EARTH ENGINEERING INCORPORATED

Geotechnical Engineers & Geologists

REPORT OF GEOTECHNICAL INVESTIGATION

TWIN OAKS TO NEWARK 14 INCH PIPELINE

JACOBS CREEK HDD PIPELINE RELOCATION

UPPER MAKFILED TOWNSHIP, PENNSYLVANNIA

HOPEWELL TOWNSHIP, NEW JERSEY

Prepared For:

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TABLE OF CONTENTS

FIGURES AND DRAWINGS

APPENDIX

I. OBJECTIVE AND SCOPE OF WORK

Earth Engineering Incorporated (EEI) has completed the geotechnical investigation for the proposed Jacobs Creek Pipeline Relocation located in Upper Makfield Township, Pennsylvania and Ewing and Hopewell Township, New Jersey. The objective of the project has been to investigate, document, and analyze the subsurface conditions present along the proposed pipeline relocation. Based upon the subsurface conditions observed in relation to the planned construction, recommendations regarding the pipeline installation, as well as general construction guidelines for the project, have been formulated according to industry standards and included within this report.

The scope of work for this project included a field investigation, a geologic analysis of the site conditions, laboratory testing of soil, and a geotechnical engineering analysis. This report was prepared for STV, Incorporated (Client) in general accordance with EEI's proposal BB-16268R and presents the results of our work.

II. PROJECT AND SITE DESCRIPTIONS

The investigated area of the proposed pipeline traverses the Delaware River in Upper Makfield Township, Pennsylvania and Ewing and Hopewell Township, New Jersey. Three (3) locations were investigated for the proposed 14-inch pipeline, which consists of the relocation of an existing 14-inch SXL pipeline that currently exists beneath the Delaware River. The proposed pipeline will be installed using horizontal directional drilling (HDD) techniques beneath the Delaware River. The HDD bore is proposed to be three thousand five hundred (3,500) feet long, with a minimum depth of 50 feet below the Delaware River crossing, and a 1,600 foot vertical radius. The proposed HDD alignment is south of the existing SXL pipeline. The Upper Makfield Township, Pennsylvania site location, test boring SB-1, is situated in the area of the proposed HDD bore exit point located along River Road/PA Route 32, approximate Station 4+50. The Delaware River boring location, test boring SB-3, was is located adjacent to the eastern shoreline of the Delaware River, approximated station 12+50. The Ewing Township, New Jersey location, test boring SB-4, is situated in the area of the entry point of the HDD, adjacent to River Road/NJ Route 29, approximate Station 21+00. *Plate 1*, which is included in the Appendix, shows the approximate location of the proposed pipeline alignment on a topographic map of the area.

As previously stated, an 14-inch SXL pipeline currently crosses the Delaware River to the north of the proposed relocation. The provided PRELIMINARY DRAFT 14-INCH TWIN OAKS TO NEWARK JACOBS CREEK 11_06_99.01_10 ACCESS HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILE by STV, dated 03/29/2019, shows the existing SXL line and the proposed 14-inch relocation. The underground utilities in the area were not known at the time of the field investigation. Public utility location services did not identify any utilities in conflict with test borings. However, possible utilities in the area may include, but are not limited to, pipelines, telecommunications, water, sewer, and electricity.

Based on the approximate surface elevations estimated by EEI from the aforementioned plan, the maximum relief across the subject area is approximately 10.0 feet. This relief corresponds to elevations across the site ranging from 30 feet near the HDD entry point and 30 feet near the HDD exit point. The locations of the test borings, in relation to the existing site features, are shown on the *Testing Location Plan*, EEI Drawing No. 31585.00-D-101, included within the Appendix of this report.

III. FIELD INVESTIGATION

Three (3) test borings, designated as SB-1, SB-3, and SB-4 were conducted at the designated locations shown on the aforementioned plan by TRC Solutions of Cinnaminson, New Jersey utilizing an Acker Soil XLS track-mounted drill rig. The Upper Makfield Township, Pennsylvania site location, test boring SB-1, is situated in the area of the proposed HDD bore exit point located along River Road/PA Route 32, approximate Station 4+50. The Delaware River boring location, test boring SB-3, was is located adjacent to the eastern shoreline of the Delaware River, approximated station 12+50. The Ewing Township, New Jersey location, test boring SB-4, is situated in the area of the entry point of the HDD, adjacent to River Road/NJ Route 29, approximate Station 21+00. Supervision and monitoring of the test boring program were provided by representatives of EEI. Test borings were field located by a representative of EEI based on the plan provided by the Client. The locations of the completed test borings are shown on the *Testing Location Plan* included in the Appendix.

The borings were advanced through soil using two (2) inch outer diameter spilt-barrel samplers and three (3.00) inch outer diameter casing. Split-barrel samples, conducted in accordance with ASTM standard D1586, were taken at five (5) foot intervals at the land and water boring locations to depths ranging from 9.0 to 28.0 feet below existing grade. Standard Penetration Test (SPT) values were recorded for each split-barrel sample. An SPT value, which is a measure of soil density and consistency, is the number of blows required to drive a two (2) inch

outer diameter split-barrel sampler six (6) inches using a one-hundred and forty (140) pound weight dropped thirty (30) inches. The hammer system utilized for this investigation was an automatic trip hammer. The number of blows required to advance the sampler over the twelve (12) inch interval from six (6) to eighteen (18) inches is considered the N-value. Each of the borings were additionally advanced through the bedrock utilizing a two (2) inch inner diameter NQ2 diamond-tip core barrel to A depth of 120.0 feet below existing grade.

The borings were conducted to a total depth of 120.0 feet below existing grade. Existing FILL materials were encountered at boring location SB-4 to a depth ranging of 3.5 feet. Alluvial materials ranging from a fine to coarse sand with cobbles and boulders were observed to the weathered bedrock surface at SB-1. Very dense weathered rock, as indicated by hard drilling rates and/or N-values of greater than 50 blows per foot, was encountered at each boring location ranging at initial depths ranging from 1.5 feet to 25.5 feet. The bedrock surface was encountered at depths ranging from 9.0 to 28.0 feet. Groundwater readings were not conducted due to the drilling methods conducted. The conditions encountered are detailed on the *Boring Logs* and graphically displayed on the *Boring Profiles*, which are included in the Appendix.

IV. LABORATORY TESTING

A. Classification Testing

Four (4) representative samples of the soil recovered from the field investigation were submitted for classification and hydrometer testing. These samples were tested in accordance with ASTM D2487, to verify visual classifications and to establish engineering parameters required for analysis. The classification tests performed included Particle Size Analysis (ASTM D422), Atterberg Limits Determination (ASTM D4318) and Natural Moisture Content (ASTM D2216). Unified Soil Classification System (USCS) Group Symbols and ASTM Group Names have been assigned to each of the analyzed soil samples based on the results of the laboratory testing. The individual results of the laboratory classification testing are presented in the table below. Gradation curves, which numerically and graphically depict the results of the particle size analyses, are included in the Appendix.

TABLE I CLASSIFICATION TESTING RESULTS				
Sample Location	SB-1	SB-1	SB-1	B-1
Sample Number	S-2 to S-5	S-6 & S-7	S-8 to S-10	S-3 & S-4
Sample Depths (feet)	2.0-10.0	10.0-14.0	14.0-20.0	4.0-8.0
Stratum	I	I	I	II
Atterberg Limits				
Liquid Limit	NP	NP	NP	NP
Plastic Limit	NP	NP	NP	NP
Plasticity Index	NP	NP	NP	NP
Natural Moisture Content (%)	7.9	6.6	10.6	11.6
Percent Passing #200 Sieve (%)	8.1	8.3	11.6	15.9
Percent Finer 2μ, clay fraction (%)	3.0	3.7	4.7	-
Unified Soil Classification System (USCS) Group Symbol	GP-GM	GP-GM	SW-SM	SM
ASTM Group Name	Poorly-graded Gravel with Silt and Sand	Poorly-graded Gravel with Silt and Sand	Well-graded Sand with Silt and Gravel	Silty Sand with Gravel

B. Unconfined Compressive Strength of Rock Testing

In addition to the soil laboratory testing conducted, sixteen (16) rock samples retrieved from the test borings were submitted for unconfined compressive strength in accordance with ASTM D7012. A summary of the results of the rock testing are presented in the following table. Additional details of the Unconfined Compressive Strength of Rock Testing results are included in the Appendix.

TABLE II UNCONFINED COMPRESSIVE STRENGTH OF ROCK TESTING RESULTS					
Boring Location	**Run Number**	**Recovery (%)**	**Rock Quality Designation (%)**	**Sample Depth (feet)**	**Compressive Strength (psi)**
SB-1	R-2	90	86	33.0 – 38.0	24,645
SB-1	R-6	100	100	53.0 – 55.0	24,600
SB-1	R-10	100	98	73.0 - 78.0	26,632
SB-1	R-14	94	90	93.0 – 98.0	23,783
SB-1	R-18	100	80	113.0 – 118.0	28,895
SB-3	R-2	100	38	13.0 – 18.0	21,218

TABLE II - Continued UNCONFINED COMPRESSIVE STRENGTH OF ROCK TESTING RESULTS					
Boring Location	**Run Number**	**Recovery (%)**	**Rock Quality Designation (%)**	**Sample Depth (feet)**	**Compressive Strength (psi)**
SB-3	R-6	100	100	33.0 – 38.0	17,299
SB-3	R-10	90	58	53.0 – 58.0	15,272
SB-3	R-14	100	92	73.0 – 78.0	28,477
SB-3	R-18	100	96	93.0 – 98.0	22,140
SB-3	R-22	100	70	113.0 – 118.0	12,189
SB-4	R-3	100	36	22.0 – 27.0	7,964
SB-4	R-8	100	66	47.0 – 52.0	22,569
SB-4	R-12	100	94	67.0 – 72.0	20,987
SB-4	R-16	100	96	87.0 – 92.0	25,853
SB-4	R-20	100	94	107.0 – 112.0	15,477

V. SUBSURFACE CONDITIONS

A. Geology

According to the Commonwealth of Pennsylvania, Topographic and Geologic Survey, *Engineering Characteristics of The Rocks of Pennsylvania*, Fourth (4th) Series, Revised 1982, the site is situated within an area of the Trenton Gravel formation (Geologic Symbol – Qt). The Trenton Gravel is composed of a gray to reddish-brown very gravelly sand with interbedded sand and clay/silt layers. This formation is typically well bedded and exhibits some cross bedding. The Trenton Gravel Formation, which was deposited by the Delaware River, typically features good surface drainage and high porosity and permeability. Boulders are a common occurrence in this formation. If these boulders are encountered, excavation difficulties may be experienced. The residual soil sampled, appeared to be a typical deposit of the Trenton Gravel. Plate 2, included in the Appendix, shows the location of the site on a geologic map of the area.

According to the U.S. Geological Survey, Geologic Map of the Newark Quadrangle, New Jersey, Pennsylvania and New York, 1987, the site investigated is underlain by the Lockatong Formation (Geologic Symbol - Trl). Plate 3, included in the Appendix, shows the location of the site on a geologic map of the area.

According to the Pennsylvania Topographic and Geologic Survey, Commonwealth of Pennsylvania, *Engineering Characteristics of The Rocks of Pennsylvania*, Fourth (4th) Series, Revised 1982, the Lockatong Formation is composed of dark gray to black argillite having some

zones of black shale. The bedding within this formation is typically well developed, and flaggy to thick. The fracturing and jointing within this rock type have a blocky pattern. This rock type is moderately resistant to weathering and the overlying soil mantle is typically thin. Low porosity and permeability are characteristic of this formation. Localized groundwater springs are a common occurrence within the fractured bedrock of the Lockatong Formation. The excavation of this material varies from easy in completely to highly weathered rock to difficult in the moderately weathered to fresh bedrock.

Residual soil and highly weathered rock samples retrieved during the subsurface investigation appeared typical of the various stages of the weathering of the Lockatong Formation shale.

Based upon the soils and rock cores observed during the field investigation, the weathered rock fragments and cores recovered appeared typical of the Lockatong Formation shale. Alluvial deposits were also observed above the weathering by-products of the Trenton Gravel Formation. Alluvial deposits are soil materials transported by streams which traversed the area in the historical and/or geologic past.

B. Soil

The soil samples recovered from the field investigation were examined and visually classified by EEI, in the field. One (1) material designated as FILL and two (2) naturally-occurring strata were characterized to exist at the investigated locations. Based upon the soil samples and conditions observed residual soils typical of the Trenton Gravel and Lockatong Formation were encountered at this site during the field investigation.

A cross-section of both borings, displaying the various strata, as well as other information obtained from the field investigation, are included within the Appendix on the *Boring Profile*. The test boring information is further detailed on the *Boring Logs,* which are also included in the Appendix. A general description of each stratum is as follows:

1. Existing Fill

The material designated as Existing FILL is visually described as silty fine sand trace to some stone and gravel, trace brick. As determined by visual classification, the USCS Group Symbol for a representative sample of this material is SM. The assigned ASTM Group Names is Silty Sand with Gravel. The Existing FILL material was observed at the existing ground surface at boring SB-4 to a depth of 3.5 feet below existing grades. The Existing FILL is indicative of an urban fill material likely placed without compaction or engineering controls.

The N-values recorded during the sampling of this material ranged from 19 blows per foot of penetration to 29 blows per foot of penetration. Based upon the N-values, as well as monitoring

of the drilling rates, the density of this material is medium dense. The moisture level observations of the Existing FILL material are moist. The degree of difficulty during the drilling within this material ranged from easy to moderate.

2. Stratum I

The soil designated as Stratum I is visually described as a fine to course sand, trace to some gravel trace cobbles, and boulders. As determined by laboratory testing, the USCS Group Symbol for representative samples of this material are GP-GM and SW-SM. The assigned ASTM Group Names are *Poorly Graded Gravel with Silt and Sand* and *Well Graded Sand with Silt and Gravel*. The Stratum I soil was observed at the surface at SB-1 to 25.5 feet below existing grades. The Stratum I soil is indicative of a course-grained alluvial soil that has been transported and deposited by water.

The N-values recorded during the sampling of this material ranged from 1 to 24 blows per foot of penetration. Based upon the N-values, as well as monitoring of the drilling rates, the relative density of this soil ranges from very loose to dense. Moisture level observations of this stratum were observed to range from moist to wet. The degree of difficulty during the drilling within this stratum was described as easy to hard.

3. Stratum II

The soil designated as Stratum II (Decomposed to Weathered Shale) is visually described as a silty sand with gravel. As determined by laboratory testing, the USCS Group Symbol for representative samples of this material USCS Group Symbol is SM. The assigned ASTM Group Name is *Silty Sand with Gravel*. The Stratum II soil were encountered beneath the Stratum I soil at boring SB-1 to a depth of 28.0 feet and beneath the water at SB-3 and existing FILL material at SB-3 and SB-4 to depths of 9.0 feet and 16.2 feet respectively.

The N-values recorded during the sampling of this soil were greater than 50 blows per foot of penetration. Based upon the N-value, as well as monitoring of the drilling rates, the consistency of this soil is very dense. The degree of difficulty during the drilling within this stratum was described as hard.

