**HORIZONTAL DIRECTIONAL DRILL ANALYSIS**
**HIGHWAY 15 CROSSING**
**PADEP SECTION 105 PERMIT NO.: E21-449**
**PA-CU-0176.0019-RD-16**
**(SPLP HDD No. S2-0247-16)**

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This reevaluation of the horizontal directional drill (HDD) installation of a 16-inch diameter pipeline that traverses Highway 15 in Upper Allen Township, Cumberland County, Pennsylvania, is in accordance with the Stipulated Order issued under Environmental Hearing Board Docket No. 2017-009-L for HDDs listed on Exhibit 3 of the Stipulated Order. This HDD is number 10 on the list of HDDs included on Exhibit 3 of the Order.

The first pipeline HDD had one inadvertent return (IR), which was remediated in conjunction with the installation of the 20-inch diameter pipeline.

The 16-inch pipeline HDD is referred to herein as HDD S2-0247-16.

## PIPE INFORMATION

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: 16-INCH

- Horizontal length: 1,983 foot (ft)
- Entry/Exit angle: 10-12 degrees
- Maximum Depth of cover: 93 ft
- Pipe design radius: 1,600 ft

## ROOT CAUSE ANALYSIS FOR THE 20-INCH PIPELINE INSTALLATION INADVERDENT RETURNS

The 20-inch HDD pilot was initiated in June of 2017. Based upon analysis of the drilling profile, location of the IR, phase of drilling (pilot hole) and interviews with supervisory personnel on site during this HDD, SPLP drilling specialists conclude that a clogged annulus behind the pilot drilling tool induced the IR event. Craft inspectors who were on-site during this HDD recall several Loss of Circulation events after the pilot tool had progressed from west to east and passed under the entry-exit roadway interchange between Highway 15 and Interstate 76. Furthermore, it was noted that the materials under the interchange roads appeared to be un-compacted fill based upon the behavior of the pilot tool while passing through this section of the profile. These observations about conditions when the pilot tool passed under the interchange support the clogged annulus conclusion.

## GEOLOGIC AND HYDROGEOLOGIC ANALYSIS

Based upon publications by the Pennsylvania Bureau of Topographic and Geologic Survey (PABTGS), the site is in the Great Valley Section of the Ridge and Valley Physiographic Province of Pennsylvania and is underlain by very finely crystalline limestone with minor occurrences of dolomite and chert. The site geology for the redesigned 16-inch HDD profile is mapped as the Orr: Rockdale Run Formation. The Rockdale Run Formation contains a very light gray, very fine-grained pure limestone in the lower part of the formation, while the middle and upper portions of the formation consist mostly of light-gray limestone, commonly containing abundant fine carbonate grains and fossil fragments. Dolomite is sparsely distributed throughout the formation but is primarily concentrated towards the top of the unit (Becher and Root, 1981). The formation also contains lenses of pink to brown chert and white quartz rosettes are found near the top of the formation. The lower third of the formation is medium bedded, while the upper

two thirds are thickly bedded. Joints tend to have a blocky pattern, are moderately well developed, moderately abundant, and regularly spaced. Fractures in the formation tend to have a moderate distance between them, are open and steeply dipping. The Rockdale Run Formation tends to be moderately resistant to weathering and is moderately weathered to a deep depth. The weathered product consists of irregular and blocky-shaped fragments resulting from prolonged weathering. From an engineering stand point, the formation is considered difficult to excavate, due to the degree and extent of bedrock pinnacle development, while drilling rates are expected to be fast but may be slowed by chert and quartz lenses.

Karst geology is present in the immediate vicinity of this HDD location. RETTEW completed a multi-technique geophysical survey at the Highway 15 HDD site from November 12-20, 2018. The purpose of the survey was to provide supplemental information to the geotechnical investigations to aid in detecting and delineating subsurface voids or low-density zones. Results from these geophysical techniques are consistent with each other, and with the geology as mapped by the PA Geological Survey, all suggesting that the local bedrock (limestone) is karstified, with potential concentrations of dissolution cavities (of various sizes) indicated by the geophysical anomalies detected. In the limestone, the top-of-rock is expected to be pinnacled (highly irregular) with interfingered competent rock and residual clay soil as well as potential bedrock voids.

This HDD was near completion before the Stipulated Order, and as a result there are no logs by the monitoring geologists to verify the reported geology to the geologic materials and conditions drilled through during installation of the 20-inch pipeline.

Attachment 1 provides an extensive discussion on the geology and results of the geotechnical and geophysical investigations performed at this location.

## HYDROGEOLOGY, GROUND WATER, AND WELL PRODUCTION ZONES

Groundwater at the site occurs in a fractured, solution-prone, carbonate bedrock aquifer system within the Rockdale Run Formation. In carbonate rocks, water-bearing zones generally occur in solution-enhanced secondary openings that form along bedding planes, joints, faults and fractures. Most of the water-bearing zones penetrated by supply wells occur in individual fractures or groups of interconnected fractures that are sufficiently enlarged by dissolution of bedrock to provide pathways for the transport of groundwater. Groundwater flow paths within the karstic limestone beneath the site have both local and regional components. Locally, shallow groundwater discharges to the gaining portions of nearby streams and deeper regional groundwater flow is toward points of regional groundwater discharge such as the Susquehanna River. Groundwater divides may be different for each zone of groundwater flow and, therefore, may not coincide with surface water divides.

Of the 91 yielding zones reported within the Rockdale Run Formation, 58 are at depths of less than 100 feet and only seven occur below 250 feet. No large specific-capacity or high-yielding wells produce from zones below 200 feet (Becher and Root, 1981). The median depth of water supply wells in the Rockdale Run Formation is reported to be 82 feet bgs with a median depth to water of 30 feet bgs. Well records for 8 individual water supply wells within a 0.5-mile radius of the Highway 15 HDD were obtained from the Pennsylvania Groundwater Information System (PaGWIS). Well construction details were not reported for all of the wells; however, the majority of the identified wells were completed as 6-inch-diameter open-rock wells with total depths ranging from 200 to 280 feet bgs. Reported well yields range from 5 to 150 gpm, while the reported water levels ranged from 21 to 54 feet bgs.

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

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## INADVERTENT RETURN (IR) DISCUSSION

As discussed above, the SPLP drilling specialist have concluded that a clogged annulus behind the pilot drilling tool induced the IR event.

As outlined below in the Conclusions Section, SPLP will require the implementation of the drilling BMP's as listed. The implementation of these drilling tool, procedures, and corrective actions significantly reduce the probability of an IR during drilling and installation of the 16-inch pipeline.

## ADJACENT FEATURES ANALYSIS

This HDD location is located 1.8 miles southeast of the Town of Mechanicsburg in Cumberland County, Pennsylvania. The pipeline alignment and HDD crosses under Highway 15 and a clover-leaf interchange to Interstate 76. This HDD location is set within an urban area. No aquatic resources are crossed by this HDD.

SPLP performed a preconstruction survey of landowners within 450 feet and greater from the alignment. SPLP sent each of these landowners a notice letter via both certified and first-class mail 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.

As a result of these communications, no known private water wells were identified within 450 radius of the HDD profile.

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 the revised HDD alignment.

## ALTERNATIVES 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 (PennDOT) cover requirements under public roadways is 60-inches of cover. As discussed above, this HDD crosses under Highway 15, and an entry-exit interchange to Interstate 76. The profile of the HDD is bound by Highway 15 to the east, Interstate 76 to the south, and the interstate entry-exit interchange to Highway 15 to the west and north.

An open cut of the linear footage for the entire length of the HDD is not possible to due interruption it would cause to public users of the roadways. A subset of this length can be open cut as is discussed below.

**Use of Conventional Auger Bore**

Planning for a conventional bore must account for the extent or width of the feature (road, stream, etc.) being bored under, as well as the length and width of the setup-entry pit for setting the boring equipment within while operating, and the receiving pit through which the product pipeline is pulled back through after the boring machinery exits.

Based on experience gained during construction of the Mariner II Pipeline project, conventional auger bores should be limited to approximately 200 linear foot at a time, or less, varying by the underlying substrate. Conventional auger bores for the 20-inch pipeline, attempted at longer distances, have at times had alignment drift and elevation deflections occur which have complicated installation.

A conventional bore crossing of the interstate entry-exit roadways would require a bore of approximately 540 ft in length and is not a recommended action due to the nature of the soils and geology underlying the construction area.

Assuming PennDOT approval, a combination of conventional bore under Highway 15, an open cut of the grounds between Highway 15 and the interstate entry-exit, and a guided bore (or mini-HDD) under the interstate entry-exit is potentially feasible. This approach, however, would require a large permitted area of disturbance within the open lands between all the roadways along with a vehicle entry-exit to Highway 15 that could accommodate semi-truck/trailer use, and a truck turnaround area. The open land area would be used for pipe and equipment staging, equipment operations, worker parking, and receiving pits for the bore under Highway 15 and guided bore under the interstate entry-exit. Due to the logistics of traffic management on Highway 15, and since a large portion of the HDD footage would be replaced with a shallow guided bore or mini-HDD and risks associated with this construction method in a weak shallow zone between road surfaces; the impact to the public's use of the roadways from construction traffic, and high probability of one or more IRs during the guided bore make this alternative undesired.

**Re-Route Analysis**

This HDD is set within an area bounded by public roadway and surrounding commercial development. There are no existing utility corridors to the north or south that provide a practical alternative route. Any alternate route considered to the north or south would require a significant deviation many miles in extent to avoid developments and establishment of a new "greenfield" corridor through existing agricultural land, woodlands, potentially encounter stream crossings, and possibly encroach on additional private residences before it could rejoin the current route.

In summary, due to the setting surrounding the overall route of the Mariner II pipelines in this area, there is no practical 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 Highway 15 HDD confirms the conclusions reached in the previously submitted alternatives analysis.

## REVISED HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 16-INCH

Additional geologic investigations have been completed, and the "as built" record for the 20-inch pipeline has been utilized in the redesign of the planned 16-inch HDD. The redesign adjusts the HDD profile deeper to minimize the risk of drilling fluid loss, drilling difficulties, and IRs. A summary of the redesign factors is provided below. The original and redesigned 16-inch HDD plan and profile drawings are provided in Attachment 2.

- Horizontal length: 1,985 ft
- Entry/Exit angle: 16 degrees
- Maximum Depth of cover: 135 ft
- Pipe design radius: 2000 ft

## CONCLUSION

As shown on Figure 2, the redesigned HDD profile for the 16-inch pipeline increases the entry-exit angles to allow for a profile depth that is 42 ft deeper than the permitted design. The redesign of the HDD will not prevent all IRs. IRs are common on entry and exit of the drilling tool and other measures are required to minimize IR potential. In particular, upon the start of this HDD, SPLP will employ the following HDD best management practices:

- The drilling contractor, craft inspector, and monitoring geologists will be provided an orientation on the IR that occurred during drilling of the 20-inch pipeline installation, and the contractor will be required to utilize low drilling fluid pressure during pilot entry down to the bedrock face, and will monitor pilot tool progress on the exit radius to attempt to cut drilling fluid pressures immediately upon exiting out of bedrock into overburden;

- 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, to help manage development pressures that can induce an IR;

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

- SPLP will implement short-tripping of the reaming tools, as indicated by monitoring of return flows, 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;

- During all drilling phases, the use of Loss Control Materials (LCMs) will be implemented upon detection of a Loss of Circulation (LOC) or indications of a potential IR are noted or an IR is observed. The use of LCMs, however, is less effective below 70 ft of the ground surface.

Accordingly, the preferred corrective action needed to address the presence of fractures or LOC at greater depths below ground will require grouting of the HDD annulus. Two types of grouting may be utilized for corrective actions to seal fractures. These are: 1) grouting using "neat cement"; and 2) grouting using a sand/cement mix. Neat cement grout is a slurry of Portland cement and water which is highly reactive to bentonite and induces solidification. The sand/cement grout mix is a slurry of mostly sand with a small percentage of Portland cement and activators that after setup results in a material having the competency of a friable sandstone or mortar. Both grouting actions require tripping out the drilling tool, and then tripping in with an open-ended drill stem to apply or inject the grout mixes. Either of these grouting actions may be implemented upon the first detection of an LOC with the selection of the treatment based upon the circumstances of the LOC, being small or large in magnitude.

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## FEASIBILITY DETERMINATION

Based on the information reviewed by the Geotechnical Evaluation Leader, Professional Geologists, Professional Engineers, and HDD specialists, the HDD Reevaluation Team's opinion is that the proposed HDD design and implementation of the management measures contained within this re-revaluation report will minimize the risk of IRs

Pertaining to Horizontal Directional Drilling Practices and Procedures; Conventional Construction; Alternatives; and Environmental Effects

2-28-2019
Date

Larry J. Gremminger, CWB
Vice President – Environmental
Geotechnical Evaluation Leader
Mariner East 2 Pipeline Project

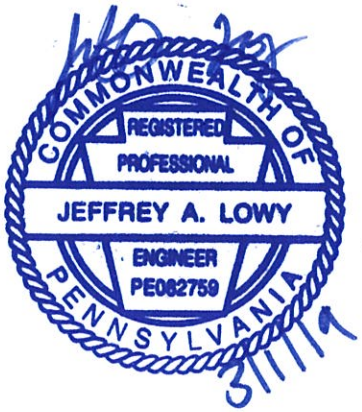
Pertaining to the practice of geology

3/1/2019
Date


Douglas J. Hess, P.G.
License No. PG-000186-G
Skelly and Loy, Inc.
Director of Groundwater
and Site Characterization
Geo-Environmental Services

Pertaining to the pipeline stress and HDD geometry

3/1/19
Date




Jeffrey A. Lowy, P.E
License No. PE 082759
Rooney Engineering, Inc.
Civil Engineer

**HIGHWAY 15 CROSSING**
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# ATTACHMENT 1

# GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT

**HIGHWAY 15 CROSSING**
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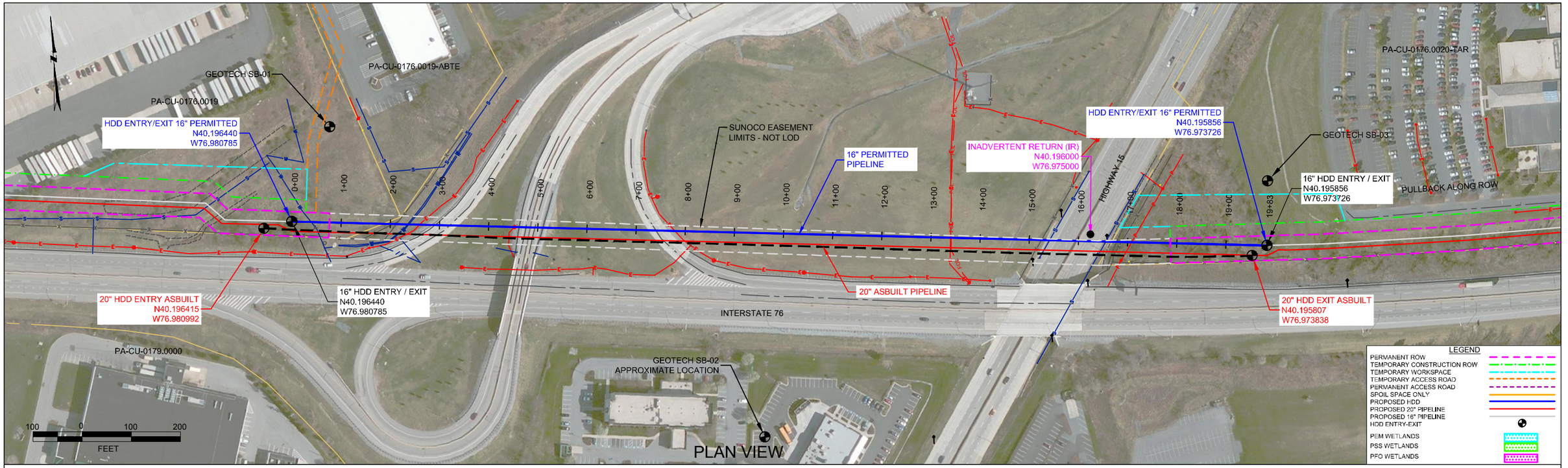
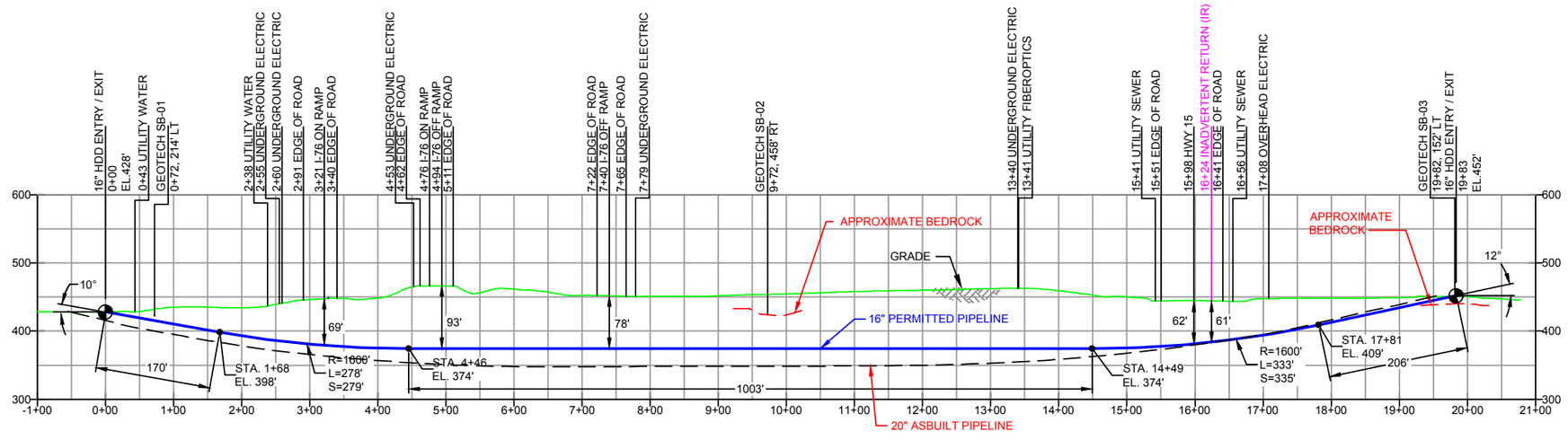
# ATTACHMENT 2

# HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES




PLAN VIEW

## PROFILE VIEW




GEOTECH SB-01
-NG EL. 422'
-TOPSOIL (0' - 0.3')
-CL (0.3' - 30.0')
-COMPLETION DEPTH EL. 392'

GEOTECH SB-02
-NG EL. 458'
-TOPSOIL (0' - 0.3')
-CL (0.3' - 13.5')
-WEATHERED LIMESTONE (13.5' - 13.9')
-AUGER REFUSAL (14.0')
-FRACTURED LIMESTONE (14.0' - 21.4')
-COMPLETION DEPTH EL. 437'

GEOTECH SB-03
-NG EL. 445'
-TOPSOIL (0' - 0.3')
-CLAY / LIMESTONE FRAGMENTS (USCS:CH) (0.3' - 12.0')
-LIMESTONE FRAGMENTS (12.0' - 12.1')
-AUGER REFUSAL (12.0')
-COMPLETION DEPTH EL. 433'

NOTE: REFER TO TEST BORING LOG S2-0247 FOR COMPLETE SOIL MATERIAL DESCRIPTION

CUMBERLAND COUNTY PENNSYLVANIA, UPPER ALLEN TOWNSHIP
S2-0247-16

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 HOR2. LENGTH (L=):1983'
   HDD PIPE LENGTH (S=):1993'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE:1480 PSIG (SEAM FACTOR 1.0, DESIGH 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 ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

Figure 1. Permitted 16-inch HDD Plan and Profile with 20-Inch IR Data

### NOTES

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

### REVISIONS

| NO. | DESCRIPTION | BY | DATE | CHK | DATE | APP | DATE |
|---|---|---|---|---|---|---|---|
| 5 | DRILL ENTRY/EXIT LAT LONG UPDATE | DLM | 04/03/17 | RMB | 04/03/17 | CAG | 04/03/17 |
| 4 | REVISED PROFILE WITH 2017 LIDAR | MRS | 02/24/17 | RMB | 02/24/17 | CAG | 02/24/17 |
| 3 | REVISED PER ENGINEERING COMMENTS | MRS | 08/31/16 | RMB | 08/31/16 | AAW | 08/31/16 |
| 2 | REVISED PER COMMENTS FROM REI REVIEW | MRS | 02/19/16 | RMB | 02/19/16 | AAW | 02/19/16 |
| 1 | DESIGN CHANGE | DLM | 02/19/16 | RMB | 02/19/16 | AAW | 02/19/16 |
| 0 | ISSUED FOR CONSTRUCTION | MRS | 01/19/16 | RMB | 01/19/16 | AAW | 01/19/16 |

Sunoco Logistics Partners L.P.

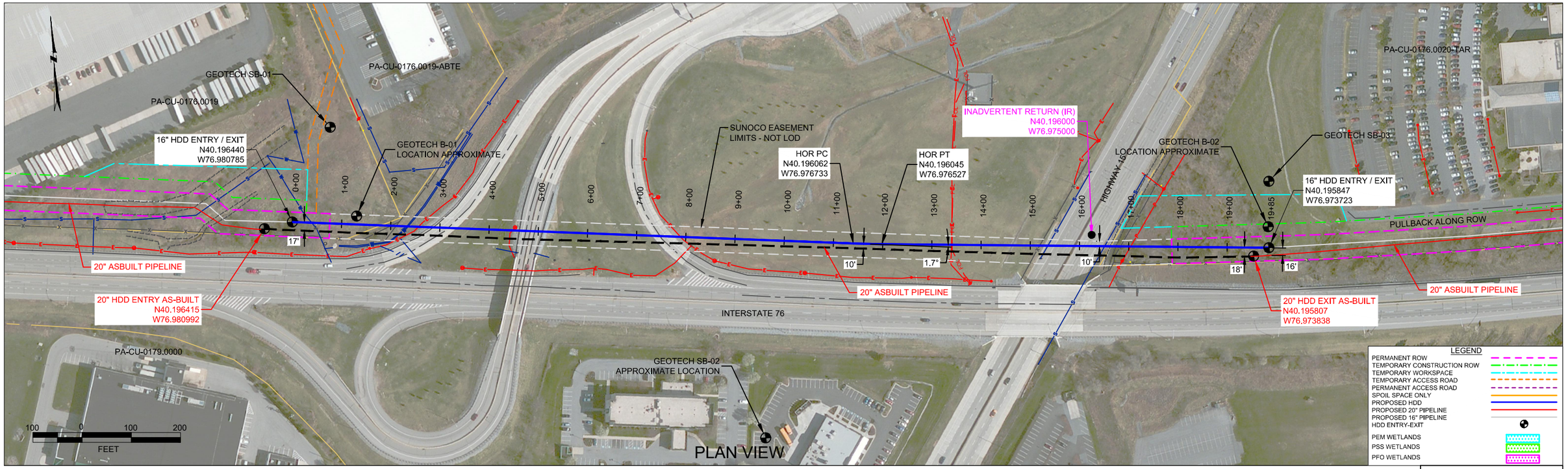
TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
HWY 15
PENNSYLVANIA PIPELINE PROJECT

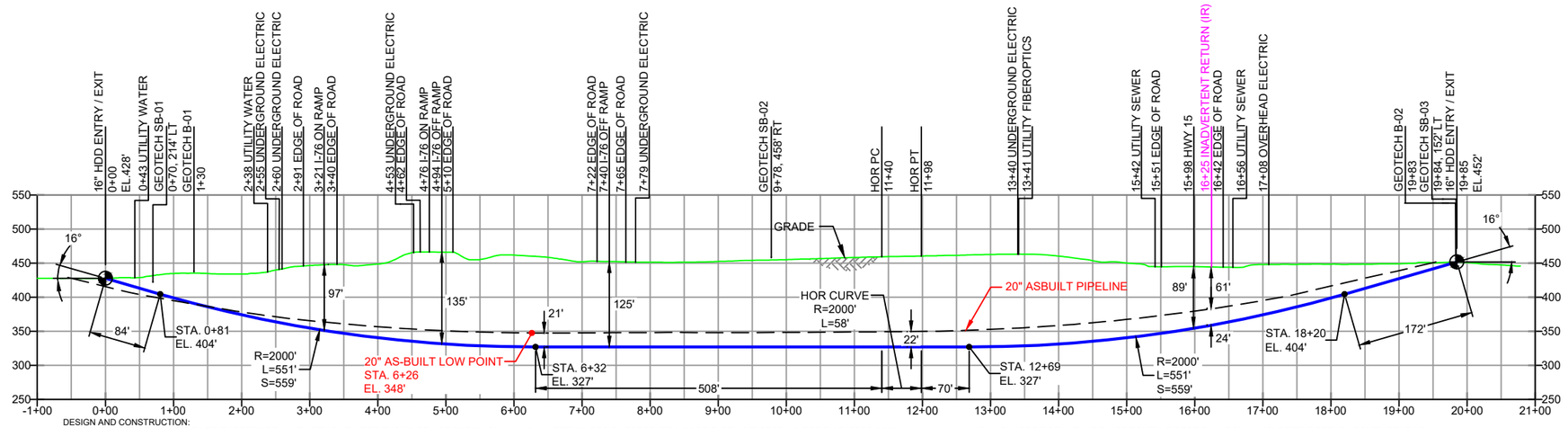
SCALE: 1"=200'

DWG. NO: PA-CU-0176.0019-RD-16




CUMBERLAND COUNTY PENNSYLVANIA, UPPER ALLEN TOWNSHIP
S2-0247-16

## PROFILE VIEW




DESIGN AND CONSTRUCTION:
1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):1985'
   HDD PIPE LENGTH (S=):2010'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 2100 PSIG (SEAM FACTOR 1.0, DESIGH 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 2625 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

**GEOTECH SB-01**
- NG EL. 422'
- -TOPSOIL (0' - 0.3')
- -CL (0.3' - 30.0')
- -COMPLETION DEPTH EL. 392'

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- NG EL. 458'
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- -FRACTURED LIMESTONE (14.0' - 21.4')
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- -TOPSOIL (0' - 0.3')
- -CLAY / LIMESTONE FRAGMENTS (USCS:CH) (0.3' - 12.0')
- -LIMESTONE FRAGMENTS (12.0' - 12.1')
- -AUGER REFUSAL (12.0')
- -COMPLETION DEPTH EL. 433'

NOTE: REFER TO TEST BORING LOG S2-0247 FOR COMPLETE SOIL MATERIAL DESCRIPTION

**GEOTECH B-01**
- NG EL. 437'
- -RESIDUUM SILT ML (0.0' - 8.5')
- -GROUNDWATER (17.3')
- -HIGHLY WEATHERED LIMESTONE (8.5' - 10.0')
- -LIMESTONE/DOLOMITE (10.0' - 85.0')
- -BORING TERMINATED EL.352'

NOTE: REFER TO TEST BORING LOG B-01 INTERTEK PROJECT #04911465 FOR COMPLETE SOIL MATERIAL DESCRIPTION

**GEOTECH B-02**
- NG EL. 449'
- -PROBABLE FILL CL (0.0' - 2.5')
- -RESIDUUM CLAYEY SAND SC (2.5' - 6.5')
- -RESIDUUM CLAY CL (6.5' - 9.75')
- -RESIDUUM CLAYEY GRAVEL GC (9.75' - 10.5')
- -GROUNDWATER (27.8')
- -LIMESTONE/DOLOMITE (10.5' - 111.0')
- -BORING TERMINATED EL.338'

NOTE: REFER TO TEST BORING LOG B-02 INTERTEK PROJECT #04911465 FOR COMPLETE SOIL MATERIAL DESCRIPTION

Figure 2. Redesigned 16-Inch HDD Plan and Profile

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

| REF. DRAWING | | | | | REVISIONS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ES-4.89 | TO | ES-4.90 | EROSION & SEDIMENT PLAN | EP3 | DESIGN CHANGE - LOWERED DRILL AND ADDED GEOTECH | MRS | 01/30/19 | RMB | 01/30/19 | AMC | 01/30/19 |
| SHEET 54 | TO | SHEET 54 | AERIAL SITE PLAN | EP2 | REVISED PER PADEP COMMENTS RECEIVED 09-06-16 | MRS | 10/07/16 | RMB | 10/07/16 | AAW | 10/07/16 |
| | | | | EP1 | REVISED PER PADEP COMMENTS | MRS | 05/11/16 | RMB | 05/11/16 | AAW | 05/11/16 |
| | | | | EP | | JTW | 11/23/15 | RMB | 11/23/15 | AAW | 11/23/15 |
| | | | | B | ADDED GEOTECH INFO | MRS | 09/18/15 | RMB | 09/18/15 | AAW | 09/18/15 |
| | | | | A | ISSUED FOR BID | DLM | 08/31/15 | RMB | 08/31/15 | AAW | 08/31/15 |
| DWG NO | | DWG NO | DESCRIPTION | NO. | DESCRIPTION | BY | DATE | CHK | DATE | APP | DATE |


Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911


SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
HWY 15
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200' | DWG. NO: PA-CU-0176.0019-RD-16

RETTEW

We answer to you.

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Engineers
Environmental Consultants
Surveyors
Landscape Architects
Safety Consultants

March 1, 2019

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

RE: Sunoco Pipeline, LP Pipeline Project - Mariner East II
Highway 15 HDD (S2-0247), PA- CU-0176.0019-RD-16
Hydrogeological Re-Evaluation Report for the 16-inch Pipeline
Upper Allen Township, Cumberland County, Pennsylvania
RETTEW Project No. 096302011

**EXECUTIVE SUMMARY**

1. The Corrected Stipulated Order dated August 10, 2017, requires a re-evaluation of the Highway 15 horizontal directional drill (HDD) location S2-0247, including a geologic report. This HDD is listed as No. 10 of the HDDs in Exhibit 3. Due to the occurrence of an inadvertent return (IR) during HDD operations for the 20-inch pipeline, this hydrogeological report was also prepared to address the potential for IRs during the proposed 16-inch HDD operations.
2. The site is underlain by limestone of the Ordovician age Rockdale Run Formation (Orr). Geologic mapping, published reports, geophysical surveys, and field observations indicate steeply south-southeasterly dipping beds with regularly spaced jointing and fracturing with karst features.
3. Water-bearing zones generally occur in secondary openings along bedding planes, joints, faults, fractures and karst features. The permeability of these features is enhanced by dissolution of the limestone and dolomite bedrock.
4. Water-bearing zones in the Rockdale Run Formation are typically within 200 feet of the ground surface. 91 groundwater yielding zones are reported within the Rockdale Run Formation, with 58 of them being at depths of less than 100 feet and only seven occur below 250 feet. The calculated median sustained groundwater yield for the formation is 405 gallons per minute.
5. The HDD profile for the permitted 16-inch drill has been redesigned to increase the amount of cover under Highway 15.
6. Based on the hydro-structural characteristics of the underlying geology, results of the geotech investigations, geophysical survey, and the occurrence of an IR during the installation of the 20-inch pipeline pilot hole, the Highway HDD is susceptible to an IR of drilling fluid during HDD operations for the planned 16-inch drill. The redesigned 16-inch HDD profile along with engineering controls and proactive HDD best management practices during drilling operations will be used to reduce the risk of an IR.

## 1.0 INTRODUCTION

The purpose of this report is to describe the geologic and hydrogeologic setting of the Highway 15 S2-0247 horizontal directional drill (HDD) location on the Sunoco Pipeline, LP (SPLP) Pennsylvania Pipeline Project - Mariner East II (PPP-ME2) Project. The Highway 15 HDD is located in Upper Allen Township, Cumberland County, Pennsylvania as shown on **Figure 1**. The HDD will be drilled under the Pennsylvania Turnpike (Interstate 76) and Highway (State Route) 15. This re-evaluation report is part of the response to the Corrected Stipulated Order dated August 10, 2017 related to the potential for IRs of drilling fluids during proposed drilling operations. This re-evaluation report was also prepared as a result of an IR that occurred on June 27, 2017, as the 20-inch pilot hole was being advanced.

The original 16-inch HDD profile was redesigned on January 30, 2019. The overall boring length of the proposed HDD was increased and the inclination of the entry and exit angles has been increased to increase the amount of cover at the location of the June 27, 2017 IR and to install the boring into bedrock quicker than the original, shallower profile. The redesigned western HDD entry/exit is at a surface elevation of approximately 428 feet above mean sea level (AMSL) and the redesigned eastern entry/exit is at an elevation of approximately 452 feet AMSL. The inclination of the eastern and western entry/exit angles has been increased to 16° to install the pipe through the soils and bedrock in closer proximity to the entry and exit points, and to deepen the profile to approximately 89 feet at Highway 15 (approximately 25 feet deeper than the 20-inch pipe) and 85 feet at the June 27, 2017 IR location. The horizontal length and the boring/pipe length are 1,985 and 2,010 feet, respectively. The locations of the as-built 20-inch and proposed 16-inch, Highway 15 HDD locations are shown on **Figure 1**, and the redesigned 16-inch profile detail is included as **Attachment 1.**

## 2.0 GEOLOGY AND SOILS

Based upon publications by the Pennsylvania Bureau of Topographic and Geologic Survey (PABTGS), the site is in the Great Valley Section of the Ridge and Valley Physiographic Province of Pennsylvania and is underlain by very finely crystalline limestone with minor occurrences of dolomite and chert. Local topography is characterized by rolling valleys of low relief and natural slopes that are gentle and relatively stable. Geologic structures are characterized as thrust sheets, nappes, overturned folds and steeply inclined faults (Sevon, 2000). Areas underlain by these rock units typically have good subsurface drainage and poor surface drainage where bedrock dissolution results in the development of bedrock pinnacles and solution cavities (e.g., sinkholes, voids, caves). Based on the United States Geological Survey (USGS) 7.5-Minute Mechanicsburg and Lemoyne Topographic Quadrangle Maps as shown on **Figure 1**, the site is situated at an approximate elevation of 460 to 440 feet AMSL. Surface topography at the site generally slopes towards the north/northeast towards the un-named tributary to Cedar Run Run. The major surface water feature is the unnamed tributary to Cedar Run that flows northeast to Cedar Run which ultimately discharges into Yellow Breeches Creek.

