HORIZONTAL DIRECTIONAL DRILL ANALYSIS
WETLAND J-47 CROSSING
PADEP SECTION 105 PERMIT NO.S:
PA-LE-0001.0000-SR & PA-LE-0001.0000-SR-16
(SPLP HDD No. S3-0090)

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This reanalysis of the horizontal directional drill (HDD) installation of a 16-inch and 20-inch diameter pipeline crossing under Wetland J-47, has been completed in accordance with paragraphs 4 and 5 of the Stipulated Order issued under Environmental Hearing Board Docket No. 2017-009-L. This HDD is number 15 on the list of HDDs included on Exhibit 2 of the Stipulated Order.

PIPE INFORMATION

20-Inch: 0.456 wall thickness; X-65
16-Inch: 0.438 wall thickness; X-70

Pipe stress allowances are an integral part of the design calculations performed for each HDD.

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 20-INCH

- Horizontal length: 1,020 foot (ft)
- Entry/Exit angle: 10-15 degrees
- Maximum Depth of cover: 60 ft
- Pipe design radius: 2,000 ft

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 16-INCH

- Horizontal length: 1,070 ft
- Entry/Exit angle: 10-12 degrees
- Maximum Depth of cover: 75 ft
- Pipe design radius: 1,600 ft

GEOLOGIC AND HYDROGEOLOGIC ANALYSIS

Based upon publications by the Pennsylvania Bureau of Topographic and Geologic Survey (BTGS, 2001 and Sevon, 2000), the site is in the Gettysburg-Newark Lowland Section of the Piedmont Physiographic Province of Pennsylvania, underlain by sedimentary rocks of the Newark Group. Local topography is characterized by rolling lowlands, shallow valleys, and isolated hills (Geyer and Wilshusen, 1982).

The HDD site geology is mapped as the Gettysburg Formation and Gettysburg Formation-Conglomerate. The Gettysburg Formation is described as red shale, red, brown and gray sandstone, and quartz and limestone conglomerate (Geyer and Wilshusen, 1982). The Gettysburg Formation-Conglomerate is described as coarse, quartz conglomerate containing rounded pebbles and cobbles in a matrix of red sand (Geyer and Wilshusen, 1982). The general structure of the Newark Group is a north-northwestward dipping homocline. Typical dip directions are north or northwest and range from 20° to 40° (Newport, 1971). Intrusive diabase has been mapped north and south of the HDD.

Karst geology is not present at this HDD location. At this HDD location the use of geophysics assessments was considered but not conducted because the results from these types of assessments provide limited useable data after 20 to 50 ft below the ground surface (bgs) varying by the nature of the geologic structure.

Attachment 1 provides an extensive discussion on the geology, hydrogeology and results of the geotechnical investigation performed at this location.

HYDROGEOLOGY, GROUND WATER, AND WELL PRODUCTION ZONES

Groundwater in the vicinity of the Wetland J-47 HDD moves in interconnected, secondary openings such as fractures and joints in the sedimentary bedrock aquifer system. Typically, these openings are best developed and found more frequently near the surface. At depth, these openings occur less frequently and tend to be smaller due to compressional loading (Wood, 1980).

Based upon reported data on 332 wells in the Gettysburg Formation, water-bearing zones range from 5 to 900 feet below the ground surface (bgs). Fifty percent of the 669 reported water-bearing zones were penetrated at a depth of 115 feet or less, with 90% of the water-bearing zones encountered at a depth of 288 feet bgs or less. The greatest density of water-bearing zones is from approximately 51 to 100 feet bgs. The density of water-bearing zones encountered at depths greater than 401 feet are based on five or fewer zones per 50-foot interval. Overall density of water-bearing zones in the Gettysburg Formation is 0.41 per 50-feet of well depth (Low, et. al., 2002).

Attachment 1 provides an extensive discussion on the geology, hydrogeology and results of the geotechnical investigation performed at this location.

INADVERTENT RETURN (IR) DISCUSSION

HDD specialists for Sunoco Pipeline, L.P. (SPLP) reviewed the original HDD designs summarized above, and predicted that that the design profiles for the 16 and 20-inch HDDs would produce an IR at or before 100 ft into the pilot profile for either pipe, where the drill crossed the first stream, and an IR to a water of the state may occur.

As presented and discussed in the Conclusion section below, the profile for both the 16 and 20-inch pipelines have been redesigned so that they are longer and deeper, and with the maximum degree of entry and exit angles allowed by the stress radius of the pipelines, to sharpen the pilot run down to horizontal depth and return exit to the land surface.

As shown on Figures 2 and 4 in Attachment 2, the weakest point in both profiles is the first stream undercrossing, occurring at Station 5+66 on the 20-inch profile, and Station 5+33 on the 16-inch profile. The revised design profiles provide for 78 ft of cover above the 20-inch pilot drill, and 91 ft of cover over the 16-inch pilot drill.

These new profile designs are based upon the fracture pressure of the overlying bedrock. As shown on the core data set forth in the attached hydrogeology report, these siltstone, sandstone and conglomeratic sandstone layers had moderate to high recovery, and varied from poor to high quality in value (RQD) indicative of good structural integrity, and low to very high strength, depending on depth in the formation. As shown on Figure 1 - Annular Pressure and Formation Pressure Capacity Curves in Attachment 3, the revised design pressures are below the bedrock fracture pressure at Drill Rod 19, so long as the return fluids and cuttings are kept below 10.5 pounds per gallon (ppg). Achieving this return fluid flow weight requires monitoring of the recycling of the return flows to ensure that cuttings are adequately removed prior to returning the recycled fluids into the drilling process. The entire HDD profile is designed to manage drilling pressures under this point in the profile.

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ADJACENT FEATURES ANALYSIS

The crossing of Wetland J-47 is located in rural Dauphin and Lebanon counties, approximately 3.6 miles southeast of Hershey, PA. The pipeline route follows parallel to two previously existing Sunoco pipelines.

This HDD location is within unmanaged deciduous woodlands. The HDD would cross under two streams and one wetland, none of which are designated as exceptional value. A 3.5 acre impoundment occurs approximately 385 ft north-northwest of the HDD location.

In addition to the resources listed above, based upon the data from the Pennsylvania Groundwater Information System (PaGWIS) and review of aerial photography, five domestic (private) supply wells were identified within 450 feet of the proposed HDD. Of these, three occur north of the HDD profile at distances between 180 and 530 ft. Based upon the data in PaGWIS, the well depths are 100 to 150 ft bgs, with a reported static water level of 30 bgs. Typically, a "good drilling mud program" forms a "cake wall" around the diameter of the pilot or reamer during drilling process which seals fissures within the profile geology and limits the horizontal and vertical movement of drilling fluids. Secondly, controlling the down hole mud weights and pressures should minimize the lateral movement of these materials through the geology. These wells will have to be monitored during the HDD process in accordance with PADEP requirements.

To further avoid and mitigate any adverse effects from the HDD to private water wells, and in accordance with the requirements of the Stipulated Order, SPLP will transmit a copy of this HDD analysis to all landowners having a property line within 450 ft of any direction of this HDD location. SPLP will also inform these landowners that SPLP will conduct pre-, during, and post-construction sampling of their private water wells to ensure that mitigating actions are taken, if necessary.

ALTERNATIVES ANALYSIS

The proposed HDD is an alternative plan of installation to a conventional open trench construction plan. Using the HDD method avoids new unavoidable direct impacts to the stream, wetlands, and associated forested woodland and riparian habitats. Alteration of the current permitted route and plans for installation would require major modifications of the state Chapter 102 and Chapter 105 permits, and authorization issued by the U.S. Army Corps of Engineers.

Both of these HDDs are 2,200 ft in horizontal length and include the crossings of two stream channels, and approximately 620 ft of an emergent and forested wetland complex.

Open-cut and Conventional Bore Analysis

Sunoco Pipeline, L.P. (SPLP) specifications require a minimum of 48-inches of cover over the installed pipelines. To meet these cover requirements, during construction through the stream and wetlands would require a minimum authorized open cut work space 75 ft in width to accommodate the 16 and 20-inch pipelines, allowing for each pipeline to be installed with sufficient separation for integrity management. The assessed area of impact by this open cut plan would directly affect approximately 0.09 acres of state water bottoms, 0.12 acres of emergent wetland, and 1.12 acres of forested wetland.

Due to the existing saturated ground conditions, a significant volume of produced groundwater will fill all the excavations during the open cut process. These water volumes can be pumped to a discharge filtration structure; however the current feasible filtration ability does not exceed 50 microns, therefore,

cloudy water (from suspended fine clay and silt particles) will be discharged downstream regardless of all control methods employed for the entire duration of this open cut installation until completion.

The crossing distance of the emergent and forested wetlands, which are the most expansive natural features crossed by the HDDs, is beyond the technical limits of a conventional auger bore.

In sum, a combination of open-cut and conventional bores would not work as an alternative to the Wetland J-47 HDD.

Re-Route Analysis

The pipeline route as currently permitted follows parallel to two existing Sunoco pipelines.

There are no existing utility corridors to the north or south that provide a practical alternative route. Any alternate route considered north or south of the existing utility corridor would require the clearing of a new "greenfield" corridor through existing woodlands and croplands, increase the number of stream crossings, and possibly encroach on additional private residences before it could rejoin the current route.

During the PADEP Chapter 105 permit process for the Mariner II East Project, SPLP created and submitted for review a project wide alternatives analysis. The baseline route provided for the pipeline construction to cross every wetland and stream on the project by open cut construction procedures. The alternatives analysis submitted to PADEP conceptually analyzed the feasibility of any alternative to trenched resource crossings (e.g., reroute, bore, HDD). The decision making processes for switching from an open cut to HDD is discussed thoroughly in the previously-submitted alternatives analysis and was an important part of the permit application package of HDD plans as currently permitted. The re-route analysis conducted for the Joanna Road HDD confirms the conclusions reached in the previously submitted alternatives analysis.

HORIZONTAL DIRECTIONAL DRILL REDESIGN

Additional geologic investigations have been completed and utilized in the redesign of the planned HDDs. These redesigns adjust the HDD profile deeper to place the HDD pathway under and through bedrock having better structural integrity than a shallower profile and increase the overall length of the HDD due to pipe design requirements. A summary of the redesign factors is provided below. The original and redesigned HDD plan and profile drawings are provided in Attachment 2.

REVISED HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 20-INCH

- Horizontal length: 2,200 ft
- Entry/Exit angle: 16 degrees
- Maximum Depth of cover: 119 ft
- Pipe design radius: 2,400 ft

REVISED HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 16-INCH

- Horizontal length: 2,200 ft
- Entry/Exit angle: 16 degrees
- Maximum Depth of cover: 137 ft
- Pipe design radius: 1,800 ft

As shown on Figure 2, the redesigned HDD profile for the 20-inch pipeline is 1,180 ft longer, with a maximum depth of cover increased by 59 ft from the permitted design. In addition, the entry/exit angles have been increased from 10-15 degrees to 16 degrees allowing for a sharper and quicker descent into more competent rock. As shown on Figure 4 the redesigned HDD profile for the 16-inch pipeline is 1,130 ft longer, with a depth of cover increased by 62 ft, and designed for a sharp and quick entry and exit from the horizontal depth.

CONCLUSION

HDD specialists and geologists employed by SPLP have investigated the HDD design and subsurface geologic conditions and concluded that the original HDD design for the 16 and 20 inch pipelines, as summarized in the introduction, have an increased risk of IRs to the land surface, wetlands, and streams if implemented; therefore, the HDD for the 16-inch and 20-inch diameter pipeline have been redesigned as set forth above to maximize the potential to complete each HDD without an occurrence of an IR.

Upon the start of these HDDs, SPLP will employ the following HDD best management practices:

- SPLP will mandate annular pressure monitoring during the drilling of the pilot hole, which assists in immediate identification of pressure changes indicative of loss of return flows or over pressurization of the annulus, and allows the operator to manage the development of pressures that can induce an IR;

- SPLP inspectors will ensure that an appropriate diameter pilot tool, relative to the diameter of the drilling pipe, is used to ensure adequate “annulus spacing” around the drilling pipe exits to allow good return flows during the pilot drilling;

- SPLP will mandate short-tripping of the reaming tools to ensure an open annulus is maintained to manage the potential inducement of IRs;

- SPLP will require monitoring of the drilling fluid viscosity, such that fissures and fractures in the subsurface are sealed during the drilling process;

- SPLP will mandate monitoring of the drilling fluid cleaning, such that the return weight of the recycled drilling fluids is kept below 10.5 ppg;

- During the reaming phase, the use of Loss Control Materials may be implemented if indications of a potential IR are noted or an IR is observed, and

- If necessary, the pilot hole and reaming phases at the point of entry for the HDD may utilize casing, hammered into the substrate down to structurally better rock, to prevent vertical or lateral movement of drilling fluids at shallow depths.

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ATTACHMENT 1

GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT

RETTEW

We answer to you.

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Engineers
Environmental Consultants
Surveyors
Landscape Architects
Safety Consultants

September 22, 2017

Mr. Matthew Gordon
Sunoco Pipeline, L.P.
535 Fritztown Road
Sinking Spring, PA 19608

RE: Sunoco Pipeline, L.P. Pipeline Project - Mariner East II
Wetland J-47 Horizontal Directional Drill Location (S3-0090)
Hydrogeological Reevaluation Report
Conewago Township, Dauphin County and
South Londonderry Township, Lebanon County, Pennsylvania
RETTEW Project No. 096302011

EXECUTIVE SUMMARY

1. The Stipulated Order dated August 8, 2017 requires a reevaluation of the Wetland J-47 Horizontal Directional Drill (HDD) location, including a geologic report.
2. HDD Wetland J-47 is underlain by sedimentary rocks of the Gettysburg Formation (Trg) and Gettysburg Formation-Conglomerate (Trgc).
3. Geologic mapping and published reports indicate typically open and moderate to steeply dipping beds, with regularly spaced bedrock joints and fractures.
4. Water-bearing zones generally occur in secondary openings along bedding planes, joints, faults and fractures. Water-bearing zones in both formations are most frequent within approximately 300 to 200 feet of the ground surface.
5. To date, no HDD operations have started for either the 16-inch or 20-inch pipeline.
6. Based on the hydro-structural characteristics of the underlying geology, and proposed bore path through shallow unconsolidated soil materials and generally shallow bedrock, the Wetland J-47 HDD is susceptible to the inadvertent return (IR) of drilling fluids during HDD operations for the planned 16-inch and 20-inch drills. The revised HDD profile and HDD best management practices during drilling operations will be used to reduce the risk of an IR.

1.0 INTRODUCTION

The purpose of this report is to describe the geologic and hydrogeologic setting of the Wetland J-47 (S3-0090) HDD location (the site) on the Sunoco Pipeline, L.P. (SPLP) Pennsylvania Pipeline Project - Mariner East II (PPP-ME2) Project. The site is located in Conewago Township, Dauphin County and South Londonderry Township, Lebanon County, Pennsylvania (refer to **Figure 1**). The HDD was designed to be drilled under two small streams (S-A47 and S-A48) and Wetland J-47. This reevaluation report is part of the response to the Stipulated Order dated August 8, 2017.

The HDD profile was lengthened on September 25, 2017 to provide additional protective cover beneath the streams and wetland. The HDD entry on the western side of the profile is at an elevation of approximately 525 feet above mean sea level (AMSL) for the proposed 16-inch drill and 527 feet AMSL for the proposed 20-inch drill. The exit on the eastern side of the profile is at an elevation of approximately of 566 feet AMSL for the proposed 16-inch drill and 554 feet AMSL for the proposed 20-inch drill. The inclination of the entry and exit angles has been increased as a means to install the pipe through these protective soils, residual soils, and bedrock in closer proximity to the entry and exit points than the original, shorter profile.

Based on the annular pressure and formation pressure capacity curves provided by Directional Project Support (DPS) as part of the overall reevaluation submittal, the weakest point in the profile is beneath the first crossing of stream S-A47. At this location, the HDD profile is approximately 91 feet below the stream for the proposed 16-inch drill and 78 feet for the proposed 20-inch drill. Copies of the revised HDD profiles are included in **Attachment 1.**

2.0 GEOLOGY AND SOILS

Based upon publications by the Pennsylvania Bureau of Topographic and Geologic Survey (BTGS, 2001 and Sevon, 2000), the site is in the Gettysburg-Newark Lowland Section of the Piedmont Physiographic Province of Pennsylvania, underlain by sedimentary rocks of the Newark Group. Local topography is characterized by rolling lowlands, shallow valleys, and isolated hills (Geyer and Wilshusen, 1982).

According to the United States Department of Agriculture (USDA) Soil Surveys of Dauphin County and Lebanon County, Pennsylvania, soils within approximately 450 feet of the drill path for HDD S3-0090 consist of Basher silt loam (Bc), Brinkerton silt loam, 0 to 3 percent slopes (BrA), Brinkerton and Armagh silt loams, 0 to 3 percent slopes (BtA), Bucks silt loam, 3 to 8 percent slopes (ByB), Croton silt loam, occasionally ponded, 0 to 3 percent slopes (Cr), Lewisberry gravelly sandy loam, 3 to 8 percent slopes, moderately eroded (LrB2), Lewisberry gravelly sandy loam, 8 to 15 percent slopes, moderately eroded (LrC2), Lewisberry very stony sandy loam, 5 to 25 percent slopes (LsD), Lewisberry very stony sandy loam, 25 to 60 percent slopes (LsF), Penn channery silt loam, 3 to 8 percent slopes (PeB2), Penn channery silt loam, 8 to 15 percent slopes (PeC and PeC2), Ungers loam, 3 to 8 percent slopes (UnB), and Ungers loam, 8 to 15 percent slopes (UnC). A USDA map identifying the general area, along with the soil profile descriptions is included as **Attachment 2**.

The site geology is mapped as the Gettysburg Formation and Gettysburg Formation-Conglomerate, as shown on **Figure 2** (Berg and Dodge, 1981). The Gettysburg Formation is described as red shale, red, brown and gray sandstone, and quartz and limestone conglomerate (Geyer and Wilshusen, 1982). The Gettysburg Formation-Conglomerate is described as coarse, quartz conglomerate containing rounded pebbles and cobbles in a matrix of red sand (Geyer and Wilshusen, 1982). The general structure of the Newark Group is a north-northwestward dipping homocline. Typical dip directions are north or northwest and range from 20° to 40° (Newport, 1971). Intrusive diabase has been mapped north and south of the HDD.

The Gettysburg Formation is moderately well bedded, thin to flaggy, moderately weathered and moderately resistant to weathering. Joint and bedding plane openings provide moderate secondary porosity. Permeability is described as moderate. Weathered rock is reported to be moderately easy to

excavate whereas unweathered rock is reported to be difficult to excavate. Drilling rates are moderate to fast. Foundation stability is good when material is excavated to sound rock (Geyer and Wilshusen, 1982).

The Gettysburg Formation-Conglomerate is well bedded and thick to massive. Bedrock fracturing is described as jointed with a blocky pattern that is moderately developed and moderately abundant. The joints are regularly spaced with a moderate distance between fractures that are open and steeply dipping. The joint, bedding and fracture-plane openings provide a secondary porosity of low magnitude and low permeability. Overall, the formation is moderately resistant to weathering. These rocks reportedly provide good foundation stability (Geyer and Wilshusen, 1982).

3.0 HYDROGEOLOGY

Groundwater in the vicinity of the Wetland J-47 HDD moves in interconnected, secondary openings such as fractures and joints in the sedimentary bedrock aquifer system. Typically, these openings are best developed and found more frequently near the surface. At depth, these openings occur less frequently and tend to be smaller because compressional loading results in an increase of closed openings (Wood, 1980).

Bedrock geology ultimately influences the storage, transmission, and use of groundwater. Geologic factors such as rock type, intergranular porosity, rock strata inclination, faults, joints, bedding planes, and solution channels affect groundwater movement and availability. Groundwater within the Gettysburg Formation and Gettysburg Formation-Conglomerate can occur under both unconfined (i.e., water table) and confined conditions. In general, groundwater generally occurs under unconfined conditions within the upper portion of the aquifer, and under confined or semiconfined conditions in the deeper portions of the aquifer. The groundwater flow system is described as a series of sedimentary beds with relatively high transmissivity separated by beds exhibiting lower transmissivities. This sequence of beds exhibits different hydraulic properties that collectively act as a series of alternating aquifers and confining or semi-confining units forming a leaky multi-aquifer system (LMAS). The groundwater flow direction within the Gettysburg and Gettysburg Formation-Conglomerate is controlled by hydraulic gradients and variability of hydraulic conductivity. The predominant flow direction is parallel to bedding (Wood, 1980).

Groundwater flow paths within the sedimentary rocks have both local and regional components. Locally, shallow groundwater discharges to the gaining portions of nearby streams and deeper regional groundwater flow is toward points of regional groundwater discharge such as the Susquehanna River. Groundwater divides may be different for each zone of groundwater flow, and therefore may not coincide with surface water divides. Based on our review of available reference sources, no regional water table mapping is available for the Wetland J-47 HDD or surrounding area. As a result, no water table mapping was available for review or inclusion with this HDD reevaluation report.

Based upon reported data on 332 wells in the Gettysburg Formation, water-bearing zones range from 5 to 900 feet below the ground surface (bgs). Fifty percent of the 669 reported water-bearing zones were penetrated at a depth of 115 feet or less, with 90% of the water-bearing zones encountered at a depth of 288 feet bgs or less. The greatest density of water-bearing zones is from approximately 51 to 100 feet bgs. The density of water-bearing zones encountered at depths greater than 401 feet are based on five or fewer zones per 50-foot interval. Overall density of water-bearing zones in the Gettysburg Formation is 0.41 per 50-feet of well depth (Low, et. al., 2002).

Well records reviewed within a 0.5-mile radius of the HDD location were obtained from the Pennsylvania Groundwater Information System (PaGWIS) on September 20, 2017. Records and information from 10 wells in this radius were available and are summarized below. These well locations are shown on **Figures 2** and **3.**

Well No.	Well Use	Casing Depth (feet)	Total Depth (feet)	Water Level (feet)	Yield (gpm)
86665	DOMESTIC	48	100	Not Available	12
86346	DOMESTIC	43	100	Not Available	20
637244	DOMESTIC	61	160	35	40
625206	DOMESTIC	84	140	38	50
617996	DOMESTIC	258	380	200	20
541860	DOMESTIC	99	225	26	8
491472	GEOTHERMAL	60	375	Not Available	Not Available
490905	GEOTHERMAL	80	375	Not Available	Not Available
415899	DOMESTIC	95	150	Not Available	20
258993	OTHER	60	100	30	40

4.0 FRACTURE TRACE ANALYSIS

Fracture traces underlying, or in close proximity to, the site were evaluated using historical aerial photographs from the years 1992 through 2016 (Google Earth, 2017), the Elizabethtown and Palmyra Quadrangle Geologic Maps (Berg and Dodge, 1981), Plate 1-Part 2 in Wood (1980), and the United States Geological Survey (USGS) 7.5-Minute Topographic Quadrangle Maps. The photographs, publications and maps were reviewed to estimate lineaments or natural linear features on the ground surface. The linear features may be the surficial representation of deeper fractures, joints, faults or bedding planes within the subsurface which can transmit groundwater in the fractured bedrock aquifer at the site.

Figures 2 and **3** show the results of the fracture trace analysis overlain on the geologic map of the site and an aerial basemap. Five fracture traces were identified within close proximity to the Wetland J-47 HDD that are likely related to the primary geologic structure. Two of the fracture traces trend approximately northwest-southeast, similar to the general structure of the regional homocline. The three perpendicular fracture traces trend approximately northeast-southwest and may represent stress-related joints.

5.0 GEOTECHNICAL EVALUATION

Two geotechnical drilling evaluations were performed at the site; one was performed in 2014 and the other in 2017. Test borings were advanced by hollow-stem augers. An NQ core barrel/bit was used for rock coring. Geotechnical boring logs are included in **Attachment 1**. The locations of the borings are depicted on **Figure 2** and **Figure 3.**

The first geotechnical drilling program was performed on November 18, 2014, prior to the initiation of HDD operations. Soil Boring 01 (SB-01) was located approximately 45 feet north of the approximate mid-point of the bore path on the north side of Stream A-47 and Wetland J-47. Soil Boring 02 (SB-02) was located approximately 400 feet west of the eastern entry point and 75 feet north of the bore path. Soil Boring 03 (SB-03) was located approximately 400 feet east of the eastern entry point and 210 feet south of bore path.

Two additional borings were advanced between August 28 and September 7, 2017, prior to the initiation of HDD operations. Boring B-1 was installed near the HDD exit point on the west side of the HDD profile. Boring B-2 was installed near the HDD entry on the east side of the profile.