C. Bedrock

Shale (mudstone) bedrock was encountered at all boring locations at depths ranging from 9.0 to 28.0 feet below existing grades. Bedrock is defined herein as auger/casing refusal within residual materials where the drilling equipment encounters the moderately weathered to fresh bedrock surface. Very dense weathered rock, as indicated by hard drilling rates and/or N-values of greater than 50 blows per foot, was encountered at each boring location at initial depths ranging

from 1.5 to 25.5 feet. The depths to bedrock and very dense weathered rock with corresponding elevations are shown in the following table.

TABLE III
DEPTHS TO VERY DENSE WEATHERED ROCK AND BEDROCK

Boring Location	[1.] Ground Surface Elevation (feet)	[2.] Approximate Depth to Very Dense Weathered Rock (feet)	Approximate Very Dense Weathered Rock Elevation (feet)	[2.] Approximate Depth to Bedrock (feet)	Approximate Bedrock Elevation (feet)
SB-1	30.0	25.5	4.5	28.0	2.0
SB-3	25.2	1.5	23.7	9.0	11.0
SB-4	30.0	7.5	22.5	16.2	13.8

[1.] Ground surface elevations based on approximate profile information provided by STV, Inc. (Client)
[2.] Depths were measured from existing site grades at the time of the investigation.

Rock coring was conducted at each boring location at casing refusal depths ranging from 9.0 to 28.0 feet and extended to the boring termination depths of 120.0 feet to further characterize the underlying bedrock. Based on observations of the rock samples retrieved during the coring operation, the site is underlain by the Lockatong Formation. The shale bedrock within the areas of the test borings was described as having extremely close spaced fractures, laminated, and medium hard to very hard. The bedrock was further characterized to be broken to massive with degrees of weathering ranging from highly weathered to fresh. Furthermore, the relative dip of the bedrock was shallow (5 to 10 degrees).

The percent recovery and Rock Quality Designation (RQD) for the coring runs within the test borings are presented in the following table. The percent recovery ratio is calculated as the actual recovered rock core length divided by the total length of the coring run. The RQD ratio is calculated as the summation length of all rock core sections four (4) inches or greater in length divided by the total length of the coring run. Both the recovery and RQD are expressed as percentages. The recorded RQD values correspond to Rock Mass Quality ratings ranging from very poor to excellent.

TABLE IV - ROCK CORING DATA					
Boring Location	**Run Number**	**Run Depths (feet)**	**Recovery (%)**	**RQD (%)**	[1.)] **Rock Mass Quality Rating**
SB-1	R-1	28.0 – 33.0	86	48	Fair
SB-1	R-2	33.0 – 38.0	90	86	Good
SB-1	R-3	38.0 – 43.0	100	92	Excellent
SB-1	R-4	43.0 – 48.0	98	94	Excellent
SB-1	R-5	48.0 – 53.0	100	82	Good
SB-1	R-6	53.0 – 58.0	100	100	Excellent
SB-1	R-7	58.0 – 63.0	98	78	Good
SB-1	R-8	63.0 – 68.0	78	42	Poor
SB-1	R-9	68.0 – 73.0	100	96	Excellent
SB-1	R-10	73.0 – 78.0	100	98	Excellent
SB-1	R-11	78.0 – 83.0	100	86	Good
SB-1	R-12	83.0 – 88.0	98	94	Excellent
SB-1	R-13	88.0 – 93.0	100	100	Excellent
SB-1	R-14	93.0 – 98.0	94	90	Excellent
SB-1	R-15	98.0 – 103.0	94	94	Excellent
SB-1	R-16	103.0 – 108.0	100	78	Good
SB-1	R-17	108.0 – 113.0	100	82	Good
SB-1	R-18	113.0 – 118.0	100	80	Good
SB-1	R-19	118.0 – 120.0	100	100	Excellent
SB-3	R-1	9.0 – 13.0	100	78	Good
SB-3	R-2	13.0 – 18.0	100	100	Excellent
SB-3	R-3	18.0 – 23.0	100	98	Excellent
SB-3	R-4	23.0 – 28.0	100	100	Excellent
SB-3	R-5	28.0 – 33.0	100	98	Excellent
SB-3	R-6	33.0 – 38.0	100	100	Excellent
SB-3	R-7	38.0 – 43.0	100	100	Excellent
SB-3	R-8	43.0 – 48.0	100	100	Excellent
SB-3	R-9	48.0 – 53.0	100	100	Excellent
SB-3	R-10	53.0 – 58.0	100	90	Excellent
SB-3	R-11	58.0 – 63.0	100	100	Excellent
SB-3	R-12	63.0 – 68.0	100	100	Excellent

TABLE IV - ROCK CORING DATA - Continued					
SB-3	R-13	68.0 – 73.0	100	98	Excellent
SB-3	R-14	73.0 – 78.0	100	100	Excellent
SB-3	R-15	78.0 – 83.0	100	100	Excellent
SB-3	R-16	83.0 – 88.0	100	100	Excellent
SB-3	R-17	88.0 – 93.0	100	100	Excellent
SB-3	R-18	93.0 – 98.0	100	100	Excellent
SB-3	R-19	98.0 – 103.0	100	100	Excellent
SB-3	R-20	103.0 – 108.0	100	94	Excellent
SB-3	R-21	108.0 – 113.0	100	98	Excellent
SB-3	R-22	113.0 – 118.0	100	100	Excellent
SB-3	R-23	118.0 – 120.0	100	100	Excellent
SB-4	R-1	16.2 – 17.0	62	0	Very Poor
SB-4	R-2	17.0 - 22.0	94	0	Very Poor
SB-4	R-3	22.0 – 27.0	100	36	Poor
SB-4	R-4	27.0 – 32.0	100	82	Good
SB-4	R-5	32.0 – 37.0	100	88	Good
SB-4	R-6	37.0 – 42.0	100	74	Good
SB-4	R-7	42.0 – 47.0	100	74	Good
SB-4	R-8	47.0 – 52.0	100	66	Fair
SB-4	R-9	52.0 – 57.0	100	86	Good
SB-4	R-10	57.0 – 62.0	100	98	Excellent
SB-4	R-11	62.0 – 67.0	100	92	Excellent
SB-4	R-12	67.0 – 72.0	100	94	Excellent
SB-4	R-13	72.0 – 77.0	100	80	Good
SB-4	R-14	77.0 – 82.0	100	86	Good
SB-4	R-15	82.0 – 87.0	100	80	Good
SB-4	R-16	87.0 – 92.0	100	96	Excellent
SB-4	R-17	92.0 – 97.0	100	80	Good
SB-4	R-18	97.0 – 102.0	100	78	Good
SB-4	R-19	102.0 – 107.0	100	100	Excellent
SB-4	R-20	107.0 – 112.0	100	94	Excellent
SB-4	R-21	112.0 – 117.0	100	94	Excellent
SB-4	R-22	117.0 – 120.0	100	93	Excellent

[1.)] Ratings referenced from *NAVFAC DM-7.01, Soil Mechanics, Table II,* September 1986

Further details regarding the bedrock and very dense weathered rock can be found in the *Excavation Methods* section of this report.

D. Groundwater

Due to the drilling methods (mud and water rotary) conducted groundwater readings were not feasible due to the drilling fluids introduced during rotary drilling and rock coring. Long term groundwater measurement were not included within the proposed scope of this investigation.

Due to the proximity of the Delaware River, Jacobs Creek and Houghs Creek, EEI anticipates groundwater will be encountered during trench excavation required for pipeline installation. Likewise, directional drilling operations will extend below river elevation depths. Groundwater encountered during trench excavation will require temporary dewatering measures. Measures to minimize the impact of groundwater during construction are discussed in the *Groundwater Control* section of this report.

The depth to groundwater should be considered during the design of the proposed pipeline relocation in order to minimize the need for groundwater control during installation. The contractor should be advised that they may conduct their own investigations to verify groundwater elevations prior to performing excavations on site.

VI. PIPELINE CONSTRUCTION RECOMMENDATIONS

The results of the field investigation, revealed that the subsurface conditions consist of one (1) material designated as Existing FILL and two (2) naturally-occurring soil strata along the proposed pipeline relocation alignment. Based upon the information supplied by the client two (2) areas will require trench excavation to tie into existing pipeline sections.

A. Directional Drilling Suitability

The proposed directional drilling in the vicinity of the investigated borings could potentially occur within the medium dense FILL material, loose to very dense Stratum I, very dense Stratum II, and/or medium hard to very hard shale bedrock. The subsurface soil conditions encountered during the field investigation, which were determined by EEI based on and visual classifications of the collected soil samples, were compared to accepted and published industry standards as listed in *TABLE 1 – Soil Conditions and Suitability of Horizontal Directional Drilling* included in ASTM F1962-11. These soil parameters and associated HDD correlations, which should be utilized during the design of the HDD installation program, are shown in the following table.

SOIL CONDITIONS AND SUITABILITY OF HORIZONTAL DIRECTIONAL DRILLING			
Soil Conditions	**Generally Suitable**	**Difficulties May Occur**	**Substantial Problems**
Soft to very soft clays, silts, and organic deposits		X	
Medium to very stiff clays and silts	X		
Hard clays and highly weathered shales	X		
Very loose to loose sands above and below the water table (not more than 30% gravel by weight)		X	
Medium to dense sands above or below the water table (not more than 30% gravel by weight)	X		
Very loose to dense gravelly sand (30% to 50% gravel by weight)		X	
Very loose to dense gravelly sand (50% to 85% gravel by weight)			X
Very loose to very dense gravel			X
Soils with significant cobbles, boulders, and obstructions			X
Weathered rocks, marls, chalks, and firmly cemented soils	X		
Slightly weathered to unweathered rocks		X	

1. HDD Suitability by Subsurface Strata

Based on the previously mentioned *Plan and Profile* provided by the Client, the HDD may marginally begin within the Existing FILL materials. The Existing FILL, noted as medium dense silty sand (SM), the HDD suitability is designated as “Generally Suitable”, according to ASTM F1962-11.

The HDD suitability of the Stratum I soils to a depth of 25.5 feet in SB-1 and 9.0 feet in SB-3, noted as a loose to very dense Silty Sand with Gravel, Cobbles and Boulders (SP & GP, is designated at “Difficulties May Occur” and “Substantial Problems” according to ASTM F1962-11.

The Stratum II soils, noted as very dense Silty Sand with Gravel (SM & GM), the HDD suitability is designated at “Difficulties May Occur”, according to ASTM F1962-11.

The highly weathered bedrock encountered in boring SB-3 and SB-4 and shown in Table IV as very poor to poor quality is designated as “Generally Suitable”, per ASTM F1962-11. The slightly weathered to fresh bedrock of fair to excellent quality encountered in boring SB-1, SB-3, SB-4 is categorized as “Difficulties May Occur”, per the referenced publication.

2. HDD Suitability by Condition

Soil conditions described in the referenced table as “Very loose to loose sands above and below the water table” include the upper Stratum I soils in SB-1. “Very loose to dense gravelly sand” includes Stratum I applies to the lower Stratum I soils found in boring SB-1. “Medium to dense sands above or below the water table” includes Stratum II soils found in boring SB-4. “Soils with significant cobbles, boulders, and obstructions” includes Stratum I and Stratum II soils found in borings SB-1, SB-3 and SB-4. The Stratum II soils are described by the condition “Very loose to dense gravelly sand (30% to 50% gravel by weight)” which are found in borings SB-1, SB-3 and SB-4. “Very loose to dense gravelly sand (30% to 50% gravel by weight)” and “weathered rocks, marls, chalks, and firmly cemented soils” also describe Stratum II. The coreable shale bedrock at the site is described by two categories “weathered rocks, marls, chalks, and firmly cemented soils” and “slightly weathered to unweathered rocks”.

3. Conclusions on HDD Suitability

According to the correlations discussed in the previous paragraphs, the expected pipeline depths, and the subsurface profile encountered, two strata are considered “Generally Suitable” for HDD installation operations: the Existing FILL material and Stratum I soils in SB-4 categorized as “medium to dense sands above and below the water table (not more than 30% gravel by weight)”.

Each of the encountered strata include zones which are considered strata where “Difficulties May Occur”: Stratum I soils categorized as “Very loose to dense gravelly sand” (30% to 50% gravel by weight); Stratum II soils categorized as “very loose to loose sands above and below the water table (not more than 30% gravel by weight)”; and Shale bedrock categorized as “slightly weathered to unweathered rocks”.

Stratum II material in test boring SB-3 is considered a stratum where “Substantial Problems” may occur. This portion of the Stratum II material is categorized as “soils with significant cobbles, boulders, and obstructions” due to cobbled and boulders within the soil matrix.

Based on the overall profile of the subsurface conditions observed, rock drilling techniques will be required during horizontal directional drilling operations if projected through the Stratum II weathered rock and/or shale bedrock. It should be noted that this information is provided to facilitate the planning for the HDD portion of the project, and the final means and methods for installation of the pipe remain the responsibility of the selected HDD contractor.

B. Excavation Methods and Trenching

Trench excavation necessary for the pipeline installation and connections will occur predominately in the Existing FILL material, Stratum I and Stratum II soils. In general, these materials should be easy to excavate using conventional equipment and techniques. If excavation difficulties are experienced within dense to very dense portions of the Stratum II material, improved excavation rates will be realized utilizing a late-model high-powered track-mounted excavator.

Excavations must be sloped, benched or shored to prevent collapse during the soil excavation and construction. In general, sidewall stability of excavations within the Existing FILL material soils will be poor due to the granular content and non-plastic nature of the majority of these materials. Poor sidewall stability will be exacerbated where shallow groundwater is encountered in these materials. The slopes of all construction excavations should be in accordance with established Occupational Safety and Health Administration (OSHA) guidelines. If sloping is not possible, an approved trench box or other bracing and sheeting should be utilized along with appropriate groundwater control measures. The actual excavation sloping and/or bracing requirements should be determined in the field based on the required depth of cuts and soil types encountered during construction by a qualified Engineer. The above recommendations are provided for planning purposes only and the contractor will remain the entity in "Responsible Charge" of all health and safety on the site.

C. Groundwater Control

As detailed in the *Groundwater* section of this report, excavation necessary for the pipeline installation will approach and/or extend below river elevation depths. Based on the granular nature of the Existing FILL material, Stratum I and Stratum II soils, trench excavation necessary for shallow pipeline installation within these materials will likely encounter considerable groundwater flow. Consequently, a dewatering system would be required during trench excavation and backfilling. The dewatering specifications for this system should be of the performance type requiring the contractor to maintain the static water table a minimum of two (2) feet below the base elevation of the excavation required for the pipeline construction.

The dewatering system should be capable of dewatering the excavation continually during construction activities. A backup system should be available in the event that the primary system fails. It is recommended that the final selection of the dewatering system for this project be made by the successful contractor. Water produced during the dewatering operation should be handled in accordance with applicable statutes and regulations.

The appropriate measures to be taken for groundwater control are the responsibilities of

the contractor and should be determined prior to construction and verified at the time of excavation.

D. In-Situ Materials for Use as Fill

1. On-Site Fill Criteria

Fill material that supports foundations, pavements, and used for roadway embankments and retaining wall backfill, is considered structural fill. Deep pipeline installation, in addition to excavation necessary for trenches during shallow pipeline installation, will make the Existing FILL material and underlying alluvial and residual soils available for use as structural fill. These materials are generally suitable for reuse as structural fill provided the moisture content deviates nominally from optimum and any organics or deleterious materials are removed prior to placement. Consequently, the materials generated during required excavation and/or directional drilling should be carefully evaluated for reuse by a representative of the Geotechnical Engineer of Record at the time of excavation. Any materials which are deemed unsuitable for reuse as structural fill should be stockpiled separately and removed from the site or placed in non-structural areas.