The site geology for the redesigned 16-inch HDD profile is mapped as the Orr as shown on **Figure 2**. The Rockdale Run Formation contains a very light gray, very fine-grained pure limestone in the lower part of the formation, while the middle and upper portions of the formation consist mostly of light-gray limestone, commonly containing abundant fine carbonate grains and fossil fragments. Dolomite are sparsely distributed throughout the formation but are primarily concentrated towards the top of the unit (Becher and Root, 1981). The formation also contains lenses of pink to brown chert and white quartz rosettes are found near the top of the formation.

The lower third of the formation is medium bedded, while the upper two thirds are thickly bedded. Joints tend to have a blocky pattern, are moderately well developed, moderately abundant, and regularly spaced. Fractures in the formation tend to have a moderate distance between them, are open and steeply dipping. The Rockdale Run Formation tends to be moderately resistant to weathering and is moderately weathered to a deep depth. The weathered product consists of irregular and blocky-shaped fragments resulting from prolonged weathering. The overlying mantle is moderately thick and in most places the bedrock-mantle interface is characterized by bedrock pinnacles. From an engineering stand point, the formation is considered difficult to excavate, due to the degree and extent of bedrock pinnacle development, while drilling rates are expected to be fast but may be slowed by chert and quartz lenses. Cut slope stability is good, provided solution opening and local intense pinnacle development are investigated. Subsurface drainage is good but there is little surface drainage. Secondary porosity provided by interconnections between joints and solution cavities is moderate to high in magnitude; while permeability for the formation is low to moderate (Geyer and Wilshusen, 1982).

According to the United States Department of Agriculture (USDA) (2018) Soil Survey of Cumberland County, Pennsylvania, soils in the vicinity of the Highway 15 HDD consist of eight separate soil units. A USDA soils map depicting the mapped area, along with the soil profile descriptions, is included as **Attachment 2**.

## 3.0 HYDROGEOLOGY

Groundwater at the site occurs in a fractured, solution-prone, carbonate bedrock aquifer system within the Rockdale Run Formation. In carbonate rocks, water-bearing zones generally occur in solution-enhanced secondary openings that form along bedding planes, joints, faults and fractures. Most of the water-bearing zones penetrated by supply wells occur in individual fractures or groups of interconnected fractures that are sufficiently enlarged by dissolution of bedrock to provide pathways for the transport of groundwater.

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

The median depth of water supply wells in the Rockdale Run Formation is reported to be 82 feet bgs with a median depth to water of 30 feet bgs. A medium specific capacity of 12 gallons per minute (gpm) per foot was calculated from 43 water supply wells in the Rockdale Run Formation. This medium specific capacity is nearly double that of the other carbonate aquifers within the Cumberland Valley, with the exception of the Tomstown Formation. The calculated median sustained yield of 405 gpm attributed to well-developed fractures and solution openings. Sustained yields of 500 gpm and 600 gpm are the reported maximum yields for this formation. Of the 91 yielding zones reported within the Rockdale Run Formation, 58 are at depths of less than 100 feet and only seven occur below 250 feet. No large specific-capacity or high-yielding wells produce from zones below 200 feet (Becher and Root, 1981).

Well records for 8 individual water supply wells within a 0.5-mile radius of the Highway 15 HDD were obtained from the Pennsylvania Groundwater Information System (PaGWIS). The well locations are shown on **Figures 2** and **3**. Well construction details were not reported for all of the wells; however, the majority of the identified wells were completed as 6-inch-diameter open-rock wells with total depths ranging from 200 to 280 feet bgs. Reported well yields range from 5 to 150 gpm, while the reported water levels ranged from 21 to 54 feet bgs. The information obtained from these well records is summarized in the following table:

| Well No. | Well Use | Casing Depth (feet) | Total Depth (feet) | Water Level (feet) | Yield (gpm) |
|---|---|---|---|---|---|
| 99126 | DOMESTIC | 63 | 280 | 40 | 5 |
| 99108 | DOMESTIC | NOT REPORTED | NOT REPORTED | 21 | NOT REPORTED |
| 99023 | INSTITUTIONAL | 64 | 200 | 54 | 150 |
| 561774 | DOMESTIC | NOT REPORTED | NOT REPORTED | NOT REPORTED | NOT REPORTED |
| 561772 | DOMESTIC | NOT REPORTED | NOT REPORTED | NOT REPORTED | NOT REPORTED |
| 561770 | DOMESTIC | NOT REPORTED | NOT REPORTED | NOT REPORTED | NOT REPORTED |
| 262303 | IRRIGATION | 105 | 250 | 43 | 24 |
| 17095 | DOMESTIC | NOT REPORTED | NOT REPORTED | 21.4 | NOT REPORTED |

In January 2019, other Sunoco subcontractors provided a map depicting the locations of researched private water supplies located within a 450-foot radius of the Highway 15 HDD. No private water supply wells were identified within the 450-foot radius as shown on **Attachment 3**. However, one private water well was identified approximately 876 feet southeast of the eastern HDD entry/exit point. No specific information pertaining to the total depth, depth to water or pump depth could be obtained.

## 4.0 FRACTURE TRACE ANALYSIS

Fracture traces underlying, or in close proximity to, the Highway 15 HDD were evaluated using historical aerial photographs from the years 1993 through 2016 (Google Earth, 2019), the Mechanicsburg and Lemoyne, PA USGS 7.5 Minute Quadrangle Topographic Map and the Geologic Map of the Mechanicsburg Quadrangle (Root, 1978) and the Geologic Map of the Harrisburg West Area (Root, 1977). The aerial photographs and maps were used to approximate locations of natural linear features or lineaments expressed on the ground surface. The linear features may be the surficial representation of deeper fractures, joints, faults or bedding planes within the subsurface which can transmit groundwater through the fractured bedrock aquifer underlying the Highway 15 HDD.

**Figures 2** and **3** show the results of the fracture trace analysis overlain on the geologic map and aerial base map, respectively. Three fracture traces were identified in close proximity to the proposed Highway 15 HDD. Two of the fracture traces trend approximately north/northeast-south/southwest, parallel to geologic strike. The remaining fracture trace, which is almost perpendicular to and intercepting the other two fracture traces, trends east-west.

## 5.0 GEOTECHNICAL EVALUATION

Two geotechnical drilling investigations were performed at the Highway HDD site. The initial investigation was performed in February and April, during the preliminary investigation for the Highway 15 HDD and prior to initiating the 20-inch HDD operations. A second phase of geotechnical drilling was performed in September of 2017. The 2015 test borings were advanced by hollow-stem auger drilling to auger refusal or a maximum depth of 30 feet bgs was reached. NQ-sized wireline rock coring was utilized in the boring that was advanced past auger refusal. These borings are designated as SB-01, SB-02 and SB-03. The second phase test borings completed in 2017 were advanced using hollow-stem auger drilling and NQ-sized wireline rock coring methods. The 2017 borings were designated as B-01 and B-02. Soil, residual soil and weathered bedrock collected during both investigations were sampled using split-spoon sampling techniques. Geotechnical boring logs are included in **Attachment 1**.

Boring SB-01 was located approximately 200 feet northeast of the HDD entry point near the western end of the profile. Boring SB-02 was located approximately 1,100 feet southeast of the HDD entry point (in the parking lot of the Cracker Barrel Restaurant) and near the midpoint of the profile. Boring SB-03 was located approximately 150 feet north of the exit point near the eastern end of the profile. Boring B-01 was located approximately 100 feet northeast of the HDD entry point and B-02 was located approximately 75 feet north of the HDD exit point. The locations of the borings are identified on **Figure 2** and **Figure 3.**

The generalized subsurface profile at the site, as observed in the borings, is described as follows:

- Residual soil depths vary boring from boring; 30.0 feet bgs at SB-01, 13.9 feet bgs at SB-02, 12.1 feet bgs at SB-03, 10.0 feet bgs at B-01, and 10.5 feet bgs at B-02. The residual soils are described as follows:
    - **Boring SB-01**: Topsoil, mottled silty CLAY (CL) and fine sand, trace unweathered fine rock fragments; silty CLAY (CL) with some fine sand, soft. The boring was terminated at 30.0 feet bgs. Groundwater was not encountered in the boring.
    - **Boring SB-02**: Topsoil, mottled silty CLAY (CL) and fine sand, trace fine gravel, silty CLAY (CL), gray partially weathered LIMESTONE. Auger refusal was encountered at 14.0 feet bgs. Groundwater was not encountered in the boring.
    - **Boring SB-03**: Topsoil, CLAY (CH) of high plasticity, trace fine limestone fragments, gray LIMESTONE fragments. Auger refusal was encountered at 12.0 feet bgs. Groundwater was not encountered in the boring.
    - **Boring B-01**: Medium stiff, SILT (ML) with sand, moist to moist/wet, highly weathered LIMESTONE. Split spoon refusal occurred at 10 feet bgs and the remainder of the boring was cored with NQ-sized wireline rock coring methods. Groundwater was encountered at 7.8 feet bgs.
    - **Boring B-02:** Probable fill consisting of lean CLAY (CL) with sand, trace gravel, moist, medium dense, clayey SAND (SC) with gravel, moist/wet, very soft, lean CLAY (CL) trace sand,

moist/wet, very loose, clayey GRAVEL (GC) with sand, moist/wet, highly weathered gravel sized LIMESTONE fragments. Casing refusal occurred at 10.3 feet bgs and the remainder of the boring was cored with NQ-sized wireline rock coring methods. Groundwater was not encountered in the residual soil.

- At depths of auger or split-spoon refusal, and to the total depth of the NQ cores, weathered bedrock and bedrock were encountered and are described as follows:
  - **Boring SB-01:** Rock coring was not completed at this location.
  - **Boring SB-02:** Boring SB-02 was completed to a total depth of 21.4 feet bgs. From 14.0 to 21.4 feet, light gray, moderately to intensely fractured LIMESTONE with calcite was encountered. Rock recoveries ranged from 92% to 100% and Rock quality designations (RQDs) ranged from very poor (13) to poor (49).
  - **Boring SB-03:** Rock coring was not completed at this location.
  - **Boring B-01:** B-01 was completed to a total depth of 85.0 feet bgs. From 10.0 to approximately 24 feet bgs, light-gray to black, very fine-grained, slightly weathered, very broken to massive, hard to very hard LIMESTONE was encountered. Rock recoveries were 100% and RQDs ranged from 97 to 100 (excellent). From approximately 24 to 30.0 feet bgs, gray to dark gray, very fine-grained, slightly weathered, massive, very hard DOLOMITE was encountered. Rock recovery was 98% and RQD value was excellent (98). From 30.0 to 85.0 feet bgs, light gray to black, very fine-grained slightly weathered, very broken to massive, hard to very hard LIMESTONE was encountered. A broken seam (approximately 1.5-inch thick) was observed at 54.2 feet bgs., and an approximately 2.5-inches thick weathered seam was observed at 62.5 feet bgs. A nearly vertical fracture was observed at 70.2 feet bgs. Rock recoveries were 100% and RQD values ranged from good (82) to excellent (100). Groundwater was observed at a depth of 17.3 feet at the completion of coring operations.
  - **Boring B-02:** B-02 was completed to a depth of 110.0 feet bgs. From 10.5 feet bgs to approximately 31 feet bgs, light gray to black, very fine-grained, slightly weathered, broken to massive, moderately hard to very hard LIMESTONE with trace calcite stringers was encountered. A weathered fracture was observed at 11.9 feet bgs. Rock recoveries ranged from 81% to 100% and the RQDs ranged from good (81) to excellent (100). From approximately 31 to 34.5 feet bgs, light gray to dark gray, very fine grained, slightly weathered, very broken to massive, hard to very hard DOLOMITE with trace calcite stringers was encountered. From 34.5 to 57.5 feet bgs, light gray to black, very fine grained, slightly weathered, broken to massive, moderately hard to very hard, LIMESTONE with trace calcite stringers was observed. An approximately 2.25-inch thick broken seam was observed at 42.7 feet bgs, while a weathered seam, approximately 2-inch thick, was observed at 47.8 feet bgs. From 57.5 feet bgs to 110.0 feet below bgs, alternating layers of LIMESTONE and DOLOMITE, as previously described, were observed. Broken layers ranging in thickness from 4- to 4.5-inches thick were observed at 59.5, 92.2 and 103.3 feet bgs, while approximately 2.25-inch thick broken seams were observed at 71.7 and 104.5 feet bgs. A vertical fracture was observed from 87.1 to 87.8 feet bgs. Rock recoveries were 100% and RQD values ranged from fair (73) to excellent (100). Groundwater was observed at 27.8 feet bgs at the completion of coring operations.

Unconfined compressive strength testing was performed on the core samples, and these testing results are summarized in the table below.

| Boring | Sample Depth (feet bgs) | Compressive Strength (pounds per square inch) |
|---|---|---|
| SB-02 | 19.0 | 13,320 |
| B-01 | 11 | 495.04 |
| B-01 | 22.1 | 552.79 |
| B-01 | 28.4 | 1319.18 |
| B-01 | 34.9 | 301.38 |
| B-01 | 40.6 | 695.34 |
| B-01 | 57 | 503.52 |
| B-01 | 67.4 | 564.48 |
| B-01 | 78.2 | 290.38 |
| B-02 | 11.1 | 546.32 |
| B-02 | 21.5 | 666.23 |
| B-02 | 31.7 | 853.51 |
| B-02 | 40.8 | 229.87 |
| B-02 | 47.5 | 1336.64 |
| B-02 | 58.7 | 992.64 |
| B-02 | 67.8 | 578.50 |
| B-02 | 79.9 | 513.45 |
| B-02 | 88.5 | 668.55 |
| B-02 | 102.6 | 791.47 |

Please note that RETTEW Associates, Inc. (RETTEW) and Skelly and Loy did not oversee or direct the geotechnical drilling program associated with the Highway 15 HDD including, but not limited to, the selection of boring locations and target depths, observations of rock cores during drilling operations, or preparation of boring logs. The geotechnical reports, boring logs, and core photographs that resulted from these programs were generated by other Sunoco Pipeline, L.P. contractors. RETTEW and Skelly and Loy relied on these reports and incorporated the data into the general geologic and hydrogeologic framework included in this report.

## 6.0 GEOPHYSICAL SURVEY

RETTEW completed a multi-technique geophysical survey at the Highway 15 HDD site from November 12-20, 2018. The purpose of the survey was to provide supplemental information to the geotechnical investigations to aid in detecting and delineating subsurface voids or low-density zones

beneath three portions of the HDD path that could increase the risk of IRs and/or a loss of returns, and to determine the rock profile and rock rippability for ease-of-excavation.

Four different geophysical techniques were utilized to detect and delineate subsurface voids or low-density zones and to develop a rock profile. These analytical methods, and their general results are summarized as follows:

- A microgravity survey delineated low-density zones throughout the three survey areas. These zones could represent minor karst-related air-, water-, or mud-filled voids, or locally deeper rock and thicker soils.
- A seismic refraction survey confirmed the presence of an irregular bedrock surface or "epikarst" zone.
- A multi-spectral analysis of surface waves survey identified low-velocity zones above (soft soils) and below (possible voids) the bedrock surface.
- An electrical resistivity imaging survey identified conductive features which could represent fractures or wet soils in each of the three areas.

Results from these geophysical techniques are consistent with each other, and with the geology as mapped by the PA Geological Survey, all suggesting that the local bedrock (limestone) is karstified, with potential concentrations of dissolution cavities (of various sizes) indicated by the geophysical anomalies detected. In the limestone, the top-of-rock is expected to be pinnacled (highly irregular) with interfingered competent rock and residual clay soil as well as potential bedrock voids.

## 7.0 FIELD OBSERVATIONS

RETTEW staff were on-site during all 20-inch HDD operations which began on June 12, 2017. An IR occurred while the pilot hole was being advanced on June 27, 2017 with drilling fluid surfacing in the northbound lanes of Highway 15 at the location shown on **Figures 2 and 3** and identified on the profile included as **Attachment 1**. The events that occurred during the 20-inch HDD pipeline installation are summarized below.