In general, the subsurface profile at the site, as observed in the borings, is described as follows:

- Soil and residual soil depths vary from west to east; 6.3 feet at B-1, 21.5 feet at SB-01, 32.5 feet at SB-02, 9.4 feet at B-2, and 30 feet at SB-03. The residual soils are described as follows:
    - **Boring B-1**: Sandy lean CLAY (CL) and poorly graded SAND with gravel (SP) (weathered sandstone);
    - **Boring SB-01**: SILT with sand (ML) and fine SAND with silt and gravel (sandstone);
    - **Boring SB-02:** Fine to medium SAND with silt and gravel (SM); Silty CLAY with sand (CL); Fine SAND with clay (SC); Silty CLAY with sand (CL); and weathered sandstone;
    - **Boring B-2**: Sandy SILT (ML) and poorly graded SAND with silt (SP-SM) (weathered sandstone); and
    - **Boring SB-03**: Silty CLAY with sand (CL); Fine to medium SAND with clay (SC); Silty CLAY with sand (CL-claystone); and weathered sandstone.
- Refusal, defined as naturally occurring rock that cannot be penetrated by standard soil sampling methods consisting of split-spoon samplers and augers, was encountered at 6.3 feet in B-1, 21.5 feet in SB-01, 32.5 feet at SB-02, 9.4 feet in B-2.
- Beneath auger refusal to the total depth of the NQ cores, bedrock was encountered and is described as follows:
    - **Boring B-1:** B-1 was completed to a total depth of 159 feet. Alternating sequences of grayish to reddish brown, conglomeratic to coarse- to fine-grained, SANDSTONE and reddish brown SILTSTONE were encountered. Two layers of CONGLOMERATE were encountered (at 40.0 to 45.6 feet and 95.3 to 96.7 feet). A total of 21 distinct strata composed of sandstone, siltstone, and conglomerate bedrock were identified, with thicknesses ranging from 1.5 feet to 34.5 feet. Rock recoveries were generally excellent (100%) in the majority of the core runs. One core run had poor core recovery (44%) from 84.0 to 87.4 feet in a highly weathered siltstone/sandstone zone. RQDs were very poor to excellent (0 to 99%), and in general the lower RQD values correlated to the siltstone layers and the higher RQD values correlate to the sandstone/conglomerate layers. Multiple soil seam and highly weathered rock were encountered in the upper 24 feet of the boring. Fractures ranging from generally horizontal to high angle were recorded in the core logs.

- **Boring B-2:** B-2 was completed to a total depth of 201 feet. Alternating sequences of grayish to reddish brown, conglomeratic and coarse- to fine-grained SANDSTONE and reddish brown SILTSTONE were encountered. Two layers of SHALE were encountered (at 84.8 to 102 feet and 153.4 to 170.8 feet). A total of 18 distinct strata of sandstone, siltstone, and shale bedrock were identified, with thicknesses ranging from 2.0 feet to 28.0 feet. Rock recoveries were generally excellent (100%) in the majority of the core runs. RQDs were poor to excellent (40 to 100%) below a depth of 20 feet. Fractures ranging from generally horizontal to high angle were recorded on the core logs.

Please note that RETTEW did not oversee or direct the geotechnical drilling program associated with the Wetland J-47 HDD, including but not limited to, the selection of boring locations and target depths, observations of rock cores during drilling operations, or preparation of boring logs. The geotechnical reports, boring logs, and core photographs that resulted from these programs were generated by other Sunoco Pipeline, L.P. contractors. RETTEW relied on these reports and incorporated their data into the general geologic and hydrogeologic framework of the analysis of the Wetland J-47 HDD in this report.

6.0 FIELD OBSERVATIONS

A field investigation was performed by a RETTEW geologist on September 18, 2017, to identify rock outcrops for fracture fabric analysis, evaluation and possible ground-truthing of fracture traces identified during the desktop evaluation, and to identify potential sensitive receptors to IRs. Readily accessible bedrock outcrops were not observed. No additional sensitive receptors to IRs were identified during the site reconnaissance.

7.0 CONCEPTUAL HYDROGEOLOGIC MODEL AND CONCLUSION

Based on published geologic and hydrogeologic information, and the evaluation of geotechnical borings from the site, the Wetland J-47 HDD location is underlain by sedimentary rocks of the Gettysburg Formation and Gettysburg Formation-Conglomerate. The hydrogeologic setting is dominated by groundwater flow in secondary openings along geologic features that include bedding planes, fractures, and joints. In these formations, secondary openings are more common near the surface. Well records indicate 90% of the water-bearing zones in the Gettysburg Formation are within 280 feet of the surface. Geotechnical core observations indicate that bedrock near the center of the HDD profiles is fractured.

The proposed 16-inch and 20-inch HDD profiles are relatively shallow compared to the land surface, streams S-A47 and S-A48, and Wetland J-47, and pass through both the unconsolidated overburden and fractured bedrock. The weakest point of the profile is beneath the first crossing of Stream S-A47. Based on the hydro-structural characteristics of the underlying geology described in this report and the known HDD profile through shallow soils and bedrock, the Wetland J-47 HDD site is susceptible to the inadvertent return of drilling fluids during HDD operations. The HDD profile has been lengthened to allow for deeper crossings beneath the streams and wetland. The inclination of the entry and exit angles has been increased as a means to install the pipe through these protective soils, residual soils, and bedrock in closer proximity to the entry and exit points than the original, shorter profile. From a geologic perspective, the longer and deeper profile, in conjunction with the proposed engineering controls and/or drilling best management practices will be used to reduce the risk of an IR.

8.0 REFERENCES

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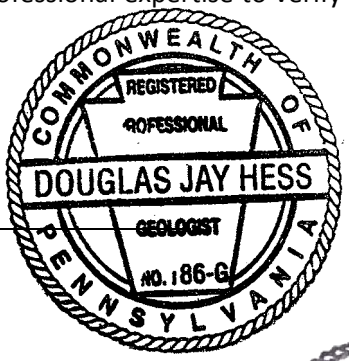
9.0 CERTIFICATION

The studies and evaluations presented in this report (other than Section 5) were completed under the direction of a licensed professional geologist (P.G.), and are covered under the P.G. seals that follow.

By affixing my seal to this document, I am certifying that, to my knowledge and belief, the information herein is true and correct. I further certify, that I am licensed to practice in the Commonwealth of Pennsylvania and that it is within my professional expertise to verify the correctness of the information herein.



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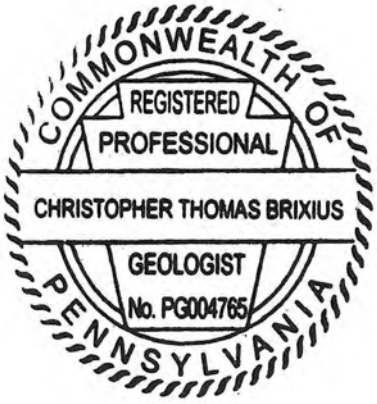

Christopher T. Brixius, P.G.
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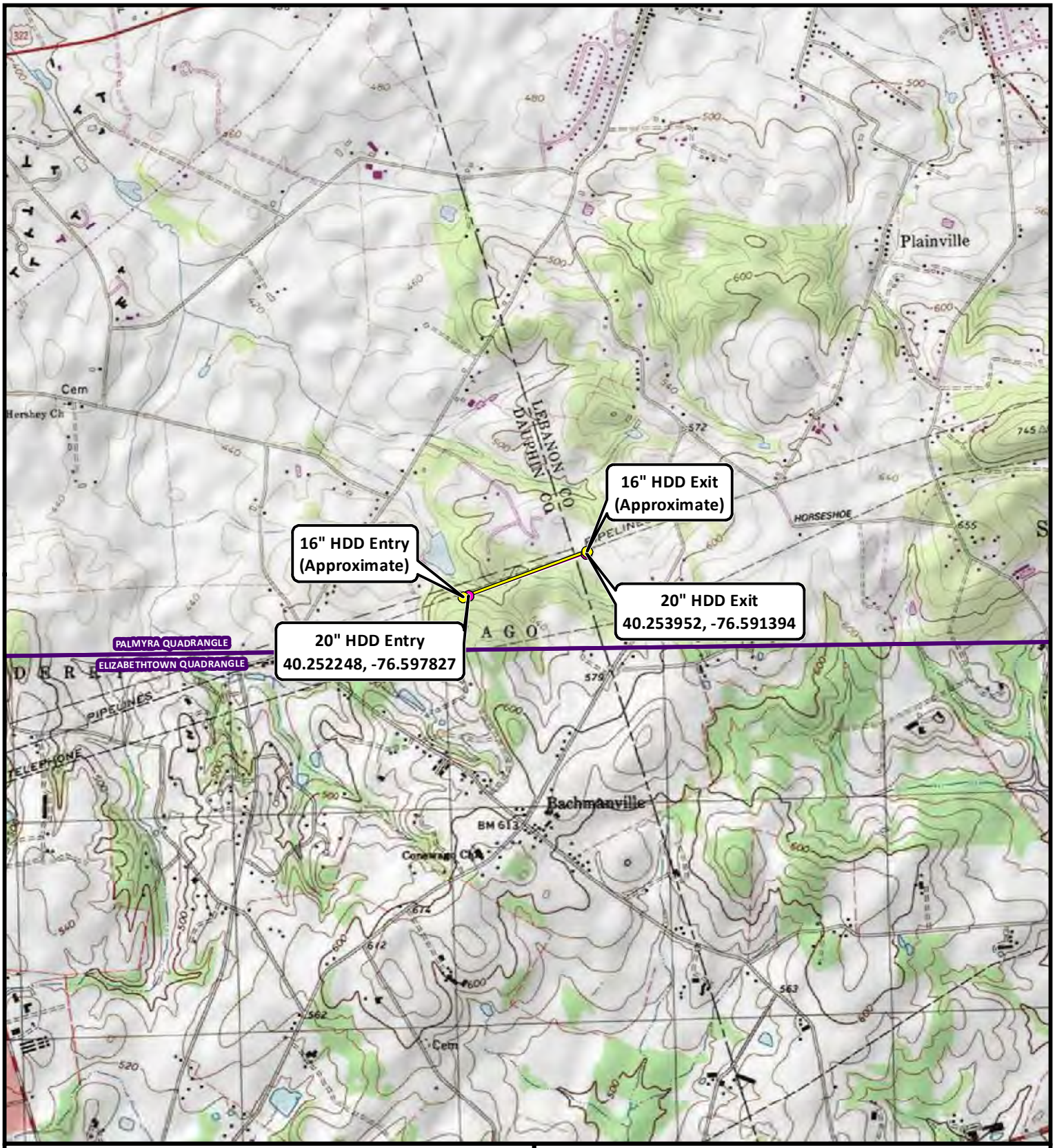
RETTEW

FIGURES



16" HDD Entry/Exit

20" HDD Entry/Exit

16" HDD Profile

20" HDD Profile

Elizabethtown & Palmyra, PA USGS 7.5' Topographic Quadrangles 9/21/2017

Sunoco Pipeline, L.P.

Wetland J-47 HDD Location

Figure 1 - Topographic Basemap

Conewago Twp., Dauphin County, & South Londonderry Twp., Lebanon County, PA

Project No. 096302011

0 1,000 2,000 Feet

1 inch = 2,000 feet

Sunoco Logistics Partners L.P.

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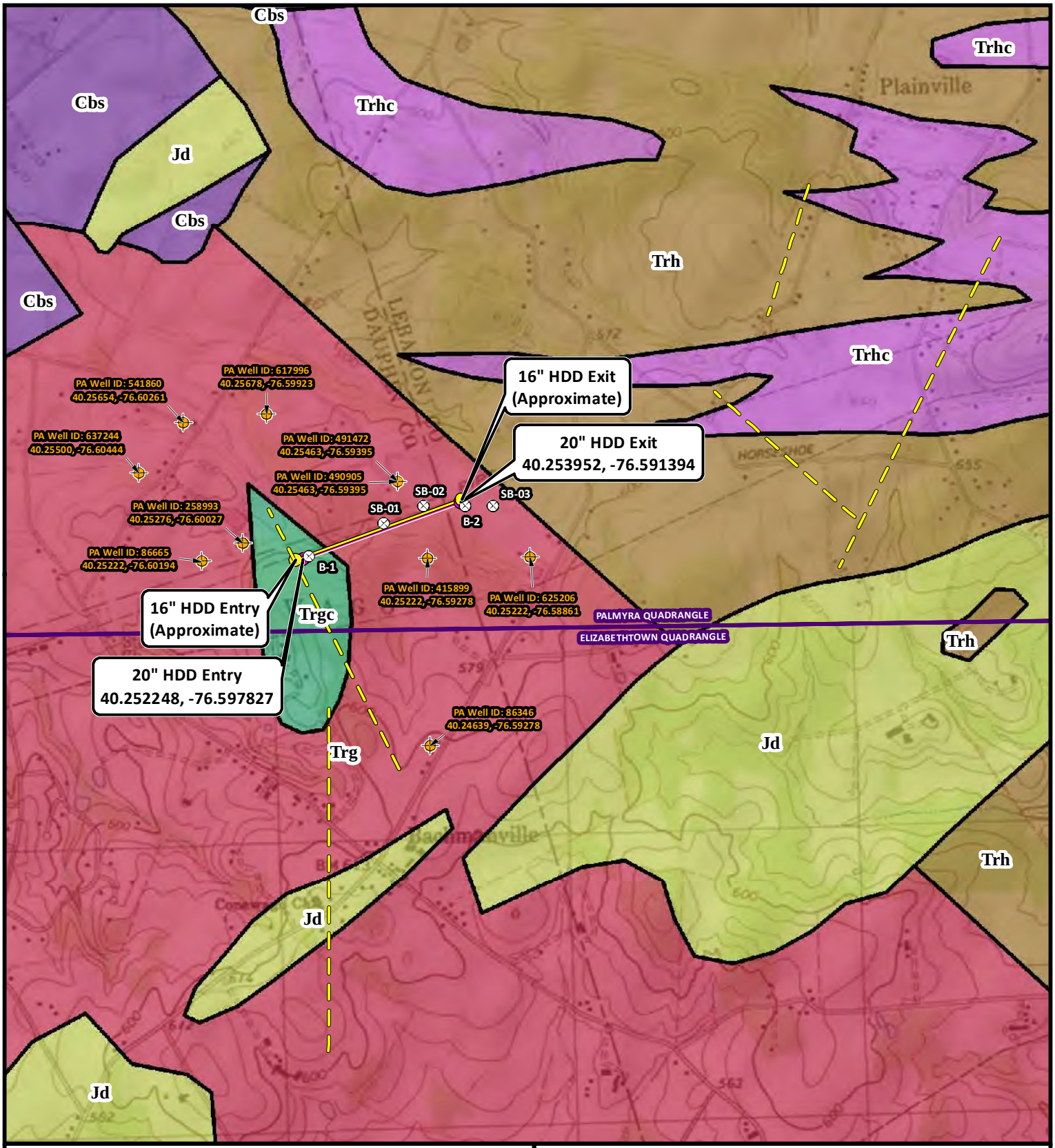

Sunoco Pipeline, L.P.

Wetland J-47 HDD Location

Figure 2 - Geologic Map

Conewago Twp., Dauphin County, & South Londonderry Twp., Lebanon County, PA

Project No. 096302011

0 1,500 Feet

1 inch = 1,500 feet

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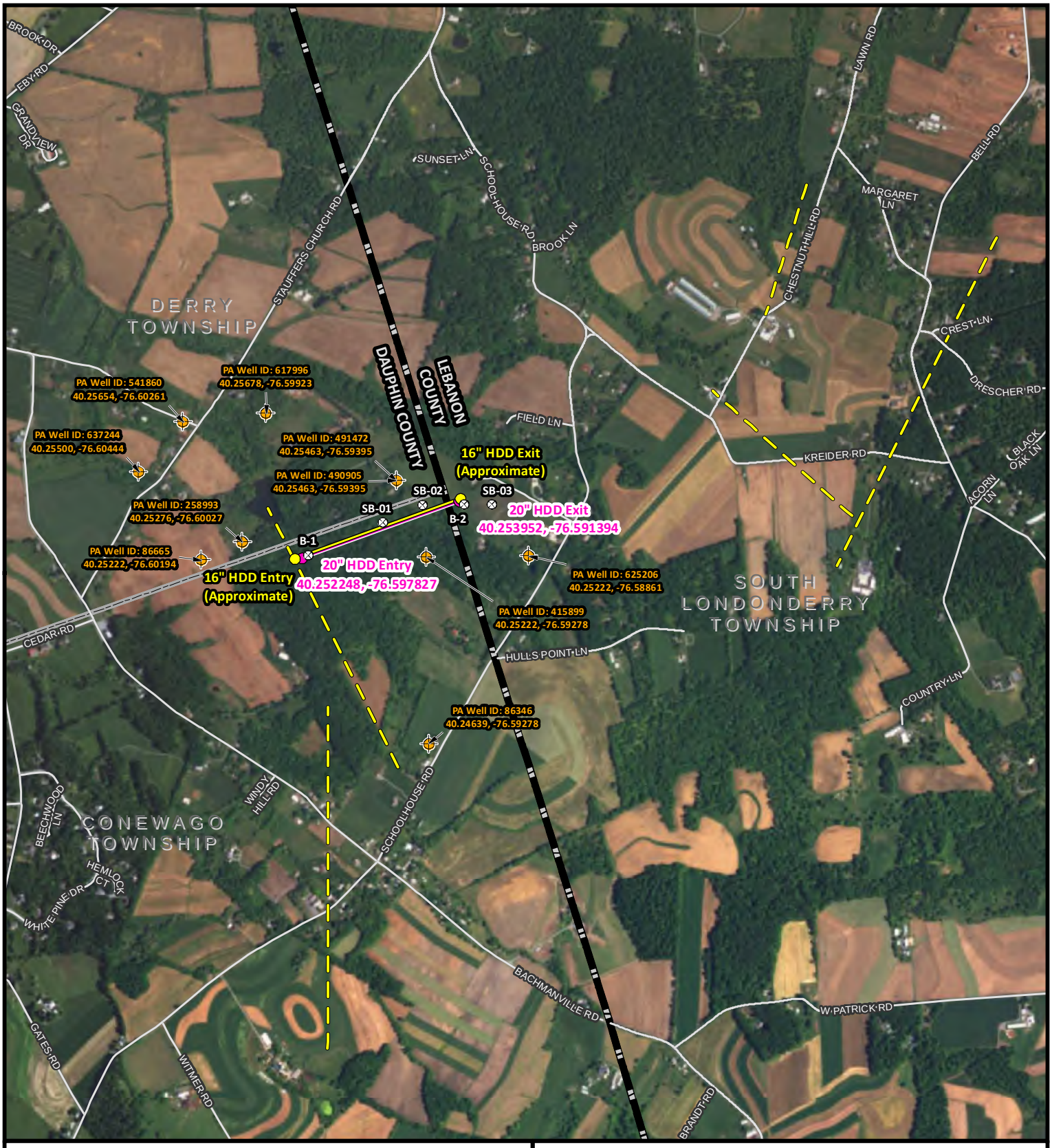

Residential Well

Boring Location

16" HDD Entry/Exit

20" HDD Entry/Exit

16" HDD Profile

20" HDD Profile

Inferred Fracture Trace

Road

Municipal Boundary

County Boundary

9/21/2017

Sunoco Pipeline, L.P.

Wetland J-47 HDD Location

Figure 3 - Aerial Basemap

Conewago Twp., Dauphin County, & South Londonderry Twp., Lebanon County, PA

Project No. 096302011

0 1,500 Feet

1 inch = 1,500 feet

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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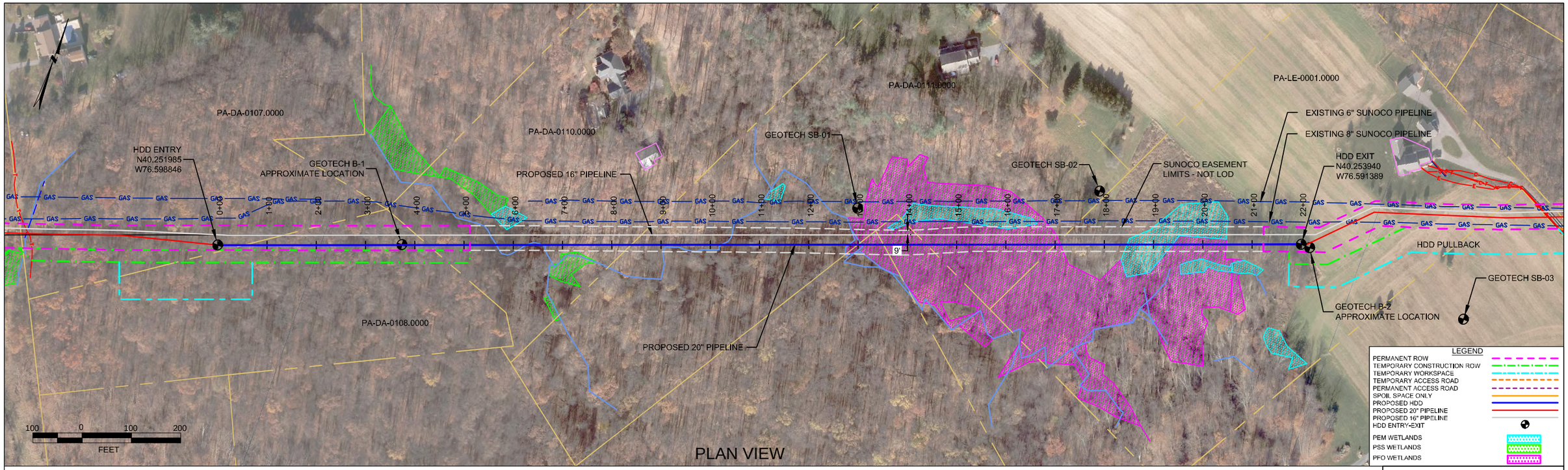
RETTEW

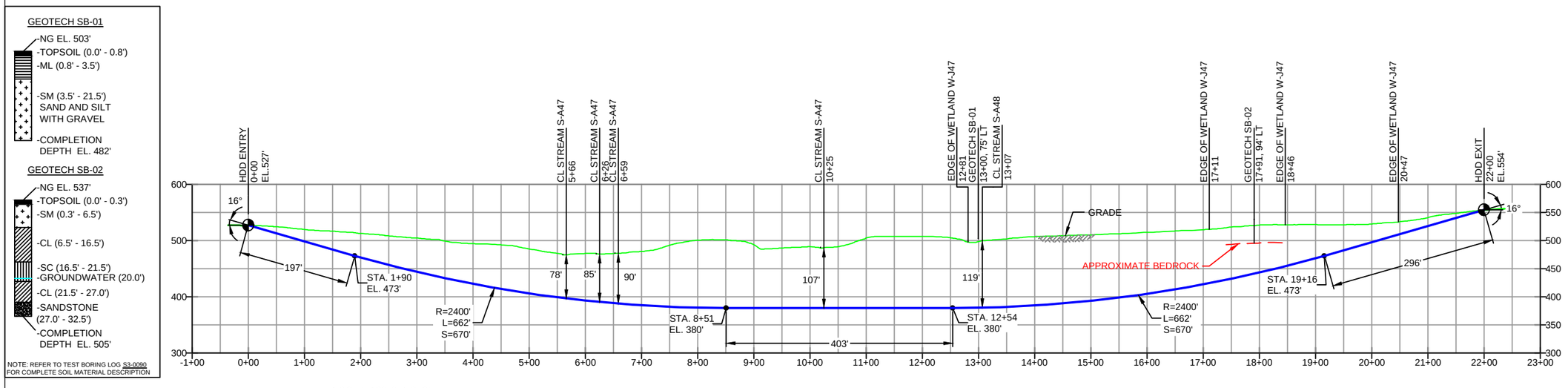
ATTACHMENT 1
GEOTECHNICAL BORING LOGS



PLAN VIEW

PROFILE VIEW

LEBANON COUNTY, PENNSYLVANIA - CONEWAGO TOWNSHIP
S3-0090



GEOTECH SB-01

-NG EL. 503'
-TOPSOIL (0.0' - 0.8')
-ML (0.8' - 3.5')
-SM (3.5' - 21.5') SAND AND SILT WITH GRAVEL
-COMPLETION DEPTH EL. 482'

GEOTECH SB-02

-NG EL. 537'
-TOPSOIL (0.0' - 0.3')
-SM (0.3' - 6.5')
-CL (6.5' - 16.5')
-SC (16.5' - 21.5')
-GROUNDWATER (20.0')
-CL (21.5' - 27.0')
-SANDSTONE (27.0' - 32.5')
-COMPLETION DEPTH EL. 505'

NOTE: REFER TO TEST BORING LOG S3-0090 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B-1

-NG EL. 496'
-RESIDUUM-SANDY LEAN CLAY CL (0.0' - 3.5')
-SANDSTONE SP (3.5' - 24.0')
-GROUNDWATER (17.0')
-SILTSTONE (24.0' - 34.0')
-SANDSTONE/SILTSTONE (44.0' - 160.0')
-COMPLETION DEPTH EL.337'

NOTE: REFER TO TEST BORING LOG B-1 EICHELBERGER'S INC. PROJECT # 04911456 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B-2

-NG EL. 556'
-TOPSOIL (0'-0.25')
-RESIDUUM ML (0.25'-2')
-RESIDUUM SP/SM (2.0'-6.0')
-SANDSTONE (6.0'-38.0')
-GROUNDWATER (22.3')
-SANDSTONE/SILTSTONE (38.0' - 200.0')
-COMPLETION DEPTH EL.356'

NOTE: REFER TO TEST BORING LOG B-2 EICHELBERGER'S INC. PROJECT # 04911456 FOR COMPLETE SOIL MATERIAL DESCRIPTION

DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=): 2200'
   HDD PIPE LENGTH (S=): 2236'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

Figure 2. Revised 20-Inch HDD Plan and Profile

NOTES

1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
2. STATIONING IS BASED ON HORIZONTAL DISTANCES.
3. ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP ARE NOT RESPONSIBLE FOR LOCATION OF FOREIGN UTILITIES SHOWN IN PLOT PLAN OR PROFILE. THE INFORMATION SHOWN HEREON IS FURNISHED WITHOUT LIABILITY ON THE PART OF ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP, FOR ANY DAMAGES RESULTING FROM ERRORS OR OMISSIONS THEREIN.
4. CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.
5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-4.38	TO	ES-5.01	EROSION & SEDIMENT PLAN
SHEET 24	TO	SHEET 1	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	DESIGN CHANGE - EXTENDED DRILL PER LANEY DRILLING AND CM SPREAD 5 APPROVAL	MRS	09/25/17	RMB	09/25/17	AMC	09/25/17
EP2	REVISED PER PADEP COMMENTS RECEIVED 09/06/16	DLM	09/30/16	RMB	09/30/16	AAW	09/30/16
EP1	REVISED PER PADEP COMMENTS	DLM	05/10/16	RMB	05/10/16	AAW	05/10/16
EP		MRS	03/15/16	RMB	03/15/16	AAW	03/15/16
C	ADDED GEOTECH INFO / DESIGN ADJUSTMENT	MRS	09/22/16	RMB	09/22/16	AAW	09/22/16
B	ISSUED FOR BID	DLM	07/31/15	RMB	07/31/15	AAW	07/31/15

Sunoco Logistics Partners L.P.

