;

- Segment AP-3: 20 inch pipe from MP 0.0 (vicinity of AP-1 MP 300, and AP-3 MP 0.0) on the Virginia/Virginia State Line east to MP 78.3;
- Segment AP-4: 16 inch pipe extending west from AP-1 MP 279.6, through Brunswick County, Virginia for 0.4 miles; and,
- Segment AP-5: 16 inch pipe extending southwest from AP-1 MP 284.4, through Greensville County, Virginia for 1.1 miles.

Along its alignment, the pipeline will cross streams, water bodies, U.S. Routes and other major highways. At some of these crossings HDD pipeline installation techniques will be used. Dominion has contracted Geosyntec to perform geotechnical investigations at the proposed HDD crossing locations to obtain subsurface information for feasibility evaluations, engineering design and contractor information.

1.2 Scope of Services

Geosyntec's scope of services included completion of the following tasks:

- Conduct two geotechnical borings at locations selected by Dominion in the Route 58 HDD crossing site to final depths of approximately 117 ft bgs (below ground surface) and 115 ft bgs, to recover samples for classification and geotechnical laboratory testing;
- Conduct a geotechnical laboratory testing program using selected samples from the borings to characterize the subsurface materials (soil) at the site, and to aid in the estimation of the geotechnical parameters specified by Dominion;
- Prepare geotechnical boring logs; and
- Prepare a Geotechnical Site Investigation Report summarizing the findings of the geotechnical site investigation at the Route 58 crossing (this report).

Potential environmental issues, such as soil contamination were not within Geosyntec's scope of work. This report was prepared for the Route 58 crossing.

1.3 Organization of This Report

Following this introductory section, the remainder of the report is organized as follows:

- Section 2 provides information on the location of the project site and the exploratory borings, describes the site topography, and summarizes the regional geologic setting;
- Section 3 provides a description of the drilling and sampling equipment and procedures, and information about the backfilling of the borings;
- Section 4 describes the geotechnical laboratory testing program, and summarizes the results;
- Section 5 describes the soil stratigraphy at the boring locations and groundwater conditions;
- Section 6 provides information on the methodologies used for developing geotechnical strength and compressibility parameters, as well as unit weights presents a summary of the geotechnical parameters measured;
- Section 7 provides summary of geotechnical parameters of soil samples;
- Section 8 provides closing comments; and
- Section 9 lists the references used in this report.

1.4 Coordinate System and Unit System

The coordinate system used in this report is Universal Transverse Mercator (UTM) Zone 17, and North American Datum of 1983 (NAD83). The datum for the elevations is World Geodetic System 1984 (WGS84), and are referenced to mean sea level (MSL).

This report is presented using US customary system units, where length is described in feet (ft), miles (mi) and inches (in), stresses and pressures in kips per square feet (ksf), and unit weight in pounds per cubic feet (pcf).

2. SITE DESCRIPTION

2.1 Site Location and Proposed Crossing

The proposed HDD drill path will cross approximately perpendicular to the Route 58, reaching a maximum depth of about 85 ft below ground surface (bgs), relative to both the southern entry point and the northern exit points (as shown in profile produced by Jeffrey S. Puckett, P.E, an independent consultant to Dominion, dated 09 January 2017 and provided in Appendix A) on AP3-072.

As shown in the site map of Figure 1, the proposed Route 58 HDD crossing site is generally oriented northeast-southwest, nearly perpendicular to Route 58, about 3 miles southwest of the community of Bowers Hill, Virginia which is located in the independent city of Chesapeake, Virginia.

2.2 Site Topography

A topographic map of the Bowers Hill quadrangle, produced by the United States Geological Survey (USGS) and presented as Figure 2, confirms the visual observations by our field geotechnical engineers that the areas in the vicinity of the drilling locations are nearly flat. The approximate elevation at Boring Route (RT) 58 B-1 is 28.9 ft (MSL) and RT58 B-2 is 25.3 ft (MSL). The elevations of the boring locations summarized in Table 1 agree well with the topographic map, as well as the plan and profile by Jeffrey S. Puckett, P.E. (Appendix A).

2.3 Regional and Local Geology

Geologic maps (Coch, 1971 shown on Figure 3) indicate that the geology (in the vicinity of the HDD entry and exit points) is underlain by lagoonal and estuarine sediments of the upper member of the Sand Bridge Formation which includes a series of unconformable Quaternary (Q) marine, estuarine, fluvial, tidal channel fill, beach and dune deposits of variable thickness which lie unconformably on top of the Norfolk Formation and then over deep deposits of the Yorktown Formation which consist of Tertiary (T) marine silt, sand and clay.

On the western and eastern sides of the crossing, in the vicinity of the HDD exit and entry point, the Alluvium (Qal) and the Sand Bridge Formation deposits (Qsb) lie unconformably Norfolk Formation (Qn) which lies over the Yorktown Formation (Ty).

Although the subsurface conditions under Route 58 were not investigated, it is inferred that Alluvium (Qal) consisting of alluvium, estuarine beach sediments, and fluvial estuarine fills lie unconformably over the Sand Bridge Formation (Qsb) consisting of marsh and tidal flat silty clay that lie unconformably over the Norfolk Formation (Qn) consisting of estuarine clay and fine-grained sand which lies unconformably over the Yorktown Formation (Ty).

The Sand Bridge Formation (Qsb) generally consists of is heterogeneous and generally consists of cross-bedded sands, massive sands, silty sands, silts, and clayey sands and has a sharp contact with the underlying Norfolk Formation.

The Norfolk Formation unconformably overlies the Yorktown Formation except where the Norfolk was removed during erosion prior to the deposition of the overlying Sand Bridge formation. South of the James River, the Norfolk is overlain by the Sand Bridge formation; north of the James it is the surficial unit. The Norfolk has an average thickness of 20 feet and is more than 40 feet thick in the central parts of channel-fill sequences.

The Yorktown Formation (Ty) which is common throughout southeastern Virginia, generally consists of fossiliferous (typically shells) marine fine silty sands, with deposits of clays and silts. According to the USGS geologic map, the primary rock type in this area is unconsolidated sand.

3. EXPLORATION PROGRAM

3.1 Introduction

Geosyntec contracted Fishburne Drilling Inc. (Fishburne) of Chesapeake, Virginia, to conduct geotechnical drilling and sampling at the proposed Route 58 HDD crossing. The original coordinates of the boring locations and their target termination depths were pre-determined by Dominion and their HDD design consultant, Jeffrey S. Puckett, P.E. The work was performed with the following objectives:

i. Establish the likely subsurface stratigraphy and major soil units present at the proposed HDD crossing will be installed;
ii. Obtain penetration resistance data of the major soil units for correlations with engineering parameters; and
iii. Obtain soil samples suitable for classification and laboratory testing purposes.

The geotechnical site investigation consisted of two borings advanced to depths of 117 ft bgs and 115 ft bgs, for Borings RT58 B-1 and RT58 B-2, respectively. The borings were completed in one mobilization with drilling for Boring RT58 B-1 completed on 16 February 2017 and drilling for Boring RT58 B-1 completed on 17 February 2017.

Boring RT58 B-1 is located on the southern side of the crossing, at the end corner of a parking lot, encapsulated by woods in the other three sides. Boring RT58 B-2 is located on the northern side of the crossing on a narrow dirt road across through a woodland. The two boreholes were offset from the originally proposed locations, at the request of the landowner and in consultation with Dominion, to avoid drilling in, and potentially damaging fields or to avoid tree clearing.

Table 1 presents the coordinates of each boring location, together with elevation, and termination depths. The as-built coordinates were surveyed using a Trimble Geo 7X global positioning unit (GPS) with post processing.

Table 1 – Coordinates of Boring Locations

Boring ID	Coordinates – UTM, Zone 17N, NAD84				Offset from Pipeline Centerline	As-Built Ground Surface Elev. WGS84	Final Depth
	Proposed (ft)		As-Built (ft)				
	Easting	Northing	Easting	Northing	(ft)	(MSL-ft)	(ft)
RT58 B-1	2,968,675.17	13,382,036.37	2,968,622.92	13,382,050.78	81.36-W	28.9	117
RT58 B-2	2,967,833.18	13,383,066.35	2,967,833.18	13,383,041.41	66.68 W	25.3	115

3.2 Drilling and Sampling Procedures

A track-mounted CME-55 drill rig was used to advance the 6-in. diameter geotechnical soil borings and to the final depths via mud rotary methods.

Soil samples were obtained using a split-spoon sampler of length of 24-in., in accordance with ASTM D1586 [ASTM, 2011], continuously from the ground surface to 10 ft bgs, and at 5-foot intervals thereafter until terminal depth was encountered. The soil penetration resistance was measured at all sample depths using the Standard Penetration Test (SPT). Each split-spoon sample was advanced 24 inches, and blow counts were recorded over each 6-in. interval. The SPT N-value is the number of blows required for a 140-lb hammer dropping 30 in, to drive the split-spoon sampler through the middle 12-in interval of the 24-in penetration. The SPT N-values are presented in the boring logs.

In addition to split-spoon sampling, one large 3-inch diameter sampling tube called a "Shelby Tube" was used to collect undisturbed samples of cohesive soil for strength testing.

Our drilling inspectors prepared descriptions of each soil sample using visual-manual methods according to ASTM D2488 and placed the samples in individual sealed containers, labeled, and stored for transport to the laboratory facilities. The observations of our drilling inspectors were recorded on the field boring logs as the drilling operations progressed.

3.3 Boring Backfilling

After completion, each boring was backfilled with a bentonite-grout slurry. The collar of each boring was backfilled with drill cuttings and, if needed, bentonite chips were placed at the very top of the boring to create a low permeability clay plug at the surface. Remaining cuttings and residual bentonite-clay slurry were graded to match the surrounding topography, and diluted with water to disperse the cuttings and slurry.

4. LABORATORY TESTING

4.1 Introduction

Geosyntec contracted Geotesting Express, Inc. (GTX) of Acton, Massachusetts, to conduct laboratory testing assigned by Geosyntec on selected soil samples to measure the pertinent index properties of the soils. The laboratory testing program, on soil samples, was primarily focused on soil classification and index testing. The laboratory testing program consisted of:

Soil Samples

- Natural water (moisture) contents (ASTM D2216)
- Grain-size distributions (ASTM D422)
- Atterberg limits (ASTM D4318)
- TXUU test – 1 point (ASTM D2850)

Table 2 summarizes the number and types of laboratory testing conducted on soil samples from the Route 58 HDD crossing.

Table 2 – Number and Types of Laboratory Tests

	Number of Tests	
Laboratory Testing	**Boring RT58 B-1**	**Boring RT58 B-2**
Water (Moisture) Content	8	9
Grain-Size Distribution	8	9
Atterberg Limits	7	8
TXUU	1	2

5. SUBSURFACE CONDITIONS

5.1 Introduction

The soil stratigraphy at the Route 58 crossing is based on our drilling inspectors' observations made during drilling operations, the classification of the soil samples recovered from the soil borings, and the results of the geotechnical laboratory testing. The soil stratigraphy, including details of soil descriptions such as color and inclusions, is presented on the boring logs (Appendix B). As part of this work, Geosyntec developed a Generalized Geologic Profile (Figure 4).

Soil stratigraphy presented in this report corresponds to soil conditions at the location of the borings and can be extrapolated with confidence to the area in close vicinity of the boring locations (e.g., 50 ft). However, subsurface conditions described herein do not necessarily represent conditions along the entire HDD alignment. Extrapolations should be made with consideration of this limitation.

5.2 Soil Stratigraphy

5.2.1 Boring RT58 B-1

The soil stratigraphy at Boring RT58 B-1 consists of:

- **Stratum I-1: Clayey Sand (SC).** This stratum extends from the ground surface to a depth of 5.0 ft bgs.
- **Stratum II-1: Sand (SP) and Clayey Sand (SC).** This stratum extends from 5.0 to 13.0 ft bgs.
- **Stratum III-1: Clayey Sand (SC) and Organic Clay (OH).** This stratum extends from 13.0 ft to 23.0 ft bgs.
- **Stratum IV-1: Silt (ML) and Organic Clay (OH).** This stratum extends from 23.0 ft bgs to a depth of 34.0 ft bgs.
- **Stratum V-1: Sand (SP) and Clayey Sand (SC).** This stratum extends from 34.0 ft bgs to a depth of 53.0 ft bgs.
- **Stratum VI-1: Silty Sand (SM).** This stratum extends from 53.0 ft bgs to a depth of 63.0 ft bgs.
- **Stratum VII-1: Silty Sand (SM).** This stratum extends from 63.0 ft bgs to a depth of 83.0 ft bgs.

- **Stratum VIII-1: Lean Clay (CL).** This stratum extends from 3.0 ft bgs to the termination depth of 117.0 ft bgs.

5.2.2 Boring RT58 B-2

The soil stratigraphy at Boring RT58 B-2 consists of:

- **Stratum I-1: Silty Sand (SM).** This stratum extends from the ground surface to a depth of 2.0 ft bgs.
- **Stratum II-1: Lean Clay (CL) and Organic Silt (OH).** This stratum extends from 2.0 to 7.0 ft bgs.
- **Stratum III-1: Silty Sand (SM).** This stratum extends from 7.0 ft to 19.0 ft bgs.
- **Stratum IV-1: Silt (ML) and Organic Clay (OH).** This stratum extends from 19.0 ft bgs to a depth of 38.0 ft bgs.
- **Stratum V-1: Silty Sand (SM).** This stratum extends from 38.0 ft bgs to a depth of 43.0 ft bgs.
- **Stratum VI-1: Organic Clay (OH).** This stratum extends from 43.0 ft bgs to a depth of 49.0 ft bgs.
- **Stratum VII-1: Silty Sand (SM).** This stratum extends from 49.0 ft bgs to a depth of 73.0 ft bgs.
- **Stratum VIII-1: Silty Sand (SM).** This stratum extends from 73.0 ft bgs to a depth of 83.0 ft bgs.
- **Stratum IX-1: Silty Sand (SM) and Clayey Sand (SC).** This stratum extends from 83.0 ft bgs to the termination depth of 115.0 ft bgs.

5.3 Groundwater Conditions

The groundwater level was estimated as 6 ft bgs for RT58 B-1 based on the field logs, and 6 ft bgs for RT58 B-2 based the log.

6. INDEX PROPERTIES

6.1 Index Properties and Laboratory Test Results

Tables 3 present a summary of the index properties of the soil laboratory test results of water content, gradation, Atterberg limits, and shear strength which are also plotted in the boring logs (Appendix B). Individual test results are presented in detail in Appendix C.

6.2 Unit Weight

6.2.1 Sand Materials (SM, SP, SC)

Unit weights were estimated based on compiled values in literature, e.g. Das (2005) and laboratory test. Poorly-graded and (SP) and well-graded sand (SW) has unit weight of 125 pcf; sand with fine-grained materials (SC, SM, SP-SC) were assigned a unit weight of 115 pcf.

6.2.2 Silt and Clay Materials (ML, MH, CL, CH)

Unit weights of was obtained from laboratory tests, an average value of unit weight of 110 pcf is used.

6.2.3 Organic Soils (OH)

Unit weights of was obtained from laboratory tests, an average value of unit weight of 100 pcf is used.

6.2.4 Soil Testing

Table 3 presents a summary of the laboratory test results conducted on soil samples.

Table 3 – Summary of Laboratory Test Results on Soil Samples

Boring ID	Sample ID	Unified Soil Classification System (USCS)	Sample Depth Interval (ft-bgs)	Water Content (%)	Percent Fines (< #200 Sieve) (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Shear Strength[(1)] (ksf)	Strain at Failure (%)
Rte. 58 B-1	SS-1 (S-3)	SC	4-6	31.9	47.4	34	22	12	-	-
Rte. 58 B-1	SS-2 (S-6)	OH	13-15	59.9	69.1	59	20	39	-	-
Rte. 58 B-1	Shelby-1	SC	15-17	40.0	33.4	30	14	16	0.25	5.15
									0.33	4.08
									0.29	5.2
Rte. 58 B-1	SS-3 (S-7)	SC	18-20	36.7	21.2	26	14	12	-	-
Rte. 58 B-1	SS-4 (S-10)	OH	33-35	80.7	97.5	77	24	53	-	-
Rte. 58 B-1	SS-5 (S-12)	-	43-45	22.1	11	-			-	-
Rte. 58 B-1	SS-6 (S-18)	SM	73-75	36.4	31.7	Non-plastic			-	-
Rte. 58 B-1	SS-7 (S-24)	CL	103-105	36.0	56.2	44	26	18	-	-
Rte. 58 B-2	SS-1 (S-2)	CL	2-4	20.9	51.6	28	15	13	-	-
Rte. 58 B-2	SS-2 (S-5)	SM	8-10	35.4	27.3	Non-plastic				
Rte. 58 B-2	SS-3 (S-6)	-	13-15	30.6	14	-			-	-
Rte. 58 B-2	Shelby-1	OH	30-32	57	81.2	77	24	53	0.69	2.77
									0.75	2.18
									0.66	3.82
Rte. 58 B-2	Shelby-2	OH	45-47	64	76.2	82	29	53	0.83	5.7
									0.71	13.2
									0.93	3.33
Rte. 58 B-2	SS-4 (S-15)	SM	58-60	29.4	17.9	Non-plastic			-	-
Rte. 58 B-2	SS-5 (S-20)	SC	83-85	31.7	48.0	36	23	13	-	-
Rte. 58 B-2	SS-6 (S-23)	CL	98-100	37.1	56.5	46	23	23		
Rte. 58 B-2	SS-7 (S-26)	SM	113-115	34.6	35.6	Non-plastic			-	-

Note: Strata defined above.

(1) Shear strength is obtained from UU test.

6.3 Strength Parameters

6.3.1 Sand Deposits (SC, SM, SP)

The effective friction angles (ϕ') of the sand deposits were estimated from the SPT results using the empirical correlation proposed by Kulhawy and Mayne (1990), which uses corrected SPT blow counts corrected for overburden stresses as follows:

$$(N_1)_{60} = C_N N_{60}$$

Where $(N_1)_{60}$ is the corrected SPT blowcount, C_N is the overburden correction factor (P_{atm}/σ'_{vo}, where σ'_{vo} being the vertical effective stress), and N_{60} is the SPT blowcount corrected to hammer energy efficiency.

The hammer energy efficiency of the drill rig used during this work (Fishburne's CME 55 drill rig, Serial Number 395465) was measured to be 86.3%. (Report of SPT Hammer Energy Measurements is attached in Appendix D).

Appendix E summarizes the results of all SPTs performed in each boring, and the effective friction angle based on the mentioned correlation.

6.3.2 Silt and Clay Deposits (ML, CL, CH, OH)

In lieu of laboratory test measurements, estimates of undrained shear strength (s_u) of silt and clay deposits were obtained from N-SPT correlations by Terzaghi and Peck (1967) as follows:

$$s_u = 0.13N$$

Where N is the measured SPT N-value. The s_u results based on this methodology are presented in Appendix E.

6.4 Compressibility Parameters

6.4.1 Sand Deposits (SC, SM, SP, SP-SC)

The Young's modulus (E) of the sand deposits was estimated from the SPT results using the empirical correlation proposed by Kulhawy and Mayne (1990) for normally consolidated sands with fines as follows:

$$\frac{E}{P_{atm}} = 5N_{60}$$

Appendix E presents the variation of Young's modulus at the boring locations.

6.4.2 Silt and Clay Deposits (ML, CL, CH, OH)

The Young's modulus (E) of the silt and clay deposits during undrained loading conditions was estimated from correlations compiled by Bowles (1988) for normally consolidated clays as follows:

$$E = 500\ s_u$$

Appendix E presents the variation of Young's modulus at both boring locations.

7. GEOTECHNICAL PARAMETERS

Selected geotechnical parameters were developed for the primary soil materials encountered at each boring location at the Route 58 HDD crossing based on the methodologies described in Section 6. These parameters are presented in Table 4 and Table 5. The summary of soil index test results and SPT correlation results are presented in Appendix E.

Table 4 –Geotechnical Parameters for Boring RT58 B-1

Strata	Top Depth (ft)	Thick-ness (ft)	Descriptions	Total Unit Weight $\gamma_t^{(2)}$ (pcf)	Effective Friction Angle $\phi'^{(2)}$ (degree)		Undrained Shear Strength $s_u^{(2)}$ (ksf)		Young's Modulus $E^{(2)}$ (ksf)	
					Range	Avg.	Range	Avg.	Range	Avg.
I-1	0.0	5.0	Medium Dense, Brown and Black, Moist, CLAYEY SAND (SC), Medium Coarse, With Gravel and Wood	115	31.7 to 38.1	35.1	-	-	91 to 228	162
II-1	5.0	8.0	Medium Dense, Light Gray, CLAYEY SAND (SC), Transition to Loose Moist Light Gray Poorly-graded Sand Medium Dense, Light Gray, Wet, POORLY-GRADED SAND (SP)	125	33.3 to 33.6	33.5	-	-	122 to 134	129
III-1	13.0	10.0	Very Soft, Greenish-gray, Wet, SANDY ORGANIC CLAY (OH), Very Loose, Greenish-gray, Wet, CLAYEY SAND (SC), With Shell Fragments	115	-	26.9	-	-	0 to 15	8
IV-1	23.0	11.0	Soft, Brown, Moist, SILT (ML), Trace Fine Sand, Becomes Green-gray. Very Soft, Brown, Wet, ORGANIC CLAY (OH), Sandy	100	-	-	0.18 to 0.37	0.24	91 to 183	122
V-1	34.0	19.0	Loose to Medium Dense, Light Gray, Wet, POORLY-GRADED SAND With Clay (SP-SC), Medium Coarse, With Silt, Trace Gravel	115	29.2 to 30.6	29.8	-	-	91 to 137	107
VI-1	53.0	10.0	Dense, Dark Gray With Tan, POORLY-GRADED SAND (SP), With Shell Fragments. Medium Dense to Dense, Moist, Dark Greenish Gray, SILTY SAND (SM), Shell Fragments	115	34.6 to 37.6	36.1	-	-	320 to 441	380
VII-1	63.0	20.0	Medium Dense, Moist, Dark Greenish Gray, SILTY SAND (SM), Shell Fragments	115	29.6 to 32.3	31.1	-	-	137 to 228	190
VIII-1	83.0	34.0	Stiff to Very Stiff, Dark Greenish Gray, Moist, SANDY LEAN CLAY (CL), With Silt, Trace Fine Sand and Shell Fragments	110	-	-	1.10 to 1.28	1.21	548 to 639	603

Notes:
1) USCS: Unified Soil Classification System.
2) Parameters for use in HDD design only.
3) Detailed soil descriptions are presented in the borehole logs included in Appendix B. The soil description presented in this table are generalized, and may not reflect the actual characteristics of the material.

Table 5 Geotechnical Parameters for Boring RT58 B-2

Strata	Top Depth (ft)	Thick-ness (ft)	Descriptions	Total Unit Weight γ_t $^{(2)}$ (pcf)	Effective Friction Angle ϕ' $^{(2)}$ (degree)		Undrained Shear Strength $s_u$$^{(2)}$ (ksf)		Young's Modulus E $^{(2)}$ (ksf)	
					Range	Avg.	Range	Avg.	Range	Avg.
I-2	0.0	2.0	Medium Dense, Gray to Brown, Moist, Fine SILTY SAND (SM)	115	-	32.7	-	-	-	107
II-2	2.0	5.0	Medium, Black, Moist, ORGANIC SILT (OH) Medium, Medium Gray, Saturated, Fine SANDY LEAN CLAY (CL)	100	-	-	0.73 to 0.73	0.73	-	365
III-2	7.0	12.0	Very Loose, Gray, Saturated, Fine SILTY SAND (SM)	115	26.5 to 33.3	28.9	-	-	0 to 122	46
IV-2	19.0	19.0	Very Soft, Gray, ORGANIC CLAY With Sand (OH) Soft, SILT (ML), With Fine Sand	100	-	-	0.00 to 0.75	0.44	0 to 180	86
V-2	38.0	5.0	Medium Dense, Gray, Saturated, SILTY SAND (SM), Fine To Medium, With Shell Fragments	115	-	35.2	-	-	-	274
VI-2	43.0	6.0	Soft, Dark Brown Gray, Saturated ORGANIC CLAY (OH)	100	-	-	0.36 to 0.93	0.64	25 to 180	108
VII-2	49.0	24.0	Very Loose to Medium Dense, Gray, Saturated, SILTY SAND (SM), Fine To Medium, With Shell Fragments	115	30.6 to 36.6	33.4	-	-	137 to 396	263
VIII-2	73.0	10.0	Medium Dense, Gray, Saturated, SILTY SAND (SM), Fine To Medium, With Shell Fragments	115	29.6 to 30.3	29.9	-	-	122 to 152	137
IX-2	83.0	32.0	Loose, Gray, Saturated, CLAYEY SAND (SC), Fine To Medium, Loose to Medium Dense, Gray, Saturated, SILTY SAND (SM), Fine	115	27.7 to 30.3	28.8	-	-	61 to 183	112

Notes:
1) USCS: Unified Soil Classification System.
2) Parameters for use in HDD design only.
3) Detailed soil descriptions are presented in the borehole logs included in Appendix B. The soil description presented in this table are generalized, and may not reflect the actual characteristics of the material.

8. CLOSING

Geosyntec is pleased to provide Dominion with the geotechnical investigation results for the ACP HDD Route 58 crossing.

Please contact Tim Kelly at 804.665.2815 and/or Scott Sheridan at 804.665.2810 with any questions regarding this report or the geotechnical investigation.

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9. REFERENCES

P. B. Attewell and I. W. Farmer (1976). Principles of engineering geology, Chapman and Hall. London and New York

Bowles, J. E. (1988). Foundation Analysis and Design. Fourth Edition. Peoria, Illinois

Coch, Nicholas K., 1971, Geology of the Newport News South and Bowers Hill quadrangles, Virginia: Virginia Division of Mineral Resources Rept. Inv. 29, 26p. Online source as of January 13 2017: https://www.dmme.virginia.gov/commercedocs/RI_28.pdf

Das, B. M. (2005). Fundamentals of Geotechnical Engineering. 2nd Edition. Toronto, Ontario, Canada.

Day, R. W. (2009). Foundation Engineering Handbook, Design and Construction with the 2009 International Building Code. Second Edition.

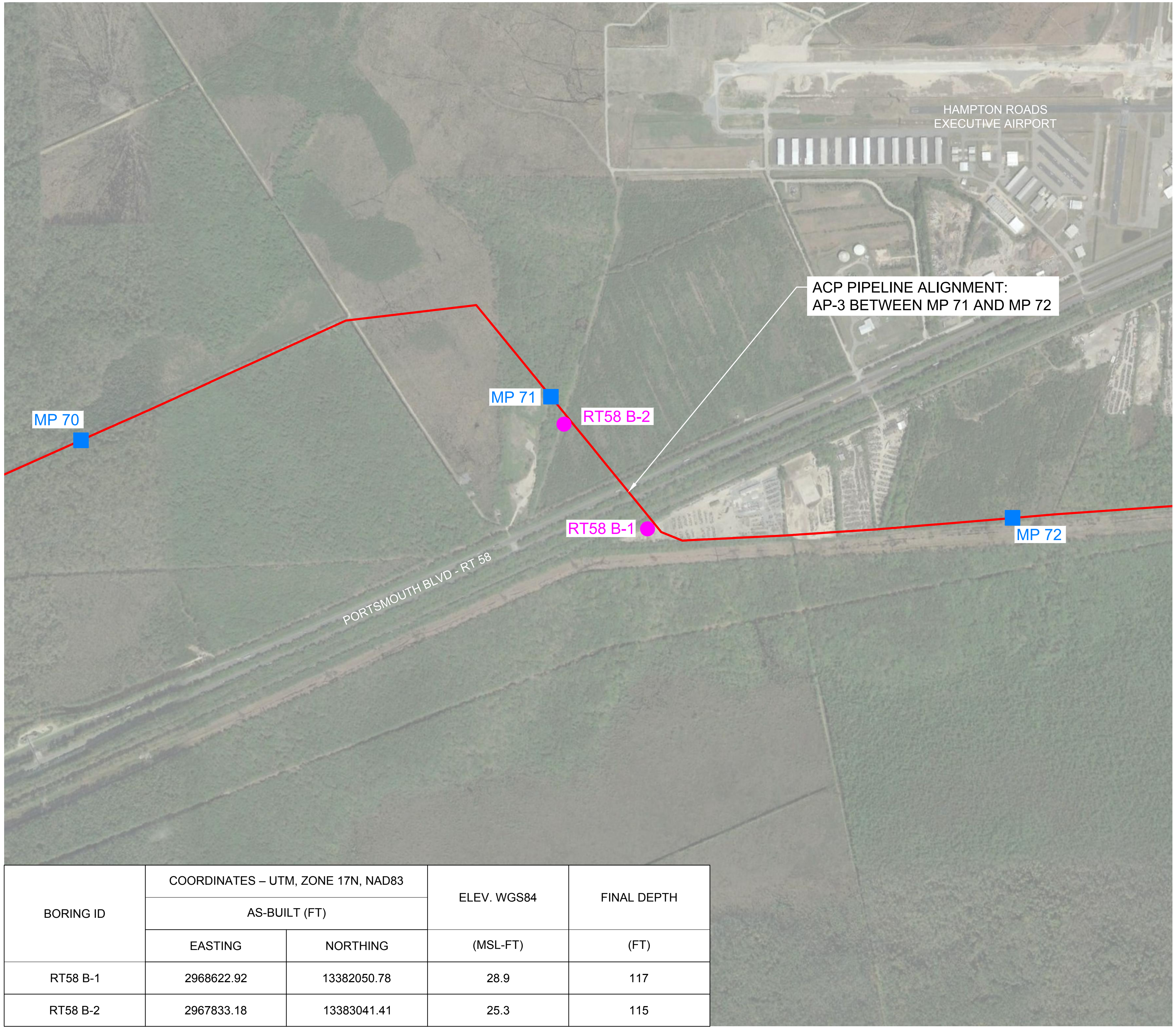
Kulhawy F.H. and Mayne P.W. (1990), Manual on Estimating Soil Properties for Foundation Design. Cornell University, Ithaca, New York.

McCarthey D.F. (2007), Essentials of Soil Mechanics and Foundations. 7th Edition, Pearson Education, Columbus, Ohio.

Puckett, J.S. (2017), Plan and Profile, 36-inch Pipeline Crossing of the Route 58 by Horizontal Directional Drilling, Tulsa, Oklahoma.

Terzaghi, K., and Peck, R. B. (1967). Soil Mechanics in Engineering Practice. 2nd Edition. John Wiley and Sons. New York, NY.

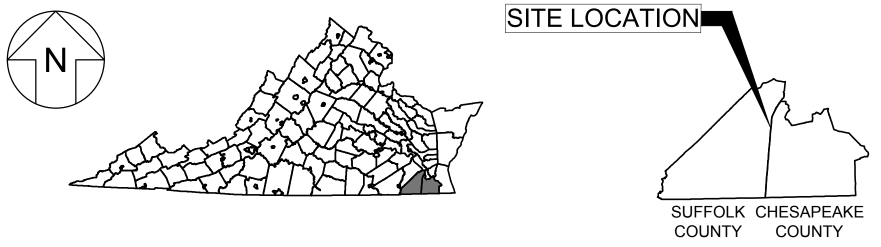
FIGURES

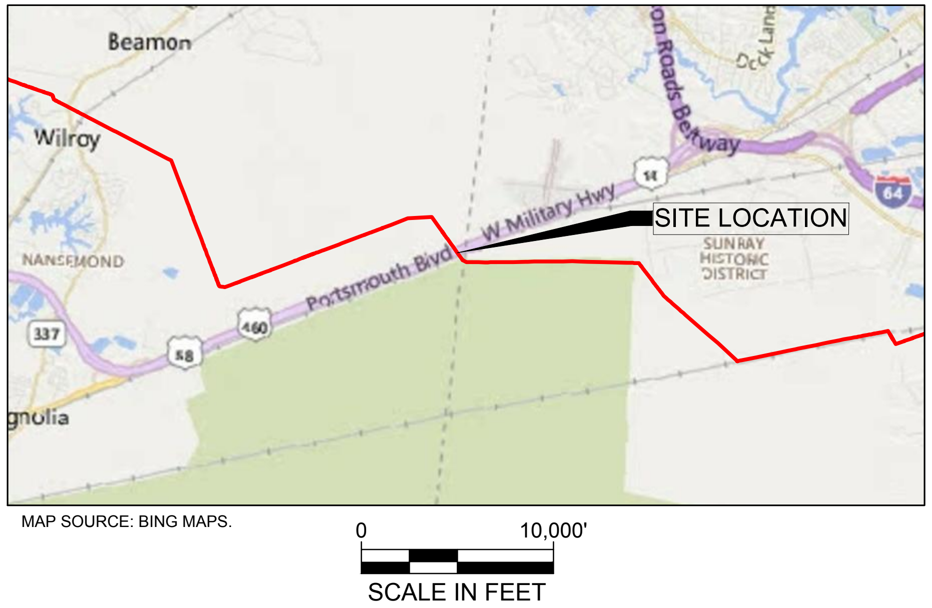


ACP PIPELINE ALIGNMENT:
AP-3 BETWEEN MP 71 AND MP 72

BORING ID	COORDINATES – UTM, ZONE 17N, NAD83		ELEV. WGS84	FINAL DEPTH
	AS-BUILT (FT)			
	EASTING	NORTHING	(MSL-FT)	(FT)
RT58 B-1	2968622.92	13382050.78	28.9	117
RT58 B-2	2967833.18	13383041.41	25.3	115

MAP SOURCE: GOOGLE EARTH PRO 2016.





MAP SOURCE: BING MAPS.

LEGEND

━━	PIPELINE ALIGNMENT (NOTE 3)
● RT58 B-1	BORING
■ MP 71	MILE POST

NOTES:

1. BORING RT58 B-1 COMPLETED ON 16 FEBRUARY 2017.
2. BORING RT58 B-2 COMPLETED ON 17 FEBRUARY 2017.
3. PIPELINE ALIGNMENT IS BASED ON 2017-02-20_REV12_SHAPES_TO_JDHAIR-UPDATED CENTERLINE.

0 1,000'
SCALE IN FEET

PREPARED FOR:

DOMINION TRANSMISSION, INC.

Dominion

SITE LOCATION MAP
US ROUTE 58, VIRGINIA
AP-3 MP 70 TO 72 ATLANTIC COAST PIPELINE

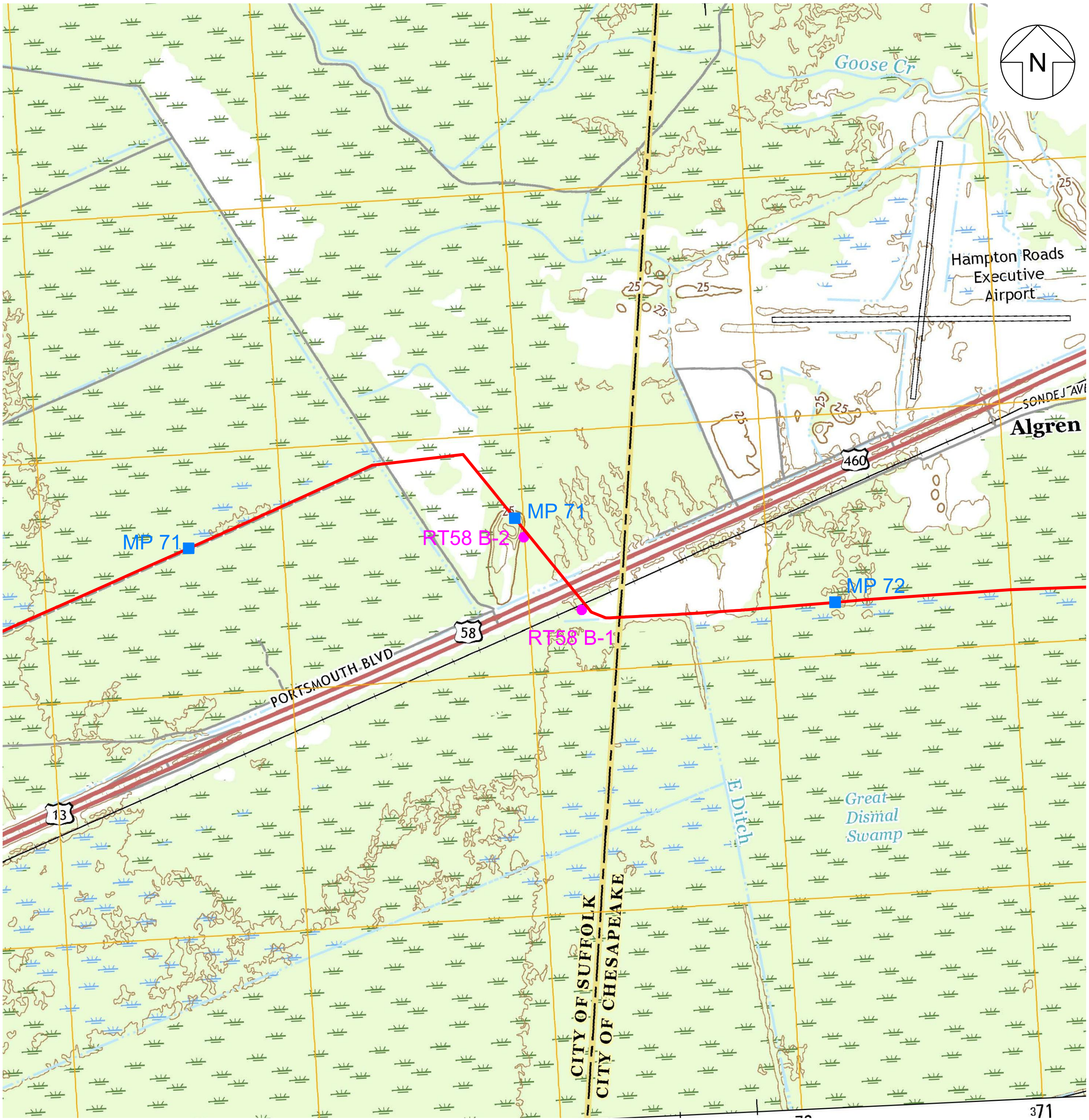
Geosyntec
consultants

PROJECT NO:	MV1290A		MARCH 2017		
DRAWN:	TAW	REVIEWED:	SKS	APPROVED:	TMK

FIGURE

1

L:\D\DOMINION\ACP HDD GEOTECHNICAL INVESTIGATION MV1290\PRELIMINARY\FIGURES2\RTE 58\MV1290RTE58F1; LAST EDITED BY: TWanex



MAP SOURCE: UNITED STATES DEPARTMENT OF THE INTERIOR, U.S. GEOLOGICAL SURVEY (USGS), 7 1/2 MINUTE SERIES QUADRANGLE TOPOGRAPHIC MAP OF BOWERS HILL, VIRGINIA DATED 2016.
HORIZONTAL DATUM = NAD83/WGS84; VERTICAL DATUM = NAVD88;
UNITS = FEET; CONTOUR INTERVAL = 10'.

0 2,000'
SCALE IN FEET

LEGEND

━━	PIPELINE ALIGNMENT (NOTE 3)
● RT58 B-1	BORING (AS-BUILT)
■ MP 70	MILE POST

NOTES:
1. BORING RT58 B-1 COMPLETED ON 16 FEBRUARY 2017.
2. BORING RT58 B-2 COMPLETED ON 17 FEBRUARY 2017.
3. PIPELINE ALIGNMENT IS BASED ON 2017-02-20_REV12_SHAPES_TO_JDHAIR-UPDATED CENTERLINE.

PREPARED FOR:
DOMINION TRANSMISSION, INC.

Dominion

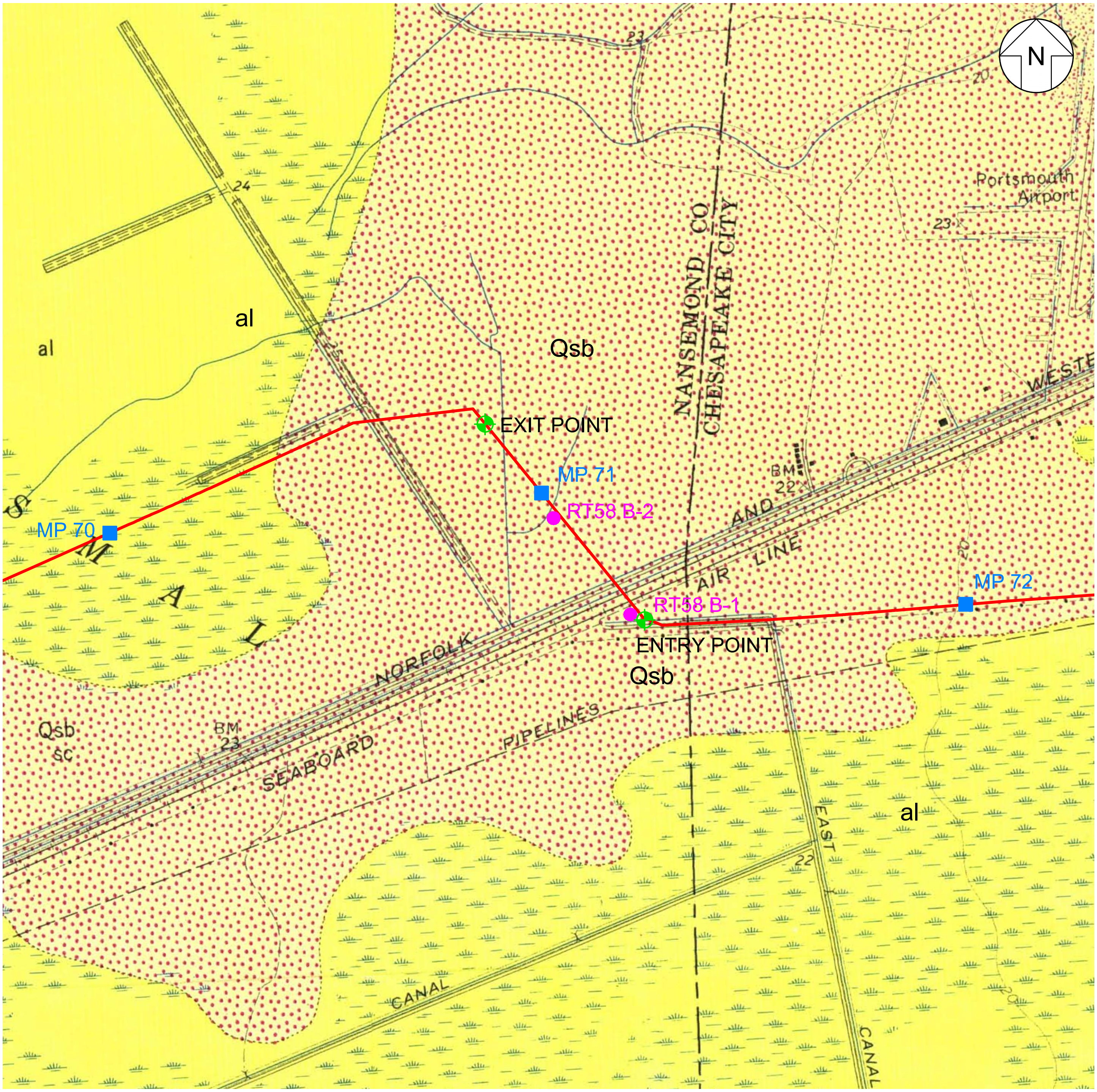
SITE LOCATION MAP
US ROUTE 58, VIRGINIA
AP-3 MP 70 TO 72 ATLANTIC COAST PIPELINE

Geosyntec
consultants

FIGURE
2

PROJECT NO:	MV1290A	MARCH 2017	
DRAWN: TAW	REVIEWED: SKS	APPROVED: TMK	

L:\D\DOMINION\ACP HDD GEOTECHNICAL INVESTIGATION MV1290\PRELIMINARY\FIGURES2\RTE 58\MV1290RTE58F2; LAST EDITED BY: TWanex



MAP SOURCE: U.S. GEOLOGICAL SURVEY 1965
GEOLOGICAL MAP OF THE BOWERS HILL QUADRANGLE 7 1/2 MINUTE SERIES, VIRGINIA
GEOLOGICAL DESCRIPTIONS BY NICHOLAS K. COCH
(MAP DATE: 1971)

0 1,500'
SCALE IN FEET

LEGEND

🟥	PIPELINE ALIGNMENT (NOTE 3)
● RT58 B-1	BORING (AS-BUILT)
■ MP 70	MILE POST
⊕	ENTRY AND EXIT POINTS
al	ALLUVIUM ESTUARINE-BEACH SEDIMENTS, ESTUARINE FILL, PEAT IN DISMAL SWAMP
Qsb	SAND BRIDGE FORMATION UPPER MEMBER: FACIES-sc, MARSH AND TIDAL FLAT, SILTY CLAY; cs, TIDAL CHANNEL, CLAYEY SAND; AND ss, SHOAL LAGOON, SILTY SAND. LOWER MEMBER NOT DESIGNATED ON MAP.