- **June 12, 2017:** Michels Directional Crossings (Michels) spudded in the 20-inch pilot hole from the western entry/exit point.
- **June 19, 2017:** Michels reported a partial loss of circulation (LOC) at a trajectory length of 673 feet. Michels began to trip out drill rods and swab the boring, in conjunction with increasing the drilling fluid viscosity. After tripping out four drill rods, full circulation was regained, and pilot hole advancement was resumed.
- **June 24, 2017:** Michels reported a LOC at an approximate trajectory length of 1,525 feet and tripped out/swabbed the boring in an effort to regain full circulation. After regaining full circulation Michels began to trip the pilot bit back to the face of the boring.
- **June 26, 2017:** After tripping the pilot bit back to the face of the boring and resuming pilot hole advancement, Michels reported LOCs for the rest of the day ranging from 50% to 90% losses.
- **June 27, 2017:** Michels regained full circulation and continued to advance the pilot bit from an approximate trajectory length of 1,587 feet. At a trajectory length of 1,768.49 feet and a depth of approximately 32 feet, an IR was observed in the northbound lanes of Highway 15. All drilling activities were immediately suspended and after traffic control was established, cleanup efforts were initiated.

- **June 28 – July 3, 2017:** Michels tripped out of the boring and mobilized the drill rig to the eastern end of the profile to initiate an intercept boring.
- **July 5, 2017:** Michels completed rigging up the drill rig and initiated an interceptor boring from the eastern end of the HDD profile.
- **July 7, 2017:** Michels reports loss of drilling returns ranging from a full loss of returns (LOR) to 50% loss of drilling fluids. Pilot bit reaches trajectory length for intercept, but appeared to be too deep. Michels began efforts to adjust borehole to the proper depth for intercept.
- **July 8, 2017:** Michels appeared to have encountered a void at an approximate trajectory length of 1,722 feet and a depth of 40 feet. Michels tripped out to an approximate trajectory length of 100 feet and a depth of 19 feet to re-orient the boring to make another attempt at intersecting the pilot hole from the western end of the profile.
- **July 13, 2017:** Michels completed intercept of the eastern and western pilot borings and tripped drill rods through the boring to initiate the reaming phase.
- **July 15, 2017:** Michels initiated the 30-inch ream pass from the western end of the boring (pull ream). A 20% to 25% LOC was observed after the reamer had been advanced to an approximate trajectory length of 70 feet. No IRs were observed.
- **July 16 – July 25, 2017:** Michels continued the 30-inch ream to a trajectory length of 764.2 feet on July 25$^{th}$, 2017 when all HDD activities across the MEII Project were suspended pending legal action.
- **August 28, 2017:** Michels resumed the 30-inch reaming phase and advanced the reamer to a trajectory length of 864.8 feet.
- **August 29, 2017:** Michels reported a LOC of approximately 20% to 30% and suspended reaming until an IR survey/patrol was completed. When no IR was observed Michels resumed the 30-inch ream and increased the viscosity of the drilling fluid to regain full circulation.
- **August 30, 2017:** Michels reported a full LOR and suspended drilling until an IR survey/patrol could be completed. Michels tripped the 30-inch reamer out of the boring to fully clear the borehole of cuttings when no IRs were observed.
- **August 31 – September 1, 2017:** Michels continued to trip the 30-inch reamer in and out of the borehole.
- **September 2, 2017:** Michels resumed the 30-inch ream pass.
- **September 5 – 8, 2017**: Michels advanced the 30-inch reamer from an approximate trajectory length of 985 to 1,327 feet.
- **September 9, 2017:** Michels reported a full LOR at a trajectory length of 1,407 feet.
- **September 11 – 13, 2017:** Michels tripped the 30-inch reamer in and out of the boring in conjunction with a clean out tool to remove cuttings that had accumulated in the borehole.
- **September 14, 2017:** Michels resumed the 30-inch ream pass from the eastern end of the boring (push ream).
- **September 15 – 21 2017:** Michels continued the 30-inch ream pass.
- **September 22, 2017:** Michels completed the 30-inch ream pass and initiated the 30-inch swab pass.
- **September 23, 2017:** Michels completed the first swab pass and initiated the second and final swab pass.

- **September 25, 2017:** Second swab pass was completed.
- **September 26, 2017:** The 20-inch product pipe pull was completed.

A field investigation was performed by RETTEW staff on February 19, 2018, to identify rock outcrops for fracture fabric analysis, evaluation and ground-truthing of fracture traces identified during the desktop exercise, to collect additional bedrock strike and dip measurements to accompany published data, and to identify potential sensitive receptors to IRs. Readily accessible bedrock outcrops were not observed. No additional sensitive receptors to IRs were identified during the site reconnaissance.

## 8.0 CONCEPTUAL HYDROGEOLOGIC MODEL AND CONCLUSION

Based on published geologic and hydrogeologic information, results of geotechnical investigations, geophysical surveys, and field observations during completion of the 20-inch HDD, the Highway 15 HDD site is underlain by slightly weathered limestone and dolomite of the Rockdale Run Formation. The hydrogeologic setting is dominated by groundwater flow in secondary openings along geologic features including bedding planes, fractures, and joints. In this formation, secondary openings may be enlarged by solutioning to form karst features (e.g., pinnacled bedrock, sinkholes). Water-bearing zones in the Rockdale Run Formation are typically within 200 feet of the ground surface. 91 groundwater yielding zones are reported within the Rockdale Run Formation, with 58 of them being at depths of less than 100 feet and only seven occur below 250 feet. Geotechnical core observations indicate that the uppermost bedrock along the proposed 16-inch HDD profile is slightly weathered and fractured.

The originally proposed 16-inch HDD profile was relatively shallow at the western entry and eastern exit points and passed through both the unconsolidated overburden and fractured bedrock for an extended period. Based on the hydro-structural characteristics of the underlying geology described in this report and the previous occurrence of an IR during installation of the 20-inch pipe, the Highway 15 HDD site is susceptible to an IR of drilling fluids during HDD operations. As a result, the 16-inch HDD profile was redesigned to allow for deeper crossings beneath Highway 15 and the location of the June 27, 2017 IR. The revised 16-inch HDD profile is approximately 89 and 85 feet beneath Highway 15 and the IR location (approximately 24 feet deeper than the as-built 20-inch pipe), respectively. The inclination of the eastern and western entry angle was increased to allow the pipe to be installed through protective soils, residual soils, and bedrock, and in closer proximity to the entry point than the original profile. From a geologic perspective, the deeper profile, in conjunction with the proposed proactive engineering controls and drilling best management practices (BMPs), will be used to reduce the risk of an IR and/or a loss of drilling fluid. Drilling BMPs are described in the Horizontal Directional Drill Analysis component of the overall re-evaluation package.

## 9.0 REFERENCES

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A.R. Geyer 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.

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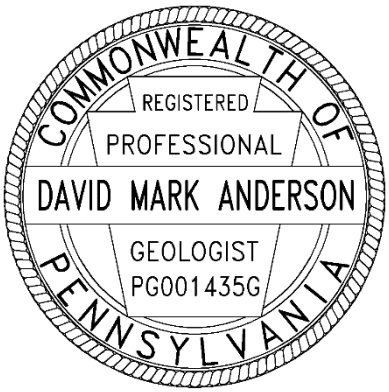
## 10.0 CERTIFICATION

The studies and evaluations presented in this report (other than Section 5.0) were completed under the direction of a licensed professional geologist (PG) and are covered under the PG seals that follow.

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

Douglas J. Hess, PG
License No. PG000186G


David M. Anderson, PG
License No. PG001435G




Enclosures

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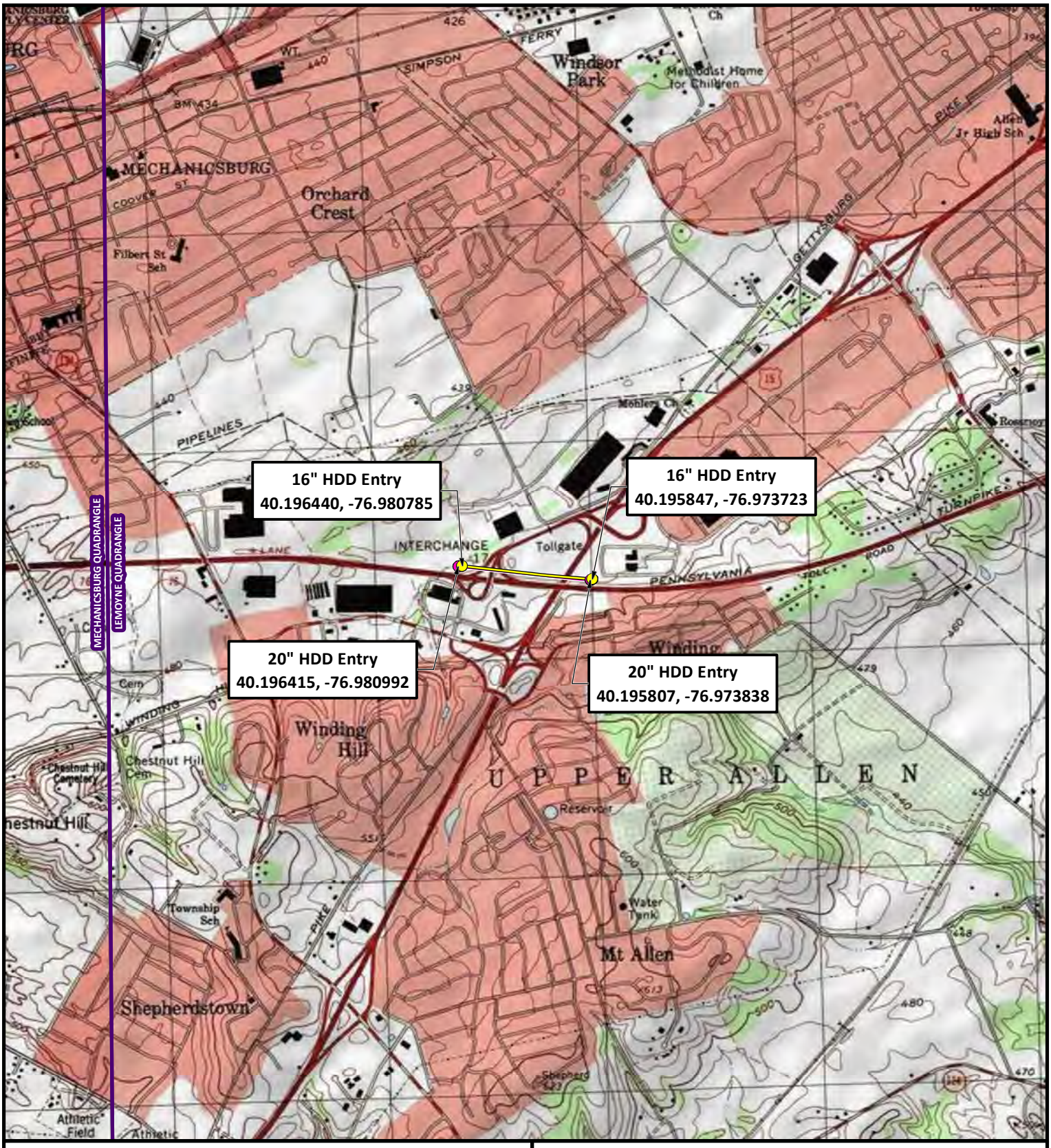
# FIGURES




16" HDD Entry/Exit

20" HDD Entry/Exit

16" HDD Profile

20" HDD Profile

Lemoyne, PA USGS 7.5' Topographic Quadrangle

2/21/2019

# Sunoco Pipeline, L.P.

## Highway 15 HDD Location

**Figure 1 - Topographic Basemap**

Upper Allen Township, Dauphin County, PA

Project No. 096302011

N

W E

S

0 2,000 Feet

1 inch = 2,000 feet



Sunoco Logistics Partners L.P.

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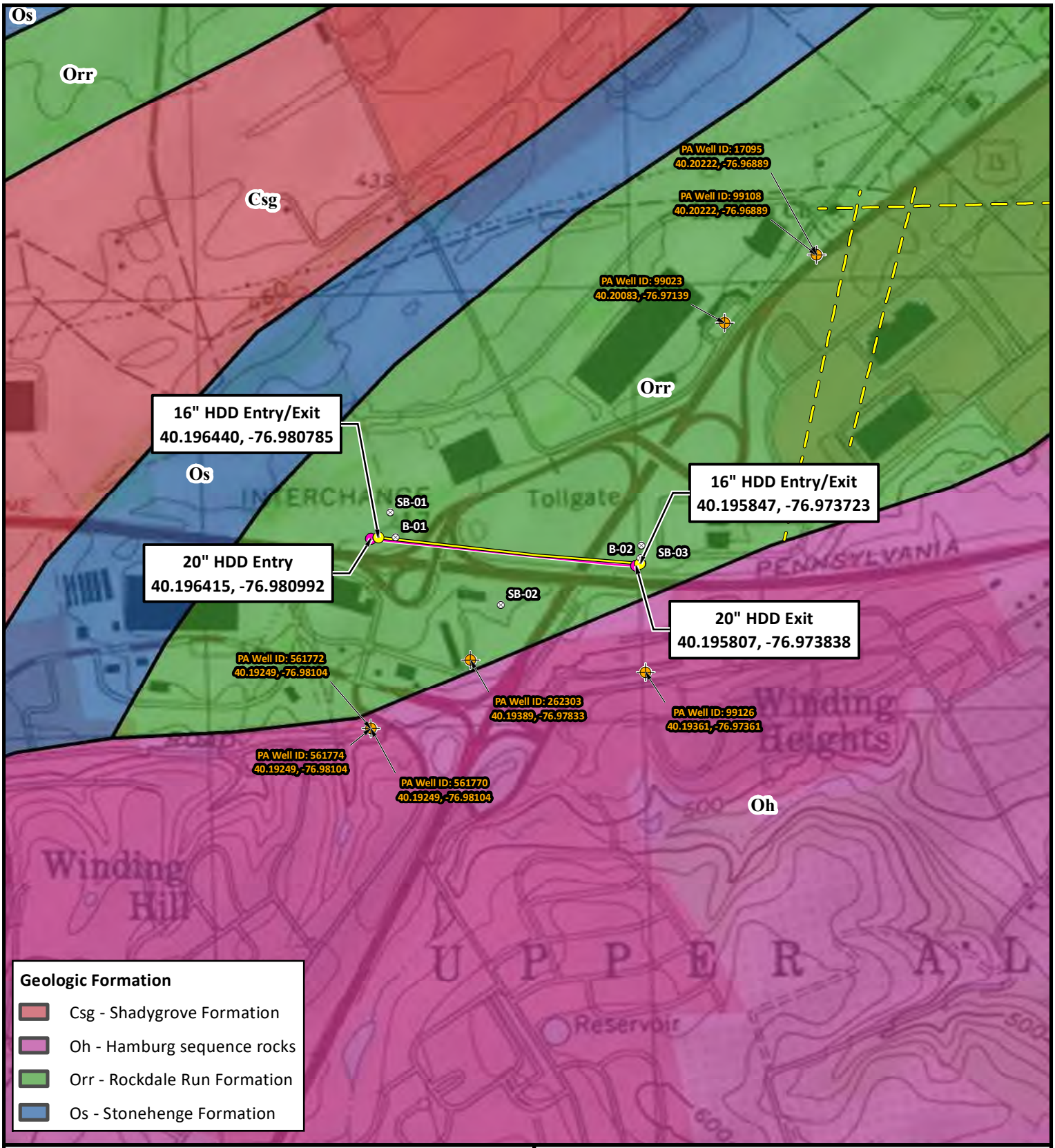


# Sunoco Pipeline, L.P.

## Highway 15 HDD Location

**Figure 2 - Geologic Map**

Upper Allen Township, Dauphin County, PA

Project No. 096302011

0 1,000 Feet

1 inch = 1,000 feet

Lemoyne, PA USGS 7.5' Topographic Quadrangle

2/20/2019



Sunoco Logistics Partners L.P.