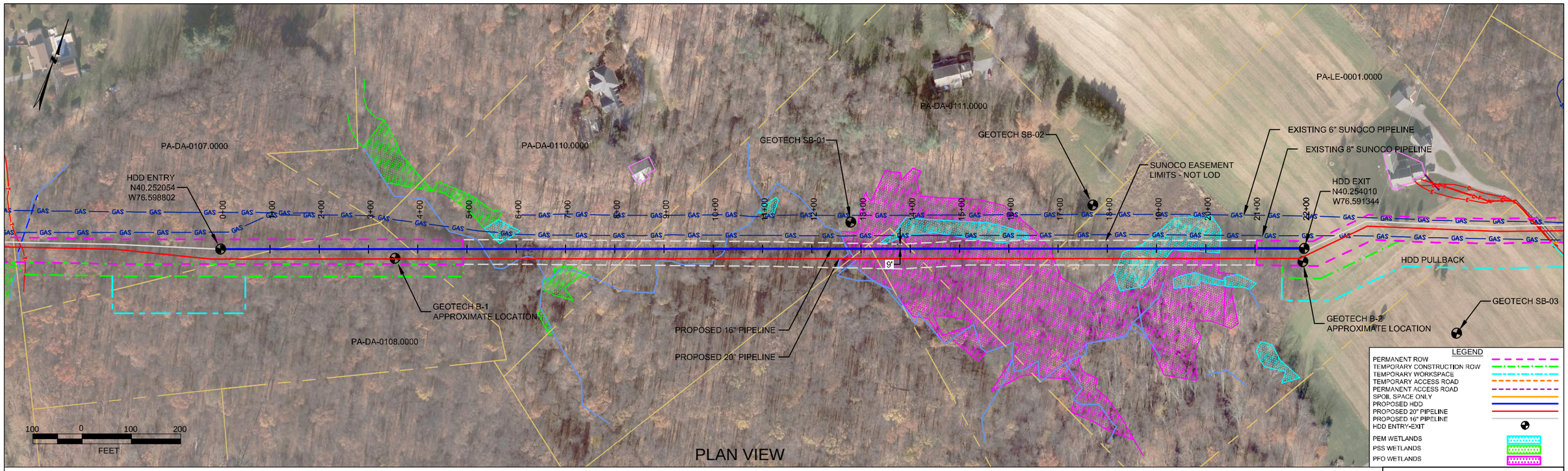
TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
WETLAND
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200'

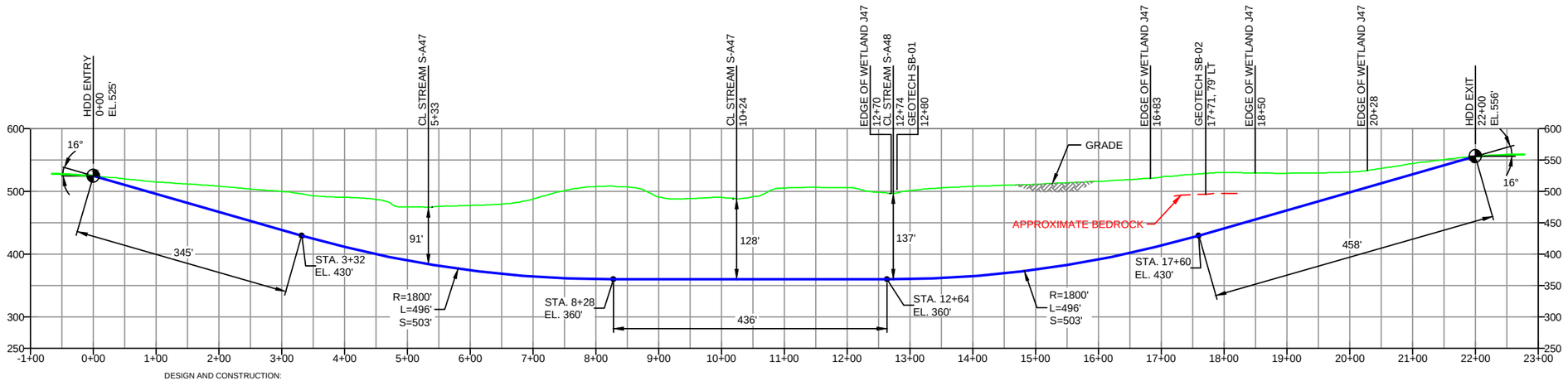
DWG. NUMBER: PA-LE-0001.0000-SR



PLAN VIEW

PROFILE VIEW

LEBANON COUNTY, PENNSYLVANIA - CONEWAGO TOWNSHIP
S3-0090-16

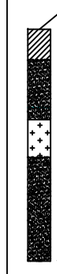


GEOTECH SB-01

GEOTECH SB-02

NOTE: REFER TO TEST BORING LOG S3-0090 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B-1



NOTE: REFER TO TEST BORING LOG B-1 EICHELBERGER'S INC. PROJECT # 04911456 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B-2

NOTE: REFER TO TEST BORING LOG B-2 EICHELBERGER'S INC. PROJECT # 04911456 FOR COMPLETE SOIL MATERIAL DESCRIPTION

DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=): 2200'
   HDD PIPE LENGTH (S=): 2245'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

Figure 4. Revised 16-Inch Plan and Profile

NOTES

1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
2. STATIONING IS BASED ON HORIZONTAL DISTANCES.
3. ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP ARE NOT RESPONSIBLE FOR LOCATION OF FOREIGN UTILITIES SHOWN IN PLOT PLAN OR PROFILE. THE INFORMATION SHOWN HEREON IS FURNISHED WITHOUT LIABILITY ON THE PART OF ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP, FOR ANY DAMAGES RESULTING FROM ERRORS OR OMISSIONS THEREIN.
4. CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.
5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REF. DRAWING

ES-4.38	TO	ES-5.01	EROSION & SEDIMENT PLAN	
SHEET 24	TO	SHEET 1	AERIAL SITE PLAN	
DWG NO		DWG NO	DESCRIPTION	

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	DESIGN CHANGE - EXTENDED DRILL PER LANEY DRILLING AND CM SPREAD 5 APPROVAL	MRS	09/25/17	RMB	09/25/17	AMC	09/25/17
EP2	REVISED PER PADEP COMMENTS RECEIVED 09/06/16	MRS	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	DLM	05/17/16	RMB	05/17/16	AAW	05/17/16
EP		MRS	03/05/16	RMB	03/05/16	AAW	03/05/16
B	ADDED GEOTECH INFO	MRS	09/22/15	RMB	09/22/15	AAW	09/22/15
A	ISSUED FOR BID	MRS	08/31/15	RMB	08/31/15	AAW	08/31/15

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
WETLAND
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200'

DWG. NO: PA-LE-0001.0000-SR-16

BORING B-1

DATE STARTED:	8/28/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	8/31/17	**DRILLER:** S. Taylor	**LOGGED BY:** L. Proczko
COMPLETION DEPTH	159.0 ft	**DRILL RIG:**	Diedrich D-50
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

Water

While Drilling	Not Enc.
Post-Core	17 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL (0 25 50) STRENGTH, tsf ▲ Qu ✳ Qp (0 2.0 4.0)	Additional Remarks
	0			S-1	24	**RESIDUUM**-Medium Stiff, Gray-brown, Sandy Lean CLAY, moist	CL	1-2-3-3 N=5	15		LL = 26 PL = 19
						Highly Weathered SANDSTONE Sampled as Soil-Very Dense, Silty SAND with Gravel, moist	SM				
	5			S-2	15			27-29-42-50/1" N=71	7		>>◎ Fines=12.2%
				R-1	32	**Conglomeratic SANDSTONE**-Dark brown to dark gray-brown, Fine to coarse grained, Weathered to Highly Weathered, very broken to massive, very hard		RQD=0 Rec=94%			
	10					**Conglomeratic SANDSTONE**-Gray-brown to dark gray-brown, Fine to very coarse grained, Weathered, very broken to slightly broken, very hard					
				R-2	60	**SANDSTONE**-Light gray-brown to dark brown, Fine to medium grained, Weathered to Highly Weathered, very broken to massive, moderately soft to very hard		RQD=15 Rec=71%			26 min.
	15			R-3	12			RQD=0 Rec=100%			7 min. 6 min.
	20			R-4	37	Multiple soil seams and layers, trace pits from 17 to 24 feet.		RQD=0 Rec=44%			
	25			R-5	42	**SILTSTONE**-Brown to red-brown, Very fine grained, Highly Weathered, very broken to broken, moderately hard		RQD=0 Rec=70%			22 min. 20 min.
	30					*Continued Next Page*					

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Professional Service Industries, Inc.
1707 S. Cameron Street, Suite B
Harrisburg, PA 17104
Telephone: (717) 230-8622

PROJECT NO.: 04911456
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Wetland "J47" (PPP5)
Dauphin Co., PA
PA-LE-0001.0000-SR/PO#201770816-2

The stratification lines represent approximate boundaries. The transition may be gradual.

BORING B-1

DATE STARTED:	8/28/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	8/31/17	**DRILLER:** S. Taylor	**LOGGED BY:** L. Proczko
COMPLETION DEPTH	159.0 ft	**DRILL RIG:**	Diedrich D-50
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

Water: While Drilling — Not Enc.; Post-Core — 17 feet

BORING LOCATION: See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ / Moisture × / PL ◪ / LL ✚ (0–25–50); STRENGTH, tsf ▲ Qu ✳ Qp (0–2.0–4.0)	Additional Remarks
	30			R-6	48	**SILTSTONE**-Brown to red-brown, Very fine grained, Weathered to Highly Weathered, very broken to slightly broken, moderately hard		RQD=0 Rec=80%			17 min.
	35			R-7	60	**Conglomeratic SANDSTONE**-Gray-brown to dark gray-brown, Fine to very coarse grained, Weathered to Slightly Weathered, very broken to massive, hard to very hard		RQD=59 Rec=100%			>> Q_u = 425.1 tsf 155.7 pcf 14 min.
	40			R-8	60	**CONGLOMERATE**-Light gray-brown to gray-brown, Fine to very coarse grained, Weathered to Slightly Weathered, very broken to massive, hard to very hard, trace pits and vugs		RQD=70 Rec=100%			>> Q_u = 379.0 tsf 154.5 pcf 9 min.
	45			R-9	48	**Conglomeratic SANDSTONE**-Dark gray-brown, Fine to coarse grained, Weathered to Highly Weathered, very broken to massive, very hard		RQD=26 Rec=100%			4 min. 2 min.
				R-10	12	**Conglomeratic SANDSTONE**-Gray to gray-brown, Fine to very coarse grained, Slightly Weathered, slightly broken to massive, hard to very hard		RQD=88 Rec=100%			2 min. 3 min. 4 min.
	50			R-11	60			RQD=98 Rec=100%			3 min. >> Q_u = 283.6 tsf 149.5 pcf 3 min. 4 min.
	55			R-12	60	**SANDSTONE**-Light gray to dark gray-brown, Fine to coarse grained, Slightly Weathered, very broken to massive, hard to very hard, trace pits		RQD=77 Rec=100%			4 min. >> Q_u = 441.1 tsf 149.0 pcf 3 min. 3 min. 3 min. 3 min. 3 min.
	60					*Continued Next Page*					

Professional Service Industries, Inc.
1707 S. Cameron Street, Suite B
Harrisburg, PA 17104
Telephone: (717) 230-8622

PROJECT NO.: 04911456
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Wetland "J47" (PPP5)
Dauphin Co., PA
PA-LE-0001.0000-SR/PO#201770816-2

The stratification lines represent approximate boundaries. The transition may be gradual.

DATE STARTED:	8/28/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	8/31/17	**DRILLER:** S. Taylor	**LOGGED BY:** L. Proczko
COMPLETION DEPTH	159.0 ft	**DRILL RIG:**	Diedrich D-50
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

BORING B-1

Water

While Drilling	Not Enc.
Post-Core	17 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL (0 25 50) STRENGTH, tsf ▲ Qu ✳ Qp (0 2.0 4.0)	Additional Remarks
	60					**SANDSTONE**-Red-brown, Fine grained, Weathered to Slightly Weathered, very broken to slightly broken, moderately hard					4 min.
				R-13	60			RQD=63 Rec=100%			3 min.
						Conglomeratic SANDSTONE-Red-brown to dark gray-brown, Fine to very coarse grained, Slightly Weathered, broken to massive, moderately hard to very hard					3 min.
						Weathered/Highly Weathered layer @ 61.3 feet (~ 5-3/4 inches thick)					3 min.
											3 min.
	65										3 min.
				R-14	60			RQD=99 Rec=100%			4 min.
											4 min.
						SILTSTONE-Red-brown to dark brown, Very fine grained, Slightly Weathered, broken to massive, moderately hard				>> Q_u = 359.4 tsf	5 min. 166.5 pcf
											6 min.
	70										5 min.
				R-15	60			RQD=93 Rec=100%			5 min.
											5 min.
											6 min.
						SANDSTONE-Red-brown, Fine to coarse grained, Slightly Weathered, massive, hard					7 min.
						SILTSTONE-Red-brown, Very fine grained, Slightly Weathered, slightly broken to massive, moderately hard					7 min.
	75									>> Q_u = 162.8 tsf	5 min. 165.7 pcf
				R-16	60			RQD=99 Rec=100%			4 min.
						SANDSTONE-Red-gray-brown to dark gray-brown, Fine grained, Slightly Weathered, massive, very hard					4 min.
											4 min.
						SANDSTONE-Red-gray-brown, Fine grained, Weathered to Slightly Weathered, slightly broken to massive, hard					4 min.
	80			R-17	21			RQD=33 Rec=88%			5 min.
				R-18	2	Soil-filled, nearly vertical fracture from 79.3 to 79.8 feet .		RQD=0 Rec=83%			3 min.
						SILTSTONE-Red-brown to dark brown, Very fine grained, Weathered to Slightly Weathered, very broken to massive, moderately hard to hard					12 min.
				R-19	34			RQD=42 Rec=101%			7 min.
											5 min.
	85					**SILTSTONE/SANDSTONE**-Red-brown to dark gray-brown, Very fine grained to medium grained, Highly Weathered to Completely Weathered, very broken to broken, moderately hard to hard					7 min.
				R-20	18			RQD=0 Rec=44%			7 min.
											5 min.
						SILTSTONE-Red-brown, Very fine grained, Weathered to Slightly Weathered, very broken to slightly broken, moderately hard					7 min.
				R-21	19			RQD=65 Rec=99%			8 min.
	90										

Continued Next Page

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PROJECT NO.: 04911456
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Wetland "J47" (PPP5)
Dauphin Co., PA
PA-LE-0001.0000-SR/PO#201770816-2

The stratification lines represent approximate boundaries. The transition may be gradual.

DATE STARTED:	8/28/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	8/31/17	**DRILLER:** S. Taylor	**LOGGED BY:** L. Proczko
COMPLETION DEPTH	159.0 ft	**DRILL RIG:**	Diedrich D-50
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

BORING B-1

Water

While Drilling	Not Enc.
Post-Core	17 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL (0 25 50) STRENGTH, tsf ▲ Qu ✳ Qp (0 2.0 4.0)	Additional Remarks
	90			R-22	57	**Conglomeratic SANDSTONE**-Red-brown to gray, Fine to coarse grained, Slightly Weathered, slightly broken to massive, very hard		RQD=66 Rec=95%			9 min. 10 min. >> Q_u = 335.9 tsf 165.3 pcf 7 min. 6 min. 5 min.
	95			R-23	58	**CONGLOMERATE**-Light gray-brown to dark gray-brown, Fine to very coarse grained, Weathered to Slightly Weathered, broken to slightly broken, very hard, pits and vugs Highly Weathered/Completely Weathered layer @ 96.2 feet (~ 4-1/2 inches thick)		RQD=73 Rec=97%			5 min. 3 min. 3 min. 8 min. 7 min.
	100			R-24	60	**SILTSTONE**-Red-brown to dark brown, Very fine grained, Slightly Weathered, very broken to massive, moderately hard **SILTSTONE**-Red-brown to light gray-brown, Very fine grained, Weathered to Slightly Weathered, very broken to massive, moderately hard **SANDSTONE**-Red-brown to dark gray-brown, Fine grained, Weathered to Highly Weathered, very broken to slightly broken, moderately hard to hard		RQD=23 Rec=100%			10 min. 6 min. 6 min. 9 min. 9 min.
	105			R-25	60	**SANDSTONE**-Light gray-brown to dark gray-brown, Fine to medium grained, Weathered to Slightly Weathered, broken to massive, hard to very hard		RQD=38 Rec=100%			5 min. 5 min. >> Q_u = 511.1 tsf 159.4 pcf 8 min.
	110			R-26	48	**SANDSTONE**-Brown to gray-brown, Fine to medium grained, Weathered to Highly Weathered, very broken to slightly broken, moderately hard to hard		RQD=8 Rec=100%			8 min. 9 min. 6 min. 6 min.
	115			R-27 R-28	12 60	**Conglomeratic SANDSTONE**-Light gray to dark brown, Fine to very coarse grained, Slightly Weathered, broken to massive, very hard to extremely hard Developing, soil-filled, diagonal fracture @ 115.2 feet.		RQD=58 Rec=100% RQD=68 Rec=100%			9 min. 7 min. >> Q_u = 518.7 tsf 160.1 pcf 5 min. 5 min. 4 min.
	120					**SILTSTONE**-Red-brown, Very fine grained, Weathered to Slightly Weathered, very broken to massive, moderately hard					5 min. 5 min.
						Continued Next Page					

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DATE STARTED:	8/28/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	8/31/17	**DRILLER:** S. Taylor	**LOGGED BY:** L. Proczko
COMPLETION DEPTH	159.0 ft	**DRILL RIG:**	Diedrich D-50
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

BORING B-1

Water

While Drilling	Not Enc.
Post-Core	17 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL (0 25 50) STRENGTH, tsf ▲ Qu ✳ Qp (0 2.0 4.0)	Additional Remarks
	120			R-29	60	**SANDSTONE**-Gray-brown to red-gray-brown, Fine to coarse grained, Slightly Weathered, very broken to massive, hard		RQD=61 Rec=100%			9 min. 9 min. 6 min. 3 min. 3 min.
	125			R-30	26	**Conglomeratic SANDSTONE**-Gray-brown to dark brown, Fine to very coarse grained, Weathered to Highly Weathered, hard to very hard		RQD=13 Rec=87%			4 min. 3 min. 7 min.
				R-31	30	**SILTSTONE**-Red-brown to dark red-brown, Very fine grained, Weathered, very broken to slightly broken, moderately hard		RQD=0 Rec=100%			6 min. 6 min.
	130			R-32	50	**SANDSTONE**-Gray-brown, Fine grained, Weathered to Slightly Weathered, very broken to massive, moderately hard, multiple fractures throughout		RQD=73 Rec=83%			5 min. 3 min. 3 min. 3 min. 3 min.
	135			R-33	42	**SANDSTONE**-Light gray-brown to dark gray-brown, Fine grained, Weathered to Highly Weathered, very broken to massive, hard to very hard		RQD=14 Rec=69%			2 min. 3 min. 3 min. 3 min. 4 min.
	140			R-34	60	**Conglomeratic SANDSTONE**-Gray-brown to dark gray-brown, Fine to medium grained, Weathered, very broken to massive, very hard **Conglomeratic SANDSTONE**-Light gray-brown to dark gray-brown to brown, Fine to very coarse grained, Slightly Weathered, very broken to massive, hard to extremely hard Weathered layer @ 142.4 feet (~ 7 inches thick)		RQD=78 Rec=100%			4 min. 3 min. 4 min. 3 min. 3 min.
	145			R-35	55	Conglomerate seam @ 147.3 feet (~ 3 inches thick)		RQD=58 Rec=92%			3 min. 2 min. 3 min. 3 min.
	150					*Continued Next Page*					

>> ▲ Q_u = 818.5 tsf, 162.4 pcf

>> ▲ Q_u = 801.6 tsf, 151.1 pcf

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PROJECT: Energy Transfer HDD (DPS)
LOCATION: Wetland "J47" (PPP5)
Dauphin Co., PA
PA-LE-0001.0000-SR/PO#201770816-2

The stratification lines represent approximate boundaries. The transition may be gradual.

BORING B-1

DATE STARTED:	8/28/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	8/31/17	**DRILLER:** S. Taylor	**LOGGED BY:** L. Proczko
COMPLETION DEPTH	159.0 ft	**DRILL RIG:**	Diedrich D-50
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

Water

While Drilling	Not Enc.
Post-Core	17 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ / Moisture × / PL ◪ / LL ✚ (0, 25, 50) / STRENGTH, tsf ▲ Qu ✳ Qp (0, 2.0, 4.0)	Additional Remarks
	150			R-36	60	**Conglomeratic SANDSTONE**-Light gray-brown to dark gray-brown to brown, Fine to very coarse grained, Slightly Weathered, very broken to massive, hard to extremely hard		RQD=86 Rec=100%			3 min. 2 min. >> ▲ Q_u = 412.9 tsf 152.2 pcf 2 min.
						SILTSTONE-Red-brown, Very fine grained, Weathered to Highly Weathered, very broken to broken, moderately hard					3 min.
	155					**SILTSTONE**-Dark red-brown, Very fine grained, Slightly Weathered, slightly broken to massive, moderately hard					4 min.
				R-37	60	**Conglomeratic SANDSTONE**-Light gray to red-brown, Fine to coarse grained, Slightly Weathered, massive, hard Siltstone seam @ 156.9 feet (~ 2-1/2 inches thick)		RQD=87 Rec=100%			7 min. 4 min. 4 min. 5 min.
						SILTSTONE-Dark red-brown, Very fine grained, Slightly Weathered, massive, moderately hard Test boring terminated @ 159 feet					5 min.