Field observations indicate that the majority of the encountered soils exist in a generally moist to wet state. However, reuse of the Existing FILL, Stratum I, and Stratum II materials as structural fill should be feasible. It is emphasized that these excavated soils will likely require some moisture conditioning prior to placement as structural fill to achieve the required densities and percentage compaction values. Soils excavated from below the groundwater level, if any, should be stockpiled separately from the overlying soils. Excavated rock fragments or cobbles, if encountered, may also be utilized as structural fill provided, they are processed to less than three (3) inches in diameter and mixed properly with suitable soils to produce a well-graded matrix.

The on-site soils will require some moisture control as portions are fine-grained and sensitive to moisture changes. Caution should be exercised during construction to not stockpile and/or expose these soils to weather conditions for long periods of time. Materials stockpiled for use as structural fill should be graded to shed water and rolled to maintain the soils. During periods of wet site conditions, travel upon the construction areas should be limited to minimize disturbance of the subgrade which will lead to instabilities.

2. Imported Fill Criteria

Any **imported** structural or load bearing soil should meet the project specifications or meet the following criteria:

- Free of organic matter, ash, cinders, deleterious or frozen materials, and demolition debris.
- Particle size distribution that is well graded.
- Plasticity index less than ten (10).
- Less than fifteen (15) percent by weight rock fragments larger than three (3) inches, less than thirty (30) percent by weight larger than three quarters (3/4) of an inch, and less than thirty (30) percent by weight smaller than the No. 200 sieve.
- Materials must meet Clean Fill specifications according to PADEP Management of Fill Policy, Document Number 258-2182-773.

Material not specifically meeting the above criteria should be submitted to the geotechnical engineer, on a per source basis, for approval prior to importation to the site.

3. Compaction Criteria

Structural fill should generally be placed in lifts not exceeding eight (8) inches in loose thickness and compacted with a smooth drum or sheepsfoot vibratory roller with a minimum static weight of ten (10) tons (where possible). Use of a sheepsfoot roller will aid in crushing excavated rock fragments or cobbles, if encountered, for use as structural fill. The fill should be placed in horizontal lifts of six (6) inches in loose thickness where compaction by hand-operated equipment is necessary. The optimum lift thickness and number of repetitions necessary to achieve the required percentage compaction values should be determined in the field with test passes of the chosen compaction equipment. The fill material should be placed at, or deviate nominally from, the optimum moisture content as determined in accordance with ASTM D698 or ASTM D1557, and compacted to a minimum percentage of the maximum dry density as indicated in the following table.

TABLE V
COMPACTION CRITERIA

Fill Placement Area	Percent of Maximum Dry Density according to ASTM D698	Percent of Maximum Dry Density according to ASTM D1557
Foundation and Slab Support	98	95
Retaining Walls, Pavements, Walkways, and Embankments	95	92
Non-Structural	92	90

The compaction criteria provided above are recommended by EEI. State, county, and township specifications should be adhered to if they are more stringent than those provided herein.

VII. LIMITATIONS

The conclusions and recommendations contained in this report are based upon the subsurface data collected, details stated in this report, and the assumption that the subsurface conditions do not deviate from those disclosed by the data acquisition activities performed. It is recommended that final design plans be provided to EEI for review as part of any subsequent investigations or analyses. Any substantial change in the proposed pipeline alignment should be brought to the attention of EEI so that its impact on the recommendations presented within this report may be evaluated. Should any conditions arise which differ from those specifically stated herein, our office should be notified immediately so that our recommendations can be reviewed and revised, if necessary.

The recommendations provided herein are for the design of the pipeline installation and associated connections to existing pipeline sections. Should sheeting, shoring, underpinning, or bracing be required, EEI should be contacted so that proper design of such measures may be formulated.

Unless specifically indicated to the contrary in this report, the scope of this report is limited to only investigations and evaluations of the geotechnical aspects of the site conditions and does not include any considerations of potential site pollution or contamination. This report offers no facts or opinions related to potential pollution or contamination on the site.

The procedures followed during the subsurface exploration, and the analyses and conclusions contained herein, have followed generally accepted practices of geotechnical engineering. EEI provides no other warranties, either expressed or implied, as to the professional advice provided under the terms of EEI's agreement and included in this report. The conclusions and recommendations presented in this report are based on the assumption that recognized, proper construction practices will be followed throughout the pipeline construction operation.

It is emphasized that this analysis was performed for the Jacobs Creek Crossing associated with the 14-inch Twin Oaks to Newark Pipeline Relocation Project located in Upper Makefield Township, Pennsylvania and Hopewell Township, New Jersey. EEI does not assume any responsibility in using this report to generate designs other than at the specific site addressed.

Respectfully submitted,
EARTH ENGINEERING INCORPORATED

David Rude, P.G.
Senior Geologist / Project Manager

Patrick McNamara, P.E.
Director - Geotechnical Investigations

G:\PROJECTS\31000\31585.00 - Jacobs Creek Pipeline Relocation - Delaware River Crossing - EN Geotech\REPORT\31585.00 - STV Jacobs Creek Pipeline Relocation- Geotechnical Report.doc

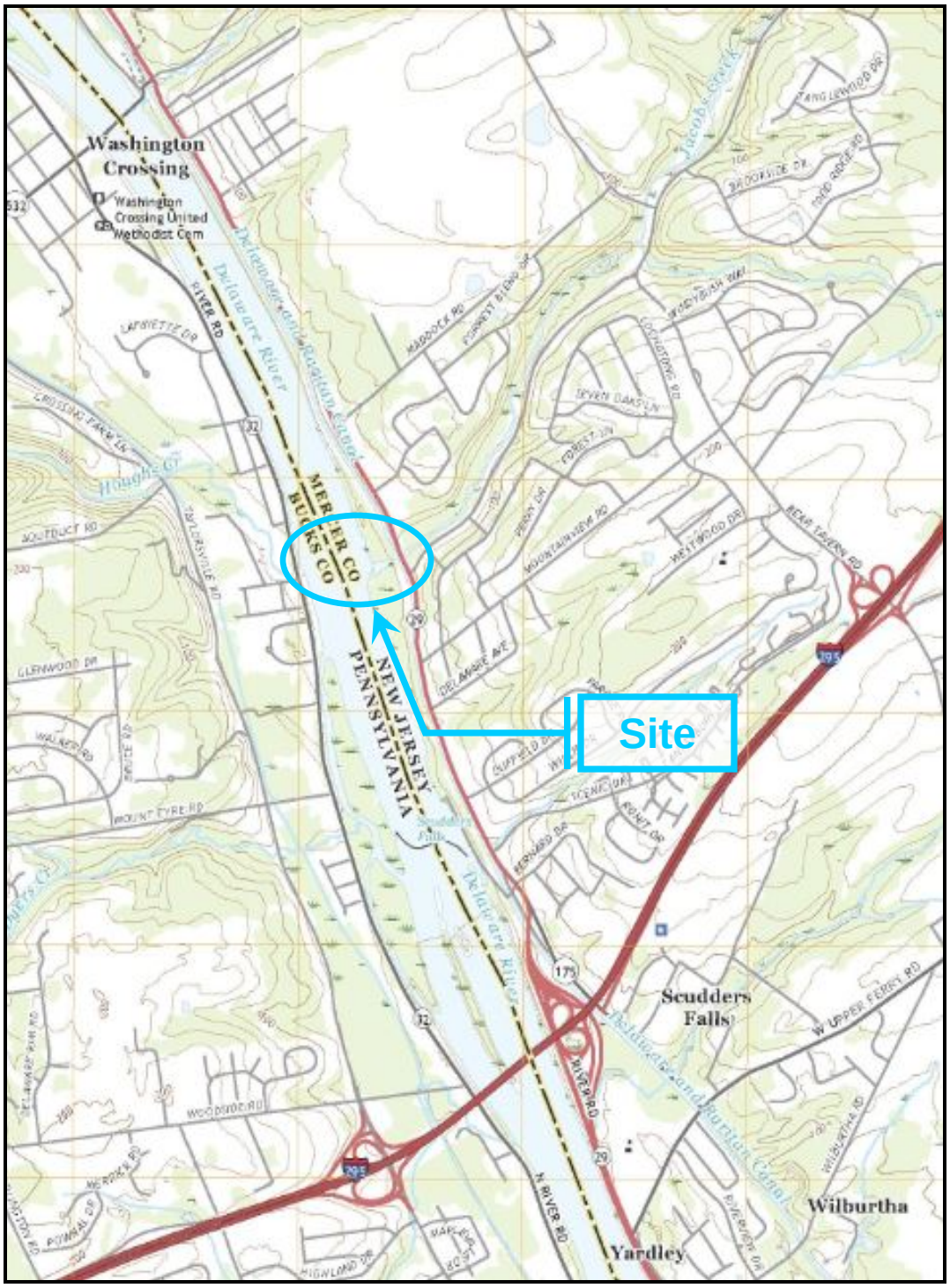


PLATE 1 – TOPOGRAPHIC MAP OF SITE

Reprinted from the United States Geological Survey, Topographic Maps of Pennsylvania and New Jersey, Pennington, NJ Quadrangle, Photorevised 2019.

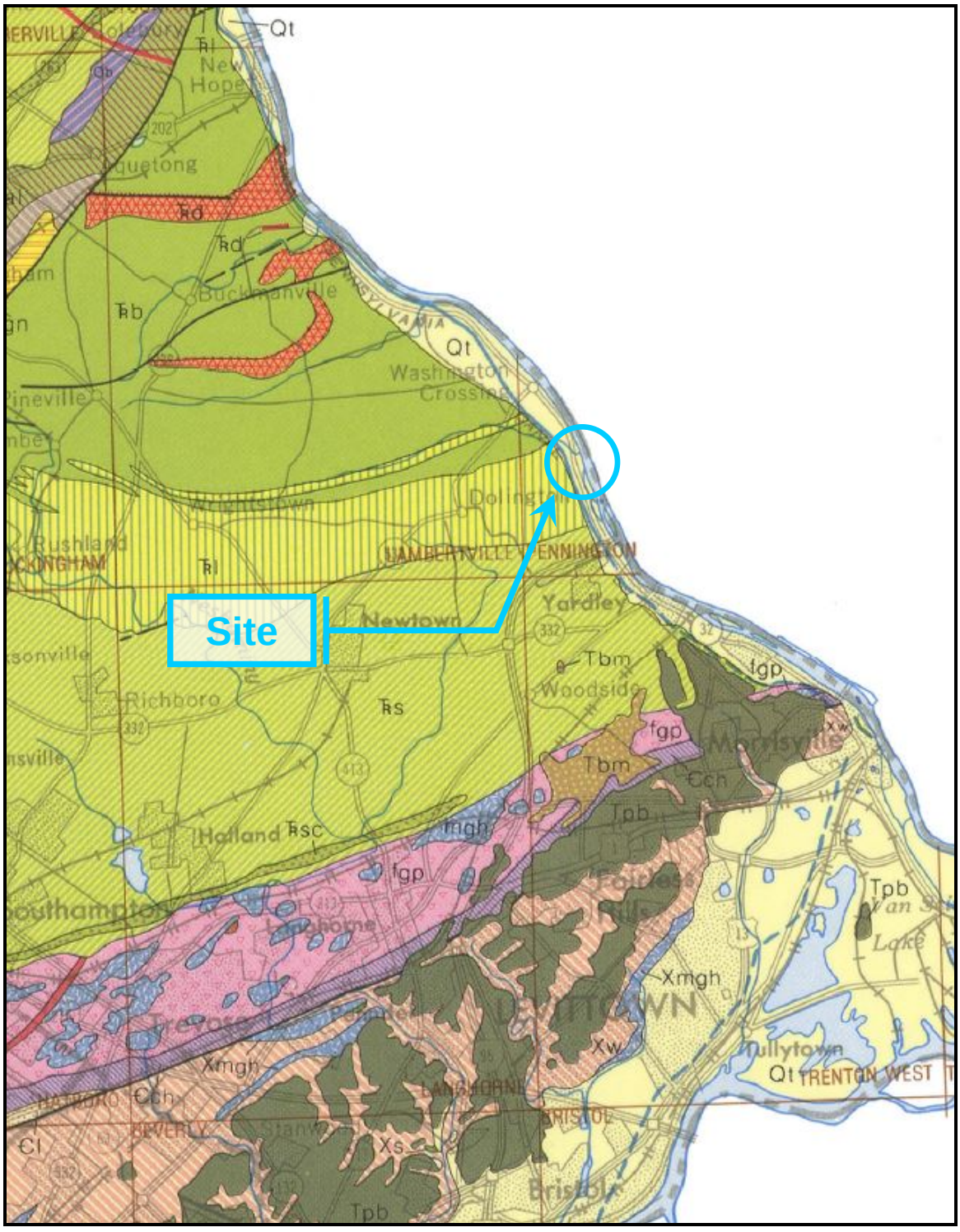


PLATE 2 - GEOLOGIC MAP OF SITE

Reprinted from the Pennsylvania Geological Survey, Geologic Map of Pennsylvania,1980.