RETTEW

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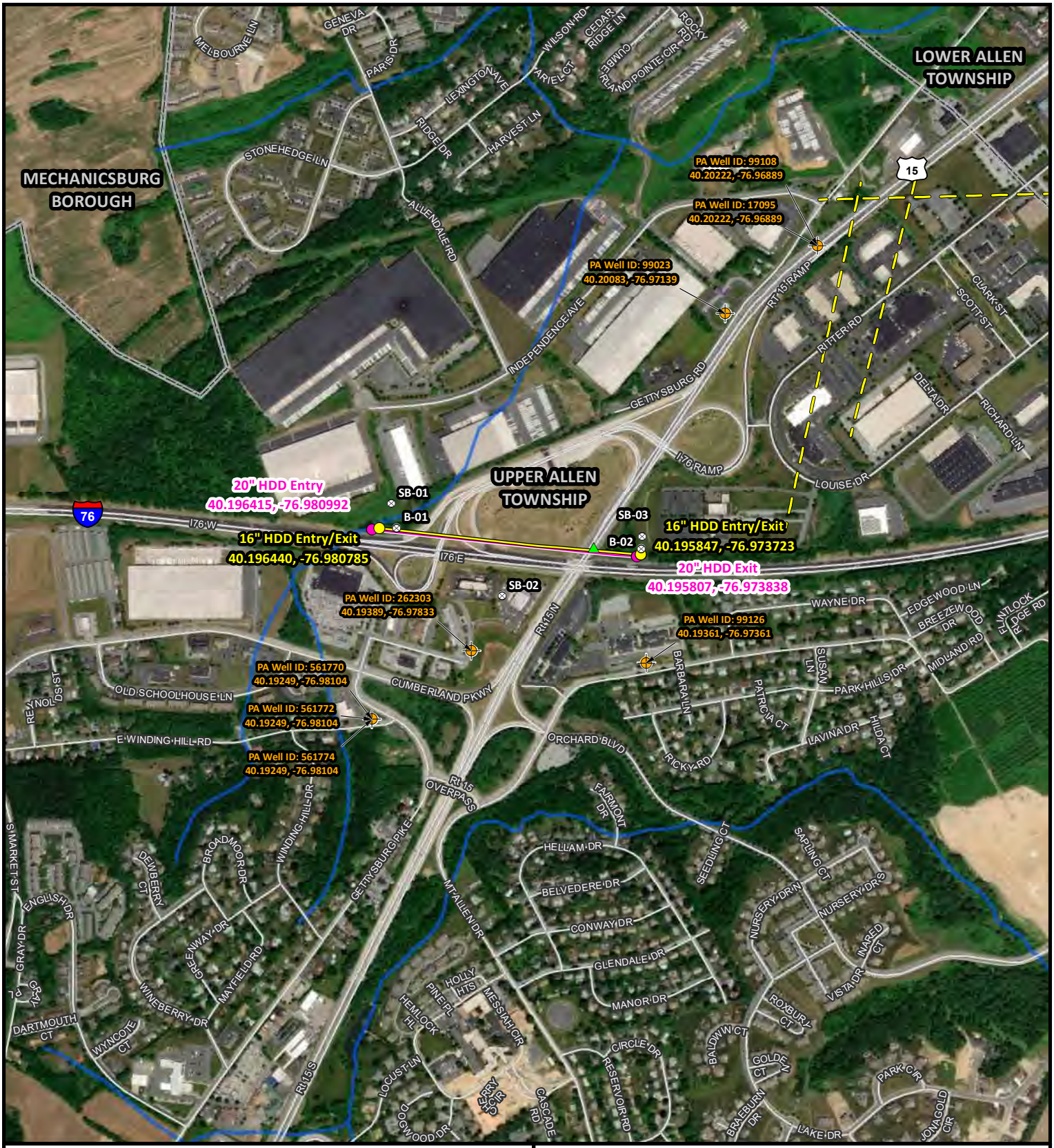


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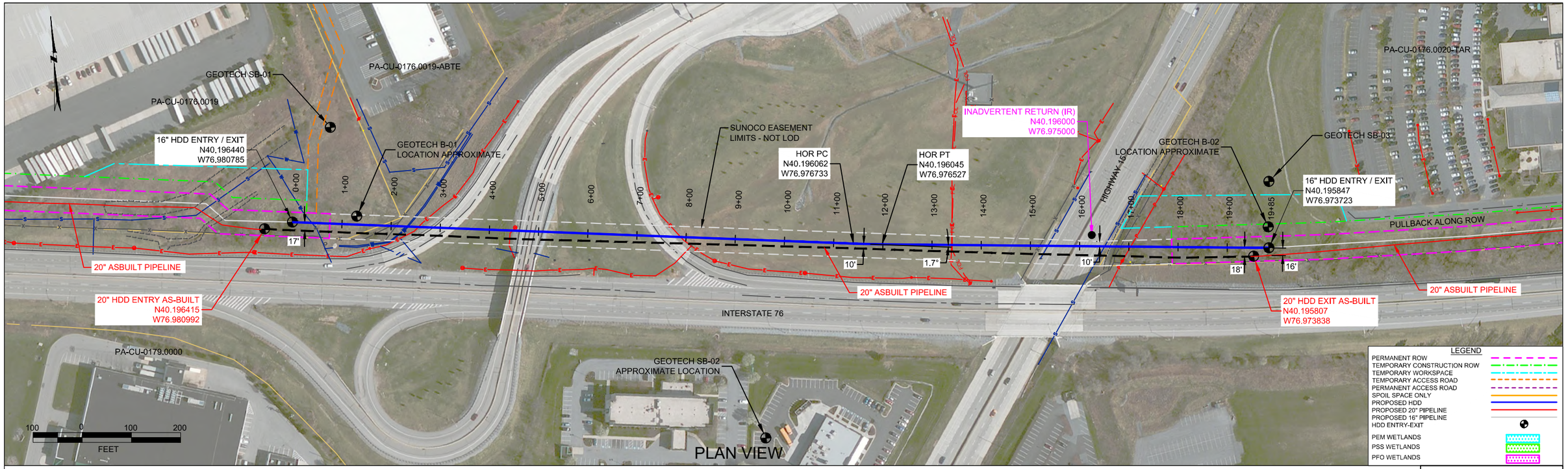
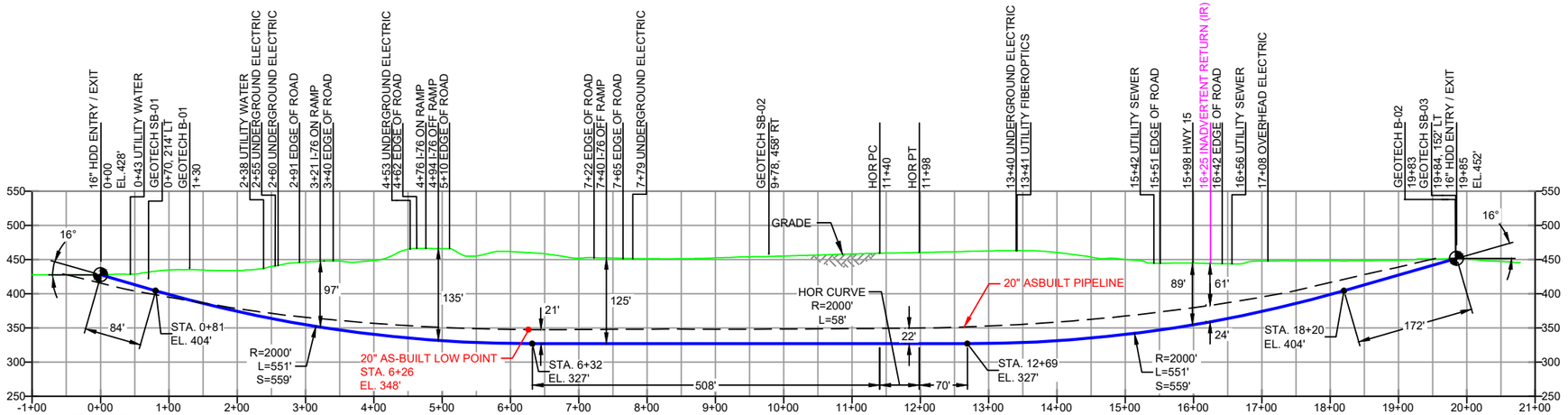
# ATTACHMENT 1
# HDD PROFILES AND GEOTECHNICAL BORING LOGS




PLAN VIEW

## PROFILE VIEW




DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=): 1985'
   HDD PIPE LENGTH (S=): 2010'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 2100 PSIG (SEAM FACTOR 1.0, DESIGH 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 2625 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

CUMBERLAND COUNTY PENNSYLVANIA, UPPER ALLEN TOWNSHIP
S2-0247-16

**GEOTECH SB-01**
- NG EL. 422'
- -TOPSOIL (0' - 0.3')
- -CL (0.3' - 30.0')
- -COMPLETION DEPTH EL. 392'

**GEOTECH SB-02**
- NG EL. 458'
- -TOPSOIL (0' - 0.3')
- -CL (0.3' - 13.5')
- -WEATHERED LIMESTONE (13.5' - 13.9')
- -AUGER REFUSAL (14.0')
- -FRACTURED LIMESTONE (14.0' - 21.4')
- -COMPLETION DEPTH EL. 437'

**GEOTECH SB-03**
- NG EL. 445'
- -TOPSOIL (0' - 0.3')
- -CLAY / LIMESTONE FRAGMENTS (USCS:CH) (0.3' - 12.0')
- -LIMESTONE FRAGMENTS (12.0' - 12.1')
- -AUGER REFUSAL (12.0')
- -COMPLETION DEPTH EL. 433'

NOTE: REFER TO TEST BORING LOG S2-0247 FOR COMPLETE SOIL MATERIAL DESCRIPTION

**GEOTECH B-01**
- NG EL. 437'
- -RESIDUUM SILT ML (0.0' - 8.5')
- -GROUNDWATER (17.3')
- -HIGHLY WEATHERED LIMESTONE (8.5' - 10.0')
- -LIMESTONE/DOLOMITE (10.0' - 85.0')
- -BORING TERMINATED EL.352'

NOTE: REFER TO TEST BORING LOG B-01 INTERTEK PROJECT #04911465 FOR COMPLETE SOIL MATERIAL DESCRIPTION

**GEOTECH B-02**
- NG EL. 449'
- -PROBABLE FILL CL (0.0' - 2.5')
- -RESIDUUM CLAYEY SAND SC (2.5' - 6.5')
- -RESIDUUM CLAY CL (6.5' - 9.75')
- -RESIDUUM CLAYEY GRAVEL GC (9.75' - 10.5')
- -GROUNDWATER (27.8')
- -LIMESTONE/DOLOMITE (10.5' - 111.0')
- -BORING TERMINATED EL.338'

NOTE: REFER TO TEST BORING LOG B-02 INTERTEK PROJECT #04911465 FOR COMPLETE SOIL MATERIAL DESCRIPTION

### 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 | | | | | REVISIONS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ES-4.89 | TO | ES-4.90 | EROSION & SEDIMENT PLAN | EP3 | DESIGN CHANGE - LOWERED DRILL AND ADDED GEOTECH | MRS | 01/30/19 | RMB | 01/30/19 | AMC | 01/30/19 |
| SHEET 54 | TO | SHEET 54 | AERIAL SITE PLAN | EP2 | REVISED PER PADEP COMMENTS RECEIVED 09-06-16 | MRS | 10/07/16 | RMB | 10/07/16 | AAW | 10/07/16 |
| | | | | EP1 | REVISED PER PADEP COMMENTS | MRS | 05/11/16 | RMB | 05/11/16 | AAW | 05/11/16 |
| | | | | EP | | JTW | 11/23/15 | RMB | 11/23/15 | AAW | 11/23/15 |
| | | | | B | ADDED GEOTECH INFO | MRS | 09/18/15 | RMB | 09/18/15 | AAW | 09/18/15 |
| | | | | A | ISSUED FOR BID | DLM | 08/31/15 | RMB | 08/31/15 | AAW | 08/31/15 |
| DWG NO | | DWG NO | DESCRIPTION | NO. | DESCRIPTION | BY | DATE | CHK | DATE | APP | DATE |

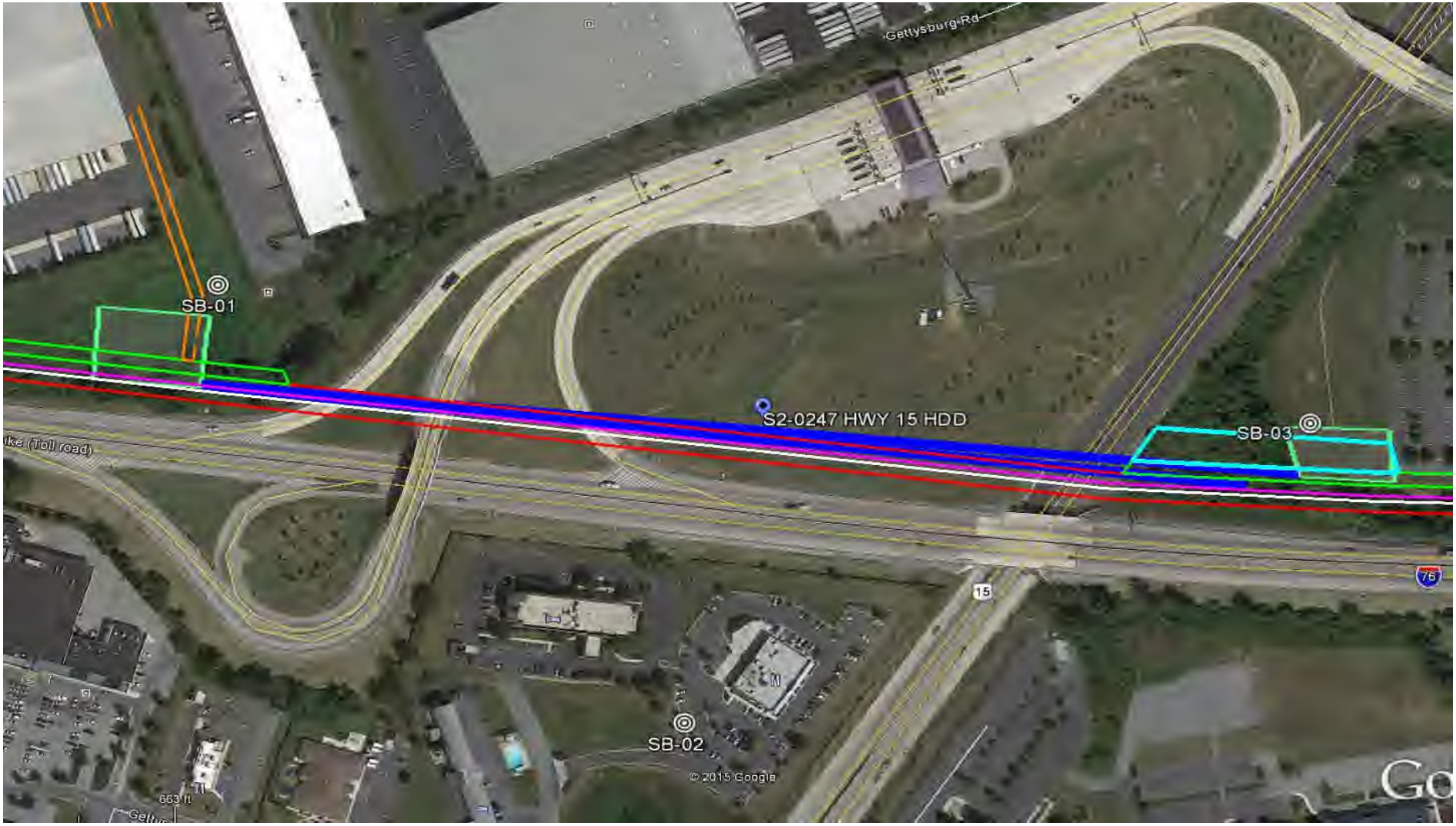
**Sunoco Logistics Partners L.P.**

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
HWY 15
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200' | DWG. NO: PA-CU-0176.0019-RD-16




LEGEND:

◎ Geotechnical Soil Boring (SB) Locations

TETRA TECH

GEOTECHNICAL BORING LOCATIONS
HDD S2-0247 HWY 15
CUMBERLAND COUNTY, UPPER ALLEN TOWNSHIP, PA
SUNOCO PENNSYLVANIA PIPELINE PROJECT

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

# TEST BORING LOG

| | | | |
|---|---|---|---|
| Project Name: | SUNOCO PENNSYLVANIA PIPELINE PROJECT | | Project No.: 103IP3406 |
| Project Location: | INDEPENDENCE AVENUE, MECHANICSBURG, PA | | Page 1 of 1 |
| HDD No.: | S2-0247 | Dates(s) Drilled: 02-03-15 | Inspector: E. WATT |
| Boring No.: | SB-01 | Drilling Method: SPT - ASTM D1586 | Driller: S. HOFFER |
| Drilling Contractor: | HAD DRILLING | Groundwater Depth (ft): NOT ENCOUNTERED | Total Depth (ft): 30.0 |
| Boring Location Coordinates: | | 40° 11' 49.015" N | 76° 58' 49.632" W |

| Sample No. | Sample Depth (ft) From | Sample Depth (ft) To | Strata Depth (ft) From | Strata Depth (ft) To | Recov. (in) | Strata (USCS) | Description of Materials | 6" Increment Blows * | | | | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0.0 | 0.3 | | | TOPSOIL (4") | | | | | |
| 1 | 3.0 | 5.0 | 0.3 | | 19 | | MOTTLED BROWN AND GRAY SILTY CLAY. | 3 | 3 | 7 | 10 | **10** |
| | | | | | | | | | | | | |
| 2 | 8.0 | 10.0 | | | 24 | | MOTTLED BROWN AND GRAY SILTY CLAY AND FINE SAND, TRACE | 5 | 8 | 11 | 12 | **19** |
| | | | | | | | UNWEATHERED FINE ROCK FRAGMENTS. (USCS: CL). | | | | | |
| 3 | 13.0 | 15.0 | | | 24 | | MOTTLED BROWN AND GRAY SILTY CLAY, TRACE UNWEATHERED | 2 | 4 | 5 | 5 | **9** |
| | | | | | | CL | FINE ROCK FRAGMENTS. | | | | | |
| 4 | 18.0 | 20.0 | | | 24 | | BROWN SILTY CALY. | 2 | 4 | 6 | 6 | **10** |
| | | | | | | | | | | | | |
| 5 | 23.0 | 25.0 | | | 24 | | BROWN SILTY CLAY, SOFT, WITH SOME FINE SAND. | 1 | 2 | 3 | 3 | **5** |
| | | | | | | | (USCS: CL). | | | | | |
| 6 | 28.0 | 30.0 | | 30.0 | 24 | | BROWN SILTY CLAY, SOFT. | 1 | 1 | 2 | 4 | **3** |
| | | | | | | | | | | | | |
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| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | DRY AND CAVED AT 30'. | | | | | |
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Notes/Comments:

Pocket Pentrometer Testing

S1: 3 TSF S4: 0.5 TSF
S2: 2.5 TSF S5: 0.5 TSF
S3: 2.5 TSF S6: 0.5 TSF

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: | CRAKER BARREL PROPERTY, SOUTH SIDE OF I-76, MECHANICSBURG, PA | | Page 1 of 1 |
| HDD No.: | S2-0247 | Dates(s) Drilled: 04-28-15 | Inspector: E. WATT |
| Boring No.: | SB-02 | Drilling Method: SPT - ASTM D1586 | Driller: S. HOFFER |
| Drilling Contractor: | HAD DRILLING | Groundwater Depth (ft): NOT ENCOUNTERED | Total Depth (ft): 21.4 |
| Boring Location Coordinates: | | 40° 11' 40.770" N | 76° 58' 39.169" W |

| Sample No. | Sample Depth (ft) From | Sample Depth (ft) To | Strata Depth (ft) From | Strata Depth (ft) To | Recov. (in) | Strata (USCS) | Description of Materials | 6" Increment Blows * | | | | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0.0 | 0.3 | | | TOPSOIL (4") | | | | | |
| 1 | 3.0 | 5.0 | 0.3 | | 13 | CL | MOTTLED REDDISH BROWN, TAN, GRAY SILTY CLAY AND FINE SAND, | 1 | 2 | 4 | 6 | **6** |
| | | | | | | | TRACE FINE GRAVEL. | | | | | |
| 2 | 8.0 | 10.0 | | | 12 | | REDDISH BROWN SILTY CLAY (USCS: CL). | 2 | 8 | 10 | 14 | **18** |
| | | | | 13.5 | | | | | | | | |
| 3 | 13.0 | 13.9 | 13.5 | 13.9 | 5 | | GRAY PARTIALLY WEATHERED LIMESTONE. | 5 | 50/5" | | | **>50** |
| | | | | | | | AUGER REFUSAL AT 14'. | | | | | |
| | | | | | | | <u>ROCK CORING</u> | | | | | |
| RUN 1 | 14.0 | 18.0 | 14.0 | 18.2 | 44 | LIMESTONE ROCK | LIGHT GRAY INTENSELY FRACTURED LIMESTONE WITH CALCITE. | TCR: 92%, SCR: 18%, RQD: 13% | | | | |
| RUN 2 | 18.0 | 21.4 | 18.2 | 20.4 | 41 | | LIGHT GRAY MODERATELY FRACTURED LIMSTONE WITH CALCITE. | TCR: 100%, SCR: 65%, RQD: 49% | | | | |
| | | | 20.4 | 21.4 | | | LIGHT GRAY INTENSELY FRACTURED LIMESTONE WITH CALCITE. | | | | | |
| | | | | | | | <u>CORE TESTING RESULTS (DEPTH 19'):</u> | | | | | |
| | | | | | | | COMPRESSIVE STRENGTH: 13,320 PSI | | | | | |
| | | | | | | | UNIT WEIGHT: 169.9 PCF | | | | | |

Notes/Comments:

<u>Pocket Pentrometer Testing</u>
4': 3.25 TSF
10': > 4 TSF

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: | DELTA DRIVE, MECHANICSBURG, PA | | Page 1 of 1 |
| HDD No.: | S2-0247 | Dates(s) Drilled: 02-03-15 | 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): 12.1 |
| Boring Location Coordinates: | | 40° 11' 46.376" N | 76° 58' 25.257" W |

| Sample No. | Sample Depth (ft) From | Sample Depth (ft) To | Strata Depth (ft) From | Strata Depth (ft) To | Recov. (in) | Strata (USCS) | Description of Materials | 6" Increment Blows * | | | | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0.0 | 0.3 | | | TOPSOIL (3") | | | | | |
| 1 | 3.0 | 5.0 | 0.3 | | 10 | | ORANGE BROWN CLAY OF HIGH PLASTICITY, TRACE FINE ROCK | 1 | 6 | 8 | 10 | **14** |
| | | | | | | CH | FRAGMENTS. | | | | | |
| 2 | 8.0 | 10.0 | | | 22 | | MOTTLED ORANGE AND YELLOWISH BROWN CLAY, HIGH PLASTICITY, | 5 | 6 | 8 | 10 | **14** |
| | | | | 12.0 | | | TRACE FINE LIMESTON ROCK FRAGMENTS. (USCS: CH). | | | | | |
| 3 | 12.0 | 12.1 | 12.0 | 12.1 | <1 | | GRAY LIMESTONE FRAGMENTS. | 50/.5" | | | | **0** |
| | | | | | | | AUGER REFUSAL AT 12'. OFF-SET BORING 15' SOUTH AND AUGERED | | | | | |
| | | | | | | | TO REFUSAL AT 11'. OFF-SET AGAIN AND AUGERED TO REFUSAL | | | | | |
| | | | | | | | AT 11.5'. | | | | | |
| | | | | | | | REFUSAL MATERIAL MIGHT BE A RESULT OF BOULDERY | | | | | |
| | | | | | | | SUBSURFACE CONDITIONS. | | | | | |
| | | | | | | | DRY AND CAVED AT 12'. | | | | | |

Notes/Comments:

Pocket Pentrometer Testing
S1: 3.5 TSF
S2: 2.5 TSF

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

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

# GEOTECHNICAL LABORATORY TESTING SUMMARY
# SUNOCO PENNSYLVANIA PIPELINE PROJECT
# HDD S2-0247 Hwy 15

| HDD No. | Test Boring No. | Sample No. | Depth of Sample (ft.) From | Depth of Sample (ft.) To | Water Content, % (ASTM D2216) | Percent Silts/Clays, % (ASTM D1140) | Atterburg Limits (ASTM D4318) Liquid Limit, % | Atterburg Limits (ASTM D4318) Plastic Limit, % | Atterburg Limits (ASTM D4318) Plasticity Index, % | USCS Classif. (ASTM D2487) |
|---|---|---|---|---|---|---|---|---|---|---|
| S2-0247 | SB-01 | 1 | 3.0 | 5.0 | 23.7 | 99.2 | - | - | - | - |
| | | 2 | 8.0 | 10.0 | 16.2 | 55.5 | 36 | 21 | 15 | CL |
| | | 4 | 18.0 | 20.0 | 37.2 | 95.5 | - | - | - | - |
| | | 5 | 23.0 | 25.0 | 39.6 | 74.1 | 46 | 26 | 20 | CL |
| | | 6 | 28.0 | 30.0 | 40.5 | 99.0 | - | - | - | - |
| | SB-02 | 1 | 3.0 | 5.0 | 22.5 | 59.8 | - | - | - | - |
| | | 2 | 8.0 | 10.0 | 28.8 | 99.9 | 49 | 27 | 22 | CL |
| | SB-03 | 1 | 3.0 | 5.0 | 25.4 | 97.7 | - | - | - | - |
| | | 2 | 8.0 | 10.0 | 29.5 | 99.4 | 60 | 27 | 33 | CH |

| Rock Core Testing Results | | | | |
|---|---|---|---|---|
| Boring No. | Core Run | Approximate Depth (ft) | Compressive Strength (psi) | Unit Weight (pcf) |
| SB-02 | Run 2 | 19.0 | 13,320 | 169.9 |
| | | | | |
| | | | | |
| | | | | |

Notes:

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

**ROCK CORE DESCRIPTION SUMMARY**
**SUNOCO PENNSYLVANIA PIPELINE PROJECT**
**HDD S2-0247 HYW 15**

| 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 | | | | | |
| S2-0247 | SB-2 | 1 | 14 | 18 | 92 | 18 | 13 | 14 | 21.4 | Slight | Limestone | Massive | Alternating light and dark gray, darker with depth | Visible laminations with varying coloration, likely due to changes in depositional chemistry, bedding not visible; Fracturing along laminations, ranging from 30° to 50°, Avg. 37°; Large eroded vertical fracture from 16.5 to 18 ft |
| | | 2 | 18 | 21.4 | 100 | 65 | 49 | | | | | | | |

**REGIONAL GEOLOGY SUMMARY**
**SUNOCO PENNSYLVANIA PIPELINE PROJECT**
**HDD S2-0247 HWY 15**

| HDD No. | NAME | BORING NO. | REGIONAL GEOLOGY DESCRIPTION | GENERAL TOPOGRAPHIC SETTING | BEDROCK FORMATION | GENERAL ROCK TYPE | APPROX MAX FM THICKNESS (FT) | DEPTH TO ROCK (Ft bgs) based on nearby well drilling logs | NOTES / COMMENTS |
|---|---|---|---|---|---|---|---|---|---|
| S2-0247 | Highway 15 | SB-01 | **Rockdale Run** - Formation consists of very light gray, finely laminated, fine-grained limestone with pink to brown lenses of chert and a few dolomite beds. | Level terrain | Rockdale Run | Limestone with dolomite and chert | 2,500 | Variable; 15-89 ft bgs, average DTB ~30 ft bgs | 500 ft section of pinkish, marbley limestone and chert. Some stromatolies in the chert in middle of fm |
| | | SB-02 | | | | | | | |
| | | SB-03 | | | | | | | |

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

# FIELD DESCRIPTION AND LOGGING SYSTEM FOR SOIL EXPLORATION

## GRANULAR SOILS

(Sand, Gravel & Combinations)

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

***Relative Proportions***

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

***Particle Size Identification***

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

## COHESIVE SOILS

(Silt, Clay & Combinations)

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

***Plasticity***

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

## ROCK

(Rock Cores)

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

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

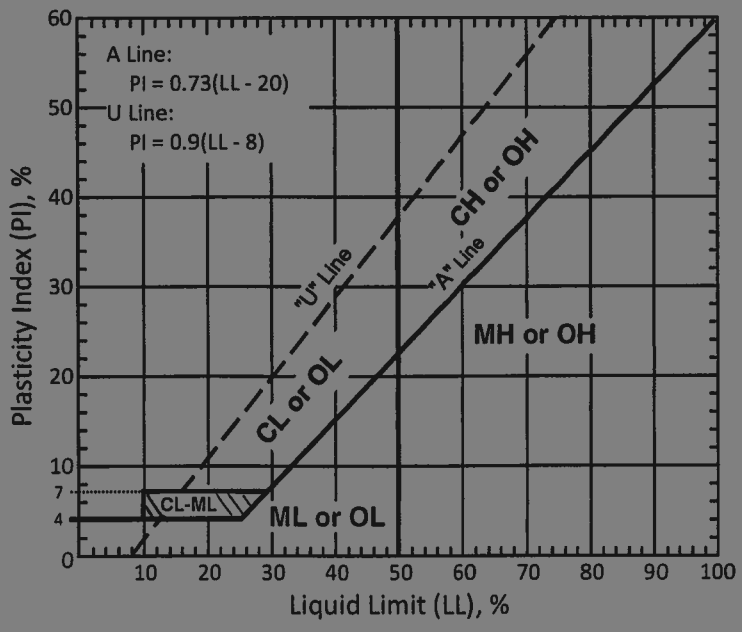
***Groundwater*** observations were made at the times indicated. Groundwater elevations fluctuate throughout a given year, depending on actual field porosity and variations in seasonal and annual precipitation.

## UNIFIED SOIL CLASSIFICATION SYSTEM [Casagrande (1948)]

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

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

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




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

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# Figure 1: Site Vicinity Plan

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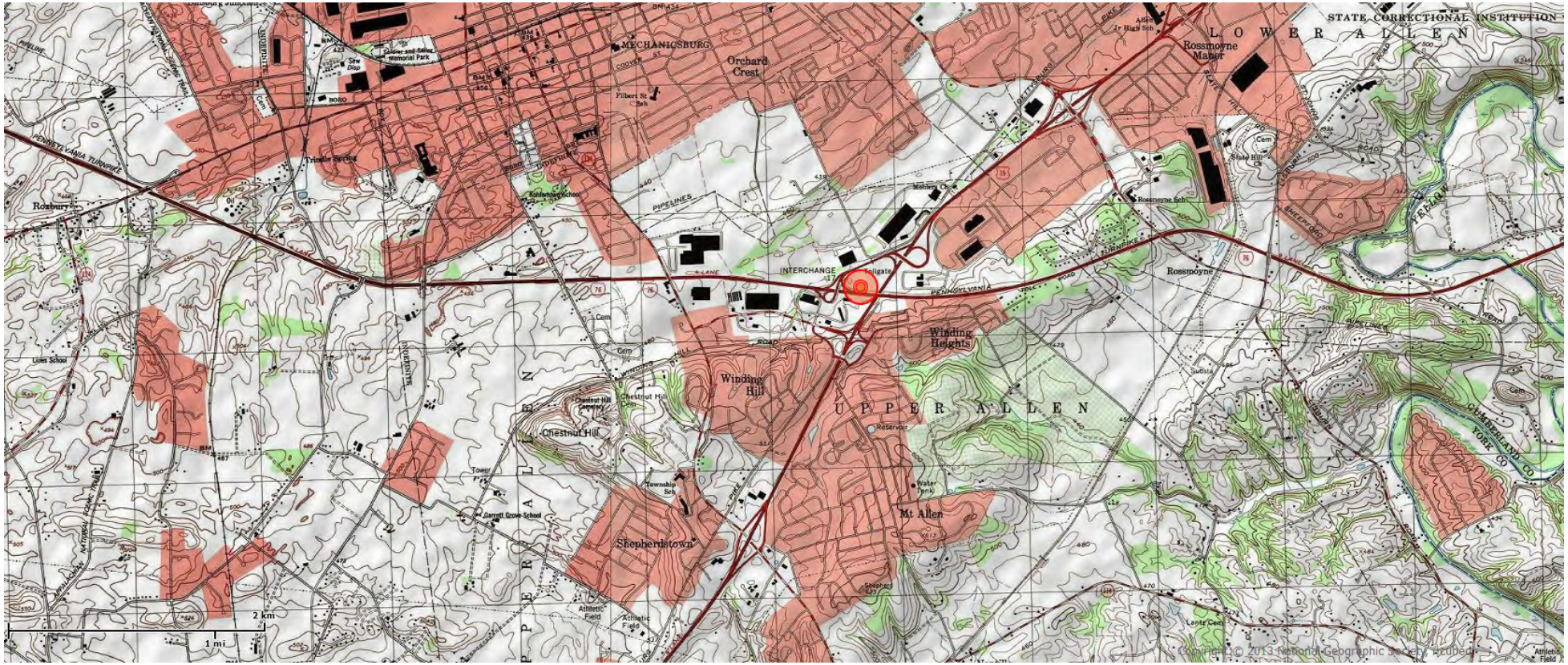
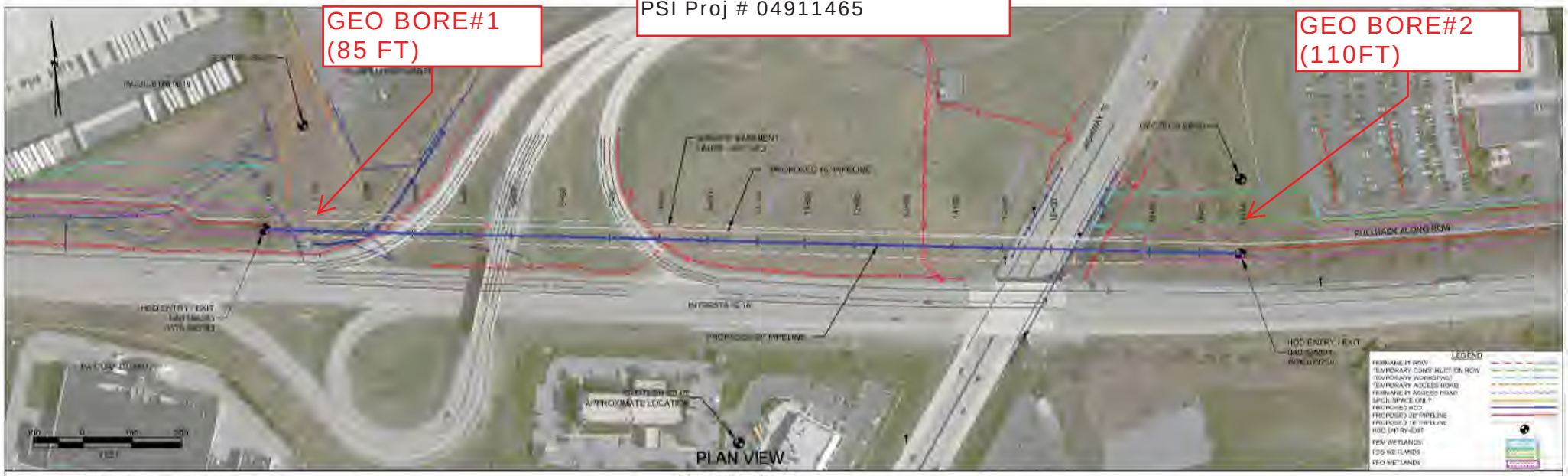
*or call toll-free 888-PA-PARKS*