NOTES:

1. BORING RT58 B-1 COMPLETED ON 16 FEBRUARY 2017.
2. BORING RT58 B-2 COMPLETED ON 17 FEBRUARY 2017.
3. PIPELINE ALIGNMENT IS BASED ON 2017-02-20_REV12_SHAPES_TO_JDHAIR-UPDATED CENTERLINE.

PREPARED FOR:
DOMINION TRANSMISSION, INC.

Dominion

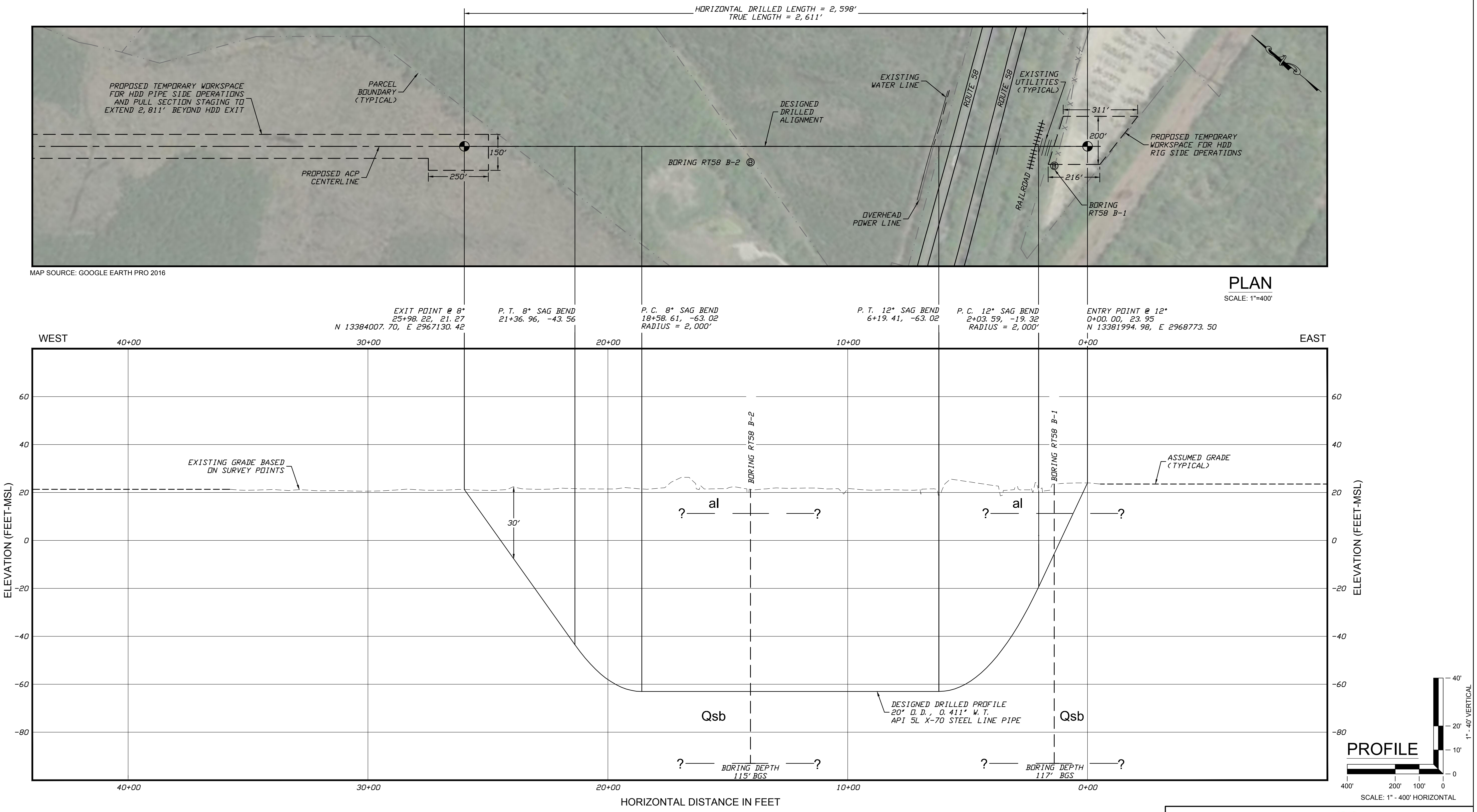
SITE LOCATION MAP
US ROUTE 58, VIRGINIA
AP-3 MP 70 TO 72 ATLANTIC COAST PIPELINE

Geosyntec
consultants

PROJECT NO: MV1290A
MARCH 2017
DRAWN: TAW
REVIEWED: SKS
APPROVED: TMK

FIGURE
3

L:\D\DOMINION\ACP HDD GEOTECHNICAL INVESTIGATION MV1290\PRELIMINARY\FIGURES2\RTE 58\MV1290RTE58F3; LAST EDITED BY: TWanex



GENERAL LEGEND

◒	DRILLED PATH ENTRY/EXIT POINT
— —— —	LITHOLOGIC CONTACT
Ⓑ	BORING LOCATION

GEOTECHNICAL LEGEND

ALLUVIUM (al)	- ESTUARINE-BEACH SEDIMENTS, ESTUARINE FILL, PEAT IN DISMAL SWAMP
SAND BRIDGE FORMATION (Qsb)	- SILTY CLAY, TIDAL CHANNEL, CLAYEY SAND, SHOAL LAGOON, SILTY SAND

GEOTECHNICAL NOTES

1. STRATIGRAPHIC LINES AND SUBSURFACE MATERIAL DESCRIPTION SHOWN ON THIS DRAWING HAVE BEEN SIMPLIFIED FOR PRESENTATION PURPOSES. REFER TO THE PROJECT GEOTECHNICAL REPORT FOR MORE DETAILED SUBSURFACE INFORMATION.
2. GENERAL GEOLOGIC CONDITIONS AND STRUCTURAL (FORMATION) DATA BASED ON U.S. GEOLOGICAL SURVEY 1965 "GEOLOGICAL MAP OF THE BOWERS HILL QUADRANGLE 7 1/2 MINUTE SERIES, VIRGINIA." GEOLOGICAL DESCRIPTIONS BY NICHOLAS K. COCH (MAP DATE: 1971).

TOPOGRAPHIC SURVEY NOTES

1. TOPOGRAPHIC SURVEY DATA PROVIDED BY GAI CONSULTANTS, CANONSBURG, PENNSYLVANIA.
2. PIPELINE ALIGNMENT FROM ATLANTIC COAST PIPELINE PROJECT, PLAN AND PROFILE, 36-INCH PIPELINE CROSSING OF US ROUTE 58 BY HORIZONTAL DIRECTIONAL DRILLING, REVISION P0 BY JEFFREY S. PUCKETT, P.E.
3. NORTHINGS AND EASTINGS ARE IN U.S. SURVEY FEET REFERENCED TO UTM COORDINATES, ZONE 17, NAD 83.
4. ELEVATIONS ARE IN FEET-MAN SEA LEVEL REFERENCED TO NAVD 88.
5. PIPELINE ALIGNMENT BASED ON 2017-02-20_REV12_SHAPES_TO_JDHAIR-UPDATED CENTERLINE.

PREPARED FOR:
DOMINION TRANSMISSION, INC.

Dominion

GENERALIZED GEOLOGIC PROFILE
US ROUTE 58, VIRGINIA
AP-3 MP 70 TO 71 ATLANTIC COAST PIPELINE

Geosyntec consultants

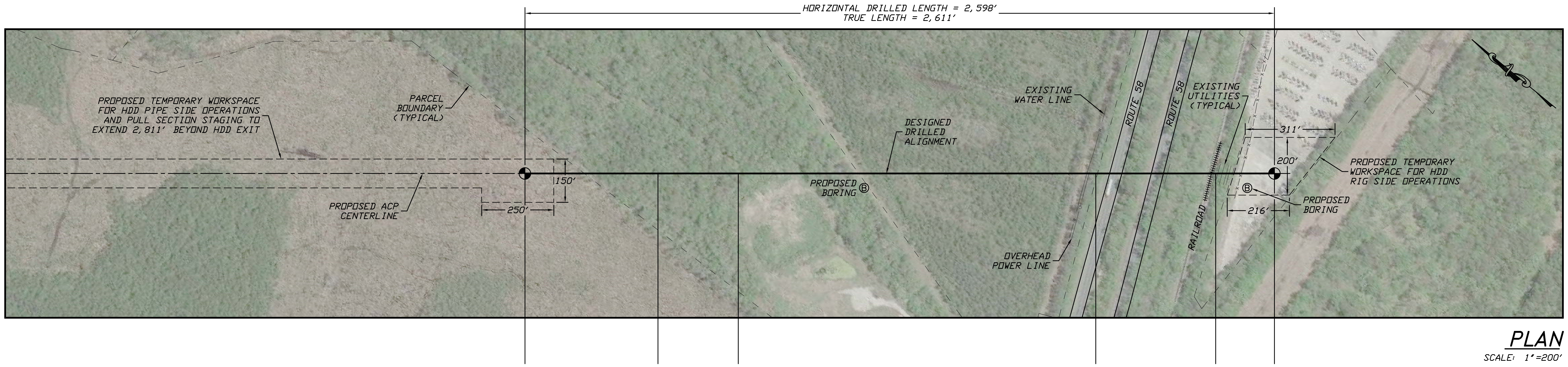
FIGURE 4

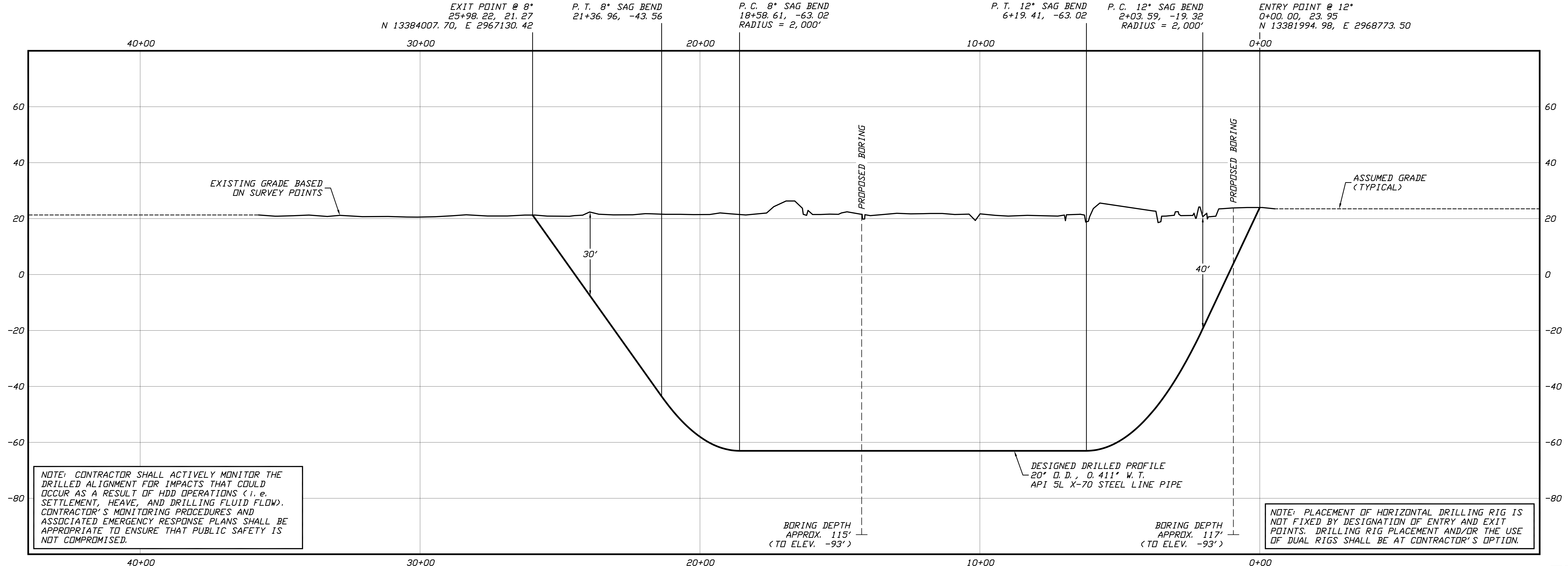
PROJECT NO:	MV1290A	MARCH 2017	
DRAWN: TAW	REVIEWED: SKS	APPROVED: TMK	

APPENDICES

APPENDIX A

PLAN AND PROFILE BY JEFFREY S. PUCKETT, P.E.





NOTE: CONTRACTOR SHALL ACTIVELY MONITOR THE DRILLED ALIGNMENT FOR IMPACTS THAT COULD OCCUR AS A RESULT OF HDD OPERATIONS (i.e. SETTLEMENT, HEAVE, AND DRILLING FLUID FLOW). CONTRACTOR'S MONITORING PROCEDURES AND ASSOCIATED EMERGENCY RESPONSE PLANS SHALL BE APPROPRIATE TO ENSURE THAT PUBLIC SAFETY IS NOT COMPROMISED.

NOTE: PLACEMENT OF HORIZONTAL DRILLING RIG IS NOT FIXED BY DESIGNATION OF ENTRY AND EXIT POINTS. DRILLING RIG PLACEMENT AND/OR THE USE OF DUAL RIGS SHALL BE AT CONTRACTOR'S OPTION.

PROFILE

SCALE: 1"=200' HORIZONTAL
1"= 20' VERTICAL

400 200 100 0
20 10 0

GENERAL LEGEND

⊕ DRILLED PATH ENTRY/EXIT POINT

TOPOGRAPHIC SURVEY NOTES

1. TOPOGRAPHIC SURVEY DATA PROVIDED BY GAI CONSULTANTS, CANONSBURG, PENNSYLVANIA.
2. NORTHINGS AND EASTINGS ARE IN U.S. SURVEY FEET REFERENCED TO UTM COORDINATES, ZONE 17, NAD 83.
3. ELEVATIONS ARE IN FEET REFERENCED TO NAVD 88.

DRILLED PATH NOTES

1. DRILLED PATH STATIONING IS IN FEET BY HORIZONTAL MEASUREMENT AND IS REFERENCED TO CONTROL ESTABLISHED FOR THE DRILLED SEGMENT.
2. DRILLED PATH COORDINATES REFER TO CENTERLINE OF PILOT HOLE AS OPPOSED TO TOP OF INSTALLED PIPE.

PILOT HOLE TOLERANCES

THE PILOT HOLE SHALL BE DRILLED TO THE TOLERANCES LISTED BELOW. HOWEVER, IN ALL CASES, RIGHT-OF-WAY RESTRICTIONS AND CONCERN FOR ADJACENT FACILITIES SHALL TAKE PRECEDENCE OVER THESE TOLERANCES.

1. ENTRY POINT: UP TO 10 FEET FORWARD OR BACK FROM THE DESIGNED ENTRY POINT; UP TO 5 FEET RIGHT OR LEFT OF THE DESIGNED ALIGNMENT
2. EXIT POINT: UP TO 10 FEET SHORT OR 30 FEET LONG RELATIVE TO THE DESIGNED EXIT POINT; UP TO 5 FEET RIGHT OR LEFT OF THE DESIGNED ALIGNMENT
3. ELEVATION: UP TO 5 FEET ABOVE AND 30 FEET BELOW THE DESIGNED PROFILE
4. ALIGNMENT: UP TO 10 FEET RIGHT OR LEFT OF THE DESIGNED ALIGNMENT
5. CURVE RADIUS: NO LESS THAN 1,350 FEET BASED ON A 3-JOINT AVERAGE (RANGE 2 DRILL PIPE)

PROTECTION OF EXISTING FACILITIES

CONTRACTOR SHALL UNDERTAKE THE FOLLOWING STEPS PRIOR TO COMMENCING DRILLING OPERATIONS.

1. CONTACT THE UTILITY LOCATION/NOTIFICATION SERVICE FOR THE CONSTRUCTION AREA.
2. POSITIVELY LOCATE AND STAKE ALL EXISTING UNDERGROUND FACILITIES. ANY FACILITIES LOCATED WITHIN 10 FEET OF THE DESIGNED DRILLED PATH SHALL BE EXPOSED.
3. MODIFY DRILLING PRACTICES AND DOWNHOLE ASSEMBLIES AS NECESSARY TO PREVENT DAMAGE TO EXISTING FACILITIES.

PRELIMINARY

ATLANTIC COAST PIPELINE PROJECT

PLAN AND PROFILE
20 -INCH PIPELINE CROSSING OF ROUTE 58
BY HORIZONTAL DIRECTIONAL DRILLING

LOCATION: SUFFOLK, VIRGINIA

DRAWN	DATE	CHECKED	APPROVED	SCALE	DRAWING LABEL	REVISION
KMN	01/09/17	DMP	JSP	SHOWN FOR D-SIZED PLOT	ROUTE 58	P0

NO.	DATE	REVISION DESCRIPTION	BY	CHK'D	APP.

Jeffrey S. Puckett, P.E.
Consulting Engineer

2424 East 21st Street
Suite 510
Tulsa, Oklahoma 74114

PROJECT NO.
Dominion\1508

AP3-072

APPENDIX B

BORING LOGS

Geosyntec consultants

9211 Arboretum Parkway, Suite 200
Richmond, VA 23236
Office: (804) 767-2206
Fax: (804) 767-2182

LOG OF BORING RT58 B-1

Project Name: ACP HDD - Route 58
Project Number: MV1290
Start Date: 2/16/2017
Finish Date: 2/16/2017

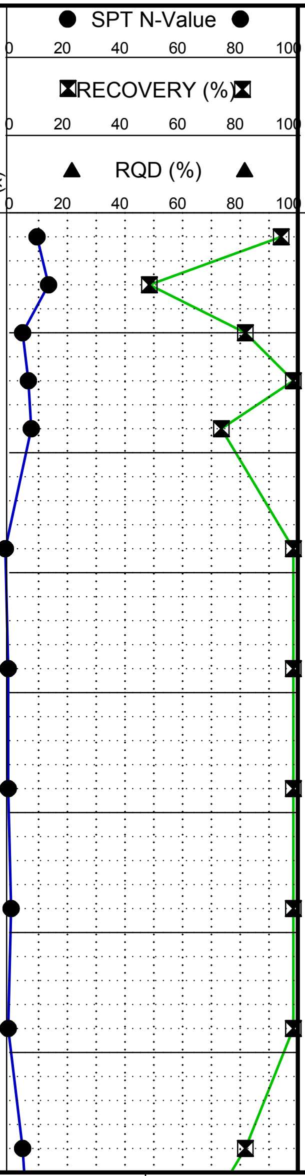
Drilling Contractor: Fishburne Drilling
Drilling Rig: CME 55
Drilling Method: HSA + NQ
Drilling Mud: Bentonite

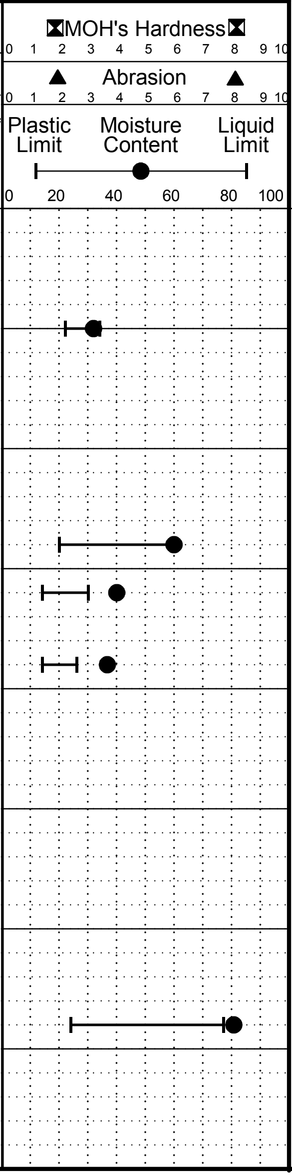
LOCATION:

RT58 B-1

Northing: 13382050.78 Easting: 2968622.92
Surface Elevation: 28.9 MSL-feet
Datum: UTM Zone 17S, NAD83
Vertical Datum: WGS84-MSL

Sample Number	USCS	MATERIAL DESCRIPTION	SPT (blows per 6 inches) N-value (x)	Rock Unconfined Compressive Strength (ksf)	UU Test Shear Strength (ksf)	UU Test Failure Strain (%)	UU Test Confining Pressure (psi)	MOISTURE CONTENT (%)	LIQUID LIMIT LL	PLASTIC LIMIT PL	PLASTICITY INDEX PI	PASSING #200 SIEVE (%)
S-1	SC	Medium Dense, Brown and Black, Moist, CLAYEY SAND (SC), Medium Coarse, With Gravel and Wood	4-6-5-25 (11)									
S-2		SAA, Gray, Wet	6-10-5-4 (15)									
S-3	OH	@4': SAA, Loose ▽5-6.5' Dark Brown, Moist, SANDY ORGANIC CLAY (OH)	3-3-3-3 (6)					31.9	34	22	12	47.4
S-4	SC	6.5-7.5' Medium Dense, Light Gray, CLAYEY SAND (SC), Transition to Loose Moist Light Gray Poorly-graded Sand	4-4-4-3 (8)									
S-5	SP	7.5-13' Medium Dense, Light Gray, Wet, POORLY-GRADED SAND (SP)	4-5-4-3 (9)									
S-6	OH	13-15' Very Soft, Greenish-gray, Wet, SANDY ORGANIC CLAY (OH), Trace Medium Coarse Sand	0-0-0-0 (0)					59.9	59	20	39	69.1
SH-1		Very Loose, Greenish-gray, Wet, CLAYEY SAND (SC), With Shell Fragments			0.25 0.33 0.29	5.15 4.08 5.2		40	30	14	16	33.4
S-7	SC	SAA	0-0-1-1 (1)					36.7	26	14	12	21.2
S-8	ML	Soft, Brown, Moist, SILT (ML), Trace Fine Sand, Becomes Green-gray Organic Clay @24'	1-0-1-1 (1)									
S-9	OH	Very Soft, Brown, Wet, ORGANIC CLAY (OH), Sandy from 28' to 30', With Organics	1-1-1-1 (2)									
S-10	SP-SC	Loose, Light Gray, Wet, POORLY-GRADED SAND With Clay (SP-SC), Medium Coarse, With Silt, Trace Gravel	0-0-1-2 (1)					80.7	77	24	53	97.5
S-11			2-3-3-3 (6)									





Water Level Est.: ▽ Measured: ▼ Perched: ▼
Water Observations:

Sample Key: ☒ SPT ■ Shelby Tube ◪ California Sampler ▯ Rock Core

Key to Abbreviations:
SPT - Standard Penetration Test
N - SPT Data (Blows/Ft)

Notes:
Automatic 140-lb hammer (Average ETR = 86.3%)

Logged by: D. Garrett

Geosyntec consultants
9211 Arboretum Parkway, Suite 200
Richmond, VA 23236
Office: (804) 767-2206
Fax: (804) 767-2182

LOG OF BORING RT58 B-1

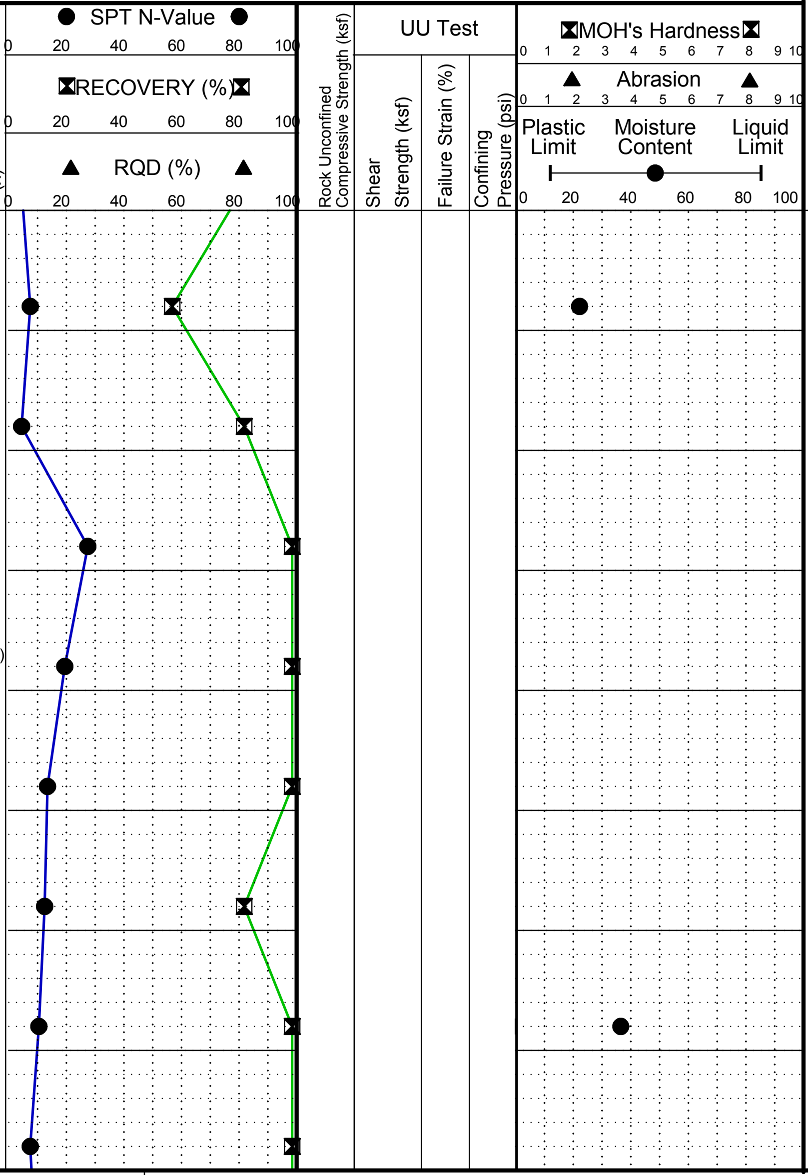
Project Name: ACP HDD - Route 58
Project Number: MV1290
Start Date: 2/16/2017
Finish Date: 2/16/2017

Drilling Contractor: Fishburne Drilling
Drilling Rig: CME 55
Drilling Method: HSA + NQ
Drilling Mud: Bentonite

LOCATION:
RT58 B-1

Northing: 13382050.78 Easting: 2968622.92
Surface Elevation: 28.9 MSL-feet
Datum: UTM Zone 17S, NAD83
Vertical Datum: WGS84-MSL

Elevation (ft.)	Depth (ft.)	Sample Number	USCS	MATERIAL DESCRIPTION	SPT (blows per 6 inches) N-value (x)	MOISTURE CONTENT (%)	LIQUID LIMIT LL	PLASTIC LIMIT PL	PLASTICITY INDEX PI	PASSING #200 SIEVE (%)
-15	45	S-12	SP-SC	SAA, Medium Dense	3-3-6-8 (9)	22.1				11
-20	50	S-13		SAA, Loose, Light Tannish/White, Shell Fragments With Pockets Green-gray SILT	8-3-3-7 (6)					
-25	55	S-14	SP	Dense, Dark Gray With Tan, POORLY-GRADED SAND (SP), With Shell Fragments	12-14-15-13 (29)					
-30	60	S-15		Dense, Moist, Dark Greenish Gray, SILTY SAND (SM), Shell Fragments	6-10-11-12 (21)					
-35	65	S-16		SAA, Medium Dense, With Shell Fragments	5-6-9-12 (15)					
-40	70	S-17	SM	SAA, Sand Size Particles Finer	4-5-9-12 (14)					
-45	75	S-18		SAA, With Shell Fragments	4-4-8-11 (12)	36.4	NP	NP	NP	32
-50		S-19		SAA, With Shell Fragments	3-3-6-9 (9)					



Water Level Est.: ▽ Measured: ▼ Perched: ▼
Water Observations:

Sample Key: ☒ SPT ■ Shelby Tube ◪ California Sampler ▯ Rock Core

Key to Abbreviations:
SPT - Standard Penetration Test
N - SPT Data (Blows/Ft)

Notes:
Automatic 140-lb hammer (Average ETR = 86.3%)

Logged by: D. Garrett

Geosyntec consultants
9211 Arboretum Parkway, Suite 200
Richmond, VA 23236
Office: (804) 767-2206
Fax: (804) 767-2182

LOG OF BORING RT58 B-1

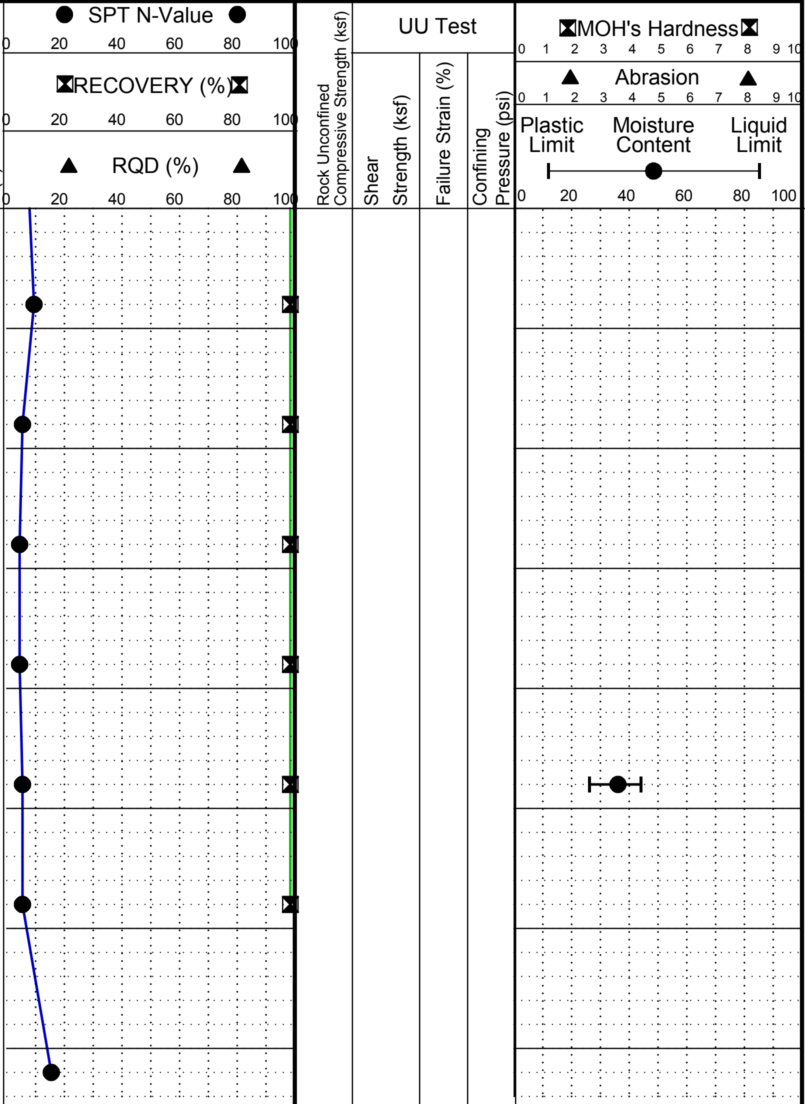
Project Name: ACP HDD - Route 58
Project Number: MV1290
Start Date: 2/16/2017
Finish Date: 2/16/2017

Drilling Contractor: Fishburne Drilling
Drilling Rig: CME 55
Drilling Method: HSA + NQ
Drilling Mud: Bentonite

LOCATION:
RT58 B-1

Northing: 13382050.78 Easting: 2968622.92
Surface Elevation: 28.9 MSL-feet
Datum: UTM Zone 17S, NAD83
Vertical Datum: WGS84-MSL

Elevation (ft.)	Depth (ft.)	Samples	Sample Number	Graphic Log	USCS	MATERIAL DESCRIPTION	SPT (blows per 6 inches) N-value (x)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LIQUID LIMIT LL	PLASTIC LIMIT PL	PLASTICITY INDEX PI	PASSING #200 SIEVE (%)
				▨	SM							
-55	85	☒	S-20	▨		Very Stiff, Dark Greenish Gray, Moist, SANDY LEAN CLAY (CL), With Silt, Trace Fine Sand and Shell Fragments	3-4-7-11 (11)					
-60	90	☒	S-21	▨		SAA, Stiff, With 1/8" Clay Lenses	3-3-4-7 (7)					
-65	95	☒	S-22	▨		SAA, No Clay Lenses	3-3-3-4 (6)					
-70	100	☒	S-23	▨	CL	SAA, With 1/8" Clay Lenses	3-3-3-5 (6)					
-75	105	☒	S-24	▨		SAA	3-3-4-6 (7)	36	44	26	18	56.2
-80	110	☒	S-25	▨		SAA	3-4-3-7 (7)					
-85	115			▨		SAA, Very Stiff, With Fine Sand						
		☒	S-26	▨			4-6-11-16 (17)					
						BOREHOLE TERMINATED AT 117 FT BGS						



Water Level Est.: ▽ Measured: ▼ Perched: ▼
Water Observations:

Sample Key: ☒ SPT ■ Shelby Tube ⧄ California Sampler ▯ Rock Core

Key to Abbreviations:
SPT - Standard Penetration Test
N - SPT Data (Blows/Ft)

Notes:
Automatic 140-lb hammer (Average ETR = 86.3%)

Logged by: D. Garrett

Geosyntec consultants
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Office: (804) 767-2206
Fax: (804) 767-2182

LOG OF BORING RT58 B-2

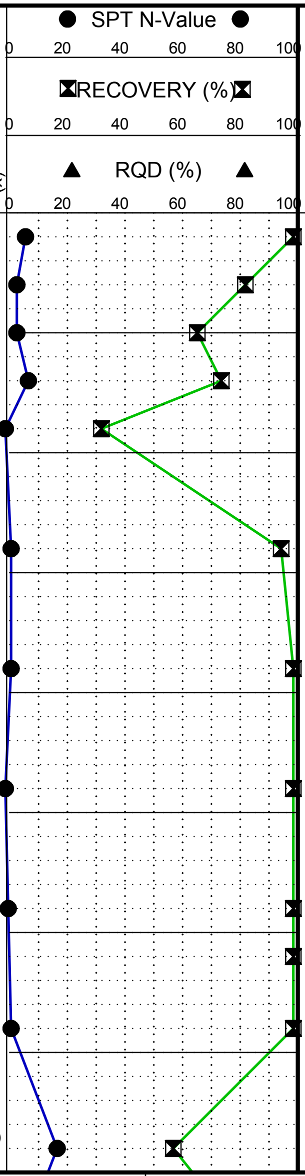
Project Name: ACP HDD - Route 58
Project Number: MV1290
Start Date: 2/17/2017
Finish Date: 2/17/2017

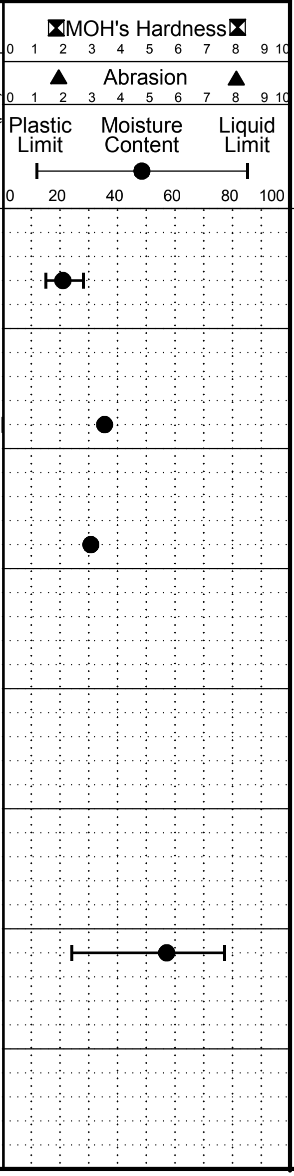
Drilling Contractor: Fishburne Drilling
Drilling Rig: CME 55
Drilling Method: HSA + NQ
Drilling Mud: Bentonite

LOCATION:
RT58 B-2

Northing: 13382063.8 Easting: 2968618.37
Surface Elevation: 25.3 MSL-feet
Datum: UTM Zone 17S, NAD83
Vertical Datum: WGS84-MSL

Elevation (ft.)	Depth (ft.)	Sample Number	USCS	MATERIAL DESCRIPTION	SPT (blows per 6 inches) N-value (x)	Rock Unconfined Compressive Strength (ksf)	UU Test Shear Strength (ksf)	UU Test Failure Strain (%)	UU Test Confining Pressure (psi)	MOISTURE CONTENT (%)	LL	PL	PI	PASSING #200 SIEVE (%)
		1	SM OH	0-1.5' Medium Dense, Gray to Brown, Moist, Fine SILTY SAND (SM) 1.5-2' Medium, Black, Moist, ORGANIC SILT (OH)	4-4-3-2 (7)									
		2		Medium, Medium Gray, Saturated, Fine SANDY LEAN CLAY (CL)	3-2-2-2 (4)					20.9	28	15	13	51.6
20	5	3	CL	SAA ▽	2-2-2-3 (4)									
		4		Very Loose, Gray, Saturated, Fine SILTY SAND (SM)	3-4-4-3 (8)									
15	10	5			1-0-0-1 (0)					35.4	NP	NP	NP	27.3
10	15	6	SM	SAA	1-1-1-1 (2)					30.6				14
5	20	7		18-19' SAA, With Some Shell Fragments 19-33.7' Very Soft, Gray, ORGANIC CLAY With Sand (OH)	2-1-1-1 (2)									
0	25	8		SAA	0-0-0-1 (0)									
-5	30	9	OH	SAA	1-0-1-1 (1)									
		SH-1					0.69 0.75 0.66	2.77 2.18 3.82		57	77	24	53	81.2
-10	35	10		33.7-38' Soft, SILT (ML), With Fine Sand	1-1-1-1 (2)									
			ML											
		11	SM	Medium Dense, SILTY SAND (SM), Fine	8-8-10-12 (18)									





Water Level Est.: ▽ Measured: ▼ Perched: ▼
Water Observations:

Sample Key: ☒ SPT ■ Shelby Tube ▯ California Sampler ▯ Rock Core

Key to Abbreviations:
SPT - Standard Penetration Test
N - SPT Data (Blows/Ft)

Notes:
Automatic 140-lb hammer (Average ETR = 86.3%)

Logged by: K.Warwick

Geosyntec consultants
9211 Arboretum Parkway, Suite 200
Richmond, VA 23236
Office: (804) 767-2206
Fax: (804) 767-2182

LOG OF BORING RT58 B-2

Project Name: ACP HDD - Route 58
Project Number: MV1290
Start Date: 2/17/2017
Finish Date: 2/17/2017

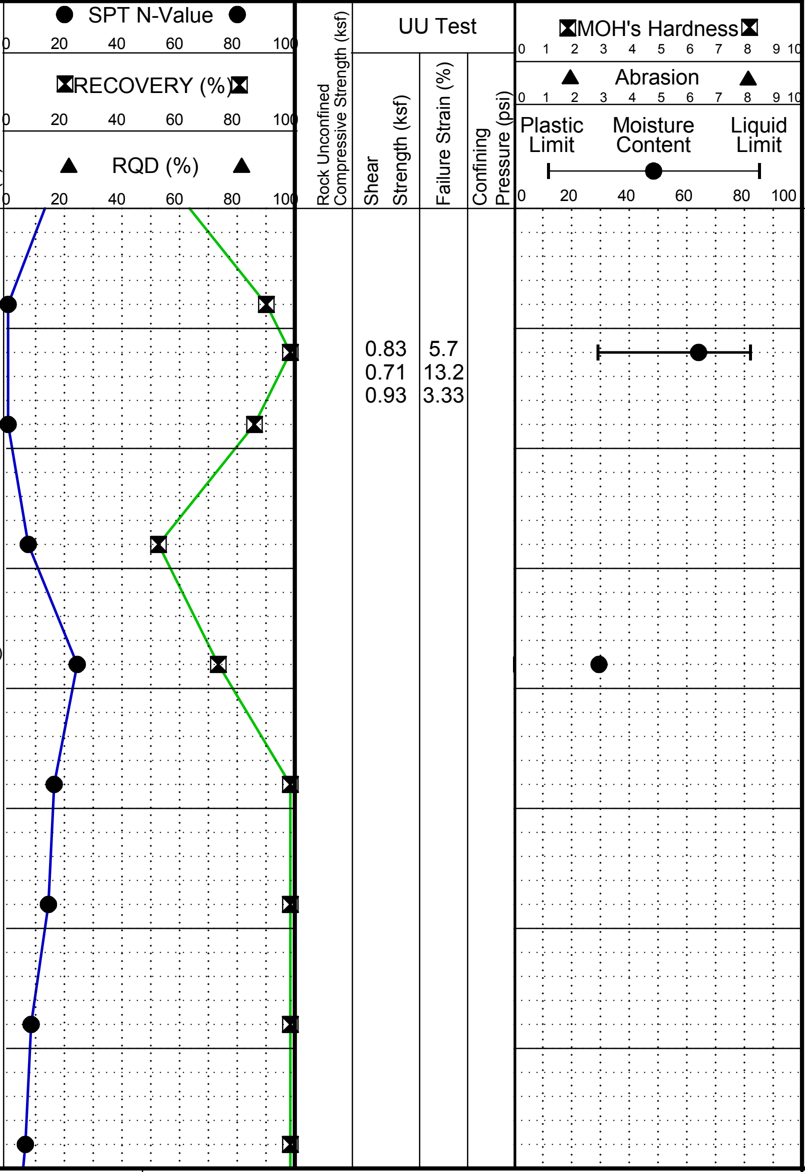
Drilling Contractor: Fishburne Drilling
Drilling Rig: CME 55
Drilling Method: HSA + NQ
Drilling Mud: Bentonite

LOCATION:
RT58 B-2

Northing: 13382063.8 Easting: 2968618.37
Surface Elevation: 25.3 MSL-feet
Datum: UTM Zone 17S, NAD83
Vertical Datum: WGS84-MSL

Elevation (ft.)	Depth (ft.)
-20	45
-25	50
-30	55
-35	60
-40	65
-45	70
-50	75

Sample Number	USCS	MATERIAL DESCRIPTION	SPT (blows per 6 inches) N-value (x)	UU Test Shear Strength (ksf)	UU Test Failure Strain (%)	MOISTURE CONTENT (%)	LIQUID LIMIT LL	PLASTIC LIMIT PL	PLASTICITY INDEX PI	PASSING #200 SIEVE (%)
	SM									
12		Soft, Dark Brown Gray, Saturated, ORGANIC CLAY With Sand (OH), Sand Size Is Fine	2-1-1-1 (2)							
SH-2	OH			0.83 0.71 0.93	5.7 13.2 3.33	64	82	29	53	76.2
13		Very Loose, Gray, Saturated, SILTY SAND (SM), Fine To Medium, With Shell Fragments	1-1-1-3 (2)							
14		SAA, Medium Dense	7-6-3-6 (9)							
15		SAA, Dense, Saturated	8-11-15-15 (26)			29.4	NP	NP	NP	17.9
16	SM	SAA, Medium Dense	4-9-9-13 (18)							
17		SAA, With Shell Fragments	6-8-8-8 (16)							
18		SAA, With Some Larger Shell Fragments	4-4-6-12 (10)							
19		SAA, Sand Size Becomes Finer	3-3-5-8 (8)							



Water Level Est.: ▽ Measured: ▼ Perched: ▼
Water Observations:

Sample Key: ☒ SPT ■ Shelby Tube ▯ California Sampler ▯ Rock Core

Key to Abbreviations:
SPT - Standard Penetration Test
N - SPT Data (Blows/Ft)

Notes:
Automatic 140-lb hammer (Average ETR = 86.3%)

Logged by: K.Warwick

Geosyntec consultants

9211 Arboretum Parkway, Suite 200
Richmond, VA 23236
Office: (804) 767-2206
Fax: (804) 767-2182

LOG OF BORING RT58 B-2

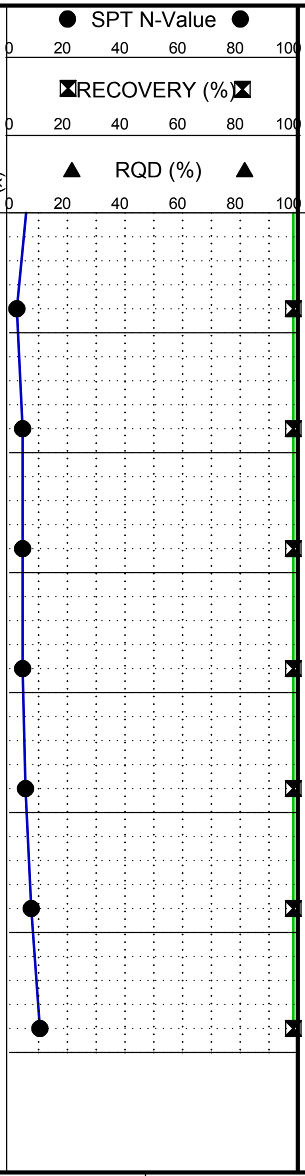
Project Name: ACP HDD - Route 58
Project Number: MV1290
Start Date: 2/17/2017
Finish Date: 2/17/2017