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LOCATION: Wetland "J47" (PPP5)
Dauphin Co., PA
PA-LE-0001.0000-SR/PO#201770816-2

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Geo Bore B-1
8-28-17
Box 1 of
Run
Depth (ft.)
Recovery
RQD (in.)
R-1
6'3"–9
31.5
5.5
R-2
9-16
60
13
R-3
16-17
12
0.0
R-4
17-24
37
0.0
16
17
24'


04911456
Geo Bore B-1
8-28-17
24-39
Box 2 of
Wetland J47
RUN | Depth (ft.) | Rec (in.) | RQD (in.)
R-5 | 24-29 | 42 | 0.0
R-6 | 29-34 | 48 | 14
R-7 | 34-39 | 60 | 40
29
34
39


0491 1456
Geo Boring B-1
8.28.17
39-52.9
Box 3 of
WETLAND J47
8.28.17
RUN | Depth (ft.) | Rec (in.) | RQD (in.)
R-8 | 39-44 | 60 | 47
R-9 | 44-48 | 48 | 18
R-10 | 48-49 | 12 | 10.5
R-11 | 49-54 | 60 | 59
39
44
48
49
52.9


047A456
Geo Bore B-1
8.29.17/8.30.17
67.9-82.7
Box 5 of
Wetland J47
RUN | Depth (ft) | Rec (in.) | RQD (in.)
R-12 | 54-59 | 60 | 46
R-13 | 59-64 | 60 | 37.5
R-14 | 64-69 | 60 | 57.5


PPA#5
0479114.56
B-1
B-29.17
679.82.7
Box 1 of
Wetland J47
B-29.17
B-30.17
RUN | Depth(Ft.) | Rec(in.) | RQD(in.)
R-15 | 69-74 | 60 | 55.5
R-16 | 74-79 | 60 | 59.5
R-17 | 79-81 | 21 | 8
R-18 | 81-81.2 | #2 | 0
R-19 | 81.2-84 | 34 | 14
69
74
81
81.2


PPP#5
04911456
Geo Bore B-1
8-30-17
82.7-99
Box 6 of
Wetland J47
Run | Depth (ft.) | Rec (in.) | RQD (in.)
R-20 | 84-87.4 | 18 | 0
R-21 | 87.4-89 | 19 | 12.5
R-22 | 89-94 | 57 | 39.5
R-23 | 94-99 | 58 | 43.5
water @ 17'
82.7
87.4
89
94
99


PPP#5
049114 56
Geo Bore B-1
8.30.17 / 8.31.17
99-114
Box 7 of
Wetland J47
8.30.17
8.31.17
Run | Depth(ft.) | Rec(in.) | RQD(in.)
R-24 | 99-104 | 60 | 14
R-25 | 104-109 | 60 | 22.5
R-26 | 109-113 | 48 | 4
R-27 | 113-114 | 12 | 7
99
104
109
113
114


PPP#5
04911456
B-1
.8-31-17
.114-128.6
Box 8 of
Wetland J47
RUN | Depth(ft.) | Rec(in.) | RQD(in.)
R-28 | 114-119 | 5460 | 41
R-29 | 119-124 | 60 | 36.5
R-30 | 124-126.5 | 26 | 4
R-31 | 126.5-129 | 32 | 0
114
119
124
126.5
128.6


PPP#5
04911456
B-1
8.31.17
136 - 145.2
Box 9 of
Wetland J47
Run | Depths(ft.) | Rec(in.) | RQD(in.)
R-32 | 129-134 | 50 | 44
R-33 | 134-139 | 41.5 | 8.5
R-34 | 139-144 | 60 | 46.5
R-35 | 144-149 | 55 | 35
129
134
139
144
145.2


PPP#5
04911456
B-1
8-31-17
145.2-159
Box 10 of 10
Wetland J47
RUN | Depth(ft.) | REC(in.) | RQD(in.)
R-36 | 149-154 | 60 | 51.5
R-37 | 154-159 | 60 | 52
145.2
149
154
159
04911456

BORING B-2

DATE STARTED:	9/5/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	9/7/17	**DRILLER:** T. Growden	**LOGGED BY:** C. Lehman
COMPLETION DEPTH	201.0 ft	**DRILL RIG:**	Diedrich D-50
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

Water

While Drilling	Not Enc.
Post-Core	22.3 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL (0 25 50) STRENGTH, tsf ▲ Qu ✳ Qp (0 2.0 4.0)	Additional Remarks
	0					3 inches topsoil					
				S-1	14	**RESIDUUM**-Medium Stiff, Red-brown, Sandy SILT, trace roots, moist	ML	2-2-5-7 N=7	14		
				S-2	8	**RESIDUUM**-Medium Dense, Red-brown, Silty SAND, trace Gravel, moist	SM	12-13-13-12 N=26	10		Fines=26.8%
	5					**Highly Weathered SANDSTONE Sampled as Soil**-Very Dense, Red-brown, Silty SAND, dry/moist	SM				
				S-3	17			33-41-50/4"	10		Fines=17.9%
	10					**SANDSTONE**-Brown to red-brown, Fine to medium grained, Highly Weathered, very broken to broken, moderately hard					4 min.
				R-1	24			RQD=0 Rec=56%			4 min.
											4 min.
											4 min.
											2 min.
	15					**SANDSTONE**-Red-brown, Fine grained, Weathered to Highly Weathered, very broken to massive, moderately hard					3 min.
											>> Q_u = 594.2 tsf
											165.6 pcf
				R-2	76			RQD=27 Rec=90%			3 min.
											3 min.
											3 min.
											3 min.
	20					**SANDSTONE**-Red-brown to red-gray-brown, Fine grained, Slightly Weathered, very broken to massive, moderately hard					3 min.
											3 min.
											3 min.
											3 min.
											>> Q_u = 564.7 tsf
											163.5 pcf
	25			R-3	110			RQD=54 Rec=92%			3 min.
											3 min.
											3 min.
											3 min.
						SANDSTONE-Red-gray-brown to gray-brown, Fine grained, Weathered to Highly Weathered, very broken to slightly broken, moderately hard to hard					3 min.
	30										3 min.
						Continued Next Page					

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PROJECT NO.: 04911456
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Wetland "J47" (PPP5)
Dauphin Co., PA
PA-LE-0001.0000-SR/PO#201770816-2

The stratification lines represent approximate boundaries. The transition may be gradual.

DATE STARTED:	9/5/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	9/7/17	**DRILLER:** T. Growden	**LOGGED BY:** C. Lehman
COMPLETION DEPTH	201.0 ft	**DRILL RIG:**	Diedrich D-50
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

BORING B-2

Water

While Drilling	Not Enc.	
Post-Core	22.3 feet	

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ / Moisture × / PL ◪ / LL ✚ (0, 25, 50) / STRENGTH, tsf Qu ▲ / Qp ✳ (0, 2.0, 4.0)	Additional Remarks
	30					**SANDSTONE**-Brown to gray-brown, Fine grained, Weathered to Slightly Weathered, very broken to massive, hard					3 min.
											3 min.
											3 min.
				R-4	96			RQD=49 Rec=100%			3 min.
	35										3 min.
											3 min.
											3 min.
						SANDSTONE-Brown to gray-brown, Fine grained, Highly Weathered, very broken to broken, moderately hard, multiple soil seams and layers					3 min.
											>> Qu = 43.6 tsf 3 min. 168.8 pcf
						SILTSTONE-Red-brown to red-gray-brown, Very fine grained, Slightly Weathered, broken to massive, moderately hard					3 min.
	40					**SANDSTONE**-Light gray to dark gray-brown, Fine to medium grained, Slightly Weathered, slightly broken to massive, hard to very hard, trace calcite seams					3 min.
				R-5	84			RQD=89 Rec=100%			3 min.
											4 min.
											3 min.
						Broken/very broken layer @ 44.7 feet (~ 3-1/2 inches thick)					3 min.
	45					**SILTSTONE**-Brown to red-brown to red-gray-brown, Very fine grained, Slightly Weathered, slightly broken to massive, moderately hard					>> Qu = 417.3 tsf 4 min. 167.6 pcf
											4 min.
											4 min.
											4 min.
	50			R-6	120			RQD=75 Rec=100%			4 min.
											4 min.
											4 min.
						SANDSTONE-Light gray-brown to red-gray-brown to dark brown, Fine to medium grained, Slightly Weathered, very broken to massive, moderately hard to very hard					4 min.
						Nearly vertical fracture from 54.4 to 54.8 feet. Weathered/Highly Weathered seam @ 54.8 (~ 2-1/2 inches thick)					4 min.
	55										>> Qu = 603.0 tsf 4 min. 161.1 pcf
											4 min.
											4 min.
				R-7	70			RQD=72 Rec=97%			4 min.
											4 min.
	60					*Continued Next Page*					

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Telephone: (717) 230-8622

PROJECT NO.: 04911456
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Wetland "J47" (PPP5)
Dauphin Co., PA
PA-LE-0001.0000-SR/PO#201770816-2

The stratification lines represent approximate boundaries. The transition may be gradual.

DATE STARTED:	9/5/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	9/7/17	**DRILLER:** T. Growden	**LOGGED BY:** C. Lehman
COMPLETION DEPTH	201.0 ft	**DRILL RIG:**	Diedrich D-50
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

BORING B-2

Water

While Drilling	Not Enc.
Post-Core	22.3 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL (0 25 50) STRENGTH, tsf ▲ Qu ✳ Qp (0 2.0 4.0)	Additional Remarks
	60					**SANDSTONE**-Gray-brown to dark gray-brown, Fine grained, Weathered to Slightly Weathered, very broken to massive, very hard to extremely hard					4 min.
											4 min. >> Q_u = 163.7 tsf 164.7 pcf
						SILTSTONE-Red-brown to dark red-brown, Very fine grained, Weathered to Slightly Weathered, broken to massive, moderately hard					4 min.
											4 min.
	65			R-8	76	**SILTSTONE**-Dark gray-brown, Very fine grained, Highly Weathered, very broken to broken, moderately hard		RQD=49 Rec=84%			4 min.
						SILTSTONE-Red-brown to red-gray-brown, Very fine grained, Slightly Weathered, broken to massive, moderately hard					4 min.
											4 min.
						SILTSTONE-Red-gray-brown, Very fine grained, Highly Weathered, very broken to slightly broken, moderately hard					4 min.
											3 min.
											3 min.
	70					**SILTSTONE**-Red-brown to red-gray-brown, Very fine grained, Slightly Weathered, broken to massive, moderately hard					3 min.
											3 min. >> Q_u = 411.2 tsf 167.7 pcf
				R-9	78			RQD=97 Rec=100%			3 min.
											3 min.
											3 min.
	75										3 min.
											4 min.
											4 min.
											4 min.
						SILTSTONE/SANDSTONE-Red-brown to dark gray-brown, Very fine to fine grained, Weathered, broken to slightly broken, moderately hard to very hard					4 min.
											4 min. >> Q_u = 836.8 tsf 161.1 pcf
	80			R-10	120	**SANDSTONE**-Gray-brown to dark gray-brown, Fine to medium grained, Weathered to Slightly Weathered, hard to very hard, trace calcite stringers		RQD=62 Rec=100%			4 min.
						Broken layer @ 80.1 feet (~ 5-1/4 inches thick)					4 min.
						Weathered seam @ 82.5 feet (~ 1-1/2 inches thick)					4 min.
											4 min.
	85					Broken layer @ 83.3 feet (~ 4-1/2 inches thick)					4 min. >> Q_u = 106.1 tsf 163.5 pcf
						SHALE-Red-brown, Very fine grained, Slightly Weathered, very broken to massive, moderately hard					4 min.
				R-11	60			RQD=88 Rec=100%			4 min.
											4 min.
	90					*Continued Next Page*					4 min.

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PROJECT NO.: 04911456
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Wetland "J47" (PPP5)
Dauphin Co., PA
PA-LE-0001.0000-SR/PO#201770816-2

The stratification lines represent approximate boundaries. The transition may be gradual.

BORING B-2

DATE STARTED:	9/5/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	9/7/17	**DRILLER:** T. Growden	**LOGGED BY:** C. Lehman
COMPLETION DEPTH	201.0 ft	**DRILL RIG:**	Diedrich D-50
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

Water

While Drilling	Not Enc.
Post-Core	22.3 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ / Moisture / PL / LL (0, 25, 50) / STRENGTH, tsf Qu / Qp (0, 2.0, 4.0)	Additional Remarks
	90					Broken layer @ 89.6 feet (~ 5 inches thick) **SHALE**-Red-brown, Very fine grained, Slightly Weathered, very broken to massive, moderately hard					4 min. 5 min. 5 min. 5 min. >> Q_u = 161.1 tsf 164.8 pcf 5 min.
	95			R-12	120			RQD=95 Rec=100%			5 min. 5 min. 5 min. 5 min. 5 min. 5 min.
	100					Weathered layer @ 99.7 feet (~ 3-1/2 inches thick)					>> Q_u = 352.4 tsf 169.5 pcf 4 min.
				R-13	60	**SANDSTONE**-Gray to gray-brown, Fine to medium grained, Slightly Weathered, slightly broken to massive, very hard to extremely hard		RQD=54 Rec=100%			4 min. 3 min. 3 min.
	105					**SANDSTONE**-Gray to dark gray-brown, Fine to medium grained, Weathered, very broken to massive, extremely hard					3 min.
						SANDSTONE-Gray to gray-brown, Fine to medium grained, Slightly Weathered, massive, extremely hard					3 min. >> Q_u = 848.8 tsf 155.5 pcf 3 min. 3 min.
	110			R-14	120	**SILTSTONE**-Gray-brown to dark red-brown, Very fine grained, Weathered to Slightly Weathered, very broken to massive, moderately hard		RQD=55 Rec=100%			4 min. 4 min. 4 min. 4 min.
						SANDSTONE-Light gray-brown to dark gray-brown, Fine grained, Weathered to Slightly Weathered, broken to massive, very hard to extremely hard					4 min. 4 min.
	115					**Conglomeratic SANDSTONE**-Gray-brown to dark gray-brown, Fine to very coarse grained, Slightly Weathered, slightly broken to massive, hard to very hard					4 min. 4 min. 4 min. 4 min. 4 min.
	120					*Continued Next Page*					

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PROJECT NO.: 04911456
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Wetland "J47" (PPP5)
Dauphin Co., PA
PA-LE-0001.0000-SR/PO#201770816-2

The stratification lines represent approximate boundaries. The transition may be gradual.

DATE STARTED: 9/5/17 **DRILL COMPANY:** Eichelberger's, Inc.
DATE COMPLETED: 9/7/17 **DRILLER:** T. Growden **LOGGED BY:** C. Lehman
COMPLETION DEPTH 201.0 ft **DRILL RIG:** Diedrich D-50
BENCHMARK: N/A **DRILLING METHOD:** Casing/Rock Coring
ELEVATION: N/A **SAMPLING METHOD:** 2-in SS1.874-in Core
LATITUDE: n/a° **HAMMER TYPE:** Automatic
LONGITUDE: n/a° **EFFICIENCY** N/A
STATION: N/A **OFFSET:** N/A **REVIEWED BY:** F. Hoffman
REMARKS:

BORING B-2

Water While Drilling Not Enc.
Post-Core 22.3 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ Moisture × PL ◪ LL ✚ (0 25 50) STRENGTH, tsf Qu ▲ Qp ✳ (0 2.0 4.0)	Additional Remarks
	120			R-15	85	**SILTSTONE**-Red-brown to dark red-gray-brown, Very fine grained, Highly Weathered, very broken to slightly broken, moderately hard		RQD=53 Rec=71%			4 min. 4 min. 4 min. 3 min.
						SILTSTONE-Red-gray-brown, Very fine grained, Slightly Weathered, broken to massive, moderately hard					>> Q_u = 496.4 tsf 4 min. 166.0 pcf
	125					**SANDSTONE**-Gray to red-brown, Fine grained, Slightly Weathered, slightly broken to massive, moderately hard to extremely hard, trace calcite stringers					4 min. 4 min. 4 min.
				R-16	60	**Conglomeratic SANDSTONE**-Gray to red-gray-brown, Fine to very coarse grained, Slightly Weathered, broken to massive, hard to extremely hard, trace calcite		RQD=50 Rec=100%			4 min. 4 min. 4 min.
	130										4 min. 4 min.
											>> Q_u = 409.5 tsf 4 min. 160.4 pcf
						Conglomeratic SANDSTONE-Gray-brown to dark red-brown, Fine to coarse grained, Weathered to Slightly Weathered, very broken to massive, moderately hard to very hard, trace pits					4 min. 4 min. 4 min.
	135			R-17	120			RQD=75 Rec=100%			4 min. 4 min.
						SANDSTONE-Red-brown to dark brown, Fine to very coarse grained, Slightly Weathered, broken to massive, moderately hard to hard, trace calcite stringers					>> Q_u = 789.7 tsf 4 min. 160.4 pcf
	140										4 min. 4 min.
						SILTSTONE-Brown to red-brown, Very fine grained, Slightly Weathered, slightly broken to massive, moderately hard					4 min. 4 min.
											>> Q_u = 380.6 tsf 4 min. 165.6 pcf
						Broken/very broken layer @ 144 feet (~ 10-1/2 inches thick)					4 min.
	145			R-18	120	**SANDSTONE**-Light gray-brown to dark red-brown, Fine to medium grained, Slightly Weathered, broken to massive, moderately hard to very hard, trace calcite stringers		RQD=78 Rec=100%			4 min. 4 min. 4 min. 4 min.
						Broken layer @ 149.5 feet (~ 6-1/2 inches					4 min.
	150					*Continued Next Page*					

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PROJECT: Energy Transfer HDD (DPS)
LOCATION: Wetland "J47" (PPP5)
Dauphin Co., PA
PA-LE-0001.0000-SR/PO#201770816-2

The stratification lines represent approximate boundaries. The transition may be gradual.

DATE STARTED:	9/5/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	9/7/17	**DRILLER:** T. Growden	**LOGGED BY:** C. Lehman
COMPLETION DEPTH	201.0 ft	**DRILL RIG:**	Diedrich D-50
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

BORING B-2

Water

While Drilling	Not Enc.	
Post-Core	22.3 feet	

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ Moisture × PL ◪ LL ✚ (0 25 50) STRENGTH, tsf Qu ▲ Qp ✳ (0 2.0 4.0)	Additional Remarks
	150					thick) **SANDSTONE**-Light gray-brown to dark red-brown, Fine to medium grained, Slightly Weathered, broken to massive, moderately hard to very hard, trace calcite stringers					4 min. 4 min. >> Q_u = 383.3 tsf 4 min. 163.9 pcf 4 min. 4 min.
	155			R-19	115	**SHALE**-Red-brown to dark red-brown, Very fine grained, Weathered to Slightly Weathered, very broken to massive, moderately hard Weathered/Highly Weathered seam @ 157.1 feet (~ 2-3/4 inches thick) Highly Weathered layer @ 158.3 feet (~ 5 inches thick)		RQD=59 Rec=96%			4 min. 4 min. 4 min. 4 min. 4 min. 4 min.
	160			R-20	58	**SHALE**-Dark red-brown to dark red-gray-brown, Very fine grained, Slightly Weathered, very broken to massive, moderately hard Weathered layer @ 160 feet (~ 4-1/2 inches thick)		RQD=60 Rec=96%			4 min. 4 min. 4 min. 4 min. 4 min. >> Q_u = 410.3 tsf 165.6 pcf 4 min.
	165										4 min. >> Q_u = 284.8 tsf 168.5 pcf 4 min.
	170			R-21	120	Weathered/Highly Weathered layer @ 168.4 feet (~ 11 inches thick)		RQD=54 Rec=100%			4 min. 4 min. 4 min. 4 min. >> Q_u = 846.0 tsf 4 min. 165.0 pcf
	175			R-22	60	**SANDSTONE**-Light gray-brown to dark red-brown, Fine grained, Slightly Weathered, very broken to massive, hard to very hard Broken/very broken layer @ 174.7 feet (~ 4 inches thick)		RQD=42 Rec=100%			4 min. 4 min. 4 min. 4 min. 4 min. 4 min.
	180					Broken/very broken layer @ 178.1 feet (~ 8 inches thick)					4 min.

Continued Next Page

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PROJECT NO.: 04911456
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Wetland "J47" (PPP5)
Dauphin Co., PA
PA-LE-0001.0000-SR/PO#201770816-2

The stratification lines represent approximate boundaries. The transition may be gradual.

BORING B-2

DATE STARTED:	9/5/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	9/7/17	**DRILLER:** T. Growden	**LOGGED BY:** C. Lehman
COMPLETION DEPTH	201.0 ft	**DRILL RIG:**	Diedrich D-50
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

Water

While Drilling	Not Enc.
Post-Core	22.3 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ / Moisture × / PL ◪ / LL ✚ (0, 25, 50) / STRENGTH, tsf ▲ Qu ✳ Qp (0, 2.0, 4.0)	Additional Remarks
	180					**Conglomeratic SANDSTONE**-Light gray-brown to gray-brown, Fine to very coarse grained, Slightly Weathered, very broken to massive, hard to very hard Broken seam @ 180.6 feet (~ 2 inches thick)					4 min. >> ▲ Q_u = 661.4 tsf 150.6 pcf 3 min. 3 min. 3 min.
	185			R-23	118	**SANDSTONE**-Red-gray-brown, Fine to medium grained, Weathered to Highly Weathered, very broken to slightly broken, hard **Conglomeratic SANDSTONE**-Gray-brown to dark red-brown, Fine to very coarse grained, Slightly Weathered, massive, moderately hard to very hard **SILTSTONE**-Brown to dark red-brown, Very fine grained, Slightly Weathered, very broken to massive, moderately hard		RQD=69 Rec=98%			3 min. 3 min. 3 min. 3 min. 3 min. 3 min. 3 min.
	190			R-24	60			RQD=100 Rec=100%		3 min. >> ▲ Q_u = 772.4 tsf 168.9 pcf	3 min. 3 min. 3 min. 3 min. 3 min. 3 min.
	195			R-25	60	**SANDSTONE**-Light gray to dark red-brown, Fine to coarse grained, Slightly Weathered, slightly broken to massive, hard to very hard		RQD=86 Rec=100%			3 min. 3 min. 3 min. 3 min. 3 min.
	200					Weathered seam @ 200 feet (~ 2 inches thick) Test boring terminated @ 201 feet					3 min.

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PROJECT NO.: 04911456
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Wetland "J47" (PPP5)
Dauphin Co., PA
PA-LE-0001.0000-SR/PO#201770816-2

The stratification lines represent approximate boundaries. The transition may be gradual.


0491-1456
PPDS
Wetland J47
B-2
9/5/17
Box 1 of _
Run | Depth | Rec | RQD
R-1 | 9.4 - 13.0 | 2.0 | 0.0
R-2 | 13.0-20.0 | 6.3 | 1.9
R-3 | 20.0-30.0 | 9.2 | 5.4
TOP
13.0
20.0


04491-1456
PPPS
Wetland J47
B-2
9/5/17
Box 1 of _
Run | Depth | Rec. | RQD
R-3(Cont) | 20.0-30.0 | 9.2 | 5.4
R-4 | 30.0-38.0 | 8.0 | 3.9
R-5 | 38.0-45.0 | 7.5 | 6.2
TOP
30.0


0491-1456
PPPS
Wetland J47
B-2
Box 3 of
9/5/17
Run
Depth
Rec.
RQD
R-5(cont)
38.0-45.0
7.5
6.2
R-6
45.0-55.0
10.0
7.5
TOP
45.0
55.0


0491-1456
PPP5
Wetland J47
B-2
Box 4 of _
9/6/17
Run | Depth | Rec. | RQD
R-7 | 55.0-61.0 | 5.8 | 4.3
R-8 | 61.0-68.5 | 6.3 | 3.7
R-9 | 68.5-75.0 | 6.5 | 6.3
TOP
55
61.0
68.5


9491-1956
PPP5
Wetland 547
B-2
Box 5 of —
91617
Run
Depth
Rec.
RQD
R-10
750-850
10.0
6.2
TOP
75.0
85.0


D491-1456
PPP5
Wetland J47
B-2
Box 6 of _
9/6/17
Run | Depth | Rec. | RQD
R-11 | 85.0 - 90.0 | 5.0 | 4.4
R-12 | 90.0 - 100.0 | 10.0 | 9.5
TOP
90.0


0491-1456
PPDS
Wetland J47
B-2
Box 7 of _
9/6/17
Run | Depth | Rec. | RQD
R-13 | 100.0 - 105.0 | 5.0 | 2.7
R-14 | 105.0 - 115.0 | 10.0 | 5.5
TOP
100.0
105.0
115.0


0491-1456
PPP5
Wetland J47
B-2
Box 8 of
9/6/17
Run | Depth | Rec. | RQD
R-15 | 115.0-125.0 | 7.1 | 5.3
R-16 | 125.0-130.0 | 5.0 | 2.5
R-17 | 130.0-140.0 | 10.0 | 7.5
TOP
115.0
125.0
130.0


0491-1456
PPPS
Wetland J47
B-2
Box 9 of
9/7/17
Run
Depth
Rec.
RQD
R-77
130.0-140.0
100
75
R-78
140.0-150.0
10.0
7.8
TOP
140.0
140.0


0491-1456
PPPS
Wetland J47
B-2
Box 10 of –
9/5/17
Run | Depth | Rec | RQD
R-18(cont) | 140.0-150.0 | 10.0 | 7.8
R-19 | 150.0-160.0 | 9.6 | 5.9
R-20 | 160.0-165.0 | 4.8 | 3.0
TOP
150.0
160.0


0491-1456
PPP5
Wetland 547
B-2
Box 11 of
9/7/17
Run | Depth | Rec. | RQD
R-20(cont) | 160.0 - 165.0 | 4.8 | 3.0
R-21 | 165.0 - 175.0 | 10.0 | 5.4
R-22 | 17 50 - 180.0 | 5.0 | 2.1
Top
1750

0491-1456
PPP5
Wetland 547
B-2
Box 12 of 6
917117

Run	Depth	Rec.	RQD
R-22 (cont.)	175.0 - 180.0	5.0	2.1
R-23	180.0 - 190.0	9.8	6.9
R-24	190.0 - 195.0	5.0	5.0


0491-1456
PPPS
Wetland 547
B-2
Box 13 of 13
9/7/17
Run | Depth | Rec. | RQD
R-24 (Cont) | 190.0-195.0 | 5.0 | 5.0
R-25 | 195.0-200.0 | 5.0 | 4.3
EOB
TOP
195.0
200.0
201.0

GENERAL NOTES

SAMPLE IDENTIFICATION

The Unified Soil Classification System (USCS), AASHTO 1988 and ASTM designations D2487 and D-2488 are used to identify the encountered materials unless otherwise noted. Coarse-grained soils are defined as having more than 50% of their dry weight retained on a #200 sieve (0.075mm); they are described as: boulders, cobbles, gravel or sand. Fine-grained soils have less than 50% of their dry weight retained on a #200 sieve; they are defined as silts or clay depending on their Atterberg Limit attributes. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size.