*Created using PA DCNR Map Viewer*

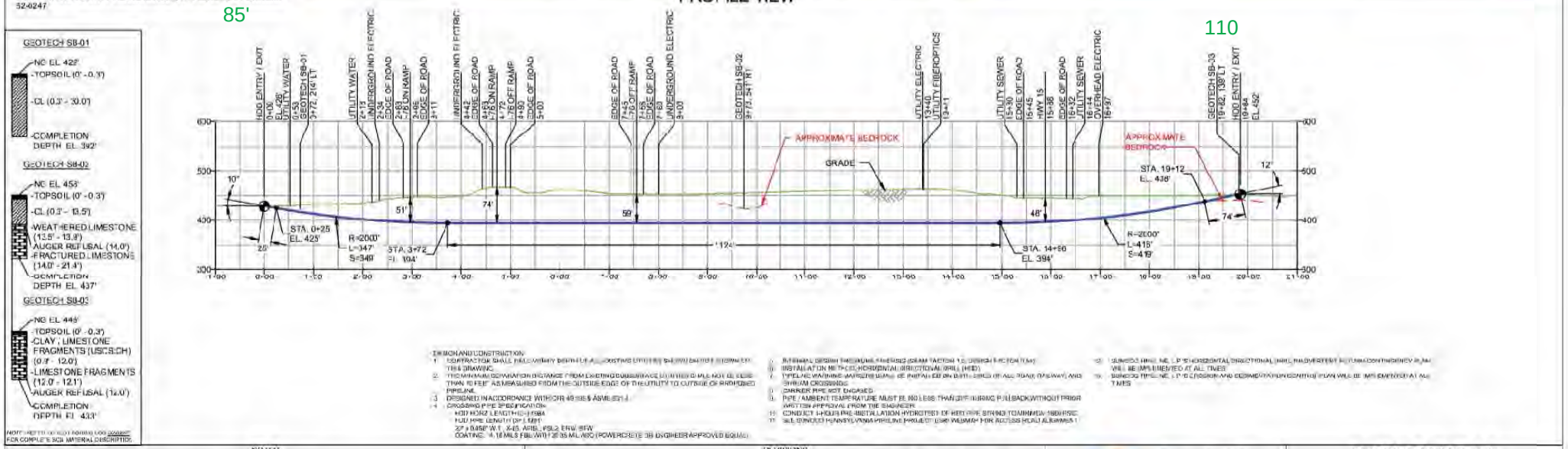
*Map created on Fri Sep 22 2017*

FIGURE 2: Boring Location Plan
HWY 15 - PPP4
DPS PO#20170824-1
PSI Proj # 04911465




CUMBERLAND COUNTY PENNSYLVANIA, UPPER ALLEN TOWNSHIP
524247

PROFILE VIEW




NOTES

1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL SURVEY DATA ARE NAD83.
2. STATIONING IS BASED ON HORIZONTAL DISTANCES.
3. RUDY 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 RUDY ENGINEERING, INC. AND SUNOCO PIPELINE, LP, FOR ANY DAMAGES RESULTING FROM ERRORS OR OMISSIONS THEREIN.
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5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REVISIONS

| NO. | DESCRIPTION | BY | DATE | CHK | DATE | APP | DATE |
|---|---|---|---|---|---|---|---|
| 5 | DRILL ENTRY/EXIT LAT LONG UPDATE | DLM | 04/02/17 | RMB | 04/02/17 | CAG | 04/02/17 |
| 4 | REVISED PROFILE WITH 2017 ROAD | MRS | 05/24/17 | RMB | 05/24/17 | CAG | 05/24/17 |
| 3 | REVISED PER ENGINEERING COMMENTS | MRS | 08/31/16 | RMB | 08/31/16 | AAW | 09/07/16 |
| 2 | REVISED PER COMMENTS FROM REI REVIEW | MRS | 02/19/16 | RMB | 02/19/16 | AAW | 02/19/16 |
| 1 | DESIGN CHANGE | DLM | 02/15/16 | RMB | 02/19/16 | AAW | 02/19/16 |
| 0 | ISSUED FOR CONSTRUCTION | MRS | 01/12/16 | RMB | 01/13/16 | AAW | 01/15/16 |

Sunoco Logistics Partners L.P.

TETRA TECH (303) 792-5911

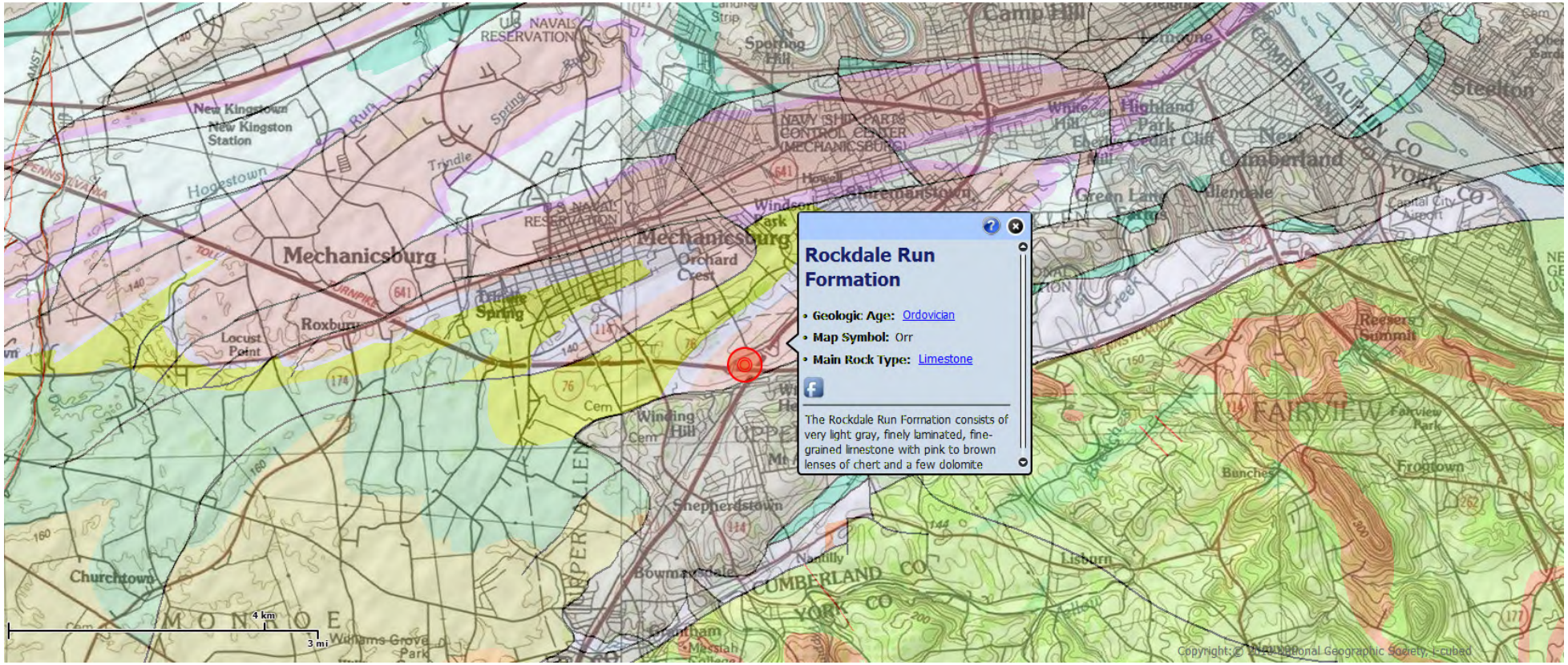
SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
HWY 15
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200' DWG. NUMBER: PA-CU-0176.0019-RD

# Figure 3: Site Geology Plan





# BORING B-01

| | |
|---|---|
| **DATE STARTED:** | 9/7/17 |
| **DATE COMPLETED:** | 9/7/17 |
| **COMPLETION DEPTH** | 85.0 ft |
| **BENCHMARK:** | N/A |
| **ELEVATION:** | N/A |
| **LATITUDE:** | n/a° |
| **LONGITUDE:** | n/a° |
| **STATION:** | N/A **OFFSET:** N/A |
| **REMARKS:** | |

| | |
|---|---|
| **DRILL COMPANY:** | AWK Drilling |
| **DRILLER:** | T. Growden, Jr **LOGGED BY:** M. Wildman |
| **DRILL RIG:** | CME 55 Track Mount |
| **DRILLING METHOD:** | Casing/Rock Coring |
| **SAMPLING METHOD:** | 2-in SSNQ2-in Core |
| **HAMMER TYPE:** | Automatic |
| **EFFICIENCY** | N/A |
| **REVIEWED BY:** | F. Hoffman |

**Water**

| | | |
|---|---|---|
| Pre-Core | 7.8 | feet |
| 9/9/2017 @ 5:13 p.m. | 11.7 | feet |
| 9/10/2017 @ 8:17 a.m. | 17.3 | feet |

**BORING LOCATION:**
See Boring Location Plan

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows per 6-inch (SS) RQD & Recovery % (NX) | Moisture, % | STANDARD PENETRATION TEST DATA N in blows/ft ◎ Moisture × PL ◪ LL ✚ (0, 25, 50) STRENGTH, tsf Qu ▲ Qp ✳ (0, 2.0, 4.0) | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | S-1 | 14 | **RESIDUUM**-Medium Stiff, Brown, SILT with Sand, moist to moist/wet | ML | 2-2-3-3 N=5 | 22 | | |
| | 5 | | | S-2 | 24 | Moist/wet from 5 to 7 feet. | | 2-2-4-3 N=6 | 36 | | LL = 37 PL = 28 |
| | | | | | | **Highly Weathered LIMESTONE**-No split-spoon sample recovery. | | | | | |
| | 10 | | | S-3 | 0 | | | 50/1" | | >> | |
| | | | | R-1 | 35 | **LIMESTONE**-Light gray to black, Very fine grained, Slightly Weathered, very broken to massive, hard to very hard | | RQD=97 Rec=100% | | >> | $Q_u$ = 495.0 tsf 168.0 pcf 1 min. 1 min. 1 min. |
| | 15 | | | R-2 | 60 | | | RQD=100 Rec=100% | | | 1 min. 1 min. 1 min. 1 min. 1 min. 1 min. |
| | 20 | | | R-3 | 60 | | | RQD=98 Rec=100% | | >> | 1 min. $Q_u$ = 552.8 tsf 168.3 pcf 1 min. 1 min. |
| | 25 | | | R-4 | 71 | **DOLOMITE**-Gray to dark gray, Very fine grained, Slightly Weathered, massive, very hard | | RQD=98 Rec=98% | | >> | 1 min. 1 min. 2 min. 3 min. $Q_u$ = 1319.2 tsf 172.6 pcf 2 min. |
| | 30 | | | | | *Continued Next Page* | | | | | |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**PROJECT NO.:** 04911465
**PROJECT:** Energy Transfer HDD (DPS)
**LOCATION:** HWY 15 (PPP4)
Cumberland Co., PA
PA-CU-0176.0019-RD/PO#20170824-1

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

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 9/7/17 | **DRILL COMPANY:** | AWK Drilling |
| **DATE COMPLETED:** | 9/7/17 | **DRILLER:** | T. Growden, Jr **LOGGED BY:** M. Wildman |
| **COMPLETION DEPTH** | 85.0 ft | **DRILL RIG:** | CME 55 Track Mount |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Casing/Rock Coring |
| **ELEVATION:** | N/A | **SAMPLING METHOD:** | 2-in SSNQ2-in Core |
| **LATITUDE:** | n/a° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | n/a° | **EFFICIENCY** | N/A |
| **STATION:** | N/A **OFFSET:** N/A | **REVIEWED BY:** | F. Hoffman |

**REMARKS:**

# BORING B-01

| Water | | |
|---|---|---|
| Pre-Core | 7.8 | feet |
| 9/9/2017 @ 5:13 p.m. | 11.7 | feet |
| 9/10/2017 @ 8:17 a.m. | 17.3 | feet |

**BORING LOCATION:**
See Boring Location Plan

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows per 6-inch (SS) RQD & Recovery % (NX) | Moisture, % | STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL (0 25 50) STRENGTH, tsf ▲ Qu ✳ Qp (0 2.0 4.0) | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 | | | R-5 | 48 | **LIMESTONE**-Light gray to black, Very fine grained, Slightly Weathered, very broken to massive, hard to very hard | | RQD=100 Rec=100% | | | 2 min. 2 min. 2 min. 2 min. 3 min. |
| | 35 | | | R-6 | 60 | | | RQD=100 Rec=100% | | >> $Q_u$ = 301.4 tsf 167.9 pcf | 2 min. 2 min. 2 min. 2 min. 1 min. |
| | 40 | | | R-7 | 60 | | | RQD=100 Rec=100% | | >> $Q_u$ = 695.3 tsf 167.7 pcf | 2 min. 1 min. 1 min. 1 min. 1 min. |
| | 45 | | | R-8 | 60 | | | RQD=100 Rec=100% | | | 1 min. 2 min. 1 min. 2 min. 2 min. |
| | 50 | | | R-9 | 60 | | | RQD=100 Rec=100% | | | 2 min. 2 min. 2 min. 2 min. 2 min. |
| | 55 | | | R-10 | 60 | Broken seam @ 54.2 feet (~ 1-1/2 inches thick) | | RQD=100 Rec=100% | | >> $Q_u$ = 503.5 tsf 167.1 pcf | 1 min. 1 min. 1 min. 1 min. 1 min. |
| | 60 | | | | | *Continued Next Page* | | | | | |


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**PROJECT NO.:** 04911465
**PROJECT:** Energy Transfer HDD (DPS)
**LOCATION:** HWY 15 (PPP4)
Cumberland Co., PA
PA-CU-0176.0019-RD/PO#20170824-1

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

# BORING B-01

| | |
|---|---|
| **DATE STARTED:** | 9/7/17 |
| **DATE COMPLETED:** | 9/7/17 |
| **COMPLETION DEPTH** | 85.0 ft |
| **BENCHMARK:** | N/A |
| **ELEVATION:** | N/A |
| **LATITUDE:** | n/a° |
| **LONGITUDE:** | n/a° |
| **STATION:** | N/A **OFFSET:** N/A |
| **REMARKS:** | |

| | |
|---|---|
| **DRILL COMPANY:** | AWK Drilling |
| **DRILLER:** | T. Growden, Jr **LOGGED BY:** M. Wildman |
| **DRILL RIG:** | CME 55 Track Mount |
| **DRILLING METHOD:** | Casing/Rock Coring |
| **SAMPLING METHOD:** | 2-in SSNQ2-in Core |
| **HAMMER TYPE:** | Automatic |
| **EFFICIENCY** | N/A |
| **REVIEWED BY:** | F. Hoffman |

**Water**

| | | |
|---|---|---|
| Pre-Core | 7.8 | feet |
| 9/9/2017 @ 5:13 p.m. | 11.7 | feet |
| 9/10/2017 @ 8:17 a.m. | 17.3 | feet |

**BORING LOCATION:**
See Boring Location Plan

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows per 6-inch (SS) RQD & Recovery % (NX) | Moisture, % | STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL (0 25 50) STRENGTH, tsf ▲ Qu ✳ Qp (0 2.0 4.0) | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 60 | | | R-11 | 60 | **LIMESTONE**-Light gray to black, Very fine grained, Slightly Weathered, very broken to massive, hard to very hard<br><br>Weathered seam @ 62.5 feet (~ 2-1/2 inches thick) | | RQD=90<br>Rec=100% | | | 1 min.<br>1 min.<br>1 min.<br>1 min.<br>2 min. |
| | 65 | | | R-12 | 60 | | | RQD=100<br>Rec=100% | | | 2 min.<br>2 min.<br>2 min.<br>>> $Q_u$ = 564.5 tsf<br>166.9 pcf<br>2 min. |
| | 70 | | | R-13 | 60 | Nearly vertical fracture @ 70.2 feet | | RQD=88<br>Rec=100% | | | 2 min.<br>1 min.<br>2 min.<br>2 min.<br>2 min.<br>2 min. |
| | 75 | | | R-14 | 60 | | | RQD=82<br>Rec=100% | | | 2 min.<br>2 min.<br>2 min.<br>2 min.<br>>> $Q_u$ = 290.4 tsf<br>169.8 pcf<br>2 min. |
| | 80 | | | R-15 | 60 | | | RQD=94<br>Rec=100% | | | 1 min.<br>2 min.<br>2 min.<br>1 min. |
| | 85 | | | R-16 | 24 | Test boring terminated @ 85 feet | | RQD=100<br>Rec=100% | | | 1 min.<br>2 min. |