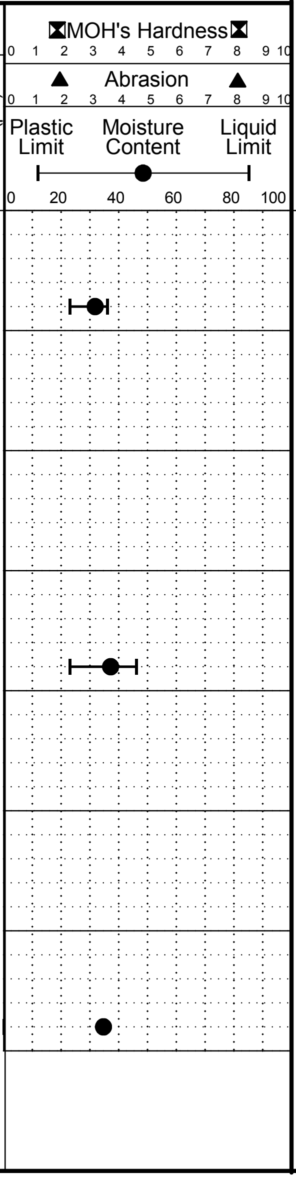
Drilling Contractor: Fishburne Drilling
Drilling Rig: CME 55
Drilling Method: HSA + NQ
Drilling Mud: Bentonite

LOCATION:
RT58 B-2

Northing: 13382063.8 Easting: 2968618.37
Surface Elevation: 25.3 MSL-feet
Datum: UTM Zone 17S, NAD83
Vertical Datum: WGS84-MSL

Elevation (ft.)	Depth (ft.)	Samples	Sample Number	Graphic Log	USCS	MATERIAL DESCRIPTION	SPT (blows per 6 inches) N-value (x)	Rock Unconfined Compressive Strength (ksf)	UU Test Shear Strength (ksf)	UU Test Failure Strain (%)	UU Test Confining Pressure (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LIQUID LIMIT LL	ATTERBERG LIMITS(%) PLASTIC LIMIT PL	ATTERBERG LIMITS(%) PLASTICITY INDEX PI	PASSING #200 SIEVE (%)
					SM											
-60	85	☒	20		SC	Loose, Gray, Saturated, CLAYEY SAND (SC), Fine To Medium	3-2-2-7 (4)					31.7	36	23	13	48
-65	90	☒	21			Loose, Gray, Saturated, SILTY SAND (SM), Fine	3-3-3-5 (6)									
-70	95	☒	22		SM		2-3-3-3 (6)									
-75	100	☒	23		CL	Stiff, Gray, SANDY LEAN CLAY (CL), Saturated	3-3-3-3 (6)					37.1	46	23	23	56.5
-80	105	☒	24			Medium Dense, Gray, Saturated, SILTY SAND (SM), Fine To Medium	3-4-3-6 (7)									
-85	110	☒	25		SM	SAA	3-3-6-7 (9)									
	115	☒	26			SAA, With Shell Fragments	4-5-7-12 (12)					34.6	NP	NP	NP	35.6
						BOREHOLE TERMINATED AT 115 FT BGS										





Water Level Est.: ▽ Measured: ▼ Perched: ▼
Water Observations:

Sample Key: ☒ SPT ■ Shelby Tube ▯ California Sampler ▯ Rock Core

Key to Abbreviations:
SPT - Standard Penetration Test
N - SPT Data (Blows/Ft)

Notes:
Automatic 140-lb hammer (Average ETR = 86.3%)

Logged by: K.Warwick

APPENDIX C

LABORATORY TEST RESULTS

Client:	Geosyntec Consultants				
Project:	I-58 Crossing				
Location:	VA			Project No:	GTX-306079
Boring ID:	---	Sample Type:	---	Tested By:	cam
Sample ID:	---	Test Date:	03/06/17	Checked By:	emm
Depth :	---	Test Id:	405557		

USCS Classification - ASTM D2487

Boring ID	Sample ID	Depth	Group Name	Group Symbol	Gravel, %	Sand, %	Fines, %
RT58 B-1	S-3	4-6	Clayey sand	SC	0.1	52.5	47.4
RT58 B-1	S-6	13-15	Sandy Organic clay	OH	0.0	30.9	69.1
RT58 B-1	Shelby	15-17	Clayey sand	SC	0.0	66.6	33.4
RT58 B-1	S-7	18-20	Clayey sand	SC	0.0	78.8	21.2
RT58 B-1	S-10	33-35	Organic clay	OH	0.0	2.5	97.5
RT58 B-1	S-18	73-75	Silty sand	SM	0.0	68.3	31.7
RT58 B-1	S-24	103-105	Sandy Lean clay	CL	0.0	43.8	56.2

Remarks: Grain Size analysis performed by ASTM D422 results enclosed
Atterberg Limits performed by ASTM D4318, results enclosed

GeoTesting EXPRESS

Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079
Boring ID: ---
Sample Type: ---
Tested By: cam
Sample ID: ---
Test Date: 03/06/17
Checked By: emm
Depth : ---
Test Id: 405563

USCS Classification - ASTM D2487

Boring ID	Sample ID	Depth	Group Name	Group Symbol	Gravel, %	Sand, %	Fines, %
RT58 B-2	S-2	2-4	Sandy Lean clay	CL	0.0	48.4	51.6
RT58 B-2	S-5	8-10	Silty sand	SM	0.0	72.7	27.3
RT58 B-2	Shelby	30-32	Organic clay with sand	OH	0.0	18.8	81.2
RT58 B-2	Shelby	45-47	Organic clay with sand	OH	0.0	23.8	76.2
RT58 B-2	S-15	58-60	Silty sand	SM	0.0	82.1	17.9
RT58 B-2	S-20	83-85	Clayey sand	SC	0.0	55.0	45.0
RT58 B-2	S-23	98-100	Sandy Lean clay	CL	0.0	43.5	56.5
RT58 B-2	S-26	113-115	Silty sand	SM	0.0	64.4	35.6

Remarks: Grain Size analysis performed by ASTM D422 results enclosed
Atterberg Limits performed by ASTM D4318, results enclosed

Client:	Geosyntec Consultants				
Project:	I-58 Crossing				
Location:	VA			Project No:	GTX-306079
Boring ID:	---	Sample Type:	---	Tested By:	jbr
Sample ID:	---	Test Date:	03/01/17	Checked By:	emm
Depth :	---	Test Id:	405526		

Moisture Content of Soil and Rock - ASTM D2216

Boring ID	Sample ID	Depth	Description	Moisture Content, %
RT58 B-1	S- 3	4-6	Moist, very dark brown clayey sand	31.9
RT58 B-1	S- 6	13-15	Moist, olive sandy organic clay	59.9
RT58 B-1	S- 7	18-20	Moist, olive clayey sand	36.7
RT58 B-1	S- 10	33-35	Wet, olive organic clay	80.7
RT58 B-1	S- 12	43-45	Moist, dark gray sand with silt	22.1
RT58 B-1	S- 18	73-75	Moist, olive silty sand	36.4
RT58 B-1	S- 24	103-105	Moist, dark gray sandy clay	36.0

Notes: Temperature of Drying : 110° Celsius

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Client:	Geosyntec Consultants				
Project:	I-58 Crossing				
Location:	VA			Project No:	GTX-306079
Boring ID:	---	Sample Type:	---	Tested By:	jbr
Sample ID:	---	Test Date:	03/01/17	Checked By:	emm
Depth :	---	Test Id:	405533		

Moisture Content of Soil and Rock - ASTM D2216

Boring ID	Sample ID	Depth	Description	Moisture Content, %
RT58 B-2	S- 2	2-4	Moist, grayish brown sandy clay	20.9
RT58 B-2	S- 5	8-10	Moist, olive silty sand	35.4
RT58 B-2	S- 6	13-15	Moist, olive silty sand	30.6
RT58 B-2	S- 15	58-60	Moist, olive silty sand	29.4
RT58 B-2	S- 20	83-85	Moist, dark gray clayey sand	31.7
RT58 B-2	S- 23	98-100	Moist, olive sandy clay	37.1
RT58 B-2	S- 26	113-115	Moist, olive silty sand	34.6

Notes: Temperature of Drying : 110° Celsius

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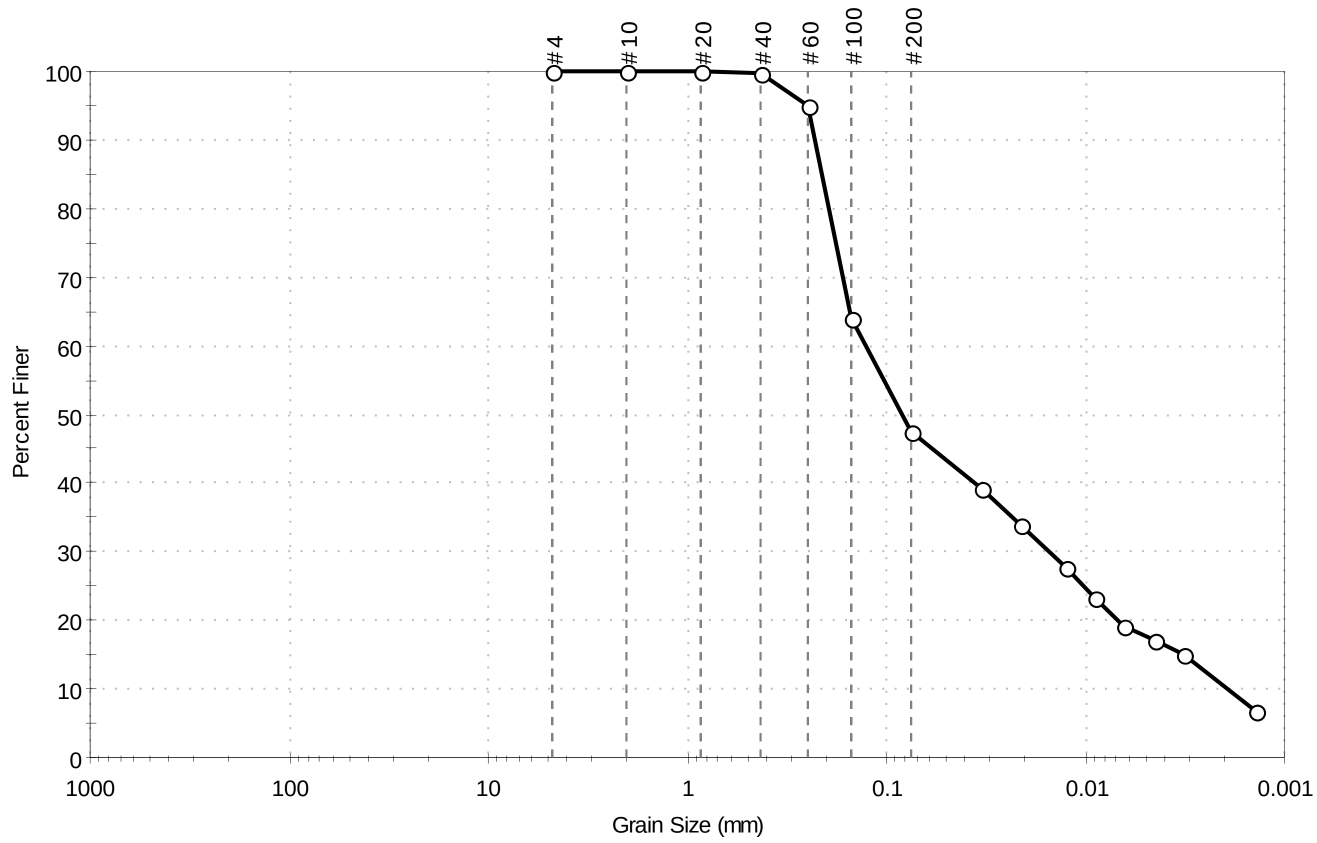
GeoTesting EXPRESS

Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079
Boring ID: RT58 B-1
Sample Type: jar
Tested By: jbr
Sample ID: S-3
Test Date: 03/06/17
Checked By: emm
Depth : 4-6
Test Id: 405567
Test Comment: ---
Visual Description: Moist, very dark brown clayey sand
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.1	52.5	47.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	95		
#100	0.15	64		
#200	0.075	47		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0330	39		
---	0.0210	34		
---	0.0126	28		
---	0.0091	23		
---	0.0064	19		
---	0.0045	17		
---	0.0032	15		
---	0.0014	7		

Coefficients

D_{85} =0.2119 mm
D_{30} =0.0153 mm
D_{60} =0.1267 mm
D_{15} =0.0033 mm
D_{50} =0.0835 mm
D_{10} =0.0019 mm
C_u =66.684
C_c =0.972

Classification

ASTM Clayey sand (SC)

AASHTO Clayey Soils (A-6 (3))

Sample/Test Description

Sand/Gravel Particle Shape : ---
Sand/Gravel Hardness : ---
Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Specific Gravity : 2.65
Separation of Sample: #200 Sieve

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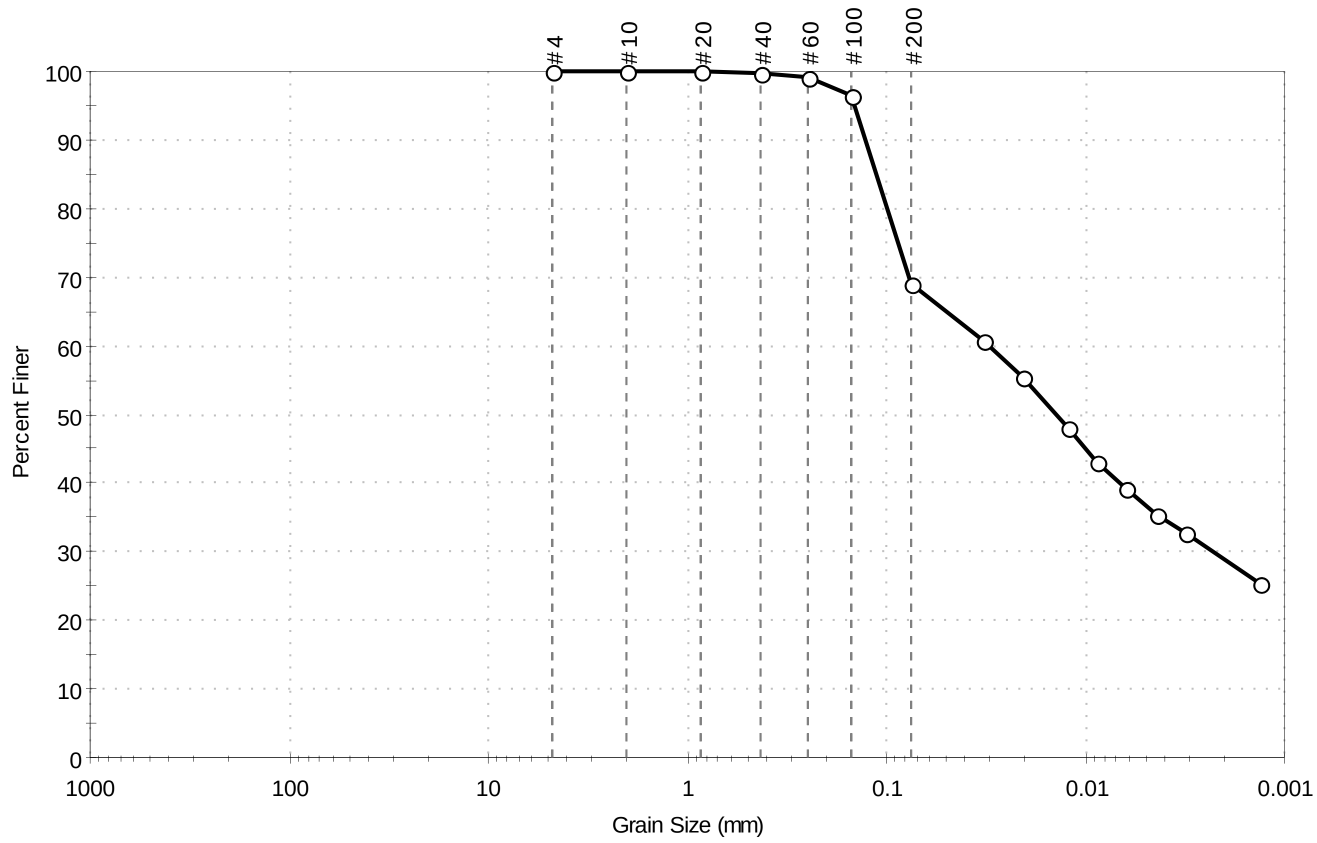
Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079
Boring ID: RT58 B-1
Sample Type: jar
Tested By: jbr
Sample ID: S-6
Test Date: 03/06/17
Checked By: emm
Depth : 13-15
Test Id: 405858
Test Comment: ---
Visual Description: Moist, olive sandy organic clay
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	30.9	69.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	99		
#100	0.15	96		
#200	0.075	69		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0323	61		
---	0.0206	56		
---	0.0123	48		
---	0.0088	43		
---	0.0062	39		
---	0.0044	35		
---	0.0031	33		
---	0.0013	25		

Coefficients

D_{85} =0.1123 mm	D_{30} =0.0023 mm
D_{60} =0.0305 mm	D_{15} =N/A
D_{50} =0.0141 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM	Sandy Organic clay (OH)
AASHTO	Clayey Soils (A-7-6 (26))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Specific Gravity : 2.65

Separation of Sample: #200 Sieve

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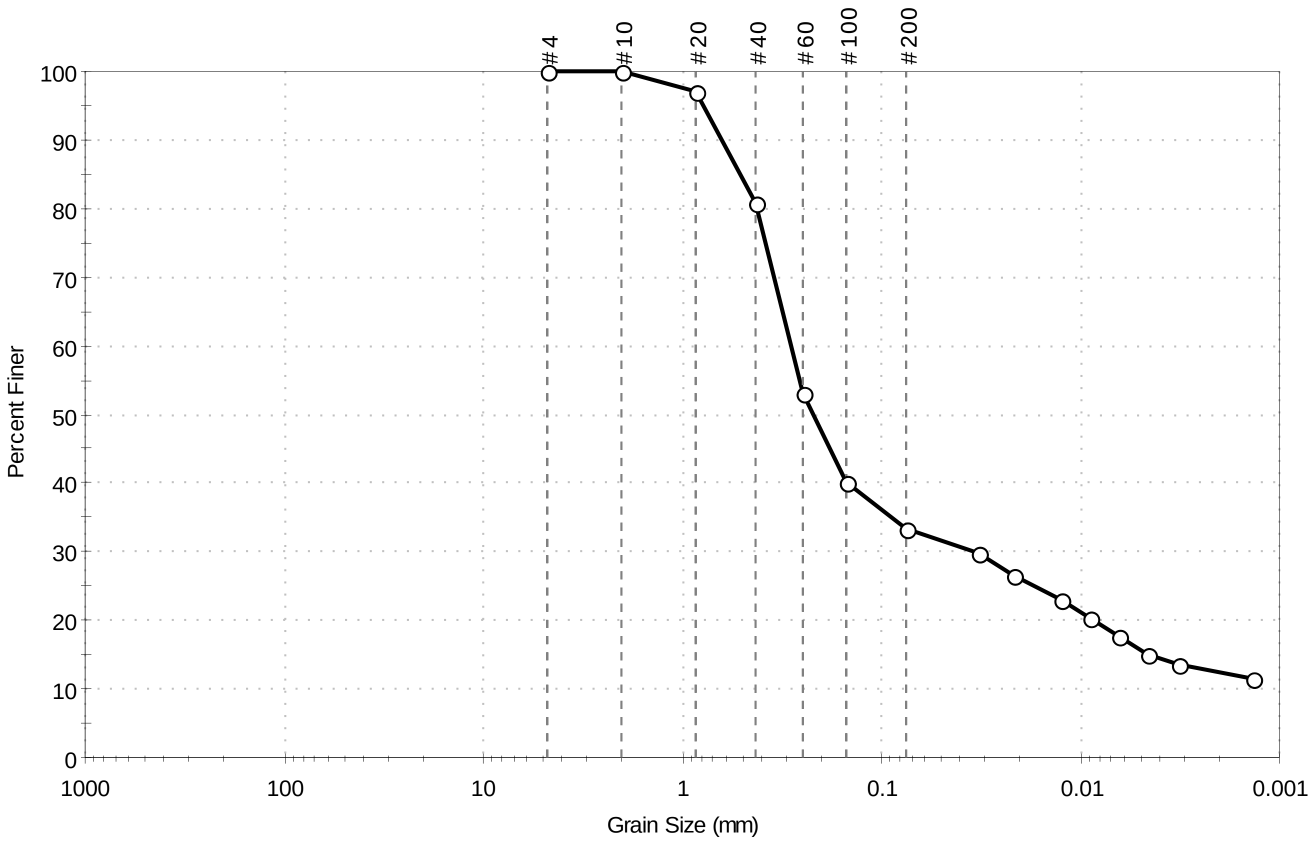
Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079

Boring ID: RT58 B-1
Sample Type: tube
Tested By: jbr
Sample ID: Shelby
Test Date: 03/06/17
Checked By: emm
Depth : 15-17
Test Id: 405564

Test Comment: ---
Visual Description: Wet, olive gray clayey sand
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	66.6	33.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	97		
#40	0.42	81		
#60	0.25	53		
#100	0.15	40		
#200	0.075	33		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0323	30		
---	0.0216	26		
---	0.0124	23		
---	0.0089	20		
---	0.0064	18		
---	0.0046	15		
---	0.0032	14		
---	0.0014	12		

Coefficients

D_{85} = 0.5072 mm
D_{30} = 0.0332 mm
D_{60} = 0.2851 mm
D_{15} = 0.0046 mm
D_{50} = 0.2212 mm
D_{10} = N/A
C_u = N/A
C_c = N/A

Classification

ASTM Clayey sand (SC)

AASHTO Clayey Gravel and Sand (A-2-6 (1))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Specific Gravity : 2.65

Separation of Sample: #200 Sieve

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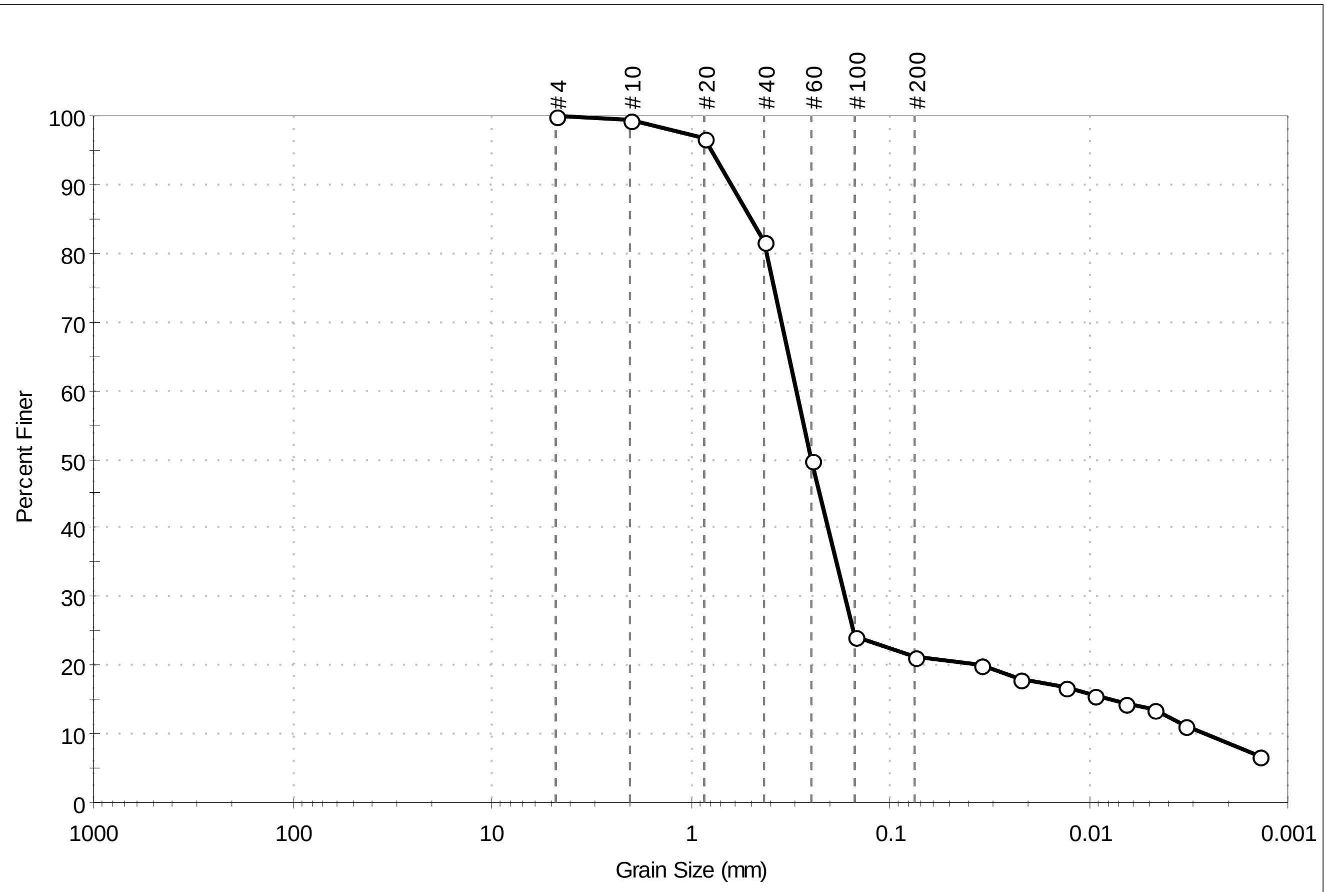
Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079

Boring ID: RT58 B-1
Sample Type: jar
Tested By: jbr
Sample ID: S-7
Test Date: 03/03/17
Checked By: emm
Depth : 18-20
Test Id: 405569

Test Comment: ---
Visual Description: Moist, olive clayey sand
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	78.8	21.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	99		
#20	0.85	97		
#40	0.42	82		
#60	0.25	50		
#100	0.15	24		
#200	0.075	21		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0350	20		
---	0.0224	18		
---	0.0132	17		
---	0.0094	16		
---	0.0066	15		
---	0.0047	13		
---	0.0033	11		
---	0.0014	7		

Coefficients

D_{85} =0.4947 mm
D_{30} =0.1686 mm
D_{60} =0.2965 mm
D_{15} =0.0075 mm
D_{50} =0.2512 mm
D_{10} =0.0026 mm
C_u =114.038
C_c =36.874

Classification

ASTM Clayey sand (SC)

AASHTO Clayey Gravel and Sand (A-2-6 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---
Sand/Gravel Hardness : ---
Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Specific Gravity : 2.65
Separation of Sample: #200 Sieve

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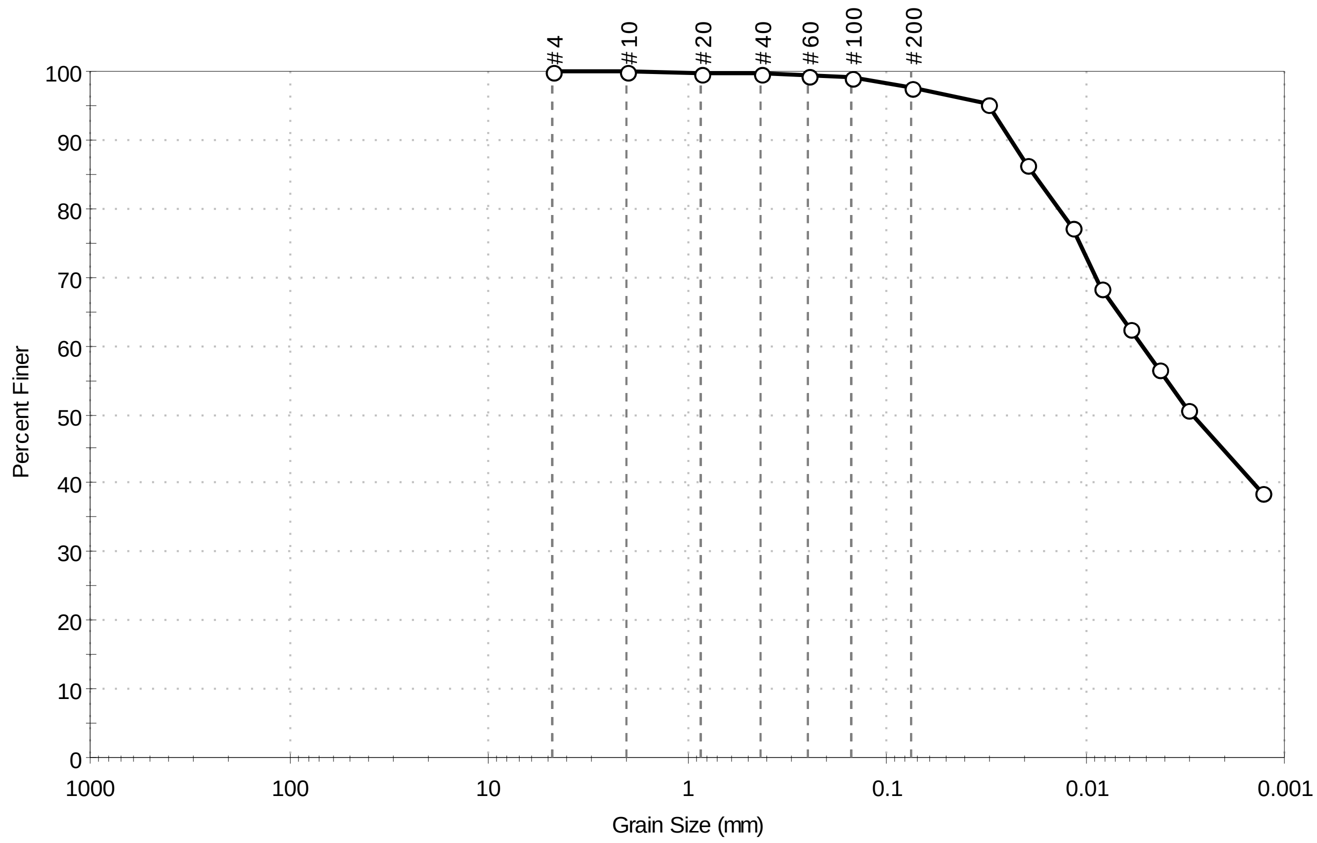
GeoTesting EXPRESS

Client:	Geosyntec Consultants		
Project:	I-58 Crossing		
Location:	VA	Project No:	GTX-306079
Boring ID:	RT58 B-1	Sample Type:	jar
Tested By:	jbr		
Sample ID:	S-10	Test Date:	03/03/17
Checked By:	emm		
Depth :	33-35	Test Id:	405570
Test Comment:	---		
Visual Description:	Wet, olive organic clay		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	2.5	97.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	99		
#100	0.15	99		
#200	0.075	98		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0307	95		
---	0.0197	86		
---	0.0117	77		
---	0.0084	68		
---	0.0060	63		
---	0.0043	57		
---	0.0031	51		
---	0.0013	39		

Coefficients

D_{85} =0.0182 mm
D_{30} =N/A
D_{60} =0.0052 mm
D_{15} =N/A
D_{50} =0.0029 mm
D_{10} =N/A
C_u =N/A
C_c =N/A

Classification

ASTM Organic clay (OH)

AASHTO Clayey Soils (A-7-6 (60))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Specific Gravity : 2.65

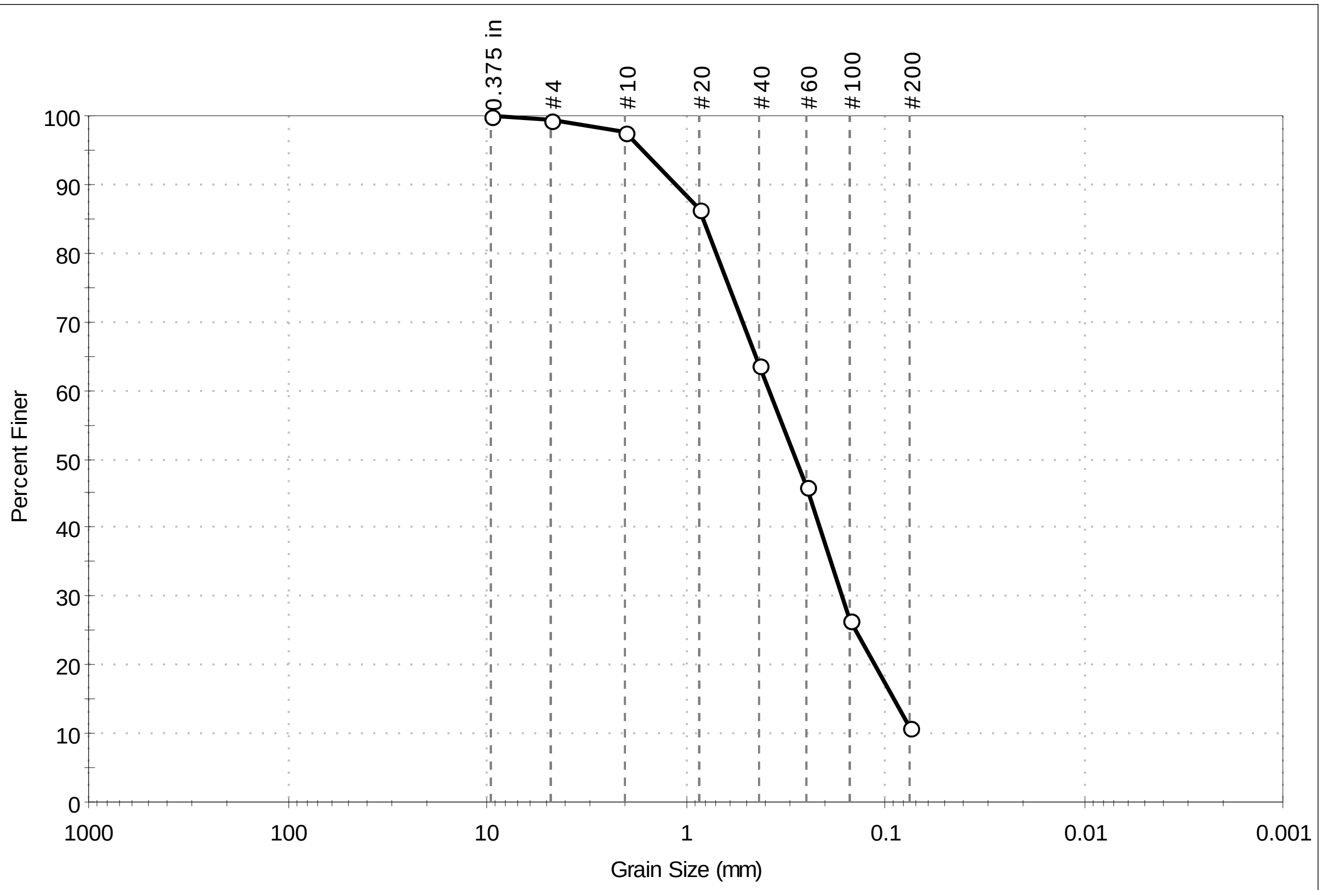
Separation of Sample: #200 Sieve

Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079

Boring ID: RT58 B-1
Sample ID: S-12
Depth : 43-45
Sample Type: jar
Test Date: 03/03/17
Test Id: 405579
Tested By: jbr
Checked By: emm

Test Comment: ---
Visual Description: Moist, dark gray sand with silt
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.5	88.7	10.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	100		
#10	2.00	98		
#20	0.85	86		
#40	0.42	64		
#60	0.25	46		
#100	0.15	26		
#200	0.075	11		

Coefficients

D_{85} =0.8129 mm
D_{30} =0.1645 mm
D_{60} =0.3798 mm
D_{15} =0.0903 mm
D_{50} =0.2811 mm
D_{10} =N/A
C_u =N/A
C_c =N/A

Classification

ASTM N/A

AASHTO Silty Gravel and Sand (A-2-4 (0))

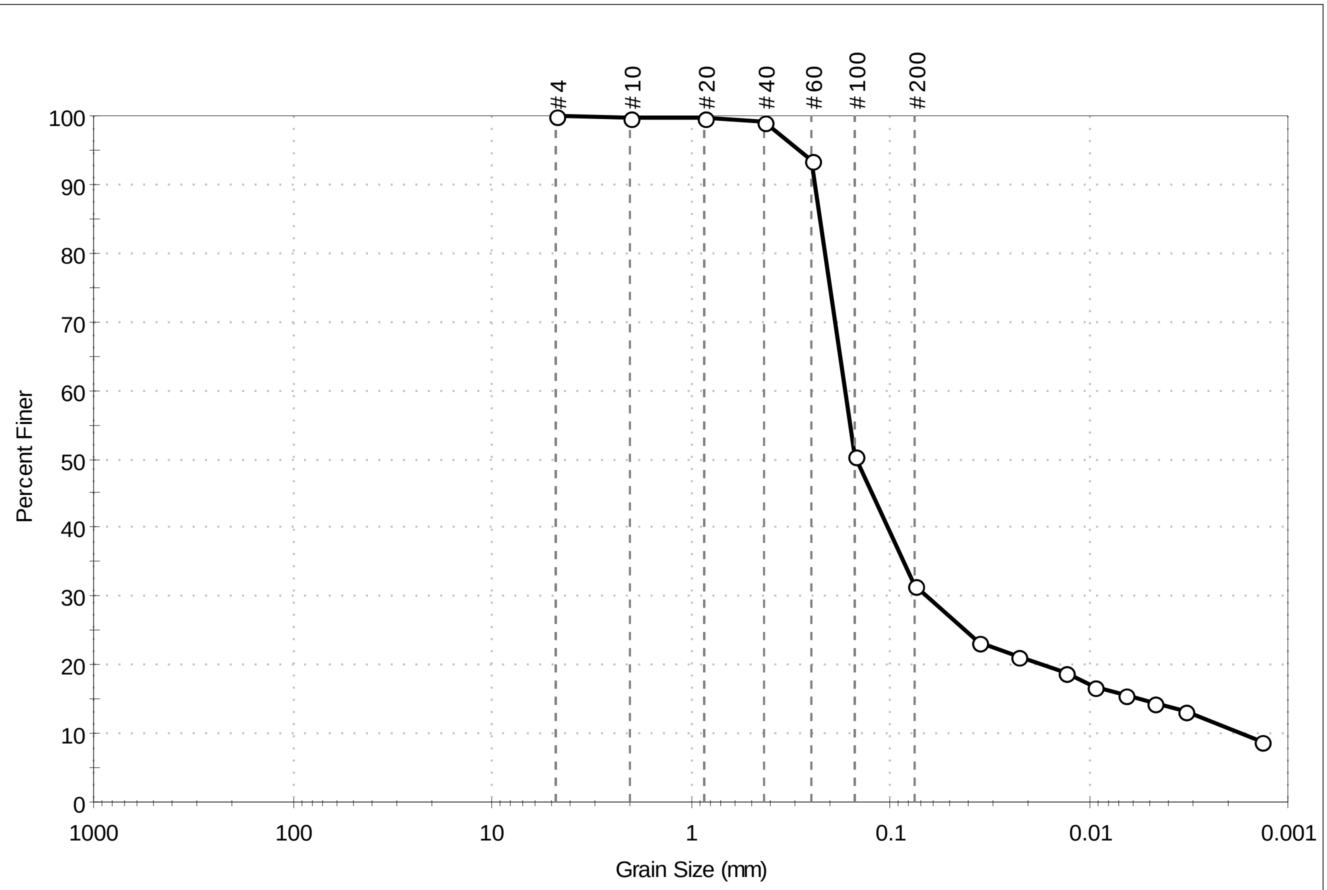
Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Client:	Geosyntec Consultants		
Project:	I-58 Crossing		
Location:	VA	Project No:	GTX-306079
Boring ID: RT58 B-1	Sample Type: jar	Tested By:	jbr
Sample ID: S-18	Test Date: 03/07/17	Checked By:	emm
Depth : 73-75	Test Id: 405991		
Test Comment:	---		
Visual Description:	Moist, olive silty sand		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	68.3	31.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	99		
#60	0.25	93		
#100	0.15	50		
#200	0.075	32		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0357	23		
---	0.0227	21		
---	0.0132	19		
---	0.0094	17		
---	0.0066	16		
---	0.0047	14		
---	0.0033	13		
---	0.0014	9		

Coefficients

D_{85} =0.2261 mm	D_{30} =0.0645 mm
D_{60} =0.1681 mm	D_{15} =0.0055 mm
D_{50} =0.1476 mm	D_{10} =0.0017 mm
C_u =98.882	C_c =14.558

Classification

ASTM	Silty sand (SM)
AASHTO	Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Specific Gravity : 2.65

Separation of Sample: #200 Sieve

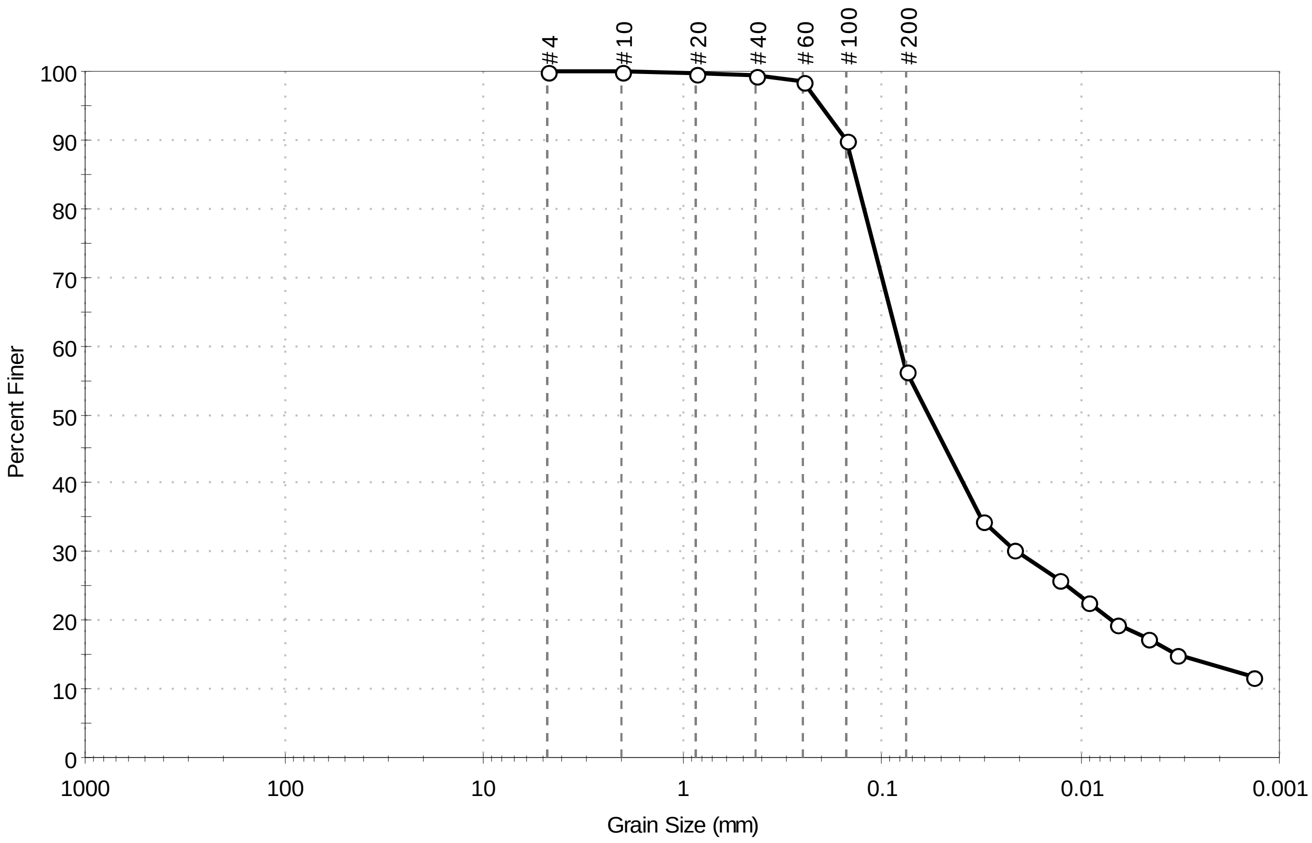
printed 3/7/2017 10:29:32 AM

Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079

Boring ID: RT58 B-1
Sample Type: jar
Tested By: jbr
Sample ID: S-24
Test Date: 03/03/17
Checked By: emm
Depth : 103-105
Test Id: 405572

Test Comment: ---
Visual Description: Moist, dark gray sandy clay
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	43.8	56.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	99		
#60	0.25	99		
#100	0.15	90		
#200	0.075	56		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0314	35		
---	0.0215	30		
---	0.0129	26		
---	0.0092	23		
---	0.0065	19		
---	0.0046	17		
---	0.0033	15		
---	0.0014	12		

Coefficients

D_{85} = 0.1357 mm	D_{30} = 0.0209 mm
D_{60} = 0.0810 mm	D_{15} = 0.0032 mm
D_{50} = 0.0584 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM	Sandy Lean clay (CL)
AASHTO	Clayey Soils (A-7-6 (8))