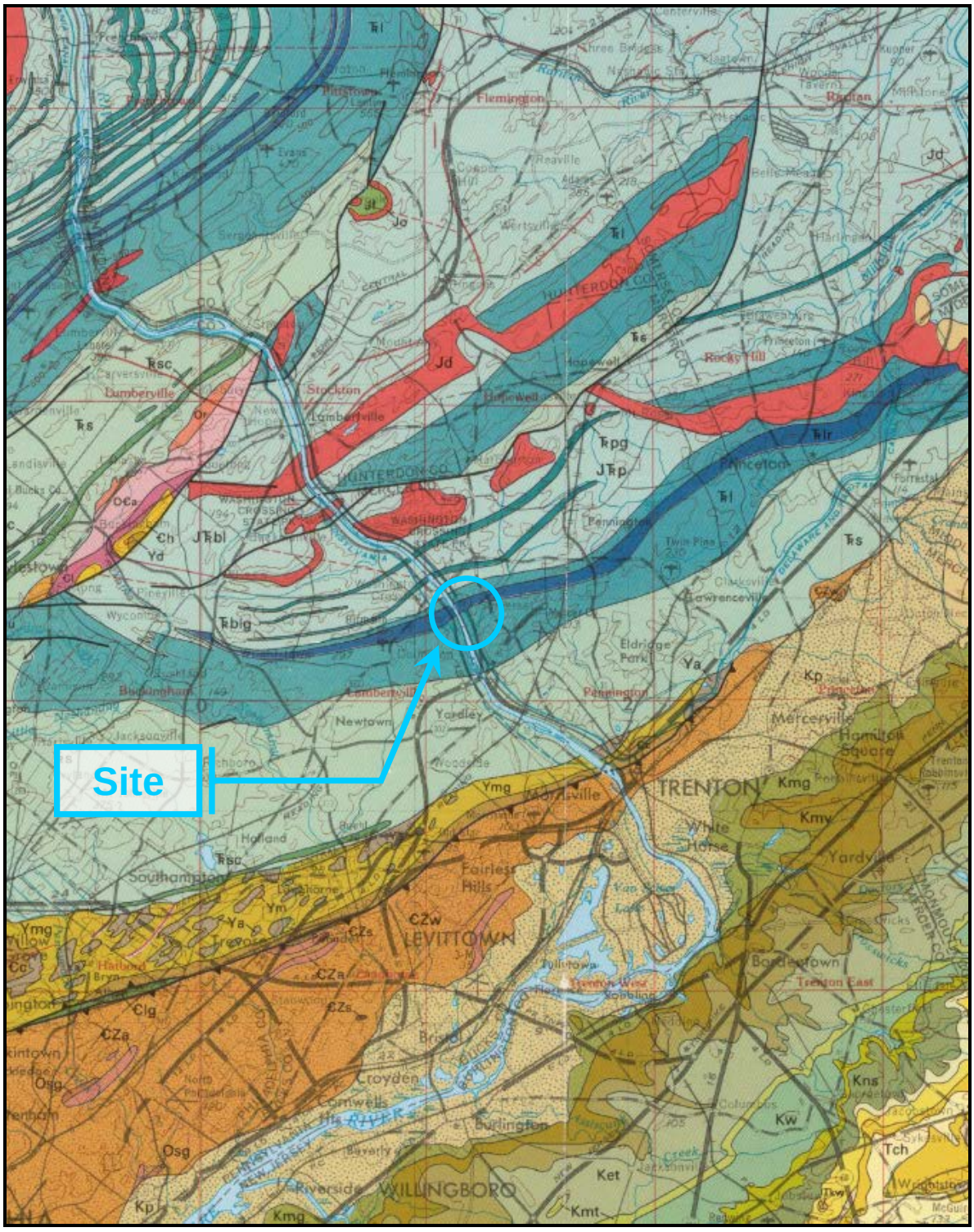
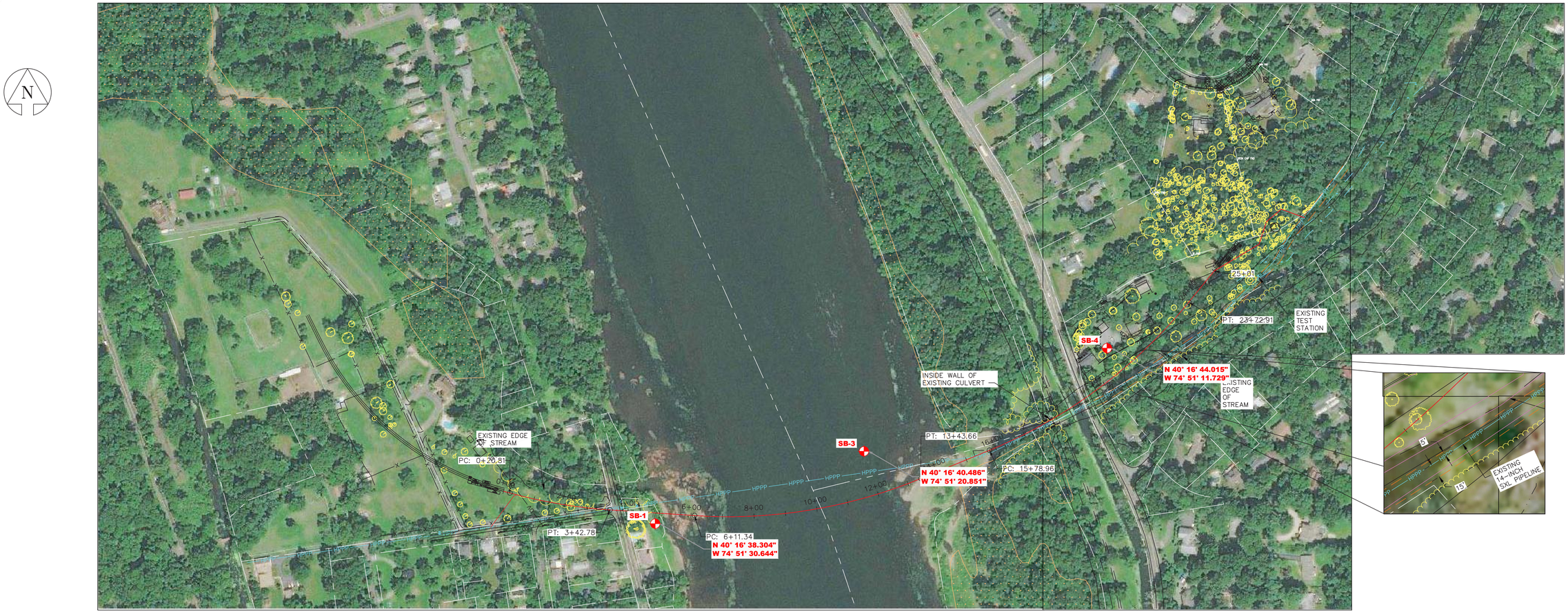
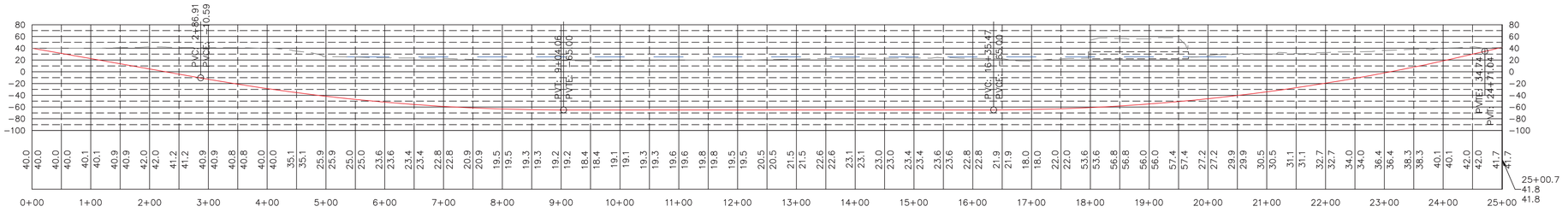


PLATE 3 - GEOLOGIC MAP OF SITE

Reprinted from the U.S. Geological Survey, Geologic Map of the Newark Quadrangle, New Jersey, Pennsylvania and New York ,1987.





LEGEND:

- EXISTING SXL PIPELINE
- PROPOSED SXL PIPELINE
- EXISTING PIPELINE RIGHT-OF-WAY
- PROPERTY LINE
- EDGE OF WATER
- EXISTING FENCE
- EXISTING TREE LINE
- POLITICAL BOUNDARY
- 100 YEAR FLOODPLAIN
- FLOODWAY
- EXISTING WETLAND (STV DELINIATED)
- EXISTING WETLAND (NWI)
- SOIL BORING

PROFILE LEGEND:

- PROPOSED PIPELINE
- EXISTING GRADE
- EXISTING GRADE ELEV / PROPOSED TOP OF PIPE ELEV (825.2 / 821.3)

NOAA DELAWARE RIVER AT WASHINGTON CROSSING GAUGE ELEVATION CHART		
DATUM	GAUGE ELEVATION	FLOOD STAGE ELEVATION
NAVD88	25.18'	41.175

KEY:

- APPROXIMATE BORING LOCATION

BASE PLAN PROVIDED BY: STV ENERGY SERVICES, INC.

EARTH ENGINEERING INCORPORATED
Geotechnical Engineers & Geologists
115 W Germantown Pike
East Norriton, PA 19401
(610)277-0880
FAX (610)277-0878
www.earthengineering.com

TESTING LOCATION PLAN

PREPARED FOR

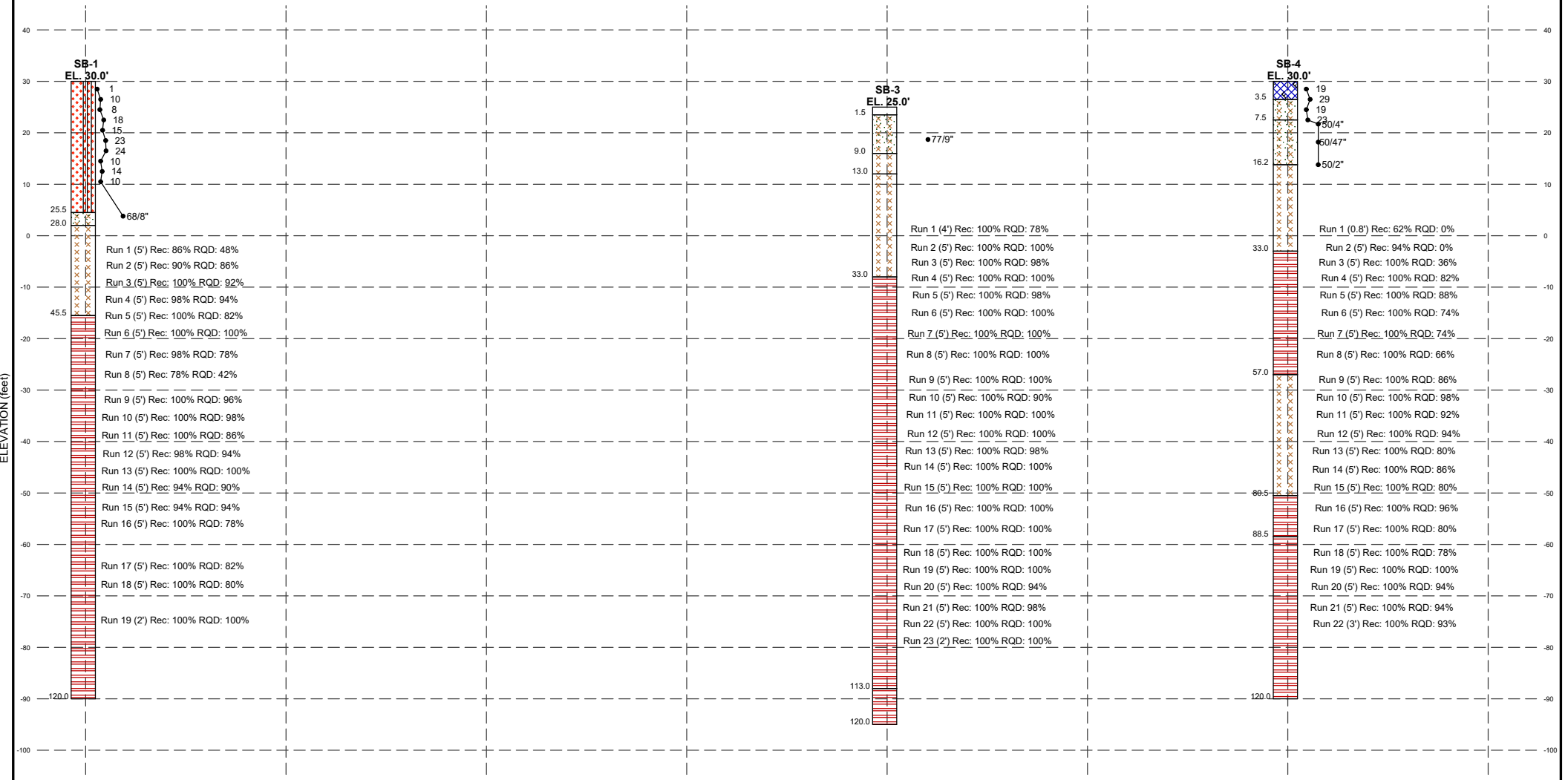
STV JACOBS CREEK RELOCATION HDD

HOPEWELL & EWING TOWNSHIP NEW JERSEY – UPPER MAKEFIELD TOWNSHIP PENNSYLVANIA

Scale:	Date:	Drawn By:	Checked By:
AS SHOWN	12/31/2019	JRK	JMC

Drawing Number: 31585.00-D-101

Approved By: PMM



Lithology Graphics

- Stratum I - fine to coarse SAND trace GRAVEL, COBBLES and BOULDERS
- Stratum II - Silty SAND to Silty GRAVEL trace to some COBBLES and BOULDERS (Decomposed to Weathered Siltstone)
- Siltstone Bedrock
- Shale Bedrock
- FILL - Silty fine SAND trace GRAVEL, STONE and BRICK
- Initial Groundwater Level
- Subsequent Groundwater Level

EARTH ENGINEERING INCORPORATED
Geotechnical Engineers & Geologists

BORING PROFILES
PREPARED FOR
STV - JACOBS CREEK HDD

UPPER MAKEFIELD TOWNSHIP, BUCKS COUNTY, PENNSYLVANIA

Project Number: 31585.00	Date: 12/31/19	Check: P. McNamara

EARTH ENGINEERING INCORPORATED
Geotechnical Engineers & Geologists

BORING LOG

BORING NO. **SB-1**
SHEET **1** OF **3**
DATE: START **6/5/19**
END **6/7/19**
SURFACE ELEV. (FT) **30.0**

PROJECT NAME **STV - Jacobs Creek HDD**
PROJECT LOCATION **Upper Makefield Township, Bucks County, Pennsylvania**
PROJECT NUMBER **31585.00**
INSPECTOR NAME **J. Kufta**
EQUIPMENT USED **Acker Soil XLS**
DRILLER NAME/COMPANY **Jeff Dotzler/TRC**
DRILLING METHODS **2" split spoon sampling continuously to 20'; 5' sampling intervals thereafter.**
AUGER: SIZE: **3" O.D. casing** ; AUGER DEPTH: **28.0'** ; WATER: DEPTH: ____ TIME: ____ DATE: ____
CHECKED BY: **P. McNamara** ; DATE: **12/31/19** DEPTH: ____ TIME: ____ DATE: ____
NOT ENCOUNTERED [X]

DEPTH (FT)	SAMPLE NO./ TYPE/CORE RUN	BLOWS/0.5 FT. ON SAMPLER	RECOVERY (Ft.)	RECOVERY(%) / RQD (%)	USCS / AASHTO	H_2O CONTENT	GRAPHIC LOG	DESCRIPTION	REMARKS
0.0								DEPTH ELEVATION	
2.0	S-1	0 0 1 1	0.4'	20 -	sm/sp	m		fine - coarse sand, trace silt, gravel, cobbles and boulders; pale brown, brown	easy drilling 0.0' - 2.5'
4.0	S-2	6 6 4 2	0.5'	25 -	GP-GM	7.9			
6.0	S-3	3 4 4 5	0.2'	10 -	GP-GM	7.9			difficult drilling - heavy cobbles/boulders 2.5' - 10.0', auger deflection.
8.0	S-4	18 11 7 8	0.3'	15 -	GP-GM	7.9			
10.0	S-5	11 8 7 8	1.0'	50 -	GP-GM	7.9			
12.0	S-6	9 11 12 17	1.3'	65 -	GP-GM	6.6			
14.0	S-7	15 14 10 9	0.9'	45 -	GP-GM	6.6			moderate to difficult drilling 10.0' - 25.5', gravel and cobble bedding throughout
16.0	S-8	9 6 4 5	0.9'	45 -	SW-SM	10.6			
18.0	S-9	8 9 5 5	0.2'	10 -	SW-SM	10.6			
20.0	S-10	8 4 6 6	1.5'	75 -	SW-SM	10.6			
25.0								25.5 4.5	
26.2	S-11	13 18 50/2"	0.5'	42 -	gp/gm	w		sandy gravel, trace silt; brown, red brown	difficult drilling 25.5' - 28.0'
28.0								28.0 2.0	
33.0	R-1	NA	4.3'	86 / 48		NA		siltstone, red brown, hard, slightly weathered to fresh, very thinly to thickly bedded, extremely closely jointed/fractured, broken to massive	casing refusal at 28.0' rock coring 28.0' - 120.0
38.0	R-2	NA	4.5'	90 / 86		NA			
	R-3	NA	5.0'	100 / 92		NA			DIP 65 - 90

