

**HORIZONTAL DIRECTIONAL DRILL ANALYSIS  
ARCH BISHOP/SOUTH CHESTER ROAD CROSSING  
PADEP SECTION 105 PERMIT NO.: E15-862  
PA-CH-0421.0000-RD & PA-CH-0421.0000-RD-16  
(SPLP HDD No. S3-0541)**

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This reanalysis of the horizontal directional drill (HDD) installation of a 16-inch and 20-inch diameter pipeline parallel to South Chester Road has been completed in accordance with Stipulated Order issued under Environmental Hearing Board Docket No. 2017-009-L for HDDs listed on Exhibit 2 of the Stipulated Order. This HDD is number 19 on the list of HDDs included on Exhibit 2. This HDD was not initiated before the issuance of the 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: 6,346 foot (ft)
- Entry/Exit angle: 10-12 degrees
- Maximum Depth of cover: 176 ft
- Pipe design radius: 2,000 ft

**ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 16-INCH**

- Horizontal length: 6,312 ft
- Entry/Exit angle: 16 degrees
- Maximum Depth of cover: 170 ft
- Pipe design radius: 1,600 ft

These HDDs are planned as “intercept drills”. An intercept drill utilizes a drilling rig on each end of the HDD, drilling the pilot hole towards an “intercept point” near the middle of the planned profile. Once the two pilot holes meet up and are joined together, then one drilling rig chases the other rig’s drilling stem string out to maintain drilling stem within the pilot hole for the entire length of the profile. Reaming of the profile is completed by one drilling rig alone, typically pulling the reaming tool through the profile. The reasoning for establishing this HDD as an “intercept” drill is due to the “compound” nature of the of the profile design required to follow the Sunoco easement. In this instance, each HDD rig is required to both steer the pilot tool down to horizontal depth and steer left or right as required to stay within the easement limits. Use of two rigs during the pilot phase reduces the steering complications to complete the pilot hole.

**GEOLOGIC AND HYDROGEOLOGIC ANALYSIS**

This HDD is located within the Piedmont Uplands Section of the Piedmont Physiographic Province in southeastern Pennsylvania. The Piedmont Uplands Section is characterized by broad, rounded to flat-topped hills and shallow valleys with low to moderate topographic relief. The geologic structure of this section is complexly folded and faulted. Bedrock in the area of HDD S3-0541 is comprised of crystalline, Precambrian-aged weathered Baltimore Gneiss having quartzofeldspathic granulite facies and undifferentiated amphibolite facies. Regional fabric (relict bedding and structure) trends are to the northeast.

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Karst geology is not present at this HDD location; therefore, the use of geophysics assessments was considered but not conducted because the results from these types of assessments would provide no data to assist in the redesign of these HDDs.

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**

The Baltimore gneiss unit mapped beneath the HDD S3-0541 location is identified as a unit of poor groundwater production. A limited network of fractures with small apertures generally provides the secondary porosity needed to support low groundwater discharges from this rock formation. Based upon the well information reported to the Pennsylvania Groundwater Information System (PAGWIS), well depths vary from 70 to 300 ft below ground surface (bgs). Median well yields for this geologic setting are reported as variable but generally less than 10 gpm (Geyer and Wilshusen, 1982). Domestic well yields as reported by PAGWIS range from 1 to 40 gpm. The reported static water level in these wells varies from 15-60 ft bgs. The production zone for waters wells within rock formations is from the well bottom to highest point of water inflow from the water bearing seams, joints, and fractures in the rock formation.

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 determined that the design profiles for the 16 and 20-inch HDDs have no apparent faults given the setting and nature of the geologic strata. The single feature of concern from this HDD review is the shallow depth of passage under Highway 926 at the southeast end of the HDD, and revisions to the HDD profiles have been recommended to increase the depths below the roadway.

Based on recent experiences with HDDs in the same geology, the gneiss geology in this area of the project at profile depth is a porous yet hard substrate that tends towards a detectable loss of fluids during the pilot phase but is resistant to IR's where depth of cover is sufficient. IR's during the pilot phase have occurred at some nearby HDD's and not at others. During the pilot phase, the loss of fluids can be managed by the injection of loss control materials, or cement grouting. During the reaming phase, the maintenance of full returns back to the HDD entry points has not been problematic.

Two recent geotechnical cores at each end of the HDD reveal that the designed horizontal profile is below and within bedrock with recovery percentages varying from 30-60%, with RQD values of 60-80. These test results are indicative of bedrock having fair to good integrity and good to very good strength.

### **ADJACENT FEATURES ANALYSIS**

This HDD location is 4.4 miles east of the city of West Chester in Chester and Delaware Counties, Pennsylvania. The pipeline alignments follow parallel to South Chester Road and cross under Highway 926 between Paoli Pike Road and East Boot Road, and will co-join other gas utilities lines along the roadway.

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This HDD location is set within urban residential developments for the majority of its length as it proceeds parallel to South Chester Road. The HDD crosses under stream S-B35 which is not a high quality or exceptional value resource.

SPLP has identified all landowners with property located within 450 ft of the HDD alignment. There are two hundred-seventeen (217) individual landowners with properties located within 450 ft of the HDD alignment. SPLP sent each of these landowners a notice letter via both certified and first-class mail on October 30, 2017, that included an offer to sample the landowner's private water supply/well in accordance with the terms of the Order and the Water Supply Assessment, Preparedness, Prevention and Contingency Plan. The letter also requested that each landowner contact the Right-of-Way agent for the local area and provide SPLP with information regarding: (1) whether the landowner has a well; (2) where that well is located, and its depth and size if known; and (3) whether the landowner would like to have the well sampled. In accordance with paragraph 10 of the Order, copies of the certified mail receipts for the letters sent to landowners have been provided to Karyn Yordy, Executive Assistant, Office of Programs at the Department's Central Office.

To date, SPLP has received twenty-six responses from individual landowners. Of these, twenty-five have confirmed the use of a private water well, and the remaining landowner response verified the use of public water supply. Sixteen of the private water wells have been located and tested; the remainder are scheduled for testing in the near future.

Agents for SPLP will initiate direct contact by phone or in person to attempt to determine the potable water source for each landowner. Based on the response to the mailings and direct contact, the landowners with private water wells determined to be at risk during the HDD will be offered alternative water supplies until the HDD is complete.

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.

## **ALTERNATIVES ANALYSIS**

As required by the Order, the reanalysis of HDD S3-0541 includes an evaluation of open cut alternatives and a re-route analysis. As part of the PADEP Chapter 105 permit process for the Mariner II East Project, SPLP developed and submitted for review a project-wide Alternatives Analysis. During the development and siting of the Project, SPLP considered several different routings, locations, and designs to determine whether there was a practicable alternative to the proposed impact. SPLP performed this determination through a sequential review of routes and design techniques, which concluded with an alternative that has the least environmental impacts, taking into consideration cost, existing technology, and logistics. The baseline route provided for the pipeline construction was to cross every wetland and stream on the project by open cut construction procedures. The Alternatives Analysis submitted to PADEP conceptually analyzed the potential feasibility of any alternative to baseline route trenched resource crossings (e.g., reroute, conventional bore, HDD). The decision-making processes for selection of the HDD instead of an open cut crossing methodology is discussed thoroughly in the submitted alternatives analysis and was an important part of the overall PADEP approval of HDD plans as currently permitted. As described below, the open cut and re-route analyses have confirmed the conclusions reached in the previously submitted Alternatives Analysis.

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### **Open-cut Analysis**

Sunoco Pipeline, L.P. (SPLP) specifications require a minimum of 48-inches of cover over the installed pipelines. The Pennsylvania Department of Transportation (PADOT) cover requirements under public roadways is 60-inches of cover.

While an open cut installation of the pipeline is possible, the logistics associated with this method would significantly increase the length of time the affected properties would be subject to construction disturbance. To minimize impact to the public users of the primary and intersecting roadways, open cut construction would require obtaining a permit from PADOT to undertake night-time construction with a lane closure while “stove piping” the new pipeline installations. Under this construction scenario the pipeline construction proceeds in 80-170 ft segments; a trench is cut, pipe segments held in place and welded to the preceding segment end; the weld is inspected and approved and coated and then backfilled to within 20-30 ft of the segment end. Only 1 to 2 segments of pipe could be completed per night due to the time requirements to complete each welding and coating procedure to specification. Steel plates are laid over the backfilled segments and minimally permitted open end before the stop of construction to allow for daytime roadway use. This sequence of construction events is repeated until the entire lay segment is completed.

There are two minor stream crossings within the HDD profiles, neither of which are high quality or exceptional value. Open cut impacts to these resources would be minimal, but would require modification of the state and federal permits. Moreover, any produced groundwater in the open excavations would be pumped to a discharge filtration structure. The current feasible filtration ability, however, does not exceed 50 microns. Therefore, cloudy water (from suspended fine clay and silt particles) would be discharged downstream regardless of all control methods employed for the entire duration of the use of open cut construction techniques.

Finally, conventional auger bore is technically limited to less than 200 linear foot at a time varying by the underlying substrate. Due to the spacing constraints at the location of these HDDs, there are no subset locations within this length of area to feasibly employ this type of installation method.

### **Re-Route Analysis**

The pipeline route as currently permitted follows an existing SPLS easement under the public right-of-way of South Chester Road through urban development east-northeast of the City of West Goshen. This alignment bypasses or avoids directly impacting South Chester Road, seven (7) intersecting public roads, and thirty-seven intersecting (37) private driveways.

The general route of the Mariner II project in this area of the state is from northwest to the southeast.

Approximately 1.1 mile east, an existing pipeline utility corridor parallels the route of the Mariner II project, generally at a 1.0 to 1.5-mile offset. Use of this corridor as an alternative route to replace the HDD proposed for this crossing would require deviating from the current route and proceeding east parallel to West Chester Pike to intersect the alternate utility corridor. Residential and commercial developments line both sides of the roadway and the general area offset from either side of the road, and these developments would be impacted under this alternative route. Furthermore, once the alternate corridor is accessed, the Mariner pipeline would need to be aligned to the outside, northeast or southwest, of the three existing pipelines. Although this alignment would not create a new corridor, the addition of two new pipelines to this corridor would significantly expand the area of pipeline use within the corridor. This corridor passes through numerous developments and there is significant encroachment on the easement edge by homesites and developments. Lastly, the alternate route would need to deviate and return to the continued direction of the existing Mariner II route because the alternate corridor proceeds to a different endpoint.

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There are no existing utility corridors to the southwest that provide a practical alternative route. Any alternate route considered to the southwest 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.

In summary, due to the urban setting surrounding the overall route of the Mariner II pipelines in this area, there is no alternative route that could avoid conflicts with existing development. Since SPLP possesses no prior rights for multiple utility lines in any nearby existing corridor, nor any new corridor that could be developed, SPLP anticipates significant legal action to acquire a new easement.

This re-route analysis conducted for the South Chester Road HDD confirms the conclusions reached in the previously submitted alternatives analysis.

## **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 a minimal risk of inadvertent returns (IRs) if implemented. Minor adjustments to the profile design were made to increase the depth of cover at the crossing of Highway 926.

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, managing development 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;
- The HDD entry point southeast of Highway 926 will have the pilot hole cased to control drilling returns during drilling of the pilot hole and reaming phases;
- 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; and
- During the reaming phase, the use of Loss Control Materials can be implemented if indications of a potential IR are noted or an IR is observed.

Other than the implementation of the above described drilling practices and procedures, no significant changes to the HDD plans for the pipelines at this location are recommended or planned.

As there were no major alterations of these HDD designs, the final designs are attached as Figures 1 A & B, and Figures 2 A & B in Attachment 2.

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**ATTACHMENT 1**

**GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT**



# **HDD HYDROGEOLOGIC REEVALUATION REPORT**

**Mariner East II  
Spread 6  
HDD S3-0541  
Arch Bishop/South Chester Road  
Westtown/Edgemont Townships, Chester/Delaware Counties, Pennsylvania**

*Prepared for:*

**Sunoco Pipeline, L.P.**

*Prepared by:*

**Groundwater & Environmental Services, Inc.  
440 Creamery Way, Suite 500  
Exton, Pennsylvania 19341**

**November 2017**





## **HDD HYDROGEOLOGIC REEVALUTION REPORT**

**Mariner East II  
Spread 6  
HDD S3-0541  
Westtown/Edgemont Townships, Chester/Delaware County, Pennsylvania**

**November 2017**

*Prepared for:*

**Sunoco Pipeline, L.P.  
535 Fritztown Road  
Sinking Spring, Pennsylvania 19608**

*Prepared by:*

A handwritten signature in blue ink, reading "Samuel H. Baughman".

Samuel Baughman, P.G.  
Senior Hydrogeologist

*Reviewed by:*

A handwritten signature in blue ink, reading "David J. Demko".

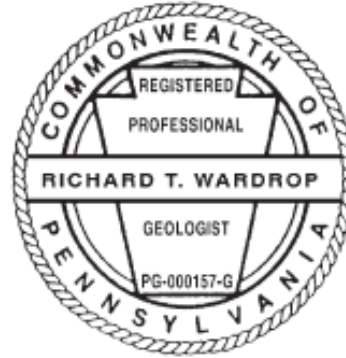
David J. Demko, P.G.  
VP, Principal Hydrogeologist

Groundwater & Environmental Services, Inc.  
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Exton, Pennsylvania 19341  
(610) 458-1077

By affixing my seal to this document, I am certifying that the information is true and correct. I further certify 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.



November 27, 2017



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Richard T. Wardrop, P. G.

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date

Lic. No. PG000157G

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## **FIGURES**

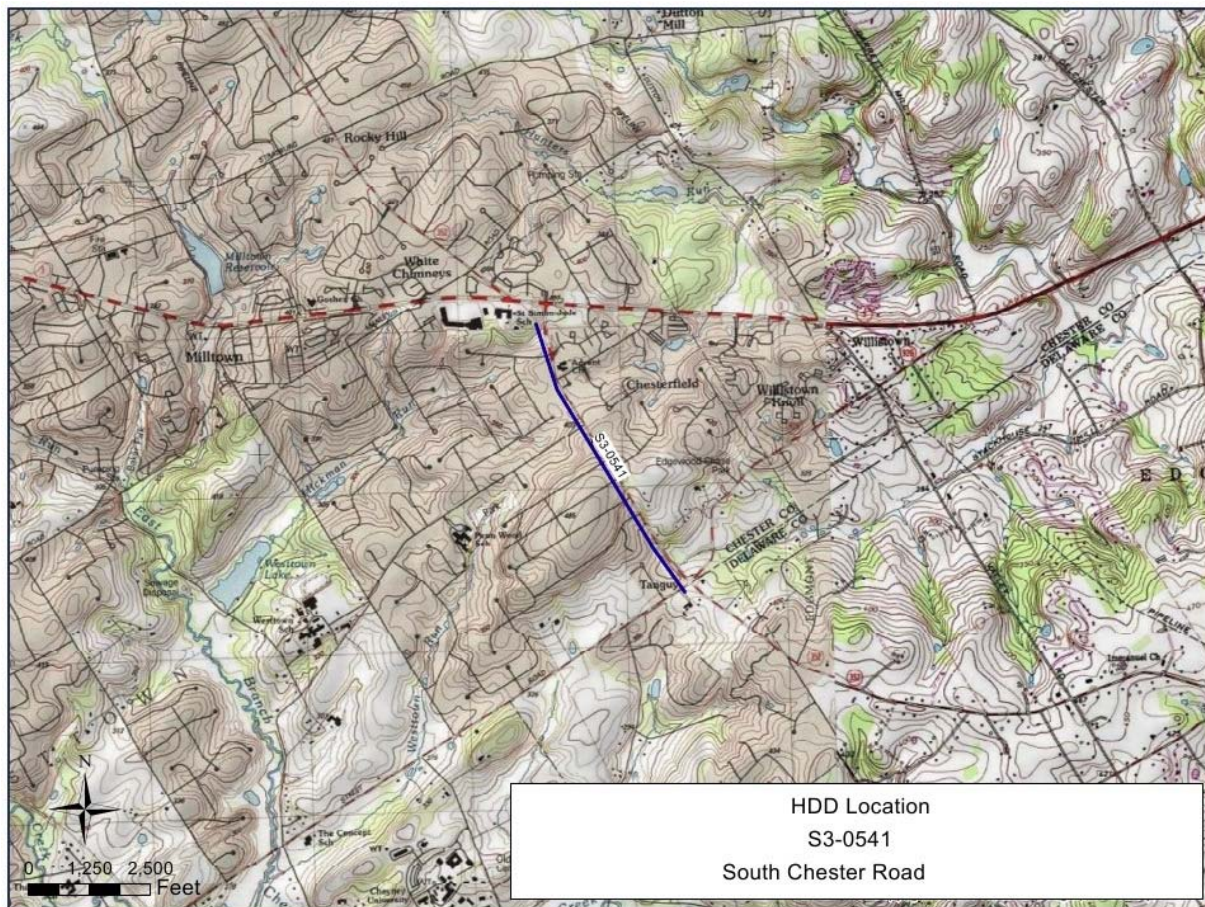
Figure 1. Site Location Map  
Figure 2. Regional Geologic Map  
Figure 3. Fracture Trace Analysis

## **ATTACHMENTS**

Attachment A. Original and Revised Plan and Profile  
Attachment B. Geotechnical Information

## 1.0 INTRODUCTION

Sunoco Pipeline, L.P., (SPLP) retained Groundwater & Environmental Services, Inc. (GES) to prepare HDD Hydrogeologic Reevaluation Reports for horizontal directional drills (HDDs) listed on Exhibit 2 of Stipulated Order EHB Docket No. 2017-009-L signed August 10, 2017. This report discusses the hydrogeologic reevaluation for HDD S3-0541, the 20-inch line, and HDD S3-0541-16 the 16-inch line, hereinafter referred collectively to as HDD S3-0541. HDD S3-0541 is aligned adjacent to South Chester Road in Westtown and Edgemont Townships, Chester and Delaware Counties, PA. A map depicting the location of the HDD with topographic information for the surrounding area is presented as **Figure 1**. The original profile (original boring, revised May 10, 2016, was presented in the risk assessment for HDD S3-0541, in the IR PPC Plan for Chester County. A proposed revised profile (revised boring) was developed by OZ Directional Drilling, Inc., revised April 26, 2017, and is considered in this reevaluation, as well. Both profiles are provided in **Attachment A**. They are nearly identical with the same entry/exit point locations and elevations. The entrance angle for the revised boring on the NW entry/exit is 2 degrees greater, and there the vertical curve radii was increased from 2,000 to 2,200 feet to provide more steering flexibility. The revised profile is up to 15 feet deeper than the original in the first 700 feet of the northwestern part of the profile (Station 0+00 to 7+00) and is approximately 5 feet deeper along the horizontal section, moving southeast from Station 7+00 to the southeast entry/exit at Station 63+46. This drill is designated as an “intersect drill” indicating that pilot advancement will occur at both the entry and exit locations of the drill profile and the borings will intersect each other at some point.