DRILLING AND SAMPLING SYMBOLS

SFA: Solid Flight Auger - typically 4" diameter flights, except where noted.
HSA: Hollow Stem Auger - typically 3¼" or 4¼ I.D. openings, except where noted.
M.R.: Mud Rotary - Uses a rotary head with Bentonite or Polymer Slurry
R.C.: Diamond Bit Core Sampler
H.A.: Hand Auger
P.A.: Power Auger - Handheld motorized auger

SS: Split-Spoon - 1 3/8" I.D., 2" O.D., except where noted.
ST: Shelby Tube - 3" O.D., except where noted.
RC: Rock Core
TC: Texas Cone
BS: Bulk Sample
PM: Pressuremeter
CPT-U: Cone Penetrometer Testing with Pore-Pressure Readings

SOIL PROPERTY SYMBOLS

N: Standard "N" penetration: Blows per foot of a 140 pound hammer falling 30 inches on a 2-inch O.D. Split-Spoon.
N_{60}: A "N" penetration value corrected to an equivalent 60% hammer energy transfer efficiency (ETR)
Q_u: Unconfined compressive strength, TSF
Q_p: Pocket penetrometer value, unconfined compressive strength, TSF
w%: Moisture/water content, %
LL: Liquid Limit, %
PL: Plastic Limit, %
PI: Plasticity Index = (LL-PL),%
DD: Dry unit weight, pcf
▼,▽,▼ Apparent groundwater level at time noted

RELATIVE DENSITY OF COARSE-GRAINED SOILS

Relative Density	N - Blows/foot
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	50 - 80
Extremely Dense	80+

ANGULARITY OF COARSE-GRAINED PARTICLES

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

GRAIN-SIZE TERMINOLOGY

Component	Size Range
Boulders:	Over 300 mm (>12 in.)
Cobbles:	75 mm to 300 mm (3 in. to 12 in.)
Coarse-Grained Gravel:	19 mm to 75 mm (¾ in. to 3 in.)
Fine-Grained Gravel:	4.75 mm to 19 mm (No.4 to ¾ in.)
Coarse-Grained Sand:	2 mm to 4.75 mm (No.10 to No.4)
Medium-Grained Sand:	0.42 mm to 2 mm (No.40 to No.10)
Fine-Grained Sand:	0.075 mm to 0.42 mm (No. 200 to No.40)
Silt:	0.005 mm to 0.075 mm
Clay:	<0.005 mm

PARTICLE SHAPE

Description	Criteria
Flat:	Particles with width/thickness ratio > 3
Elongated:	Particles with length/width ratio > 3
Flat & Elongated:	Particles meet criteria for both flat and elongated

RELATIVE PROPORTIONS OF FINES

Descriptive Term	% Dry Weight
Trace:	< 5%
With:	5% to 12%
Modifier:	>12%

intertek psi
Total Quality. Assured.

GENERAL NOTES

(Continued)

CONSISTENCY OF FINE-GRAINED SOILS

Q_U - TSF	N - Blows/foot	Consistency
0 - 0.25	0 - 2	Very Soft
0.25 - 0.50	2 - 4	Soft
0.50 - 1.00	4 - 8	Firm (Medium Stiff)
1.00 - 2.00	8 - 15	Stiff
2.00 - 4.00	15 - 30	Very Stiff
4.00 - 8.00	30 - 50	Hard
8.00+	50+	Very Hard

MOISTURE CONDITION DESCRIPTION

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

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term	% Dry Weight
Trace:	< 15%
With:	15% to 30%
Modifier:	>30%

STRUCTURE DESCRIPTION

Description	Criteria
Stratified:	Alternating layers of varying material or color with layers at least ¼-inch (6 mm) thick
Laminated:	Alternating layers of varying material or color with layers less than ¼-inch (6 mm) thick
Fissured:	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided:	Fracture planes appear polished or glossy, sometimes striated
Blocky:	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed:	Inclusion of small pockets of different soils
Layer:	Inclusion greater than 3 inches thick (75 mm)
Seam:	Inclusion 1/8-inch to 3 inches (3 to 75 mm) thick extending through the sample
Parting:	Inclusion less than 1/8-inch (3 mm) thick

SCALE OF RELATIVE ROCK HARDNESS

Q_U - TSF	Consistency
2.5 - 10	Extremely Soft
10 - 50	Very Soft
50 - 250	Soft
250 - 525	Medium Hard
525 - 1,050	Moderately Hard
1,050 - 2,600	Hard
>2,600	Very Hard

ROCK BEDDING THICKNESSES

Description	Criteria
Very Thick Bedded	Greater than 3-foot (>1.0 m)
Thick Bedded	1-foot to 3-foot (0.3 m to 1.0 m)
Medium Bedded	4-inch to 1-foot (0.1 m to 0.3 m)
Thin Bedded	1¼-inch to 4-inch (30 mm to 100 mm)
Very Thin Bedded	½-inch to 1¼-inch (10 mm to 30 mm)
Thickly Laminated	1/8-inch to ½-inch (3 mm to 10 mm)
Thinly Laminated	1/8-inch or less "paper thin" (<3 mm)

ROCK VOIDS

Voids	Void Diameter
Pit	<6 mm (<0.25 in)
Vug	6 mm to 50 mm (0.25 in to 2 in)
Cavity	50 mm to 600 mm (2 in to 24 in)
Cave	>600 mm (>24 in)

GRAIN-SIZED TERMINOLOGY

(Typically Sedimentary Rock)

Component	Size Range
Very Coarse Grained	>4.76 mm
Coarse Grained	2.0 mm - 4.76 mm
Medium Grained	0.42 mm - 2.0 mm
Fine Grained	0.075 mm - 0.42 mm
Very Fine Grained	<0.075 mm

ROCK QUALITY DESCRIPTION

Rock Mass Description	RQD Value
Excellent	90 -100
Good	75 - 90
Fair	50 - 75
Poor	25 -50
Very Poor	Less than 25

Degree of Brokeness

Characteristic	Description
Less than 1 inch	Very Broken
1 inch to 3 inches	Broken
3 inches to 6 inches	Slightly Broken
Greater than 6 inches	Massive

DEGREE OF WEATHERING

Slightly Weathered: Rock generally fresh, joints stained and discoloration extends into rock up to 25 mm (1 in), open joints may contain clay, core rings under hammer impact.

Weathered: Rock mass is decomposed 50% or less, significant portions of the rock show discoloration and weathering effects, cores cannot be broken by hand or scraped by knife.

Highly Weathered: Rock mass is more than 50% decomposed, complete discoloration of rock fabric, core may be extremely broken and gives clunk sound when struck by hammer, may be shaved with a knife.

SOIL CLASSIFICATION CHART

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

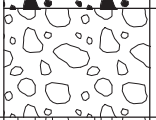
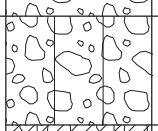
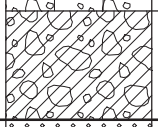
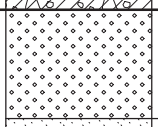
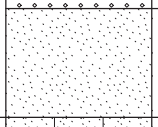
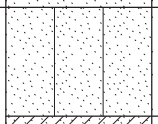
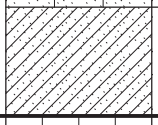
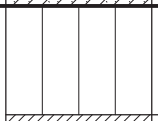
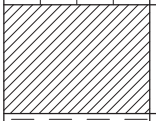
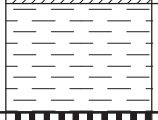
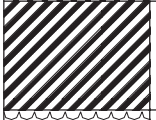
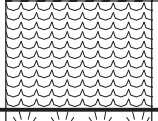
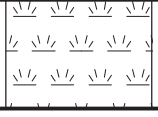
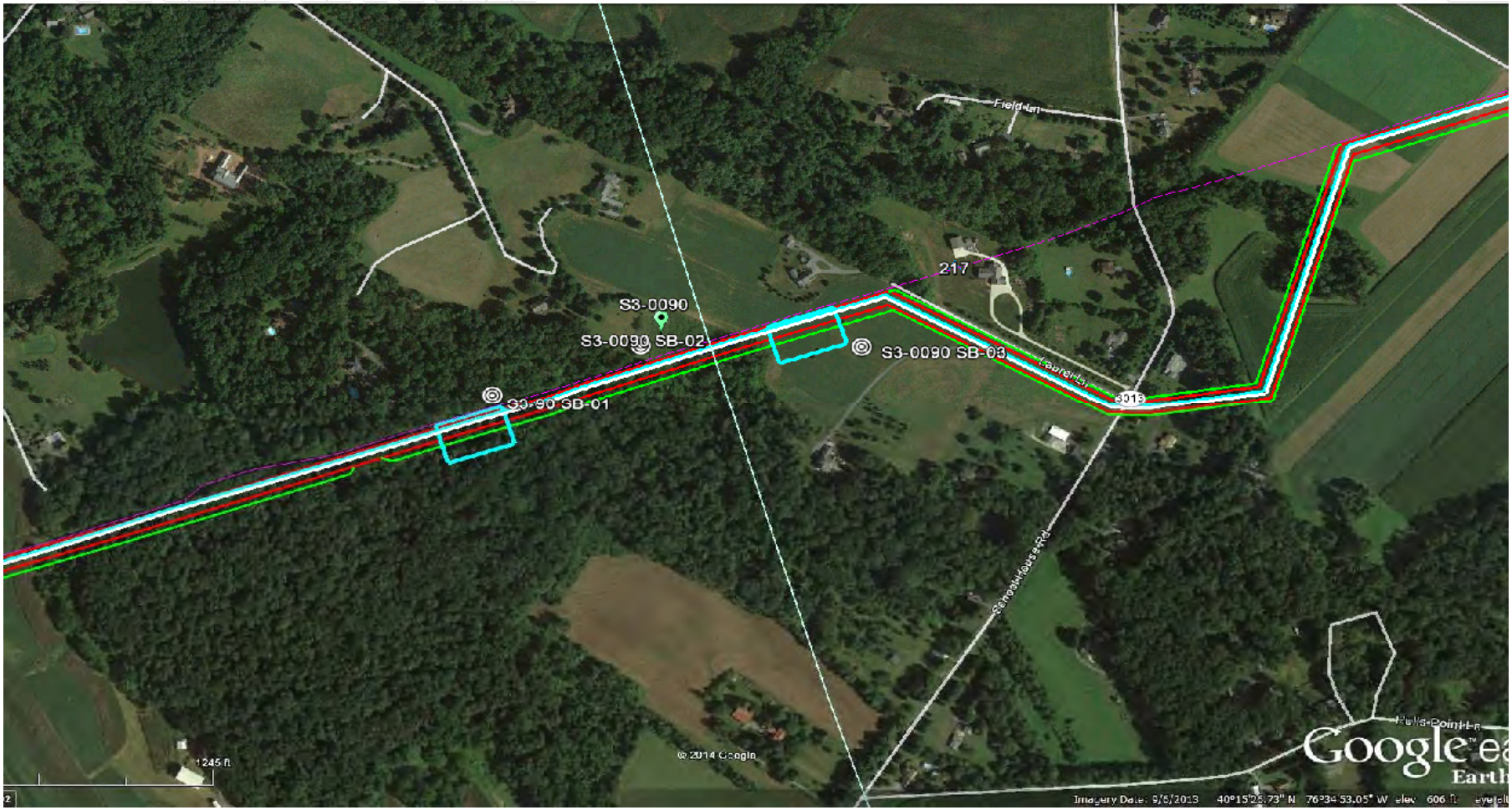
MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

Table 4–3 Hardness and unconfined compressive strength of rock materials

Hardness category	Typical range in unconfined compressive strength (MPa)	Strength value selected (MPa)	Field test on sample	Field test on outcrop
Soil*	< 0.60		Use USCS classifications	
Very soft rock or hard, soil-like material	0.60–1.25		Scratched with fingernail. Slight indentation by light blow of point of geologic pick. Requires power tools for excavation. Peels with pocket knife.	
Soft rock	1.25–5.0		Permits denting by moderate pressure of the fingers. Handheld specimen crumbles under firm blows with point of geologic pick.	Easily deformable with finger pressure.
Moderately soft rock	5.0–12.5		Shallow indentations (1–3 mm) by firm blows with point of geologic pick. Peels with difficulty with pocket knife. Resists denting by the fingers, but can be abraded and pierced to a shallow depth by a pencil point. Crumbles by rubbing with fingers.	Crumbles by rubbing with fingers.
Moderately hard rock	12.5–50		Cannot be scraped or peeled with pocket knife. Intact handheld specimen breaks with single blow of geologic hammer. Can be distinctly scratched with 20d common steel nail. Resists a pencil point, but can be scratched and cut with a knife blade.	Unfractured outcrop crumbles under light hammer blows.
Hard rock	50–100		Handheld specimen requires more than one hammer blow to break it. Can be faintly scratched with 20d common steel nail. Resistant to abrasion or cutting by a knife blade, but can be easily dented or broken by light blows of a hammer.	Outcrop withstands a few firm blows before breaking.
Very hard rock	100–250		Specimen breaks only by repeated, heavy blows with geologic hammer. Cannot be scratched with 20d common steel nail.	Outcrop withstands a few heavy ringing hammer blows but will yield large fragments.
Extremely hard rock	> 250		Specimen can only be chipped, not broken by repeated, heavy blows of geologic hammer.	Outcrop resists heavy ringing hammer blows and yields, with difficulty, only dust and small fragments.

Method used to determine consistency or hardness (check one):
Field assessment: _____ Uniaxial lab test: _____ Other: _____ Rebound hammer (ASTM D5873): _____
* See NEH631.03 for consistency and density of soil materials. For very stiff soil, SPT N values = 15 to 30. For very soft rock or hard, soil-like material, SPT N values exceed 30 blows per foot.



LEGEND:

Geotechnical Soil Boring (SB) Locations

TETRA TECH

GEOTECHNICAL BORING LOCATIONS
HDD S3-0090
LEBANON COUNTY, SOUTH LONDONDERRY TOWNSHIP &
DAUGHIN COUNTY, CONEWAGO TOWNSHIP, PA
SUNOCO PENNSYLVANIA PIPELINE PROJECT

TETRA TECH
240 Continental Drive, Suite 200
Newark, Delaware 19713
302.738.7551
fax: 302.454.5988

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT		Project No.: 103IP3406
Project Location:	95 LAUREL LANE, PALMYRA, PA		Page 1 of 1
HDD No.:	S3-0090	Dates(s) Drilled: 11-18-14	Inspector: E. WATT
Boring No.:	SB-01	Drilling Method: SPT - ASTM D1586	Driller: S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED	Total Depth (ft): 21.5
Boring Location Coordinates:		40° 15' 11.995" N	76° 35' 40.296" W

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.8			TOPSOIL (10")					
1	3.0	5.0	0.8	3.5	12	ML	REDDISH BROWN MICACEOUS SILT WITH A LITTLE FINE SAND.	4	11	18	45	**29**
			3.5				REDDISH BROWN FINE TO MEDIUM SAND AND SILT.					
2	8.0	8.7			9		REDDISH BROWN FINE SAND AND SILT WITH SOME UNWEATHERED	30	50/2"			**>50**
							SANDSTONE GRAVEL.					
3	13.0	13.8			7		REDDISH BROWN FINE SAND AND SILT WITH SOME UNWEATHERED	15	50/3"			**>50**
						SM	SANDSTONE GRAVEL.					
4	18.0	19.2			10		REDDISH BROWN FINE SAND AND SILT WITH SOME UNWEATHERED	17	50	50/2"		**>50**
							SANDSTONE GRAVEL.					
5	20.0	20.3			4		REDDISH BROWN FINE SAND AND SILT WITH SOME UNWEATHERED	50/4"				**>50**
				21.5			SANDSTONE GRAVEL.					
							AUGER GRINDING STARTING AT 12'.					
							AUGER REFUSAL AT 20'. OFFSET BORING AND CONTINUOUSLY					
							AUGERED TO REFUSAL AT 21.5'.					
							CAVED AND NO WATER AT 17', BOTTOM MUDDY.					
							PLACED CONCETE PLUG.					

Notes/Comments:
Pocket Pentrometer Testing

DR: DECOMPOSED ROCK

Strata (USCS) Designations are approximated based on visual review, except where indicated in Description of Materials.

* Number of blows of 140 lb. Hammer dropped 30 in. required to drive 2 in. split-spoon sampler in 6 in. increments.
N: Number of blows to drive spoon from 6" to 18" interval.

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Newark, Delaware 19713
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TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT		Project No.: 103IP3406
Project Location:	95 LAUREL LANE, PALMYRA, PA		Page 1 of 1
HDD No.:	S3-0090	Dates(s) Drilled: 11-18-14	Inspector: E. WATT
Boring No.:	SB-02	Drilling Method: SPT - ASTM D1586	Driller: S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): 20.0	Total Depth (ft): 32.5
Boring Location Coordinates:		40° 15' 13.887" N	76° 35' 34.446" W

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.3			TOPSOIL (3")					
1	3.0	5.0	0.3		16	SM	REDDISH BROWN FINE TO MEDIUM SAND WITH SOME SILT, WITH A	4	20	27	45	**47**
				6.5			LITTLE FINE TO COARSE SANDSTONE GRAVEL.					
2	8.0	10.0	6.5		22	CL	REDDISH BROWN MICACEOUS SILTY CLAY WITH A LITTLE FINE SAND, T	3	6	14	18	**20**
							TRACE FINE GRAVEL. (USCS: CL)					
3	13.0	15.0			24		MAROON MICACWOUS SILTY CLAYWITH SOME FINE SAND, TRACE	3	8	30	43	**38**
				16.5			FINE TO COARSE SANDSTONE GRAVEL.					
4	18.0	20.0	16.5		21	SC	MAROON FINE SAND (TRACE MICA) WITH A LITTLE SILTY CLAY,	5	11	23	40	**34**
				21.5			TRACE FINE SANDSTONE GRAVEL.					
5	23.0	24.4	21.5		15	CL	MARRON MICACEOUS SILTY CLAY WITH A LITTLE FINE SAND, WITH	3	7	50/5"		**>57**
				27.0			A LITTLE F-C SANDSTONE GRAVEL.					
6	28.0	28.5	27.0		5		PARTIALLY WEATHERED MAROON SANDSTONE.	50/6"				**>50**
7	31.0	31.6		32.5	6		PARTIALLY WEATHERED MAROON SANDSTONE.	12	50/2"			**>50**
							AUGER REFUSAL AT 31'. OFF-SET BORING AND CONTINUOUSLY					
							AUGERED TO REFUSAL AT 32.5'.					
							WET ON SPOON AT 20'.					
							WATER LEVEL THROUGH AUGERS AT 22'.					
							CAVED AT 27', WATER LEVEL ON CAVE AT 14'.					

Notes/Comments:

Pocket Pentrometer Testing
S2: > 4 TSF
S3: > 4 TSF

DR: DECOMPOSED ROCK

Strata (USCS) Designations are approximated based on visual review, except where indicated in Description of Materials.

* Number of blows of 140 lb. Hammer dropped 30 in. required to drive 2 in. split-spoon sampler in 6 in. increments.
N: Number of blows to drive spoon from 6" to 18" interval.

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TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT		Project No.: 103IP3406
Project Location:	95 LAUREL LANE, PALMYRA, PA		Page 1 of 1
HDD No.:	S3-0090	Dates(s) Drilled: 11-18-14	Inspector: E. WATT
Boring No.:	SB-03	Drilling Method: SPT - ASTM D1586	Driller: S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED	Total Depth (ft): 30.0
Boring Location Coordinates:		40° 15' 13.813" N	76° 35' 24.341" W

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.4			TOPSOIL (5")					
1	3.0	5.0	0.4		13	CL	REDDISH BROWN SILTY CLAY WITH A TRACE TO A LITTLE FINE SAND	1	6	9	10	**15**
				6.5			(USCS: CL).					
2	8.0	10.0	6.5		23	SC	MAROON FINE TO MEDIUM MICACEOUS SAND WITH SOME	2	18	26	20	**44**
							SILTY CLAY.					
3	13.0	15.0			18		MARRON FINE TO MEDIUM SAND WITH A LITTLE SILTY CLAY AND A	4	23	23	50/5"	**46**
							LITTLE FINE TO COARSE QUARTZ GRAVEL.					
4	18.0	20.0			24		MARRON FINE TO MEDIUM SAND WITH SOME SILTY CLAY AND A	4	21	35	50/6"	**56**
				21.5			LITTLE FINE TO COARSE SILT OR CLAYSTONE GRAVEL.					
5	23.0	24.4	21.5		11	CL	REDDISH BROWN WEATHERED CLAYSTONE (SILTY CLAY WITH SOME	10	27	50/5"		**>77**
				26.0			FINE SAND).					
6	28.0	28.3	26.0	30.0	4		REDDISH BROWN PARTIALLY WEATHERED SANDSTONE.	50/4"				**>50**
							CAVED AND DRY AT 28'.					

Notes/Comments:

Pocket Pentrometer Testing
S1: > 4 TSF

DR: DECOMPOSED ROCK

Strata (USCS) Designations are approximated based on visual review, except where indicated in Description of Materials.

* Number of blows of 140 lb. Hammer dropped 30 in. required to drive 2 in. split-spoon sampler in 6 in. increments.
N: Number of blows to drive spoon from 6" to 18" interval.

GEOTECHNICAL LABORATORY TESTING SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0090

HDD No.	Test Boring No.	Sample No.	Depth of Sample (ft.) From	Depth of Sample (ft.) To	Water Content, % (ASTM D2216)	Percent Silts/Clays, % (ASTM D1140)	Atterburg Limits (ASTM D4318) Liquid Limit, %	Atterburg Limits (ASTM D4318) Plastic Limit, %	Atterburg Limits (ASTM D4318) Plasticity Index, %	USCS Classif. (ASTM D2487)
S3-0090	SB-01	1	3.0	5.0	6.4	41.2	-	-	-	-
		2	8.0	8.7	3.6	39.2	-	-	-	-
		4	18.0	19.2	5.7	39.8	-	-	-	-
		5	20.0	20.3	6.3	41.9	-	-	-	-
	SB-02	1	3.0	5.0	9.2	21.9	-	-	-	-
		2	8.0	10.0	10.4	80.8	30	19	11	CL
		3	13.0	15.0	12.5	75.1	-	-	-	-
		4	18.0	20.0	14.2	16.3	-	-	-	-
		5	23.0	24.4	10.5	90.7	-	-	-	-
		6	28.0	28.5	5.7	21.4	-	-	-	-
	SB-03	1	3.0	5.0	14.2	99.2	32	19	13	CL
		2	8.0	10.0	9.2	21.1	-	-	-	-
		4	18.0	20.0	13.7	38.8	-	-	-	-
		5	23.0	24.4	9.6	75.3	-	-	-	-

Notes:

1) Sample depths based on feet below grade at time of exploration.

REGIONAL GEOLOGY SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0090

HDD No.	NAME	BORING NO.	REGIONAL GEOLOGY DESCRIPTION	GENERAL TOPOGRAPHIC SETTING	BEDROCK FORMATION	GENERAL ROCK TYPE	APPROX MAX FM THICKNESS (FT)	DEPTH TO ROCK (Ft bgs) based on nearby well drilling logs	NOTES / COMMENTS
S3-0090	Wetland J47	SB-01	**Gettysburg Fm** - reddish-brown to maroon silty mudstone and shale and soft, red-brown, medium- to fine-grained sandstone, with minor amounts of yellowish-brown shale and sandstone and thin beds of impure limestone.	Gently sloping lowland to forested wetlands	Gettysburg Fm	Silty mudstone-shale-sandstone w/ some impure limestone		12-22	
		SB-02							
		SB-03							

Note : Source of well log data - http://www.dcnr.state.pa.us/topogeo/groundwater/pagwis/records/index.htm. All other sources as referenced in comments section.