** D = DRY, M = MOIST, W = WET

EARTH ENGINEERING INCORPORATED
Geotechnical Engineers & Geologists

BORING LOG

BORING NO. **SB-1**
SHEET **2** OF **3**
DATE: START **6/5/19**
END **6/7/19**
SURFACE ELEV. (FT) **30.0**

PROJECT NAME **STV - Jacobs Creek HDD**
PROJECT LOCATION **Upper Makefield Township, Bucks County, Pennsylvania**
PROJECT NUMBER **31585.00**
INSPECTOR NAME **J. Kufta**
EQUIPMENT USED **Acker Soil XLS**
DRILLER NAME/COMPANY **Jeff Dotzler/TRC**
DRILLING METHODS **2" split spoon sampling continuously to 20'; 5' sampling intervals thereafter.**
AUGER: SIZE: **3" O.D. casing** ; AUGER DEPTH: **28.0'** ; WATER: DEPTH: _____ TIME: _____ DATE: _____
CHECKED BY: **P. McNamara** ; DATE: **12/31/19** DEPTH: _____ TIME: _____ DATE: _____
NOT ENCOUNTERED [X]

DEPTH (FT)	SAMPLE NO./ TYPE/CORE RUN	BLOWS/0.5 FT. ON SAMPLER	RECOVERY (Ft.)	RECOVERY(%) / RQD (%)	USCS / AASHTO	H_2O CONTENT	GRAPHIC LOG	DESCRIPTION	REMARKS
								DEPTH ELEVATION	
43.0				92		NA		siltstone, red brown, hard, slightly weathered to fresh, very thinly to thickly bedded, extremely closely jointed/fractured, broken to massive *(continued)*	
	R-4	NA	4.9'	98 / 94		NA		45.5 -15.5	DIP 75 - 90
48.0								shale, grey to dark blue grey, hard, slightly weathered to fresh, very thinly to thickly bedded, extremely closely jointed/fractured, broken to massive	
	R-5	NA	5.0'	100 / 82		NA			DIP 75
53.0									
	R-6	NA	5.0'	100 / 100		NA			DIP 65
58.0									
	R-7	NA	4.9'	98 / 78		NA			DIP 15
63.0									
	R-8	NA	3.9'	78 / 42		NA			
68.0									
	R-9	NA	5.0'	100 / 96		NA			
73.0									
	R-10	NA	5.0'	100 / 98		NA			
78.0									
	R-11	NA	5.0'	100 / 86		NA			DIP 15

** D = DRY, M = MOIST, W = WET

EARTH ENGINEERING INCORPORATED
Geotechnical Engineers & Geologists

BORING LOG

BORING NO. **SB-1**
SHEET **3** OF **3**
DATE: START **6/5/19**
END **6/7/19**
SURFACE ELEV. (FT) **30.0**

PROJECT NAME **STV - Jacobs Creek HDD**
PROJECT LOCATION **Upper Makefield Township, Bucks County, Pennsylvania**
PROJECT NUMBER **31585.00**
INSPECTOR NAME **J. Kufta**
EQUIPMENT USED **Acker Soil XLS**
DRILLER NAME/COMPANY **Jeff Dotzler/TRC**
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AUGER: SIZE: **3" O.D. casing** ; AUGER DEPTH: **28.0'** ; WATER: DEPTH: ____ TIME: ____ DATE: ____
CHECKED BY: **P. McNamara** ; DATE: **12/31/19** DEPTH: ____ TIME: ____ DATE: ____
NOT ENCOUNTERED [X]

DEPTH (FT)	SAMPLE NO./ TYPE/CORE RUN	BLOWS/0.5 FT. ON SAMPLER	RECOVERY (Ft.)	RECOVERY(%) / RQD (%)	USCS / AASHTO	H_2O CONTENT	GRAPHIC LOG	DESCRIPTION	REMARKS
								DEPTH ELEVATION	
83.0				86		NA		shale, grey to dark blue grey, hard, slightly weathered to fresh, very thinly to thickly bedded, extremely closely jointed/fractured, broken to massive *(continued)*	
	R-12	NA	4.9'	98 / 94		NA			
88.0									
	R-13	NA	5.0'	100 / 100		NA			DIP 10
93.0									
	R-14	NA	4.7'	94 / 90		NA			
98.0									
	R-15	NA	4.7'	94 / 94		NA			
103.0									
	R-16	NA	5.0'	100 / 78		NA			
108.0									
	R-17	NA	5.0'	100 / 82		NA			
113.0									
	R-18	NA	5.0'	100 / 80		NA			
118.0									
	R-19	NA	2.0'	100 / 100		NA			
120.0								120.0 -90.0	
									end of boring - 120.0'

** D = DRY, M = MOIST, W = WET

EARTH ENGINEERING INCORPORATED
Geotechnical Engineers & Geologists

BORING LOG

BORING NO. SB-3
SHEET 1 OF 3
DATE: START 10/1/19
END 10/2/19
SURFACE ELEV. (FT) 25.0

PROJECT NAME **STV - Jacobs Creek HDD**
PROJECT LOCATION **Upper Makefield Township, Bucks County, Pennsylvania**
PROJECT NUMBER **31585.00**
INSPECTOR NAME **J. Kufta**
EQUIPMENT USED **Acker Soil XLS**
DRILLER NAME/COMPANY **P. Flaherty/TRC**
DRILLING METHODS **2" split spoon sampling continuously to 20'; 5' sampling intervals thereafter.**
AUGER: SIZE: **3" O.D. casing** ; AUGER DEPTH: **120.0'** ; WATER: DEPTH: ____ TIME: ____ DATE: ____
CHECKED BY: **P. McNamara** ; DATE: **12/31/19** DEPTH: ____ TIME: ____ DATE: ____
NOT ENCOUNTERED [X]

DEPTH (FT)	SAMPLE NO./ TYPE/CORE RUN	BLOWS/0.5 FT. ON SAMPLER	RECOVERY (Ft.)	RECOVERY(%) / RQD (%)	USCS / AASHTO	H_2O CONTENT	GRAPHIC LOG	DESCRIPTION (DEPTH / ELEVATION)	REMARKS
								Water 1.5 / 23.5	Water 0.0' River bottom 1.5'
5.0								Silty gravel, trace to some cobbles and boulders; Brown, red brown, orange brown	
6.3	S-1	30 27 50/3"	1.3'	100	ml/gm	w			
9.0								9.0 / 16.0	
13.0	R-1	NA	4.0'	100 / 78		NA		Siltstone, red to grey, medium hard to hard, moderately weathered to fresh, intensely to thinly bedded, extremely closely fractured, very broken to massive. 13.0 / 12.0	Casing refusal 9.0' 10 Degree Dip
18.0	R-2	NA	5.0'	100 / 100		NA		Siltstone, red, hard, fresh, intensely to medium bedding, extremely closely fractured, slightly broken to massive.	10 & 70 Degree Dip
23.0	R-3	NA	5.0'	100 / 98		NA			10 Degree Dip
28.0	R-4	NA	5.0'	100 / 100		NA			35 Degree Dip
33.0	R-5	NA	5.0'	100 / 98		NA		33.0 / -8.0	10 & 80 Degree Dip
38.0	R-6	NA	5.0'	100 / 100		NA		Shale, grey, hard to very hard, fresh, intensely to medium bedding, extremely closely fractured, broken to massive.	Occasional Pyrite inclusion, quartz, and calcite 15 Degree Dip
	R-7	NA	5.0'	100 / 100		NA			10 Degree Dip

** D = DRY, M = MOIST, W = WET

EARTH ENGINEERING INCORPORATED
Geotechnical Engineers & Geologists

BORING LOG

BORING NO. **SB-3**
SHEET **2** OF **3**
DATE: START **10/1/19**
END **10/2/19**
SURFACE ELEV. (FT) **25.0**

PROJECT NAME **STV - Jacobs Creek HDD**
PROJECT LOCATION **Upper Makefield Township, Bucks County, Pennsylvania**
PROJECT NUMBER **31585.00**
INSPECTOR NAME **J. Kufta**
EQUIPMENT USED **Acker Soil XLS**
DRILLER NAME/COMPANY **P. Flaherty/TRC**
DRILLING METHODS **2" split spoon sampling continuously to 20'; 5' sampling intervals thereafter.**
AUGER: SIZE: **3" O.D. casing** ; AUGER DEPTH: **120.0'** ; WATER: DEPTH: _____ TIME: _____ DATE: _____
CHECKED BY: **P. McNamara** ; DATE: **12/31/19** DEPTH: _____ TIME: _____ DATE: _____
NOT ENCOUNTERED [X]

DEPTH (FT)	SAMPLE NO./ TYPE/CORE RUN	BLOWS/0.5 FT. ON SAMPLER	RECOVERY (Ft.)	RECOVERY(%) / RQD (%)	USCS / AASHTO	H_2O CONTENT	GRAPHIC LOG	DESCRIPTION (DEPTH / ELEVATION)	REMARKS
43.0				100		NA		Shale, grey, hard to very hard, fresh, intensely to medium bedding, extremely closely fractured, broken to massive. *(continued)*	
	R-8	NA	5.0'	100 / 100		NA			
48.0									
	R-9	NA	5.0'	100 / 100		NA			10 & 80 Degree Dip
53.0									Broken and jamming 53.0' - 54.0'
	R-10	NA	5.0'	100 / 90		NA			10 Degree Dip
58.0									
	R-11	NA	5.0'	100 / 100		NA			10 & 80 Degree Dip
63.0									
	R-12	NA	5.0'	100 / 100		NA			
68.0									
	R-13	NA	5.0'	100 / 98		NA			10 & 75 Degree Dip
73.0									Run 14, 80 degrees calcite filled fractures
	R-14	NA	5.0'	100 / 100		NA			10 & 35 Degree Dip
78.0									
	R-15	NA	5.0'	100 / 100		NA			10 & 80 Degree Dip

** D = DRY, M = MOIST, W = WET

EARTH ENGINEERING INCORPORATED
Geotechnical Engineers & Geologists

BORING LOG

BORING NO. SB-3
SHEET 3 OF 3
DATE: START 10/1/19
END 10/2/19
SURFACE ELEV. (FT) 25.0

PROJECT NAME **STV - Jacobs Creek HDD**
PROJECT LOCATION **Upper Makefield Township, Bucks County, Pennsylvania**
PROJECT NUMBER **31585.00**
INSPECTOR NAME **J. Kufta**
EQUIPMENT USED **Acker Soil XLS**
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AUGER: SIZE: **3" O.D. casing** ; AUGER DEPTH: **120.0'** ; WATER: DEPTH: ____ TIME: ____ DATE: ____
CHECKED BY: **P. McNamara** ; DATE: **12/31/19** DEPTH: ____ TIME: ____ DATE: ____
NOT ENCOUNTERED [X]

DEPTH (FT)	SAMPLE NO./ TYPE/CORE RUN	BLOWS/0.5 FT. ON SAMPLER	RECOVERY (Ft.)	RECOVERY(%) / RQD (%)	USCS / AASHTO	H_2O CONTENT	GRAPHIC LOG	DESCRIPTION	REMARKS
								DEPTH ELEVATION	
83.0				100		NA		Shale, grey, hard to very hard, fresh, intensely to medium bedding, extremely closely fractured, broken to massive. *(continued)*	
	R-16	NA	5.0'	100 / 100		NA			10 & 45 Degree Dip
88.0									
	R-17	NA	5.0'	100 / 100		NA			10 & 80 Degree Dip
93.0									
	R-18	NA	5.0'	100 / 100		NA			10 & 60 Degree Dip
98.0									
	R-19	NA	5.0'	100 / 100		NA			10 & 75 Degree Dip
103.0									
	R-20	NA	5.0'	100 / 94		NA			
108.0									
	R-21	NA	5.0'	100 / 98		NA			10 & 80 Degree Dip
113.0								113.0 -88.0	
	R-22	NA	5.0'	100 / 100		NA		Shale, grey, hard to very hard, fresh, intensely to medium bedding, extremely closely fractured, broken to massive.	
118.0									
	R-23	NA	2.0'	100 / 100		NA			
120.0								120.0 -95.0	
									End of boring - 120.0'
									Boring grouted to river bottom

** D = DRY, M = MOIST, W = WET

EARTH ENGINEERING INCORPORATED
Geotechnical Engineers & Geologists

BORING LOG

BORING NO. SB-4
SHEET 1 OF 3
DATE: START 8/13/19
END 8/14/19
SURFACE ELEV. (FT) 30.0

PROJECT NAME STV - Jacobs Creek HDD
PROJECT LOCATION Upper Makefield Township, Bucks County, Pennsylvania
PROJECT NUMBER 31585.00
INSPECTOR NAME J. Kufta
EQUIPMENT USED Acker Soil XLS
DRILLER NAME/COMPANY Roger Crum/TRC
DRILLING METHODS 2" split spoon sampling continuously to 8.3'; 5' sampling intervals thereafter.
AUGER: SIZE: 3" O.D. casing ; AUGER DEPTH: 16.2' ; WATER: DEPTH: TIME: DATE:
CHECKED BY: P. McNamara ; DATE: 12/31/19 DEPTH: TIME: DATE:
NOT ENCOUNTERED [X]

DEPTH (FT)	SAMPLE NO./ TYPE/CORE RUN	BLOWS/0.5 FT. ON SAMPLER	RECOVERY (Ft.)	RECOVERY(%) / RQD (%)	USCS / AASHTO	H_2O CONTENT	GRAPHIC LOG	DESCRIPTION	REMARKS
								DEPTH ELEVATION	
0.0	S-1	7 9 10 10	1.7'	85 -	sm/gm	NA		silty fine sand trace to some stone and gravel, trace brick; red brown, brown, red (FILL)	easy to moderate drilling 0.0' - 3.5'
2.0	S-2	11 15 14 11	1.7'	85 -	sm/gm	NA			
3.5								3.5 26.5	
4.0	S-3	10 10 9 7	0.7'	35 -	SM	11.6		silty sand trace to some gravel; red brown, grey, dark grey (Decomposed Siltstone)	moderate drilling 3.5' - 7.5'
6.0	S-4	8 11 12 19	1.8'	90 - -	SM	11.6			
7.5								7.5 22.5	
8.0	S-5	50/4"	0.2'	67	gm			silty sand some gravel trace cobbles; dark grey (Weathered Siltstone)	difficult drilling 7.5' - 16.2'
8.3	S-6	42 50/47	0.6'	75 -		NA			
11.0									
11.8									
16.0				-					
16.2	S-7	50/2"	0.0'	0 0		NA		16.2 13.8	
17.0	R-1	NA	0.5'	62		NA		Siltstone, red to grey, medium hard to hard, moderately weathered to fresh, intensely to thinly bedded, extremely closely fractured, very broken to massive.	casing refusal at 16.2'
22.0	R-2	NA	4.7'	94 0		NA			Dip 5 and 75 barrel jam at 21.0'
27.0	R-3	NA	5.0'	100 36		NA			Dip 10 and 40
32.0	R-4	NA	5.0'	100 82		NA			Dip 10 and 40
33.0								33.0 -3.0	
37.0	R-5	NA	5.0'	100 88		NA		Shale, grey, hard, slightly weathered to fresh, intensely to medium bedding, extremely closely fractured, broken to massive.	Dip 5 and 40
	R-6	NA	5.0'	100 74		NA			Dip 5 and 70