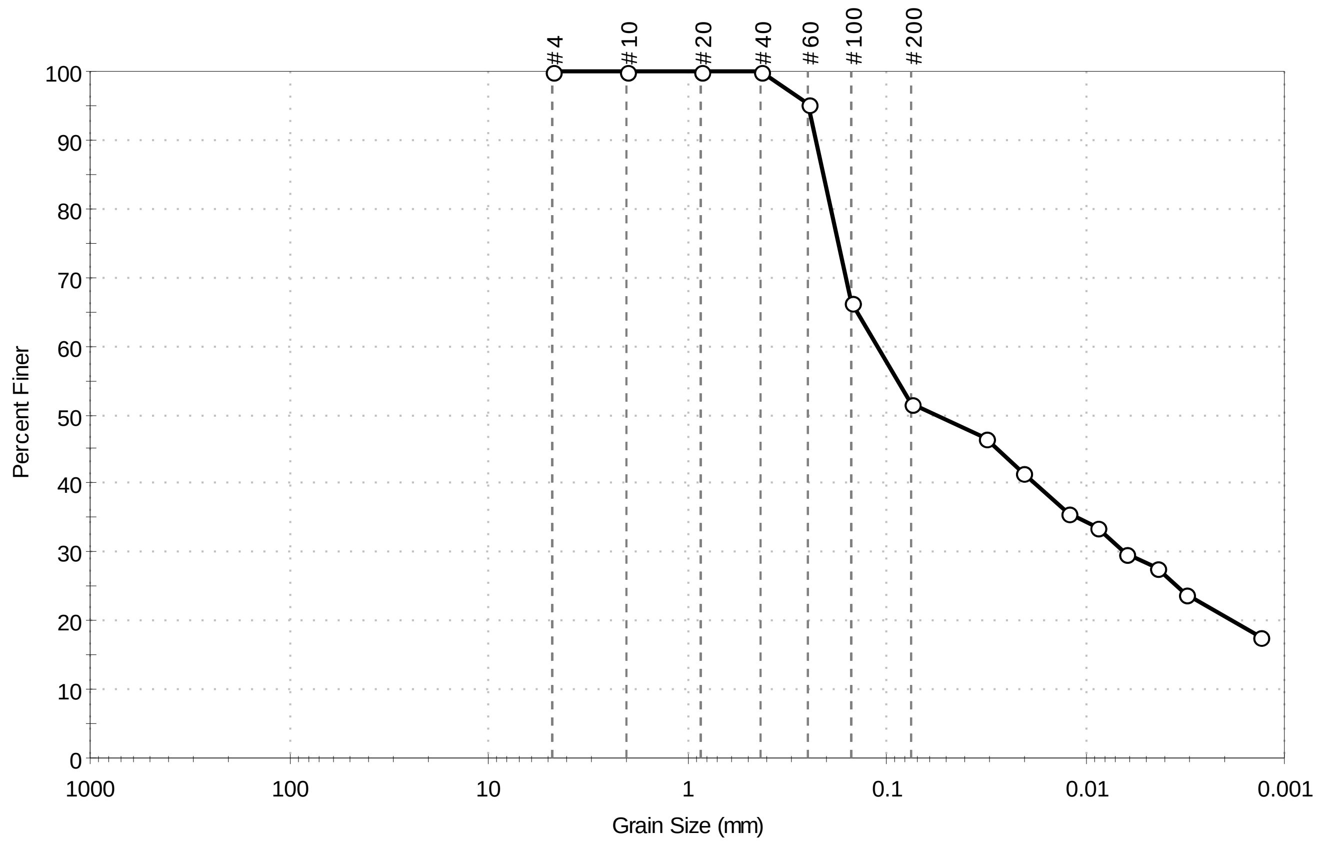
Sample/Test Description

Sand/Gravel Particle Shape : ---
Sand/Gravel Hardness : ---
Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Specific Gravity : 2.65
Separation of Sample: #200 Sieve

printed 3/7/2017 10:29:33 AM

Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079
Boring ID: RT58 B-2
Sample Type: jar
Tested By: jbr
Sample ID: S-2
Test Date: 03/03/17
Checked By: emm
Depth : 2-4
Test Id: 405573
Test Comment: ---
Visual Description: Moist, grayish brown sandy clay
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	48.4	51.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	95		
#100	0.15	66		
#200	0.075	52		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0318	47		
---	0.0209	42		
---	0.0123	36		
---	0.0087	34		
---	0.0062	30		
---	0.0044	28		
---	0.0032	24		
---	0.0013	18		

Coefficients

D_{85} =0.2085 mm
D_{30} =0.0064 mm
D_{60} =0.1113 mm
D_{15} =N/A
D_{50} =0.0567 mm
D_{10} =N/A
C_u =N/A
C_c =N/A

Classification

ASTM Sandy Lean clay (CL)

AASHTO Clayey Soils (A-6 (3))

Sample/Test Description

Sand/Gravel Particle Shape : ---
Sand/Gravel Hardness : ---
Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Specific Gravity : 2.65
Separation of Sample: #200 Sieve

printed 3/7/2017 10:29:34 AM

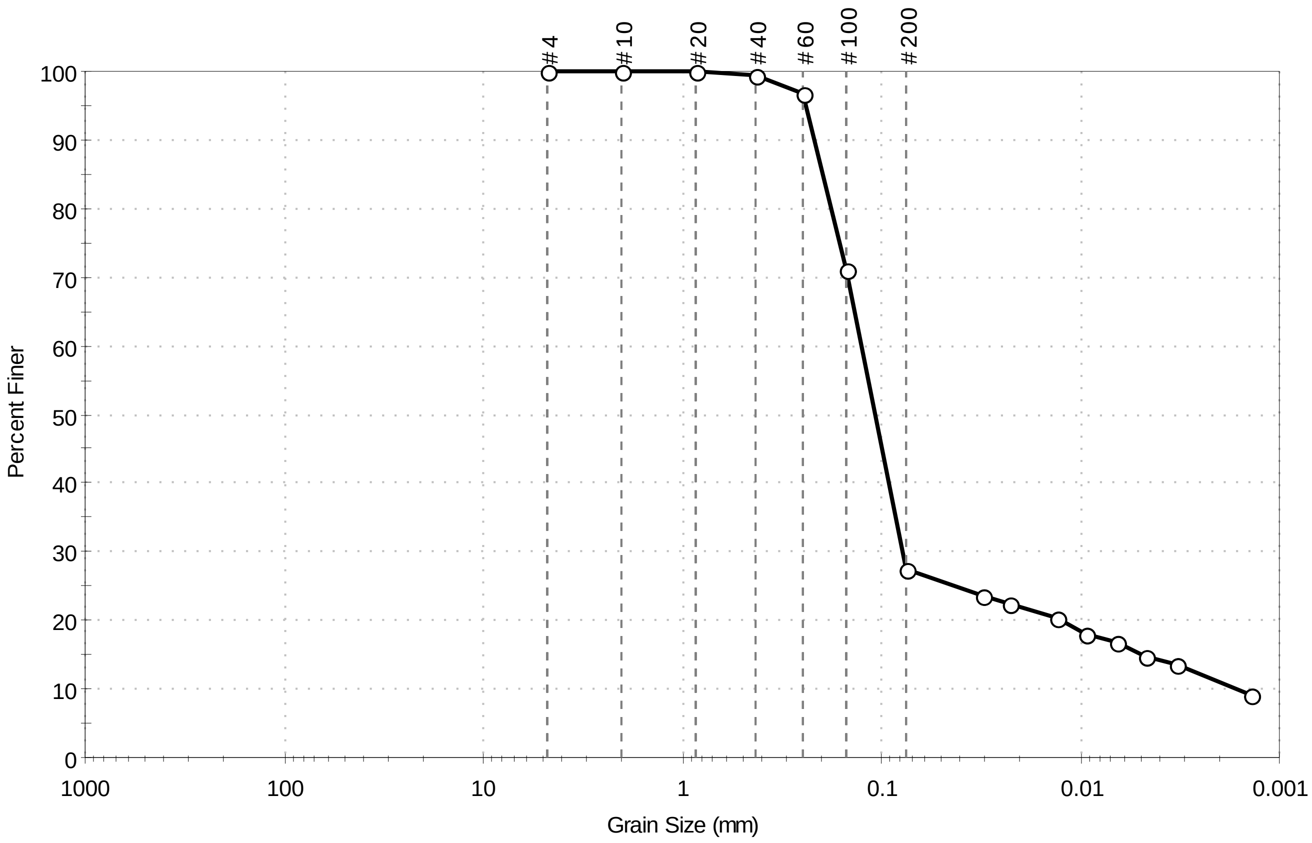
GeoTesting EXPRESS

Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079

Boring ID: RT58 B-2
Sample Type: jar
Tested By: jbr
Sample ID: S-5
Test Date: 03/06/17
Checked By: emm
Depth : 8-10
Test Id: 405574

Test Comment: ---
Visual Description: Moist, olive silty sand
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	72.7	27.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	99		
#60	0.25	97		
#100	0.15	71		
#200	0.075	27		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0310	24		
---	0.0229	23		
---	0.0130	20		
---	0.0093	18		
---	0.0066	17		
---	0.0047	15		
---	0.0033	14		
---	0.0014	9		

Coefficients

D_{85} = 0.1980 mm	D_{30} = 0.0783 mm
D_{60} = 0.1259 mm	D_{15} = 0.0050 mm
D_{50} = 0.1075 mm	D_{10} = 0.0017 mm
C_u = 74.059	C_c = 28.645

Classification

ASTM	Silty sand (SM)
AASHTO	Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Specific Gravity : 2.65

Separation of Sample: #200 Sieve

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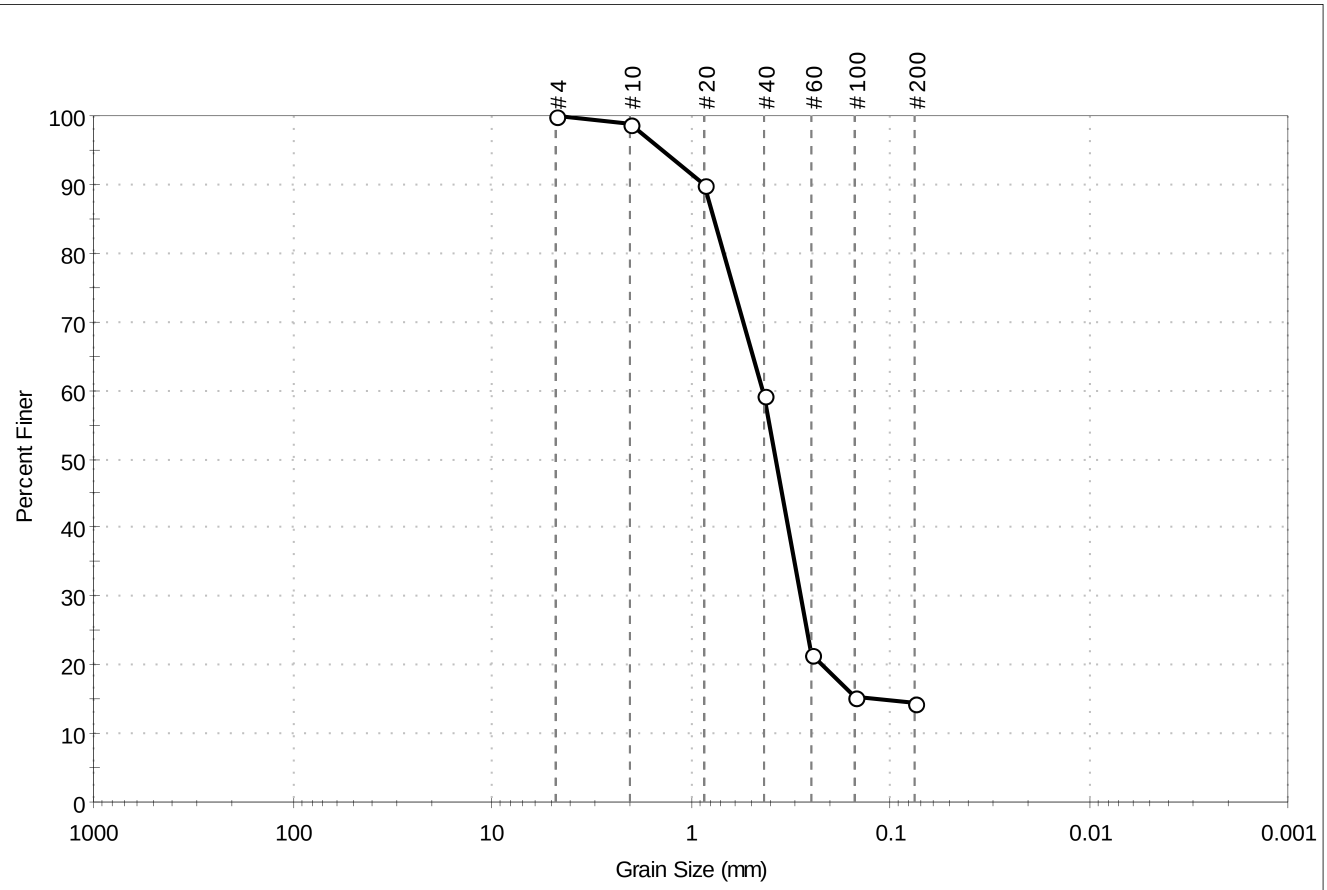
Client:	Geosyntec Consultants				
Project:	I-58 Crossing				
Location:	VA			Project No:	GTX-306079
Boring ID:	RT58 B-2	Sample Type:	jar	Tested By:	jbr
Sample ID:	S-6	Test Date:	03/03/17	Checked By:	emm
Depth :	13-15	Test Id:	405580		

Test Comment: ---
Visual Description: Moist, olive silty sand
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	85.7	14.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	99		
#20	0.85	90		
#40	0.42	59		
#60	0.25	22		
#100	0.15	15		
#200	0.075	14		

Coefficients

D_{85} =0.7605 mm D_{30} =0.2811 mm
D_{60} =0.4317 mm D_{15} =0.1190 mm
D_{50} =0.3727 mm D_{10} =N/A
C_u =N/A C_c =N/A

Classification

ASTM N/A

AASHTO Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

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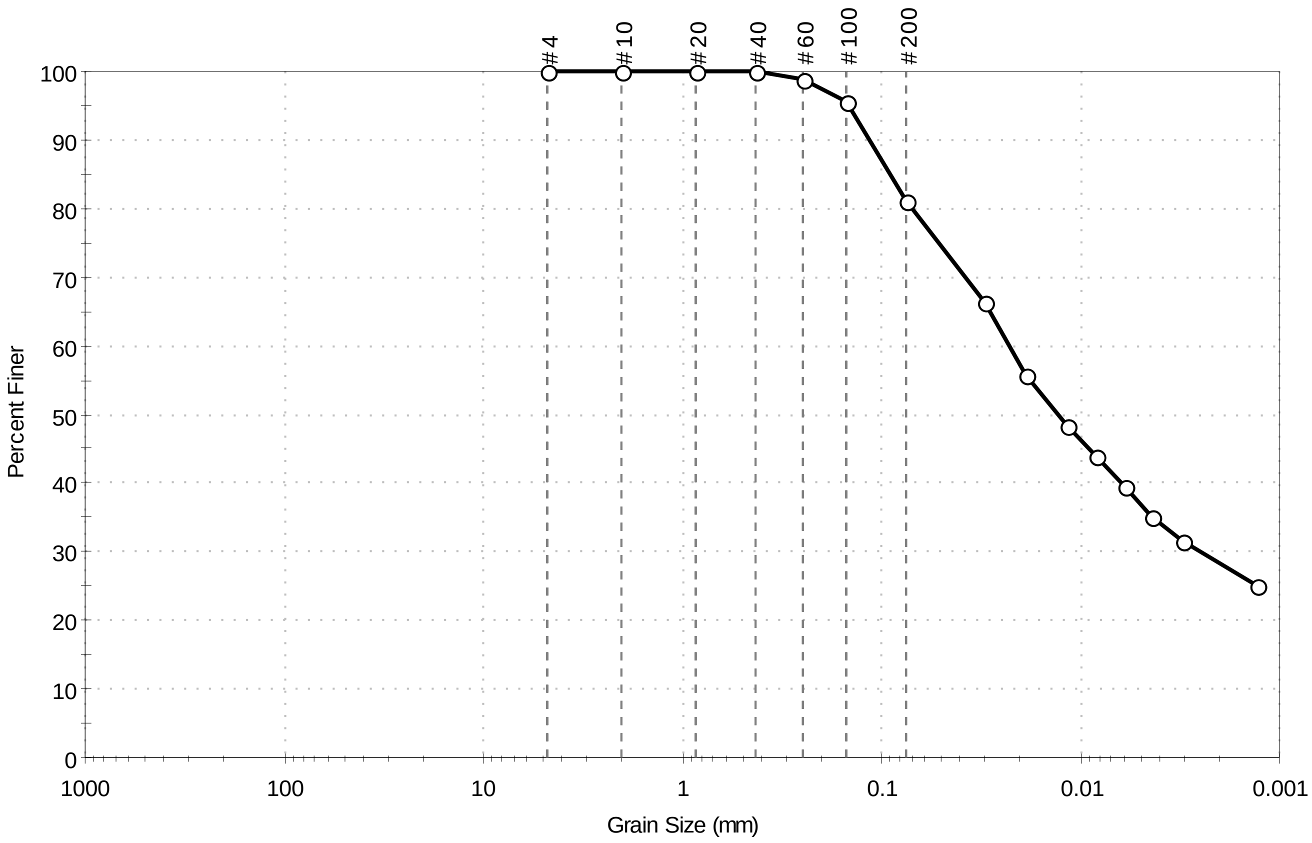
GeoTesting EXPRESS

Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079

Boring ID:	RT58 B-2	Sample Type:	tube	Tested By:	jbr
Sample ID:	Shelby	Test Date:	03/06/17	Checked By:	emm
Depth :	30-32	Test Id:	405565		

Test Comment: ---
Visual Description: Moist, gray organic clay with sand
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	18.8	81.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	99		
#100	0.15	96		
#200	0.075	81		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0307	66		
---	0.0187	56		
---	0.0116	48		
---	0.0084	44		
---	0.0060	40		
---	0.0043	35		
---	0.0031	31		
---	0.0013	25		

Coefficients

D_{85} = 0.0899 mm
D_{30} = 0.0025 mm
D_{60} = 0.0228 mm
D_{15} = N/A
D_{50} = 0.0128 mm
D_{10} = N/A
C_u = N/A
C_c = N/A

Classification

ASTM Organic clay with sand (OH)

AASHTO Clayey Soils (A-7-6 (46))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Specific Gravity : 2.65

Separation of Sample: #200 Sieve

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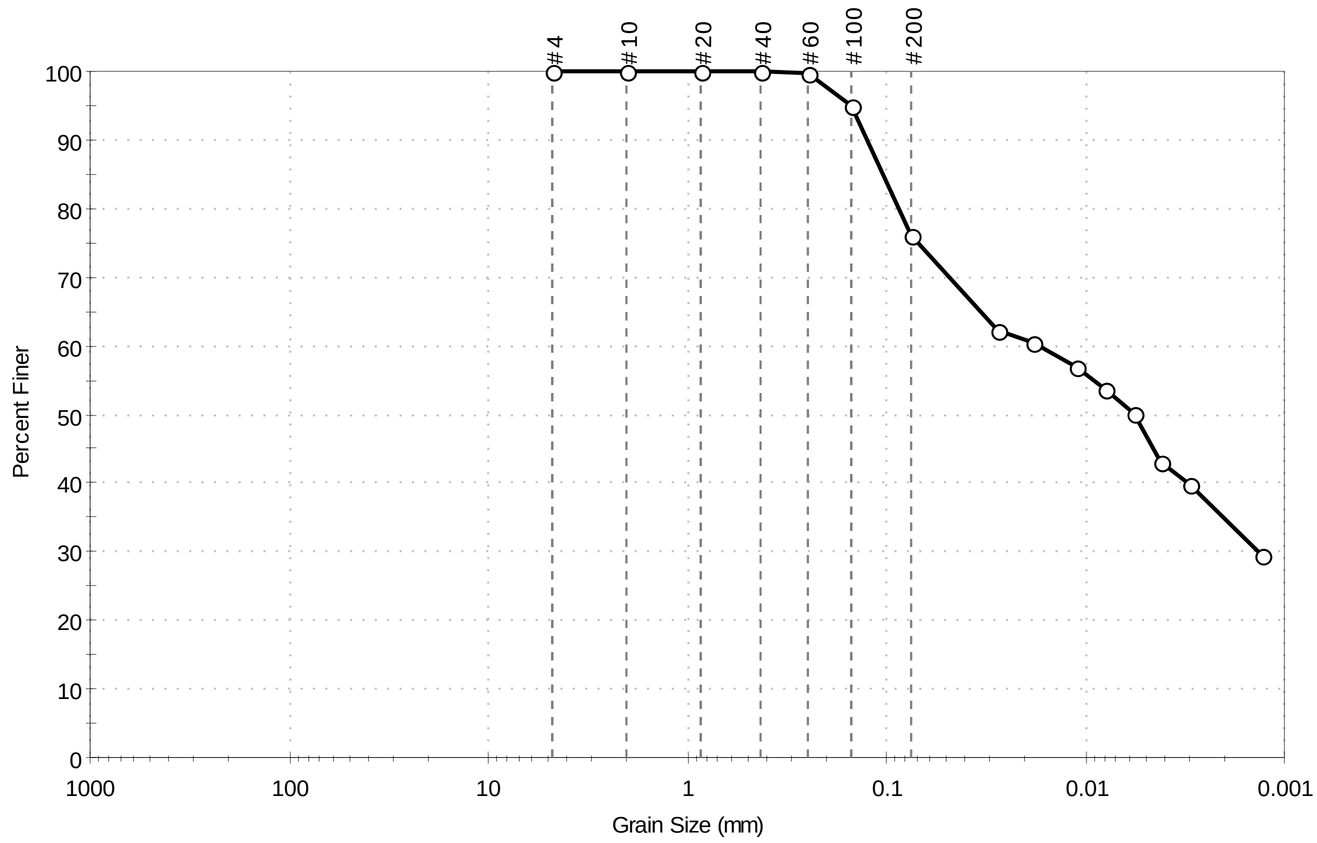
GeoTesting
EXPRESS

Client:	Geosyntec Consultants		
Project:	I-58 Crossing		
Location:	VA	Project No:	GTX-306079

Boring ID:	RT58 B-2	Sample Type:	tube	Tested By:	jbr
Sample ID:	Shelby	Test Date:	03/06/17	Checked By:	emm
Depth :	45-47	Test Id:	405859		

Test Comment: ---
Visual Description: Moist, gray organic clay with sand
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	23.8	76.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	95		
#200	0.075	76		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0276	62		
---	0.0186	60		
---	0.0111	57		
---	0.0080	54		
---	0.0057	50		
---	0.0042	43		
---	0.0030	40		
---	0.0013	29		

Coefficients

D_{85} = 0.1035 mm	D_{30} = 0.0014 mm
D_{60} = 0.0173 mm	D_{15} = N/A
D_{50} = 0.0057 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM	Organic clay with sand (OH)
AASHTO	Clayey Soils (A-7-6 (43))

Sample/Test Description

Sand/Gravel Particle Shape : ---
Sand/Gravel Hardness : ---
Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Specific Gravity : 2.65
Separation of Sample: #200 Sieve

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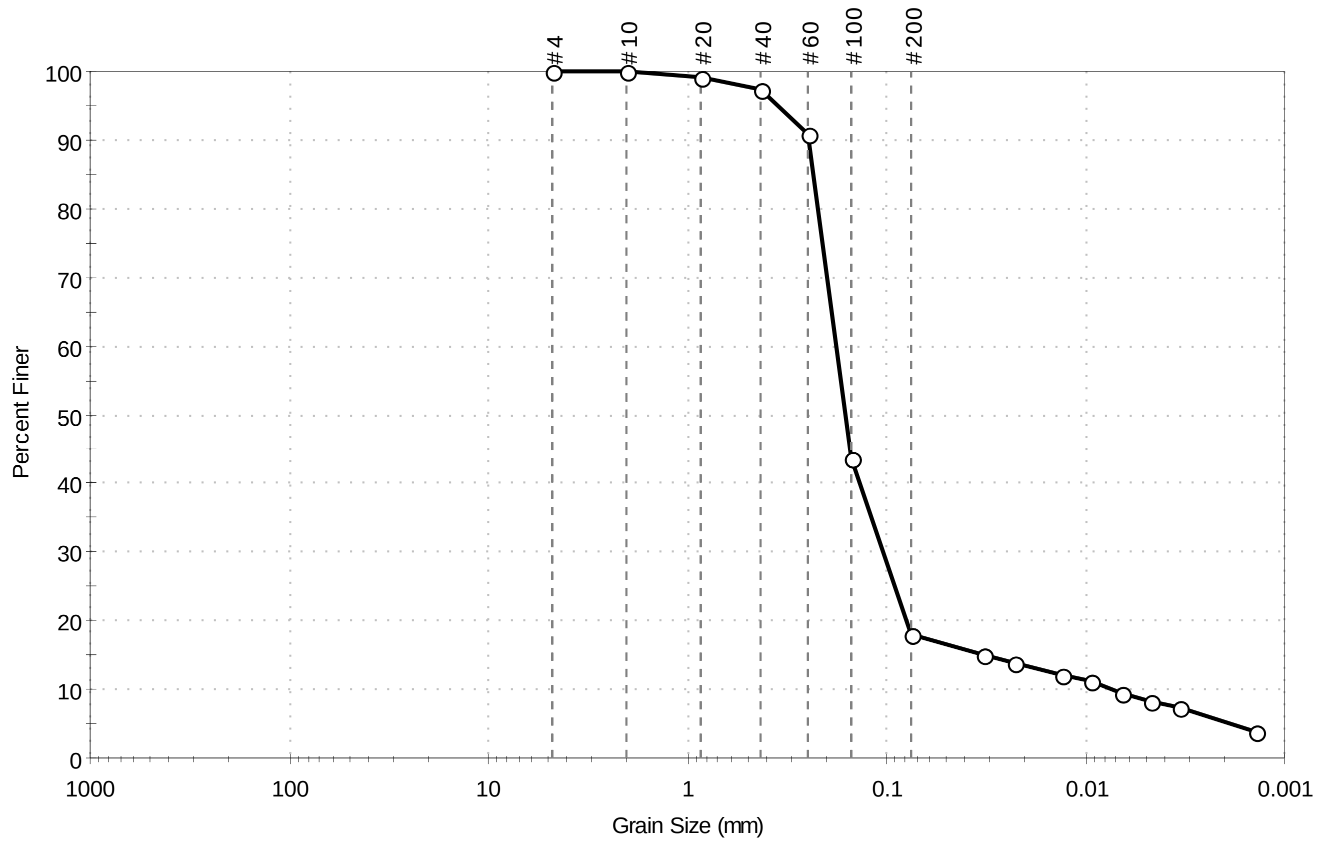
Client:	Geosyntec Consultants		
Project:	I-58 Crossing		
Location:	VA	Project No:	GTX-306079
Boring ID:	RT58 B-2	Sample Type:	jar
Tested By:	jbr		
Sample ID:	S-15	Test Date:	03/06/17
Checked By:	emm		
Depth :	58-60	Test Id:	405575
Test Comment:	---		
Visual Description:	Moist, olive silty sand		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	82.1	17.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	99		
#40	0.42	97		
#60	0.25	91		
#100	0.15	44		
#200	0.075	18		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0329	15		
---	0.0227	14		
---	0.0133	12		
---	0.0094	11		
---	0.0067	9		
---	0.0047	8		
---	0.0033	7		
---	0.0014	4		

Coefficients

D_{85} =0.2347 mm	D_{30} =0.1040 mm
D_{60} =0.1792 mm	D_{15} =0.0334 mm
D_{50} =0.1608 mm	D_{10} =0.0075 mm
C_u =23.893	C_c =8.048

Classification

ASTM	Silty sand (SM)
AASHTO	Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Specific Gravity : 2.65

Separation of Sample: #200 Sieve

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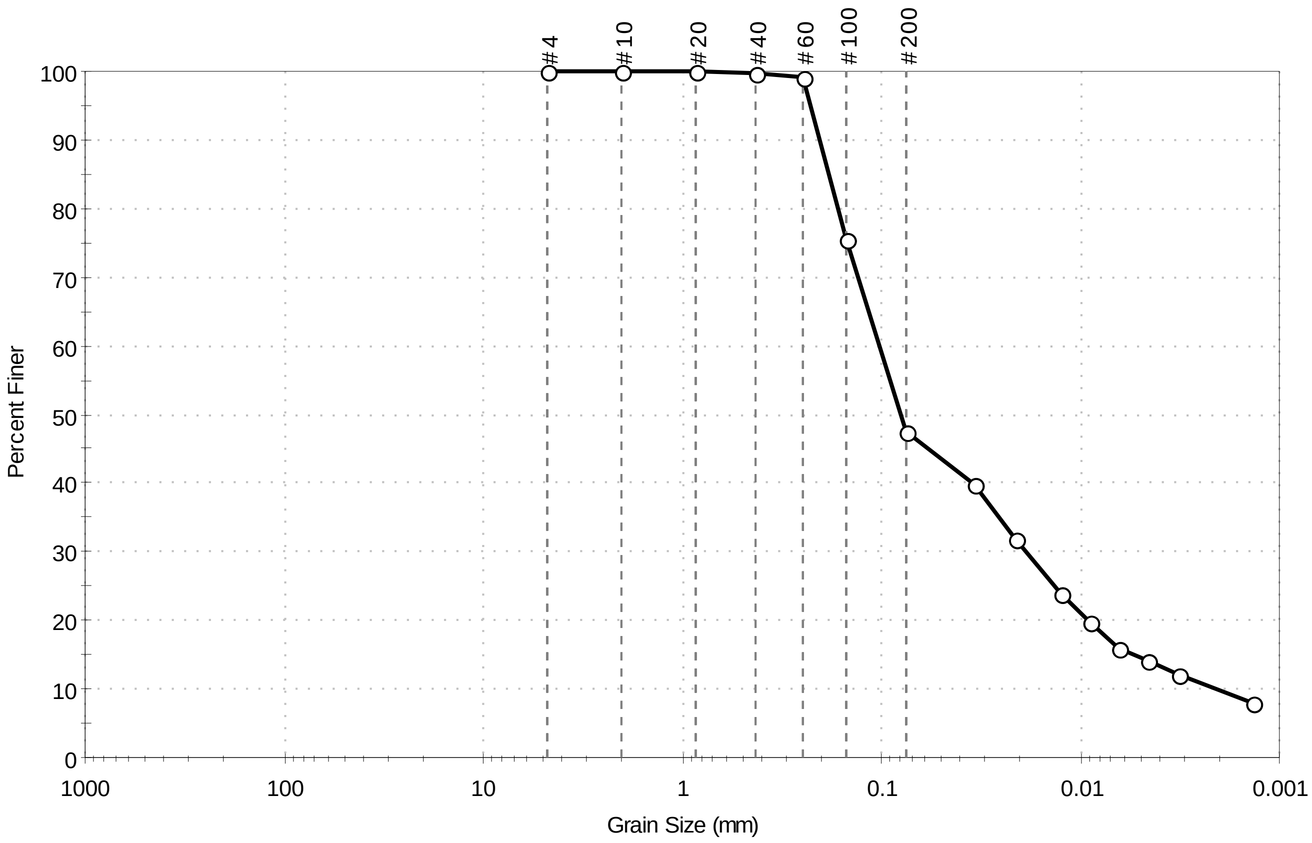
GeoTesting
EXPRESS

Client:	Geosyntec Consultants				
Project:	I-58 Crossing				
Location:	VA			Project No:	GTX-306079
Boring ID:	RT58 B-2	Sample Type:	jar	Tested By:	jbr
Sample ID:	S-20	Test Date:	03/06/17	Checked By:	emm
Depth :	83-85	Test Id:	405576		

Test Comment: ---
Visual Description: Moist, dark gray clayey sand
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	55.0	45.0

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	99		
#100	0.15	75		
#200	0.075	48		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0340	40		
---	0.0212	32		
---	0.0125	24		
---	0.0091	20		
---	0.0065	16		
---	0.0046	14		
---	0.0032	12		
---	0.0014	8		

Coefficients

D_{85} =0.1843 mm	D_{30} =0.0187 mm
D_{60} =0.1022 mm	D_{15} =0.0054 mm
D_{50} =0.0797 mm	D_{10} =0.0021 mm
C_u =48.667	C_c =1.629

Classification

ASTM	Clayey sand (SC)
AASHTO	Clayey Soils (A-6 (3))

Sample/Test Description

Sand/Gravel Particle Shape : ---
Sand/Gravel Hardness : ---
Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Specific Gravity : 2.65
Separation of Sample: #200 Sieve

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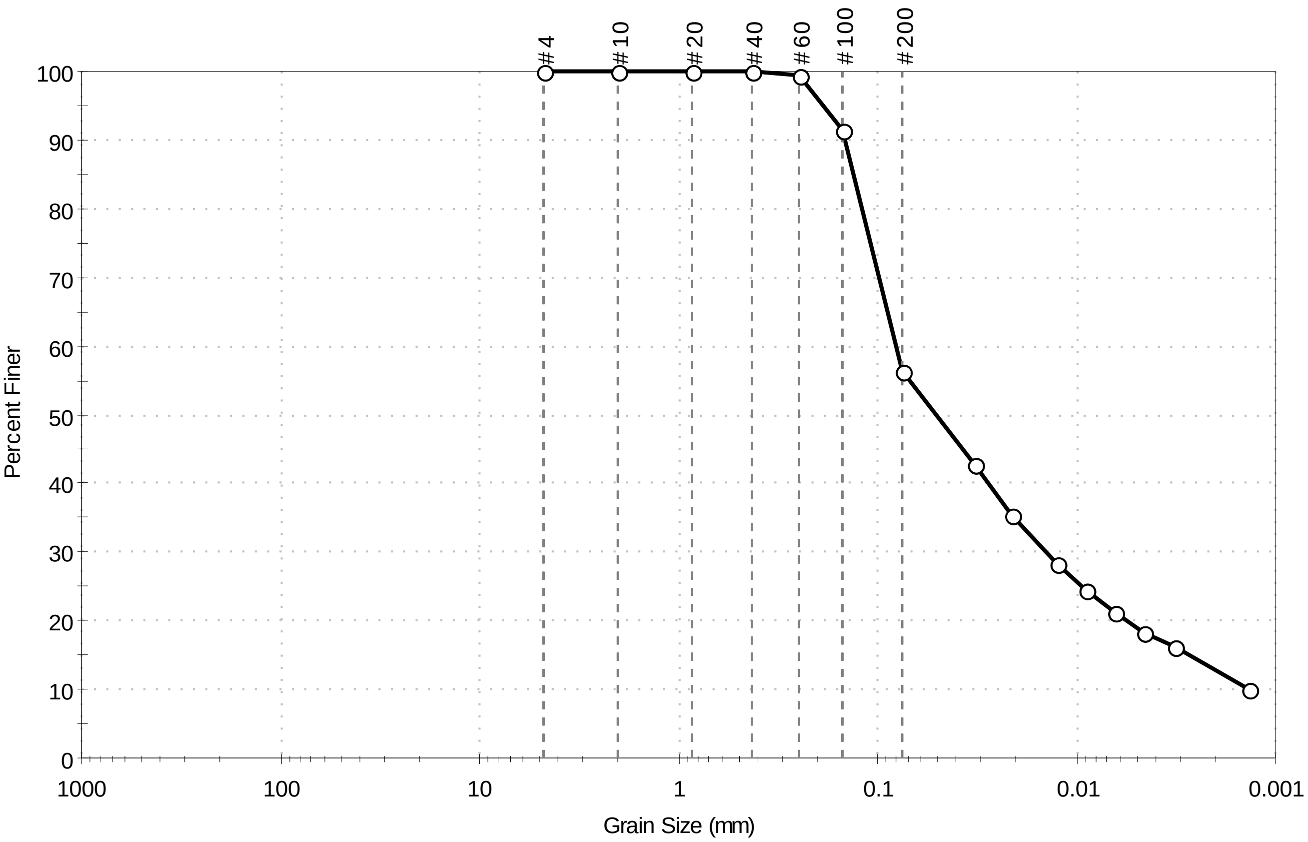
GeoTesting
EXPRESS

Client:	Geosyntec Consultants			
Project:	I-58 Crossing			
Location:	VA		Project No:	GTX-306079
Boring ID:	RT58 B-2	Sample Type: jar	Tested By:	jbr
Sample ID:	S-23	Test Date: 03/06/17	Checked By:	emm
Depth :	98-100	Test Id: 405577		

Test Comment: ---
Visual Description: Moist, olive sandy clay
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	43.5	56.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	91		
#200	0.075	56		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0327	43		
---	0.0214	36		
---	0.0125	28		
---	0.0089	24		
---	0.0064	21		
---	0.0046	18		
---	0.0033	16		
---	0.0014	10		

Coefficients

D_{85} =0.1322 mm	D_{30} =0.0141 mm
D_{60} =0.0804 mm	D_{15} =0.0027 mm
D_{50} =0.0508 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM	Sandy Lean clay (CL)
AASHTO	Clayey Soils (A-7-6 (10))

Sample/Test Description

Sand/Gravel Particle Shape : ---
Sand/Gravel Hardness : ---
Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Specific Gravity : 2.65
Separation of Sample: #200 Sieve

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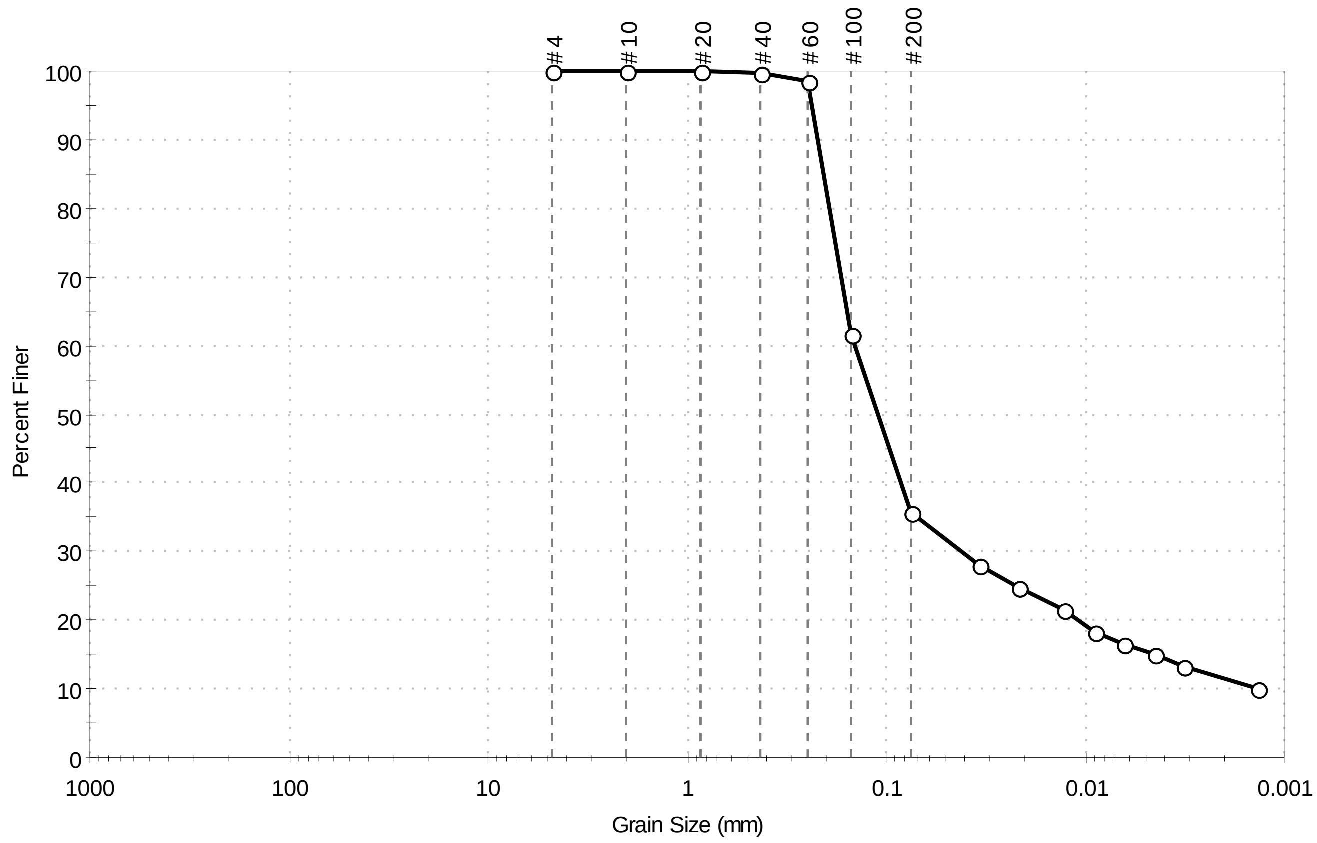
Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079
Boring ID: RT58 B-2
Sample Type: jar
Tested By: jbr
Sample ID: S-26
Test Date: 03/06/17
Checked By: emm
Depth : 113-115
Test Id: 405578
Test Comment: ---
Visual Description: Moist, olive silty sand
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	64.4	35.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	98		
#100	0.15	62		
#200	0.075	36		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0340	28		
---	0.0216	25		
---	0.0127	22		
---	0.0091	18		
---	0.0064	17		
---	0.0045	15		
---	0.0033	13		
---	0.0014	10		

Coefficients

D_{85} = 0.2075 mm
D_{30} = 0.0414 mm
D_{60} = 0.1436 mm
D_{15} = 0.0046 mm
D_{50} = 0.1100 mm
D_{10} = 0.0014 mm
C_u = 102.571
C_c = 8.525

Classification

ASTM Silty sand (SM)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Specific Gravity : 2.65

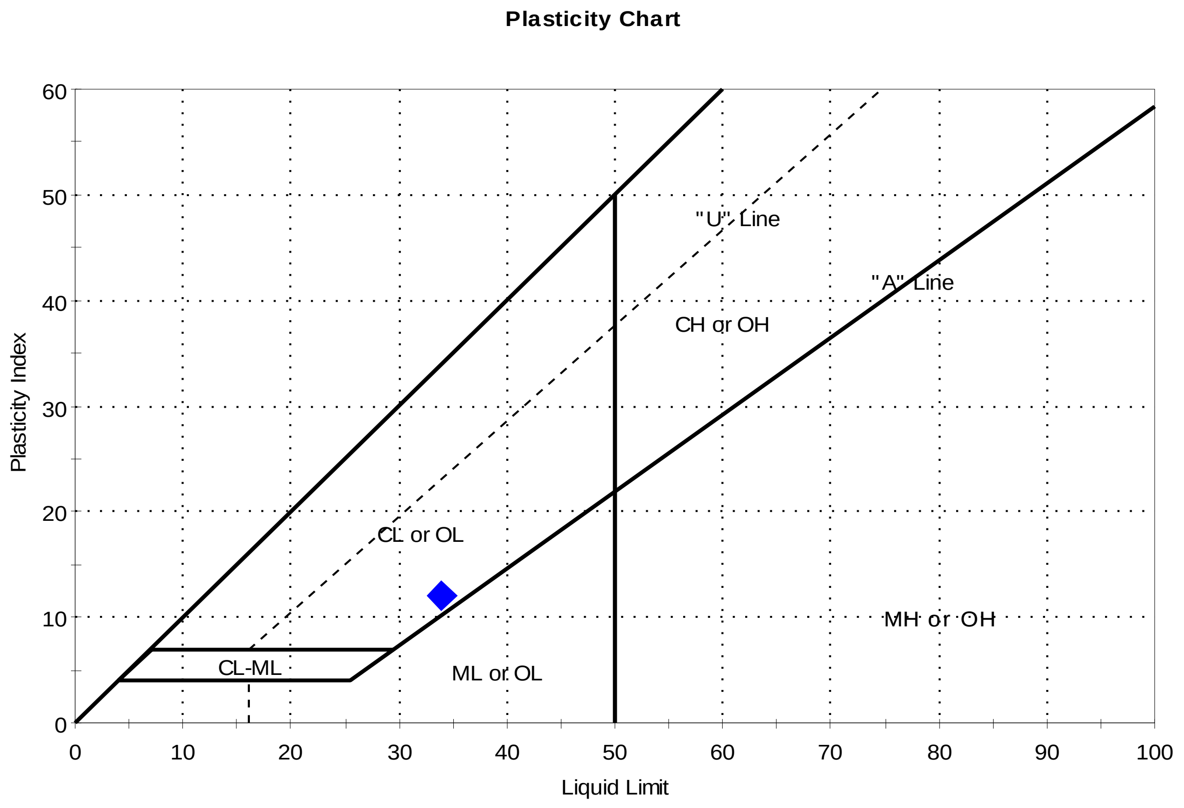
Separation of Sample: #200 Sieve

Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079

Boring ID: RT58 B-1
Sample Type: jar
Tested By: cam
Sample ID: S-3
Test Date: 03/03/17
Checked By: emm
Depth : 4-6
Test Id: 405537