FIELD DESCRIPTION AND LOGGING SYSTEM FOR SOIL EXPLORATION

GRANULAR SOILS

(Sand, Gravel & Combinations)

Density	***N (blows)****
Very Loose	5 or less
Loose	6 to 10
Medium Dense	11 to 30
Dense	31to 50
Very Dense	51 or more

Relative Proportions

Description Term	*Percent*
Trace	1 - 10
Little	11 - 20
Some	21 - 35
And	36 - 50

Particle Size Identification

Boulders	8 in. diameter or more	
Cobbles	3 to 8 in. diameter	
Gravel	Coarse (C)	3 in. to ¾ in. sieve
	Fine (F)	¾ in. to No. 4 sieve
Sand	Coarse (C)	No. 4 to No. 10 sieve (4.75mm-2.00mm)
	Medium (M)	No. 10 to No. 40 sieve (2.00mm – 0.425mm)
	Fine (F)	No. 40 to No. 200 sieve (0.425 – 0.074mm)
Silt/Clay	Less Than a No. 200 sieve (<0.074mm)	

COHESIVE SOILS

(Silt, Clay & Combinations)

Consistency	***N (blows)****
Very Soft	3 or less
Soft	4 to 5
Medium Stiff	6 to 10
Stiff	11 to 15
Very Stiff	16 to 30
Hard	31 or more

Plasticity

Degree of Plasticity	*Plasticity Index*
None to Slight	0 - 4
Slight	5 - 7
Medium	8- 22
High to Very High	> 22

ROCK

(Rock Cores)

Rock Quality Designation (RQD), %	***Rock Quality Description***
0-25	Very Poor
25-50	Poor
50-75	Fair
75-90	Good
90-100	Excellent

N - Standard Penetration Resistance. Driving a 2.0" O.D., 1-3/8" I.D. sampler a distance of 18 inches into undisturbed soil with a 140 pound hammer free falling a distance of 30.0 inches. The number of hammer blows to drive the sampler through each 6 inch interval is recorded; the number of blows required to drive the sampler through the final 12 inch interval is termed the Standard Penetration Resistance (SPR) N-value. For example, blow counts of 6/8/9 (through three 6-inch intervals) results in an SPR N-value of 17 (8+9).

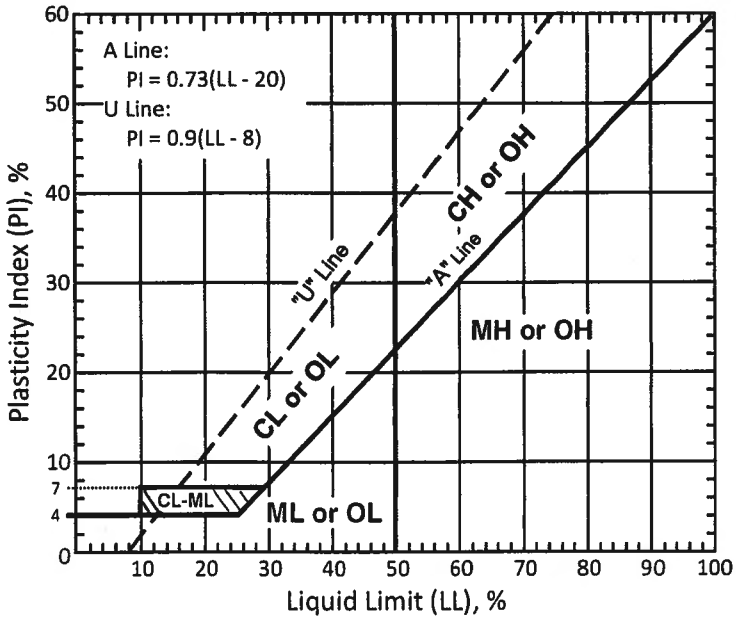
Groundwater observations were made at the times indicated. Groundwater elevations fluctuate throughout a given year, depending on actual field porosity and variations in seasonal and annual precipitation.

UNIFIED SOIL CLASSIFICATION SYSTEM [Casagrande (1948)]

Major Divisions			Group Symbols	Typical Descriptions	Laboratory Classifications		
Coarse Grained Soils (More than half of material is larger than No. 200 sieve)	Gravels More than half of coarse fraction is larger than No. 4 sieve	Clean gravel (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine Percentage of sand and gravel from grain size curve. Depending on Percentage of fines (fraction smaller than No. 200 sieve), coarse-grained soils are classified as follows: Less than 5 percent GW, GP, SW, SP; More than 12 percent GM, GC, SM, SC; 5 to 12 percent Borderline cases requiring dual symbols[1]	$C_u=\frac{D_{60}}{D_{10}}$ greater than 4: $C_c=\frac{(D_{30})2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting C_u or C_c requirements for GW	
		Gravel with fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below A Line or I_p less than 4	Limits plotting in hatched zone with I_p between 4 and 7 are borderline cases requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures		Atterberg limits above A line with I_p greater than 7	
	Sands (More than half of coarse fraction is smaller than No. 4 Sieve)	Clean sands (Little or no fines)	SW	Well graded sands, gravely sands, little or no fines		$C_u=\frac{D_{60}}{D_{10}}$ greater than 6: $C_c=\frac{(D_{30})2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	Poorly graded sands, gravelly sands, little or no fines		Not meeting C_u or C_c requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures		Atterberg limits below A Line or I_p less than 4	Limits Plotting in hatched zone with I_p between 4 and 7 are borderline cases requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures		Atterberg limits above A line with I_p greater than 7	

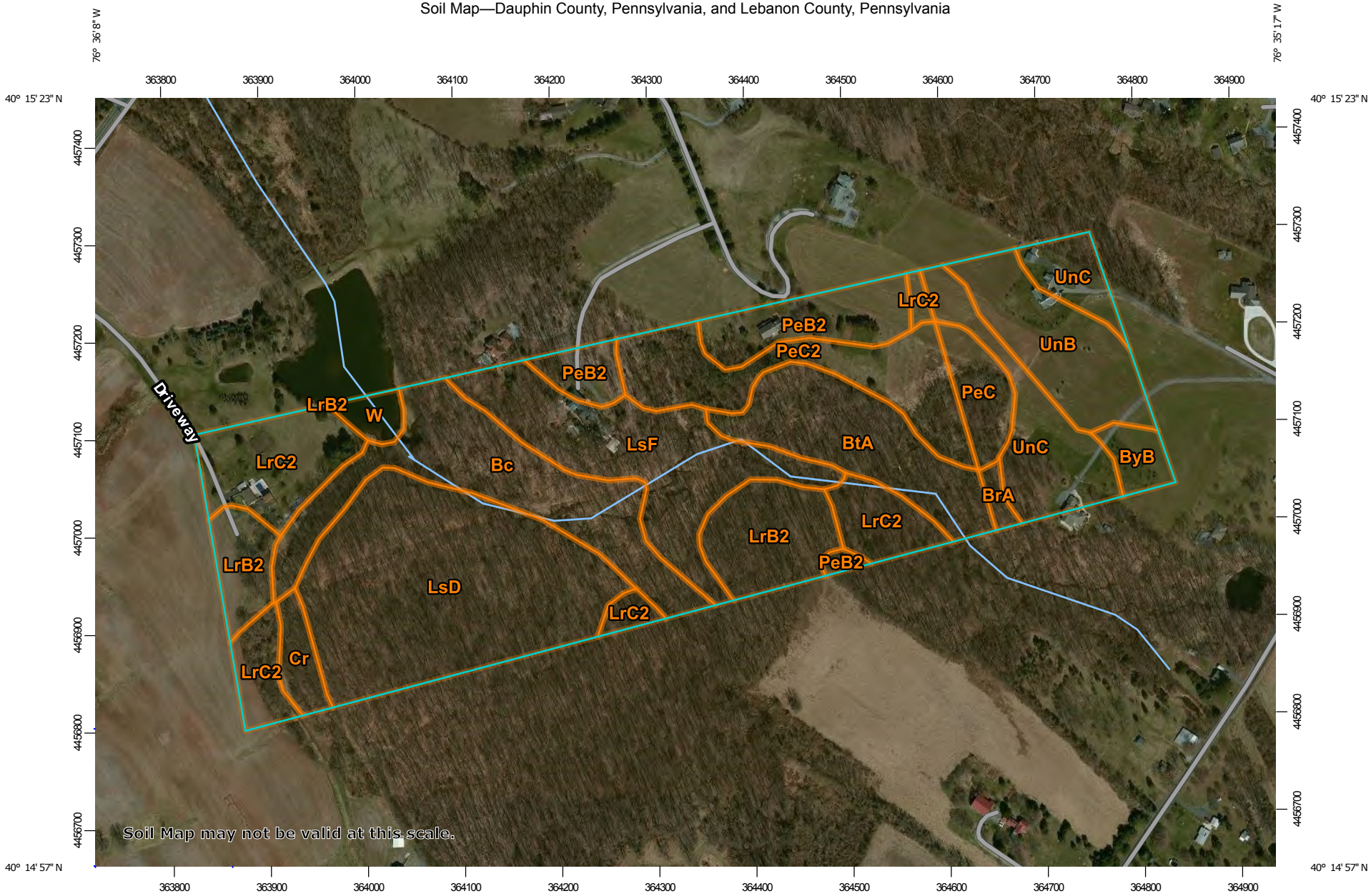
Major Divisions		Group Symbols	Typical Descriptions
Fine-grained soils (More than half of material is smaller than No. 200 sieve)	Silts and clays (Liquid limit less than 50)	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays , sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
	Silts and Clays (Liquid limit greater than 50)	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
	Highly organic soils	Pt	Peat and other highly organic soils

For soils plotting nearly on A line use dual symbols i.e ., I_p = 29.5, w_L=60 gives CH-MH. When w_L is near 50 use CL-CH or ML-MH. Take near as ± 2 percent.



(1) Borderline classifications, used for soils possessing characteristics of two groups, are designated by combinations of group symbols. For example: GW-GC. well-graded gravel-sand mixture with clay binder.

ATTACHMENT 2
SOIL RESOURCES MAP AND PROFILE DESCRIPTIONS



Map Scale: 1:5,560 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 50 100 200 300

Feet: 0 250 500 1000 1500

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 18N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at scales ranging from 1:15,800 to 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Dauphin County, Pennsylvania
Survey Area Data: Version 10, Sep 19, 2016

Soil Survey Area: Lebanon County, Pennsylvania
Survey Area Data: Version 11, Sep 19, 2016

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 29, 2011—Apr 14, 2011

MAP LEGEND

MAP INFORMATION

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

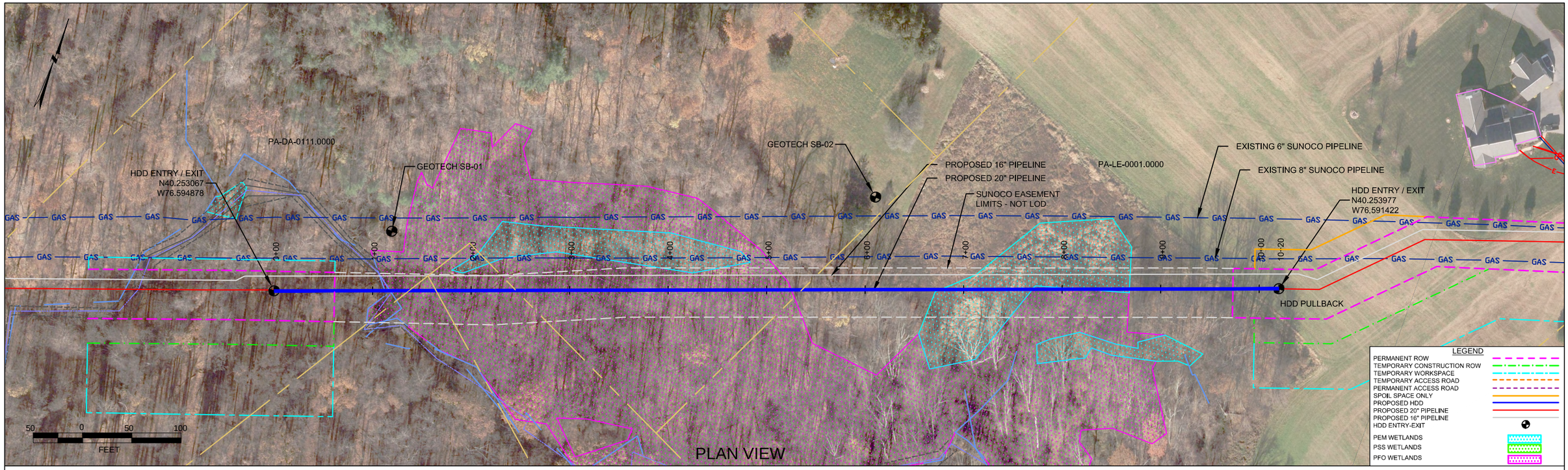
Dauphin County, Pennsylvania (PA043)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
Bc	Basher silt loam	7.5	10.9%
BtA	Brinkerton and Armagh silt loams, 0 to 3 percent slopes	5.4	7.7%
Cr	Croton silt loam, occasionally ponded, 0 to 3 percent slopes	1.1	1.5%
LrB2	Lewisberry gravelly sandy loam, 3 to 8 percent slopes, moderately eroded	4.9	7.1%
LrC2	Lewisberry gravelly sandy loam, 8 to 15 percent slopes, moderately eroded	7.3	10.5%
LsD	Lewisberry very stony sandy loam, 5 to 25 percent slopes	13.2	18.9%
LsF	Lewisberry very stony sandy loam, 25 to 60 percent slopes	7.4	10.7%
PeB2	Penn channery silt loam, 3 to 8 percent slopes	4.1	5.9%
PeC2	Penn channery silt loam, 8 to 15 percent slopes	5.4	7.7%
W	Water	0.7	1.0%
Subtotals for Soil Survey Area		**56.9**	**81.9%**
Totals for Area of Interest		**69.5**	**100.0%**

Lebanon County, Pennsylvania (PA075)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
BrA	Brinkerton silt loam, 0 to 3 percent slopes	0.4	0.5%
ByB	Bucks silt loam, 3 to 8 percent slopes	1.0	1.4%
PeC	Penn channery silt loam, 8 to 15 percent slopes	1.7	2.4%
UnB	Ungers loam, 3 to 8 percent slopes	4.4	6.4%
UnC	Ungers loam, 8 to 15 percent slopes	5.2	7.5%
Subtotals for Soil Survey Area		**12.6**	**18.1%**
Totals for Area of Interest		**69.5**	**100.0%**

WETLAND J-47 CROSSING
PADEP SECTION 105 PERMIT NO.S:
PA-LE-0001.0000-SR & PA-LE-0001.0000-SR-16
(SPLP HDD No. S3-0090)

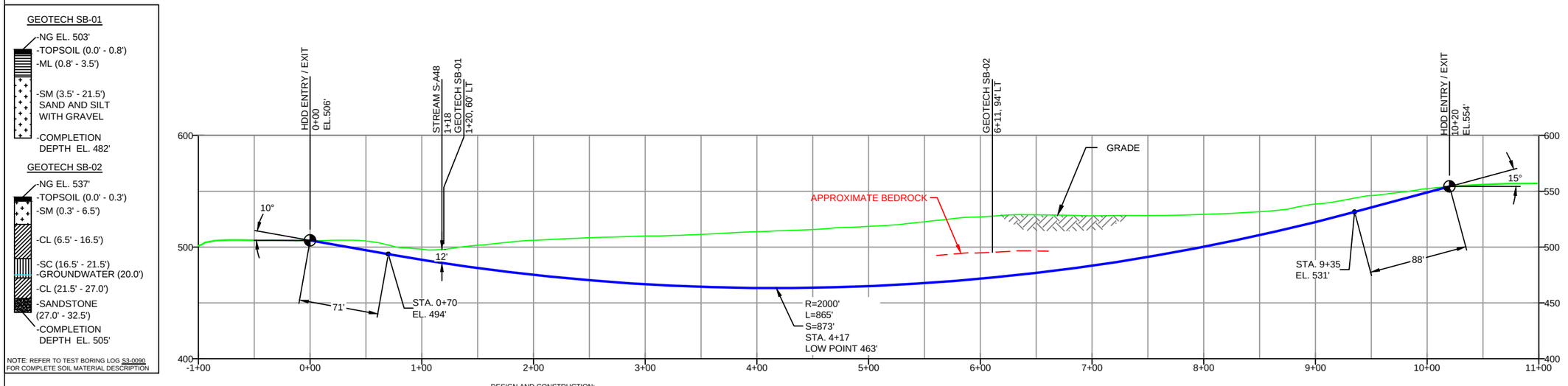
ATTACHMENT 2

ORIGINAL AND REVISED HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES



LEBANON COUNTY, PENNSYLVANIA - CONEWAGO TOWNSHIP
S3-0090

PROFILE VIEW



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXITING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):1020'
   HDD PIPE LENGTH (S=):1032'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

Figure 1. Original 20-Inch HDD Plan and Profile

NOTES

1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
2. STATIONING IS BASED ON HORIZONTAL DISTANCES.
3. ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP ARE NOT RESPONSIBLE FOR LOCATION OF FOREIGN UTILITIES SHOWN IN PLOT PLAN OR PROFILE. THE INFORMATION SHOWN HEREON IS FURNISHED WITHOUT LIABILITY ON THE PART OF ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP, FOR ANY DAMAGES RESULTING FROM ERRORS OR OMISSIONS THEREIN.
4. CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.
5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
2	REVISED PER ENGINEERING COMMENTS	MRS	08/19/16	RMB	08/19/16	AAW	08/19/16
1	REVISED PER COMMENTS FROM REI REVIEW	MRS	02/26/16	RMB	02/26/16	AAW	02/26/16
0	ISSUED FOR CONSTRUCTION	MRS	01/21/16	RMB	01/21/16	AAW	01/21/16

Sunoco Logistics Partners L.P.

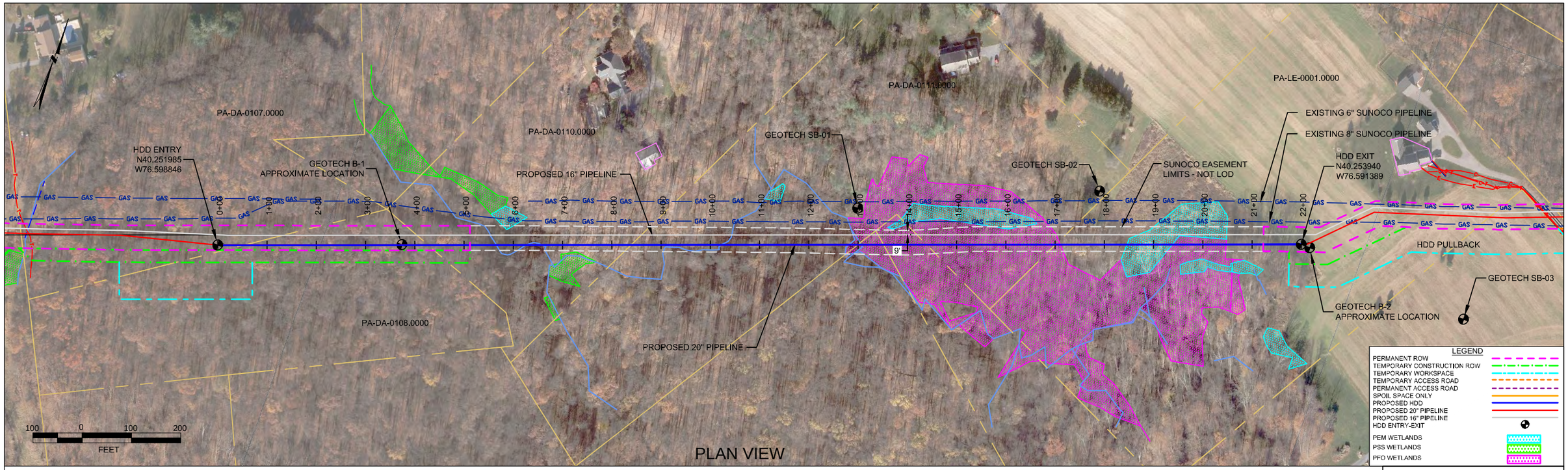
TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
WETLAND
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=100'

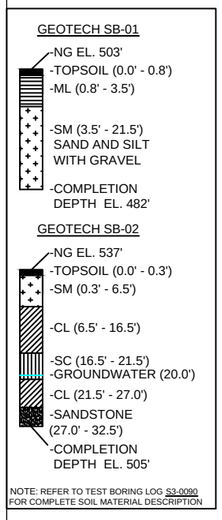
DWG. NUMBER: PA-LE-0001.0000-SR



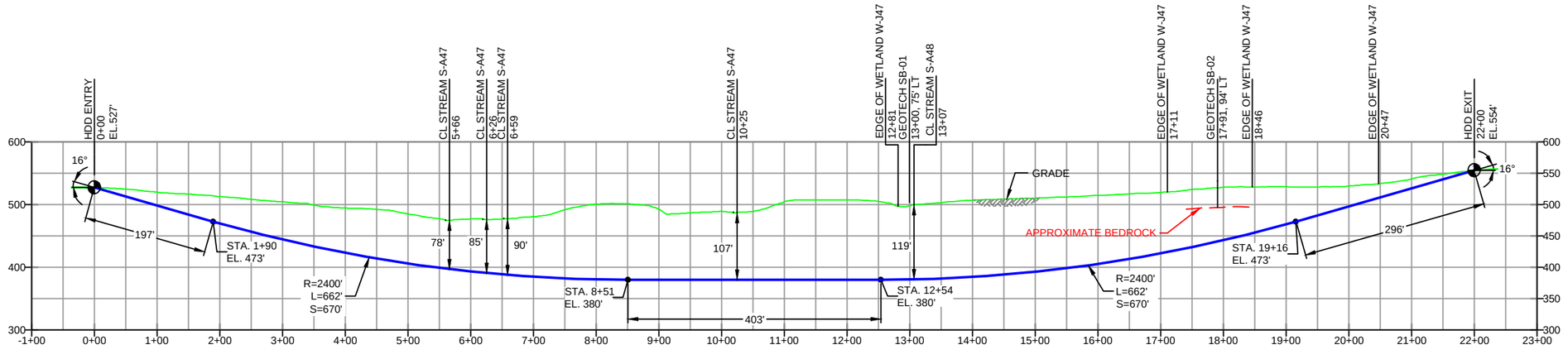
PLAN VIEW

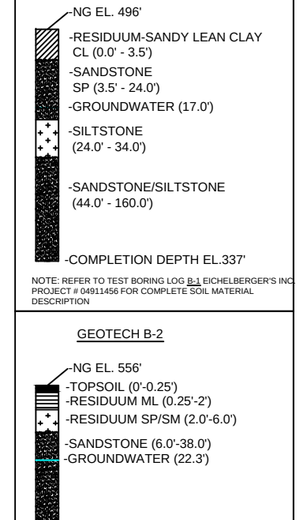
PROFILE VIEW

LEBANON COUNTY, PENNSYLVANIA - CONEWAGO TOWNSHIP
S3-0090



NOTE: REFER TO TEST BORING LOG S3-0090 FOR COMPLETE SOIL MATERIAL DESCRIPTION





NOTE: REFER TO TEST BORING LOG B-1 EICHELBERGER'S INC. PROJECT # 04911456 FOR COMPLETE SOIL MATERIAL DESCRIPTION

NOTE: REFER TO TEST BORING LOG B-2 EICHELBERGER'S INC. PROJECT # 04911456 FOR COMPLETE SOIL MATERIAL DESCRIPTION

DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=): 2200'
   HDD PIPE LENGTH (S=): 2236'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

Figure 2. Revised 20-Inch HDD Plan and Profile

NOTES

1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
2. STATIONING IS BASED ON HORIZONTAL DISTANCES.
3. ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP ARE NOT RESPONSIBLE FOR LOCATION OF FOREIGN UTILITIES SHOWN IN PLOT PLAN OR PROFILE. THE INFORMATION SHOWN HEREON IS FURNISHED WITHOUT LIABILITY ON THE PART OF ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP, FOR ANY DAMAGES RESULTING FROM ERRORS OR OMISSIONS THEREIN.
4. CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.
5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-4.38	TO	ES-5.01	EROSION & SEDIMENT PLAN
SHEET 24	TO	SHEET 1	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	DESIGN CHANGE - EXTENDED DRILL PER LANEY DRILLING AND CM SPREAD 5 APPROVAL	MRS	09/25/17	RMB	09/25/17	AMC	09/25/17
EP2	REVISED PER PADEP COMMENTS RECEIVED 09/06/16	DLM	09/30/16	RMB	09/30/16	AAW	09/30/16
EP1	REVISED PER PADEP COMMENTS	DLM	05/10/16	RMB	05/10/16	AAW	05/10/16
EP		MRS	03/15/16	RMB	03/15/16	AAW	03/15/16
C	ADDED GEOTECH INFO / DESIGN ADJUSTMENT	MRS	09/22/16	RMB	09/22/16	AAW	09/22/16
B	ISSUED FOR BID	DLM	07/31/15	RMB	07/31/15	AAW	07/31/15

Sunoco Logistics Partners L.P.