** D = DRY, M = MOIST, W = WET

EARTH ENGINEERING INCORPORATED
Geotechnical Engineers & Geologists

BORING LOG

BORING NO. SB-4
SHEET 2 OF 3
DATE: START 8/13/19
END 8/14/19
SURFACE ELEV. (FT) 30.0

PROJECT NAME STV - Jacobs Creek HDD
PROJECT LOCATION Upper Makefield Township, Bucks County, Pennsylvania
PROJECT NUMBER 31585.00
INSPECTOR NAME J. Kufta
EQUIPMENT USED Acker Soil XLS
DRILLER NAME/COMPANY Roger Crum/TRC
DRILLING METHODS 2" split spoon sampling continuously to 8.3'; 5' sampling intervals thereafter.
AUGER: SIZE: 3" O.D. casing ; AUGER DEPTH: 16.2' ; WATER: DEPTH: _____ TIME: _____ DATE: _____
CHECKED BY: P. McNamara ; DATE: 12/31/19 DEPTH: _____ TIME: _____ DATE: _____
NOT ENCOUNTERED [X]

DEPTH (FT)	SAMPLE NO./ TYPE/CORE RUN	BLOWS/0.5 FT. ON SAMPLER	RECOVERY (Ft.)	RECOVERY(%) / RQD (%)	USCS / AASHTO	H_2O CONTENT	GRAPHIC LOG	DESCRIPTION	REMARKS
42.0				74		NA		Shale, grey, hard, slightly weathered to fresh, intensely to medium bedding, extremely closely fractured, broken to massive. *(continued)*	33.0' - 57.0' calcite filled laminations and fractures
	R-7	NA	5.0'	100 / 74		NA			Dip 10 and 85
47.0	R-8	NA	5.0'	100 / 66		NA			Dip 5 and 60
52.0	R-9	NA	5.0'	100 / 86		NA			barrel jam at 51.0' Dip 10 and 85
57.0	R-10	NA	5.0'	100 / 98		NA		DEPTH 57.0 ELEVATION -27.0 Siltstone, red, hard, fresh, intensely to medium bedding, extremely closely fractured, slightly broken to massive.	Dip 10 and 85
62.0	R-11	NA	5.0'	100 / 92		NA			Dip 5
67.0	R-12	NA	5.0'	100 / 94		NA			Dip 5 and 40 57.0' - 85.0' calcite filled laminations and fractures
72.0	R-13	NA	5.0'	100 / 80		NA			Dip 5 and 40
77.0	R-14	NA	5.0'	100 / 86		NA			Dip 5 and 20
82.0								80.5 -50.5	

** D = DRY, M = MOIST, W = WET

EARTH ENGINEERING INCORPORATED
Geotechnical Engineers & Geologists

BORING LOG

BORING NO. **SB-4**
SHEET **3** OF **3**
DATE: START **8/13/19**
END **8/14/19**
SURFACE ELEV. (FT) **30.0**

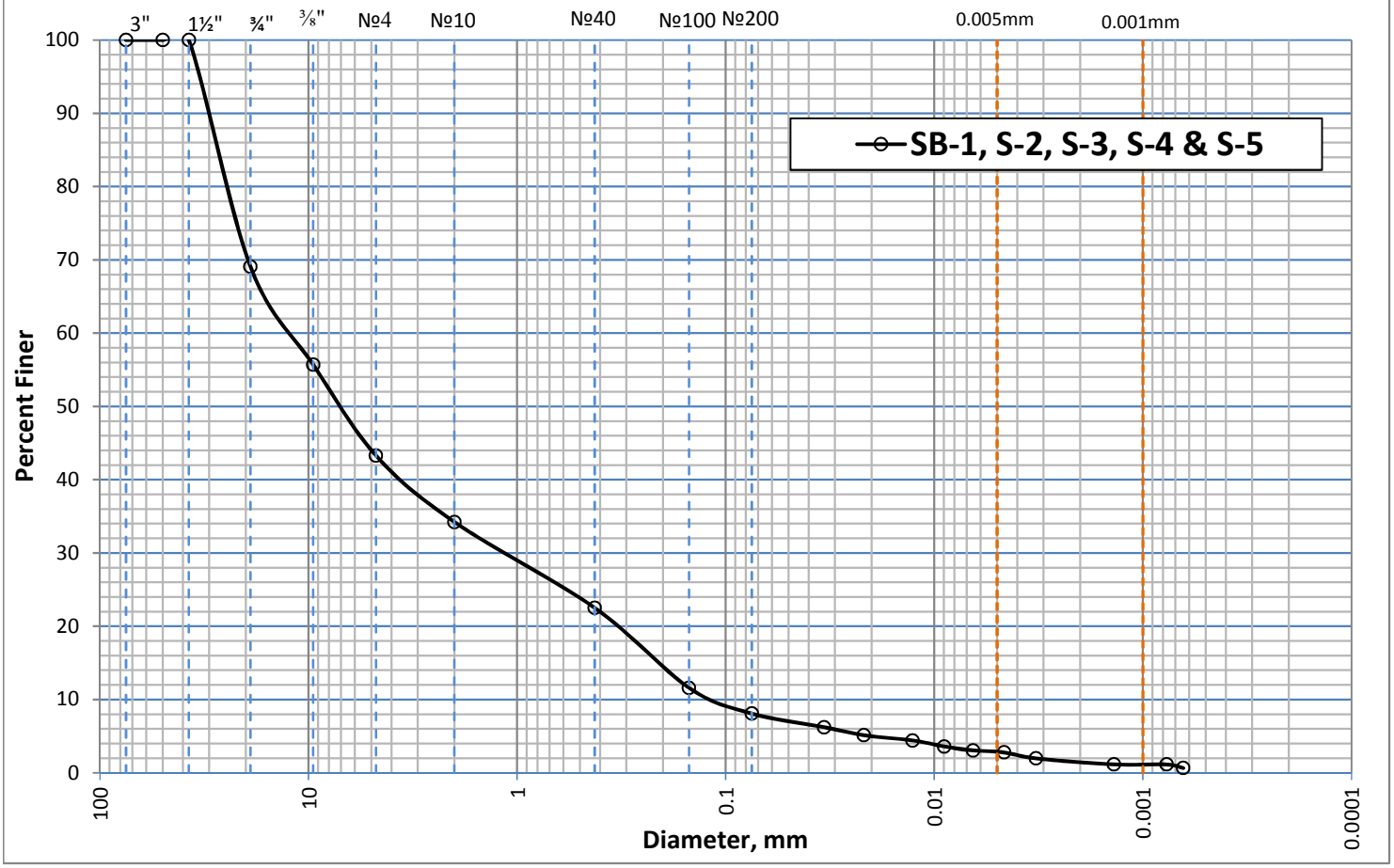
PROJECT NAME **STV - Jacobs Creek HDD**
PROJECT LOCATION **Upper Makefield Township, Bucks County, Pennsylvania**
PROJECT NUMBER **31585.00**
INSPECTOR NAME **J. Kufta**
EQUIPMENT USED **Acker Soil XLS**
DRILLER NAME/COMPANY **Roger Crum/TRC**
DRILLING METHODS **2" split spoon sampling continuously to 8.3'; 5' sampling intervals thereafter.**
AUGER: SIZE: **3" O.D. casing** ; AUGER DEPTH: **16.2'** ; WATER: DEPTH: _____ TIME: _____ DATE: _____
CHECKED BY: **P. McNamara** ; DATE: **12/31/19** DEPTH: _____ TIME: _____ DATE: _____
NOT ENCOUNTERED [X]

DEPTH (FT)	SAMPLE NO./ TYPE/CORE RUN	BLOWS/0.5 FT. ON SAMPLER	RECOVERY (Ft.)	RECOVERY(%) / RQD (%)	USCS / AASHTO	H_2O CONTENT	GRAPHIC LOG	DESCRIPTION	REMARKS
								DEPTH ELEVATION	
87.0	R-15	NA	5.0'	100 / 80		NA		Shale, grey, hard, slightly weathered to fresh, intensely to medium bedding, extremely closely fractured, broken to massive. *(continued)*	85.0' - 88.5.0' calcite filled laminations and fractures Dip 5 and 75
92.0	R-16	NA	5.0'	100 / 96		NA		88.5 -58.5 Shale, grey, hard to very hard, fresh, intensely to medium bedding, extremely closely fractured, broken to massive.	Dip 10 and 70
97.0	R-17	NA	5.0'	100 / 80		NA			Dip 5
102.0	R-18	NA	5.0'	100 / 78		NA			Dip 5 and 10 88.5 - 120.0' 0.5 cm to 1.0 cm occasional pyrite inclusions
107.0	R-19	NA	5.0'	100 / 100		NA			Dip 5
112.0	R-20	NA	5.0'	100 / 94		NA			Dip 5
117.0	R-21	NA	5.0'	100 / 94		NA			Dip 5 and 70
120.0	R-22	NA	3.0'	100 / 93		NA		120.0 -90.0	Dip 5
									end of boring - 120.0'

** D = DRY, M = MOIST, W = WET

Particle-Size Analysis of Soils

ASTM D 422-63 (07)



As-rec'd water content: 7.9		**Odor:** NR			
% Gravel: 56.7	**Coarse:** 30.9	**Fine:** 25.8			
% Sand: 35.2	**Coarse:** 9.1	**Medium:** 11.7	**Fine:** 14.4		
Gravel description: red-brown, subangular to subrounded					
Sand description: red-brown, subangular to subrounded					
Consistency: firm		**Hardness:** NR			
Cementation: NR		**Dry Strength:** NR			
Structure: homogeneous		**Dilatency:** NR			
Reaction to HCl: NR		**Toughness:** NR			
USCS Classification: GP-GM, poorly graded gravel with silt and sand					
AASHTO Classification: A-1-a					

Particle Size

US Standard Sieve Size			Diameter, mm	% Finer
GRAVEL	Coarse	3"	75	100.0
		1½"	38.1	100.0
		¾"	19.0	69.1
	Fine	⅜"	9.5	55.7
		№ 4	4.75	43.3
SAND	Coarse	№ 10	2.00	34.2
	Medium	№ 40	0.425	22.5
	Fine	№ 100	0.150	11.6
		№ 200	0.075	8.1
Hydrometer Analysis		Clay Size	0.005	3.0
		Colloids	0.001	1.3

Gs: NR	**Cu:** 114	**Cc:** 1.0	
LL: NP	**PL:** NP	**PI:** NP	

Project: 31585.00 STV - Delaware Crossing - Jacobs Creek

Client: STV Energy Services

Sample: SB-1, S-2 (6-6-4-2), S-3 (3-4-4-5), S-4 (18-11-7-8) & S-5 (11-8-8-7)

Depth: 2'-4', 4'-6', 6'-8' & 8'-10'

Description: Red-brown poorly graded gravel with silt and sand

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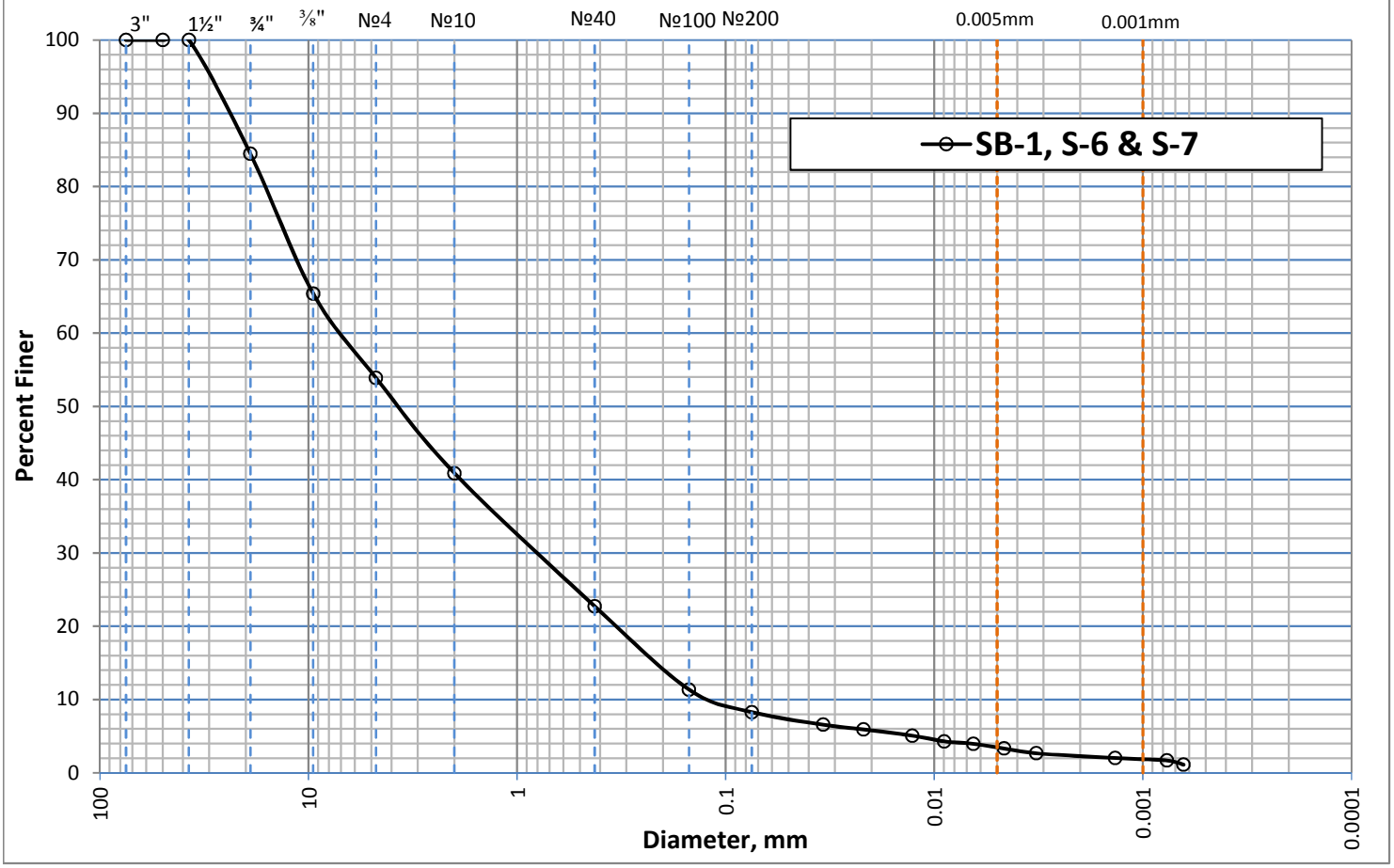
Lehigh Valley 610-967-4540

Remarks:

Particle-Size Analysis of Soils

ASTM D 422-63 (07)



As-rec'd water content: 6.6		**Odor:** NR	
% Gravel: 46.1	**Coarse:** 15.5	**Fine:** 30.6	
% Sand: 45.6	**Coarse:** 13.0	**Medium:** 18.2	**Fine:** 14.5
Gravel description: red-brown, subangular to subrounded			
Sand description: red-brown, subangular to subrounded			
Consistency: firm		**Hardness:** NR	
Cementation: NR		**Dry Strength:** NR	
Structure: homogeneous		**Dilatency:** NR	
Reaction to HCl: NR		**Toughness:** NR	
USCS Classification: GP-GM, poorly graded gravel with silt and sand			
AASHTO Classification: A-1-a			