Test Comment: ---
Visual Description: Moist, very dark brown clayey sand
Sample Comment: ---

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-3	RT58 B-1	4-6	32	34	22	12	0.8	Clayey sand (SC)

Sample Prepared using the WET method

0% Retained on #40 Sieve

Dry Strength: VERY HIGH

Dilatancy: SLOW

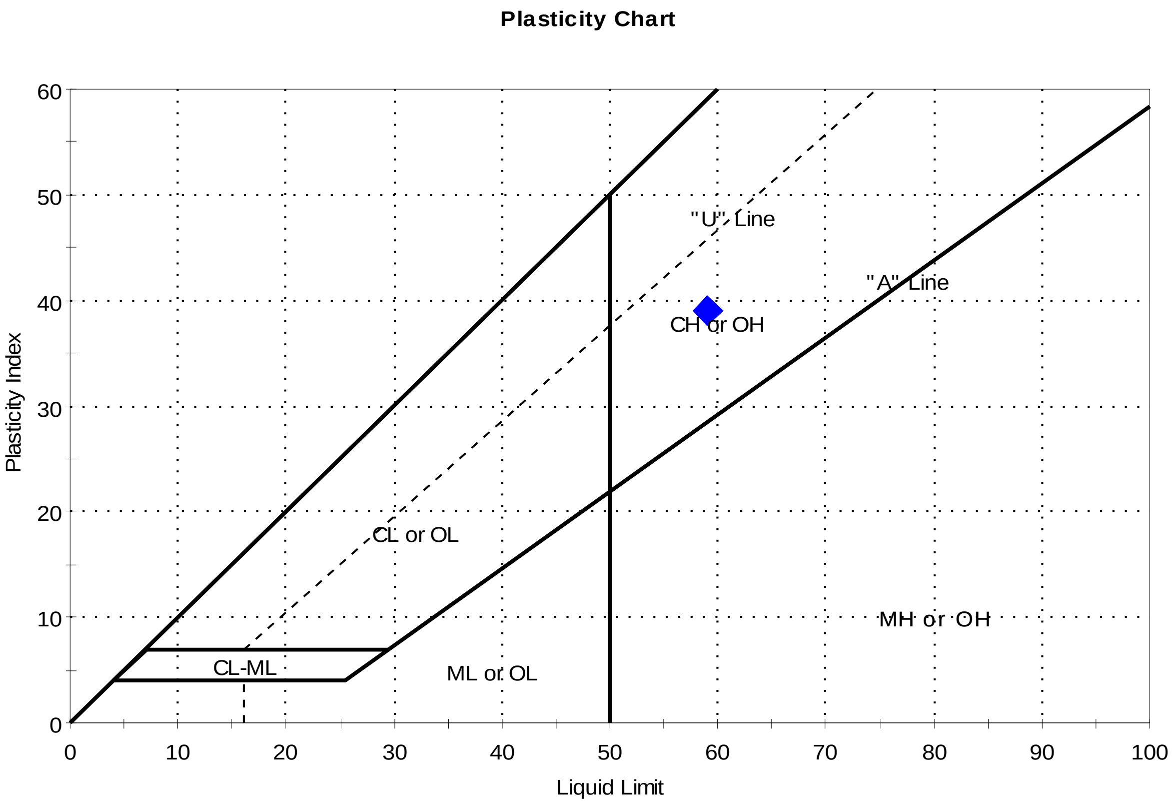
Toughness: LOW

Client:	Geosyntec Consultants		
Project:	I-58 Crossing		
Location:	VA	Project No:	GTX-306079

Boring ID:	RT58 B-1	Sample Type:	jar	Tested By:	cam
Sample ID:	S-6	Test Date:	03/02/17	Checked By:	emm
Depth :	13-15	Test Id:	405538		

Test Comment: ---
Visual Description: Moist, olive sandy organic clay
Sample Comment: ---

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-6	RT58 B-1	13-15	60	59	20	39	1	Sandy Organic clay (OH)

Sample Prepared using the WET method

0% Retained on #40 Sieve

Dry Strength: VERY HIGH

Dilatancy: SLOW

Toughness: LOW

In order to properly describe the soil an Oven Dried Liquid Limit test was performed.
The Oven Dried Liquid Limit was 33

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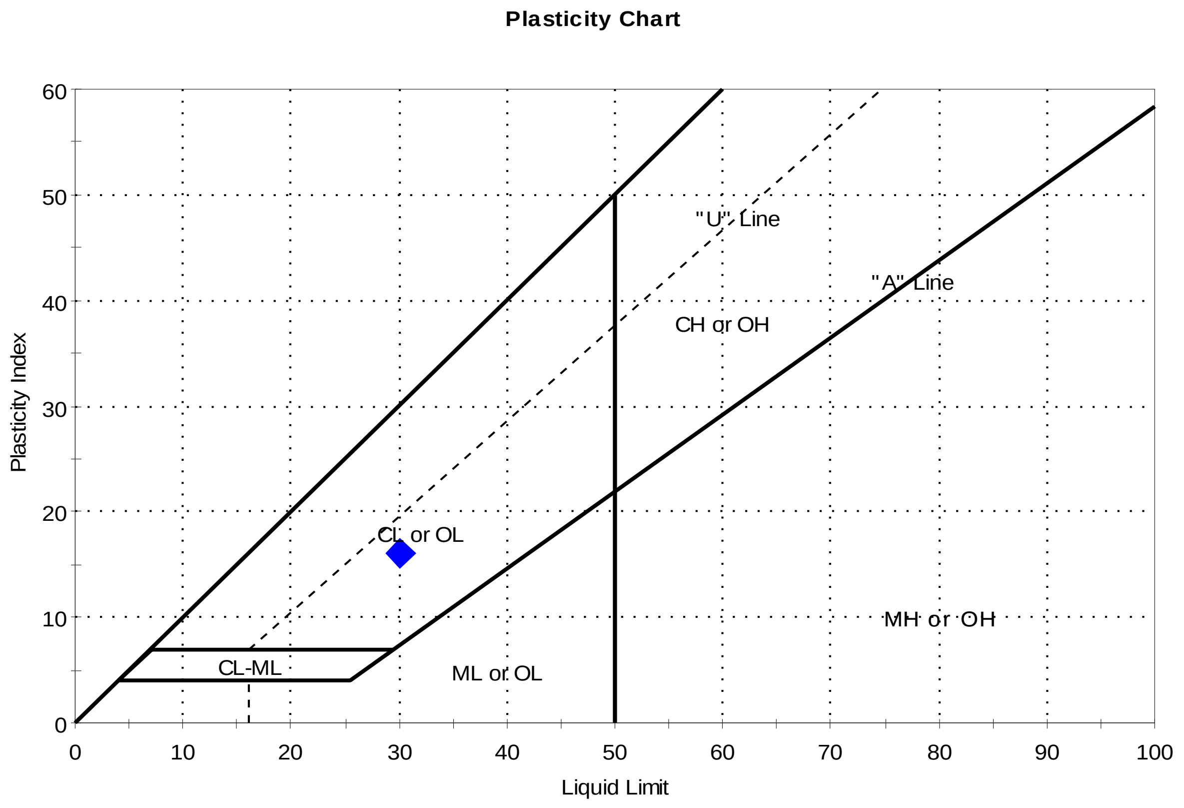
GeoTesting
EXPRESS

Client:	Geosyntec Consultants				
Project:	I-58 Crossing				
Location:	VA			Project No:	GTX-306079
Boring ID:	RT58 B-1	Sample Type:	tube	Tested By:	cam
Sample ID:	Shelby	Test Date:	03/03/17	Checked By:	emm
Depth :	15-17	Test Id:	405534		

Test Comment: ---
Visual Description: Wet, olive gray clayey sand
Sample Comment: ---

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	Shelby	RT58 B-1	15-17	40	30	14	16	1.6	Clayey sand (SC)

Sample Prepared using the WET method

19% Retained on #40 Sieve

Dry Strength: HIGH

Dilatancy: SLOW

Toughness: LOW

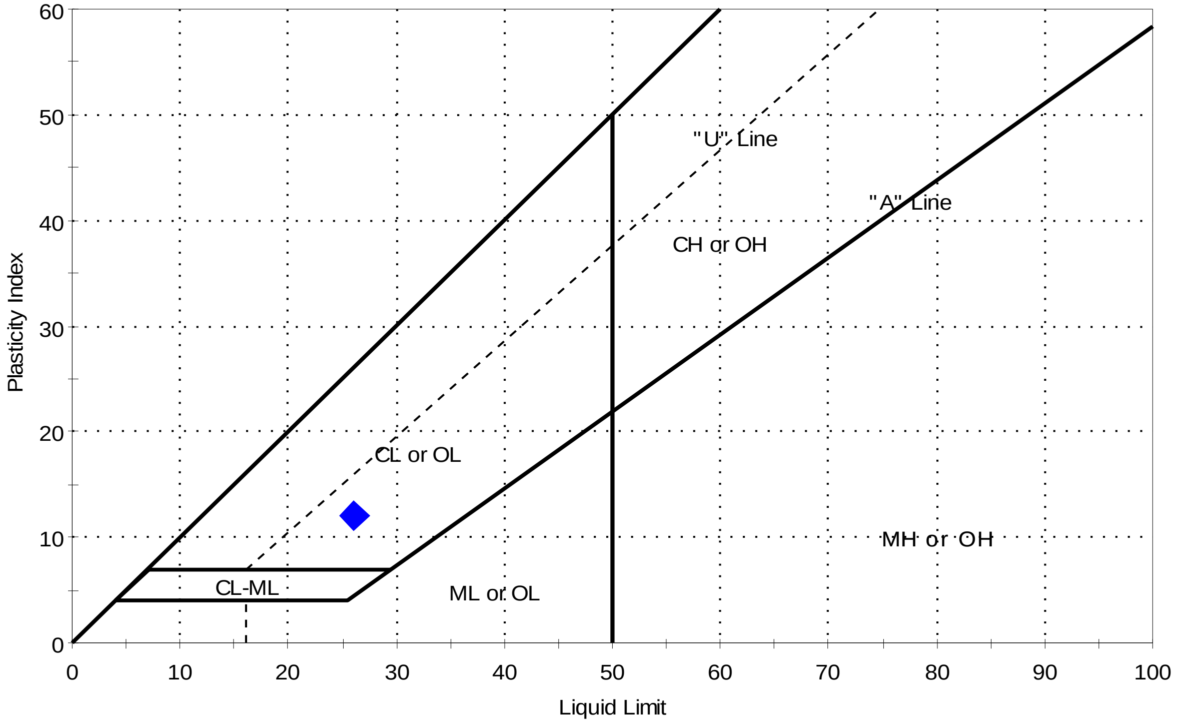
Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079

Boring ID: RT58 B-1
Sample Type: jar
Tested By: cam
Sample ID: S-7
Test Date: 03/06/17
Checked By: emm
Depth : 18-20
Test Id: 405539

Test Comment: ---
Visual Description: Moist, olive clayey sand
Sample Comment: ---

Atterberg Limits - ASTM D4318

Plasticity Chart



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-7	RT58 B-1	18-20	37	26	14	12	1.9	Clayey sand (SC)

Sample Prepared using the WET method

18% Retained on #40 Sieve

Dry Strength: HIGH

Dilatancy: SLOW

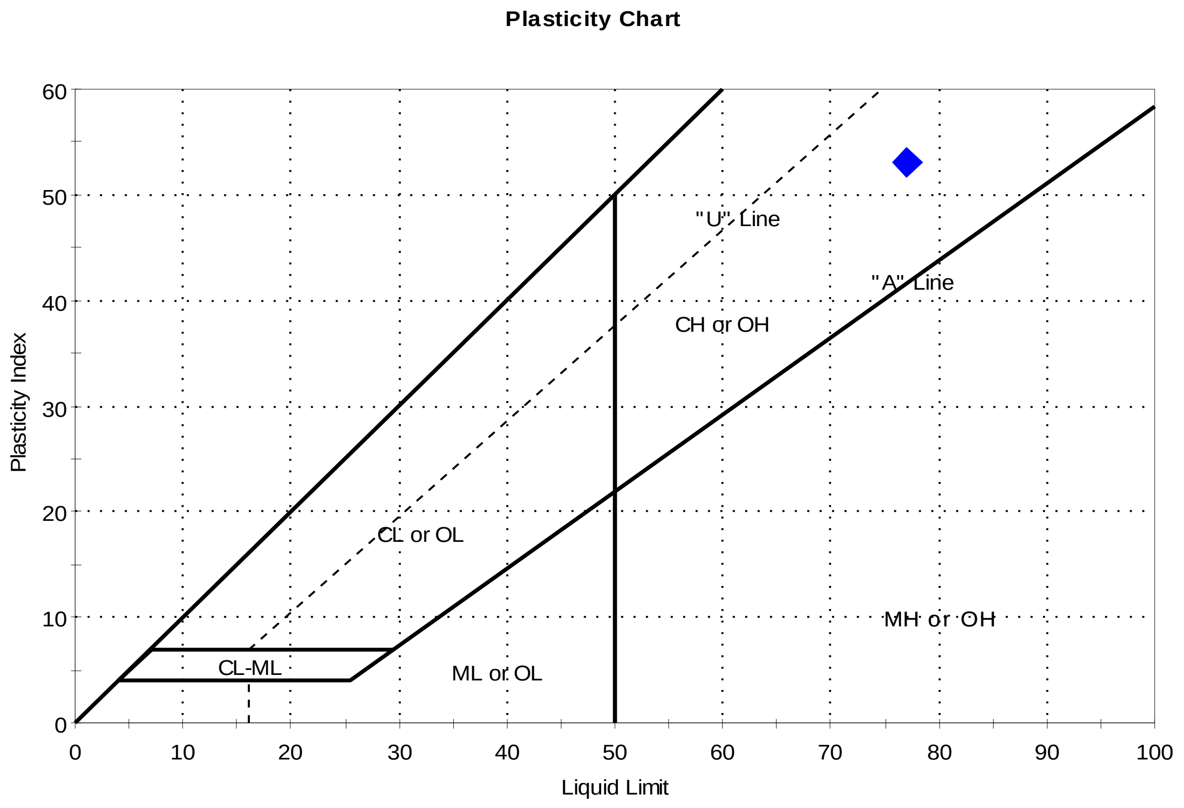
Toughness: LOW

Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079

Boring ID: RT58 B-1
Sample Type: jar
Tested By: cam
Sample ID: S-10
Test Date: 03/03/17
Checked By: emm
Depth : 33-35
Test Id: 405540

Test Comment: ---
Visual Description: Wet, olive organic clay
Sample Comment: ---

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-10	RT58 B-1	33-35	81	77	24	53	1.1	Organic clay (OH)

Sample Prepared using the WET method

0% Retained on #40 Sieve

Dry Strength: VERY HIGH

Dilatancy: SLOW

Toughness: LOW

In order to properly describe the soil an Oven Dried Liquid Limit test was performed.
The Oven Dried Liquid Limit was 44

Client:	Geosyntec Consultants				
Project:	I-58 Crossing				
Location:	VA			Project No:	GTX-306079
Boring ID:	RT58 B-1	Sample Type:	jar	Tested By:	cam
Sample ID:	S-18	Test Date:	03/03/17	Checked By:	emm
Depth :	73-75	Test Id:	405541		

Test Comment: ---
Visual Description: Moist, olive silty sand
Sample Comment: ---

Atterberg Limits - ASTM D4318

Sample Determined to be non-plastic

Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-18	RT58 B-1	73-75	36	n/a	n/a	n/a	n/a	Silty sand (SM)

1% Retained on #40 Sieve

Dry Strength: HIGH

Dilatancy: RAPID

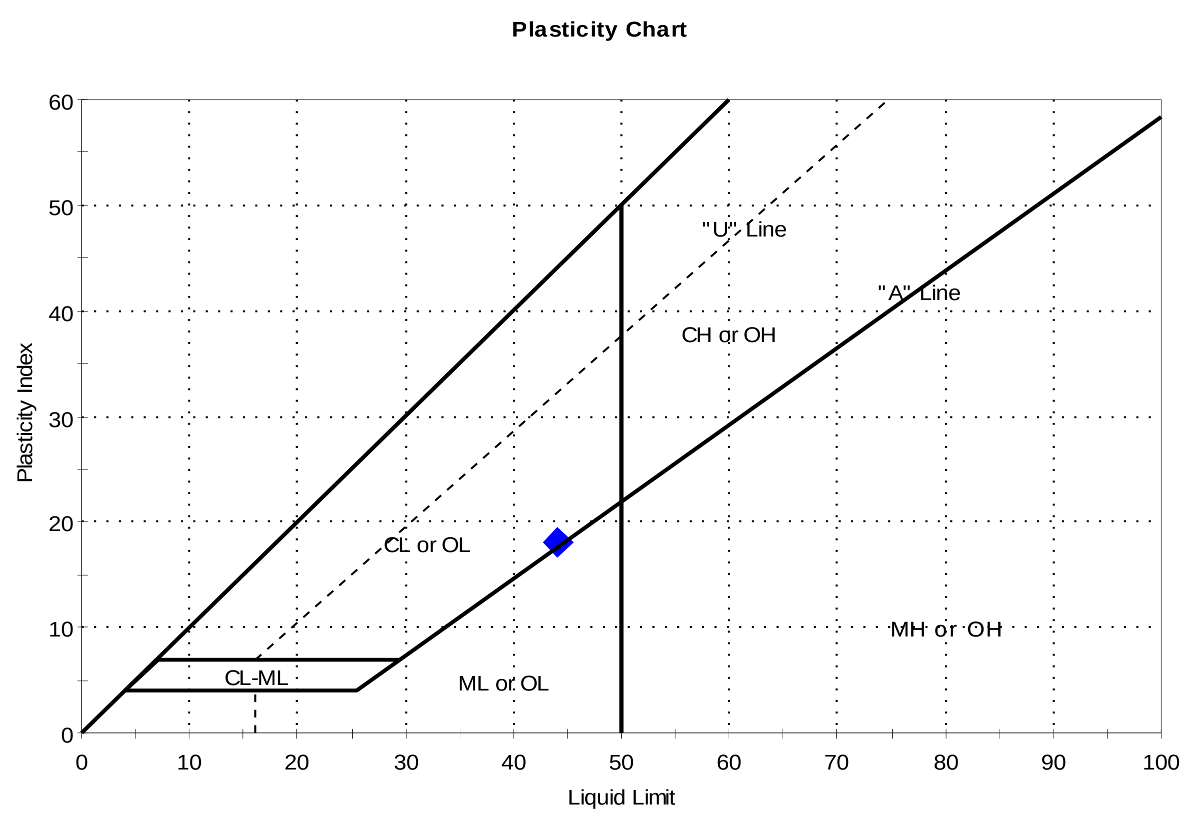
Toughness: n/a

The sample was determined to be Non-Plastic

Client:	Geosyntec Consultants				
Project:	I-58 Crossing				
Location:	VA			Project No:	GTX-306079
Boring ID:	RT58 B-1	Sample Type:	jar	Tested By:	cam
Sample ID:	S-24	Test Date:	03/02/17	Checked By:	emm
Depth :	103-105	Test Id:	405542		

Test Comment: ---
Visual Description: Moist, dark gray sandy clay
Sample Comment: ---

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-24	RT58 B-1	103-105	36	44	26	18	0.6	Sandy Lean clay (CL)

Sample Prepared using the WET method

1% Retained on #40 Sieve

Dry Strength: VERY HIGH

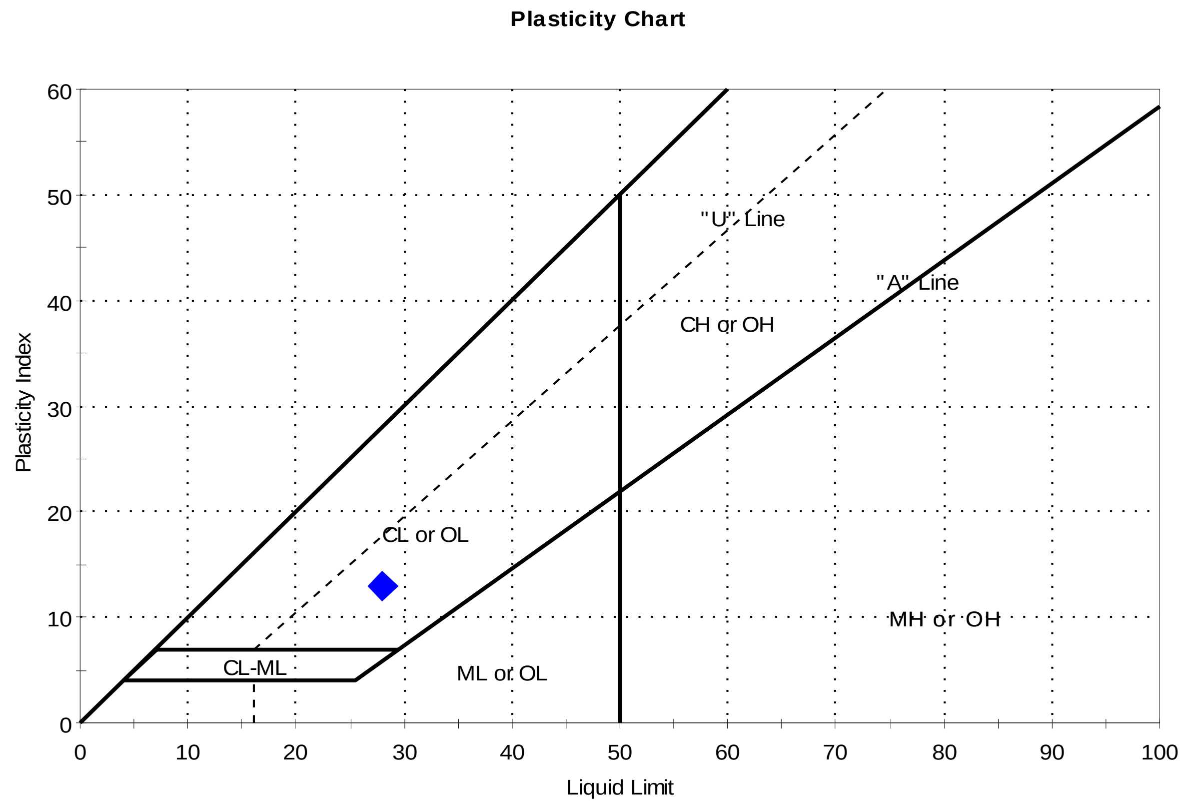
Dilatancy: SLOW

Toughness: LOW

Client:	Geosyntec Consultants				
Project:	I-58 Crossing				
Location:	VA			Project No:	GTX-306079
Boring ID:	RT58 B-2	Sample Type:	jar	Tested By:	cam
Sample ID:	S-2	Test Date:	03/02/17	Checked By:	emm
Depth :	2-4	Test Id:	405543		

Test Comment: ---
Visual Description: Moist, grayish brown sandy clay
Sample Comment: ---

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-2	RT58 B-2	2-4	21	28	15	13	0.5	Sandy Lean clay (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: SLOW
Toughness: LOW

Client:	Geosyntec Consultants				
Project:	I-58 Crossing				
Location:	VA			Project No:	GTX-306079
Boring ID:	RT58 B-2	Sample Type:	jar	Tested By:	cam
Sample ID:	S-5	Test Date:	03/02/17	Checked By:	emm
Depth :	8-10	Test Id:	405544		

Test Comment: ---
Visual Description: Moist, olive silty sand
Sample Comment: ---

Atterberg Limits - ASTM D4318

Sample Determined to be non-plastic

Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-5	RT58 B-2	8-10	35	n/a	n/a	n/a	n/a	Silty sand (SM)

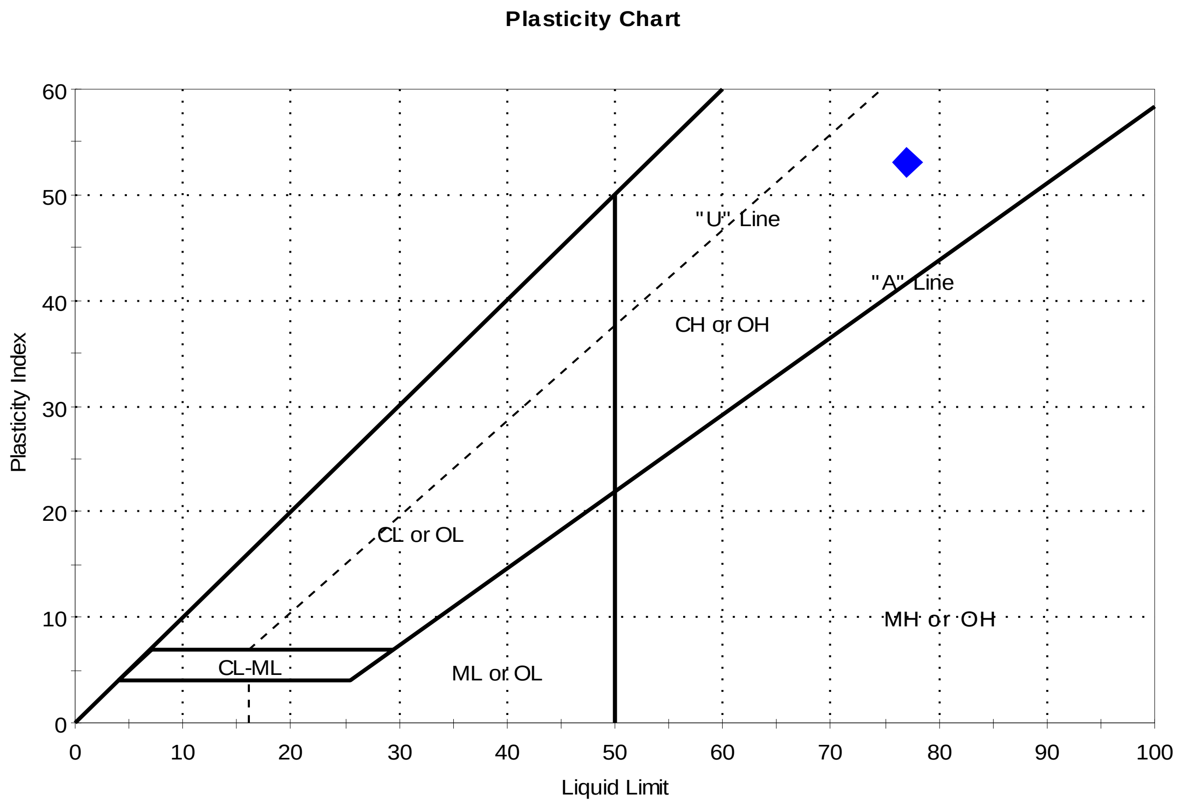
1% Retained on #40 Sieve
Dry Strength: HIGH
Dilatancy: RAPID
Toughness: n/a
The sample was determined to be Non-Plastic

Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079

Boring ID: RT58 B-2
Sample Type: tube
Tested By: cam
Sample ID: Shelby
Test Date: 03/03/17
Checked By: emm
Depth : 30-32
Test Id: 405535

Test Comment: ---
Visual Description: Moist, gray organic clay with sand
Sample Comment: ---

Atterberg Limits - ASTM D4318


Plasticity Chart

Symbol	Sample ID	Boring	Depth	Natural Moisture Content, %	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	Shelby	RT58 B-2	30-32	57	77	24	53	0.6	Organic clay with sand (OH)

Sample Prepared using the WET method

0% Retained on #40 Sieve

Dry Strength: VERY HIGH

Dilatancy: SLOW

Toughness: LOW

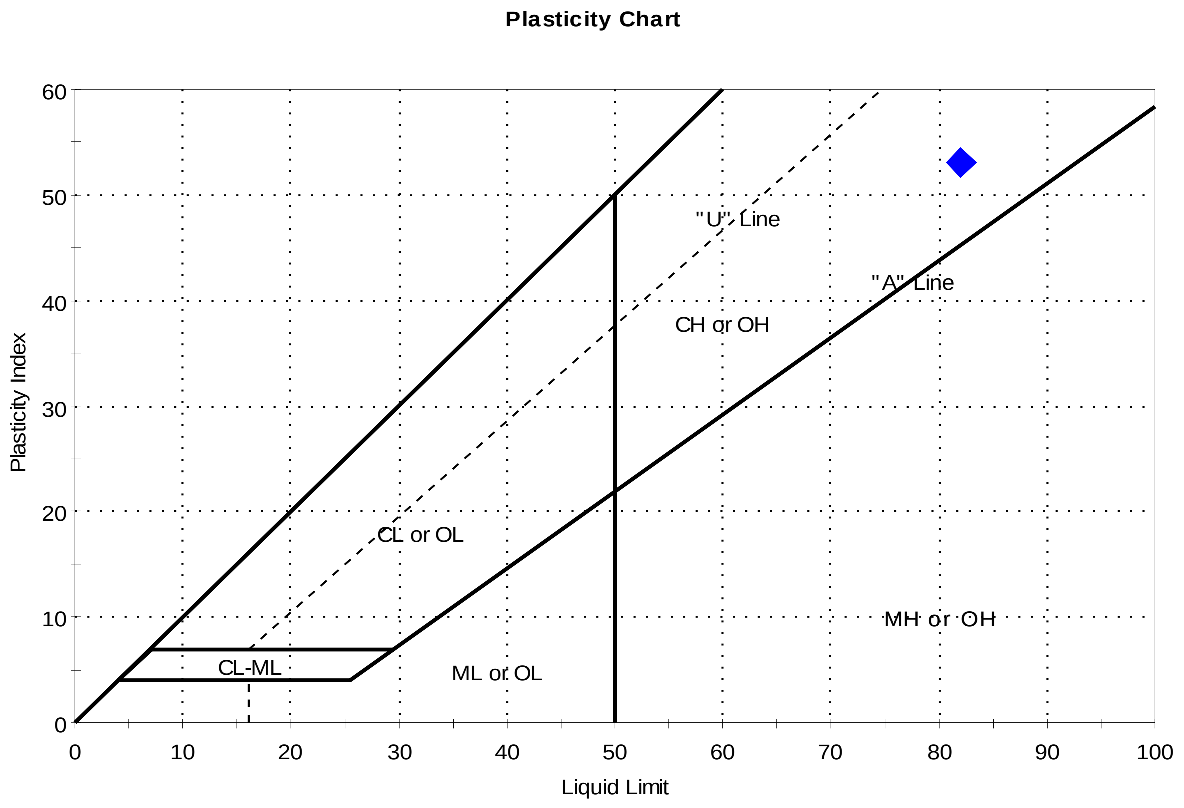
In order to properly describe the soil an Oven Dried Liquid Limit test was performed.
The Oven Dried Liquid Limit was 45

GeoTesting
EXPRESS

Client:	Geosyntec Consultants				
Project:	I-58 Crossing				
Location:	VA			Project No:	GTX-306079
Boring ID:	RT58 B-2	Sample Type:	tube	Tested By:	cam
Sample ID:	Shelby	Test Date:	03/06/17	Checked By:	emm
Depth :	45-47	Test Id:	405536		

Test Comment: ---
Visual Description: Moist, gray organic clay with sand
Sample Comment: ---

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	Shelby	RT58 B-2	45-47	64	82	29	53	0.7	Organic clay with sand (OH)

Sample Prepared using the WET method

0% Retained on #40 Sieve

Dry Strength: VERY HIGH

Dilatancy: SLOW

Toughness: LOW

In order to properly describe the soil an Oven Dried Liquid Limit test was performed.
The Oven Dried Liquid Limit was 47

Client:	Geosyntec Consultants				
Project:	I-58 Crossing				
Location:	VA			Project No:	GTX-306079
Boring ID:	RT58 B-2	Sample Type:	jar	Tested By:	cam
Sample ID:	S-15	Test Date:	03/03/17	Checked By:	emm
Depth :	58-60	Test Id:	405545		

Test Comment: ---
Visual Description: Moist, olive silty sand
Sample Comment: ---

Atterberg Limits - ASTM D4318

Sample Determined to be non-plastic

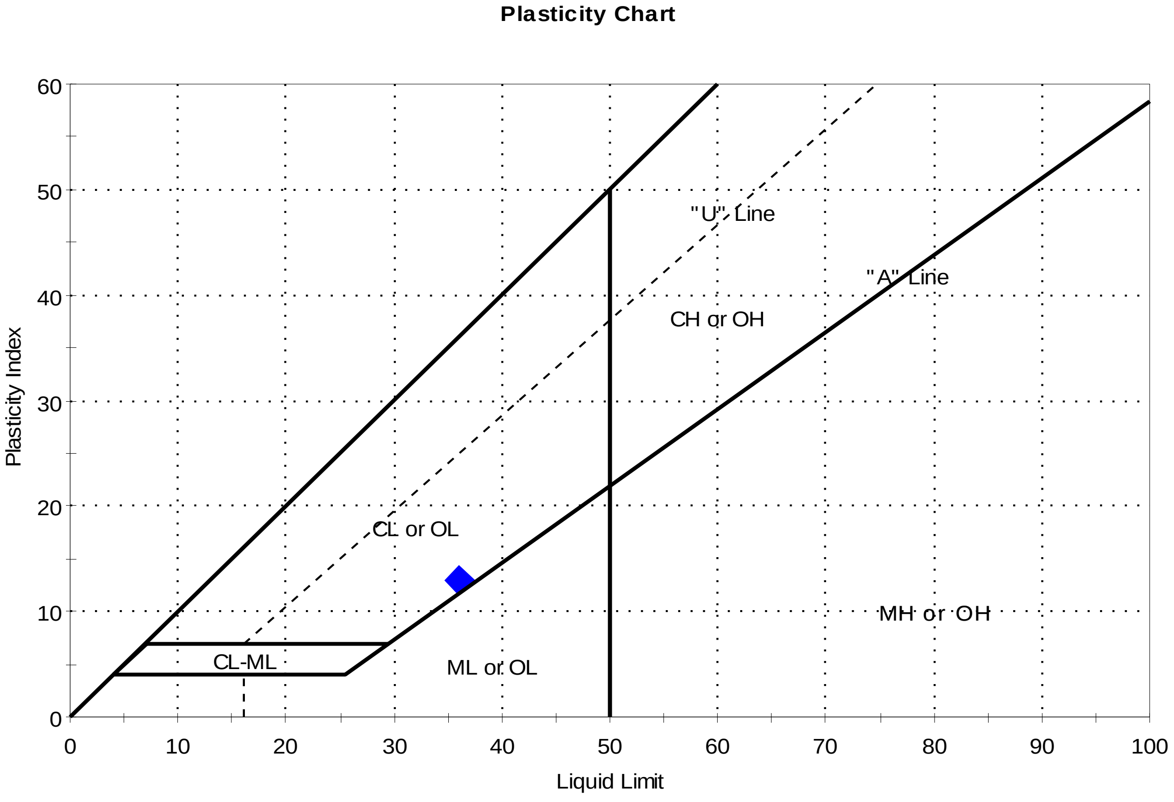
Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-15	RT58 B-2	58-60	29	n/a	n/a	n/a	n/a	Silty sand (SM)

3% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: RAPID
Toughness: n/a
The sample was determined to be Non-Plastic

Client:	Geosyntec Consultants		
Project:	I-58 Crossing		
Location:	VA	Project No:	GTX-306079
Boring ID:	RT58 B-2	Sample Type: jar	Tested By: cam
Sample ID:	S-20	Test Date: 03/03/17	Checked By: emm
Depth :	83-85	Test Id: 405546	

Test Comment: ---
Visual Description: Moist, dark gray clayey sand
Sample Comment: ---

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content, %	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-20	RT58 B-2	83-85	32	36	23	13	0.7	Clayey sand (SC)

Sample Prepared using the WET method

0% Retained on #40 Sieve

Dry Strength: VERY HIGH

Dilatancy: SLOW

Toughness: LOW

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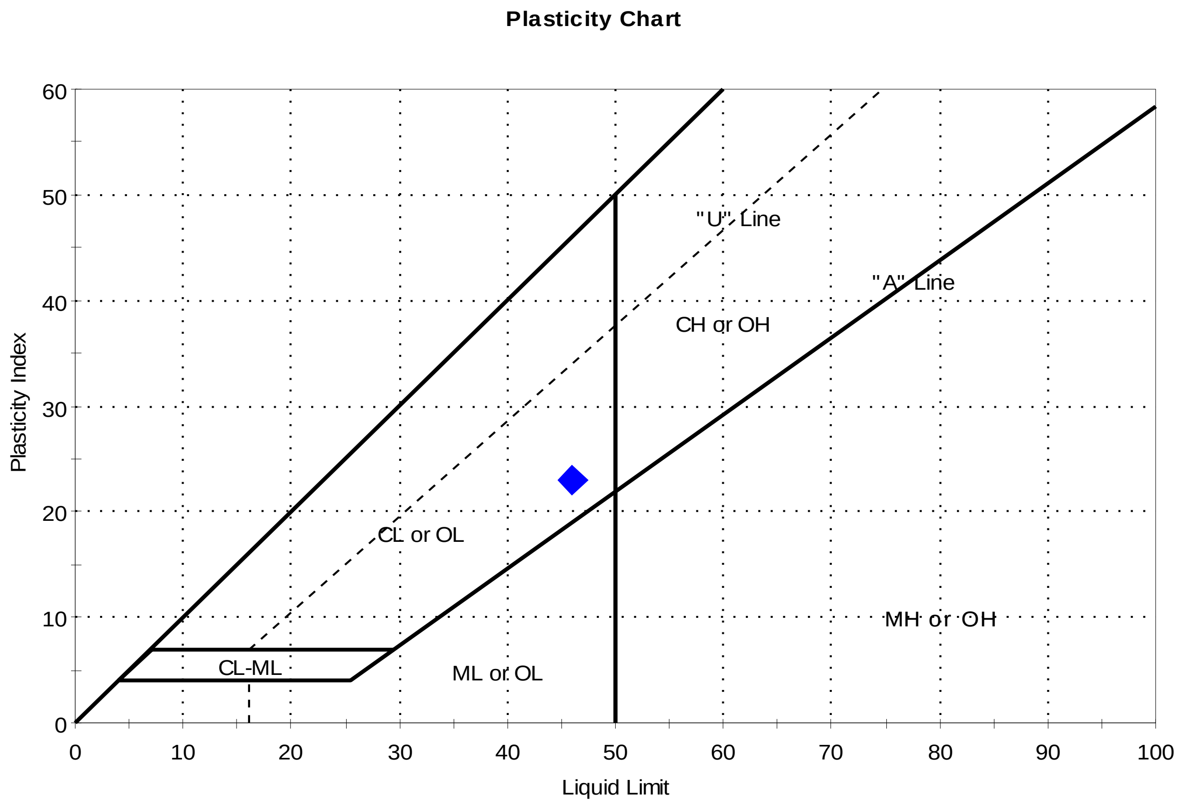
Client: Geosyntec Consultants
Project: I-58 Crossing
Location: VA
Project No: GTX-306079
Boring ID: RT58 B-2
Sample Type: jar
Tested By: cam
Sample ID: S-23
Test Date: 03/06/17
Checked By: emm
Depth : 98-100
Test Id: 405547
Test Comment: ---
Visual Description: Moist, olive sandy clay
Sample Comment: ---

Atterberg Limits - ASTM D4318



Plasticity Chart

Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-23	RT58 B-2	98-100	37	46	23	23	0.6	Sandy Lean clay (CL)

Sample Prepared using the WET method

0% Retained on #40 Sieve

Dry Strength: HIGH

Dilatancy: SLOW

Toughness: LOW

Client:	Geosyntec Consultants				
Project:	I-58 Crossing				
Location:	VA			Project No:	GTX-306079
Boring ID:	RT58 B-2	Sample Type:	jar	Tested By:	cam
Sample ID:	S-26	Test Date:	03/02/17	Checked By:	emm
Depth :	113-115	Test Id:	405548		

Test Comment: ---

Visual Description: Moist, olive silty sand

Sample Comment: ---

Atterberg Limits - ASTM D4318

Sample Determined to be non-plastic

Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-26	RT58 B-2	113-115	35	n/a	n/a	n/a	n/a	Silty sand (SM)

0% Retained on #40 Sieve

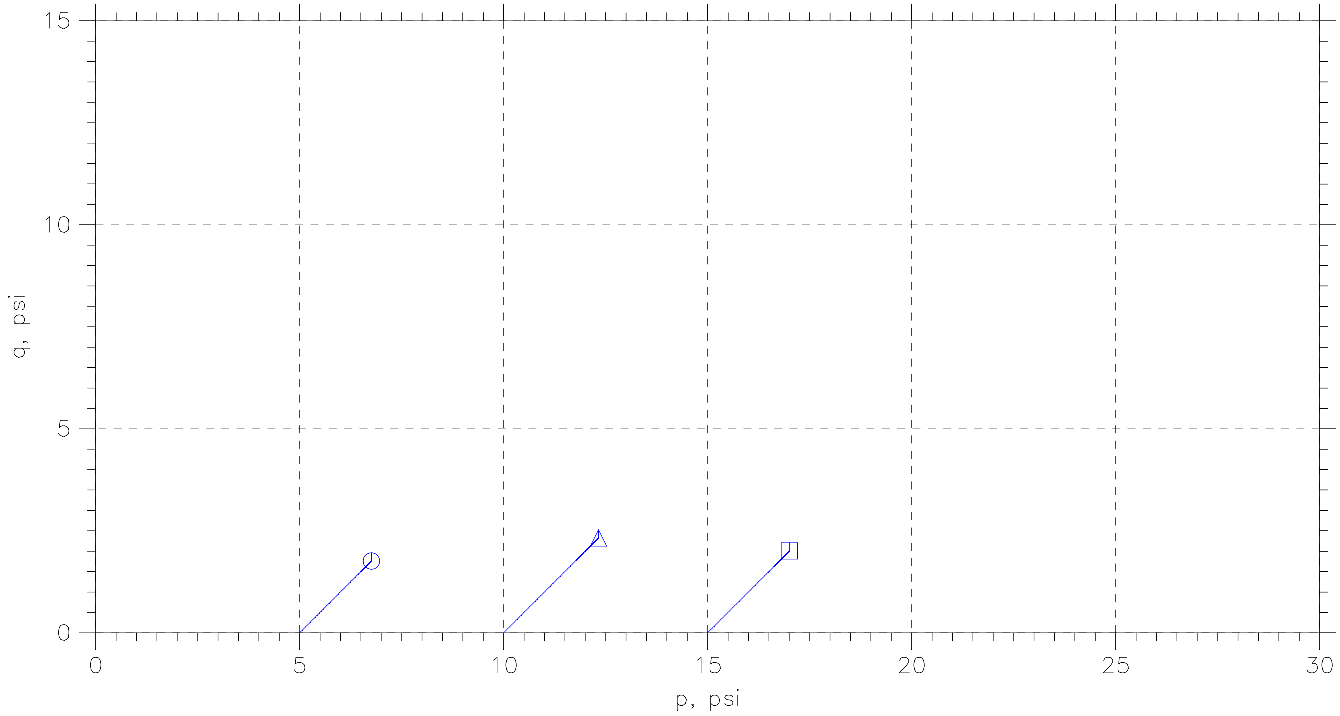
Dry Strength: HIGH

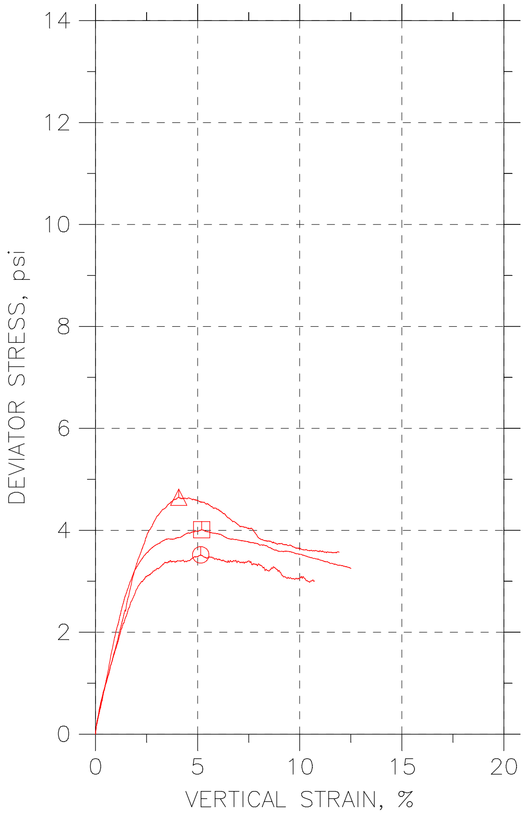
Dilatancy: RAPID

Toughness: n/a

The sample was determined to be Non-Plastic

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D2850

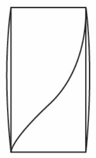


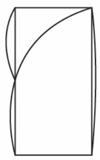


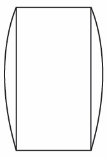
Symbol	○	△	□	
Sample No.	Shelby	Shelby	Shelby	
Test No.	UU-3-1	UU-3-2	UU-3-3	
Depth	15-17 ft	15-17 ft	15-17 ft	
Tested by	md	md	md	
Test Date	3/3/17	3/3/17	3/1/17	
Checked by	njh	njh	njh	
Check Date	3/6/17	3/6/17	3/6/17	
Diameter, in	2.87	2.87	2.87	
Height, in	6.01	6.1	6.1	
Water Content, %	49.8	39.8	32.0	
Dry Density, pcf	71.76	77.71	85.18	
Saturation, %	99.7	91.8	88.4	
Void Ratio	1.35	1.17	0.979	
Confining Stress, psi	5	10	15	
Undrained Strength, psi	1.759	2.324	2.005	
Max. Dev. Stress, psi	3.518	4.648	4.009	
Strain at Failure, %	5.15	4.08	5.2	
Strain Rate, %/min	1	1	1	
Estimated Specific Gravity	2.7	2.7	2.7	
Liquid Limit	30	30	30	
Plastic Limit	14	14	14	
Plasticity Index	16	16	16	

GeoTesting EXPRESS

Project: I-58 Crossing
Location: VA
Project No.: GTX-306079
Boring No.: RT 58 B-1
Sample Type: intact





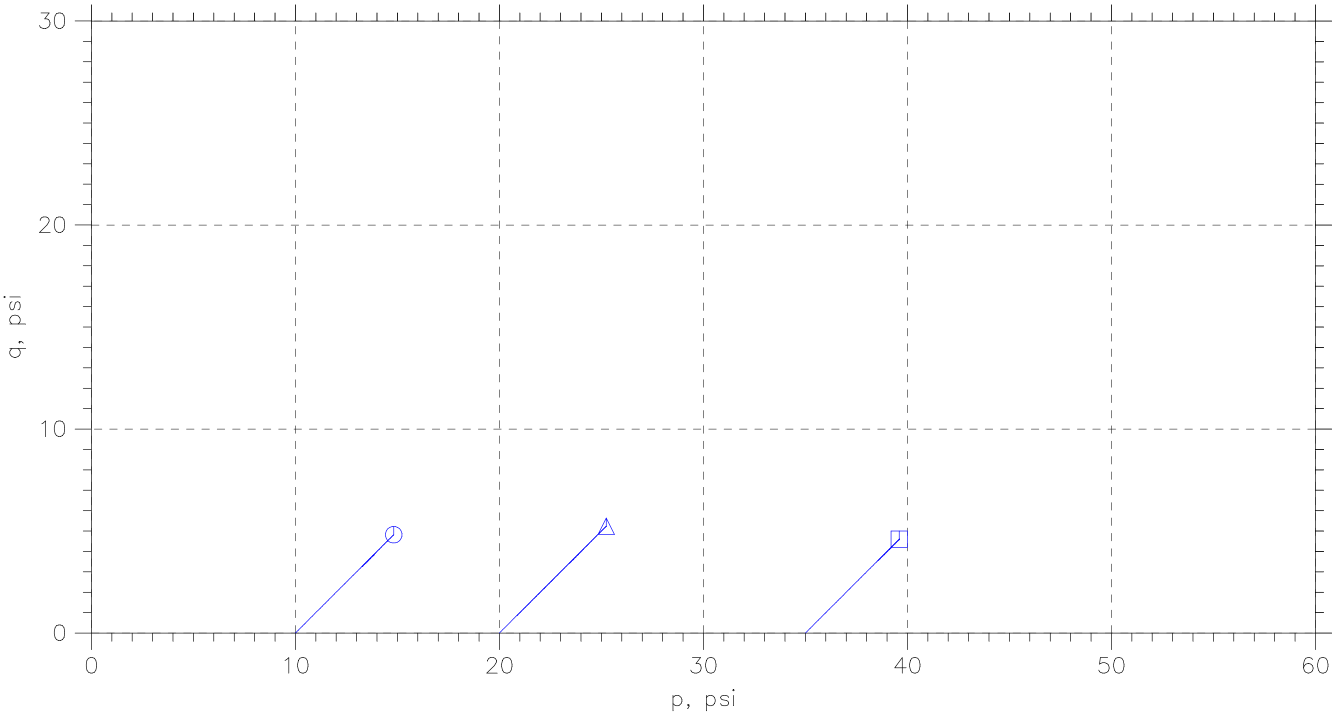


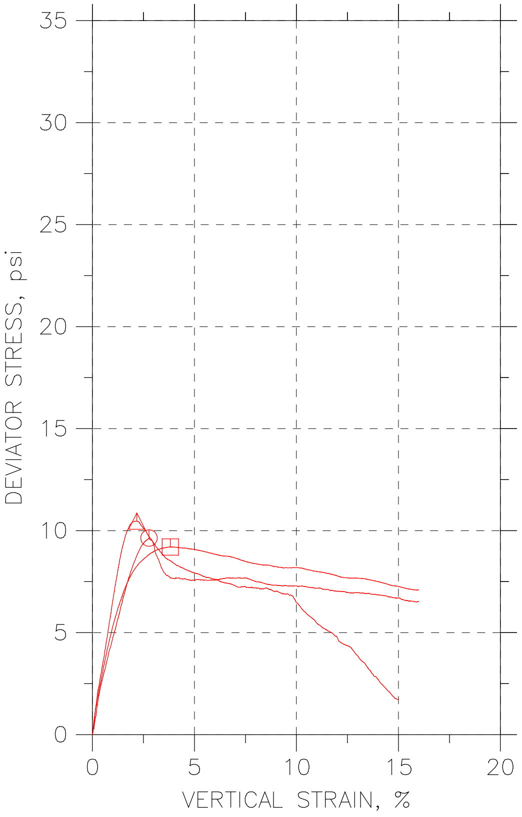
Description: Wet, olive gray clayey sand
Remarks: System R

Phase calculations based on start and end of test.