**Figure 1. Site Location Map** (modified from USGS, 1:24,000, West Chester topo. quad., rev. 1975)

The contents of this report were developed from interpretation of published information, field observations, and related field studies. Site geotechnical boring programs were conducted by Tetra Tech in 2015 and by Terracon Consultants, Inc. (Terracon), in August and September 2017 in support of the HDD S1B-0120 reevaluation. Please note that GES did not oversee or direct the geotechnical drilling programs, including, but not limited to, the selection of number and location of borings, determination of surface elevations, target depths, observations of rock cores during drilling operations, or preparation of boring logs. The geotechnical reports, boring logs, and any core photographs that resulted from these programs were generated by two SPLP contractors. GES relied on these reports and incorporated their data into the general geologic and hydrogeologic framework for this hydrogeologic reevaluation report.



## 2.0 HDD GEOLOGY / HYDROGEOLOGY

### 2.1 Physiography

HDD S3-0541 is located within the Piedmont Uplands Section of the Piedmont Physiographic Province in southeastern Pennsylvania. The Piedmont Uplands Section is characterized by broad, rounded to flat-topped hills and shallow valleys with low to moderate topographic relief. The geologic structure of this section is complexly folded and faulted.

#### 2.1.1 Topography

The topography in the area of HDD is quite flat with the ground surface elevation at the northwestern entry point identified as 401 feet above mean sea level (ft amsl) and the exit point 6,350 feet to the southeast at an elevation of 360 ft amsl. The profile shows a rise between these points with an elevation of approximately 460 ft amsl. The area surrounding the HDD is comprised of residential communities throughout the alignment and commercial properties to the northwest. Agricultural land is located east of South Chester Road between West Lynn Drive and Street Road. The site location is depicted on **Figure 1**.

#### 2.1.2 Hydrology

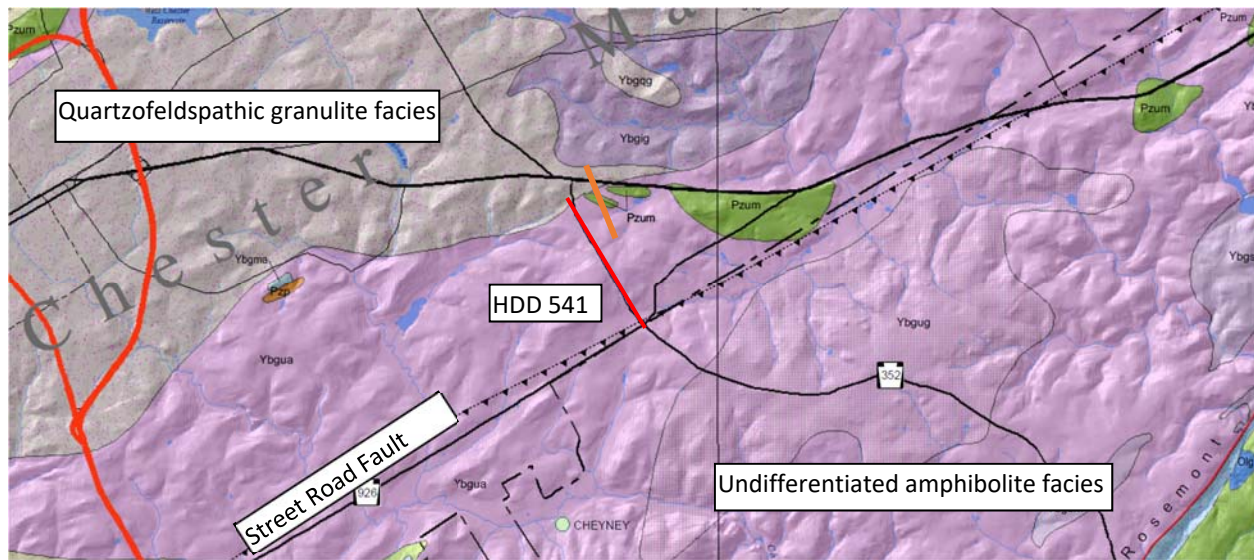
The nearest surface water bodies to the HDD location are tributaries East Branch Chester Creek, located approximately 1,000 feet to the west and flowing west and Hunters Run, located approximately 1,200 feet to the east and flowing northeast. Additional small ponds and related ephemeral streams are located in residential areas approximately 1,000 feet or more south of the HDD S3-0541 location. The lowest surface elevation along the drill is at a tributary stream (S-B35), crossing the boring at Station 57+41.

### 2.2 Geology

Bedrock in the area of HDD S3-0541 is comprised of crystalline, Precambrian-aged weathered Baltimore Gneiss – quartzofeldspathic granulite facies and undifferentiated amphibolite facies. Regional fabric (relict bedding and structure) trends are to the northeast as depicted in the geologic map below (Blackmer, 2005). **Figure 2** is a scaled map depicting site bedrock geology.

Information provided on drilling logs for eight (8) geotechnical borings was used in the development of this hydrogeologic reevaluation report (**Attachment B**). Please note that GES did not oversee or direct the geotechnical drilling programs associated with the HDD S3-0541, including but not limited to, the selection of number and location of borings, determination of surface elevations, 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. GES relied on these reports and incorporated their data into the general geologic and hydrogeologic framework for this hydrogeologic reevaluation report.

Three (3) geotechnical borings placed along the northern portion of the HDD S3-0541 alignment were advanced to auger refusal depths ranging from 18.5 to 32 feet. Three (3) geotechnical borings placed along the southern portion of the HDD S3-0541 alignment were advanced to auger refusal depths ranging from 30 to 68.5 feet. Two (2) recent geotechnical borings were also placed proximal to the northern and southern entry/exit points (B6-1W and B6-1E), and had auger refusal depths of 22 feet and 40 feet below ground surface (bgs), respectively. Based on the geotechnical boring data, overburden in the area of HDD S3-0541 can range in thickness from 18.5 to 68.5 ft bgs. This material is primarily composed of weathered in-situ gneiss bedrock and has been logged according to USCS methods as SM (silty sands and sand/silt mixtures).



**Figure 2. Regional Geologic Map** (modified from Blackmer, 2005)

### 2.2.1 Soils

Soils across the profile are comprised of loam, silt loam, gravelly silt loam, and urban land (USDA NRCS). Eastern and western entry/exit points are likely to encounter bedrock at an approximate depth of 20 feet below grade. The soil horizon across the central area of the profile are likely to encounter bedrock at an approximate depth of 20 to 40 feet below grade.

### 2.2.2 Bedrock Lithology

As noted, the HDD S3-0541 bore lies in an area of the Piedmont Uplands Section of the Piedmont physiographic province of Pennsylvania. Mapped as Pre-Cambrian Baltimore Gneiss – quartzofeldspathic granulite facies and undifferentiated amphibolite facies. As stated by Blackmer (2005):

*“Quartz-plagioclase-potassium feldspar-orthopyroxene-clinopyroxene-garnet-biotite gneiss.”*

*“Heterogeneous felsic, intermediate, and mafic amphibolite facies gneiss. Predominant lithology is intermediate plagioclase-hornblende-quartz-biotite gneiss with local orthopyroxene, clinopyroxene, potassium feldspar, and garnet. Swirling magmatic leucosome and biotite-rich restite layers are common. Felsic gneiss consists of quartz, plagioclase, microcline, and biotite with local muscovite and garnet. Mafic gneiss hornblende-plagioclase-quartz amphibolite with garnet and subordinate biotite.”*

These rocks are metamorphosed crystalline units of unknown thickness and limited primary porosity.

### 2.2.3 Structure

As shown in the regional geologic map compiled by Blackmer (2005), the amphibolite gneiss is bisected by the Street Road Thrust Fault at the southern end of HDD S3-0541 that is oriented northeast-southwest. HDD S3-0541 also lies within the West Chester Massif to the north and the Avondale Anticline to the south. Gross structural trends for the HDD S3-0541 location include folding, faulting, and foliation patterns striking northeast to nearly east-west with additional nearly orthogonal (nearly north-south) brittle features interspersed. These regional features are mapped within close proximity (i.e., one mile) of HDD S3-0541. A fracture trace study completed via analysis of stereo air photo pairs is shown below as **Figure 3** and demonstrates these regional patterns and relationships. The primary lineament trends are approximately N10°E, N80°W, and N45°E.

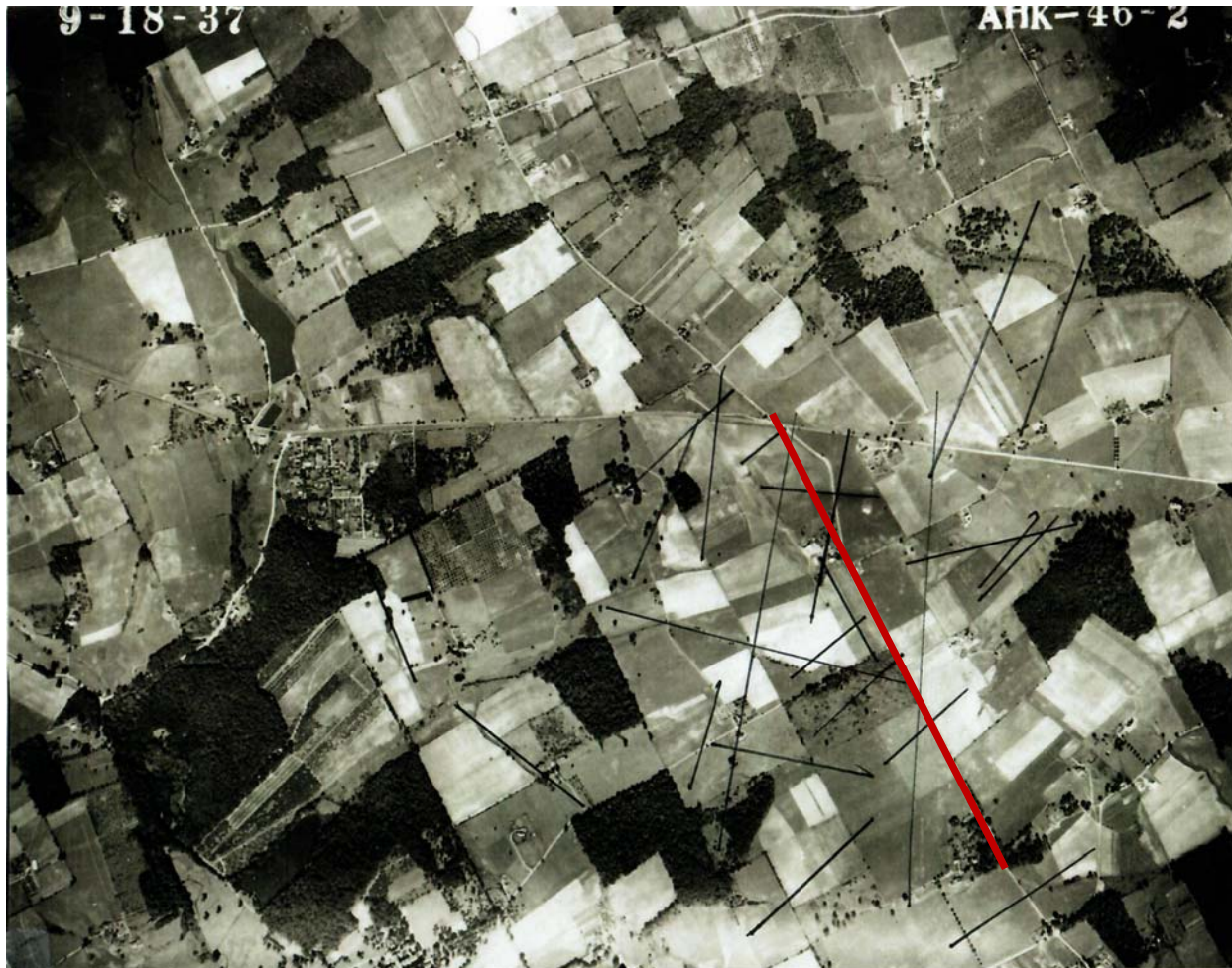


As shown on Figure 2, the Street Road fault, extends along the West Chester Massif and the Avondale Anticline intersecting the HDD near the southeastern entry/exit point at approximately 90 degrees. In the vicinity of this thrust fault, the mid-Proterozoic gneiss becomes mylonitic. The fault is not a single plane but a zone of smaller, southeast dipping planes that may represent a planar zone of enhanced secondary porosity, permitting fluids to flow more easily and farther along these planes than other discontinuities.

#### 2.2.4 Fracture Trace Analysis

Fracture trace analysis of high altitude aerial photography was performed for the area of interest to identify potential zones of bedrock weakness along drill paths. Fracture traces (one mile in length or less) and lineaments (greater than one mile in length) are the surficial expression on natural landscapes of vertical zones of bedrock fracture concentration. Fracture trace analysis is partly subjective; therefore, every mapped fracture trace does not necessarily represent a zone of bedrock fracture concentration.

**Figure 3** shows the fracture trace mapping that was performed for HDD S3-0541. This mapping was performed on aerial stereographic pairs flown in the September 18, 1937. As such, much of the land surface appears undeveloped therefore; fracture traces are more easily seen. The path of the drill is shown in red on **Figure 3** and transects six of the mapped fracture traces. These intersections with the drill path indicate potential vertical zones of weakness in the bedrock.



**Figure 3. Fracture Trace Analysis** (HDD S3-0541 approximate location shown as red line)

#### 2.2.5 Karst

The alignment of HDD S3-0541 is underlain by the Baltimore Gneiss, a metamorphic rock, non-carbonate rock formation. Therefore, karst features are not found in the vicinity of HDD S3-0541.

#### 2.2.6 Mining

No mining was identified within one mile of the HDD S3-0541 location.

#### 2.2.7 Rock Engineering Properties

Granitic Gneiss (Baltimore Gneiss) rock engineering properties are provided in Geyer and Wilshusen (1982) and listed, as follows:

- Bedding – none.
- Fractures/Joints have a blocky pattern and are moderately developed. They are further described as moderately, abundant widely spaced, and moderately dipping.
- Surface drainage is good.
- Joints provide a very low secondary porosity and low permeability. Median well yields are up to 10 gallons per minute (gpm).
- Drilling rate is slow.

#### 2.2.8 Results of Geotechnical Borings

As discussed in **Section 2.2**, drilling logs from eight geotechnical borings indicate weathered gneiss bedrock with a silty sand texture occurs at the surface in the area of HDD S3-0541 at a thickness ranging from 18.5 to 68.5 feet. Two (2) of the original set of geotechnical borings (SB-02 and SB-04) were advanced into bedrock by coring a maximum of 10 feet. The Rock Quality Determinations (RQDs) for these cores were low, ranging from 0 to 11%, as expected that close to the horizon of auger refusal. Rock cores were advanced to much deeper depths in the two more recent geotechnical borings (B6-1W and B6-1E). Bedrock in both borings was highly fractured with poor RQD values to a depth of about 55 ft bgs. Below that depth, RQDs averaged 63% but varied widely, ranging from 11 to 88 %, and displayed no trend with depth.

### 2.3 Hydrogeology

#### 2.3.1 Occurrence of Groundwater

The Baltimore gneiss unit mapped beneath the HDD S3-0541 location is identified as a unit of poor groundwater production. A limited network of fractures with small apertures generally provides the secondary porosity needed to support low groundwater discharges from this rock formation.

#### 2.3.2 Ground Elevation between HDD entry/exits

The topography in the area of HDD is relatively flat with the ground surface elevation at the northwestern entry/exit point identified as 401 ft amsl and the entry/exit point, 6,350 feet to the southeast at an elevation of 360 ft amsl. The profile shows a rise between these points with an elevation of approximately 470 ft amsl, peaking at Station 35+50, moving southeast from Station 0+00 at the northwest entry/exit. The lowest surface elevation along the drill is at stream S-B35 at approximate 352 ft amsl,

#### 2.3.3 Groundwater Levels

Groundwater was encountered at boring B6-1E near the southeast entry/exit points at a depth of 32.2 feet or 328 ft amsl. Boring B6-1W was dry to its total depth of 158.3 feet, an approximate elevation of 323 ft amsl. Groundwater was encountered in the original borings farther from the entry/exit points.