Particle Size

US Standard Sieve Size			Diameter, mm	% Finer
GRAVEL	Coarse	3"	75	100.0
		1½"	38.1	100.0
		¾"	19.0	84.5
	Fine	⅜"	9.5	65.4
		№ 4	4.75	53.9
SAND	Coarse	№ 10	2.00	40.9
	Medium	№ 40	0.425	22.7
	Fine	№ 100	0.150	11.4
		№ 200	0.075	8.3
Hydrometer Analysis		Clay Size	0.005	3.7
		Colloids	0.001	2.0

Gs: NR **Cu:** 61.3 **Cc:** 0.8

LL: NP **PL:** NP **PI:** NP

Project: 31585.00 STV - Delaware Crossing - Jacobs Creek

Client: STV Energy Services

Sample: SB-1, S-6 (9-11-12-17) & S-7 (15-14-10-9)

Depth: 10'-12' & 12'-14'

Description: Red-brown poorly graded gravel with silt and sand

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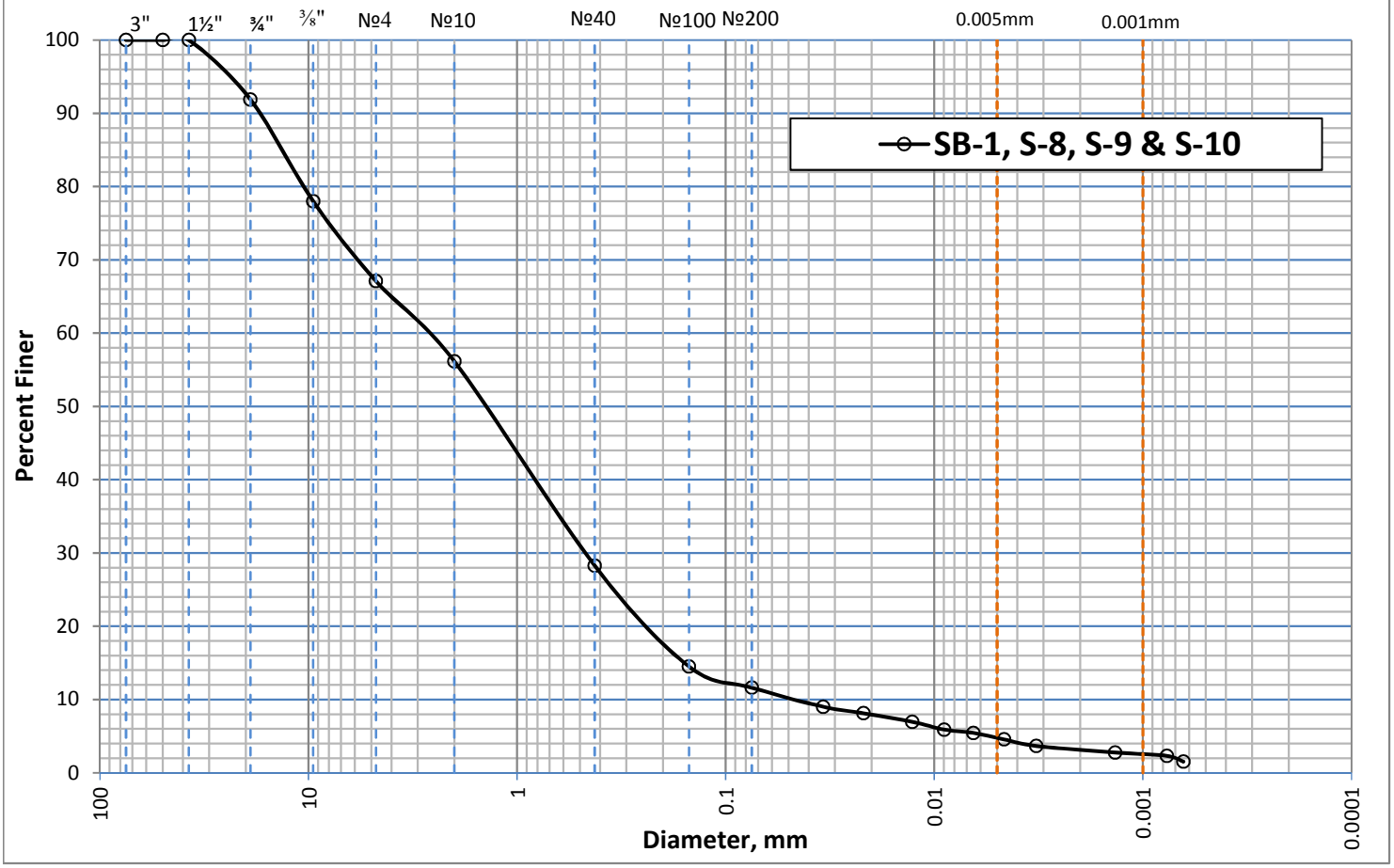
Lehigh Valley 610-967-4540

Remarks:

Particle-Size Analysis of Soils

ASTM D 422-63 (07)



As-rec'd water content: 10.6		**Odor:** NR	
% Gravel: 32.9	**Coarse:** 8.1	**Fine:** 24.8	
% Sand: 55.5	**Coarse:** 10.9	**Medium:** 27.9	**Fine:** 16.7
Gravel description: red-brown, subangular to subrounded			
Sand description: red-brown, subangular to subrounded			
Consistency: firm		**Hardness:** NR	
Cementation: NR		**Dry Strength:** NR	
Structure: homogeneous		**Dilatency:** NR	
Reaction to HCl: NR		**Toughness:** NR	
USCS Classification: SW-SM, well-graded sand with silt and gravel			
AASHTO Classification: A-1-b			

Particle Size				
US Standard Sieve Size			Diameter, mm	% Finer
GRAVEL	Coarse	3"	75	100.0
		1½"	38.1	100.0
		¾"	19.0	91.9
	Fine	⅜"	9.5	78.0
		№ 4	4.75	67.1
SAND	Coarse	№ 10	2.00	56.2
	Medium	№ 40	0.425	28.3
	Fine	№ 100	0.150	14.5
		№ 200	0.075	11.6
Hydrometer Analysis		Clay Size	0.005	4.7
		Colloids	0.001	2.3

Gs: NR	**Cu:** 66.3	**Cc:** 2.2
LL: NP	**PL:** NP	**PI:** NP

Project: 31585.00 STV - Delaware Crossing - Jacobs Creek

Client: STV Energy Services

Sample: SB-1, S-8 (9-6-4-5), S-9 (8-9-5-5) & S-10 (8-4-6-6)

Depth: 14'-16', 16'-18' & 18'-20'

Description: Red-brown well-graded sand with silt and gravel

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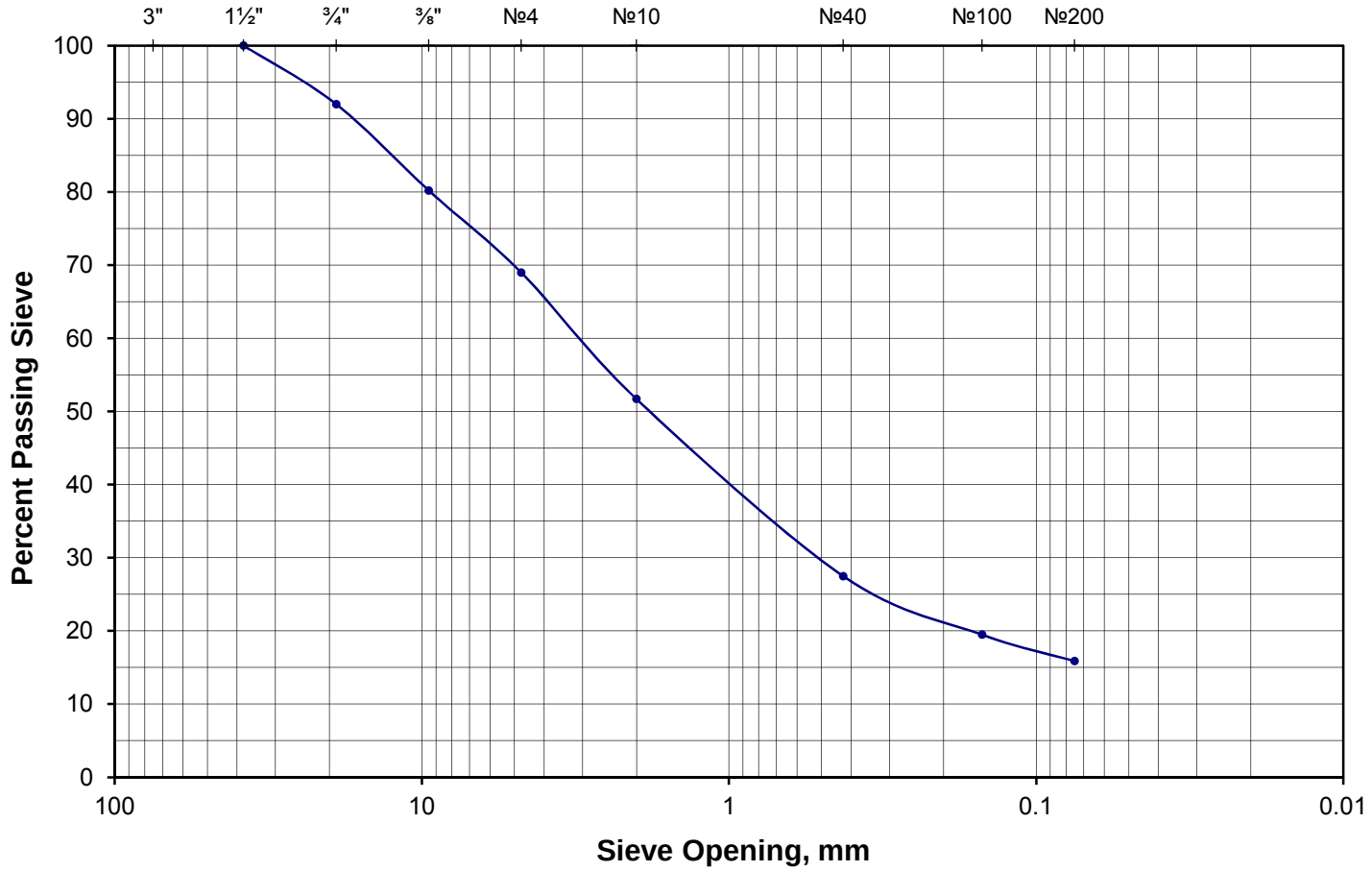
Remarks:

Particle Size Analysis of Soils



As-rec'd water content: 11.6 moist **Odor:** NR

% Gravel: 31.0 **Coarse:** 8.0 **Fine:** 23.0

% Sand: 53.1 **Coarse:** 17.3 **Medium:** 24.2 **Fine:** 11.6

Gravel description: red-brown, subangular to subrounded

Sand description: red-brown, subangular to subrounded

Consistency: firm **Hardness:** NR

Cementation: NR **Dry Strength:** NR

Structure: homogeneous **Dilatency:** NR

Reaction to HCl: NR **Toughness:** NR

USCS Classification: **SM, silty sand with gravel**

AASHTO Classification: **A-1-b**

Project: 31585.00 - STV - Delaware Crossing - Jacobs Creek

Client: STV Energy Services

Sample: SB-4, S-3 (10-10-9-7) & S-4 (8-11-12-19)

Depth: 4.0'- 6.0' & 6.0'- 8.0'

Description: Red-brown silty sand with gravel

Remarks:

Particle Size

US Standard Sieve Size			Diameter,	% Finer
GRAVEL	Coarse	3"	75	
		1½"	38.1	100.0
		¾"	19.0	92.0
	Fine	⅜"	9.5	80.2
		№ 4	4.75	69.0
SAND	Coarse	№ 10	2.00	51.7
	Medium	№ 40	0.425	27.5
	Fine	№ 100	0.150	19.5
		№ 200	0.075	15.9
Hydrometer Analysis		Clay Size	0.005	NR
		Colloids	0.001	NR

G_s: NR C_u: N/A C_c: N/A

LL: NP **PL:** NP **PI:** NP

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Classification of Soils, ASTM D 2487-11 / D 2488-09a ***December 31, 2019***

AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV-Delaware River-Jacobs Creek
Project Number:	60504020
Assignment Number:	2019-08-01
Report Date:	31-Jul-19

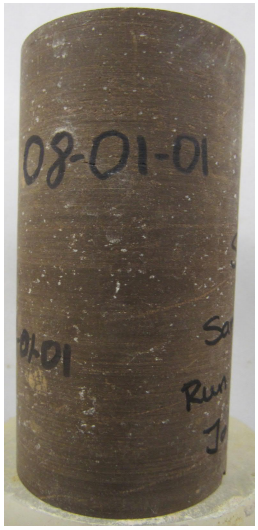
Sample Data

Boring:	SB-1	
Core:	R-2	
Depth:	33.0-38.0	(ft)
Average Length:	4.056	(in)
Average Diameter:	1.975	(in)
Area:	3.06	(in^2)
L/D Ratio:	2.1	
Description:		

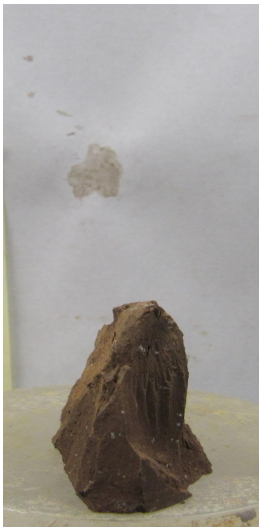
Test Results

Test Date:	26-Jul-19	
Load at Failure:	75,500	(lb)
Unconfined Compressive Strength:	24,645	(psi)
Dry Unit Weight:	162.1	(pcf)
Load Rate:	0.28	(%/min)
Tested by:	CD	
Reviewed by:	MHD	

Before Test



After Test



AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV-Delaware River-Jacobs Creek
Project Number:	60504020
Assignment Number:	2019-08-01
Report Date:	31-Jul-19

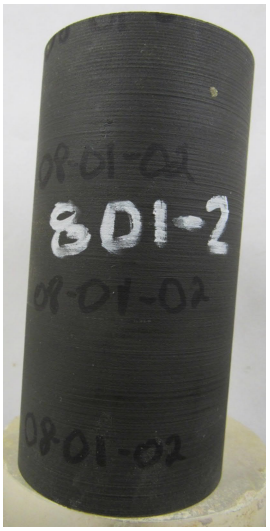
Sample Data

Boring:	SB-1	
Core:	R-6	
Depth:	53.0-58.0	(ft)
Average Length:	4.115	(in)
Average Diameter:	1.983	(in)
Area:	3.09	(in^2)
L/D Ratio:	2.1	
Description:		

Test Results

Test Date:	26-Jul-19	
Load at Failure:	76,000	(lb)
Unconfined Compressive Strength:	24,600	(psi)
Dry Unit Weight:	167.4	(pcf)
Load Rate:	0.28	(%/min)
Tested by:	CD	
Reviewed by:	MHD	

Before Test



After Test

AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV-Delaware River-Jacobs Creek
Project Number:	60504020
Assignment Number:	2019-08-01
Report Date:	31-Jul-19