Mon, 06-MAR-2017 14:46:11

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D2850

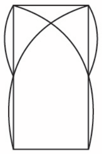


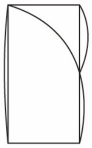


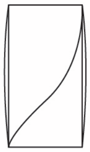
Symbol	○	△	□	
Sample No.	Shelby	Shelby	Shelby	
Test No.	UU-2-1	UU-2-2	UU-2-3	
Depth	30-32 ft	30-32 ft	30-32 ft	
Tested by	md	md	md	
Test Date	3/3/17	3/3/17	3/1/17	
Checked by	njh	njh	njh	
Check Date	3/6/17	3/6/17	3/6/17	
Diameter, in	2.86	2.86	2.86	
Height, in	6.05	6.02	6.15	
Water Content, %	79.8	77.8	42.0	
Dry Density, pcf	53.16	54.08	73.35	
Saturation, %	99.2	99.2	87.3	
Void Ratio	2.17	2.12	1.3	
Confining Stress, psi	10	20	35	
Undrained Strength, psi	4.818	5.234	4.6	
Max. Dev. Stress, psi	9.636	10.47	9.199	
Strain at Failure, %	2.77	2.18	3.82	
Strain Rate, %/min	1	1	1	
Estimated Specific Gravity	2.7	2.7	2.7	
Liquid Limit	77	77	77	
Plastic Limit	24	24	24	
Plasticity Index	53	53	53	

GeoTesting EXPRESS

Project: I-58 Crossing
Location: VA
Project No.: GTX-306079
Boring No.: RT 58 B-2
Sample Type: intact
Description: Moist, gray organic clay
Remarks: System R



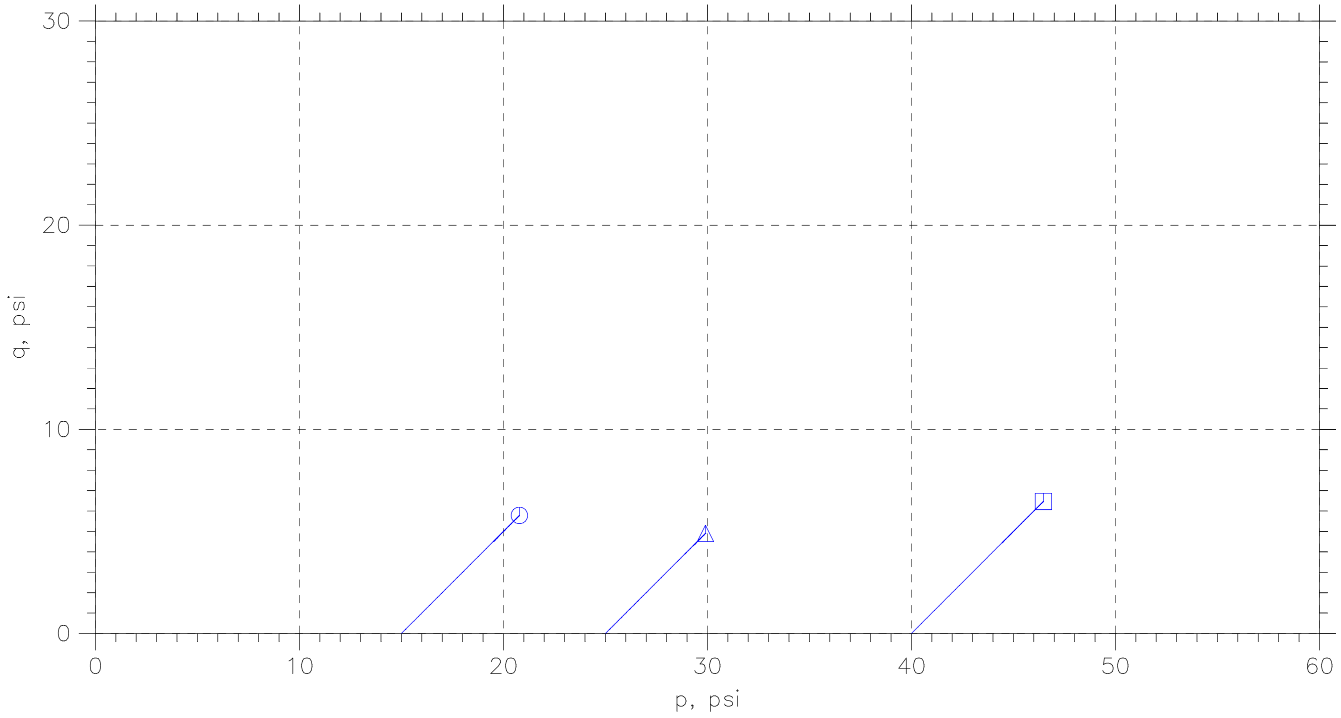


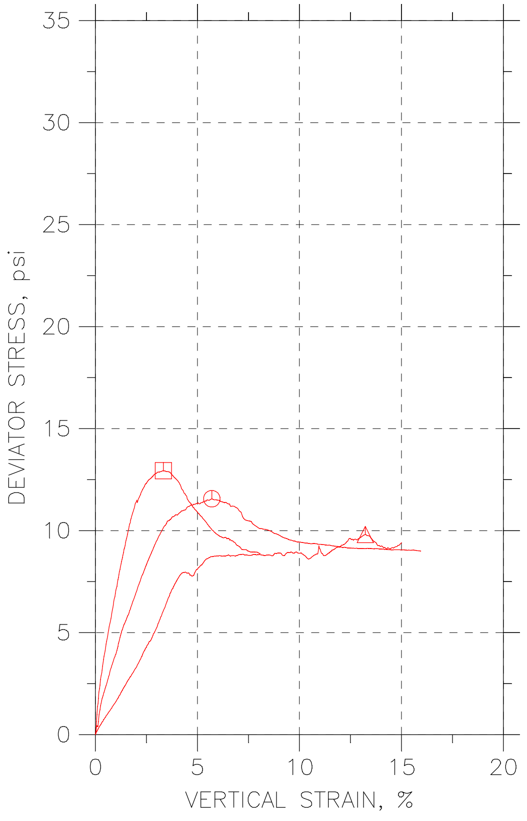


Phase calculations based on start and end of test.

Mon, 06-MAR-2017 14:00:09

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D2850

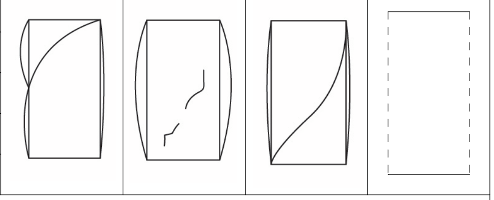




Symbol	○	△	□	
Sample No.	Shelby	Shelby	Shelby	
Test No.	UU-1-1	UU-1-2	UU-1-3	
Depth	45-47 ft	45-47 ft	45-47 ft	
Tested by	md	md	md	
Test Date	3/3/17	3/2/17	3/1/17	
Checked by	njh	njh	njh	
Check Date	3/6/17	3/6/17	3/6/17	
Diameter, in	2.86	2.87	2.02	
Height, in	6.15	6.09	4.55	
Water Content, %	60.8	65.1	66.1	
Dry Density, pcf	63.33	59.1	58.72	
Saturation, %	98.8	94.9	95.4	
Void Ratio	1.66	1.85	1.87	
Confining Stress, psi	15	25	40	
Undrained Strength, psi	5.781	4.904	6.468	
Max. Dev. Stress, psi	11.56	9.807	12.94	
Strain at Failure, %	5.7	13.2	3.33	
Strain Rate, %/min	1	1	1	
Estimated Specific Gravity	2.7	2.7	2.7	
Liquid Limit	82	82	82	
Plastic Limit	29	29	29	
Plasticity Index	53	53	53	

GeoTesting EXPRESS

Project: I-58 Crossing
Location: VA
Project No.: GTX-306079
Boring No.: RT 58 B-2
Sample Type: intact



Description: Moist, gray organic clay with sand
Remarks: System R

Phase calculations based on start and end of test.

Mon, 06-MAR-2017 14:03:00

APPENDIX D

FISHBURNE'S REPORT OF STANDARD PENETRATION TEST HAMMER CALIBRATION

FROEHLING & ROBERTSON, INC.
Engineering Stability Since 1881

Greenbrier Commerce Park
833 Professional Place, W.
Chesapeake, Virginia 23320-3601
T 757.436.1111 I F 757.436.1674

September 7, 2016

REPORT OF STANDARD PENETRATION TEST HAMMER CALIBRATION

Fishburne Drilling, Inc.
3219 South Military Highway
Chesapeake, Virginia 23323

Attn: Mr. Mike Young

Re: **SPT Hammer Energy Measurements**
Fishburne CME 55, Serial No. 395465
Chesapeake, Virginia

Dear Mr. Young:

The purpose of this report is to present the results of Standard Penetration Test (SPT) hammer energy measurements obtained for Fishburne Drilling, Inc. (Fishburne), CME 55 drill rig Serial No. 395465. Data collection and report preparation procedures were performed in general accordance with ASTM D4633-10.

Dynamic Measurement and Instrumentation

Dynamic measurements were made with one pair of foil strain transducers epoxied to, and one pair of accelerometers mechanically attached to a calibrated rod, Serial No. 304 AWJ-1. Analog signals from the sensors measured during testing were recorded and processed by the Pile Driving Analyzer (PDA) model PAK at a sampling frequency of 20,000 Hz. Printed outputs from the PDA applicable to SPT hammer calibration include blow count per six-inch increment (BLC), blows per minute (BPM), energy transferred into drill rod by Force-Velocity method (EFV), energy transfer ratio (ETR), maximum force (FMX), maximum velocity (VMX), maximum displacement (DMX), final displacement (DFN), and maximum compressive stress (CSX) for each recorded hammer strike. The force and velocity records were inspected on the PDA monitor to check for data quality. Printed outputs are available in Appendix I attached to this report, accompanied by a representative force and normalized velocity wave curve for each sample depth tested. Additionally, the testing summary including drill rig, hammer, and testing instrumentation information are included in Appendix I. Attached in Appendix II are the associated PDA and transducer calibration data.

SPT energy measurements were performed on the referenced CME 55 drill rig utilizing AW drill rod with an attached split spoon sampler. The gaged rod, fixed beneath the anvil, has a measured cross sectional area of 1.19 square inches. A standard 1.4-inch I.D., 2-inch O.D., and 30-inch long split spoon sampler, was driven into the existing subsurface material with a 140-lb automatic hammer falling 30 inches. The number of blows required to drive the sampler each 6-inch increment of penetration was recorded at the time of sampling. The sum of the second and third penetration increments is termed the SPT value, "N_{Field}".

The soil boring with hammer energy testing was performed on September 2, 2016 at the Fishburne office in Chesapeake, Virginia. Energy measurements were made at depths ranging from 48.6 to 60 feet below the existing ground surface. The soils encountered during drilling were generally described as gray, fine sand with trace silt underlain by light gray, silty fine sand with marine shell fragments. At the time of this report, a representative boring log was not available.

Measurement & Calculation

Energy induced into the drill rod for each hammer strike is measured with the gaged rod at the transducer locations. In accordance with ASTM D4633-10, the energy transferred into the drill rod (EFV) is performed with the following FV Method time varying function:

$$EFV = \max\left[\int F(t)\, v(t)\, dt\right]$$

The integration is carried from start to end of the time record of each recorded blow and the maximum energy transfer is determined at any time in the record.

Correction of SPT N_{field} values to the corrected N_{60} with an appropriate energy correction (C_E) should be performed in accordance with regional or project specific methods by a professional engineer using acceptable engineering judgment. One such method is to divide the calibrated average EFV by 60% of the theoretical energy produced by a 140-pound hammer falling 30 inches as estimated for the rope and cathead. This C_E is then multiplied to the N_{Field} for the N_{60} correction.

Summary of Results

The following Table 1 provides a summary of the test results for each sample depth. Data included in the table summarizes the blows of the second and third, 6-inch increments of sampling (N_{Field}) at the referenced sample depth in accordance with ASTM D4633, Note 10. The data and tables included in Appendix I contain averaged data for each blow of the entire data set. The average transferred energy values have been calculated by the EFV method. The energy transfer ratio (ETR) is calculated utilizing the ratio of the maximum transferred energy EFV to the theoretical energy of the 140-pound hammer dropping 30 inches (350 ft-lb).

Table 1 – Summary of SPT Hammer Performance

Sample Depth (feet BGS)	**Rod Length w/ Split Spoon (feet)**	**Blow Count (blows/6”)**	**SPT N_{Field} Value (bpf)**	**Average Energy Transfer FV Method (ft-lb)**	**Average Energy Transfer Ratio (%)**	**Blows per Minute (bpm)**	**Range of Energy Transfer (ft-lb)**	**Range of Energy Transfer Ratio (%)**
48.5-50	54	4-4-4	8	297	84.8	54.5	293-301	83.8-85.9
55-56.5	62	3-5-11	16	305	87.0	54.2	298-313	85.2-89.4
58.5-60	64	9-12-18	30	302	86.4	54.2	291-314	83.1-89.8
Average				**302**	**86.3**	**54.2**		
Standard Dev.				**5.83**	**1.65**	**0.17**		

Conclusions

Dynamic measurements of the transferred energy to the drill rod using the EFV method showed a range of 291 to 314 ft-lb for the referenced drill rig. The average transferred energy of 302 ft-lb corresponds to a transferred efficiency of 86.3 percent.

Closing

It has been our pleasure working with you on this project. Please contact us if you have any questions regarding this report or if we may be further service.

Sincerely,
FROEHLING & ROBERTSON, INC.

Thornton H. Elmore, E.I.T.
Engineering Staff

John P. Sensabaugh, P.E.
Senior Engineer

THE/JPS

Distribution: mike@fishburnedrilling.com

F:\Projects 61T\61T-0221 (Fishburne - SPT Hammer Calibrations)\395465\Fishburne CME 55 Serial No 395465.docx

COMMONWEALTH OF VIRGINIA
JOHN P. SENSABAUGH
Lic. No. 015788
9/9/2016
PROFESSIONAL ENGINEER

APPENDIX I

Standard Penetration Test Energy Calibration Data

SINCE 1881

FROEHLING & ROBERTSON, INC.

Engineering Stability Since 1881

Greenbrier Commerce Park
833 Professional Place, West
Chesapeake, Virginia 23320-3601 I USA
T 757.436.1111 I F 757.436.1674

REPORT OF ENERGY MEASUREMENT FOR DYNAMIC PENETROMETERS – ASTM D4633-10

Client: Fishburne Drilling, Inc.
3219 South Military Highway
Chesapeake, Virginia 23323
Attention: Mr. Mike Young

F&R Record No: 61T-0221
Project Name: SPT Hammer Energy Measurements

Date of Test: September 2, 2016
Date of Report: September 7, 2016

Boring Location: Fishburne Office
Chesapeake, Virginia

Drill Rig Data

Manufacturer/Model	Rig No.	Serial No.	Operator	Type
CME/55	-	395465	J. Raasio	Track

Hammer Data

Type	Model	Serial No.	Ram Weight (lbs.)	Drop Height (in.)
Automatic	CME	-	140.0	30

Drill String Data

Manufacturer	Type	OD (in.)	ID (in.)	Area (in^2)	Lengths (ft)
CME	AW	1.75	1.25	1.17	5, 10

Calibration Equipment Data (PDA Unit)

Manufacturer	Type	Serial No.	Date of Calibration	Accelerometers/Date of Calibration[1]
Pile Dynamics, Inc.	PAK	1721K	July 14, 2015	K4975 & K609/March 2015

Calibration Equipment Data (Rod)

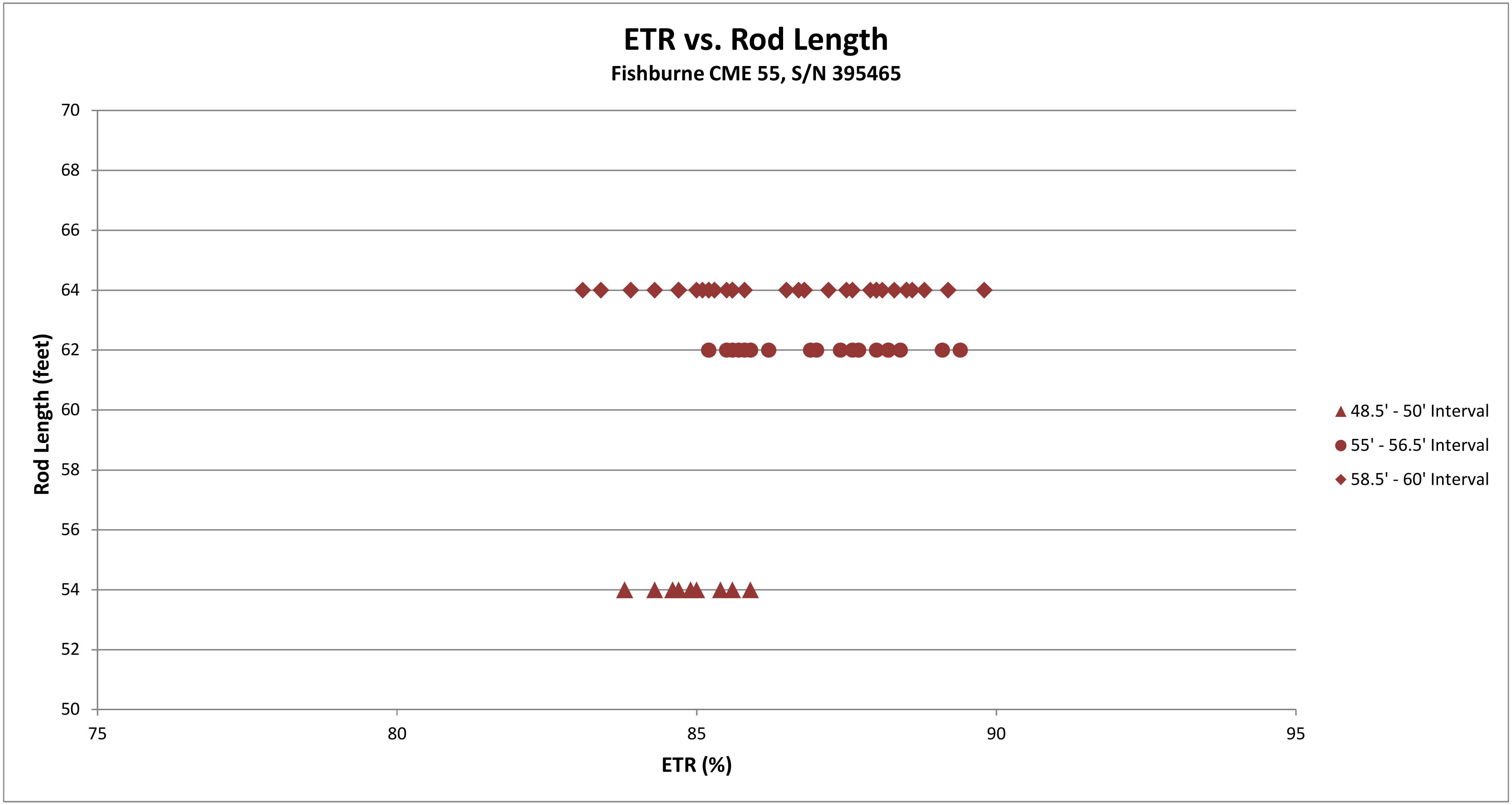
Manufacturer	Type	OD (in.)	ID (in.)	Area (in^2)	Strain Gages/Date of Calibration[1]
Pile Dynamics, Inc.	AWJ	1.75	1.25	1.19	Bridge 1 & 2/April 14, 2015

[1] - See Appendix II for calibration data.

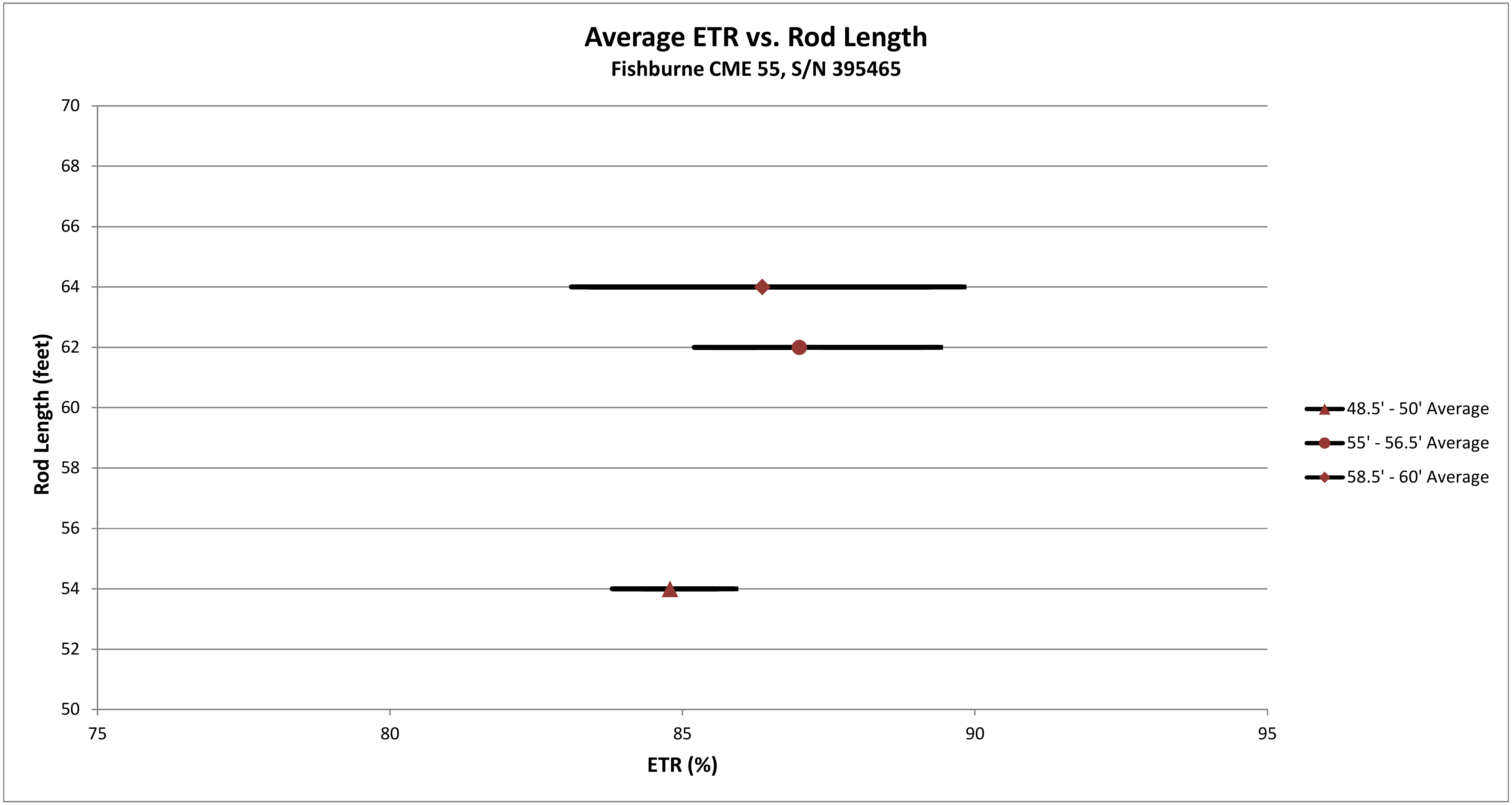
Brief Summary of Hammer Performance[2]

Avg. FV (ft-lbs)	Avg. ETR (%)	Avg. BPM	Range of Sample Depths (ft)
302	86.3	54.2	48.6 - 60

[2] - See Table 1 in report for detailed summary.



ETR vs. Rod Length
Fishburne CME 55, S/N 395465
Rod Length (feet)
70
68
66
64
62
60
58
56
54
52
50
75
80
85
90
95
ETR (%)
▲ 48.5' - 50' Interval
● 55' - 56.5' Interval
◆ 58.5' - 60' Interval

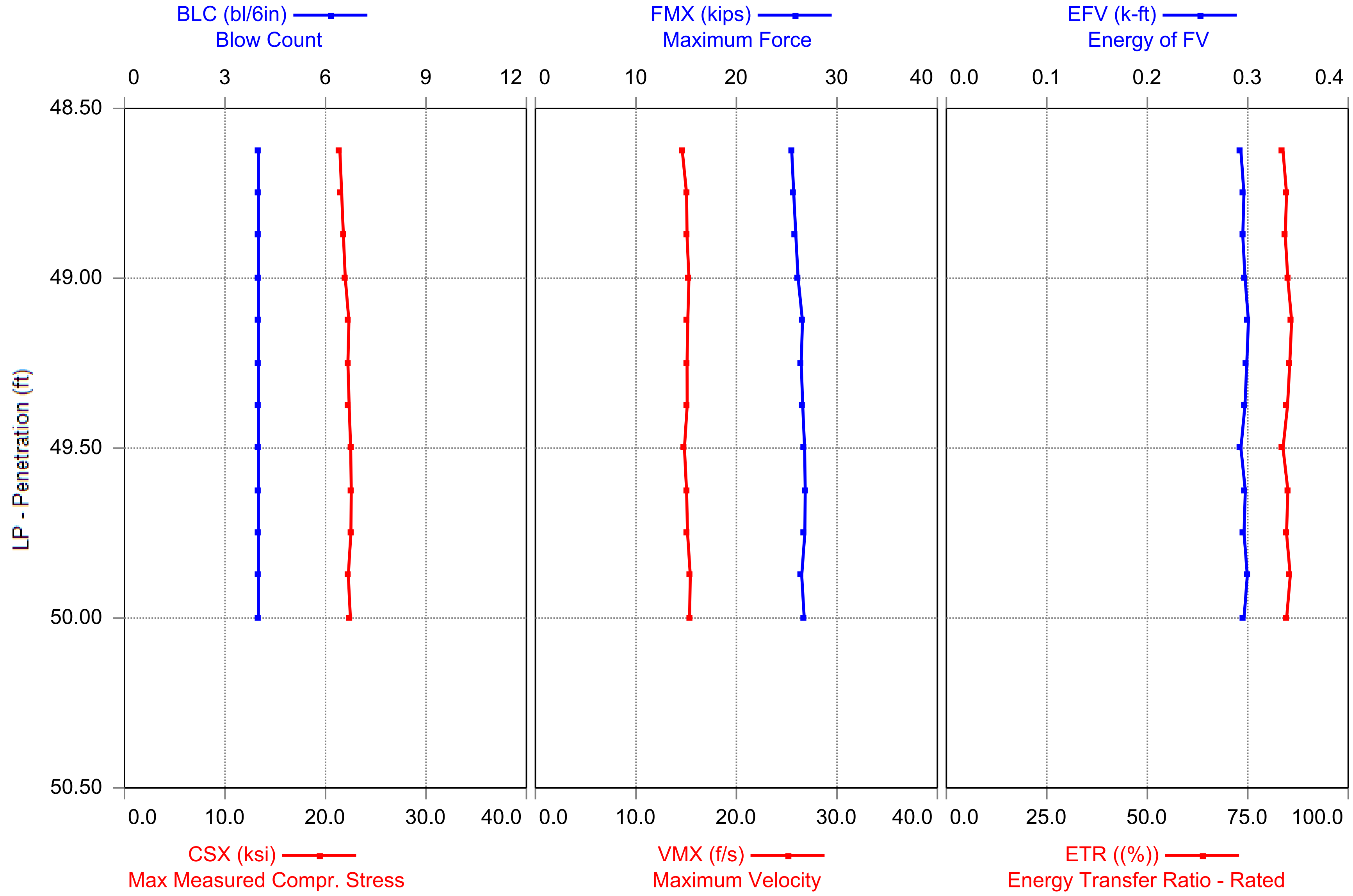
Average ETR vs. Rod Length
Fishburne CME 55, S/N 395465
Rod Length (feet)
70
68
66
64
62
60
58
56
54
52
50
75
80
85
90
95
ETR (%)
48.5' - 50' Average
55' - 56.5' Average
58.5' - 60' Average

Froehling & Robertson Inc - PDIPLOT2 Ver 2016.1.56.3 - Case Method & iCAP® Results

Printed: 06-September-2016

Test started: 01-January-2001

Fishburne S/N 395465 - 48.5' - 50'



Fishburne S/N 395465 - 48.5' - 50'
OP: T. Elmore

AW Rod
Date: 01-January-2001

AR: 1.19 in^2
LE: 54.00 ft
WS: 16,807.9 f/s

SP: 0.492 k/ft^3
EM: 30,000 ksi
JC: 0.60 []

FMX: Maximum Force
CSX: Max Measured Compr. Stress
VMX: Maximum Velocity
DMX: Maximum Displacement

DFN: Final Displacement
EFV: Energy of FV
ETR: Energy Transfer Ratio - Rated
BPM: Blows per Minute

BL#	Depth	BLC	FMX	CSX	VMX	DMX	DFN	EFV	ETR	BPM
	ft	bl/6in	kips	ksi	f/s	in	in	k-ft	(%)	bpm
1	48.63	4	25.5	21.4	14.6	1.50	1.50	0.293	83.8	54.6
2	48.75	4	25.7	21.6	15.0	1.50	1.50	0.296	84.6	54.6
3	48.88	4	25.9	21.8	15.1	1.50	1.50	0.295	84.3	54.4
4	49.00	4	26.1	22.0	15.3	1.50	1.50	0.297	84.9	54.6
5	49.13	4	26.6	22.3	15.2	1.50	1.50	0.301	85.9	54.4
6	49.25	4	26.5	22.2	15.1	1.50	1.50	0.299	85.4	54.6
7	49.38	4	26.6	22.4	15.1	1.50	1.50	0.297	84.9	54.4
8	49.50	4	26.8	22.5	14.8	1.50	1.50	0.293	83.8	54.7
9	49.63	4	26.9	22.6	15.0	1.50	1.50	0.297	85.0	54.4
10	49.75	4	26.8	22.5	15.1	1.50	1.50	0.296	84.6	54.3
11	49.88	4	26.5	22.3	15.4	1.50	1.50	0.300	85.6	54.4
12	50.00	4	26.8	22.5	15.3	1.50	1.50	0.296	84.7	54.2
		Average	26.4	22.2	15.1	1.50	1.50	0.297	84.8	54.5
		Std. Dev.	0.4	0.4	0.2	0.00	0.00	0.002	0.6	0.1
		Maximum	26.9	22.6	15.4	1.50	1.50	0.301	85.9	54.7
		@ Blow#	9	9	11	10	8	5	5	8
		Minimum	25.5	21.4	14.6	1.50	1.50	0.293	83.8	54.2
		@ Blow#	1	1	1	1	1	8	8	12

Total number of blows analyzed: 12

BL# Sensors

1-12 F3: [Bridge1] 208.4 (1.00); F4: [Bridge2] 206.8 (1.00); A3: [K4975] 325.0 (0.92);
A4: [K609] 322.0 (1.00)

Time Summary

Drive 12 seconds 1:06 AM - 1:06 AM BN 1 - 12

Froehling & Robertson Inc

Fishburne S/N 395465

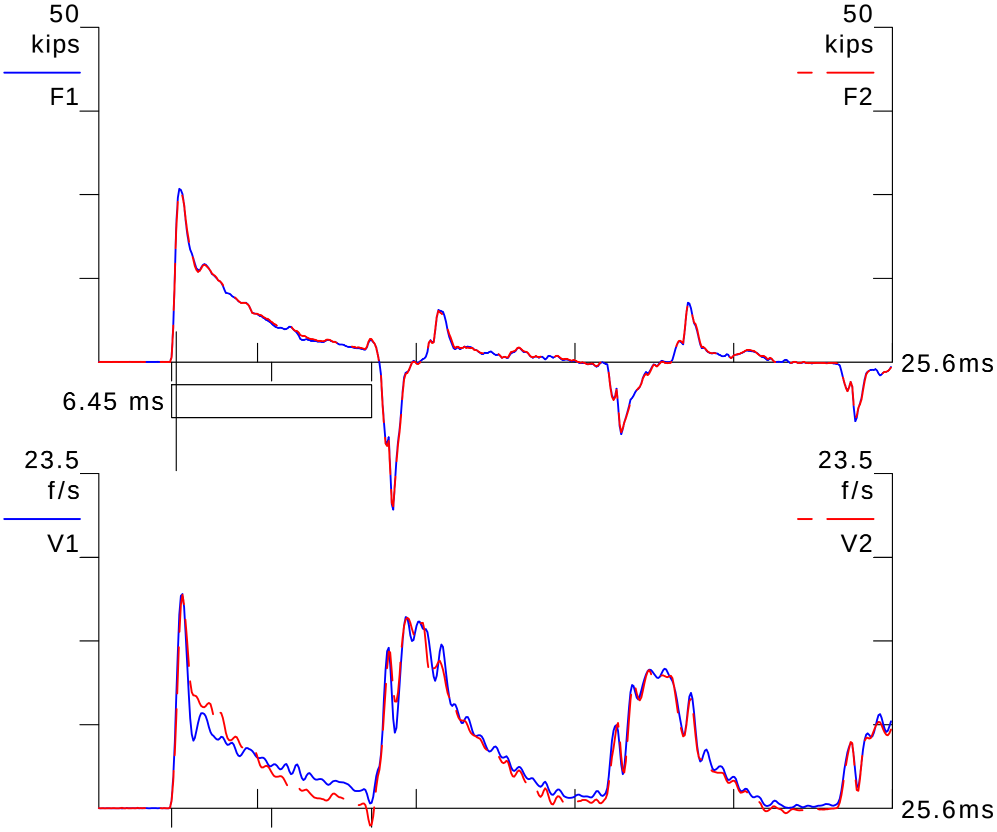
PDA OP: T. Elmore

PILE DRIVING ANALYZER ®

Version 2015.124.002

48.5' - 50'

AW Rod



BN 2

1/1/2001 1:06:14 AM

FMX	26 kips
CSX	21.6 ksi
VMX	15.0 f/s
DMX	1.50 in
DFN	1.50 in
EFV	0.3 k-ft
ETR	84.6 (%)
BPM	54.6 bpm
QNV	0.00 []
LE	54.00 ft
AR	1.19 in^2
EM	30000 ksi
SP	0.492 k/ft3
WS	16807.9 f/s
EA/C	2.1 ksec/ft
LP	48.75 ft

F34 A34

F3: [Bridge1] 208.37 (1)

F4: [Bridge2] 206.78 (1)

A3: [K4975] 325 mv/5000g's (0.92)

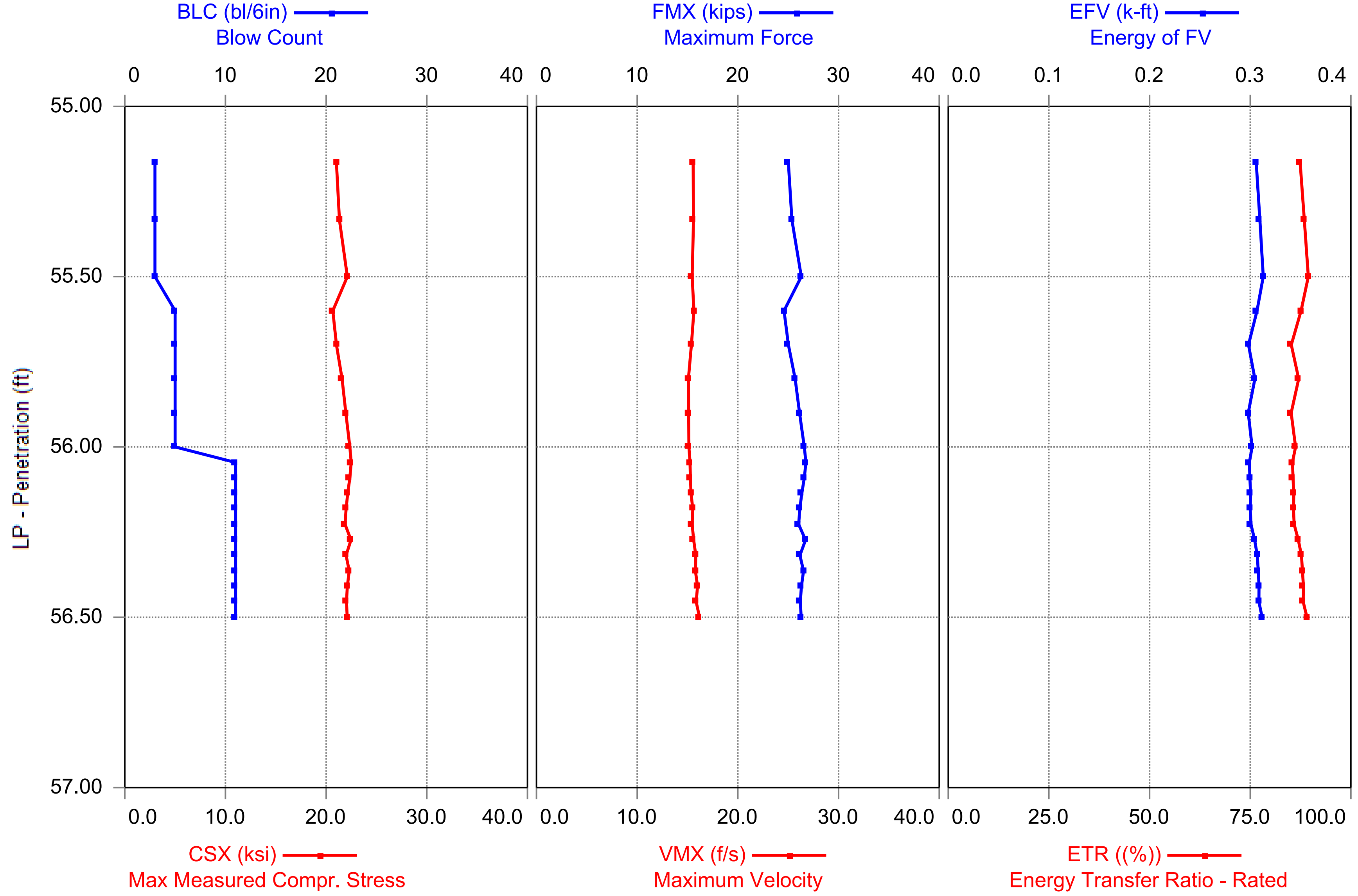
A4: [K609] 322 mv/5000g's (1)

Froehling & Robertson Inc - PDIPLOT2 Ver 2016.1.56.3 - Case Method & iCAP® Results

Printed: 06-September-2016

Test started: 01-January-2001

Fishburne S/N 395465 - 55' - 56.5'



Fishburne S/N 395465 - 55' - 56.5' AW Rod
OP: T. Elmore Date: 01-January-2001

AR: 1.19 in² SP: 0.492 k/ft³
LE: 62.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.60 []

FMX: Maximum Force DFN: Final Displacement
CSX: Max Measured Compr. Stress EFV: Energy of FV
VMX: Maximum Velocity ETR: Energy Transfer Ratio - Rated
DMX: Maximum Displacement BPM: Blows per Minute