Tetra Tech's original boring profile sheets indicate depths to groundwater of 18 and 39 ft bgs and groundwater elevations ranging between approximately 351 to 425 ft amsl across the HDD (Tetra Tech,

2017). Borings near the northwest entry/exit point had a groundwater elevation of approximately 376 ft amsl, the central portion 431 ft amsl (at the peak of the topographic high) (see **Attachments A and B**). These elevations generally reflect a water table surface that is a subdued reflection of topography.

Using the existing water level information, the difference in groundwater elevation between the borings near the entry/exit points is approximately 48 feet. The difference in surface elevations of the entry/exit points is approximately 41 feet. A topographic high exists near the midpoint of the HDD S3-0541 with an approximate surface elevation of 470 ft amsl. This topographic high may act as a groundwater divide between the entry/exit points. The difference between the surface elevations of the entry/exit points and this topographic high is 110 feet (towards the southeast point) and 69 feet (towards the northwest point). The possibility of differing groundwater head pressures between the entry/exit points and the topographic high may exist which could cause excessive groundwater discharges at the entry/exit points during HDD construction and local water table lowering in the area of the topographic high.

#### **2.3.4 Well Yields**

Median well yields for this geologic setting are reported as variable but generally less than 10 gpm (Geyer and Wilshusen, 1982). A review of 12 nearby domestic wells recorded in the PAGWIS database revealed a median well yield of 8 gpm with a minimum of 4 gpm and maximum 60 gpm. The wells were completed in gneiss between 81 and 223 ft deep. These results are consistent with the median yield of 12 gpm (range 0.3 to 270 gpm) reported by a study of 509 domestic wells completed in gneissic rocks across Southeast Pennsylvania (Low et al., 2002).

#### **2.3.5 Water Supply Wells within 150 of ROW**

An initial pre-construction sampling program for domestic wells within 150 feet of the ROW was performed and resulted in the sampling of twenty-one (21) wells to establish a base line prior to HDD drilling.

### **2.4 Summary of Geophysical Studies**

No geophysical studies were recommended or performed for the reevaluation of HDD S3-0541 as the alignment is not in a karst area.

### **3.0 OBSERVATIONS TO DATE**

#### **3.1 On This HDD Alignment**

##### **3.1.1 ME I**

No IRs were observed during the installation of ME I at the location of HDD S3-0541.

##### **3.1.2 ME II**

No IRs have been observed as neither the 16-inch nor the 20-inch HDD has not been drilled at this time. This drill is designated as an “intersect drill” indicating that pilot advancement will occur at both the entry and exit locations of the drill profile.

#### **3.2 On Other HDD Alignments in Similar Hydrogeologic Settings**

##### **3.2.1 ME I**

An IR occurred approximately one mile southeast of the southeast entry/exit point for HDD S3-0541 during the installation of ME I. This IR is listed as HDD 24 on the list of MEI IRs provided in the IR PPC Plan for Delaware County.

##### **3.2.2 ME II**

IRs associated with ME II HDDs have been observed in similar geology (gneiss bedrock in Chester and Delaware Counties) at seven (7) HDD sites to date, recognizing however that there are variations of the mineralogical of the gneiss in differing lithologic units. Typically, IRs have occurred when the HDD intersects a zone of fracture concentration (indicated by a mapped fracture trace) or softer soils with increased bit pressure. An IR from HDD S3-0631 occurred when the HDD bore intersected fracture traces and highly fractured bedrock from installation of a sanitary sewer line that required blasting. An IR from HDD S3-0620 in the S-12 tributary to Chester Creek appears to be attributed to the intersection of a fracture trace by the HDD bore and increased groundwater head pressures resulting from elevation variations along the bore path.



## 4.0 SUMMARY AND CONCLUSIONS OF HDD HYDROGEOLOGIC EVALUATIONS

### 4.1 HDD Site Conceptual Model

The horizontal portions of the pipeline profile for the revised borings for HDD S3-0154 are at an elevation of approximately 288 ft amsl. Based on the geotechnical boring data, overburden in the area of HDD S3-0541 can range in thickness from 18.5 to 68.5 ft bgs. At the lowest surface elevation along the drill, at stream S-B35, the surface elevation is at approximately 352 ft amsl, so the bore at 288 ft amsl would be 64 ft bgs. Thus, highly weathered rock could exist along the 288 ft amsl elevation horizon. Entrance and exits will be passing through weathered gneiss overburden and this material lacks cohesive strength.

Rock cores were taken from two recent geotechnical borings below approximately 55 ft bgs had RQDs that averaged 63% but varied widely, ranging from 11 to 88 %, and displayed no trend with depth. As such, HDD construction in the coreable interval of bedrock surrounding the profile could encounter weak zones caused by bedrock fracturing. Note that the profile crosses six fracture traces mapped for this reevaluation.

The revised borings for the HDD S3-0541 drills are designated as an “intersect drills” indicating that pilot advancement will occur at both the entry and exit locations of the drill profile and the borings intersect at some point in between. Steering in the gneiss bedrock in Delaware County for MEII HDD drills advanced to date has been problematic due to variations in rock hardness and magnetic minerals within the formation. The metamorphic rocks found in Spread 6 are not homogenous but more heterogenous due to a wide variety of minerals and rock types of differing degrees of hardness. These minerals and rocks can divert the drill bit from the intended alignment. Drilling along strike may be slowed by a mylonitic layer of harder rock until the harder section either pinches out or the HDD path moves out of the zone. Drilling perpendicular to strike has difficulties, as well. While a harder zone may be drilled through more quickly the variation in hardness tend to deflect the bit from the intended alignment, causing the drilling to be slowed due to extra location checks and additional steering back to the alignment.

Groundwater was encountered in geotechnical borings at elevations that generally reflect variations in surface topography. The topographic high likely represents a groundwater divide between both entry points. The difference between the surface elevations of this topographic high and the entry/exit points are 115 feet (moving east) and 74 feet (moving west). The estimated differences in groundwater level from this topographic high to the entry/exit points is 103 feet moving east and 60 feet moving west. These elevation differences could cause excessive groundwater discharge at the entry/exit points during construction and a lowering of the water table in the area of the high point, and several domestic water wells are known to be proximal to the HDD alignment. Monitoring of representative groundwater levels in the area of the topographic high, both pre-construction and during construction, could provide useful information relative to the potential for lowering water levels and whether the pipe installation actually affects water levels.

### 4.2 Recommendations

As discussed in **Section 4.1**, this hydrogeologic reevaluation for HDD S3-0541 has identified a few issues that need to be addressed to minimize the risk of IRs and potential adverse effect to the local bedrock aquifer. These issues are related to a drill that would be constructed according to the revised boring plan, dated April 16, 2017, that lowers the horizontal section of the 20-inch and 16-inch borings approximately 5 feet. Alternatives to HDD drilling, changes to the HDD design, and/or changes to drilling procedures should account for potential weakness in the overburden materials, weakness in the bedrock, and elevation differences in the water table between the high point and the entry/exit points.

Pre-construction and during construction monitoring of groundwater levels could be performed in the central, higher ground along the profile. Representative pre-construction water level data may be available as a result of the 450-foot well survey. Both pre-construction and during construction water level data could be collected from cooperative well owners in the area of interest, or by installing a couple of monitoring wells at strategic locations. In addition, monitoring of private domestic wells along the Street Road fault, northeast and southwest of the fault / alignment intersection during HDD installation would be useful for minimizing potential water supply impacts. To date, steering within the Baltimore Gneiss has been problematic and revised plans for the HDD should take steering issues into consideration, especially if intersect drills are considered. The only practical solutions for optimizing progress and staying on alignment may be to govern drilling rates and continue to use greater than typical alignment checks to maintain alignment. In addition, consideration should be given to lowering bit pressures, as well as mud pressures. Higher bit pressures can cause undue wear on and slow overall advancement of the HDD. Diamond bits may be beneficial for maintaining the cutting surface and steering through hard rock zones.

Groundwater flowback to the entry point(s) may be an issue due to the hill near the midpoint of the HDD being higher in elevation than the northwest and southeast entry points. An intercept drill, using two drill rigs is being proposed as the planned profile long, at 6,300 feet. It would be advantageous to intersect north of the intervening hill to better manage the groundwater at the southeast entry point. There is more room at this location and adjacent areas, such as the open cut section and LOD for HDD 560-16 could be utilized.

## 5.0 REFERENCES

Blackmer, G. C., 2005, *Preliminary Bedrock Geologic Map of a Portion of the Wilmington 30- by 60-Minute Quadrangle, Southeastern Pennsylvania*. Pennsylvania Geologic Survey.

Geyer, A. R. and J. P. Wilshusen, 1982, *Engineering Characteristics of the Rocks of Pennsylvania*. Pennsylvania Department of Environmental Resources, Office of Resource Management, Bureau of Topographic and Geologic Survey.

Low, D.J., D.J. Hippo, and D. Yannacci, 2002, *Geohydrology of Southeastern Pennsylvania*, United States Geological Survey, Water-Resources Investigations Report 00-4166.

Pennsylvania Geological Survey. Pennsylvania groundwater information system (PaGWIS). Pennsylvania Geological Survey, 4<sup>th</sup> series, SQL database,  
<http://dcnr.state.pa.us/topogeo/groundwater/pagwis/records/index.htm>.

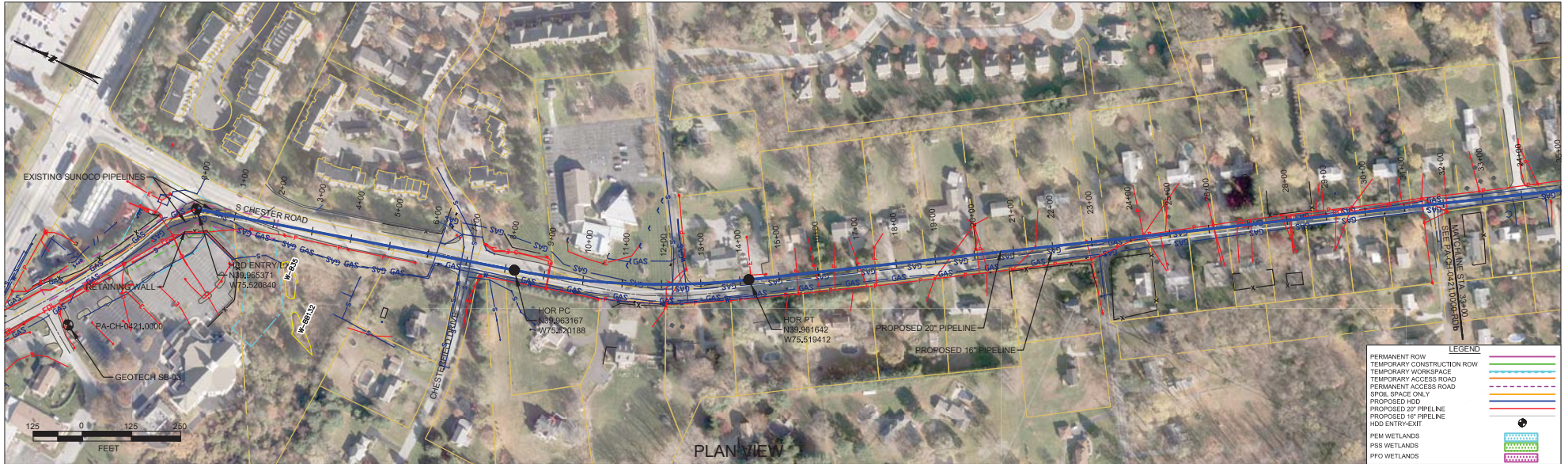
USDA NRCS WSS, United States Department of Agriculture, Natural Resources Conservation Service – Web Soil Survey for Chester County. (<https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx>).

United States Geologic Survey, 1983, *7.5 Minute Topographic Quadrangle, Downingtown, Pennsylvania*.

## **Attachment A**

Original and Revised Plan and Profile

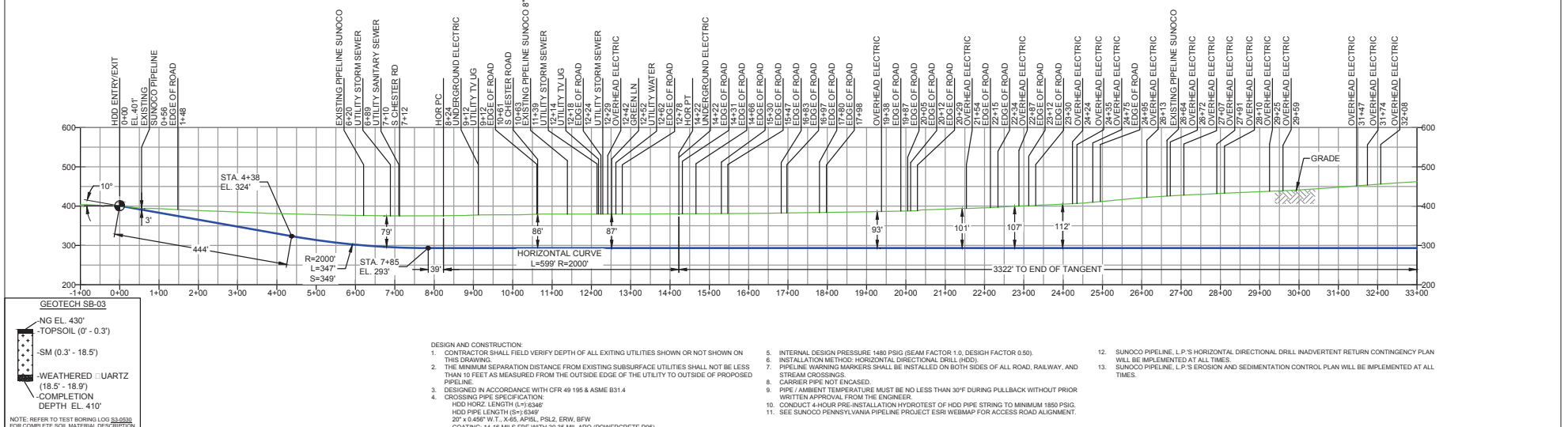




CHESTER/DELAWARE COUNTY PENNSYLVANIA, WESTTOWN/EDMONT TOWNSHIP  
S3-0541A

PLAN VIEW

PROFILE VIEW



**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, L.P. 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, L.P. 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.

**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 HORIZ. LENGTH (L)=6346'  
HDD PIPE LENGTH (D)=6346'  
20" x 0.436" W.T. X-65, API5L, PSL2, ERW, BFW  
COATING: 14-16 MILS FBE WITH 35-35 MIL ARD (POWERCONCRETE R95)

5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50).

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 ESR 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.

**REVISIONS**

NO.	DATE	BY	CHK	DATE	APP	DATE
1	05/10/16	JTW	RMB	05/10/16	AAW	05/10/16
2	02/26/16	MRS	RMB	02/26/16	AAW	02/26/16
3	02/19/16	MRS	RMB	02/19/16	AAW	02/19/16

**REF. DRAWING**

TO	FROM	DESCRIPTION
EA-6.70	EA-6.01	EROSION & SEDIMENT PLAN
SHEET 46	SHEET 1	AERIAL SITE PLAN

**LEGEND**

PERMANENT ROW  
TEMPORARY CONSTRUCTION ROW  
TEMPORARY WORKSPACE  
TEMPORARY ACCESS ROAD  
PERMANENT ACCESS ROAD  
SPOIL SPACE ONLY  
PROPOSED HDD  
PROPOSED 20" PIPELINE  
PROPOSED 16" PIPELINE  
HDD ENTRY/EXIT  
PEM WETLANDS  
PBS WETLANDS  
PFO WETLANDS

**Sunoco Logistics Partners L.P.**

**SUNOCO PIPELINE, L.P.**

20-INCH HORIZONTAL DIRECTIONAL DRILL  
S CHESTER ROAD  
PENNSYLVANIA PIPELINE PROJECT

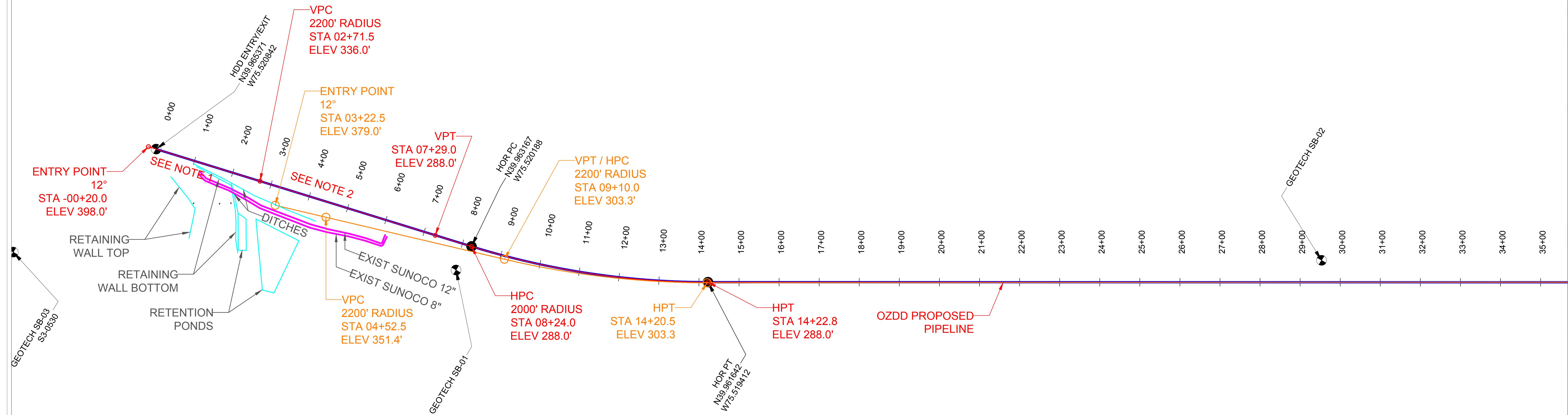
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DWG. NO: PA-CH-0421.0000-RD