Sample Data

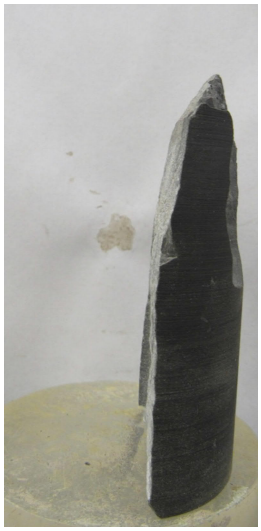
Boring:	SB-1	
Core:	R-10	
Depth:	73.0-78.0	(ft)
Average Length:	4.067	(in)
Average Diameter:	1.986	(in)
Area:	3.10	(in^2)
L/D Ratio:	2.0	
Description:		

Test Results

Test Date:	26-Jul-19	
Load at Failure:	82,500	(lb)
Unconfined Compressive Strength:	26,632	(psi)
Dry Unit Weight:	165.1	(pcf)
Load Rate:	0.28	(%/min)
Tested by:	CD	
Reviewed by:	MHD	

Before Test

After Test



AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV-Delaware River-Jacobs Creek
Project Number:	60504020
Assignment Number:	2019-08-01
Report Date:	31-Jul-19

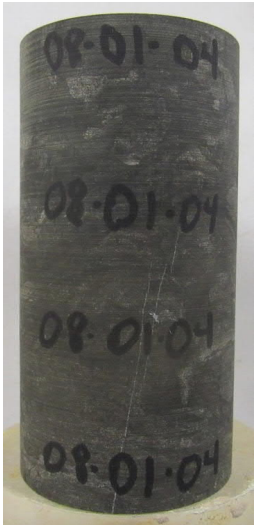
Sample Data

Boring:	SB-1	
Core:	R-14	
Depth:	93.0-98.0	(ft)
Average Length:	4.147	(in)
Average Diameter:	1.984	(in)
Area:	3.09	(in^2)
L/D Ratio:	2.1	
Description:		

Test Results

Test Date:	26-Jul-19	
Load at Failure:	73,500	(lb)
Unconfined Compressive Strength:	23,783	(psi)
Dry Unit Weight:	169.0	(pcf)
Load Rate:	0.28	(%/min)
Tested by:	CD	
Reviewed by:	MHD	

Before Test



After Test

AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV-Delaware River-Jacobs Creek
Project Number:	60504020
Assignment Number:	2019-08-01
Report Date:	31-Jul-19

Sample Data

Boring:	SB-1	
Core:	R-18	
Depth:	113.0-118.0	(ft)
Average Length:	4.081	(in)
Average Diameter:	1.952	(in)
Area:	2.99	(in^2)
L/D Ratio:	2.1	
Description:		

Test Results

Test Date:	26-Jul-19	
Load at Failure:	86,500	(lb)
Unconfined Compressive Strength:	28,895	(psi)
Dry Unit Weight:	172.4	(pcf)
Load Rate:	0.28	(%/min)
Tested by:	CD	
Reviewed by:	MHD	

Before Test

After Test

AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV - Jacobs Creek HDD
Project Number:	60504020
Assignment Number:	2019-10-08
Report Date:	11-Nov-19

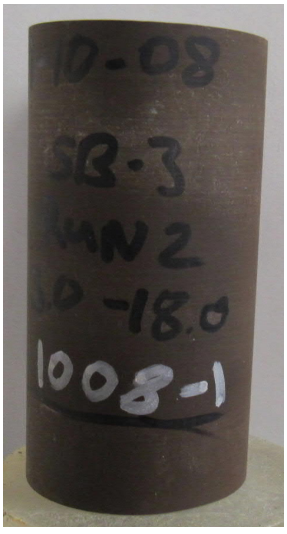
Sample Data

Boring:	SB-3	
Core:	R-2	
Depth:	13.0-18.0	(ft)
Average Length:	4.175	(in)
Average Diameter:	1.986	(in)
Area:	3.10	(in^2)
L/D Ratio:	2.1	
Description:		

Test Results

Test Date:	8-Oct-19	
Load at Failure:	65,750	(lb)
Unconfined Compressive Strength:	21,218	(psi)
Dry Unit Weight:	163.6	(pcf)
Water Content:	0.4	(%)
Load Rate:	0.28	(%/min)
Tested by:	CM	
Reviewed by:	MHD	

Before Test



After Test

AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV - Jacobs Creek HDD
Project Number:	60504020
Assignment Number:	2019-10-08
Report Date:	11-Nov-19

Sample Data

Boring:	SB-3	
Core:	R-3	
Depth:	33.0-38.0	(ft)
Average Length:	4.196	(in)
Average Diameter:	1.989	(in)
Area:	3.11	(in^2)
L/D Ratio:	2.1	
Description:		

Test Results

Test Date:	8-Oct-19	
Load at Failure:	53,750	(lb)
Unconfined Compressive Strength:	17,299	(psi)
Dry Unit Weight:	163.8	(pcf)
Water Content:	0.4	(%)
Load Rate:	0.28	(%/min)
Tested by:	CM	
Reviewed by:	MHD	

Before Test

After Test

AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV - Jacobs Creek HDD
Project Number:	60504020
Assignment Number:	2019-10-08
Report Date:	11-Nov-19

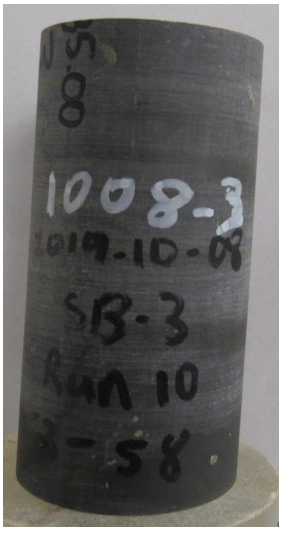
Sample Data

Boring:	SB-3	
Core:	R-10	
Depth:	53.0-58.0	(ft)
Average Length:	4.226	(in)
Average Diameter:	1.990	(in)
Area:	3.11	(in^2)
L/D Ratio:	2.1	
Description:		

Test Results

Test Date:	8-Oct-19	
Load at Failure:	47,500	(lb)
Unconfined Compressive Strength:	15,272	(psi)
Dry Unit Weight:	167.7	(pcf)
Water Content:	0.3	(%)
Load Rate:	0.28	(%/min)
Tested by:	CM	
Reviewed by:	MHD	

Before Test



After Test

AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV - Jacobs Creek HDD
Project Number:	60504020
Assignment Number:	2019-10-08
Report Date:	11-Nov-19

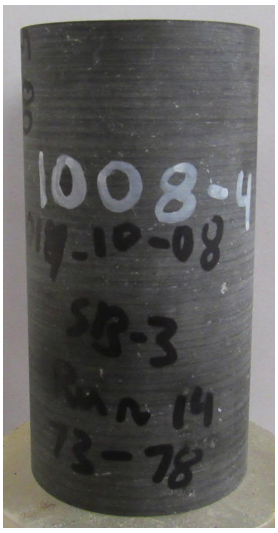
Sample Data

Boring:	SB-3	
Core:	R-14	
Depth:	73.0-78.0	(ft)
Average Length:	4.191	(in)
Average Diameter:	1.992	(in)
Area:	3.12	(in^2)
L/D Ratio:	2.1	
Description:		

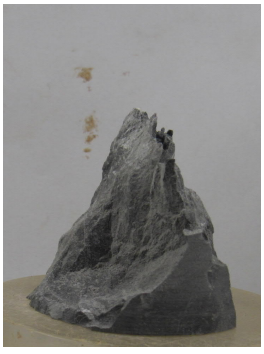
Test Results

Test Date:	8-Oct-19	
Load at Failure:	88,750	(lb)
Unconfined Compressive Strength:	28,477	(psi)
Dry Unit Weight:	168.3	(pcf)
Water Content:	0.2	(%)
Load Rate:	0.28	(%/min)
Tested by:	CM	
Reviewed by:	MHD	

Before Test



After Test



AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV - Jacobs Creek HDD
Project Number:	60504020
Assignment Number:	2019-10-08
Report Date:	11-Nov-19

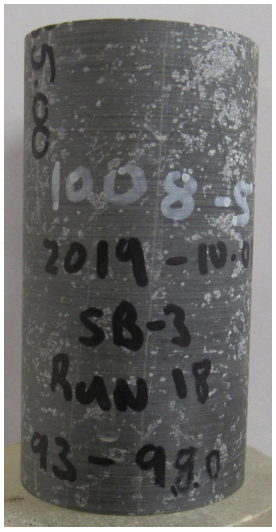
Sample Data

Boring:	SB-3	
Core:	R-18	
Depth:	93.0-98.0	(ft)
Average Length:	4.078	(in)
Average Diameter:	1.992	(in)
Area:	3.12	(in^2)
L/D Ratio:	2.0	
Description:		

Test Results

Test Date:	8-Oct-19	
Load at Failure:	69,000	(lb)
Unconfined Compressive Strength:	22,140	(psi)
Dry Unit Weight:	169.9	(pcf)
Water Content:	0.3	(%)
Load Rate:	0.28	(%/min)
Tested by:	CM	
Reviewed by:	MHD	

Before Test



After Test

AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV - Jacobs Creek HDD
Project Number:	60504020
Assignment Number:	2019-10-08
Report Date:	11-Nov-19

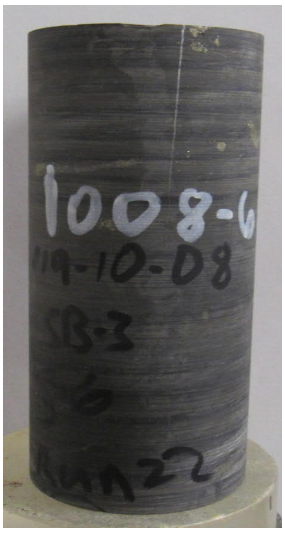
Sample Data

Boring:	SB-3	
Core:	R-22	
Depth:	113.0-118.0	(ft)
Average Length:	4.221	(in)
Average Diameter:	1.992	(in)
Area:	3.12	(in^2)
L/D Ratio:	2.1	
Description:		

Test Results

Test Date:	8-Oct-19	
Load at Failure:	38,000	(lb)
Unconfined Compressive Strength:	12,189	(psi)
Dry Unit Weight:	165.9	(pcf)
Water Content:	1.1	(%)
Load Rate:	0.28	(%/min)
Tested by:	CM	
Reviewed by:	MHD	

Before Test



After Test

AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV - Jacobs Creek HDD
Project Number:	60504020
Assignment Number:	2019-08-30
Report Date:	27-Aug-19

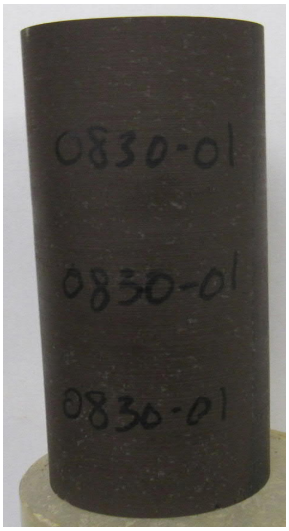
Sample Data

Boring:	SB-4	
Core:	R-3	
Depth:	22.0-27.0	(ft)
Average Length:	4.119	(in)
Average Diameter:	1.979	(in)
Area:	3.08	(in^2)
L/D Ratio:	2.1	
Description:		

Test Results

Test Date:	20-Aug-19	
Load at Failure:	24,500	(lb)
Unconfined Compressive Strength:	7,964	(psi)
Dry Unit Weight:	161.8	(pcf)
Load Rate:	0.28	(%/min)
Tested by:	CM	
Reviewed by:	MHD	

Before Test



After Test

AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV - Jacobs Creek HDD
Project Number:	60504020
Assignment Number:	2019-08-30
Report Date:	27-Aug-19

Sample Data

Boring:	SB-4	
Core:	R-8	
Depth:	47.0-52.0	(ft)
Average Length:	4.116	(in)
Average Diameter:	1.984	(in)
Area:	3.09	(in^2)
L/D Ratio:	2.1	
Description:		

Test Results

Test Date:	20-Aug-19	
Load at Failure:	69,750	(lb)
Unconfined Compressive Strength:	22,569	(psi)
Dry Unit Weight:	160.1	(pcf)
Load Rate:	0.28	(%/min)
Tested by:	CM	
Reviewed by:	MHD	

Before Test

After Test

AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV - Jacobs Creek HDD
Project Number:	60504020
Assignment Number:	2019-08-30
Report Date:	27-Aug-19

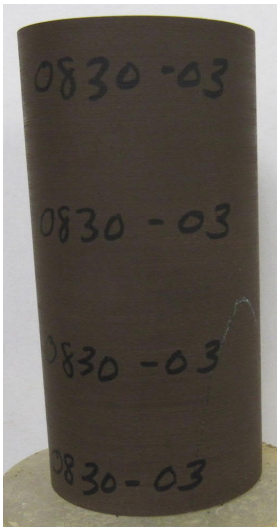
Sample Data

Boring:	SB-4	
Core:	R-12	
Depth:	67.0-72.0	(ft)
Average Length:	4.146	(in)
Average Diameter:	1.982	(in)
Area:	3.09	(in^2)
L/D Ratio:	2.1	
Description:		

Test Results

Test Date:	20-Aug-19	
Load at Failure:	64,750	(lb)
Unconfined Compressive Strength:	20,987	(psi)
Dry Unit Weight:	163.8	(pcf)
Load Rate:	0.28	(%/min)
Tested by:	CM	
Reviewed by:	MHD	

Before Test



After Test

AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV - Jacobs Creek HDD
Project Number:	60504020
Assignment Number:	2019-08-30
Report Date:	27-Aug-19

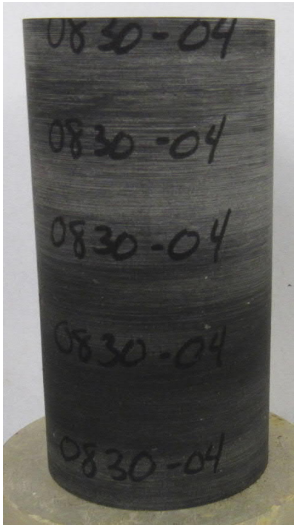
Sample Data

Boring:	SB-4	
Core:	R-16	
Depth:	87.0-92.0	(ft)
Average Length:	4.131	(in)
Average Diameter:	1.982	(in)
Area:	3.08	(in^2)
L/D Ratio:	2.1	
Description:		

Test Results

Test Date:	20-Aug-19	
Load at Failure:	79,750	(lb)
Unconfined Compressive Strength:	25,853	(psi)
Dry Unit Weight:	167.8	(pcf)
Load Rate:	0.28	(%/min)
Tested by:	CM	
Reviewed by:	MHD	

Before Test



After Test

AECOM

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS
ASTM D7012 Method C

Project Information

Project Name:	STV - Jacobs Creek HDD
Project Number:	60504020
Assignment Number:	2019-08-30
Report Date:	27-Aug-19

Sample Data

Boring:	SB-4	
Core:	R-20	
Depth:	107.0-110.0	(ft)
Average Length:	4.114	(in)
Average Diameter:	1.982	(in)
Area:	3.09	(in^2)
L/D Ratio:	2.1	
Description:		

Test Results

Test Date:	20-Aug-19	
Load at Failure:	47,750	(lb)
Unconfined Compressive Strength:	15,477	(psi)
Dry Unit Weight:	167.9	(pcf)
Load Rate:	0.28	(%/min)
Tested by:	CM	
Reviewed by:	MHD	

Before Test

After Test