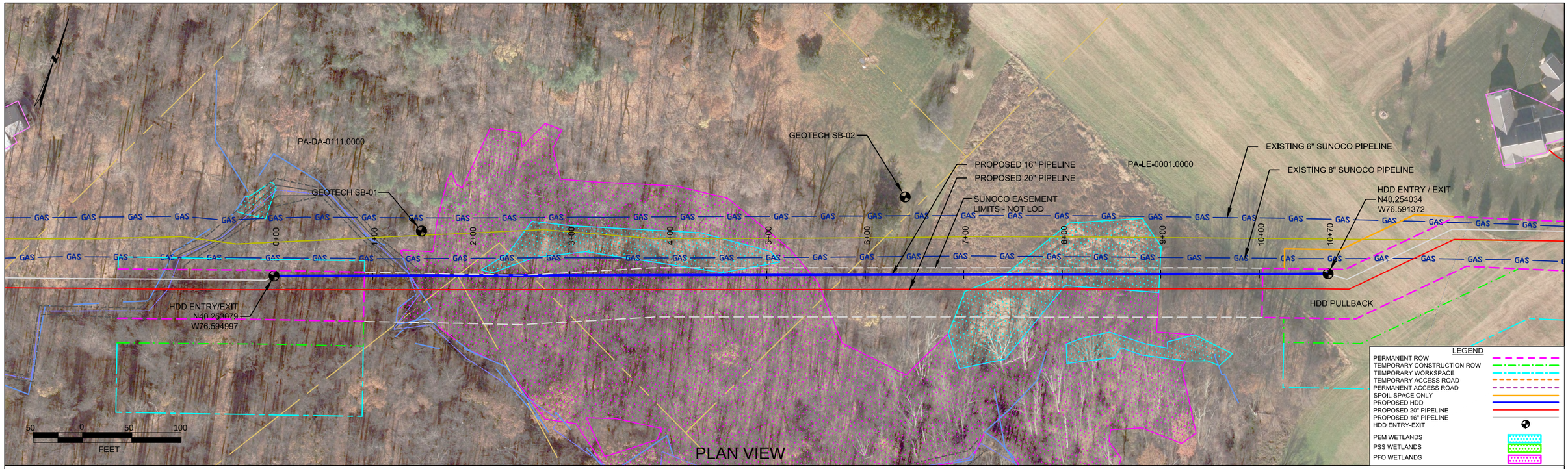
TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
WETLAND
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200'

DWG. NUMBER: PA-LE-0001.0000-SR



PLAN VIEW

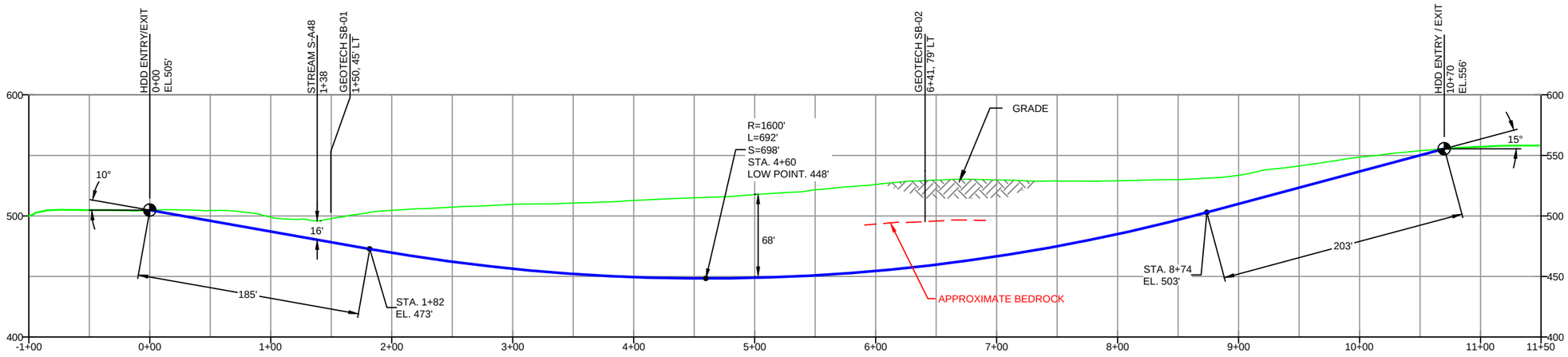
LEBANON COUNTY, PENNSYLVANIA - CONEWAGO TOWNSHIP
S3-0090-16

PROFILE VIEW

GEOTECH SB-01
-NG EL. 503'
-TOPSOIL (0.0' - 0.8')
-ML (0.8' - 3.5')
-SM (3.5' - 21.5') SAND AND SILT WITH GRAVEL
-COMPLETION DEPTH EL. 482'

GEOTECH SB-02
-NG EL. 537'
-TOPSOIL (0.0' - 0.3')
-SM (0.3' - 6.5')
-CL (6.5' - 16.5')
-SC (16.5' - 21.5')
-GROUNDWATER (20.0')
-CL (21.5' - 27.0')
-SANDSTONE (27.0' - 32.5')
-COMPLETION DEPTH EL. 505'

NOTE: REFER TO TEST BORING LOG S3-0090 FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:
1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXITING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):1070'
   HDD PIPE LENGTH (S=):1083'
   16" x 0.438" W.T., X-70, APISL, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

Figure 3. Original 16-Inch HDD Plan and Profile

NOTES
1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
2. STATIONING IS BASED ON HORIZONTAL DISTANCES.
3. ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP ARE NOT RESPONSIBLE FOR LOCATION OF FOREIGN UTILITIES SHOWN IN PLOT PLAN OR PROFILE. THE INFORMATION SHOWN HEREON IS FURNISHED WITHOUT LIABILITY ON THE PART OF ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP, FOR ANY DAMAGES RESULTING FROM ERRORS OR OMISSIONS THEREIN.
4. CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.
5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
2	REVISED PER ENGINEERING COMMENTS	MRS	08/19/16	RMB	08/19/16	AAW	08/19/16
1	REVISED PER COMMENTS FROM REI REVIEW	MRS	02/26/16	RMB	02/26/16	AAW	02/26/16
0	ISSUED FOR CONSTRUCTION	MRS	01/21/16	RMB	01/21/16	AAW	01/21/16

Sunoco Logistics Partners L.P.

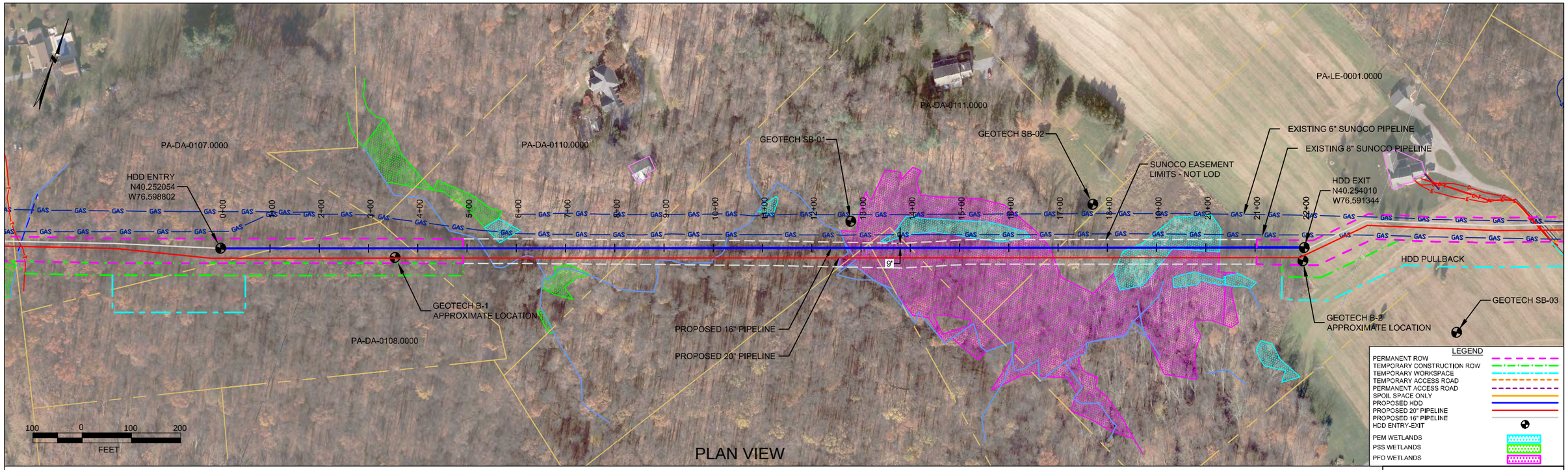
TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
WETLAND
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=100'

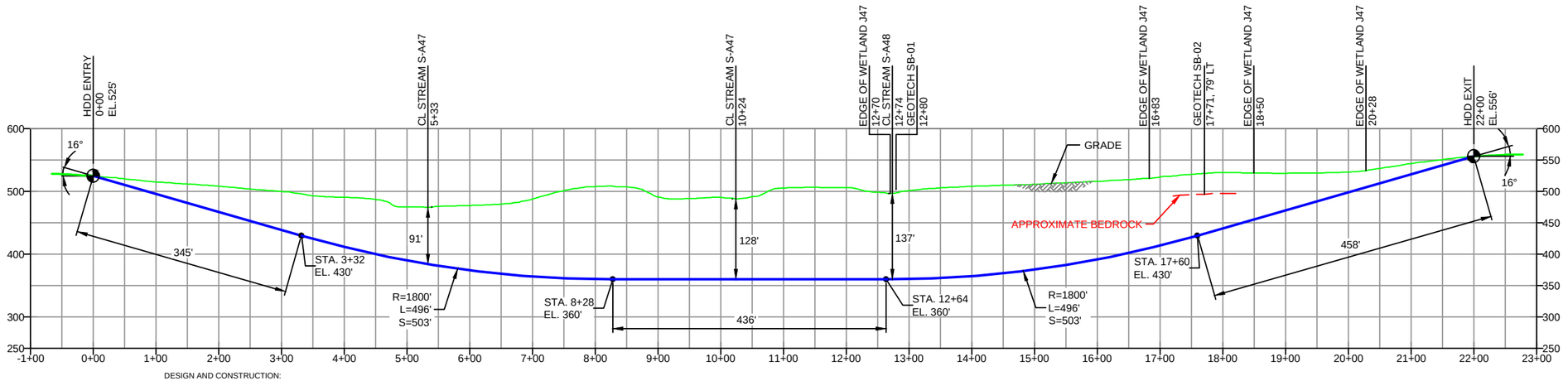
DWG. NO: PA-LE-0001.0000-SR-16



PLAN VIEW

PROFILE VIEW

LEBANON COUNTY, PENNSYLVANIA - CONEWAGO TOWNSHIP
S3-0090-16



GEOTECH SB-01

GEOTECH SB-02

NOTE: REFER TO TEST BORING LOG S3-0090 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B-1

NOTE: REFER TO TEST BORING LOG B-1 EICHELBERGER'S INC. PROJECT # 04911456 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B-2

NOTE: REFER TO TEST BORING LOG B-2 EICHELBERGER'S INC. PROJECT # 04911456 FOR COMPLETE SOIL MATERIAL DESCRIPTION

DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=): 2200'
   HDD PIPE LENGTH (S=): 2245'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

Figure 4. Revised 16-Inch Plan and Profile

NOTES

1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
2. STATIONING IS BASED ON HORIZONTAL DISTANCES.
3. ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP ARE NOT RESPONSIBLE FOR LOCATION OF FOREIGN UTILITIES SHOWN IN PLOT PLAN OR PROFILE. THE INFORMATION SHOWN HEREON IS FURNISHED WITHOUT LIABILITY ON THE PART OF ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP, FOR ANY DAMAGES RESULTING FROM ERRORS OR OMISSIONS THEREIN.
4. CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.
5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REF. DRAWING

ES-4.38	TO	ES-5.01	EROSION & SEDIMENT PLAN	
SHEET 24	TO	SHEET 1	AERIAL SITE PLAN	
DWG NO		DWG NO	DESCRIPTION	

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	DESIGN CHANGE - EXTENDED DRILL PER LANEY DRILLING AND CM SPREAD 5 APPROVAL	MRS	09/25/17	RMB	09/25/17	AMC	09/25/17
EP2	REVISED PER PADEP COMMENTS RECEIVED 09/06/16	MRS	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	DLM	05/17/16	RMB	05/17/16	AAW	05/17/16
EP		MRS	03/05/16	RMB	03/05/16	AAW	03/05/16
B	ADDED GEOTECH INFO	MRS	09/22/15	RMB	09/22/15	AAW	09/22/15
A	ISSUED FOR BID	MRS	08/31/15	RMB	08/31/15	AAW	08/31/15

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
WETLAND
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200'

DWG. NO: PA-LE-0001.0000-SR-16

WETLAND J-47 CROSSING
PADEP SECTION 105 PERMIT NO.S:
PA-LE-0001.0000-SR & PA-LE-0001.0000-SR-16
(SPLP HDD No. S3-0090)

ATTACHMENT 3

ANNULAR PRESSURE AND FRACTURE PRESSURE CALCULATIONS

HORIZONTAL DIRECTIONAL CONCEPTUAL DRILL DESIGN

PROJECT: Sunoco Pipeline, L.P.
Mariner East Pipeline
Lebanon County, Pennsylvania

CROSSING: **WETLAND J47 - West to East R1**
20-INCH STEEL PIPE

ISSUE: **APC/FPC DESIGN**

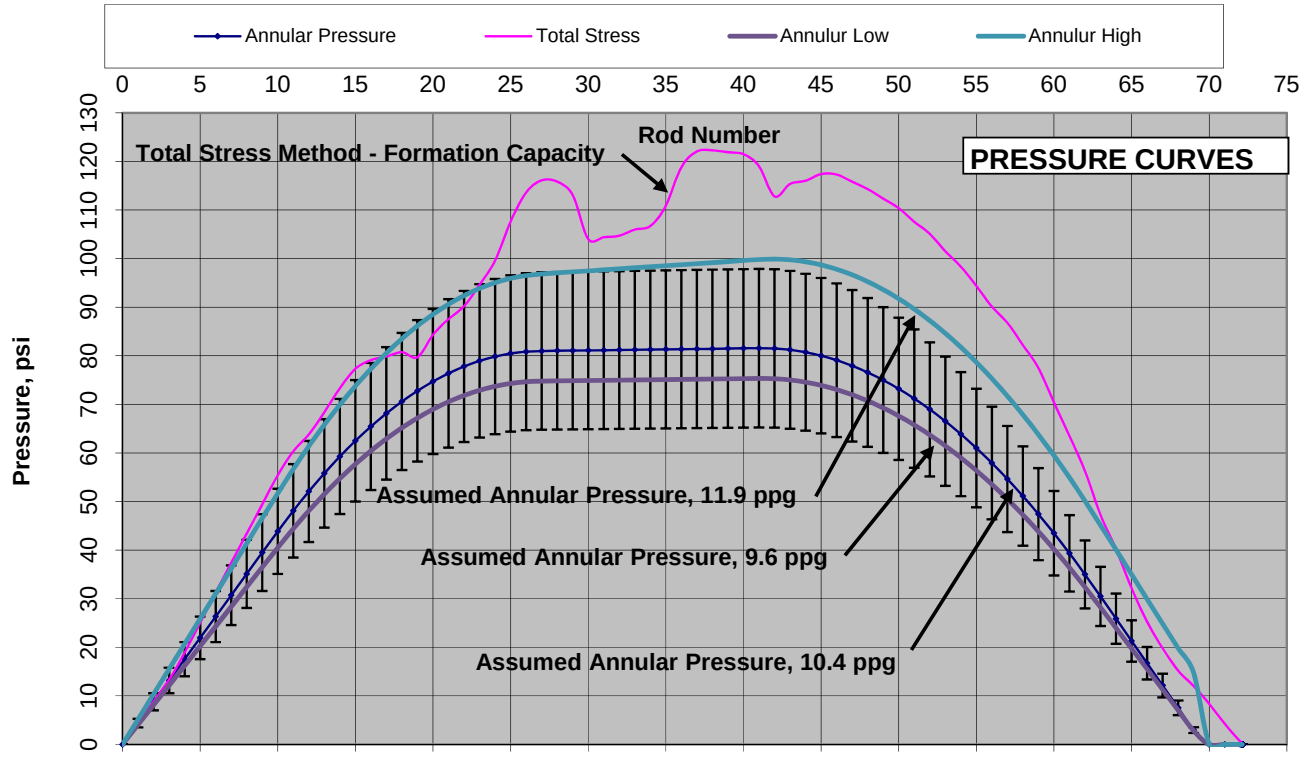
Contents:

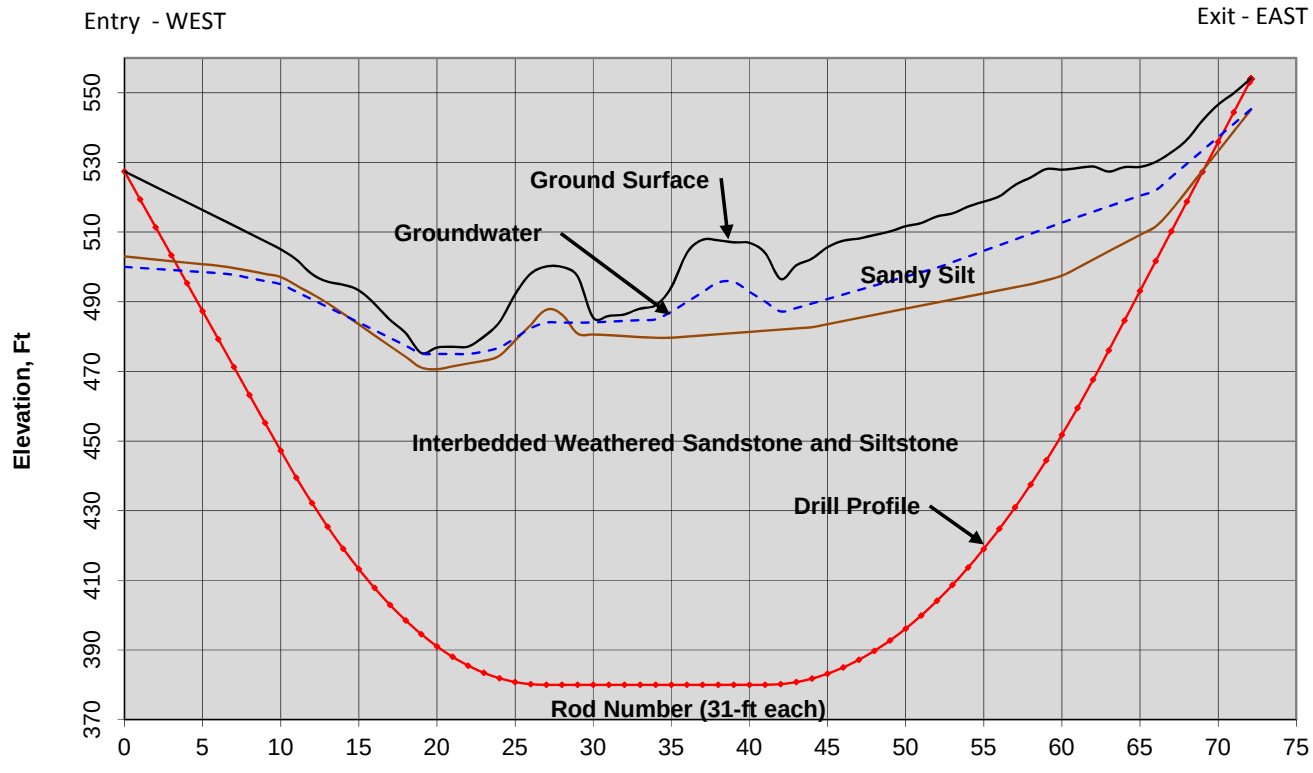
Prepared For: Sunoco Logistics Partners L.P.
525 Fritztown Road
Sinking Spring, PA 19608
855-430-4491

Prepared By: Directional Project Support
33311 Lois Lane, Suite A
Magnolia, Texas 77354
281.259.7819 (O) 617.510.8090 (C)
B. Dorwart

Project No: 0
Print Date: 22-Sep-2017

Revision	ID	DESCRIPTION	BY
9/21/2017	0	APC/FPC Design	BCD
9/22/2017	1	Moved entry 300 feet back, chg angle & radius	bcd





Notes:

1. Geology is interpreted from project data
2. APC pressure basis:

12.31 in	Pilot Hole Diameter
78.0 pcf	Assumed Fluid Weight
300 gal/min	Assumed Pump Rate
6.63 in	Drill Rod Diameter

3. Rod length: 31 Ft per rod
4. The error bars are at 20% for APC curve

ISSUED FOR: APC/FPC DESIGN

Directional Project Support
33311 Lois Lane, Suite A
Magnolia, Texas 77354

Sunoco Pipeline, L.P.
Mariner East Pipeline
Lebanon County, Pennsylvania

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
WETLAND J47 - West to East R1

Revision 1

FIGURE 1

PATH DESIGN CALCULATIONS

Entry Station	**0+00.00**	FT
Exit Station	**21+99.25**	FT

Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)

	East	North	Elevation
Entry	2289803.5501	336743.7681	527.40 ft
Horizontal Curve PI	2290837.9745	337116.7845	
Exit	2291872.3990	337489.8010	554.00 ft
Depth to Mudline	42.40 ft	Clearance Depth =	105.00 ft
Measured Plan Length at ties =	2199.2501 ft		
Coordinate Length =	2199.2501 ft		
	OK-HORIZONTAL CURVE		

Water Surface Elev.	485.30 ft
Mudline Elev.	485.00 ft
Lowest centerline Elev.	380.00 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	2289803.5501	336743.7681	10+99.63	2290837.9745	337116.7845	E 019.82945 N	1099.63		
Curve	10+99.63	2290837.9745	337116.7845	10+99.63	2290837.9745	337116.7845	E 019.82945 N	0.00	0.00	0.000 deg.
Tangent	10+99.63	2290837.9745	337116.7845	21+99.25	2291872.3990	337489.8010	E 019.82945 N	1099.63		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	1099.63	Input Radius, ft.	0.00	Plan Length, ft.	1099.63	
Entry Azimuth, deg.[5]	E 019.82945 N	Curve, deg	0.000 deg.	Exit Azimuth, deg.[5]	E 019.82945 N	
Entry Azimuth, rad.[5]	0.34609	Curve, rad	0.00000	Exit Azimuth, rad.[5]	0.34609	
		Calculate PTH		**Calculate Exit**		
Calculate PCH		Chord Length, ft.	0.00	Easting	2291872.3990	***Check***
PCH Easting	2290837.9745	Arc Length, ft.	0.00	Northing	337489.8010	***Delta***
PCH Northing	337116.7845	Chord Azimuth, deg	19.8295			**0.0000**
		PI Easting =	2291452.2366			**0.0000**
		PI Northing =	337338.2892			**OK CALC**
		PTH Easting =	2290837.9745			
		PTH Northing =	337116.7845			**Exit Station**
						21+99.25
Cum Plan Length	1099.63	Cum Plan Length	1099.63	Cum Plan Length	2199.250096	**OK STA**

Pull Geometry

Pipe Entry **EXIT** **Enter the pipe entry location into the hole: Entry/Exit**

	Elevations		Vertical Angle, (-) = Clockwise			Path	Curve
Segment	**Start**	**End**	**Start**	**End**	**Δ Angle**	**Length**	**Radius**
Entry Tangent	554.00 ft	472.97 ft	16.00 deg	16.00 deg	0.00 deg	293.97 ft	0.00 ft
Entry Curve	472.97 ft	380.00 ft	16.00 deg	0.00 deg	-16.00 deg	670.21 ft	2400.00 ft
Bottom Tangent	380.00 ft	380.00 ft	0.00 deg	0.00 deg	0.00 deg	441.73 ft	0.00 ft
Exit Curve	380.00 ft	448.15 ft	0.00 deg	-15.00 deg	-15.00 deg	523.60 ft	2000.00 ft
Exit Tangent	448.15 ft	527.40 ft	-15.00 deg	-15.00 deg	0.00 deg	306.20 ft	0.00 ft
					Total Check =	**2235.71 ft**	**OK**

Compound Curve Assessment

	Vert. Plan	Horiz. Plan	
Entry	813.41	1099.63	No, Horiz > Entry V(Tan+Curve)
Exit	944.11	1099.63	No, Horiz > Entry V(Tan+Curve)

VERTICLE PATH DESIGN CALCULATIONS (FT)

Entry Tangent Segment 1		*Entry Vert. Curve Segment 2*		*Middle Tangent Segment 3*		*Exit Vert. Curve Segment 4*		*Exit Tangent Segment 5*	
Entry Angle	-15.000 deg.	Vertical Radius	2000.00	Rod Length	441.73270	Radius	2400.00	Exit Elevation	554.00
Entry Angle, rad.	-0.2618 rad	Vert. Curve, deg.	15.000 deg.	Inclined Bottom Tan	NO	Design Exit Angle	16.000 deg.		
Rod/Path Length	306.20	Vert. Curve, rad.	0.2618 rad			Vert. Curve, rad.	0.2793 rad		
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**	
Plan Length	295.77	Plan Length	517.64	Plan Length	441.7326957	Vert. Curve, deg	16.000 deg.	Plan Length	282.58
Path Length	306.20	Arc Path Length	523.60	Path Length	441.73	Vert. Curve, rad.	0.27925268	Path Length	293.97
Tangent Depth	-79.25	Curve Vert Depth	-68.15	End Elevation	380.00	Plan Length	661.53	Elevation	554.00
End Elevation	448.15	End Elevation	380.00	Rise/drop	0.00	Path Arc Length	670.21	Rise/drop	81.03
		Lowest Elevation	380.00			Lowest Elevation	380.00		
		End Vert Angle	0.000 deg.	End Vert Angle	0.000 deg.	Elevation	472.97		
		End Vert Angle, rad	0.0000 rad	End Vert Angle, rad	0.0000 rad	Curve Vert Depth	92.97	***Prop. Plan Length***	***2199.250096***

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	2+95.77	Start Station	8+13.41	Start Station	12+55.14	Start Station	19+16.67
PVC Station	2+95.77	PTV Station	8+13.41	PCV Station	12+55.14	PTV Station	19+16.67	Exit Station	21+99.250
Cum Plan Length	295.77	Cum Plan Length	813.41	Cum Plan Length	1255.14 ft	Cum Plan Length	1916.67	Cum Plan Length	2199.250096
Cum Path Length	306.20	Cum Path Length	829.80	Cum Path Length	1271.54 ft	Cum Path Length	1941.74	Cum Path Length	2235.708991
Cum Depth	-79.25	Cum Depth	-147.40	Cum Depth	-147.40 ft	Cum Depth	-54.43	Cum Depth	26.60

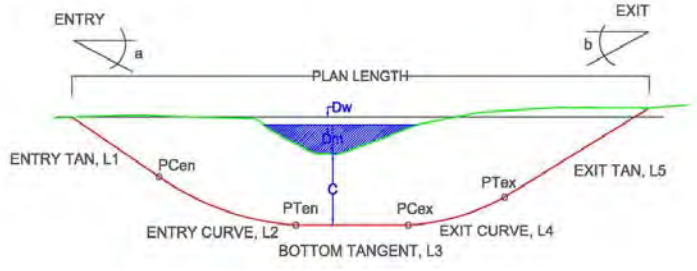
Stationing Check
OK STATIONING

Plan Length Check
OK CALCULATION

Summary of Drill Calculations

Entry to Exit Elevation Change =	**26.60 ft**
Minimum Design Elevation =	**380.00 ft**
Invert Depth below exit =	**174.00 ft**
Invert Depth below entry =	**147.40 ft**
Path Length =	**2,235.71 ft**
Plan Length =	**2,199.25 ft**
Minimum Plan Length (No Tangent) =	**1,757.52 ft**
Entry Angle =	**-15.00 deg**
Exit Angle =	**16.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

NOTES:
1. Sign convention for angles - positive (+) angles are counterclockwise. Due East is defined as 0 degrees.
2. Coordinates are in feet and reference NAD 83 Pennsylvania South State Plane
3. Elevations are in feet and reference NAVD 88.
4. All calculation locations represent the center of the drill hole.