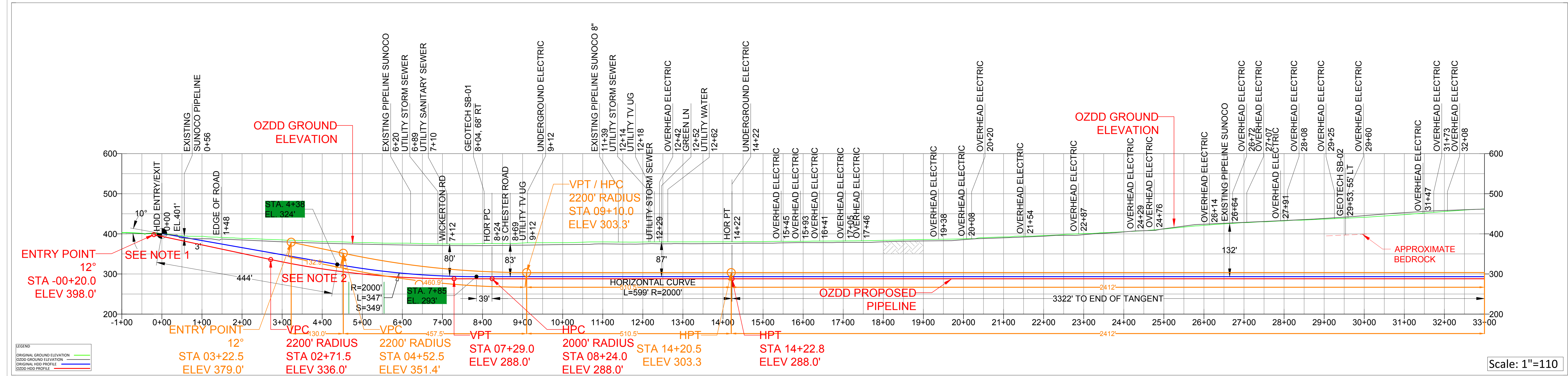





S3-541 S. Chester Road



Scale: 1"=110'



Scale: 1"=110'



**Oz Directional Drilling, Inc.**  
36660 North Pima Road Suite 402  
PHONE: (480) 306 6570  
Fax: (480) 306 6504

Project Name: **Mariner East II**

Project Owner: **Sunoco Logistics Partners L.P.**

Contractor: **Otis Eastern Service, Inc.**

HDD Name: **S3-541 S. Chester Road**

Location: **Chester / Delaware County**

OZDD Job Number: **N/A**

Design Length: **6381.2' / 6035.1'**

Vertical Radius: **2200'**

Horizontal Radius: **2000' / 2200'**

No.	Revision/Issue	Date
0	For Review Only	02.09.17
1	Option 2 For Review Only	04.26.17

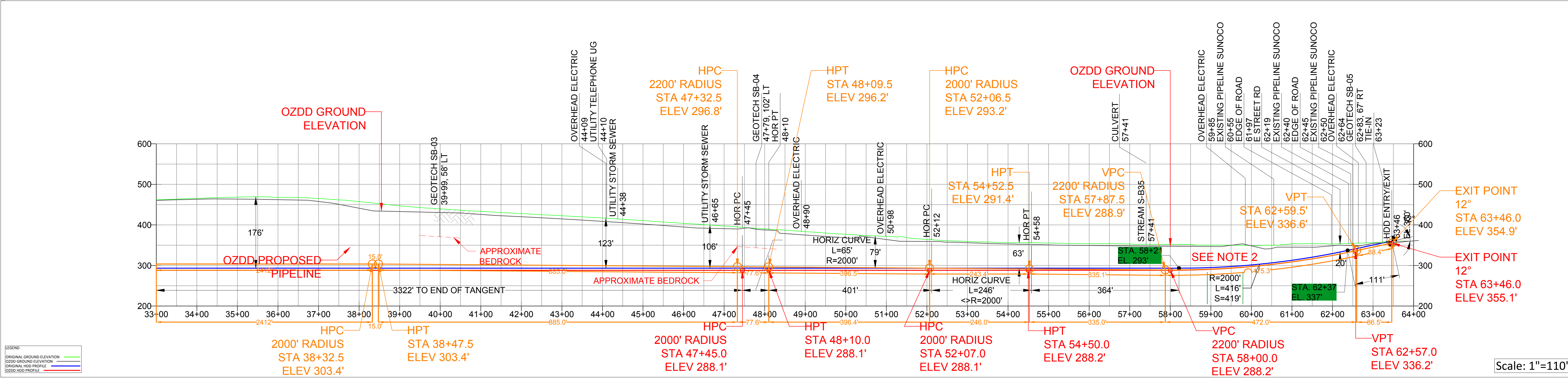
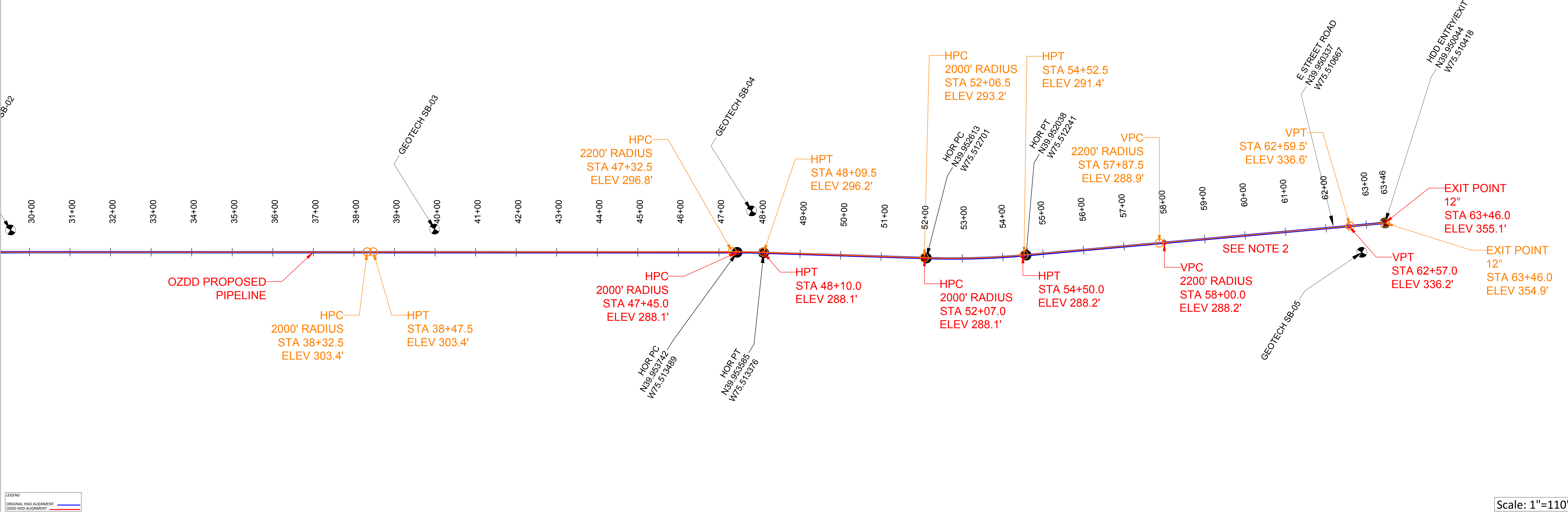
Notes


1 Entry angle has been increased from 10° to 12° and entry has been moved back 20' to provide more cover below existing Sunoco hotline.

2 Vertical curve radii have been increased from 2000' to 2200' providing more steering flexibility while building and dropping angle.



# S3-541 S. Chester Road





Oz Directional Drilling, Inc.  
36660 North Pima Road Suite 402  
PHONE: (480) 306 6570  
Fax: (480) 306 6504

Project Name: Mariner East II

Project Owner: Sunoco Logistics Partners L.P.

Contractor: Otis Eastern Service, Inc.

HDD Name: S3-541 S. Chester Road

Location: Chester / Delaware County

OZDD Job Number: N/A

Design Length: 6381.2' / 6035.1'

Vertical Radius: 2200'

Horizontal Radius: 2000' / 2200'

No.	Revision/Issue	Date
0	For Review Only	02.09.17
1	Option 2 For Review Only	04.26.17

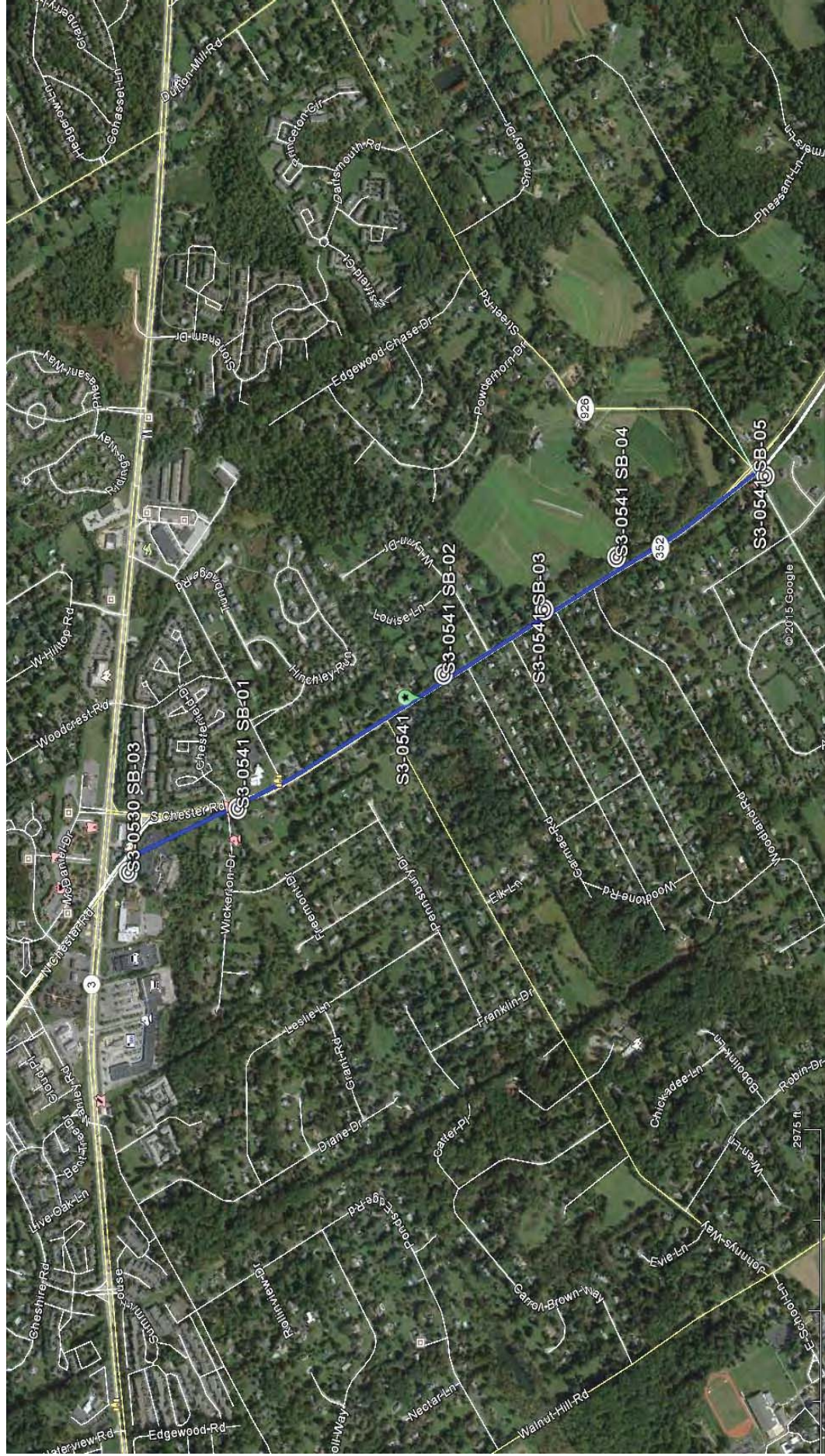
Notes

2 Vertical curve radii have been increased from 2000' to 2200' providing more steering flexibility while building and dropping angle.

## **Attachment B**

### **Geotechnical Information**





**LEGEND:**

◎ Geotechnical Soil Boring (SB) Locations



**TETRA TECH**

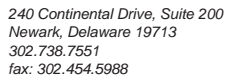
GEOTECHNICAL BORING LOCATIONS

HDD S3-0541

CHESTER COUNTY, WESTTOWN TWP, AND

DELAWARE COUNTY, THORNBURY TWP, PA

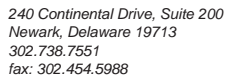
SUNOCO PENNSYLVANIA PIPELINE PROJECT



Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406
Project Location:	6 CAVANAUGH COURT, ST. SIMON & JUDE CHURCH, WEST CHESTER, PA			Page 1 of 1
HDD No.:	S3-0530	Dates(s) Drilled: 06-27-15	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):	18.9
Boring Location Coordinates:	39° 57' 57.12" N		75° 31' 20.11" W	

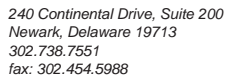
N: Number of blows to drive spoon from 6" to 18" interval.





N: Number of blows to drive spoon from 6" to 18" interval.



[illegible]

DR: DECOMPOSED ROCK

\* 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.

**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: 1009 MIDDLETOWN RD, WEST CHESTER, PA						Page 1 of 1									
HDD No.:		S3-0541		Dates(s) Drilled: 09-13-15		Inspector:		E. WATT							
Boring No.:		SB-03		Drilling Method: SPT - ASTM D1586		Driller:		S. HOFFER							
Drilling Contractor:		HAD DRILLING		Groundwater Depth (ft): SEE NOTES		Total Depth (ft):		68.5							
Boring Location Coordinates:				39° 57' 20.144" N		75° 30' 52.646" W									
Sample No.	Sample Depth (ft)		Strata Depth (ft)		Recov. (in)	Strata (USCS)	Description of Materials				6" Increment Blows *				N
	From	To	From	To											
			0.0	0.1			TOPSOIL (2")								
1	3.0	5.0	0.1		10	ML	YELLOWISH BROWN TO BROWN SILT WITH SOME FINE SAND, TRACE				5	7	8	11	15
				9.0			FINE GRAVEL.								
2	8.0	10.0	9.0		17	SM	DR, VARIEGATED BROWN, TAN, GRAY FINE TO MEDIUM SAND AND				3	6	7	9	13
							SILT, TRACE UNWEATEHRED FINE ROCK FRAGS.								
3	13.0	15.0			15		SAME				1	4	6	7	10
4	18.0	20.0			21		DR, VARIEGATED GRAY, ORANGE BROWN, TAN, WHITE F-M SAND				2	21	41	50	62
							AND SILT, WITH A LITTLE F-C UNWEATHERED ROCK FRAGS.								
5	23.0	25.0			13		DR, VARIEGATED REDDISH BROWN, GRAY, BLACK MICACEOUS FINE				1	2	4	5	6
							SAND AND SILT. (USCS: SM).								
6	28.0	29.9			16		DR, VARIEGATED REDDISH BROWN, GRAY, BLACK MICACEOUS F-C				1	4	12	50/5"	16
							SAND WITH SOME SILT, TRACE UNWEATHERED F-C ROCK FRAGS.								
7	33.0	35.0			17		DR, VARIEGATED GRAY, BROWN, ORANGE BROWN MICACEOUS F-M				13	12	32	44	44
							SAND WITH SOME SILT.								
8	38.0	39.8			14		SAME, WITH A LITTLE F-C UNWEATHERED ROCK FRAGS.				2	19	32	50/3"	51
9	43.0	45.0			13		DR, VARIEGATED GRAY, BROWN, WHITE MICACEOUS FINE TO MEDIUM				9	9	22	39	31
							SAND AND SILT, TRACE UNWEATHERED ROCK FRAGS.								
10	48.0	50.0			12		SAME				2	8	10	18	18
11	53.0	54.3			19		SAME (USCS: SM).				2	22	50/4"		>50
12	58.0	59.4			16		DR, VARIEGATED GRAY, BROWN, WHITE MICACEOUS FINE TO MEDIUM				3	25	50/5"		>50
							SAND AND SILT, WITH A LITTLE UNWEATHERED ROCK FRAGS.								
13	63.0	64.0			8		SAME				13	50/6"			>50
14	68.0	68.3		68.5	4	SAME				50/3"				>50	
							AUGER REFUSAL AT 68.5'.								

## Notes/Comments:

Pocket Pentrometer Testing  
S1: 2.75 TSF

DR: DECOMPOSED ROCK (FELSIC GNEISS ORIGIN)

PERCHED WATER AT 8'.  
WATER LEVEL THROUGH AUGERS AT 39'.  
CAVED AND WET AT 40'.

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.