BL#	Depth	BLC	FMX	CSX	VMX	DMX	DFN	EFV	ETR	BPM
	ft	bl/6in	kips	ksi	f/s	in	in	k-ft	(%)	bpm
1	55.17	3	25.0	21.0	15.6	2.00	2.00	0.306	87.4	54.2
2	55.33	3	25.4	21.3	15.6	2.00	2.00	0.310	88.4	54.4
3	55.50	3	26.3	22.1	15.5	2.00	2.00	0.313	89.4	54.0
4	55.60	5	24.6	20.7	15.6	1.20	1.20	0.307	87.6	54.6
5	55.70	5	25.0	21.0	15.4	1.20	1.20	0.298	85.2	54.2
6	55.80	5	25.7	21.6	15.1	1.20	1.20	0.305	87.0	54.2
7	55.90	5	26.1	22.0	15.1	1.20	1.20	0.298	85.2	54.4
8	56.00	5	26.6	22.4	15.1	1.20	1.20	0.302	86.2	54.2
9	56.05	11	26.8	22.5	15.3	0.59	0.55	0.299	85.5	54.2
10	56.09	11	26.6	22.3	15.3	0.56	0.55	0.300	85.6	54.2
11	56.14	11	26.3	22.1	15.3	0.55	0.55	0.300	85.8	54.1
12	56.18	11	26.2	22.0	15.5	0.55	0.55	0.300	85.7	54.3
13	56.23	11	26.0	21.9	15.5	0.55	0.55	0.301	85.9	54.2
14	56.27	11	26.7	22.5	15.6	0.56	0.55	0.304	86.9	54.1
15	56.32	11	26.2	22.0	15.8	0.57	0.55	0.307	87.7	54.2
16	56.36	11	26.5	22.3	15.8	0.57	0.55	0.308	88.0	54.1
17	56.41	11	26.3	22.1	16.0	0.57	0.55	0.309	88.2	54.2
18	56.45	11	26.2	22.0	15.9	0.56	0.55	0.309	88.2	54.1
19	56.50	11	26.3	22.1	16.2	0.55	0.55	0.312	89.1	54.0
		Average	26.0	21.9	15.5	0.96	0.95	0.305	87.0	54.2
		Std. Dev.	0.6	0.5	0.3	0.53	0.53	0.005	1.3	0.1
		Maximum	26.8	22.5	16.2	2.00	2.00	0.313	89.4	54.6
		@ Blow#	9	9	19	3	3	3	3	4
		Minimum	24.6	20.7	15.1	0.55	0.55	0.298	85.2	54.0
		@ Blow#	4	4	6	12	9	7	7	3

Total number of blows analyzed: 19

BL#	Sensors
1-19	F3: [Bridge1] 208.4 (1.00); F4: [Bridge2] 206.8 (1.00); A3: [K4975] 325.0 (0.92); A4: [K609] 322.0 (1.00)

Time Summary

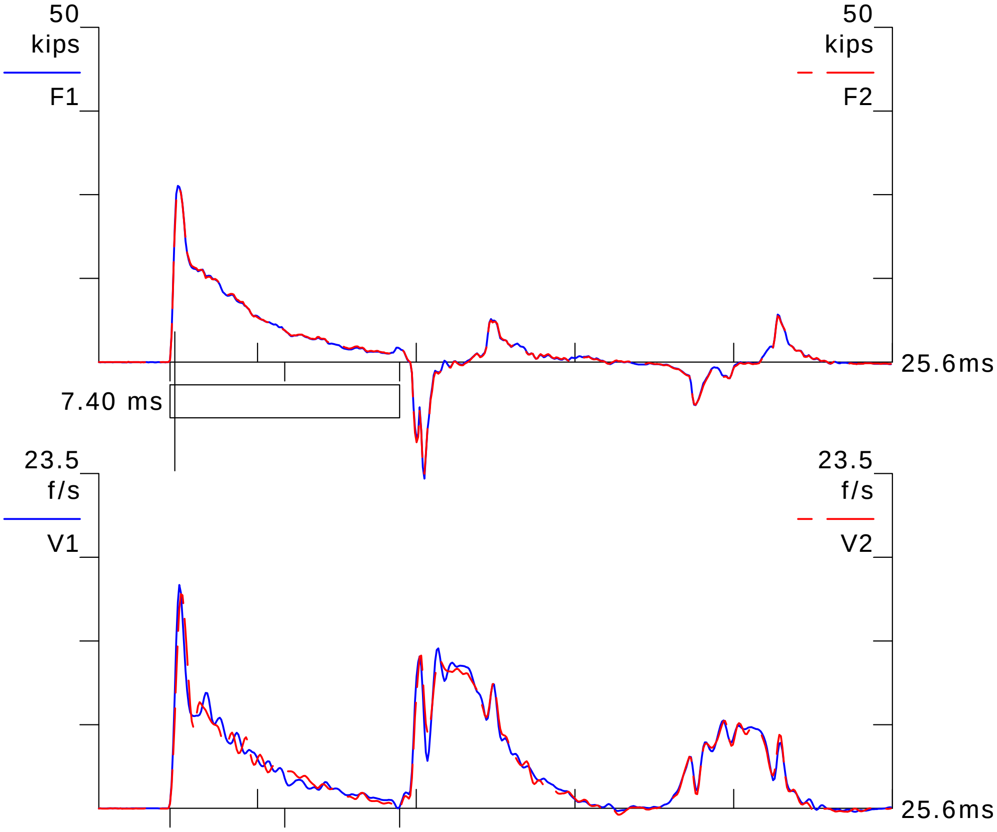
Drive 19 seconds 1:14 AM - 1:14 AM BN 1 - 19

Froehling & Robertson Inc

Fishburne S/N 395465
PDA OP: T. Elmore

PILE DRIVING ANALYZER ®
Version 2015.124.002

55' - 56.5'
AW Rod



BN 7
1/1/2001 1:14:33 AM

FMX	26 kips
CSX	22.0 ksi
VMX	15.1 f/s
DMX	1.20 in
DFN	1.20 in
EFV	0.3 k-ft
ETR	85.2 (%)
BPM	54.4 bpm
QNV	0.00 []

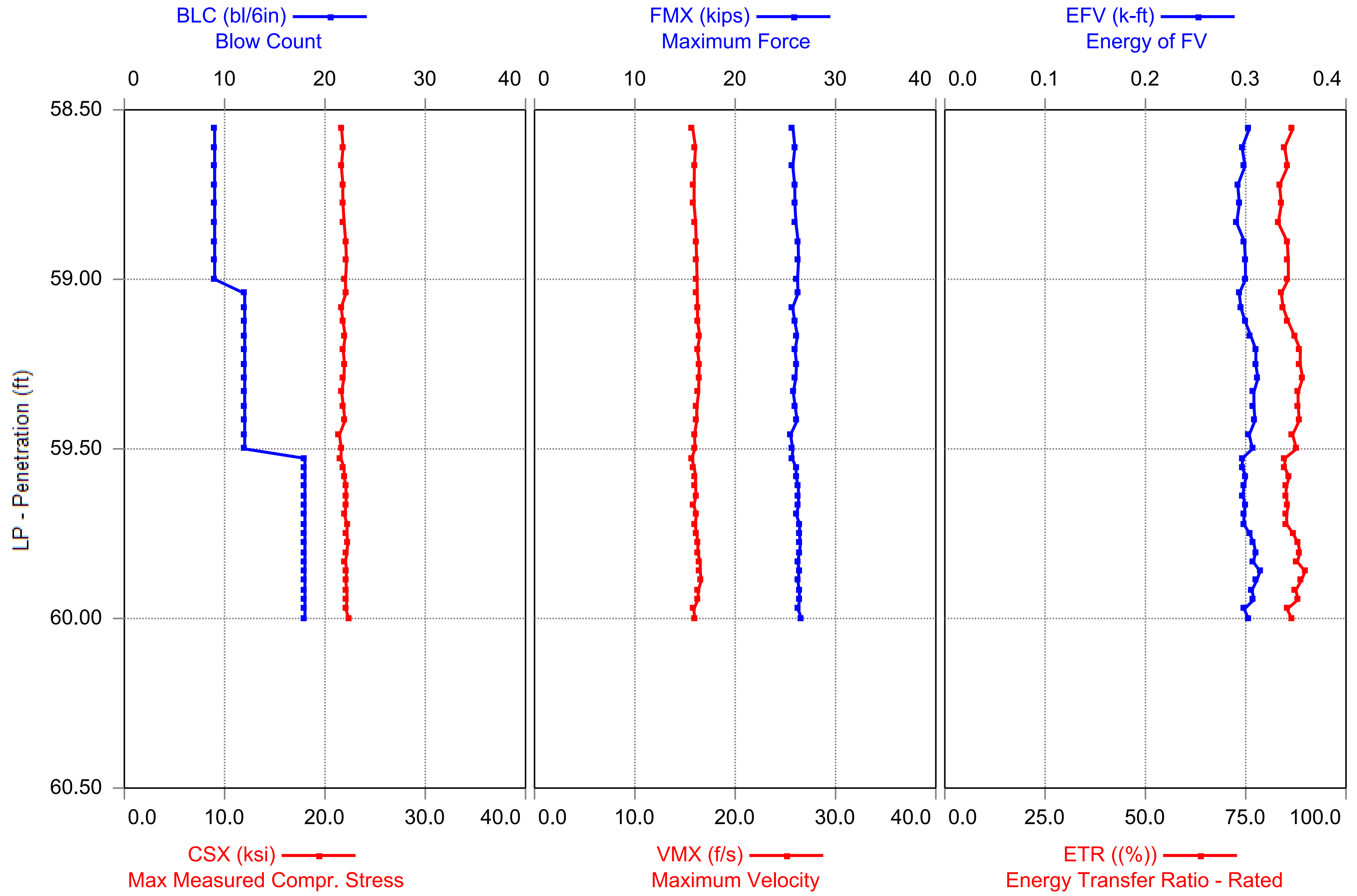
LE	62.00 ft
AR	1.19 in^2
EM	30000 ksi
SP	0.492 k/ft3
WS	16807.9 f/s
EA/C	2.1 ksec/ft
LP	55.90 ft

F34 A34

F3: [Bridge1] 208.37 (1)
F4: [Bridge2] 206.78 (1)
A3: [K4975] 325 mv/5000g's (0.92)
A4: [K609] 322 mv/5000g's (1)

Froehling & Robertson Inc - PDIPLOT2 Ver 2016.1.56.3 - Case Method & iCAP® Results
Printed: 06-September-2016
Test started: 01-January-2001

Fishburne S/N 395465 - 58.5' - 60'



Fishburne S/N 395465 - 58.5' - 60' AW Rod
OP: T. Elmore Date: 01-January-2001

AR: 1.19 in^2 SP: 0.492 k/ft^3
LE: 64.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.60 []

FMX: Maximum Force
CSX: Max Measured Compr. Stress
VMX: Maximum Velocity
DMX: Maximum Displacement
DFN: Final Displacement
EFV: Energy of FV
ETR: Energy Transfer Ratio - Rated
BPM: Blows per Minute

BL#	Depth ft	BLC bl/6in	FMX kips	CSX ksi	VMX f/s	DMX in	DFN in	EFV k-ft	ETR (%)	BPM bpm
1	58.56	9	25.8	21.7	15.8	0.69	0.67	0.304	86.8	54.4
2	58.61	9	26.0	21.8	16.0	0.67	0.66	0.296	84.7	54.4
3	58.67	9	25.7	21.6	15.9	0.70	0.67	0.299	85.5	54.3
4	58.72	9	25.9	21.8	15.9	0.70	0.67	0.292	83.4	54.3
5	58.78	9	25.9	21.8	15.9	0.69	0.67	0.294	83.9	54.5
6	58.83	9	26.0	21.9	16.1	0.68	0.66	0.291	83.1	54.1
7	58.89	9	26.3	22.1	16.1	0.67	0.67	0.299	85.3	54.4
8	58.94	9	26.3	22.1	16.2	0.67	0.67	0.300	85.6	54.2
9	59.00	9	26.2	22.0	16.2	0.67	0.67	0.300	85.6	54.2
10	59.04	12	26.3	22.1	16.2	0.53	0.50	0.294	83.9	54.2
11	59.08	12	25.7	21.6	16.2	0.53	0.50	0.295	84.3	54.3
12	59.13	12	25.9	21.8	16.3	0.53	0.50	0.300	85.6	54.1
13	59.17	12	26.2	22.0	16.5	0.54	0.50	0.305	87.2	54.2
14	59.21	12	26.0	21.8	16.2	0.55	0.50	0.310	88.6	54.2
15	59.25	12	26.1	21.9	16.4	0.55	0.50	0.310	88.5	54.2
16	59.29	12	26.0	21.9	16.4	0.54	0.50	0.312	89.2	54.2
17	59.33	12	25.8	21.7	16.4	0.51	0.50	0.308	88.0	54.2
18	59.38	12	26.0	21.8	16.2	0.50	0.50	0.308	88.1	54.1
19	59.42	12	26.2	22.0	16.2	0.50	0.50	0.309	88.3	54.2
20	59.46	12	25.5	21.4	15.9	0.50	0.50	0.303	86.7	54.2
21	59.50	12	25.7	21.6	16.0	0.51	0.50	0.307	87.6	54.1
22	59.53	18	25.7	21.6	15.7	0.49	0.33	0.297	84.7	54.2
23	59.56	18	26.1	21.9	15.9	0.47	0.33	0.297	84.7	54.1
24	59.58	18	26.1	21.9	16.0	0.49	0.33	0.300	85.8	54.2
25	59.61	18	26.3	22.1	16.1	0.48	0.33	0.298	85.1	54.2
26	59.64	18	26.3	22.1	16.1	0.47	0.33	0.297	85.0	54.2
27	59.67	18	26.3	22.1	15.9	0.48	0.33	0.300	85.6	54.0
28	59.69	18	26.1	21.9	16.1	0.47	0.33	0.298	85.2	54.2
29	59.72	18	26.4	22.2	16.0	0.45	0.33	0.298	85.2	54.2
30	59.75	18	26.4	22.2	16.2	0.47	0.33	0.304	86.8	54.0
31	59.78	18	26.5	22.3	16.3	0.48	0.33	0.308	88.0	54.1
32	59.81	18	26.4	22.2	16.3	0.46	0.33	0.310	88.5	54.2
33	59.83	18	26.2	22.1	16.5	0.45	0.33	0.308	87.9	54.1
34	59.86	18	26.4	22.2	16.5	0.45	0.33	0.314	89.8	54.1
35	59.89	18	26.3	22.1	16.6	0.44	0.33	0.311	88.8	54.1
36	59.92	18	26.4	22.2	16.3	0.42	0.33	0.306	87.5	54.1
37	59.94	18	26.4	22.2	16.3	0.43	0.33	0.308	88.0	53.9
38	59.97	18	26.3	22.1	15.9	0.40	0.33	0.298	85.3	54.2
39	60.00	18	26.6	22.4	16.0	0.41	0.33	0.303	86.5	53.8
		Average	26.1	22.0	16.1	0.53	0.46	0.302	86.4	54.2
		Std. Dev.	0.3	0.2	0.2	0.09	0.13	0.006	1.7	0.1
		Maximum	26.6	22.4	16.6	0.70	0.67	0.314	89.8	54.5
		@ Blow#	39	39	35	3	7	34	34	5
		Minimum	25.5	21.4	15.7	0.40	0.33	0.291	83.1	53.8
		@ Blow#	20	20	22	38	22	6	6	39

Total number of blows analyzed: 39

Fishburne S/N 395465 - 58.5' - 60'
OP: T. Elmore

AW Rod
Date: 01-January-2001

BL#	Depth ft	BLC bl/6in	FMX kips	CSX ksi	VMX f/s	DMX in	DFN in	EFV k-ft	ETR (%)	BPM bpm

BL#	Sensors
1-39	F3: [Bridge1] 208.4 (1.00); F4: [Bridge2] 206.8 (1.00); A3: [K4975] 325.0 (0.92); A4: [K609] 322.0 (1.00)

Time Summary

Drive 42 seconds 1:28 AM - 1:28 AM BN 1 - 39

Froehling & Robertson Inc

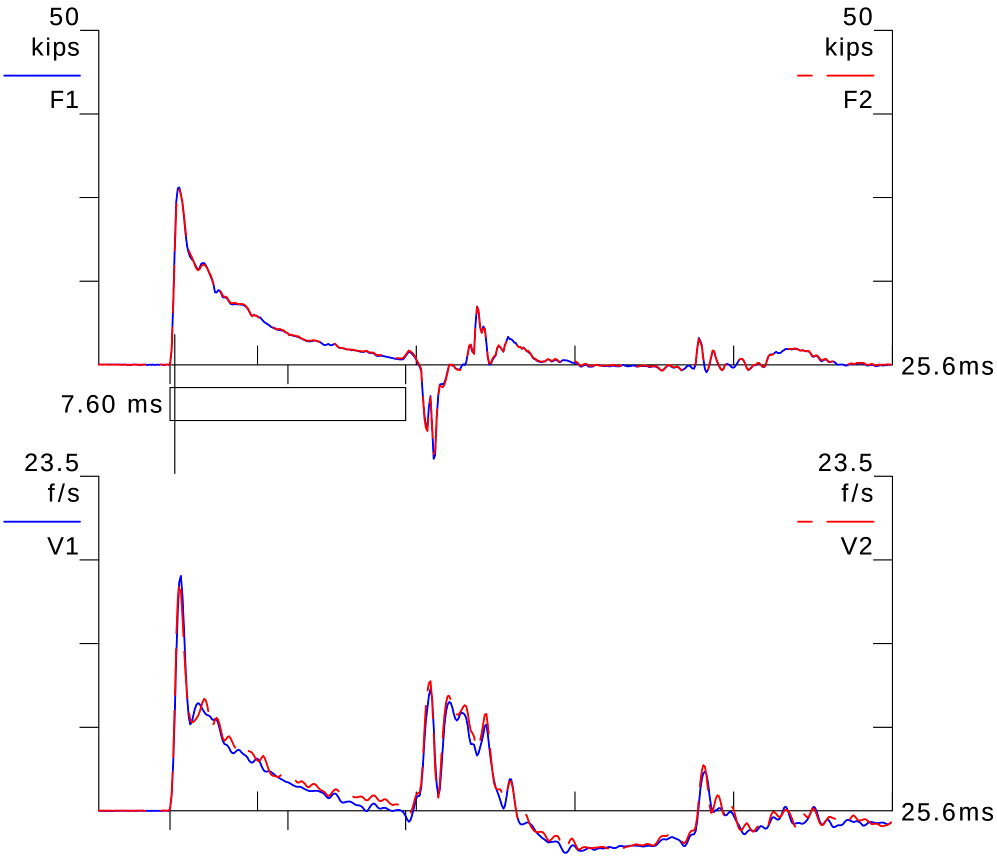
Fishburne S/N 395465

PDA OP: T. Elmore

PILE DRIVING ANALYZER ®
Version 2015.124.002

58.5' - 60'

AW Rod



BN	30
1/1/2001 1:28:45 AM	
FMX	26 kips
CSX	22.2 ksi
VMX	16.2 f/s
DMX	0.47 in
DFN	0.33 in
EFV	0.3 k-ft
ETR	86.8 (%)
BPM	54.0 bpm
QNV	0.00 []
LE	64.00 ft
AR	1.19 in^2
EM	30000 ksi
SP	0.492 k/ft3
WS	16807.9 f/s
EA/C	2.1 ksec/ft
LP	59.75 ft

F34 A34

F3: [Bridge1] 208.37 (1)
F4: [Bridge2] 206.78 (1)
A3: [K4975] 325 mv/5000g's (0.92)
A4: [K609] 322 mv/5000g's (1)

APPENDIX II

PDA and Gage Calibration Data

Certificate of Calibration

Pile Dynamics, Inc. certifies that the

Pile Driving Analyzer®, Model PAK

Serial Number: 1721K

was calibrated on 14 July 2015
using a PDA Calibration Box whose output was calibrated with test equipment traceable to NIST.
This certificate is valid for 2 years from above date.

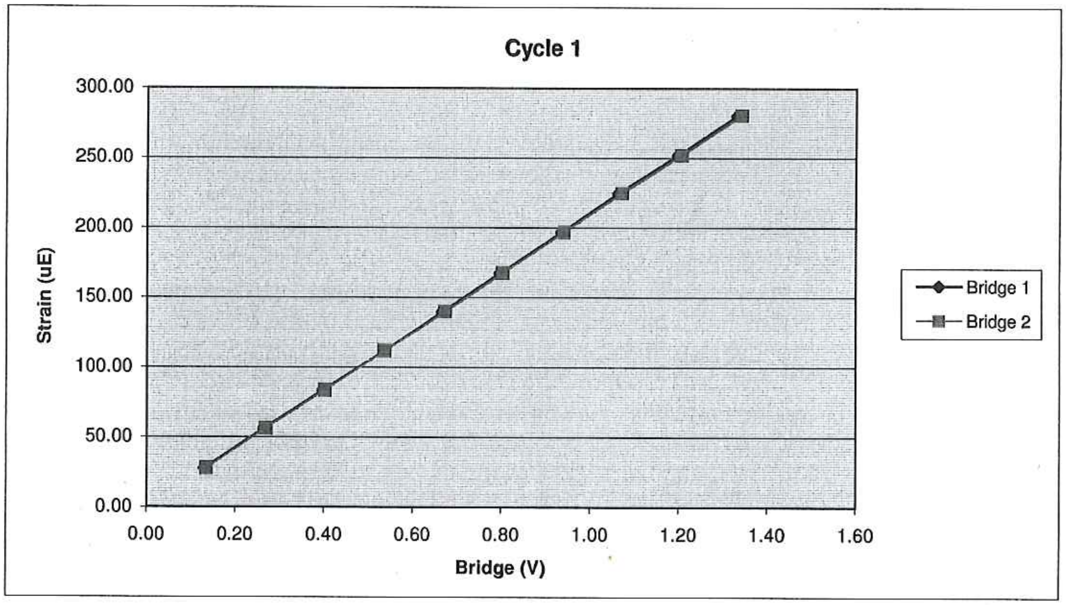
Tested by:

Pile Dynamics, Inc.
30725 Aurora Road
Cleveland, Ohio 44139 USA

304AWJ		Cycle 1		
Sample	**Force (lb)**	**Strain (µE)**	**Bridge 1 (V)**	**Bridge 2 (V)**
1	0.00	0.00	0.00	0.00
2	984.73	27.66	0.13	0.14
3	1973.79	56.16	0.27	0.27
4	2960.88	83.75	0.40	0.40
5	3964.73	111.66	0.54	0.54
6	4977.85	139.71	0.67	0.67
7	5934.19	167.14	0.80	0.80
8	6964.85	196.64	0.94	0.94
9	7930.06	224.60	1.07	1.07
10	8916.96	252.12	1.20	1.21
11	9922.97	280.45	1.33	1.34

Bridge 1		**Bridge 2**	
Force Calibration (lb/V)	**7451.08**	**Force Calibration (lb/V)**	**7409.75**
Offset	-8.56	Offset	-18.01
Correlation	0.999995	Correlation	0.999999
Strain Calibration (µE/V)	**210.70**	**Strain Calibration (µE/V)**	**209.54**
Offset	-0.46	Offset	-0.73
Correlation	0.999980	Correlation	0.999987

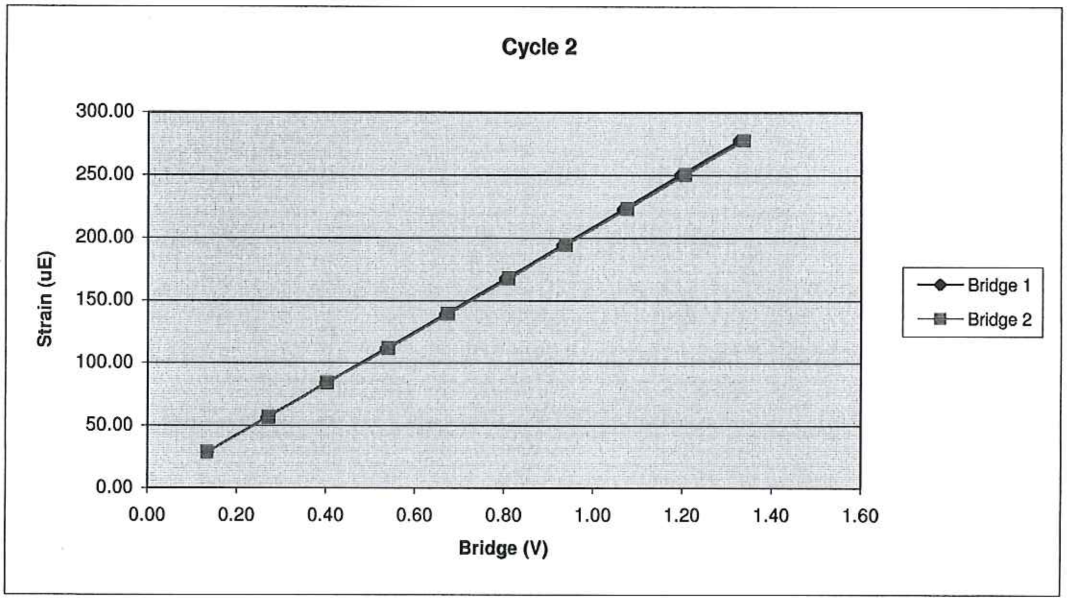
Force Strain Calibration	
EA (Kips)	**35361.78**
Offset	7.80
Correlation	0.999987



304AWJ		Cycle 2		
Sample	**Force (lb)**	**Strain (µE)**	**Bridge 1 (V)**	**Bridge 2 (V)**
1	0.00	0.00	0.00	0.00
2	1003.85	28.65	0.13	0.13
3	2006.52	56.65	0.27	0.27
4	2984.74	84.12	0.40	0.40
5	3985.83	111.76	0.53	0.54
6	4981.00	139.42	0.67	0.67
7	5986.04	167.50	0.80	0.81
8	6934.49	194.59	0.93	0.94
9	7950.37	223.12	1.07	1.08
10	8921.49	250.14	1.20	1.21
11	9907.20	277.66	1.33	1.34

Bridge 1		**Bridge 2**	
Force Calibration (lb/V)	**7460.29**	**Force Calibration (lb/V)**	**7395.71**
Offset	**-3.97**	Offset	**1.79**
Correlation	**0.999997**	Correlation	**0.999998**
Strain Calibration (µE/V)	**208.75**	**Strain Calibration (µE/V)**	**206.95**
Offset	**0.30**	Offset	**0.46**
Correlation	**0.999993**	Correlation	**0.999991**

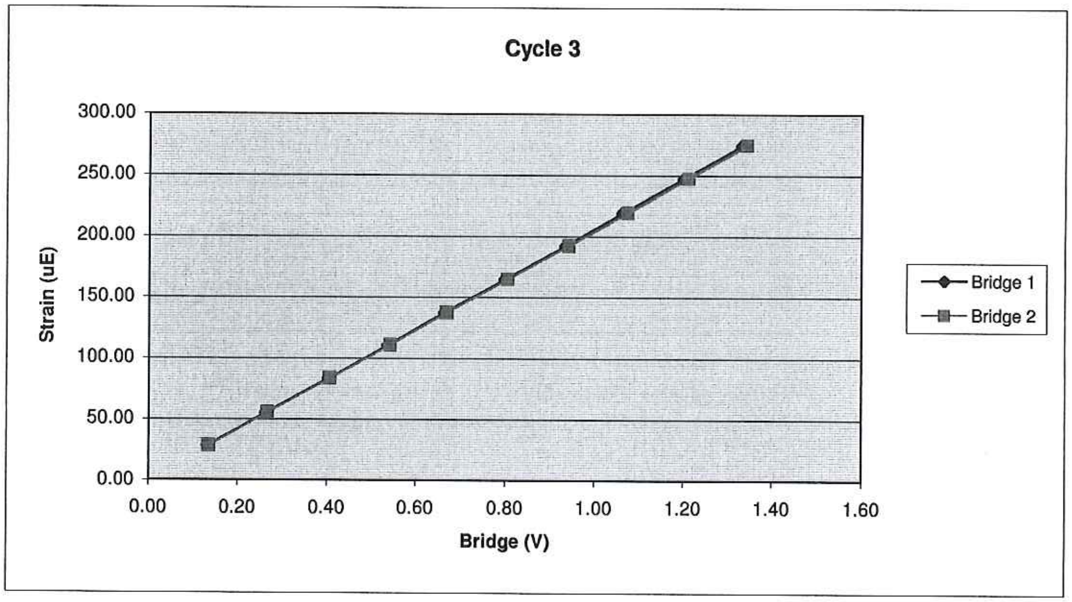
Force Strain Calibration	
EA (Kips)	**35737.08**
Offset	**-14.53**
Correlation	**0.999996**



304AWJ		Cycle 3		
Sample	**Force (lb)**	**Strain (µE)**	**Bridge 1 (V)**	**Bridge 2 (V)**
1	0.00	0.00	0.00	0.00
2	996.36	27.95	0.13	0.13
3	1979.51	55.44	0.26	0.27
4	3012.14	83.49	0.40	0.41
5	4000.81	110.68	0.54	0.54
6	4960.50	137.30	0.66	0.67
7	5960.21	164.83	0.80	0.81
8	6964.46	192.48	0.93	0.94
9	7937.95	219.52	1.06	1.07
10	8965.26	247.46	1.20	1.21
11	9939.34	274.64	1.33	1.34

Bridge 1		**Bridge 2**	
Force Calibration (lb/V)	**7461.73**	**Force Calibration (lb/V)**	**7396.50**
Offset	**0.69**	Offset	**2.25**
Correlation	**0.999997**	Correlation	**0.999998**
Strain Calibration (µE/V)	**205.65**	**Strain Calibration (µE/V)**	**203.85**
Offset	**0.59**	Offset	**0.64**
Correlation	**0.999993**	Correlation	**0.999997**

Force Strain Calibration	
EA (Kips)	**36283.40**
Offset	**-20.85**
Correlation	**0.999998**



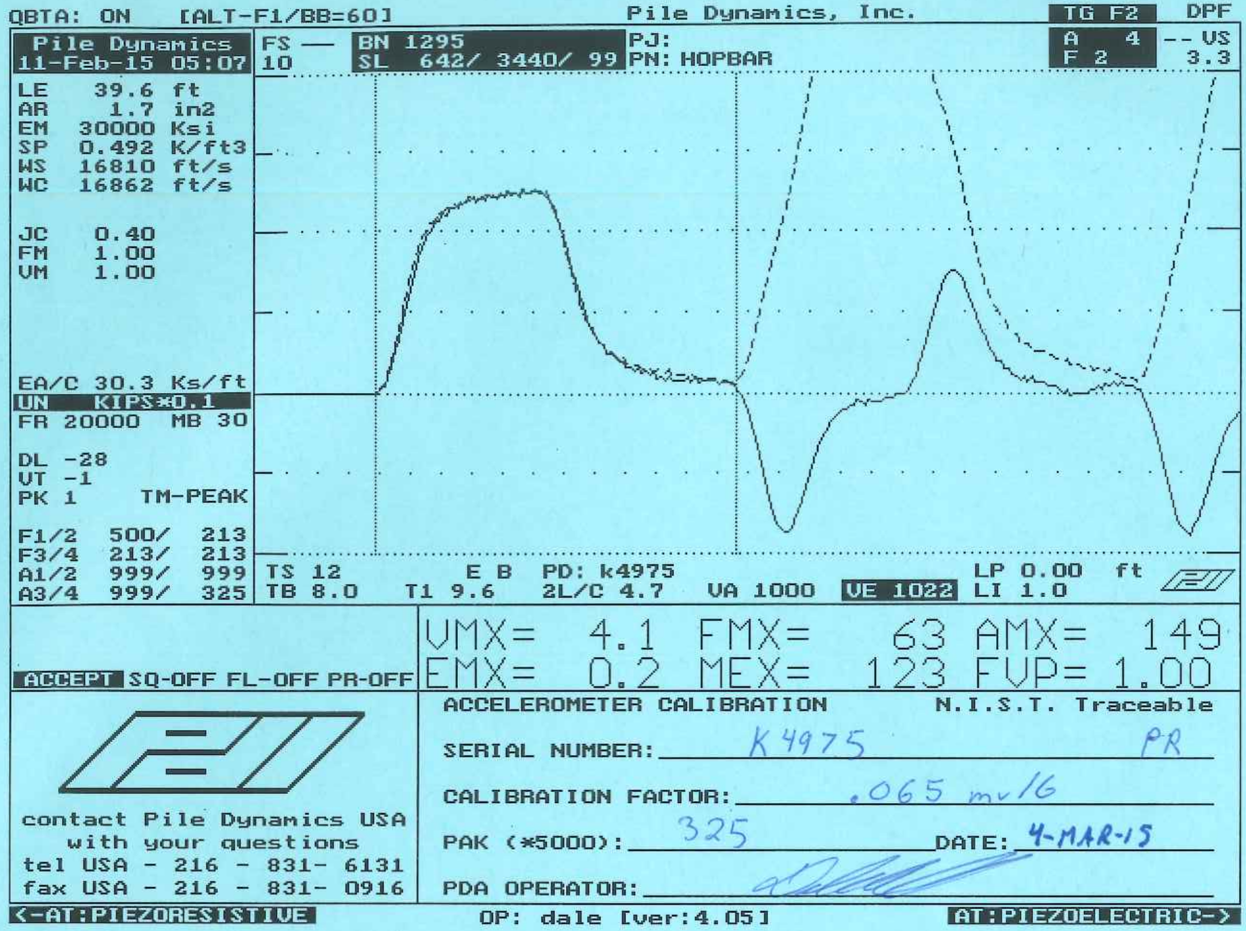
Bridge Excitation (V) 5
Shunt Resitor (ohm) 60.4k

Calibration Factors	**304AWJ**		
Bridge 1 (µE/V)	**208.37**	**Bridge 2 (µE/V)**	**206.78**
EA Factor (Kips)	**35794.09**	**Area (in^2)**	**1.19**

Calibrated by: ____________________
Calibrated Date: 4/14/2015

Pile Dynamics Inc
30725 Aurora Rd
Solon, OH 44139

Traceable to N.I.S.T.



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QBTA: ON    [ALT-F1/BB=60]                    Pile Dynamics, Inc.                TG F2    DPF
Pile Dynamics      FS --  BN 1295              PJ:                               A    4   -- VS
11-Feb-15 05:07    10     SL  642/ 3440/ 99    PN: HOPBAR                        F 2         3.3
LE     39.6  ft
AR      1.7  in2
EM    30000  Ksi
SP    0.492  K/ft3
WS    16810  ft/s
WC    16862  ft/s

JC     0.40
FM     1.00
VM     1.00

EA/C 30.3 Ks/ft
UN    KIPS*0.1
FR 20000    MB 30

DL -28
VT -1
PK 1       TM-PEAK

F1/2   500/   213
F3/4   213/   213
A1/2   999/   999  TS 12        E B   PD: k4975                    LP 0.00   ft
A3/4   999/   325  TB 8.0   T1 9.6    2L/C 4.7    VA 1000  VE 1022  LI 1.0

                                  VMX=  4.1   FMX=    63  AMX=  149
ACCEPT SQ-OFF FL-OFF PR-OFF       EMX=  0.2   MEX=   123  FVP= 1.00
```

ACCELEROMETER CALIBRATION N.I.S.T. Traceable

SERIAL NUMBER: K4975 PR

CALIBRATION FACTOR: .065 mv/G

PAK (*5000): 325 DATE: 4-MAR-15

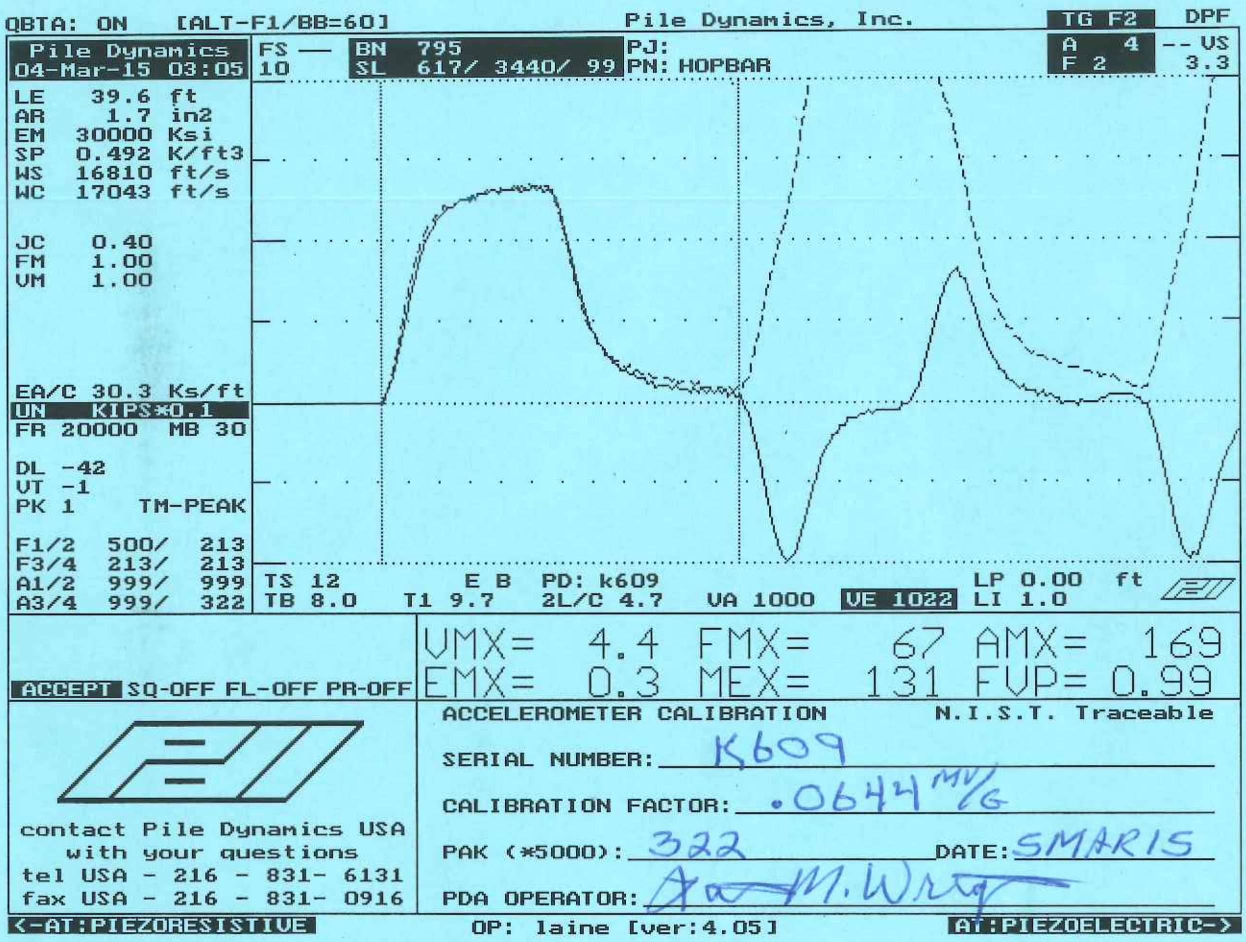
PDA OPERATOR: D

contact Pile Dynamics USA
with your questions
tel USA - 216 - 831- 6131
fax USA - 216 - 831- 0916

<-AT:PIEZORESISTIVE   OP: dale [ver:4.05]   AT:PIEZOELECTRIC->

Smart Sensor

Smart Chip Programmed By DB **on** 4-MAR-15 **CRC Value** 6770



```
QBTA: ON    [ALT-F1/BB=60]                Pile Dynamics, Inc.          TG F2   DPF
 Pile Dynamics   FS ——  BN  795              PJ:                         A   4  -- VS
04-Mar-15 03:05  10     SL  617/ 3440/ 99    PN: HOPBAR                  F 2        3.3
LE    39.6 ft
AR     1.7 in2
EM   30000 Ksi
SP   0.492 K/ft3
WS   16810 ft/s
WC   17043 ft/s

JC    0.40
FM    1.00
VM    1.00

EA/C 30.3 Ks/ft
UN    KIPS*0.1
FR 20000   MB 30

DL -42
VT -1
PK 1     TM-PEAK

F1/2  500/  213
F3/4  213/  213
A1/2  999/  999  TS 12        E B   PD: k609              LP 0.00  ft
A3/4  999/  322  TB 8.0   T1 9.7    2L/C 4.7   VA 1000  VE 1022  LI 1.0
                               VMX=  4.4  FMX=    67  AMX=  169
ACCEPT SQ-OFF FL-OFF PR-OFF    EMX=  0.3  MEX=   131  FVP= 0.99
                               ACCELEROMETER CALIBRATION      N.I.S.T. Traceable