Indicates inputs

Indicates status on internal design checks

ISSUE: **APC/FPC DESIGN**

Directional Project Support
33311 Lois Lane, Suite A
Magnolia, Texas 77354

Sunoco Pipeline, L.P.
Mariner East Pipeline
Lebanon County, Pennsylvania

TABLE 2
DESIGN DRILL PATH CALCULATION
WETLAND J47 - West to East R1
20-INCH STEEL PIPE

Revision 1 1/0/1900

C:\Users\bdonwart\Documents\DPS\Pennsylvania Pipeline\Spread 3\Wetland J47 Laney 20\Final\[S3-0090_PA-LE-0001.0000-SR-20-INCH_W-ER1.xlsx]T2 Path

TABLE 3
ESTIMATED ANNULAR PRESSURE CURVE (APC) EXAMPLE CALCULATION
Sunoco Pipeline, L.P.
Mariner East Pipeline
Lebanon County, Pennsylvania

WETLAND J47 - West to East R1
20-INCH STEEL PIPE
INPUT

1. Drill path data

	Measured Distance	Elevations	Angles	Lengths	Angle Change	
Drill Entry	0.000 ft	527.4	-15	Entry to PC	306.205 ft	
PC	306.205 ft			PC to PT	523.599 ft	-0.029 deg/ft
PT	829.804 ft			Invert Tangent	441.733 ft	
PC	1271.536 ft			PC to PT	670.206 ft	0.024 deg/ft
PT	1941.743 ft			PT to Exit	293.966 ft	
Drill Exit	**2235.709 ft**	554.00 ft	16		**2235.709 ft**	
					Length Ck	**OK**

2. Drill Fluid Hydraulic Assumptions

	Assumed		Low		High	
Density, γ_f =	78	10.43 lb/gal	72	9.62 lb/gal	89	11.90 lb/gal
Dynamic annulus pressure P_d =	0.0014 psi/ft		0.0013 psi/ft		0.0068 psi/ft	
Drill fluid viscosity, μ_p =	2 cp		6 cp		13 cp	
Yield point of drill fluid, YP =	41		19		5	

3. Drill Data Assumptions

Assumed Drill Size:	**DD660**		
Avg Rod length =	31.0 feet	Max Rig Pump =	1200 gpm
Diameter of hole, D_h =	12.31125	Number of drill rods =	72
Drill Rod Tube Diameter, D_r =	6.625 in	Estimated annular pilot uphole drill fluid velocity, V_{ha} =	68.29 ft/min
Drilling Pump rate, gpm =	300 gal/min		

4. Calculate Annular Pressure, P

Method A - (API RP) 13D

$$P_A = [\gamma_f (Y_{entry} - Y)/144] + (P_d)(MD)$$

Method B - HDD Good Practices Cavity Expansion Annular Pressure

$$P_B = [\gamma_f * (Y_{entry} - Y)/144] + MD*[\mu_p*(V_{ha}/60)/(1000*(D_h-D_r)^2)] + YP/[200*(D_h-D_r)]$$

Start Station	0+00.00	1

Drill Path			Assumed Return Density		Low Return Density		High Return Density	
			Density, γ_{fE} = 78		Density, γ_{fL} = 72		Density, γ_{fH} = 89	
Rod Measured Distance MD	Station X	Elevation Y	Annular Fluid Pressure P_A	Annular Fluid Pressure P_B	Annular Fluid Pressure P_A	Annular Fluid Pressure P_B	Annular Fluid Pressure P_A	Annular Fluid Pressure P_B
ft	ft	ft	psi	psi	psi	psi	psi	psi
0.00	0+00.00	527.40	0.00	0.00	0.00	0.00	0.00	0.00
31.00	0+29.94	519.38	4.39	5.47	4.05	4.54	5.17	5.11
62.00	0+59.89	511.35	8.78	10.93	8.10	9.07	10.34	10.22
93.00	0+89.83	503.33	13.16	16.40	12.15	13.61	15.51	15.33
124.00	1+19.77	495.31	17.55	21.86	16.21	18.14	20.68	20.44
155.00	1+49.72	487.28	21.94	27.33	20.26	22.68	25.86	25.55
186.00	1+79.66	479.26	26.33	32.79	24.31	27.21	31.03	30.66
217.00	2+09.61	471.24	30.72	38.26	28.36	31.75	36.20	35.77
248.00	2+39.55	463.21	35.10	43.73	32.41	36.29	41.37	40.88
279.00	2+69.49	455.19	39.49	49.19	36.46	40.82	46.54	45.98
310.00	2+99.44	447.19	43.86	54.64	40.50	45.34	51.69	51.08
341.00	3+29.46	439.46	48.09	59.95	44.41	49.74	56.69	56.01
372.00	3+59.60	432.19	52.07	65.01	48.08	53.89	61.39	60.65
403.00	3+89.85	425.39	55.80	69.81	51.52	57.82	65.81	65.00
434.00	4+20.19	419.06	59.27	74.36	54.73	61.51	69.93	69.07

Drill Path			Assumed Return Density		Low Return Density		High Return Density	
			Density, γ_{fE} =	78	Density, γ_{fL} =	72	Density, γ_{fH} =	89
Rod Measured Distance MD	Station X	Elevation Y	Annular Fluid Pressure P_A	Annular Fluid Pressure P_B	Annular Fluid Pressure P_A	Annular Fluid Pressure P_B	Annular Fluid Pressure P_A	Annular Fluid Pressure P_B
ft	ft	ft	psi	psi	psi	psi	psi	psi
465.00	4+50.63	413.20	62.48	78.65	57.70	64.96	73.76	72.84
496.00	4+81.16	407.82	65.44	82.69	60.43	68.18	77.31	76.32
527.00	5+11.77	402.90	68.15	86.47	62.92	71.16	80.56	79.50
558.00	5+42.45	398.47	70.59	90.00	65.18	73.90	83.51	82.40
589.00	5+73.20	394.50	72.78	93.26	67.20	76.41	86.17	85.00
620.00	6+04.00	391.02	74.71	96.27	68.99	78.67	88.54	87.30
651.00	6+34.85	388.01	76.38	99.02	70.53	80.70	90.61	89.31
682.00	6+65.75	385.48	77.79	101.51	71.83	82.49	92.38	91.02
713.00	6+96.68	383.43	78.94	103.74	72.90	84.04	93.86	92.44
744.00	7+27.64	381.86	79.84	105.71	73.72	85.35	95.04	93.56
775.00	7+58.62	380.78	80.47	107.42	74.31	86.42	95.93	94.38
806.00	7+89.62	380.17	80.84	108.87	74.65	87.24	96.52	94.91
837.00	8+20.62	379.98	80.98	110.09	74.78	87.86	96.85	95.18
868.00	8+51.62	379.98	81.02	111.21	74.82	88.39	97.06	95.33
899.00	8+82.62	379.98	81.07	112.33	74.86	88.91	97.27	95.48
930.00	9+13.62	379.98	81.11	113.45	74.90	89.43	97.48	95.63
961.00	9+44.62	379.98	81.15	114.57	74.94	89.96	97.69	95.78
992.00	9+75.62	379.98	81.19	115.69	74.98	90.48	97.91	95.93
1023.00	10+06.62	379.98	81.23	116.80	75.02	91.01	98.12	96.08
1054.00	10+37.62	379.98	81.27	117.92	75.06	91.53	98.33	96.23
1085.00	10+68.62	379.98	81.32	119.04	75.10	92.05	98.54	96.38
1116.00	10+99.62	379.98	81.36	120.16	75.14	92.58	98.76	96.53
1147.00	11+30.62	379.98	81.40	121.28	75.18	93.10	98.97	96.68
1178.00	11+61.62	379.98	81.44	122.40	75.22	93.63	99.18	96.83
1209.00	11+92.62	379.98	81.48	123.52	75.26	94.15	99.39	96.98
1240.00	12+23.62	379.98	81.53	124.64	75.30	94.67	99.61	97.13
1271.00	12+54.62	379.98	81.57	125.76	75.34	95.20	99.82	97.28
1302.00	12+85.62	380.18	81.50	126.78	75.28	95.62	99.91	97.31
1333.00	13+16.61	380.77	81.22	127.57	75.02	95.85	99.75	97.09
1364.00	13+47.59	381.77	80.73	128.16	74.57	95.88	99.35	96.63
1395.00	13+78.56	383.16	80.01	128.52	73.91	95.71	98.70	95.92
1426.00	14+09.51	384.95	79.08	128.67	73.05	95.33	97.81	94.96
1457.00	14+40.43	387.15	77.94	128.60	72.00	94.76	96.66	93.76
1488.00	14+71.33	389.74	76.57	128.32	70.74	93.99	95.27	92.30
1519.00	15+02.18	392.73	75.00	127.82	69.28	93.02	93.64	90.61
1550.00	15+32.99	396.12	73.20	127.10	67.63	91.85	91.75	88.66
1581.00	15+63.76	399.91	71.19	126.17	65.77	90.48	89.62	86.47
1612.00	15+94.48	404.09	68.97	125.02	63.72	88.91	87.25	84.04
1643.00	16+25.14	408.67	66.53	123.66	61.47	87.14	84.63	81.35
1674.00	16+55.74	413.65	63.87	122.08	59.02	85.18	81.77	78.43
1705.00	16+86.27	419.02	61.01	120.29	56.38	83.02	78.66	75.26
1736.00	17+16.73	424.79	57.93	118.29	53.53	80.66	75.31	71.85
1767.00	17+47.11	430.95	54.63	116.07	50.49	78.10	71.72	68.19
1798.00	17+77.41	437.50	51.13	113.65	47.26	75.35	67.88	64.29
1829.00	18+07.62	444.44	47.41	111.01	43.83	72.41	63.80	60.15
1860.00	18+37.74	451.77	43.48	108.15	40.20	69.26	59.48	55.77
1891.00	18+67.77	459.49	39.34	105.09	36.38	65.93	54.93	51.15
1922.00	18+97.69	467.59	34.99	101.82	32.37	62.40	50.13	46.29
1953.00	19+27.52	476.02	30.47	98.38	28.20	58.71	45.13	41.24
1984.00	19+57.32	484.56	25.88	94.87	23.96	54.96	40.07	36.11
2015.00	19+87.12	493.11	21.30	91.36	19.73	51.22	35.00	30.98
2046.00	20+16.92	501.65	16.71	87.85	15.50	47.47	29.93	25.85
2077.00	20+46.72	510.19	12.12	84.35	11.27	43.72	24.86	20.72
2108.00	20+76.52	518.74	7.54	80.84	7.03	39.97	19.79	15.59
2139.00	21+06.32	527.28	2.95	77.33	2.80	36.22	14.72	10.45
2170.00	21+36.12	535.83	0.00	0.00	0.00	0.00	0.00	0.00
2201.00	21+65.91	544.37	0.00	0.00	0.00	0.00	0.00	0.00
2232.00	21+95.71	552.92	0.00	0.00	0.00	0.00	0.00	0.00

Drill Path			Assumed Return Density		Low Return Density		High Return Density	
			Density, γ_{fE} =	78	Density, γ_{fL} =	72	Density, γ_{fH} =	89
Rod Measured Distance MD	**Station X**	**Elevation Y**	**Annular Fluid Pressure P_A**	**Annular Fluid Pressure P_B**	**Annular Fluid Pressure P_A**	**Annular Fluid Pressure P_B**	**Annular Fluid Pressure P_A**	**Annular Fluid Pressure P_B**
ft	**ft**	**ft**	**psi**	**psi**	**psi**	**psi**	**psi**	**psi**
2235.71	21+99.28	553.94	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 4
ESTIMATED FORMATION PRESSURE CURVE (FPC) EXAMPLE CALCULATION
Sunoco Pipeline, L.P.
Mariner East Pipeline
Lebanon County, Pennsylvania

WETLAND J47 - West to East R1
20-INCH STEEL PIPE
INPUT

1. Drill path data from vertical path calculations

	Measured Distance	Elevations	Angles	Lengths	Angle Change	
Entry	0.000 ft	527.4	-15	Entry to PC	306.205 ft	
PC	306.205 ft			PC to PT	523.599 ft	-0.029 deg/ft
PT	829.804 ft		0	Invert Tangent	441.733 ft	
PC	1271.536 ft			PC to PT	670.206 ft	0.024 deg/ft
PT	1941.743 ft			PT to Exit	293.966 ft	
Exit	**2235.709 ft**	554.00 ft	16		**2235.709 ft**	**Length Ck** **OK**

2. Drill Fluid Hydraulic Data for Estimated Drill Fluid

Dynamic annulus pressure =	0.00135 psi/LF	
Uphole Drill Fluid Density =	78	10.4 lb/gal
Drill fluid viscosity, cp =	2 cp	
Up hole drill fluid velocity, ft/sec =	68.29 ft/sec	
Pump rate, gpm =	300 gal/min	
Diameter of hole D_H, in =	12.31125	
Diameter of Drill Rod D_R, in =	6.625	
Yield point of drill fluid, lb/100 ft^2 =	41.00 Lb/100FT^2	

Radius

R_H =	6.156 in
R_R =	3.313 in

3. Soil Profile Data

Technical approach to generate data as no testing available

Material Layer	Dry Density γ (pcf)	Moisture Content %	Insitu Saturated Density (pcf)	Effective UW (pcf)	Phi, Φ	Undrained Cohesion c, psf	Poisson Ratio μ	Slow Shear Modulus, G psf	OCR Cohessive (Use 0 if non-cohessive)	Model Material Layer Description	Cohesive
1	110	15.0%	126.5	47.60 pcf	32	500	0.3	7,727	1	Sandy Silt	Y
2	130	10.0%	143	67.60 pcf	55	0.01	0.3	121,763	1	Sandstone	N
3								0			
4								0			
5								0			
6								0			
7								0			
8								0			
9								0			
10								0			
Water	62.4			62.40 pcf							

Dynamic Shear Velocity, $V_s = 61.4*N_{60}^{1/2}$ Based on Seed and Idris approximation

Dynamic Shear Modulus, $G_{max} = (\gamma/g)*Vs^2$ g = acceleration of gravity = 32.2 ft/s^2

Extended Strain Shear Modulus G is typically between 5% and 20% of G_{max} Select Reduction Factor, RF = 10% Ref 1

165.36

4 Select Controlling Location and list properties (Based on inspection of Figure 1 plot

Joint = 9 Away Distance from Entry = 269.49 ft Depth of Cover = 52.13 ft

Layers	*Surface 1-2*	*Surface 2-3*	*Surface 3-4*	*Surface 4-5*	*Surface 5-6*	*Surface 6-7*	*Surface 7-8*	*Surface 8-9*	*Surface 9-10*	TOTAL	Total CK
Soil Type in Layer =	1	2	2								
Dry Density in Layer, γ_d =	110.00 pcf	130.00 pcf	130.00 pcf								
Insitu Density in Layer, γ_s =	126.50 pcf	143.00 pcf	143.00 pcf								
Effective Weight in Layer, γ'_e =	47.60 pcf	67.60 pcf	67.60 pcf								
Total Layer Thickness over drill, h_s =	9.35 ft	42.78 ft	0.00 ft							52.13 ft	52.13 ft
Saturated Thickness over drill, h_{sat} =	0.00 ft	40.73 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	40.73 ft	
Dry Thickness over drill, h_{dry} =	9.35 ft	2.06 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	11.40 ft	
Contribution Effective Stress, σ' =	1,028.17 psf	3,549.81 psf	0.00 psf								
Contribution Total Stress, $\sigma = h_s*\gamma_s$	1,028.17 psf	6,091.09 psf	0.00 psf								
Shear Modulus, G =	7,727 psf	121,763 psf	121,763 psf								

Height of Water above Soil Surface, h_w =	0.00 ft
Total soil and water height above drill path, H_T =	52.13 ft
Total water height above drill path, H_W =	40.73 ft

Properties At Drill Depth for Selected Joint

R_H =	0.51 ft	Radius of drill hole
$R_{max} = h_s/FS_D$ =	34.75 ft	Maximum allowable radius of plastic zone = Height of soil above Drill Path (h_s) divided by Delft & Queens Equation FS_D

	2	Soil Layer At Drill Depth
G_w =	121,763 psf	Large Strain Shear Modulus at drill depth
$S_u = c = q_u/2$	0 psf	Cohesive material: cohesion c = unconfined compressive strength (q_u) divided by 2
ϕ =	55 deg	0.9599 rad — Granular Soil: Angle of internal friction of layer at drill path depth
H_W =	40.73 ft	Total water height above drill path
FS_D =	1.5	Factor of Safety for Delft & Queens Equation soil type: Use 1.5 for Sand and 2 for Clay at Drill Depth - Apply to R_{max} and P_{max}
μ =	0.3	Poisson ration of layer at drill path depth
OCR =	1	Over Consolidation Ratio
K_o =	0.429	Coefficient of lateral earth pressure at rest. For OCR = 1 use relation $K_o = \mu/(1 - \mu)$; For OCR >1 use $K_o = (K_{onormally\ consolidated}) * OCR^{-1/2}$
σ_o =	7,119 psf	Total Stress at drill depth, $\sigma = \gamma_d$(above water)*hdry + γ_s(saturated)*h_{sat}
u =	2,541 psf	Water pressure at drill depth, $u = \gamma_W * H_W$
σ' =	4,578 psf	Effective Stress at drill depth, $\sigma' = \sigma - u$

5. Method A - Total Stress Method (Conservative)

Calculate Allowable Controlling Formation Pressure Capacity

$P_{max} = \sigma_o = \Sigma (h_s*\gamma_s) + h_w*\gamma_w$

P_{maxA} =	7,119 psf	49.44 psi	
		49.44 psi	Check Calculation

6. Method B - Total Stress Method + Local Formation Strength

Calculate Allowable Controlling Formation Pressure Capacity

$P_{max} = \Sigma (h_s*\gamma_s) + h_w*\gamma_w + S$

P_{maxB} =	13,657 psf	94.84 psi	
		94.84 psi	Check Calculation

Based on Mohr-Coulomb

Strength = c + σ' * tan(ϕ)

6,538 psf	45.40 psi

7. Method C - Delft Equation for cavity expansion **(Assumes drained properties)**

$$P_{max} = \mu + [p'_f + c * \cot\phi] * \{[R_o/R_{pmax}]^{\zeta} + [(\sigma_o' * \sin\phi + c* \cos\phi)/ G]\}^{-\sin\phi/(1+\sin\phi)} - c*\cot(\phi)$$

Sin(ϕ) =	0.819152		A =	8328.058502	A = $p'_f + c * \cot\phi$	8328.058502
Cos(ϕ) =	0.5735764		B =	0.000217874	B = $[R_o/R_{pmax}]^{\zeta}$	0.000217872
Cot(ϕ) =	0.7002075		C =	0.030798182	C = $(\sigma_o' * \sin\phi + c* \cos\phi)/G$	0.030798182
μ =	2,541 psf	Initial Pore Pressure, $\mu = \gamma_w * H_w$	D =	-0.450293337	D = $-\sin\phi/(1+\sin\phi)$	-0.450293337
σ' =	4,578 psf	Effective Stress, $\sigma_o' = \Sigma [\gamma_d*h_d + \gamma' * h_s]$	E =	0.007002075	E = $c*\cot\phi$	0.007002075
p'_f =	8,328 psf	$p'_f = \sigma'_0(1+\sin(\phi)) + c*\cos(\phi)$	σ' =	4,577.98	Check Calculation	

P_{max} =	42,331 psf	293.97 psi	$P_{max} = \mu + A * (B + C)^D - E$	42,331 psf	Check Calculation
P_{allC} =	28,221 psf	195.98 psi	$P_{all} = P_{max}/FS$		

8. Method D - Queens Equation (Cohesive Soils Only) better for softer clay soils **(Assumes undrained properties)**

$K_o < 1$ $P_i = S_u + (1/2)*(3K_o-1)*\sigma_o - S_u*\ln[(R_o/R_{pmax})^2 + (S_u/G)]$

$K_o > 1$ $P_i = S_u + (1/2)*(3-K_o)*\sigma_o - S_u*\ln[(R_o/R_{pmax})^2 + S_u/G]$

To Determine if hydraulic fracturing or blowout occurs **(<2Su) indicates hydraulic fracturing; (>2Su) indicates blowout**

$K_o < 1$ $F_1(K_o,\sigma_o,S_u) = (3*K_o - 1)*\sigma_o$

$K_o > 1$ $F_1(K_o,\sigma_o,S_u) = (3 - K_o)*\sigma_o$

K_o =	0.429	P_i =	1,017 psf	7.06 psi	7.06 psi — Check Calculation
		F_1 =	Expect Blowout		

9. SUMMARY and Assessment of Estimated Drilling Annular Pressure and Formation Capacity

(See Annular Pressure Calculations for joint by joint calculations)

Method A - (API RP) 13D

Method B - HDD Good Practices Cavity Expansion Annular Pressure

$P_{annularA}$ =	39.49 psi	$P_A = [\gamma_f (Y_{entry} - Y)/144] + (P_d)(MD)$		
$P_{annularB}$ =	49.19 psi	$P_B = [\gamma_f * (Y_{entry} - Y)/144] + MD*[\mu_p*V_{ha}/(1000*(Dh-Dr)^2)] + YP/[200*(D_h-D_r)]$		
Method A	49.44 psi	FS =	1	Total Stress
Method B	94.84 psi	FS =	1	Total Stress + Strength
Method C	195.98 psi	At FS_D =	1.5	Delft Equation
Method D	7.06 psi	At FS_D =	1.5	Queens Equation

Comparitive Factor of Safety against Drill Fluid Loss at Critical Joint

Critical Joint =	9		Depth of Cover =	52.1 ft

Confining Pressure Calculation Method	Method A	Method B	Method C	Method D
Method (X)/$P_{annularA}$	1.25	2.40	4.96	0.18
Method (X)/$P_{annularB}$	1.01	1.93	3.98	0.14

Acceptable if Factor of Safety >=1.0