**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:	1121 S. CHESTER ROAD, WEST CHESTER, PA			Page 1 of 1	
HDD No.:	S3-0541	Dates(s) Drilled:	07-09-15	Inspector:	E. WATT
Boring No.:	SB-04	Drilling Method:	SPT - ASTM D1586	Driller:	S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft):	18.0	Total Depth (ft):	48.0
Boring Location Coordinates:	39° 57' 13.675" N		75° 30' 47.131" W		

Sample No.	Sample Depth (ft)		Strata Depth (ft)		Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
	From	To	From	To								
			0.0	0.3			TOPSOIL (4")					
1	3.0	5.0	0.3		20	ML	REDDISH TO ORANGE BROWN SILT WITH A LITTLE FINE SAND, MICACEOUS. (USCS: ML).	1	5	4	5	9
2	8.0	10.0	6.5		16	SM	DR, VARIEGATED BROWN AND GRAY FINE TO MEDIUM SAND WITH SOME SILT, TRACE FINE ROCK FRAGS.	5	7	9	7	16
3	13.0	15.0			24		DR, VARIEGATED BROWN, ORANGE BROWN AND LIGHT GRAY FINE TO MEDIUM SAND, SOME SILT.	2	3	4	4	7
4	18.0	20.0			24		DR, VARIEGATED BROWN, ORANGE BROWN AND LIGHT GRAY FINE TO MEDIUM SAND AND SILT.	2	3	4	8	7
5	23.0	25.0			24		DR, VARIEGATED BROWN AND ORANGE BROWN FINE MICACEOUS SAND AND SILT.	1	6	10	15	16
6	28.0	30.0			24		DR, VARIEGATED BROWN FINE TO MEDIUM SAND AND SILT. (USCS: SM).	3	18	25	36	43
7	33.0	33.9	31.5		11		DR, VARIEGATED LIGHT BROWN AND BROWN MICACEOUS FINE TO MEDIUM SAND AND SILT, TRACE FINE GNEISS ROCK FRAGS.	6	50/5"			>50
8	38.0	38.8			7		DR, VARIEGATED LIGHT BROWN AND BROWN MICACEOUS FINE TO MEDIUM SAND AND SILT, TRACE FINE GNEISS ROCK FRAGS.	32	50/3"			>50
9	42.0	42.0	40.0	42.0	1		PARTIALLY WEATHERED GRAY GNEISS.	50/0"				>50
							AUGER REFUSAL AT 42'.					
							<u>ROCK CORING</u>					
RUN 1	42.0	46.0	42.0		41	GNEISS ROCK	INTENSELY TO VERY INTENSELY FRACTURED LIGHT GRAY TO GRAY FELSIC GNEISS.	TCR: 85%, SCR: 21%, RQD: 8%				
RUN 2	46.0	48.0		48.0	24		SAME	TCR: 100%, SCR: 21%, RQD: 0%				
							COULD NOT TEST CORE SAMPLE FOR COMPRESSIVE STRENGTH. DUE TO FRACTURE PLANES (WOULD BREAK DURING CORE PREP.)					

## Notes/Comments:

Pocket Pentrometer Testing  
S1: 3.5 TSF

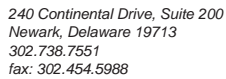
DR: DECOMPOSED ROCK

AUGER GRINDING AT 40'.  
WET ON SPOON AT 18'.  
WATER LEVEL THROUGH AUGERS AT 21'.  
CAVED AT 37.5', WATER LEVEL ON CAVE AT 16'.

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.



Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406
Project Location:	MIDDLETOWN ROAD AND RT. 926, GLEN MILLS, PA			Page 1 of 1
HDD No.:	S3-0541	Dates(s) Drilled: 11-12-15	Inspector:	J. COSTELLO
Boring No.:	SB-05	Drilling Method: SPT - ASTM D1586	Driller:	E. ODGEN
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED	Total Depth (ft):	30.0
Boring Location Coordinates:	39°57'0.29"N		75°30'38.61"W	

\* 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.

**ROCK CORE DESCRIPTION SUMMARY  
SUNOCO PENNSYLVANIA PIPELINE PROJECT  
HDD S3-0541**

Location	Boring No.	Core Run	Core Depth (ft)		TCR (%)	SCR (%)	RQD (%)	Depth (ft)		Weathering	Classification	Bedding Thickness (ft)	Color	Discontinuity Data
			From	To				From	To					
S3-0541	SB-02	1	32	37	82	33	9	32	37	Moderate	Gneiss	Massive	Gray and White	Nearly rubble, fracturing ranging from 25 to 60 degrees
		2	37	42	92	30	11	37	42	Moderate	Gneiss	Massive	Gray and White	Nearly rubble, no bedding visible.
	SB-4	1	42	46	85	21	8	42	46	Slight	Paragneiss	Massive	Gray	Fractures ranging from 30° to 65°, Avg. 60°
		2	46	48	100	21	0	46	48	Moderate	Gneiss	Thin (foliation)	Gray and White	Fractures average 45°; fractures parallel to foliation, no bedding visible

October 11, 2017



Directional Project Support, Inc.  
33311 Lois Lane, Suite A  
Magnolia, TX 77354

Attn: Mr. Robert Sessions  
P: (318) 542 6657  
E: fielduspl@hotmail.com

Re: Geotechnical Site Characterization  
Mariner East 2 Pipeline Project  
Spread 6 – South Chester Road  
Commonwealth of Pennsylvania  
Drawing #PA-CH-0459.000-RDa\_RDb  
PO #20170804-16  
Terracon Project No. J217P078

Dear Mr. Sessions:

This letter provides a summary of the bedrock characterization for the Mariner East 2 Pipeline Project crossing to be located at South Chester Road (Drawing # PA-CH-0459.000-RDa\_RDb) in the Commonwealth of Pennsylvania. Our services were performed in general accordance with our proposal number PJ2175108 dated July 28, 2017. Our scope of services included advancing two borings, designated as B6-1W and B6-1E, visual classification and photography of the rock core samples, and laboratory testing of representative rock samples.

Test borings, B6-1W and B6-1E were drilled between August 3 and September 8, 2017 to depths of 158.3 and 120.0 feet, respectively as shown on the attached **Test Boring Location Plan**. Bedrock typically consisted of metamorphic rock comprised of gneiss. Final test boring logs documenting overburden soil and bedrock conditions as well as photographs of the rock core samples are attached.

Rock compressive strength testing was performed on samples from approximately 20-foot intervals within the bedrock strata at each boring location. As an exception to the planned 20-foot intervals, a rock sample from B6-1W near 62 feet was not tested due to highly weathered conditions. Unconfined compressive strength test results are shown on the attached reports.



**Geotechnical Site Characterization**

Mariner East 2 Pipeline – Spread 6 South Chester Road ■ Pennsylvania  
Drawing #PA-CH-0459.0000-RDa\_RDb / PO #20170804-16  
October 11, 2017 ■ Terracon Project No. J217P078



When laboratory soil testing results are available, we will submit a complete data report for the subject crossing. In the meantime, if you have questions, or if we may be of further service, please contact us.

Sincerely,

**Terracon Consultants, Inc.**

A handwritten signature in blue ink, appearing to read "Lawrence J. Dwyer".

Marc A. Gullison, E.I.T.  
Staff Geotechnical Engineer

Lawrence J. Dwyer, P.E. (CT 15120)  
Principal

Attch:

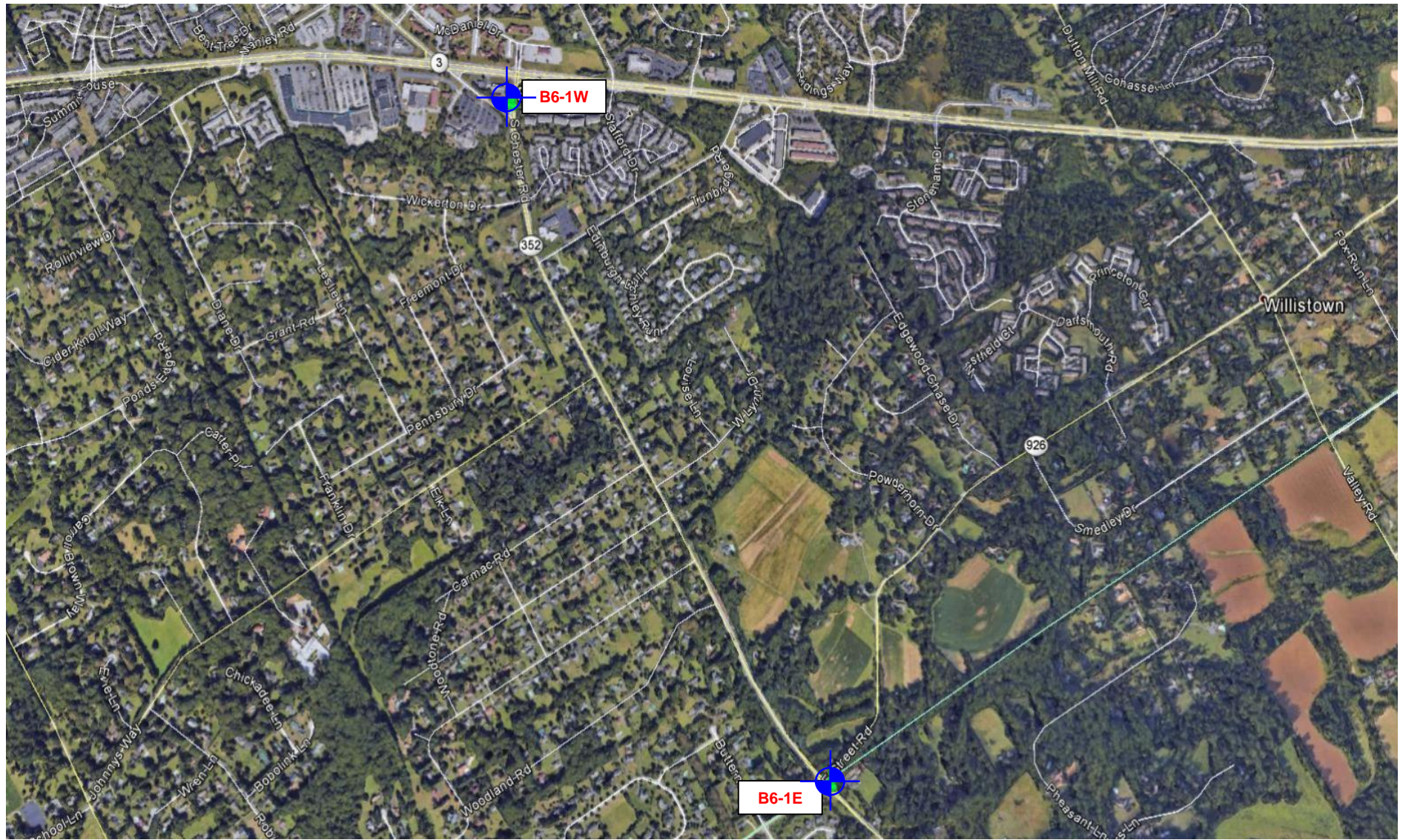
**TEST BORING LOCATION PLAN**

**EXPLORATION RESULTS** (Boring Logs, Laboratory Data, Rock Core Photographs)

**SUPPORTING INFORMATION** (Unified Soil Classification System, Description of Rock Properties)

## **TEST BORING LOCATION PLAN**





# **APPROXIMATE BORING LOCATION**

DIAGRAM IS FOR GENERAL LOCATION  
ONLY, AND IS NOT INTENDED FOR  
CONSTRUCTION PURPOSES

Project Manager:	JGS	Project No.	J217P078
Drawn by:	SBL	Scale:	N.T.S.
Checked by:	LJD	File Name:	J217P078 BLP
Approved by:	LJD	Date:	September, 2017

**Terracon**  
Consulting Engineers & Scientists

201 Hammer Mill Road Rocky Hill, Ct 06067  
PH. (860) 721-1900 FAX. (860) 721-1939

## **TEST BORING LOCATION PLAN**

South Chester Road HDD Cores B6-1W and B6-1E  
PA-CH-0459.0000-RDa\_RDb  
Chester County, Pennsylvania

Exhibit

**A-2**

## **EXPLORATION RESULTS**



## Page 1 of 6

**CLIENT: Directional Project Support Incorporated  
Magnolia, TX 77354**

[illegible]

Hammer Type: Automatic

Notes:

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL J217P078 - SPREAD 6.GPJ

# BORING LOG NO. B6-1W South Chester Road West

Page 2 of 6

**PROJECT:** Mariner East Pipeline Borings

**CLIENT:** Directional Project Support Incorporated  
Magnolia, TX 77354

**SITE:** Spread 6

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 39.96556° Longitude: -75.52087° Approximate Surface Elev: 365 (Ft.) +/- DEPTH ELEVATION (Ft.)								
	Run 2, Similar ( <i>continued</i> )				44			1 2	
32.0	Run 3, Very soft, very severely weathered, gray brown, medium-grained GNEISS, highly fractured, could not measure joints	333+/-			46.5		0	1 1 2 1 1	
37.0	Run 4, Similar	328+/-			52.5		13	1 1 1 1 1	
42.0	Run 5, Similar 42 to 48 feet, microcline GNEISS	323+/-			41		0	1 1 1 1 1	
47.0	Run 6, Soft, severely weathered, gray/light brown, medium-grained GNEISS, primary joint set low angle, very close, rough, open; secondary joint set high angle, moderately close, rough, open	318+/-			55		0	1 1 2 1 1	
52.0	Run 7, Moderately hard, moderately to severely weathered, light brown, medium-grained GNEISS, primary joint set low angle, close, rough, open; secondary joint set vertical, very close, rough, wide	313+/-			50.5		32	1 2 2 1 2	
57.0	Run 8, Moderately hard, moderately to severely weathered, light brown, medium-grained GNEISS, primary joint set low angle, close, rough, open; secondary joint set vertical, moderately close, rough, open	308+/-			60		78	1 1 2	
		60							

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:  
Mud rotary with wireline

See Exhibit A-3 for description of field procedures.  
See Appendix B for description of laboratory procedures and additional data (if any).  
See Appendix C for explanation of symbols and abbreviations.

Notes:

Abandonment Method:  
Grouted to surface

## WATER LEVEL OBSERVATIONS

Not encountered

**Terracon**  
201 Hammer Mill Rd  
Rocky Hill, CT

Boring Started: 9/7/2017

Boring Completed: 9/8/2017

Drill Rig: Mobile B-57

Driller: Terracon/S. Bray

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL J217P078 - SPREAD 6.GPJ

# BORING LOG NO. B6-1W South Chester Road West

Page 3 of 6

**PROJECT:** Mariner East Pipeline Borings

**CLIENT:** Directional Project Support Incorporated  
Magnolia, TX 77354

**SITE:** Spread 6

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 39.96556° Longitude: -75.52087°  Approximate Surface Elev: 365 (Ft.) +/- DEPTH ELEVATION (Ft.)								
	Run 8, Moderately hard, moderately to severely weathered, light brown, medium-grained GNEISS, primary joint set low angle, close, rough, open; secondary joint set vertical, moderately close, rough, open (continued)	62.0			60			2 1	
	Run 9, Moderately hard, moderately weathered, light brown/gray, medium-grained GNEISS, primary joint set low angle, very close, rough, open; secondary joint set high angle, very close, rough, open	67.0			60		37	1 2 2 2 2	
	Run 10, Similar	72.0			60		30	2 2 2 2 3	
	Run 11, Moderately hard, moderately weathered, dark gray, medium-grained GNEISS, primary joint set moderately dipping, very close, rough, open; secondary joint set high angle, close, rough, open	77.0			60		48	2 2 3 3 2	
	Run 12, Similar	82.0			60		64	2 2 2 3 3	
	Run 13, Hard, slightly weathered, gray/dark gray/white, medium-grained GNEISS, primary joint set low angle, close, rough, open; secondary joint set vertical, moderately close, rough, open	87.0			60		88	2 2 3 2 2	
	Run 14, Similar, vertical fractures at 91.5 to 92 feet				60		62	2 3 3	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:  
Mud rotary with wireline

See Exhibit A-3 for description of field procedures.  
See Appendix B for description of laboratory procedures and additional data (if any).  
See Appendix C for explanation of symbols and abbreviations.