                               SERIAL NUMBER: K609

                               CALIBRATION FACTOR: .0644 MV/G
contact Pile Dynamics USA
  with your questions          PAK (*5000): 322           DATE: 5MAR15
tel USA - 216 - 831- 6131
fax USA - 216 - 831- 0916      PDA OPERATOR: A M. Wrig
<-AT:PIEZORESISTIVE                OP: laine [ver:4.05]          AT:PIEZOELECTRIC->
```

Smart Sensor

Smart Chip Programmed By A.M.W. **on** 5MAR15 **CRC Value** 8F99

APPENDIX E

SUMMARY OF SPT CORRELATIONS, INDEX TEST ON SOIL

Summary of SPT Correlations

Atlantic Coast Pipeline - Horizontal Directionally Drilling - Route 58

Borehole ID	Sample Depth (ft)	Sample Elevation (msl) (ft)	Strata	Soil Classification	Rig ID	Hammer Energy Efficiency (%)	N-Value (blows/ft)	N_{60}-Value (blows/ft)	Effective Vertical Stress, σ'_{vo} (psf)	C_N	$N_{1,60}$-Value (blows/ft)	Friction Angle, ϕ' (degrees)	Sands with Fines $E = 5N_{60}p_{atm}$ (Callanan and Kulhawy, 1985) (ksf)	Relative Density	Undrained Shear Strength $s_u = 0.06N_{60}p_{atm}$ (Terzaghi and Peck, 1967) (ksf)	Undrained Young's Modulus $E_{us} = 500s_u$ (ksf)	Consistency
RT58 B-1	1.0	+27.9	Fill	SC	CME 55	86.3	11	16	115	1.70	27	35.4	167	Medium			
RT58 B-1	3.0	+25.9	Fill	SC	CME 55	86.3	15	22	345	1.70	37	38.1	228	Medium			
RT58 B-1	5.0	+23.9	Fill	SC	CME 55	86.3	6	9	575	1.70	15	31.7	91	Loose			
RT58 B-1	7.0	+21.9	Marsh Deposits	SC	CME 55	86.3	8	12	722	1.70	20	33.3	122	Medium			
RT58 B-1	9.0	+19.9	Marsh Deposits	SP	CME 55	86.3	9	13	842	1.59	21	33.6	137	Medium			
RT58 B-1	14.0	+14.9	Marsh Deposits	OH	CME 55	86.3	0	0	1,130	1.37	0				0.00	0	Very Soft
RT58 B-1	19.0	+9.9	Marsh Deposits	SC	CME 55	86.3	1	1	1,378	1.24	2	26.9	15	Very Loose			
RT58 B-1	24.0	+4.9	Marsh Deposits	ML	CME 55	86.3	1	1	1,636	1.14	2				0.18	91	Very Soft
RT58 B-1	29.0	-0.1	Marsh Deposits	OH	CME 55	86.3	2	3	1,864	1.07	3				0.37	183	Soft
RT58 B-1	34.0	-5.1	Marsh Deposits	OH	CME 55	86.3	1	1	2,052	1.02	1				0.18	91	Very Soft
RT58 B-1	39.0	-10.1	Marsh Deposits	SP-SC	CME 55	86.3	6	9	2,313	0.96	8	29.6	91	Loose			
RT58 B-1	44.0	-15.1	Marsh Deposits	SP-SC	CME 55	86.3	9	13	2,576	0.91	12	30.6	137	Medium			
RT58 B-1	49.0	-20.1	Marsh Deposits	SP-SC	CME 55	86.3	6	9	2,839	0.86	7	29.2	91	Loose			
RT58 B-1	54.0	-25.1	Marine Deposits	SP	CME 55	86.3	29	42	3,112	0.82	34	37.6	441	Dense			
RT58 B-1	59.0	-30.1	Marine Deposits	SM	CME 55	86.3	21	30	3,415	0.79	24	34.6	320	Dense			
RT58 B-1	64.0	-35.1	Marine Deposits	SM	CME 55	86.3	15	22	3,678	0.76	16	32.3	228	Medium			
RT58 B-1	69.0	-40.1	Marine Deposits	SM	CME 55	86.3	14	20	3,941	0.73	15	31.7	213	Medium			
RT58 B-1	74.0	-45.1	Marine Deposits	SM	CME 55	86.3	12	17	4,204	0.71	12	31.0	183	Medium			
RT58 B-1	79.0	-50.1	Marine Deposits	SM	CME 55	86.3	9	13	4,467	0.69	9	29.6	137	Medium			
RT58 B-1	84.0	-55.1	Marine Deposits	CL	CME 55	86.3	11	16	4,725	0.67	11				2.01	1,004	Very Stiff
RT58 B-1	89.0	-60.1	Marine Deposits	CL	CME 55	86.3	7	10	4,963	0.65	7				1.28	639	Stiff
RT58 B-1	94.0	-65.1	Marine Deposits	CL	CME 55	86.3	6	9	5,201	0.64	6				1.10	548	Stiff
RT58 B-1	99.0	-70.1	Marine Deposits	CL	CME 55	86.3	6	9	5,439	0.62	5				1.10	548	Stiff
RT58 B-1	104.0	-75.1	Marine Deposits	CL	CME 55	86.3	7	10	5,677	0.61	6				1.28	639	Stiff
RT58 B-1	109.0	-80.1	Marine Deposits	CL	CME 55	86.3	7	10	5,915	0.60	6				1.28	639	Stiff
RT58 B-1	114.0	-85.1	Marine Deposits	CL	CME 55	86.3	17	24	6,153	0.59	14				3.10	1,552	Very Stiff
RT58 B-2	1.0	+24.3	Fill	SM	CME 55	86.3	7	10	115	1.70	17	32.7	107	Medium			
RT58 B-2	3.0	+22.3	Marsh Deposits	CL	CME 55	86.3	4	6	338	1.70	10				0.73	365	Medium
RT58 B-2	5.0	+20.3	Marsh Deposits	CL	CME 55	86.3	4	6	558	1.70	10				0.73	365	Medium
RT58 B-2	7.0	+18.3	Marsh Deposits	SM	CME 55	86.3	8	12	715	1.70	20	33.3	122	Medium			

Summary of SPT Correlations

Atlantic Coast Pipeline - Horizontal Directionally Drilling - Route 58

Borehole ID	Sample Depth (ft)	Sample Elevation (msl) (ft)	Strata	Soil Classification	Rig ID	Hammer Energy Efficiency (%)	N-Value (blows/ft)	N_{60}-Value (blows/ft)	Effective Vertical Stress, σ'_{vo} (psf)	C_N	$N_{1,60}$-Value (blows/ft)	Friction Angle, ϕ' (degrees)	Sands with Fines $E = 5N_{60}p_{atm}$ (Callanan and Kulhawy, 1985) (ksf)	Relative Density	Undrained Shear Strength $s_u = 0.06N_{60}p_{atm}$ (Terzaghi and Peck, 1967) (ksf)	Undrained Young's Modulus $E_{us} = 500s_u$ (ksf)	Consistency
RT58 B-2	9.0	+16.3	Marsh Deposits	SM	CME 55	86.3	0	0	820	1.61	0	26.5	0	Very Dense			
RT58 B-2	14.0	+11.3	Marsh Deposits	SM	CME 55	86.3	2	3	1,083	1.40	4	28.1	30	Very Loose			
RT58 B-2	19.0	+6.3	Marsh Deposits	SM	CME 55	86.3	2	3	1,346	1.25	4	27.7	30	Very Loose			
RT58 B-2	24.0	+1.3	Marsh Deposits	OH	CME 55	86.3	0	0	1,536	1.17	0				0.00	0	Very Soft
RT58 B-2	29.0	-3.7	Marsh Deposits	OH	CME 55	86.3	1	1	1,724	1.11	2				0.18	91	Very Soft
RT58 B-2	34.0	-8.7	Marsh Deposits	ML	CME 55	86.3	2	3	1,915	1.05	3				0.37	183	Soft
RT58 B-2	39.0	-13.7	Marsh Deposits	SM	CME 55	86.3	18	26	2,158	0.99	26	35.2	274	Medium			
RT58 B-2	44.0	-18.7	Marsh Deposits	OH	CME 55	86.3	2	3	2,406	0.94	3				0.37	183	Soft
RT58 B-2	49.0	-23.7	Marsh Deposits	OH	CME 55	86.3	2	3	2,594	0.90	3				0.37	183	Soft
RT58 B-2	54.0	-28.7	Marine Deposits	SM	CME 55	86.3	9	13	2,855	0.86	11	30.6	137	Medium			
RT58 B-2	59.0	-33.7	Marine Deposits	SM	CME 55	86.3	26	37	3,118	0.82	31	36.6	396	Dense			
RT58 B-2	64.0	-38.7	Marine Deposits	SM	CME 55	86.3	18	26	3,381	0.79	20	33.6	274	Medium			
RT58 B-2	69.0	-43.7	Marine Deposits	SM	CME 55	86.3	16	23	3,644	0.76	18	32.7	244	Medium			
RT58 B-2	74.0	-48.7	Marine Deposits	SM	CME 55	86.3	10	14	3,907	0.74	11	30.3	152	Medium			
RT58 B-2	79.0	-53.7	Marine Deposits	SM	CME 55	86.3	8	12	4,170	0.71	8	29.6	122	Medium			
RT58 B-2	84.0	-58.7	Marine Deposits	SC	CME 55	86.3	4	6	4,433	0.69	4	27.7	61	Loose			
RT58 B-2	89.0	-63.7	Marine Deposits	SM	CME 55	86.3	6	9	4,696	0.67	6	28.5	91	Loose			
RT58 B-2	94.0	-68.7	Marine Deposits	SM	CME 55	86.3	6	9	4,959	0.65	6	28.5	91	Loose			
RT58 B-2	99.0	-73.7	Marine Deposits	CL	CME 55	86.3	6	9	5,217	0.64	5				1.10	548	Stiff
RT58 B-2	104.0	-78.7	Marine Deposits	SM	CME 55	86.3	7	10	5,460	0.62	6	28.8	107	Medium			
RT58 B-2	109.0	-83.7	Marine Deposits	SM	CME 55	86.3	9	13	5,723	0.61	8	29.2	137	Medium			
RT58 B-2	114.0	-88.7	Marine Deposits	SM	CME 55	86.3	12	17	5,986	0.59	10	30.3	183	Medium			

Summary of Laboratory Test Results on Soil Samples

Atlantic Coast Pipeline - Horizontal Directionally Drilling - Route 58

Borehole ID	Sample Depth (ft)	Sample Elevation (msl) (ft)	Strata	USCS Soil Symbol	USCS Soil Name	Total Unit Weight, γ_t (pcf)	Moisture Content, w_o (%)	Liquid Limit, w_l (%)	Plastic Limit, w_p (%)	Plasticity Index, I_p (%)	Liquidity Index, I_L	Percent Gravel (%)	Percent Sand (%)	Percent Fines (%)	Clay Fraction (%)	Coefficient of Uniformity, Cu (%)	Coefficient of Curvature, Cc (%)
RT58 B-1	5.0	+23.9	Fill	SC	Clayey sand		32.0	34.0	22.0	12.0	0.83	0.0	53.0	47.0	17.6	66.76	0.92
RT58 B-1	14.0	+14.9	Marsh Deposits	OH	Sandy organic clay		60.0	59.0	20.0	39.0	1.03	0.0	31.0	69.0	36.5		
RT58 B-1	16.0	+12.9	Marsh Deposits	SC	Clayey sand		40.0	30.0	14.0	16.0	1.63	0.0	67.0	33.0	15.8		
RT58 B-1	16.0	+12.9	Marsh Deposits	SC	Clayey sand	107.5	49.8										
RT58 B-1	16.0	+12.9	Marsh Deposits	SC	Clayey sand	108.6	39.8										
RT58 B-1	16.0	+12.9	Marsh Deposits	SC	Clayey sand	112.4	32.0										
RT58 B-1	19.0	+9.9	Marsh Deposits	SC	Clayey sand		37.0	26.0	14.0	12.0	1.92	0.0	79.0	21.0	13.4	110.80	36.24
RT58 B-1	34.0	-5.1	Marsh Deposits	OH	Fat clay		81.0	77.0	24.0	53.0	1.08	0.0	2.0	98.0	59.7		
RT58 B-1	74.0	-45.1	Marine Deposits	SM	Silty sand		36.0	NP	NP	NP	NP	0.0	68.0	32.0	14.4	97.38	13.80
RT58 B-1	104.0	-75.1	Marine Deposits	CL	Sandy lean clay		36.0	44.0	26.0	18.0	0.56	0.0	44.0	56.0	17.5		
RT58 B-2	3.0	+22.3	Marsh Deposits	CL	Sandy lean clay		21.0	28.0	15.0	13.0	0.46	0.0	48.0	52.0	28.7		
RT58 B-2	9.0	+16.3	Marsh Deposits	SM	Silty sand		35.0	NP	NP	NP	NP	0.0	73.0	27.0	15.4	75.90	29.49
RT58 B-2	14.0	+11.3	Marsh Deposits	SM	Silty sand		30.6					0.0	86.0	14.0			
RT58 B-2	31.0	-5.7	Marsh Deposits	OH	Organic clay with sand		57.0	77.0	24.0	53.0	0.62	0.0	19.0	81.0	37.3		
RT58 B-2	31.0	-5.7	Marsh Deposits	OH	Organic clay with sand	95.6	79.8										
RT58 B-2	31.0	-5.7	Marsh Deposits	OH	Organic clay with sand	96.2	77.8										
RT58 B-2	31.0	-5.7	Marsh Deposits	OH	Organic clay with sand	104.2	42.0										
RT58 B-2	46.0	-20.7	Marsh Deposits	OH	Organic clay with sand		64.0	82.0	29.0	53.0	0.66	0.0	24.0	76.0	47.0		
RT58 B-2	46.0	-20.7	Marsh Deposits	OH	Organic clay with sand	101.8	60.8										
RT58 B-2	46.0	-20.7	Marsh Deposits	OH	Organic clay with sand	97.6	65.1										
RT58 B-2	46.0	-20.7	Marsh Deposits	OH	Organic clay with sand	97.5	66.1										
RT58 B-2	59.0	-33.7	Marine Deposits	SM	Silty sand		29.0	NP	NP	NP	NP	0.0	82.0	18.0	8.2	22.49	7.53
RT58 B-2	84.0	-58.7	Marine Deposits	SC	Clayey sand		32.0	36.0	23.0	13.0	0.69	0.0	52.0	48.0	14.5	48.22	1.60
RT58 B-2	99.0	-73.7	Marine Deposits	CL	Sandy lean clay		37.0	46.0	23.0	23.0	0.61	0.0	44.0	56.0	18.8	57.99	1.80
RT58 B-2	114.0	-88.7	Marine Deposits	SM	Silty sand		35.0	NP	NP	NP	NP	0.0	64.0	36.0	15.6	101.58	8.62

J.D.Hair&Associates,Inc.

COMMONWEALTH OF VIRGINIA
JEFFREY SCOTT PUCKETT
Lic. No. 0402055955
PROFESSIONAL ENGINEER

4/6/2017

MEMORANDUM

DATE: April 6, 2017
TO: Ron Baker
FROM: Jeff Puckett
SUBJECT: Route 58 HDD Crossing Assessment
FILE: Dominion\1508-Atlantic Coast\Deliverable

Assessment of Technical Feasibility

The proposed HDD crossing of Route 58 has a horizontal drilled length of 2,598 feet and an outside diameter of 20 inches. This combination of length and diameter falls well within the limits of current HDD industry capabilities. The geotechnical site investigation report produced by Geosyntec presents the results of two exploratory borings conducted at the Route 58 crossing site. In general, the geotechnical investigation found that the proposed HDD crossing is anticipated to encounter primarily sand with some clay and silt, which are favorable conditions for HDD installation. Based on these considerations, it is our opinion that knowledgeable HDD contractors will submit fixed price, lump sum bids to install the proposed HDD crossing of Route 58 and that the crossing can be completed successfully.

Assessment of the Potential for Hydraulic Fracture

Hydraulic fracture, also known as hydrofracture, is a phenomenon that occurs when drilling fluid pressure in the annular space of the drilled hole exceeds the strength of the surrounding soil mass, resulting in deformation, cracking, and fracturing. The fractures may then serve as flow conduits for drilling fluid allowing the fluid to escape into the formation and possibly up to the ground surface. Drilling fluid that makes its way to the ground surface is known as an inadvertent drilling fluid return or, more commonly, a "frac-out."

Although hydrofracture may be one mechanism by which inadvertent drilling fluid returns occur, it is not the only one. In fact, it is thought that inadvertent returns due to true hydrofracture occur in only a small percentage of cases.[1] Drilling fluid flows in the path of least resistance. Ideally, the path of least resistance is through the annulus of the drilled hole and back to the fluid containment pits at the HDD endpoints. However, the path of least resistance may also be through naturally occurring subsurface features such as fissures in the soil, shrinkage cracks, or porous deposits of gravel. Drilling fluid may also flow to the surface along existing piers, piles, utility poles, or other structures.

The risk of hydrofracture can be determined by comparing the confining capacity of the subsurface (formation limit pressure) to the annular pressure necessary to conduct HDD operations. If the anticipated drilling fluid pressure in the annulus exceeds the estimated

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[1] Bennett, R.D. and K. Wallin. "Step by Step Evaluation of Hydrofracture Risks for HDD Projects." Presentation, North American Society for Trenchless Technology, NoDig Conference, Grapevine, TX, 2008.

formation limit pressure, there is a potential that inadvertent drilling fluid returns will occur as a result of hydrofracture.

The formation limit pressure for the proposed HDD crossing of Route 58 was calculated using the "Delft Method" as described in an Army Corps of Engineers publication titled *Recommended Guidelines for Installation of Pipelines beneath Levees using Horizontal Directional Drilling.*[2] The Delft Method assumes uniform soil conditions in the soil column above the point on the drilled path that is being analyzed and requires engineering judgement with respect to the selection of the geotechnical parameters that are used in the associated equations. The geotechnical parameters used in our analysis were provided by Geosyntec Consultants. The estimated minimum annular pressure necessary for HDD pilot hole operations was calculated using the Bingham Plastic Model, which is described in Chapter 4 of the Society of Petroleum Engineers' *Applied Drilling Engineering*.[3]

The formation limit pressure was calculated over the length of the proposed Route 58 crossing and compared to the estimated annular pressure necessary for HDD operations. A graphical summary of the results for of this analysis is attached to this memorandum. In reviewing this information, it should be noted that a factor of safety has not been applied to the formation limit pressure. As a result, the point at which the estimated annular pressure exceeds the formation limit pressure is the theoretical point at which plastic yielding and cracking reaches the ground surface resulting in an inadvertent drilling fluid return.

Analysis of HDD Installation Loads and Stresses

Calculation of the approximate tensile load required to install a pipeline by HDD is relatively complicated due to the fact that the geometry of the drilled path must be considered along with the properties of the pipe being installed and the subsurface conditions. Assumptions and simplifications are required. A method to accomplish this is presented in *Installation of Pipelines by Horizontal Directional Drilling, An Engineering Design Guide*, published by the Pipeline Research Council International (PRCI).[4]

The PRCI Method involves modeling the drilled path as a series of segments to define its shape and properties during installation. The individual loads acting on each segment are then resolved to determine a resultant tensile load for each segment. The estimated force required to install the entire pull section in the reamed hole is equal to the sum of the tensile loads acting on all of the defined segments. When utilizing the PRCI Method, pulling loads are affected by numerous variables, many of which are dependent upon site-specific conditions and individual contractor practices. These include prereaming diameter, hole stability, removal of cuttings, soil and rock properties, drilling fluid properties, and the effectiveness of buoyancy control measures.[5] It is also important to keep in mind that the PRCI Method considers pulling tension, pipe bending,

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[2] Kimberlie Staheli et al, *Recommended Guidelines for Installation of Pipelines beneath Levees using Horizontal Directional Drilling* (prepared for U.S. Army Corps of Engineers, April 1998).

[3] *Applied Drilling Engineering,* Society of Petroleum Engineers, Richardson, Texas, A. T. Bourgoyne, Jr. [et al], 1991

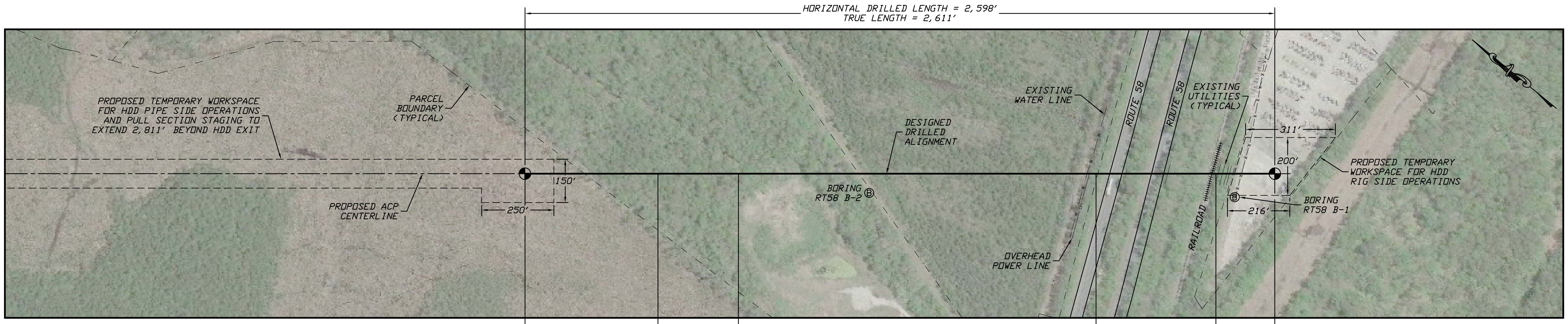
[4] *Installation of Pipelines by Horizontal Directional Drilling, An Engineering Design Guide* (Arlington, VA: Pipeline Research Council International, Inc., 2008), 26-36.

[5] *Manual of Practice No. 108,* 22.

and external pressure. It does not consider point loads that may result from subsurface conditions such as a rock ledge or boulder. Indeed, we know of no way to analyze potential point loads that may develop due to subsurface conditions. Although this type of damage is relatively rare, several cases have been observed in the last few years where pipelines suffered damage in the form of dents or pipe deformation due to point loads encountered during HDD installation.

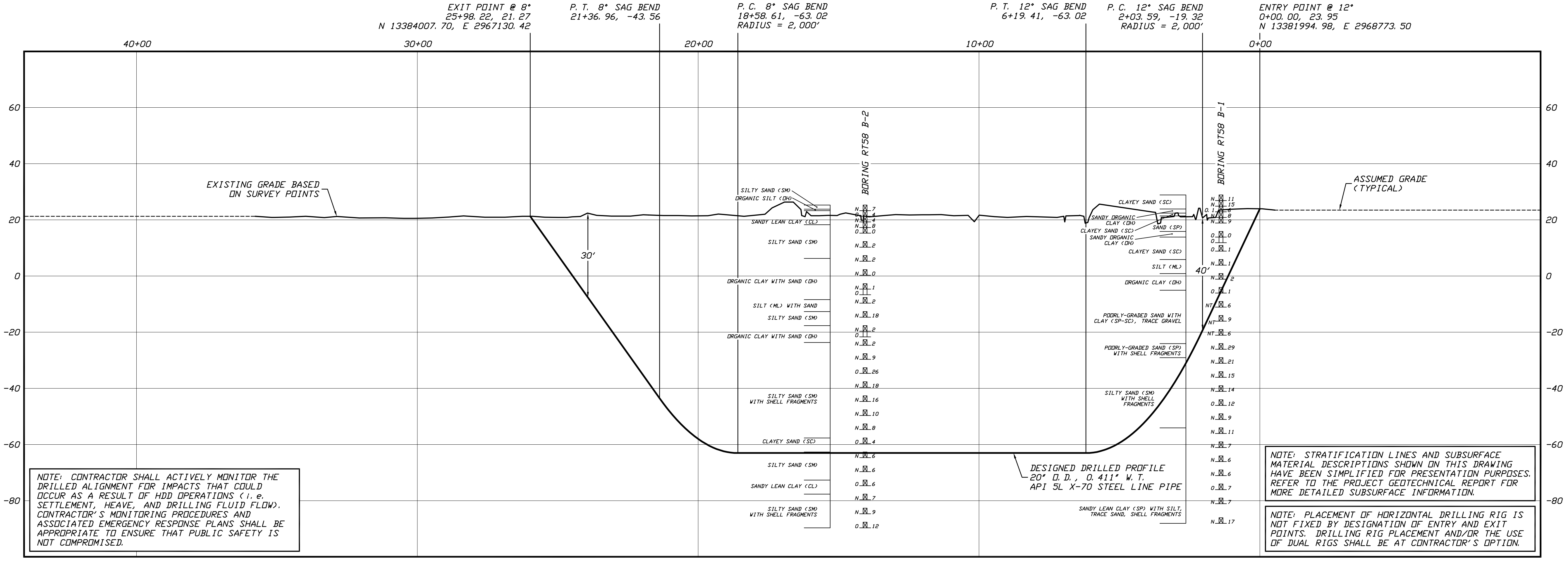
Our pulling load calculation for the proposed HDD crossing of Route 58 was based on an assumed worst-case installation model in which the pilot hole is drilled up to 40 feet longer and 30 feet deeper than the designed path with a radius of curvature equal to two-thirds of the design radius. A conservative drilling fluid density of 12 pounds per gallon was assumed for the sake of analysis and we assumed that the pull section would be installed empty since buoyancy control measures are not typically employed for steel pipe less than 30 inches in diameter.

Our installation stress calculations indicated no violations of applicable stress criteria. As a result, it is our opinion that the proposed line pipe specification is suitable for installation by HDD. This conclusion is based on three assumptions: 1) that the actual drilled path will not exceed the length or depth of the worst-case model analyzed; 2) that the HDD contractor will not employ any improper construction procedures; and 3) that problematic subsurface conditions will not be encountered. A copy of our installation stress calculation spreadsheet for the Route 58 crossing is attached to this memorandum.



PLAN

SCALE: 1"=200'



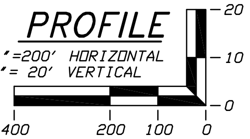
NOTE: CONTRACTOR SHALL ACTIVELY MONITOR THE DRILLED ALIGNMENT FOR IMPACTS THAT COULD OCCUR AS A RESULT OF HDD OPERATIONS (i.e. SETTLEMENT, HEAVE, AND DRILLING FLUID FLOW). CONTRACTOR'S MONITORING PROCEDURES AND ASSOCIATED EMERGENCY RESPONSE PLANS SHALL BE APPROPRIATE TO ENSURE THAT PUBLIC SAFETY IS NOT COMPROMISED.

NOTE: STRATIFICATION LINES AND SUBSURFACE MATERIAL DESCRIPTIONS SHOWN ON THIS DRAWING HAVE BEEN SIMPLIFIED FOR PRESENTATION PURPOSES. REFER TO THE PROJECT GEOTECHNICAL REPORT FOR MORE DETAILED SUBSURFACE INFORMATION.

NOTE: PLACEMENT OF HORIZONTAL DRILLING RIG IS NOT FIXED BY DESIGNATION OF ENTRY AND EXIT POINTS. DRILLING RIG PLACEMENT AND/OR THE USE OF DUAL RIGS SHALL BE AT CONTRACTOR'S OPTION.

PROFILE

SCALE: 1"=200' HORIZONTAL
1"= 20' VERTICAL



GENERAL LEGEND

⊕ DRILLED PATH ENTRY/EXIT POINT

GEOTECHNICAL LEGEND

Ⓑ BORING LOCATION

SPLIT SPOON SAMPLE

53 ☒ 23 ← PENETRATION RESISTANCE IN BLOWS PER FOOT FOR A 140 POUND HAMMER FALLING 30 INCHES
PERCENTAGE OF GRAVEL BY WEIGHT FOR SAMPLES CONTAINING GRAVEL

SHELBY TUBE SAMPLE

GEOTECHNICAL NOTES

1. GEOTECHNICAL DATA PROVIDED BY GEOSYNTEC CONSULTANTS, RICHMOND, VIRGINIA. REFER TO THE PROJECT GEOTECHNICAL REPORT DATED MARCH 2017 FOR MORE DETAILED SUBSURFACE INFORMATION.
2. THE LETTER "N" TO THE LEFT OF A SAMPLE INDICATES THAT NO GRAVEL WAS OBSERVED IN THE SAMPLE. THE LETTERS "NT" INDICATE THAT GRAVEL WAS OBSERVED BUT NO GRADATION TEST WAS PERFORMED.
3. THE GEOTECHNICAL DATA IS ONLY DESCRIPTIVE OF THE LOCATIONS ACTUALLY SAMPLED. EXTENSION OF THIS DATA OUTSIDE OF THE ORIGINAL BORINGS MAY BE DONE TO CHARACTERIZE THE SOIL CONDITIONS, HOWEVER, COMPANY DOES NOT GUARANTEE THESE CHARACTERIZATIONS TO BE ACCURATE. CONTRACTOR MUST USE HIS OWN EXPERIENCE AND JUDGMENT IN INTERPRETING THIS DATA.

TOPOGRAPHIC SURVEY NOTES

1. TOPOGRAPHIC SURVEY DATA PROVIDED BY GAI CONSULTANTS, CANONSBURG, PENNSYLVANIA.
2. NORTHINGS AND EASTINGS ARE IN U.S. SURVEY FEET REFERENCED TO UTM COORDINATES, ZONE 17, NAD 83.
3. ELEVATIONS ARE IN FEET REFERENCED TO NAVD 88.

DRILLED PATH NOTES

1. DRILLED PATH STATIONING IS IN FEET BY HORIZONTAL MEASUREMENT AND IS REFERENCED TO CONTROL ESTABLISHED FOR THE DRILLED SEGMENT.
2. DRILLED PATH COORDINATES REFER TO CENTERLINE OF PILOT HOLE AS OPPOSED TO TOP OF INSTALLED PIPE.

PILOT HOLE TOLERANCES

THE PILOT HOLE SHALL BE DRILLED TO THE TOLERANCES LISTED BELOW. HOWEVER, IN ALL CASES, RIGHT-OF-WAY RESTRICTIONS AND CONCERN FOR ADJACENT FACILITIES SHALL TAKE PRECEDENCE OVER THESE TOLERANCES.

1. ENTRY POINT: UP TO 10 FEET FORWARD OR BACK FROM THE DESIGNED ENTRY POINT; UP TO 5 FEET RIGHT OR LEFT OF THE DESIGNED ALIGNMENT
2. EXIT POINT: UP TO 10 FEET SHORT OR 30 FEET LONG RELATIVE TO THE DESIGNED EXIT POINT; UP TO 5 FEET RIGHT OR LEFT OF THE DESIGNED ALIGNMENT
3. ELEVATION: UP TO 5 FEET ABOVE AND 30 FEET BELOW THE DESIGNED PROFILE
4. ALIGNMENT: UP TO 10 FEET RIGHT OR LEFT OF THE DESIGNED ALIGNMENT
5. CURVE RADIUS: NO LESS THAN 1,350 FEET BASED ON A 3-JOINT AVERAGE (RANGE 2 DRILL PIPE)

PROTECTION OF EXISTING FACILITIES

CONTRACTOR SHALL UNDERTAKE THE FOLLOWING STEPS PRIOR TO COMMENCING DRILLING OPERATIONS.

1. CONTACT THE UTILITY LOCATION/NOTIFICATION SERVICE FOR THE CONSTRUCTION AREA.
2. POSITIVELY LOCATE AND STAKE ALL EXISTING UNDERGROUND FACILITIES. ANY FACILITIES LOCATED WITHIN 10 FEET OF THE DESIGNED DRILLED PATH SHALL BE EXPOSED.
3. MODIFY DRILLING PRACTICES AND DOWNHOLE ASSEMBLIES AS NECESSARY TO PREVENT DAMAGE TO EXISTING FACILITIES.

ATLANTIC COAST PIPELINE PROJECT

PLAN AND PROFILE
20-INCH PIPELINE CROSSING OF ROUTE 58
BY HORIZONTAL DIRECTIONAL DRILLING

LOCATION: SUFFOLK, VIRGINIA

DRAWN	DATE	CHECKED	APPROVED	SCALE	DRAWING LABEL	REVISION
KMN	04/06/17	DMP	JSP	SHOWN FOR D-SIZED PLOT	ROUTE 58	0

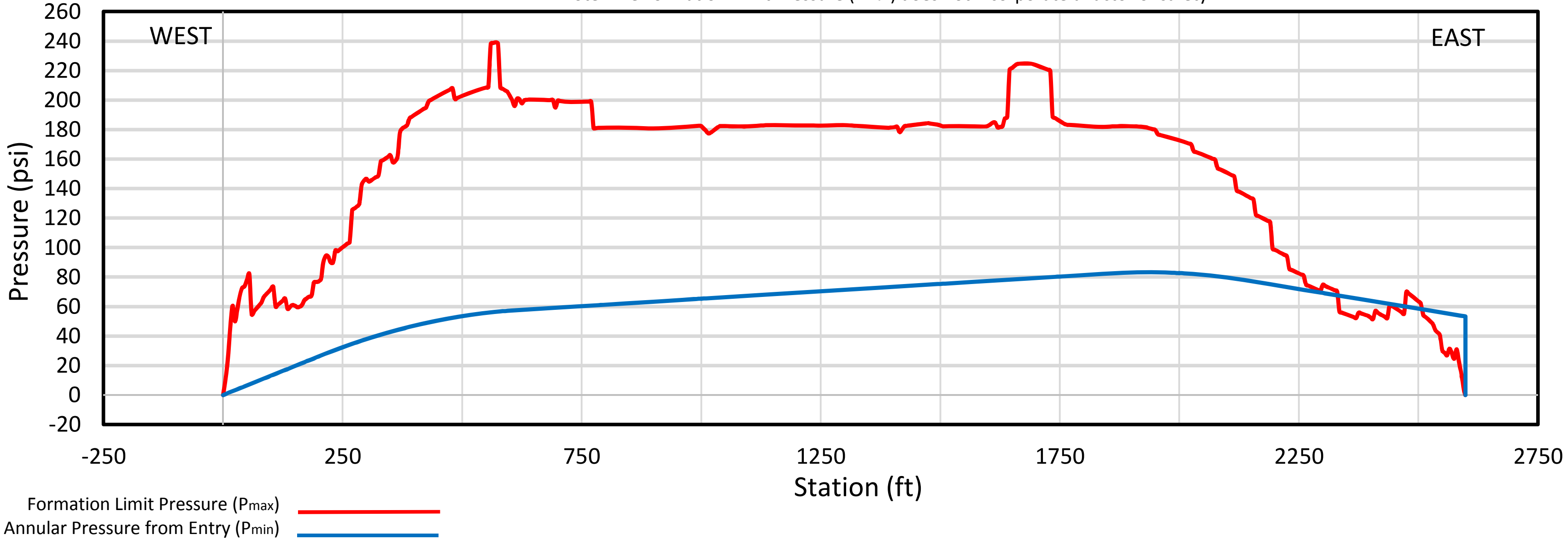
NO.	DATE	REVISION DESCRIPTION	BY	CHK'D	APP.

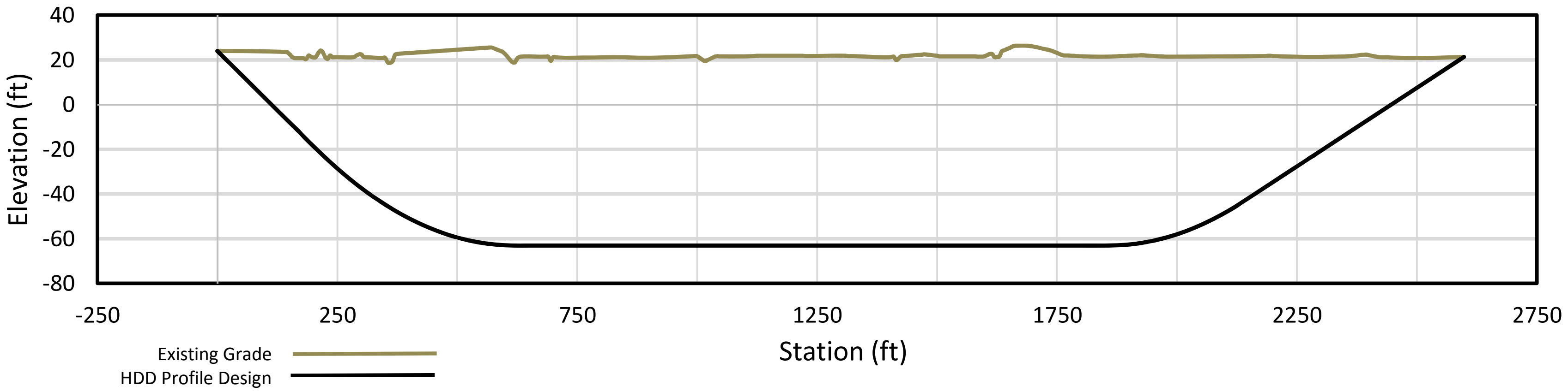
J.D. Hair & Associates, Inc.
Consulting Engineers
2424 East 21st Street
Suite 510
Tulsa, Oklahoma 74114

PROJECT NO.
Dominion\1508

AP3-072

Note: The Formation Limit Pressure (Pmax) does not incorporate a factor of safety





J.D.Hair&Associates, Inc.

HYDROFRACTURE EVALUATION
FORMATION LIMIT PRESSURE VS. ANNULAR PRESSURE
20-INCH ROUTE 58 CROSSING
BY HORIZONTAL DIRECTIONAL DRILLING

Date: 4/6/2017

Revision: 0

Route 58 R0 Installation Stress Analysis (worst-case).xlsm

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Project Information

Project :	Dominion Atlantic Coast Pipeline	User :	KMN
Crossing :	20" Route 58 Crossing	Date :	4/6/2017
Comments :	Installation stress analysis based on worst-case drilled path per tolerances (40' longer and 30' deeper than design with a 1,350' radius) with 12 ppg mud and no BC		

Line Pipe Properties

Pipe Outside Diameter =	20.000	in	
Wall Thickness =	0.411	in	
Specified Minimum Yield Strength =	70,000	psi	
Young's Modulus =	2.9E+07	psi	
Moment of Inertia =	1213.22	in^4	
Pipe Face Surface Area =	25.29	in^2	
Diameter to Wall Thickness Ratio, D/t =	49		
Poisson's Ratio =	0.3		
Coefficient of Thermal Expansion =	6.5E-06	in/in/°F	
Pipe Weight in Air =	85.99	lb/ft	
Pipe Interior Volume =	2.01	ft^3/ft	
Pipe Exterior Volume =	2.18	ft^3/ft	

HDD Installation Properties

Drilling Mud Density =	12.0	ppg	
=	89.8	lb/ft^3	
Ballast Density =	62.4	lb/ft^3	
Coefficient of Soil Friction =	0.30		
Fluid Drag Coefficient =	0.025	psi	
Ballast Weight =	125.18	lb/ft	
Displaced Mud Weight =	195.83	lb/ft	

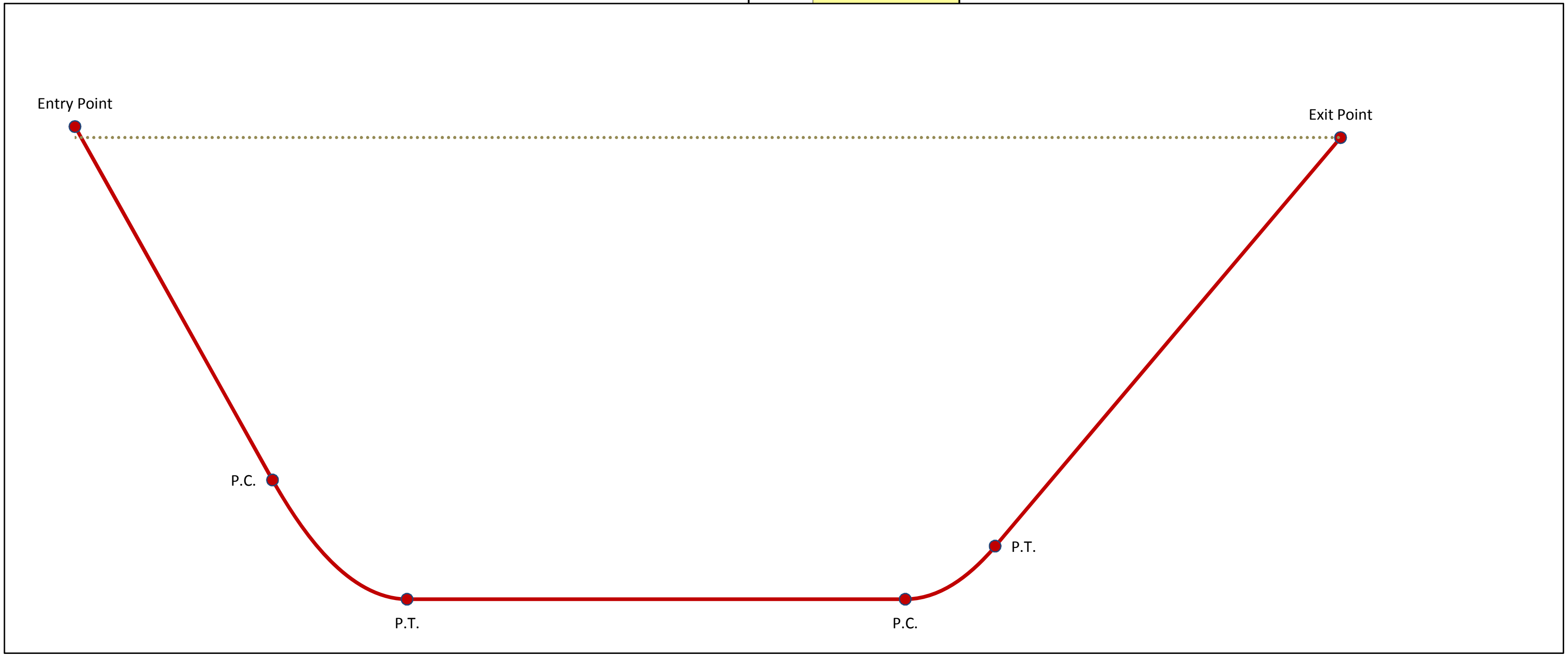
Installation Stress Limits

Tensile Stress Limit, 90% of SMYS, F_t =	63,000	psi	
For D/t <= 1,500,000/SMYS, F_b =	52,500	psi	No
For D/t > 1,500,000/SMYS and <= 3,000,000/SMYS, F_b =	44,493	psi	No
For D/t > 3,000,000/SMYS and <= 300, F_b =	45,631	psi	Yes
Allowable Bending Stress, F_b =	45,631	psi	
Elastic Hoop Buckling Stress, F_{he} =	10,777	psi	
For F_{he} <= 0.55*SMYS, Critical Hoop Buckling Stress, F_{hc} =	10,777	psi	Yes
For F_{he} > 0.55*SMYS and <= 1.6*SMYS, F_{hc} =	33,440	psi	No
For F_{he} > 1.6*SMYS and <= 6.2*SMYS, F_{hc} =	11,994	psi	No
For F_{he} > 6.2*SMYS, F_{hc} =	70,000	psi	No
Critical Hoop Buckling Stress, F_{hc} =	10,777	psi	
Allowable Hoop Buckling Stress, $F_{hc}/1.5$ =	7,185	psi	

		Station	Elevation	Angle	Radius	Length	Average Tension	Total Pull
Entry Point		-10.00	23.95	12.00				158,318
Entry Tangent						420.70		
Entry Sag Bend	PC	401.51	-63.52					146,436
	PI	540.30	-93.02	12.00	1350	282.74	133,871	
	PT	682.19	-93.02				0	121,306
Bottom Tangent				0.00		1038.41		
Exit Sag Bend	PC	1720.60	-93.02					67,514
	PI	1815.00	-93.02	8.00	1350	188.50	58,021	
	PT	1908.49	-79.88				0	48,527
Exit Tangent						726.81		
Exit Point		2628.22	21.27	8.00	Above Ground Load			0
Drilling Mud			21.27	(Graph = •••••••••)				
Ballast				(Graph = – – – – –)				

No.	Station	Elevation	
1			Grade Elevation Points
2			
3			
4			
5			
6			
7			
8			
9			
10			
1			Control Point

	= Cover at Control Point



Route 58 R0 Installation Stress Analysis (worst-case).xlsm

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Pipe and Installation Properties

Based on profile design entered in 'Step 2, Drilled Path Input'.

Pipe Diameter, D = 20.000 in

PIpe Weight, W = 86.0 lb/ft

Coefficient of Soil Friction, μ = 0.30

Fluid Drag Coefficient, C_d = 0.025 psi

Ballast Weight / ft Pipe, W_b = 125.2 lb (If Ballasted)

Drilling Mud Displaced / ft Pipe, W_m = 195.8 lb (If Submerged)

Above Ground Load = 0 lb

Exit Tangent - Summary of Pulling Load Calculations

Segment Length, L = 726.8 ft

Exit Angle, θ = 8.0 º

Effective Weight, $W_e = W + W_b - W_m$ = -109.8 lb/ft

Frictional Drag = W_e L μ cosθ = 23,717 lb

Fluidic Drag = 12 π D L C_d = 13,700 lb

Axial Segment Weight = W_e L sinθ = 11,111 lb

Pulling Load on Exit Tangent = 48,527 lb

Exit Sag Bend - Summary of Pulling Load Calculations

Segment Length, L = 188.5 ft

Segment Angle with Horizontal, θ = -8.0 º

Deflection Angle, α = -4.0 º

Average Tension, T = 58,021 lb

Radius of Curvature, R = 1,350 ft

Effective Weight, $W_e = W + W_b - W_m$ = -109.8 lb/ft

h = R [1 - cos(α/2)] = 3.29 ft

$j = [(E\ I) / T]^{1/2}$ = 779

$Y = [18\ (L)^2] - [(j)^2\ (1 - \cosh(U/2)^{-1}]$ = 3.0E+05

X = (3 L) - [(j / 2) tanh(U/2)] = 216.56

U = (12 L) / j = 2.90

N = [(T h) - W_e cosθ (Y/144)] / (X / 12) 23,316 lb

Bending Frictional Drag = 2 μ N = 13,990 lb

Fluidic Drag = 12 π D L C_d = 3,553 lb

Axial Segment Weight = W_e L sinθ = 1,444 lb

Pulling Load on Exit Sag Bend = 18,987 lb

Total Pulling Load = 67,514 lb

Bottom Tangent - Summary of Pulling Load Calculations

Segment Length, L = 1038.4 ft

Effective Weight, $W_e = W + W_b - W_m$ = -109.8 lb/ft

Frictional Drag = W_e L μ = 34,218 lb

Fluidic Drag = 12 π D L C_d = 19,574 lb

Axial Segment Weight = W_e L sinθ = 0 lb

Pulling Load on Bottom Tangent = 53,791 lb

Total Pulling Load = 121,306 lb

Entry Sag Bend - Summary of Pulling Load Calculations

Segment Length, L = 282.7 ft
Segment Angle with Horizontal, θ = 12.0 °
Deflection Angle, α = 6.0 °

Average Tension, T = 133,871 lb
Radius of Curvature, R = 1,350 ft
Effective Weight, $W_e = W + W_b - W_m$ = -109.8 lb/ft

$h = R\,[1 - \cos(\alpha/2)]$ = 7.40 ft

$j = [(E\ I) / T]^{1/2}$ = 513

$Y = [18\ (L)^2] - [(j)^2\ (1 - \cosh(U/2)^{-1}]$ = 1.2E+06

$X = (3\ L) - [\ (j\ /\ 2)\ \tanh(U/2)\ ]$ = 592.59

$U = (12\ L) / j$ = 6.62

$N = [(T\ h) - W_e \cos\theta\ (Y/144)] / (X / 12)$ = 38,411 lb

Bending Frictional Drag = $2\ \mu\ N$ = 23,047 lb

Fluidic Drag = $12\ \pi\ D\ L\ C_d$ = 5,330 lb

Axial Segment Weight = $W_e\ L \sin\theta$ = -3,246 lb

Negative value indicates axial weight applied in direction of installation

Pulling Load on Entry Sag Bend = 25,130 lb
Total Pulling Load = 146,436 lb

Entry Tangent - Summary of Pulling Load Calculations

Segment Length, L = 420.7 ft
Entry Angle, θ = 12.0 °

Effective Weight, $W_e = W + W_b - W_m$ = -109.8 lb/ft

Frictional Drag = $W_e\ L\ \mu \cos\theta$ = 13,560 lb

Fluidic Drag = $12\ \pi\ D\ L\ C_d$ = 7,930 lb

Axial Segment Weight = $W_e\ L \sin\theta$ = -9,608 lb

Negative value indicates axial weight applied in direction of installation

Pulling Load on Entry Tangent = 11,883 lb
Total Pulling Load = 158,318 lb

Summary of Calculated Stress vs. Allowable Stress

	Tensile Stress		Bending Stress		External Hoop Stress		Combined Tensile & Bending		Combined Tensile, Bending & Ext. Hoop	
Entry Point	6,259	ok	0	ok	0	ok	0.10	ok	0.01	ok
	5,790	ok	0	ok	1286	ok	0.09	ok	0.05	ok
PC										
	5,790	ok	17,901	ok	1286	ok	0.48	ok	0.25	ok
	4,796	ok	17,901	ok	1733	ok	0.47	ok	0.27	ok
PT										
	4,796	ok	0	ok	1733	ok	0.08	ok	0.07	ok
	2,669	ok	0	ok	1733	ok	0.04	ok	0.06	ok
PC										
	2,669	ok	17,901	ok	1733	ok	0.43	ok	0.23	ok
	1,919	ok	17,901	ok	1534	ok	0.42	ok	0.20	ok
PT										
	1,919	ok	0	ok	1534	ok	0.03	ok	0.05	ok
Exit Point	0	ok	0	ok	0	ok	0.00	ok	0.00	ok