Notes:

Abandonment Method:  
Grouted to surface

## WATER LEVEL OBSERVATIONS

Not encountered

**Terracon**  
201 Hammer Mill Rd  
Rocky Hill, CT

Boring Started: 9/7/2017

Boring Completed: 9/8/2017

Drill Rig: Mobile B-57

Driller: Terracon/S. Bray

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL J217P078 - SPREAD 6.GPJ


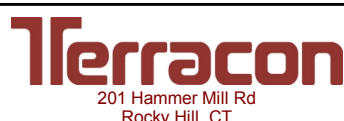
# BORING LOG NO. B6-1W South Chester Road West

Page 4 of 6

**PROJECT:** Mariner East Pipeline Borings

**CLIENT:** Directional Project Support Incorporated  
Magnolia, TX 77354

**SITE:** Spread 6

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 39.96556°    Longitude: -75.52087°  Approximate Surface Elev: 365 (Ft.) +/- DEPTH ELEVATION (Ft.)								
	Run 14, Similar, vertical fractures at 91.5 to 92 feet ( <i>continued</i> )				60			3	
	92.0 Run 15, Hard, slightly weathered to fresh, gray/brown, medium-grained GNEISS, primary joint set low angle, close, rough, open; secondary joint set moderately dipping, moderately close, rough, open	273+/-	95		60		67	3 3 3 3 3	
	97.0 Run 16, Hard, moderately weathered to fresh, brown/gray, medium-grained GNEISS, primary joint set moderately dipping, close, rough, open; secondary joint set low angle, moderately close, rough, open	268+/-	100		60		38	3 3 3 3 3	
	102.0 Run 17, Similar	263+/-	105		60		56	3 3 3 3 4	
	107.0 Run 18, Moderately hard, moderately to severely weathered, gray/brown, medium-grained GNEISS, primary joint set low angle, very close, rough, wide; secondary joint set medium angle, moderately close, rough, open	258+/-	110		60		11	3 3 3 2 2	
	112.0 Run 19, Moderately hard, moderately weathered, gray/brown, medium-grained GNEISS, primary joint set low angle, close, rough, open; secondary joint set high angle, moderately close, rough, open	253+/-	115		60		49	2 3 3 2 3	
	117.0 Run 20, Similar	248+/-	120		60		22	3 2 3	
	Stratification lines are approximate. In-situ, the transition may be gradual. Hammer Type: Automatic								
Advancement Method: Mud rotary with wireline		See Exhibit A-3 for description of field procedures. See Appendix B for description of laboratory procedures and additional data (if any).		Notes:					
Abandonment Method: Grouted to surface		See Appendix C for explanation of symbols and abbreviations.							
WATER LEVEL OBSERVATIONS		 201 Hammer Mill Rd Rocky Hill, CT		Boring Started: 9/7/2017		Boring Completed: 9/8/2017			
Not encountered				Drill Rig: Mobile B-57		Driller: Terracon/S. Bray			
				Project No.: J217P078					

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL J217P078 - SPREAD 6.GPJ

# BORING LOG NO. B6-1W South Chester Road West

Page 5 of 6

**PROJECT:** Mariner East Pipeline Borings

**CLIENT:** Directional Project Support Incorporated  
Magnolia, TX 77354

**SITE:** Spread 6

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 39.96556° Longitude: -75.52087° Approximate Surface Elev: 365 (Ft.) +/-								
	DEPTH ELEVATION (Ft.)								
	Run 20, Similar ( <i>continued</i> )				60			3 2	
	122.0 243+/-								
	Run 21, Hard, slightly weathered, gray/brown, medium-grained GNEISS, primary joint set medium angle, close, rough, open; secondary joint set high angle, close, rough, open	125			60		41	2 2 3 3 2	
	127.0 238+/-								
	Run 22, Similar, becoming less weathered	130			60		73	2 2 3 2 2	
	132.0 233+/-								
	Run 23, Very hard, fresh, gray, medium-grained GNEISS, primary joint set low angle, close to moderately close, rough, open	135			60		85	3 3 3 4 3	
	137.0 228+/-								
	Run 24, Very hard, fresh, gray, coarse to medium-grained GNEISS, primary joint set low angle, close, rough, open	140			60		76	5 5 5 6 5	
	142.0 223+/-								
	Run 25, Very hard, very slightly weathered, gray, medium-grained GNEISS, primary joint set low angle, moderately close, rough, open; secondary joint set high angle/vertical, close rough, wide	145			60		55	4 5 5 5 6	
	147.0 218+/-								
	Run 26, Similar	150			60		81	5 5 5	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:  
Mud rotary with wireline

See Exhibit A-3 for description of field procedures.  
See Appendix B for description of laboratory procedures and additional data (if any).  
See Appendix C for explanation of symbols and abbreviations.

Notes:

Abandonment Method:  
Grouted to surface

## WATER LEVEL OBSERVATIONS

Not encountered

**Terracon**  
201 Hammer Mill Rd  
Rocky Hill, CT

Boring Started: 9/7/2017

Boring Completed: 9/8/2017

Drill Rig: Mobile B-57

Driller: Terracon/S. Bray

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL J217P078 - SPREAD 6.GPJ






# BORING LOG NO. B6-1W South Chester Road West

Page 6 of 6

**PROJECT:** Mariner East Pipeline Borings

**CLIENT:** Directional Project Support Incorporated  
Magnolia, TX 77354

**SITE:** Spread 6

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 39.96556° Longitude: -75.52087°  Approximate Surface Elev: 365 (Ft.) +/- ELEVATION (Ft.)								
	Run 26, Similar (continued)				60			4	
	152.0 213+/-							4	
	Run 27, Similar				60		75	3	
	157.0 208+/-	155						3	
								3	
								3	
								3	
	<b>Boring Terminated at 158.3 Feet</b>								
<p>Stratification lines are approximate. In-situ, the transition may be gradual.</p> <p>Hammer Type: Automatic</p>									
<p>Advancement Method: Mud rotary with wireline</p>		<p>See Exhibit A-3 for description of field procedures. See Appendix B for description of laboratory procedures and additional data (if any). See Appendix C for explanation of symbols and abbreviations.</p>			<p>Notes:</p>				
<p>Abandonment Method: Grouted to surface</p>									
<p><b>WATER LEVEL OBSERVATIONS</b></p>		 <p>201 Hammer Mill Rd Rocky Hill, CT</p>		Boring Started: 9/7/2017		Boring Completed: 9/8/2017			
<p>Not encountered</p>				Drill Rig: Mobile B-57		Driller: Terracon/S. Bray			
				Project No.: J217P078					

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 6.GPJ

# BORING LOG NO. B6-1E South Chester Road East

Page 1 of 4

**PROJECT:** Mariner East Pipeline Borings

**CLIENT:** Directional Project Support Incorporated  
Magnolia, TX 77354

**SITE:** Spread 6

GRAPHIC LOG	LOCATION		DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 39.95009° Longitude: -75.510435°									
	Approximate Surface Elev: 360 (Ft.) +/-									
	DEPTH									
	ELEVATION (Ft.)									
	1.5	Topsoil, silty sand, brown	358.5+/-		X	10	3-3-4 N=7			
		Highly weathered rock, medium dense								
			5		X	15	3-4-5 N=9			
			10		X	17	9-10-13 N=23			
	15.0	Weathered rock, medium dense to very dense	345+/-		X	14	6-8-9 N=17			
			20		X	13	5-10-13 N=23			
			25		X	14	9-21-49 N=70			
			30		X	15	16-21-23 N=44			
			35							

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:  
Mud rotary with wireline

See Exhibit A-3 for description of field procedures.  
See Appendix B for description of laboratory procedures and additional data (if any).  
See Appendix C for explanation of symbols and abbreviations.

Notes:

Abandonment Method:  
Grouted to surface

## WATER LEVEL OBSERVATIONS

32.2' on 8/8/17

**Terracon**  
201 Hammer Mill Rd  
Rocky Hill, CT

Boring Started: 8/3/2017

Boring Completed: 8/8/2017

Drill Rig: Diedrich D-50

Driller: Terracon/Clayton J.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 6.GPJ

# BORING LOG NO. B6-1E South Chester Road East

Page 2 of 4

**PROJECT:** Mariner East Pipeline Borings

**CLIENT:** Directional Project Support Incorporated  
Magnolia, TX 77354

**SITE:** Spread 6

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 39.95009° Longitude: -75.510435°  Approximate Surface Elev: 360 (Ft.) +/- ELEVATION (Ft.)								
	DEPTH								
	Weathered rock, medium dense to very dense ( <i>continued</i> )			X	15	20-27-30 N=57			
	40.0 320+/-	40							
	Run 1, Moderately hard, moderately severe weathering, gray, fine-grained, GNEISS, very thin, moderately dipping foliation; primary joint set, moderately dipping, very close spacing, rough, tight to moderately open, oxidation along joints				32		7	1 1 1.5 1 1	
	45.0 315+/-	45							
	Run 2, Similar to 49 feet								
	At 49 feet: Hard, very slight weathering, gray to white, fine-grained, GNEISS, very thin, moderately dipping foliation; primary joint set, moderately dipping, very close to close spacing, rough, tight to moderately open, frequent quartz intrusions				40		10	1 1.5 2 1 2.5	
	50.0 310+/-	50							
	Run 3, Similar								
	55.0 305+/-	55			52		35	1.5 1.5 1.5 1.5 1.5	
	Run 4, Similar, very close to moderately close spacing								
	60.0 300+/-	60			60		63	2 2 2 2 2	
	Run 5, Similar, close to moderately close spacing								
	65.0 295+/-	65			57		65	2 2 2 2 2.5	
	Run 6, Similar, very close to close spacing, high angle joint from 67.5 to 68 feet								
	70.0 290+/-	70			60		63	2 3 3.5 5.5 3	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:  
Mud rotary with wireline

See Exhibit A-3 for description of field procedures.  
See Appendix B for description of laboratory procedures and additional data (if any).  
See Appendix C for explanation of symbols and abbreviations.

Notes:

Abandonment Method:  
Grouted to surface

## WATER LEVEL OBSERVATIONS

32.2' on 8/8/17

**Terracon**  
201 Hammer Mill Rd  
Rocky Hill, CT

Boring Started: 8/3/2017

Boring Completed: 8/8/2017

Drill Rig: Diedrich D-50

Driller: Terracon/Clayton J.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL J217P078 - SPREAD 6.GPJ

# BORING LOG NO. B6-1E South Chester Road East

Page 3 of 4

**PROJECT:** Mariner East Pipeline Borings

**CLIENT:** Directional Project Support Incorporated  
Magnolia, TX 77354

**SITE:** Spread 6

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 39.95009° Longitude: -75.510435° Approximate Surface Elev: 360 (Ft.) +/-								
	DEPTH	ELEVATION (Ft.)							
	Run 7, Similar, close to wide spacing				60		88	2.5 3.5 5 4.5 3	
75.0		285+/-							
	Run 8, Similar, close to moderately close spacing, high angle joint from 79 to 80 feet				60		65	3.5 2.5 3 3 3.5 4	
80.0		280+/-							
	Run 9, Similar, high angle joint from 84 to 84.5 feet				60		78	3.5 5 6 5 4.5	
85.0		275+/-							
	Run 10, Similar, very close to close spacing				57		75	2 2.5 3 2.5 3	
90.0		270+/-							
	Run 11, Similar, close to moderately close spacing, vertical joint from 94.5 to 95 feet				60		76	2.5 6.5 6 8.5 12	
95.0		265+/-							
	Run 12, Similar, increased quartz content from 95 to 96 feet, high angle joint from 96 to 96.5 feet				51		73	17 22 32 4 3.5	
100.0		260+/-							
	Run 13, Similar, high angle joint at 102 feet				60		82	3.5 3.5 3 3 3.5	
105.0		255+/-							

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:  
Mud rotary with wireline

See Exhibit A-3 for description of field procedures.  
See Appendix B for description of laboratory procedures and additional data (if any).  
See Appendix C for explanation of symbols and abbreviations.

Notes:

Abandonment Method:  
Grouted to surface

## WATER LEVEL OBSERVATIONS

32.2' on 8/8/17

**Terracon**  
201 Hammer Mill Rd  
Rocky Hill, CT

Boring Started: 8/3/2017

Boring Completed: 8/8/2017

Drill Rig: Diedrich D-50

Driller: Terracon/Clayton J.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 6.GPJ

# BORING LOG NO. B6-1E South Chester Road East

Page 4 of 4

**PROJECT:** Mariner East Pipeline Borings


**CLIENT:** Directional Project Support Incorporated  
Magnolia, TX 77354

**SITE:** Spread 6

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 39.95009° Longitude: -75.510435°  Approximate Surface Elev: 360 (Ft.) +/- ELEVATION (Ft.)								
	Run 14, Similar, high angle joints at 106, 107, and 109 feet 110.0 250+/-	110			60		63	3 3.5 3.5 3 3.5	
	Run 15, Similar, high angle joint at 112 feet 115.0 245+/-	115			58		73	2 3 4 5 4	
	Run 16, Similar, high angle joint at 119 feet 120.0 240+/-	120			57		81	3 2.5 3 3.5 3	
	<b>Boring Terminated at 120 Feet</b>								

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method: Mud rotary with wireline	See Exhibit A-3 for description of field procedures. See Appendix B for description of laboratory procedures and additional data (if any). See Appendix C for explanation of symbols and abbreviations.	Notes: Artesian pressure observed while coring from 115 to 120 feet	
Abandonment Method: Grouted to surface			
<b>WATER LEVEL OBSERVATIONS</b>	 <p>201 Hammer Mill Rd Rocky Hill, CT</p>	Boring Started: 8/3/2017	Boring Completed: 8/8/2017
 32.2' on 8/8/17		Drill Rig: Diedrich D-50	Driller: Terracon/Clayton J.
		Project No.: J217P078	

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 6.GPJ

# ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.: B6-1W  
 Sample No.: 1  
 Sample Depth: 42 feet  
 Sampling Date: 9/7/17

Lithology : Gneiss  
 Moisture Content : As received  
 Lab Temperature : 70° F  
 Loading Rate: 55 psi/s  
 Time to Failure: 4 min

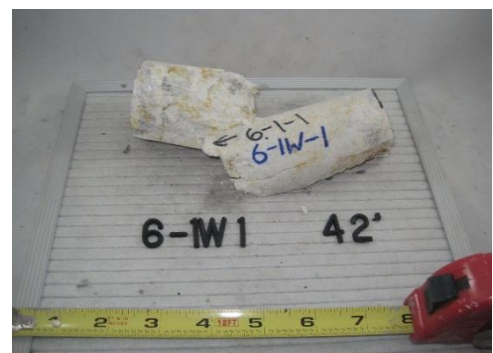
Diameter: 1.97 in  
 Length: 4.54 in  
 L/D: 2.30  
 End Area: 3.05 in<sup>2</sup>

Maximum Axial Load at Failure: 12,240 lb  
 Compressive Strength: 4,016 psi  
 Compressive Strength: 27.69 Mpa  
 Unit Weight 158 pcf


Before the Test



After the Test



Drawing # : PA-CH-0459.0000-RDa\_RDb  
 PO # : 20170804-16  
 Crossing : South Chester Road  
 Spread : Spread 6

Project:	Mariner East Pipeline	 <b>Terracon</b> 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	H. Whitford
Project No.	J217P078		Test Date:	10/9/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/10/2017

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# ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.: B6-1W  
 Sample No.: 3  
 Sample Depth: 81.5 feet  
 Sampling Date: 9/7/17

Lithology : Gneiss  
 Moisture Content : As received  
 Lab Temperature : 70° F  
 Loading Rate: 55 psi/s  
 Time to Failure: 2 min

Diameter: 1.98 in  
 Length: 4.48 in  
 L/D: 2.26  
 End Area: 3.08 in<sup>2</sup>

Maximum Axial Load at Failure: 7,340 lb  
 Compressive Strength: 2,384 psi  
 Compressive Strength: 16.44 Mpa  
 Unit Weight 133 pcf


Before the Test



After the Test



Drawing # : PA-CH-0459.0000-RDa\_RDb  
 PO # : 20170804-16  
 Crossing : South Chester Road  
 Spread : Spread 6

Project:	Mariner East Pipeline	 <b>Terracon</b> 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No.	J217P078		Test Date:	9/13/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/10/2017

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# ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.: B6-1W  
 Sample No.: 4  
 Sample Depth: 98 feet  
 Sampling Date: 9/7/17

Lithology : Gneiss  
 Moisture Content : As received  
 Lab Temperature : 70° F  
 Loading Rate: 55 psi/s  
 Time to Failure: 2 min

Diameter: 1.98 in  
 Length: 3.57 in  
 L/D: 1.80  
 End Area: 3.08 in<sup>2</sup>

Maximum Axial Load at Failure: 5,830 lb  
 Compressive Strength: 1,893 psi  
 Compressive Strength: 13.05 Mpa  
 Unit Weight 168 pcf

Comments : Due to lack of available specimens, the length to diameter ratio of the tested specimen is not conformant with ASTM D7012. The results obtained during testing may differ from those obtained from the test specimens that meet the requirements.


Before the Test



After the Test

Photograph after the test is not available

Drawing # : PA-CH-0459.0000-RDa\_RDb  
 PO # : 20170804-16  
 Crossing : South Chester Road  
 Spread : Spread 6

Project:	Mariner East Pipeline	 <b>Terracon</b> 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No.	J217P078		Test Date:	9/13/2017
Location:	Spread 6		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/10/2017

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# ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

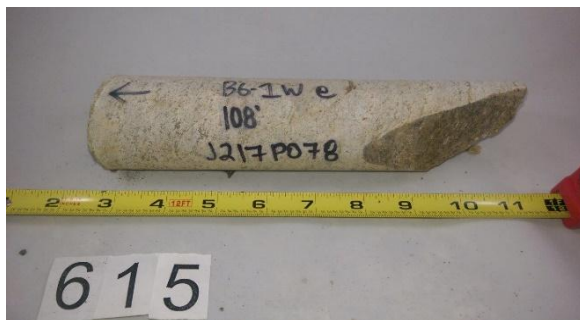
Boring No.: B6-1W  
 Sample No.: 5  
 Sample Depth: 108 feet  
 Sampling Date: 9/7/17

Lithology : Gneiss  
 Moisture Content : As received  
 Lab Temperature : 70° F  
 Loading Rate: 55 psi/s  
 Time to Failure: 6 min

Diameter: 1.98 in  
 Length: 4.57 in  
 L/D: 2.31  
 End Area: 3.08 in<sup>2</sup>

Maximum Axial Load at Failure: 18,240 lb  
 Compressive Strength: 5,924 psi  
 Compressive Strength: 40.84 Mpa  
 Unit Weight 162 pcf


Before the Test



After the Test



Drawing # : PA-CH-0459.0000-RDa\_RDb  
 PO # : 20170804-16  
 Crossing : South Chester Road  
 Spread : Spread 6

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No:	J217P078		Test Date:	9/13/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/10/2017

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# ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

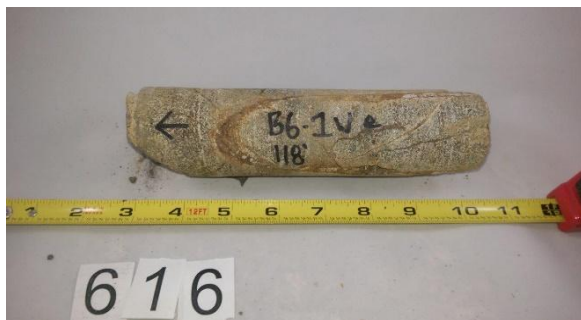
Boring No.: B6-1W  
 Sample No.: 6  
 Sample Depth: 118 feet  
 Sampling Date: 9/7/17

Lithology : Gneiss  
 Moisture Content : As received  
 Lab Temperature : 70° F  
 Loading Rate: 55 psi/s  
 Time to Failure: 2 min

Diameter: 1.98 in  
 Length: 4.62 in  
 L/D: 2.33  
 End Area: 3.08 in<sup>2</sup>

Maximum Axial Load at Failure: 6,610 lb  
 Compressive Strength: 2,147 psi  
 Compressive Strength: 14.80 Mpa  
 Unit Weight 171 pcf


Before the Test



After the Test



Drawing # : PA-CH-0459.0000-RDa\_RDb  
 PO # : 20170804-16  
 Crossing : South Chester Road  
 Spread : Spread 6

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No.	J217P078		Test Date:	9/13/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/10/2017

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# ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

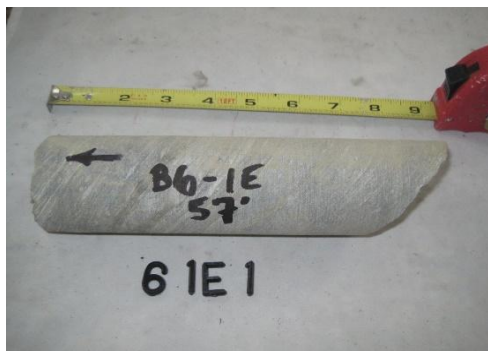
Boring No.: B6-1E  
 Sample No.: 1  
 Sample Depth: 57 feet  
 Sampling Date: 8/3/17

Lithology : Gneiss  
 Moisture Content : As received  
 Lab Temperature : 70° F  
 Loading Rate: 55 psi/s  
 Time to Failure: 5 min

Diameter: 1.98 in  
 Length: 4.48 in  
 L/D: 2.26  
 End Area: 3.08 in<sup>2</sup>

Maximum Axial Load at Failure: 14,980 lb  
 Compressive Strength: 4,865 psi  
 Compressive Strength: 33.54 Mpa  
 Unit Weight 167 pcf


Before the Test



After the Test



Drawing # : PA-CH-0459.0000-RDa\_RDb  
 PO # : 20170804-16  
 Crossing : South Chester Road  
 Spread : Spread 6

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	H. Whitford
Project No.	J217P078		Test Date:	10/11/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/11/2017

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# ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.: B6-1E  
 Sample No.: 2  
 Sample Depth: 65 feet  
 Sampling Date: 8/3/17

Lithology : Gneiss  
 Moisture Content : As received  
 Lab Temperature : 70° F  
 Loading Rate: 55 psi/s  
 Time to Failure: 10 min

Diameter: 1.99 in  
 Length: 4.52 in  
 L/D: 2.27  
 End Area: 3.11 in<sup>2</sup>

Maximum Axial Load at Failure: 32,620 lb  
 Compressive Strength: 10,488 psi  
 Compressive Strength: 72.31 Mpa  
 Unit Weight 166 pcf


Before the Test



After the Test



Drawing # : PA-CH-0459.0000-RDa\_RDb  
 PO # : 20170804-16  
 Crossing : South Chester Road  
 Spread : Spread 6

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	H. Whitford
Project No.	J217P078		Test Date:	10/11/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/11/2017

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# ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.: B6-1E  
 Sample No.: 3  
 Sample Depth: 77 feet  
 Sampling Date: 8/3/17

Lithology : Gneiss  
 Moisture Content : As received  
 Lab Temperature : 70° F  
 Loading Rate: 55 psi/s  
 Time to Failure: 0 min

Diameter: N/A in  
 Length: N/A in  
 L/D: N/A  
 End Area: N/A in<sup>2</sup>

Maximum Axial Load at Failure: N/A lb  
 Compressive Strength: N/A psi  
 Compressive Strength: N/A Mpa  
 Unit Weight N/A pcf

Specimen broke during preparation


Before the Test



After the Test



Drawing # : PA-CH-0459.0000-RDa\_RDb  
 PO # : 20170804-16  
 Crossing : South Chester Road  
 Spread : Spread 6

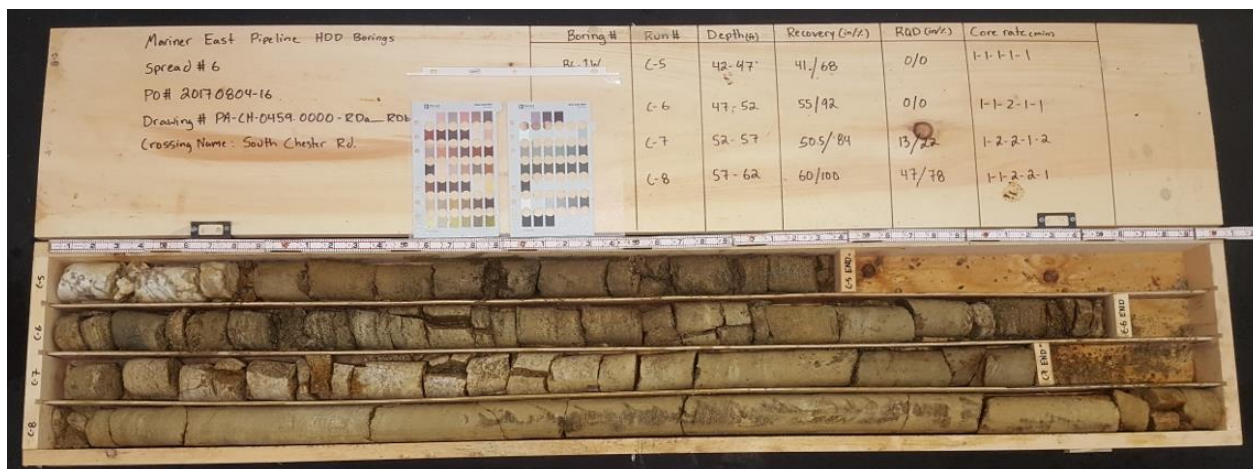
Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	H. Whitford
Project No:	J217P078		Test Date:	10/11/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/11/2017

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Photograph 1: B6-1W, Samples C-1 to C-4 (22 to 42 feet)



Photograph 2: B6-1W, Samples C-5 to C-8 (42 to 62 feet)



Photograph 3: B6-1W, Samples C-9 to C-12 (62 to 82 feet)





Photograph 4: B6-1W, Samples C-13 to C-16 (82 to 102 feet)



Photograph 5: B6-1W, Samples C-17 to C-20 (102 to 122 feet)



Photograph 6: B6-1W, Samples C-21 to C-24 (122 to 142 feet)





**Photograph 7:** B6-1W, Samples C-25 to C28 (142 to 158.3 feet)



**Photograph 1:** B6-1E, Samples C-1 to C-4 (40 to 60 feet)



**Photograph 2:** B6-1E, Samples C-5 to C-8 (60 to 80 feet)



**Photograph 3:** B6-1E, Samples C-9 to C-12 (80 to 100 feet)



**Photograph 4:** B6-1E, Samples C-13 to C-16 (100 to 120 feet)

## **SUPPORTING INFORMATION**



# UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests <sup>A</sup>					Soil Classification	
					Group Symbol	Group Name <sup>B</sup>
Coarse-Grained Soils: More than 50% retained on No. 200 sieve	Gravels: More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels:	Cu <sup>3</sup> 4 and 1 ≤ Cc ≤ 3 <sup>E</sup>		GW	Well-graded gravel <sup>F</sup>
		Less than 5% fines <sup>C</sup>	Cu < 4 and/or 1 > Cc > 3 <sup>E</sup>		GP	Poorly graded gravel <sup>F</sup>
		Gravels with Fines:	Fines classify as ML or MH		GM	Silty gravel <sup>F,G,H</sup>
		More than 12% fines <sup>C</sup>	Fines classify as CL or CH		GC	Clayey gravel <sup>F,G,H</sup>
	Sands: 50% or more of coarse fraction passes No. 4 sieve	Clean Sands:	Cu <sup>3</sup> 6 and 1 ≤ Cc ≤ 3 <sup>E</sup>		SW	Well-graded sand <sup>I</sup>
		Less than 5% fines <sup>D</sup>	Cu < 6 and/or 1 > Cc > 3 <sup>E</sup>		SP	Poorly graded sand <sup>I</sup>
		Sands with Fines:	Fines classify as ML or MH		SM	Silty sand <sup>G,H,I</sup>
		More than 12% fines <sup>D</sup>	Fines classify as CL or CH		SC	Clayey sand <sup>G,H,I</sup>
Fine-Grained Soils: 50% or more passes the No. 200 sieve	Silts and Clays: Liquid limit less than 50	Inorganic:	PI > 7 and plots on or above “A”		CL	Lean clay <sup>K,L,M</sup>
			PI < 4 or plots below “A” line <sup>J</sup>		ML	Silt <sup>K,L,M</sup>
		Organic:	Liquid limit - oven dried	< 0.75	OL	Organic clay <sup>K,L,M,N</sup>
			Liquid limit - not dried			Organic silt <sup>K,L,M,O</sup>
	Silts and Clays: Liquid limit 50 or more	Inorganic:	PI plots on or above “A” line		CH	Fat clay <sup>K,L,M</sup>
			PI plots below “A” line		MH	Elastic Silt <sup>K,L,M</sup>
		Organic:	Liquid limit - oven dried	< 0.75	OH	Organic clay <sup>K,L,M,P</sup>
			Liquid limit - not dried			Organic silt <sup>K,L,M,Q</sup>
Highly organic soils:	Primarily organic matter, dark in color, and organic odor				PT	Peat

<sup>A</sup> Based on the material passing the 3-inch (75-mm) sieve

<sup>B</sup> If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

<sup>C</sup> Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

<sup>D</sup> Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay

$$E \quad Cu = D_{60}/D_{10} \quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

<sup>F</sup> If soil contains <sup>3</sup> 15% sand, add "with sand" to group name.

<sup>G</sup> If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

<sup>H</sup> If fines are organic, add "with organic fines" to group name.

<sup>I</sup> If soil contains <sup>3</sup> 15% gravel, add "with gravel" to group name.

<sup>J</sup> If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

<sup>K</sup> If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

<sup>L</sup> If soil contains <sup>3</sup> 30% plus No. 200 predominantly sand, add "sandy" to group name.

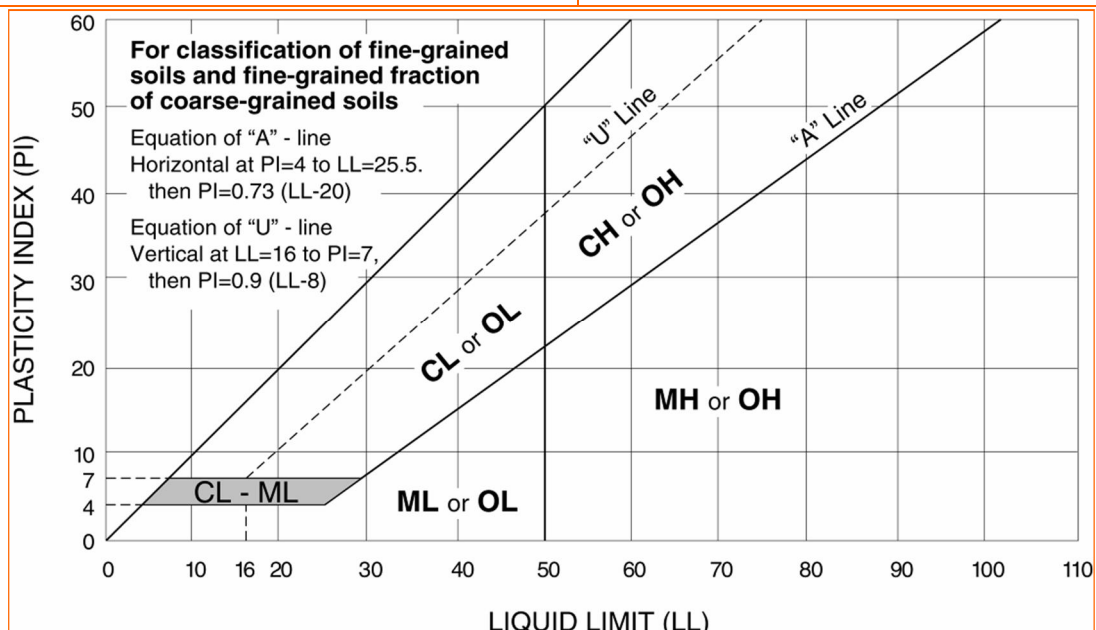
<sup>M</sup> If soil contains <sup>3</sup> 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

<sup>N</sup> PI <sup>3</sup> 4 and plots on or above "A" line.

<sup>O</sup> PI < 4 or plots below "A" line.

<sup>P</sup> PI plots on or above "A" line.

<sup>Q</sup> PI plots below "A" line.



## DESCRIPTION OF ROCK PROPERTIES

WEATHERING	
<b>Fresh</b>	Rock fresh, crystals bright, few joints may show slight staining. Rock rings under hammer if crystalline.
<b>Very Slight</b>	Rock generally fresh, joints stained, some joints may show thin clay coatings, crystals in broken face show bright. Rock rings under hammer if crystalline.
<b>Slight</b>	Rock generally fresh, joints stained, and discoloration extends into rock up to 1 in. Joints may contain clay. In granitoid rocks some occasional feldspar crystals are dull and discolored. Crystalline rocks ring under hammer.
<b>Moderate</b>	Significant portions of rock show discoloration and weathering effects. In granitoid rocks, most feldspars are dull and discolored; some show clayey. Rock has dull sound under hammer and shows significant loss of strength as compared with fresh rock.
<b>Moderately Severe</b>	All rock except quartz discolored or stained. In granitoid rocks, all feldspars dull and discolored and majority show kaolinization. Rock shows severe loss of strength and can be excavated with geologist's pick.
<b>Severe</b>	All rock except quartz discolored or stained. Rock "fabric" clear and evident, but reduced in strength to strong soil. In granitoid rocks, all feldspars kaolinized to some extent. Some fragments of strong rock usually left.
<b>Very Severe</b>	All rock except quartz discolored or stained. Rock "fabric" discernible, but mass effectively reduced to "soil" with only fragments of strong rock remaining.
<b>Complete</b>	Rock reduced to "soil". Rock "fabric" no discernible or discernible only in small, scattered locations. Quartz may be present as dikes or stringers.

HARDNESS (for engineering description of rock – not to be confused with Moh's scale for minerals)	
<b>Very Hard</b>	Cannot be scratched with knife or sharp pick. Breaking of hand specimens requires several hard blows of geologist's pick.
<b>Hard</b>	Can be scratched with knife or pick only with difficulty. Hard blow of hammer required to detach hand specimen.
<b>Moderately Hard</b>	Can be scratched with knife or pick. Gouges or grooves to ¼ in. deep can be excavated by hard blow of point of a geologist's pick. Hand specimens can be detached by moderate blow.
<b>Medium</b>	Can be grooved or gouged 1/16 in. deep by firm pressure on knife or pick point. Can be excavated in small chips to pieces about 1-in. maximum size by hard blows of the point of a geologist's pick.
<b>Soft</b>	Can be gouged or grooved readily with knife or pick point. Can be excavated in chips to pieces several inches in size by moderate blows of a pick point. Small thin pieces can be broken by finger pressure.
<b>Very Soft</b>	Can be carved with knife. Can be excavated readily with point of pick. Pieces 1-in. or more in thickness can be broken with finger pressure. Can be scratched readily by fingernail.

Joint, Bedding, and Foliation Spacing in Rock <sup>1</sup>		
Spacing	Joints	Bedding/Foliation
Less than 2 in.	Very close	Very thin
2 in. – 1 ft.	Close	Thin
1 ft. – 3 ft.	Moderately close	Medium
3 ft. – 10 ft.	Wide	Thick
More than 10 ft.	Very wide	Very thick

1. Spacing refers to the distance normal to the planes, of the described feature, which are parallel to each other or nearly so.

Rock Quality Designator (RQD) <sup>1</sup>		Joint Openness Descriptors	
RQD, as a percentage	Diagnostic description	Openness	Descriptor
Exceeding 90	Excellent	No Visible Separation	Tight
90 – 75	Good	Less than 1/32 in.	Slightly Open
75 – 50	Fair	1/32 to 1/8 in.	Moderately Open
50 – 25	Poor	1/8 to 3/8 in.	Open
Less than 25	Very poor	3/8 in. to 0.1 ft.	Moderately Wide
		Greater than 0.1 ft.	Wide

1. RQD (given as a percentage) = length of core in pieces 4 inches and longer / length of run

References: American Society of Civil Engineers. Manuals and Reports on Engineering Practice - No. 56. Subsurface Investigation for Design and Construction of Foundations of Buildings. New York: American Society of Civil Engineers, 1976. U.S. Department of the Interior, Bureau of Reclamation, Engineering Geology Field Manual.

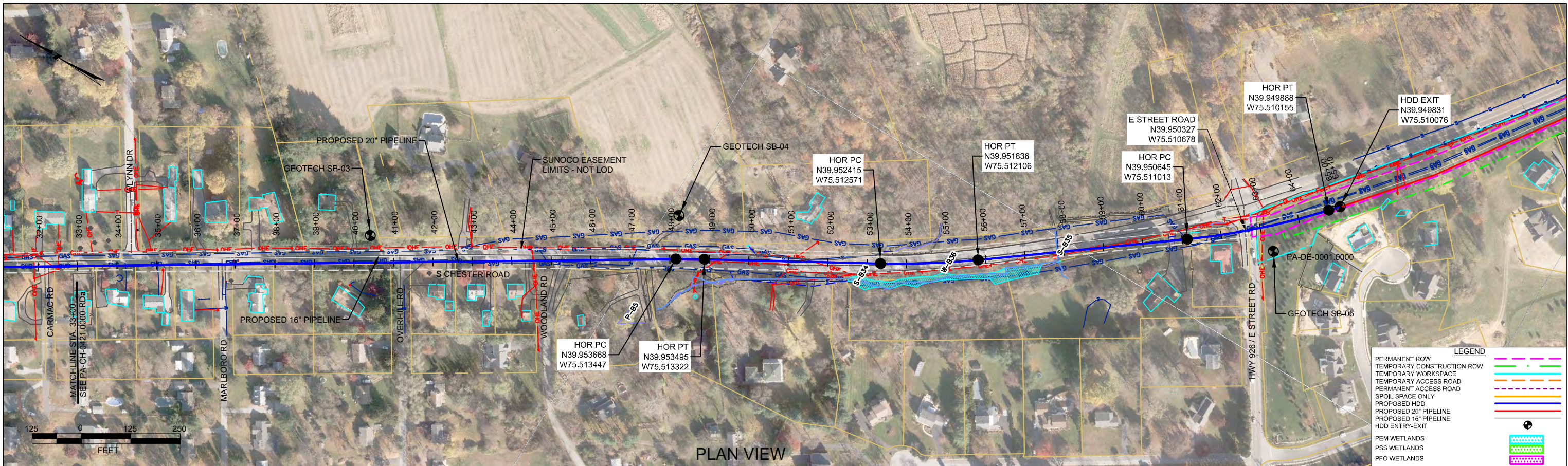
**ARCH BISHOP/SOUTH CHESTER ROAD CROSSING  
PADEP SECTION 105 PERMIT NO. E15-862  
PA-CH-0421.0000-RD & PA-CH-0421.0000-RD-16  
(SPLP HDD No. S3-0541)**

**ATTACHMENT 2  
HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES**

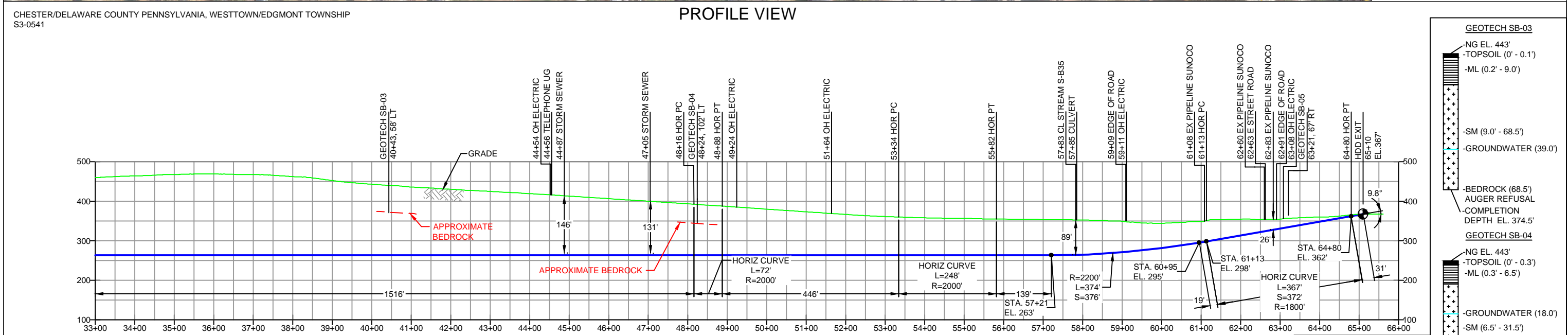








PLAN VIEW



PROFILE VIEW

CHESTER/DELAWARE COUNTY PENNSYLVANIA, WESTTOWN/EDGMONT TOWNSHIP  
S3-0541

DESIGN AND CONSTRUCTION:

- CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
- 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.
- DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
- CROSSING PIPE SPECIFICATION:  
HDD HORZ. LENGTH (L=): 6510'  
HDD PIPE LENGTH (S=): 6534'  
20" x 0.456" W.T., X-65, APIEL, PSL2, ERW, BFW  
COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
- INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50).
- INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
- PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
- CARRIER PIPE NO ENCASED.
- PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
- CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.

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-6.70	TO ES-6.01
SHEET 46	TO SHEET 1
DWG NO	DWG NO
DESCRIPTION	

REVISIONS	
EP3	UPDATED TO 20" PIPE SPEC AND CENTERLINE LOCATION PER PM, ADDED DPS GEOTECH
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16
EP1	REVISED PER PADEP COMMENTS
EP	
0	ISSUED FOR CONSTRUCTION
NO.	DESCRIPTION



**Sunoco Logistics  
Partners L.P.**



**TETRA TECH ROONEY**  
(303) 792-5911

**GEOTECH SB-03**

NG EL. 443'  
-TOPSOIL (0' - 0.1')  
-ML (0.2' - 9.0')  
  
-SM (9.0' - 68.5')  
-GROUNDWATER (39.0')  
  
-BEDROCK (68.5')  
AUGER REFUSAL  
-COMPLETION  
DEPTH EL. 374.5'

**GEOTECH SB-04**

NG EL. 443'  
-TOPSOIL (0' - 0.3')  
-ML (0.3' - 6.5')  
  
-SM (6.5' - 31.5')  
-SM (31.5' - 40.0')  
-GRAY GNEISS (40.0' - 42.0')  
-FELSIC GNEISS (42.0' - 48.0')  
-COMPLETION  
DEPTH EL. 395.0'

**GEOTECH SB-05**

NG EL. 365'  
-TOPSOIL (0' - 0.1')  
-SM (0.1' - 26.5')  
-SM (26.5' - 30.0')  
-COMPLETION  
DEPTH EL. 346'

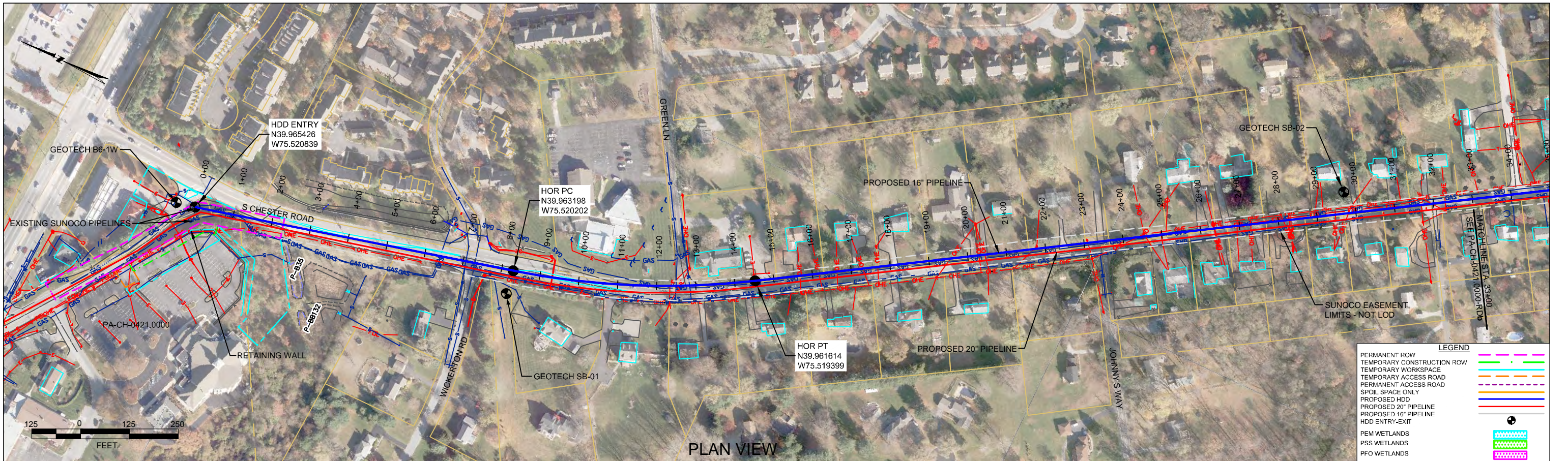
NOTE: REFER TO TEST BORING LOG S3-0541 FOR COMPLETE SOIL MATERIAL DESCRIPTION

**SUNOCO PIPELINE, L.P.**

HORIZONTAL DIRECTIONAL DRILL  
S CHESTER ROAD / HWY 926  
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250'    DWG. NUMBER PA-CH-0421.0000-RDb

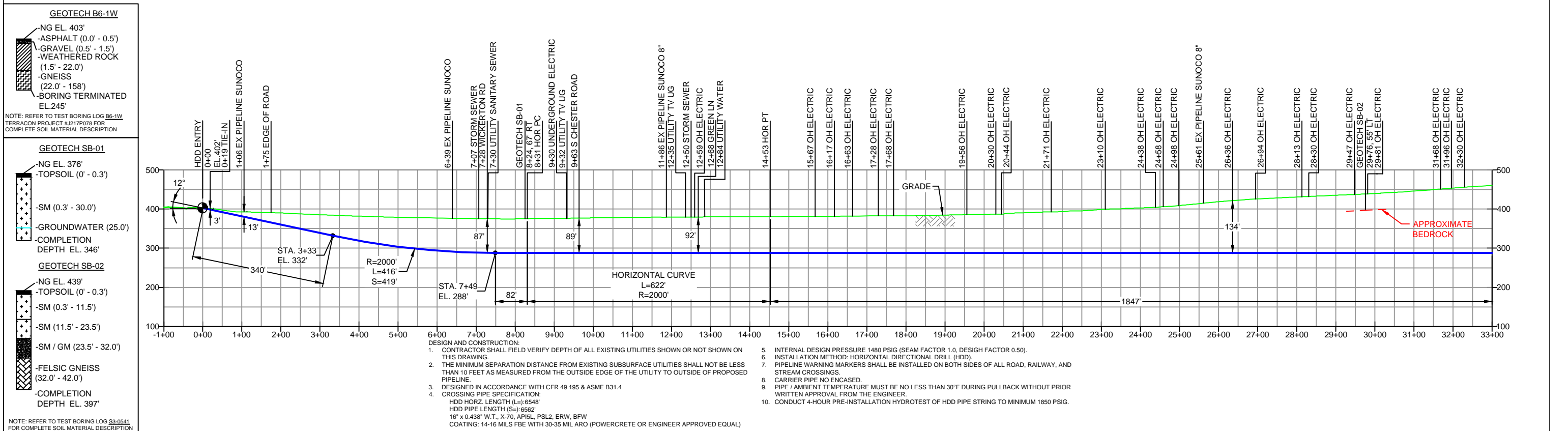






CHESTER/DELAWARE COUNTY PENNSYLVANIA, WESTTOWN/EDGMONT TOWNSHIP  
S3-0541-16

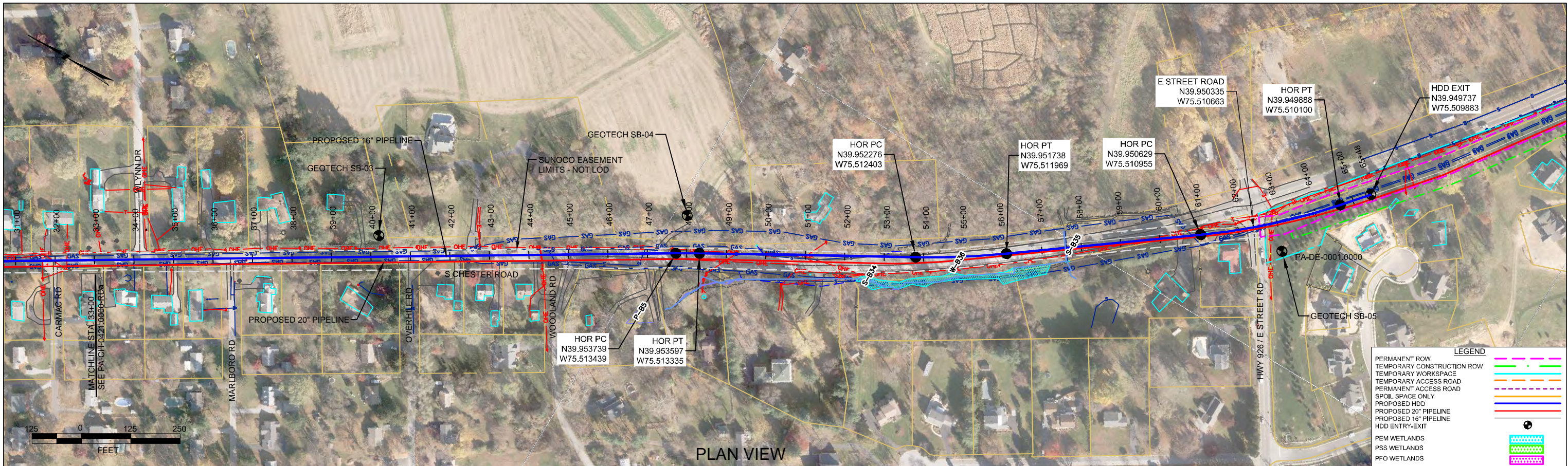
PLAN VIEW

PROFILE VIEW



NOTES	REF. DRAWING			REVISIONS										<div>  </div>		SUNOCO PIPELINE, L.P.				
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.	ES-6.70	TO	ES-6.01	EROSION & SEDIMENT PLAN													HORIZONTAL DIRECTIONAL DRILL S CHESTER ROAD / HWY 926 PENNSYLVANIA PIPELINE PROJECT			
	SHEET 46	TO	SHEET 1	AERIAL SITE PLAN			EP3	UPDATED TO 16" PIPE SPEC AND CENTERLINE LOCATION PER PM, ADDED DPS GEOTECH			MRS	11/08/17	RMB			11/08/17	AMC	11/08/17	SCALE: 1"=250'	DWG. NUMBER: PA-CH-0421.0000-RDa-16
								EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16			DLM	10/07/16			RMB	10/07/16	AAW		
							EP1	REVISED PER PADEP COMMENTS			JTW	05/10/16	RMB	05/10/16	AAW	05/10/16				
							EP				MRS	02/26/16	RMB	02/26/16	AAW	02/26/16				
							0	ISSUED FOR CONSTRUCTION			MRS	02/19/16	RMB	02/19/16	AAW	02/19/16				
	DWG NO		DWG NO	DESCRIPTION			NO.	DESCRIPTION			BY	DATE	CHK	DATE	APP	DATE				

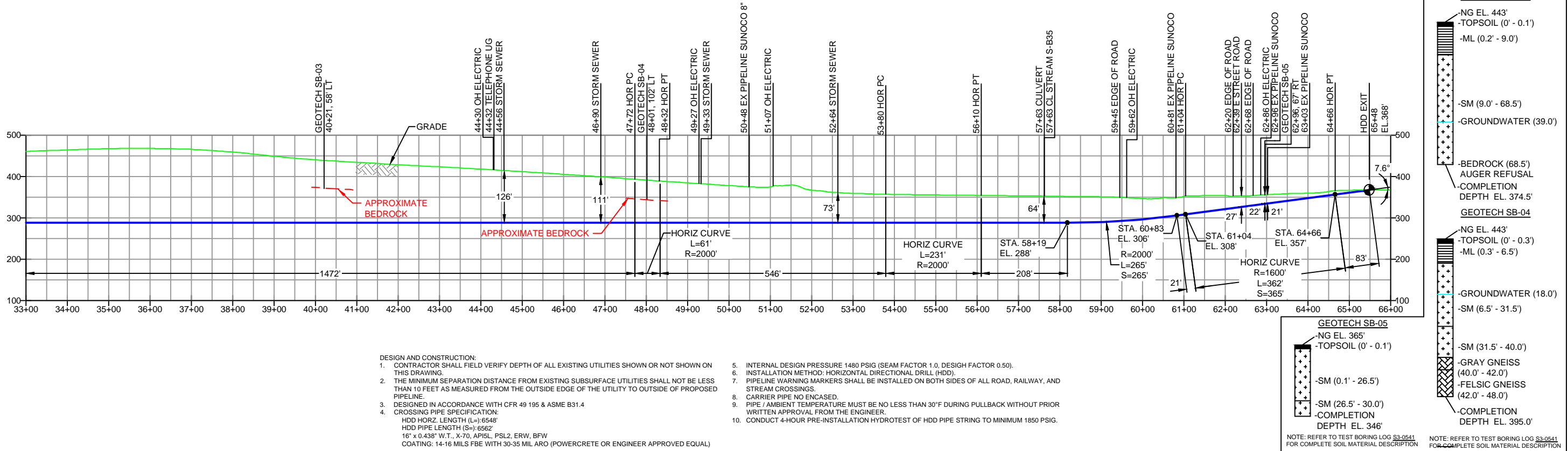






CHESTER/DELAWARE COUNTY PENNSYLVANIA, WESTTOWN/EDGMONT TOWNSHIP  
S3-0541-16

PLAN VIEW

PROFILE VIEW



NOTES			REF. DRAWING		REVISIONS								 <b>Sunoco Logistics Partners L.P.</b>	 <b>TETRA TECH ROONEY</b> (303) 792-5911		<b>SUNOCO PIPELINE, L.P.</b>  HORIZONTAL DIRECTIONAL DRILL S CHESTER ROAD / HWY 926 PENNSYLVANIA PIPELINE PROJECT	
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2. STATIONING IS BASED ON HORIZONTAL DISTANCES	SHEET 46	TO	SHEET 1	AERIAL SITE PLAN	EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	10/07/16	RBM	10/07/16	AAW	10/07/16					
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5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.	DWG NO		DWG NO	DESCRIPTION	NO.	ISSUED FOR CONSTRUCTION	MRS	02/19/16	RMB	02/19/16	AAW	02/19/16				SCALE: 1"=250'	DWG. NUMBER PA-CH-0421.0000-RDb-16