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**PROJECT NO.:** 04911465
**PROJECT:** Energy Transfer HDD (DPS)
**LOCATION:** HWY 15 (PPP4)
Cumberland Co., PA
PA-CU-0176.0019-RD/PO#20170824-1

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


PSI #: 04911465 9/7/17
Bor B-1 Depth 0 to 23.0
Spread: PPP4-HWY15
BOX 1 OF 6
DATE
STA
OFF
FROM G
ELEV
FT
Run | Depth | Rec | RQD
1 | 10.1-13.0 | 2.8 | 2.8
2 | 13.0-18.0 | 5.0 | 5.0
3 | 18.0-23.0 | 5.0 | 4.9
0.0
10.1
13.0
18.0

# BORING B-02

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 9/5/17 | **DRILL COMPANY:** | AWK Drilling |
| **DATE COMPLETED:** | 9/6/17 | **DRILLER:** T. Growden, Jr **LOGGED BY:** | D. Calvert |
| **COMPLETION DEPTH** | 110.0 ft | **DRILL RIG:** | CME 55 Track Mount |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Casing/Rock Coring |
| **ELEVATION:** | N/A | **SAMPLING METHOD:** | 2-in SSNQ2-in Core |
| **LATITUDE:** | n/a° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | n/a° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | F. Hoffman |

**REMARKS:**

**Water**

| | | |
|---|---|---|
| ▽ | 9/5/2017 @ 3:55 p.m. | 26.1 feet |
| ▼ | 9/6/2017 @ 8:17 a.m. | 27.4 feet |
| ▼ | 9/6/2017 @ 11:34 a.m. | 27.8 feet |

**BORING LOCATION:**
See Boring Location Plan

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows per 6-inch (SS) RQD & Recovery % (NX) | Moisture, % | STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL (0, 25, 50) STRENGTH, tsf ▲ Qu ✳ Qp (0, 2.0, 4.0) | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | S-1 | 9 | **Probable FILL**-Brown to gray-brown, Lean CLAY with Sand, trace Gravel, moist | CL | 3-3-5 N=8 | 23 | | |
| | 5 | | | S-2 | 10 | **RESIDUUM**-Medium Dense, Brown to red-brown, Clayey SAND with Gravel, moist/wet | SC | 7-9-9 N=18 | 18 | | Fines=26.9% |
| | | | | S-3 | 7 | **RESIDUUM**-Very Soft, Lean CLAY, trace Sand, moist/wet | CL | 1-1-1 N=2 | 45 | | LL = 43 PL = 21 |
| | 10 | | | | | **RESIDUUM**-Very Loose, Gray-brown, Clayey GRAVEL with Sand, moist/wet Casing refusal @ 10.3 feet | GC | | 38 | | |
| | | | | R-1 | 29 | **LIMESTONE**-Dark gray-brown, Highly Weathered, gravel-sized rock fragments | | RQD=81 Rec=81% | | | >> $Q_u$ = 546.3 tsf 170.3 pcf |
| | 15 | | | R-2 | 60 | **LIMESTONE**-Light gray to black, Very fine grained, Slightly Weathered, broken to massive, moderately hard to very hard, trace calcite stringers Weathered fracture @ 11.9 feet | | RQD=95 Rec=100% | | | |
| | 20 | | | R-3 | 60 | | | RQD=97 Rec=100% | | | >> $Q_u$ = 666.2 tsf 169.1 pcf |
| | 25 | | | R-4 | 60 | | | RQD=100 Rec=100% | | | |
| | 30 | | | | | | | | | | |

2 min. 2 min. 3 min. 2 min. 2 min. 2 min. 2 min. 2 min. 2 min. 2 min. 2 min. 2 min. 2 min. 2 min. 2 min. 2 min. 2 min.

*Continued Next Page*

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

**PROJECT NO.:** 04911465
**PROJECT:** Energy Transfer HDD (DPS)
**LOCATION:** HWY 15 (PPP4)
Cumberland Co., PA
PA-CU-0176.0019-RD/PO#20170824-1

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

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 9/5/17 | **DRILL COMPANY:** | AWK Drilling |
| **DATE COMPLETED:** | 9/6/17 | **DRILLER:** | T. Growden, Jr **LOGGED BY:** D. Calvert |
| **COMPLETION DEPTH** | 110.0 ft | **DRILL RIG:** | CME 55 Track Mount |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Casing/Rock Coring |
| **ELEVATION:** | N/A | **SAMPLING METHOD:** | 2-in SSNQ2-in Core |
| **LATITUDE:** | n/a° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | n/a° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | F. Hoffman |

**REMARKS:**

# BORING B-02

**Water**

| | | |
|---|---|---|
| ▽ | 9/5/2017 @ 3:55 p.m. | 26.1 feet |
| ▼ | 9/6/2017 @ 8:17 a.m. | 27.4 feet |
| ▼ | 9/6/2017 @ 11:34 a.m. | 27.8 feet |

**BORING LOCATION:**
See Boring Location Plan

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows per 6-inch (SS) RQD & Recovery % (NX) | Moisture, % | STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL (0 25 50) STRENGTH, tsf ▲ Qu ✳ Qp (0 2.0 4.0) | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 | | | R-5 | 60 | **DOLOMITE**-Light gray to black, Very fine grained, Slightly Weathered, very broken to massive, hard to very hard, trace calcite stringers | | RQD=100 Rec=100% | | | 2 min.<br>2 min.<br>>> $Q_u$ = 853.5 tsf 179.6 pcf<br>2 min.<br>2 min.<br>2 min. |
| | 35 | | | R-6 | 60 | **LIMESTONE**-Light gray to black, Very fine grained, Slightly Weathered, broken to massive, moderately hard to very hard, trace calcite stringers | | RQD=87 Rec=100% | | | 2 min.<br>2 min.<br>2 min.<br>2 min.<br>2 min. |
| | 40 | | | R-7 | 60 | | | RQD=97 Rec=100% | | | 2 min.<br>>> $Q_u$ = 229.9 tsf 167.8 pcf<br>2 min.<br>2 min.<br>1 min. |
| | 45 | | | R-8 | 60 | Broken seam @ 42.7 feet (~ 2-1/4 inches thick)<br>Weathered seam @ 47.8 feet (~ 2 inches thick) | | RQD=100 Rec=100% | | | 2 min.<br>2 min.<br>1 min.<br>>> $Q_u$ = 1336.6 tsf 170.6 pcf |
| | 50 | | | R-9 | 59 | | | RQD=83 Rec=98% | | | 2 min.<br>2 min.<br>2 min. |
| | 55 | | | R-10 | 60 | | | RQD=88 Rec=100% | | | 2 min.<br>2 min.<br>2 min.<br>2 min.<br>>> $Q_u$ = 992.6 tsf 173.7 pcf |
| | 60 | | | | | **DOLOMITE**-Light gray to dark gray, Very fine grained, Slightly Weathered, very broken to massive, very hard, trace calcite stringers<br>Broken layer @ 59.5 feet (~ 4 inches thick)<br>*Continued Next Page* | | | | | |

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**LOCATION:** HWY 15 (PPP4)
Cumberland Co., PA
PA-CU-0176.0019-RD/PO#20170824-1

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

# BORING B-02

| | |
|---|---|
| **DATE STARTED:** | 9/5/17 |
| **DATE COMPLETED:** | 9/6/17 |
| **COMPLETION DEPTH** | 110.0 ft |
| **BENCHMARK:** | N/A |
| **ELEVATION:** | N/A |
| **LATITUDE:** | n/a° |
| **LONGITUDE:** | n/a° |
| **STATION:** N/A | **OFFSET:** N/A |
| **REMARKS:** | |

| | |
|---|---|
| **DRILL COMPANY:** | AWK Drilling |
| **DRILLER:** | T. Growden, Jr **LOGGED BY:** D. Calvert |
| **DRILL RIG:** | CME 55 Track Mount |
| **DRILLING METHOD:** | Casing/Rock Coring |
| **SAMPLING METHOD:** | 2-in SSNQ2-in Core |
| **HAMMER TYPE:** | Automatic |
| **EFFICIENCY** | N/A |
| **REVIEWED BY:** | F. Hoffman |

**Water**

| | | |
|---|---|---|
| ▽ | 9/5/2017 @ 3:55 p.m. | 26.1 feet |
| ▼ | 9/6/2017 @ 8:17 a.m. | 27.4 feet |
| ▼ | 9/6/2017 @ 11:34 a.m. | 27.8 feet |

**BORING LOCATION:**
See Boring Location Plan

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows per 6-inch (SS) RQD & Recovery % (NX) | Moisture, % | STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL (0, 25, 50) STRENGTH, tsf ▲ Qu ✳ Qp (0, 2.0, 4.0) | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 60 | | | | | | | | | | |
| | | | | R-11 | 60 | **LIMESTONE**-Light gray to black, Very fine grained, Slightly Weathered, slightly broken to massive, hard to very hard, trace calcite stringers | | RQD=90 Rec=100% | | | 2 min. 2 min. 3 min. |
| | | | | | | **DOLOMITE**-Gray to dark gray, Very fine grained, Slightly Weathered, slightly broken to massive, very hard, trace calcite stringers | | | | | 2 min. 2 min. |
| | 65 | | | | | **LIMESTONE**-Light gray to dark gray, Very fine grained, Slightly Weathered, broken to massive, moderately hard | | | | | 2 min. |
| | | | | R-12 | 60 | | | RQD=97 Rec=100% | | | 3 min. 2 min. |
| | | | | | | | | | | >> $Q_u$ = 578.5 tsf | 2 min. |
| | | | | | | | | | | 169.3 pcf | |
| | | | | | | **LIMESTONE**-Light gray-brown to dark gray-brown, Very fine grained, Weathered, very broken to broken, moderately hard | | | | | 3 min. |
| | 70 | | | | | **LIMESTONE**-Light gray to black, Very fine grained, Slightly Weathered, massive, moderately hard to hard | | | | | 2 min. |
| | | | | R-13 | 60 | | | RQD=97 Rec=100% | | | 2 min. |
| | | | | | | Broken seam @ 71.7 feet (~ 2-1/4 inches thick) | | | | | 2 min. |
| | | | | | | **DOLOMITE**-Gray to dark gray, Very fine grained, Slightly Weathered, slightly broken to massive, very hard, trace calcite stringers | | | | | 2 min. |
| | 75 | | | | | **LIMESTONE**-Light gray-white to black, Very fine grained, Slightly Weathered, broken to massive, moderately hard to very hard | | | | | 2 min. |
| | | | | R-14 | 60 | | | RQD=97 Rec=100% | | | 2 min. |
| | | | | | | | | | | | 2 min. |
| | | | | | | | | | | | 3 min. |
| | | | | | | | | | | | 2 min. |
| | 80 | | | | | | | | | >> $Q_u$ = 513.5 tsf | 2 min. |
| | | | | R-15 | 60 | | | RQD=97 Rec=100% | | 168.9 pcf | 3 min. |
| | | | | | | | | | | | 2 min. |
| | | | | | | | | | | | 2 min. |
| | | | | | | | | | | | 2 min. |
| | 85 | | | | | | | | | | 2 min. |
| | | | | R-16 | 60 | | | RQD=73 Rec=100% | | | 3 min. |
| | | | | | | **DOLOMITE**-Light gray to dark gray, Very fine grained, Slightly Weathered, broken to massive, hard, trace calcite stringers Vertical fracture from 87.1 to 87.8 feet. | | | | | 3 min. |
| | | | | | | | | | | | 3 min. |
| | | | | | | | | | | >> $Q_u$ = 668.5 tsf | 3 min. |
| | | | | | | | | | | 175.1 pcf | 2 min. |
| | 90 | | | | | *Continued Next Page* | | | | | |


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Cumberland Co., PA
PA-CU-0176.0019-RD/PO#20170824-1

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

# BORING B-02

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 9/5/17 | **DRILL COMPANY:** | AWK Drilling |
| **DATE COMPLETED:** | 9/6/17 | **DRILLER:** T. Growden, Jr | **LOGGED BY:** D. Calvert |
| **COMPLETION DEPTH** | 110.0 ft | **DRILL RIG:** | CME 55 Track Mount |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Casing/Rock Coring |
| **ELEVATION:** | N/A | **SAMPLING METHOD:** | 2-in SSNQ2-in Core |
| **LATITUDE:** | n/a° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | n/a° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | F. Hoffman |

**REMARKS:**

**Water**

| | | |
|---|---|---|
| 9/5/2017 @ 3:55 p.m. | 26.1 | feet |
| 9/6/2017 @ 8:17 a.m. | 27.4 | feet |
| 9/6/2017 @ 11:34 a.m. | 27.8 | feet |

**BORING LOCATION:**
See Boring Location Plan

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows per 6-inch (SS) RQD & Recovery % (NX) | Moisture, % | STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL (0, 25, 50) STRENGTH, tsf ▲ Qu ✳ Qp (0, 2.0, 4.0) | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 90 | | | R-17 | 60 | **LIMESTONE**-Light gray to black, Very fine grained, Slightly Weathered, broken to massive, hard to very hard, trace calcite stringers<br>Broken layer @ 92.2 feet (~ 4-1/2 inches thick) | | RQD=90<br>Rec=100% | | | 2 min.<br>2 min.<br>2 min.<br>2 min.<br>2 min. |
| | 95 | | | R-18 | 60 | | | RQD=100<br>Rec=100% | | | 3 min.<br>2 min.<br>2 min.<br>3 min.<br>2 min. |
| | | | | | | Lost water return @ 9 feet | | | | | |
| | 100 | | | R-19 | 60 | | | RQD=94<br>Rec=100% | | | 2 min.<br>2 min.<br>2 min.<br>>> $Q_u$ = 791.5 tsf<br>2 min.<br>3 min. |
| | | | | | | Broken layer @ 103.3 feet (~ 4-1/2 inches thick)<br>Broken seam @ 104.5 feet (~ 2-1/4 inches thick) | | | | | |
| | 105 | | | R-20 | 60 | | | RQD=95<br>Rec=100% | | | 3 min.<br>4 min.<br>3 min.<br>3 min.<br>3 min. |
| | | | | R-21 | | | | | | | |
| | 110 | | | | | Test boring terminated @ 111 feet | | | | | |


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# GENERAL NOTES

## SAMPLE IDENTIFICATION

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

## DRILLING AND SAMPLING SYMBOLS

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

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

## SOIL PROPERTY SYMBOLS

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

## RELATIVE DENSITY OF COARSE-GRAINED SOILS

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

## ANGULARITY OF COARSE-GRAINED PARTICLES

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

## GRAIN-SIZE TERMINOLOGY

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

## PARTICLE SHAPE

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

## RELATIVE PROPORTIONS OF FINES

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

# GENERAL NOTES

(Continued)

## CONSISTENCY OF FINE-GRAINED SOILS

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

## MOISTURE CONDITION DESCRIPTION

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

## RELATIVE PROPORTIONS OF SAND AND GRAVEL

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

## STRUCTURE DESCRIPTION

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

## SCALE OF RELATIVE ROCK HARDNESS

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

## ROCK BEDDING THICKNESSES

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

## ROCK VOIDS

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

## GRAIN-SIZED TERMINOLOGY

(Typically Sedimentary Rock)

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

## ROCK QUALITY DESCRIPTION

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

## DEGREE OF WEATHERING

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

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

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

# SOIL CLASSIFICATION CHART

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

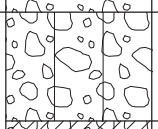
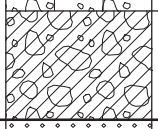
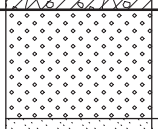
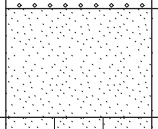
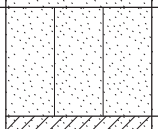
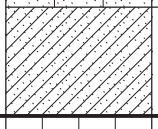
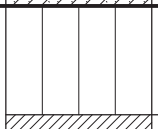
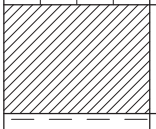
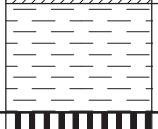
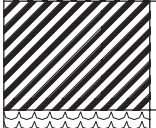
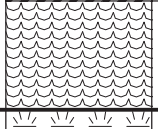
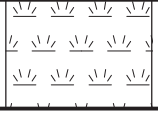
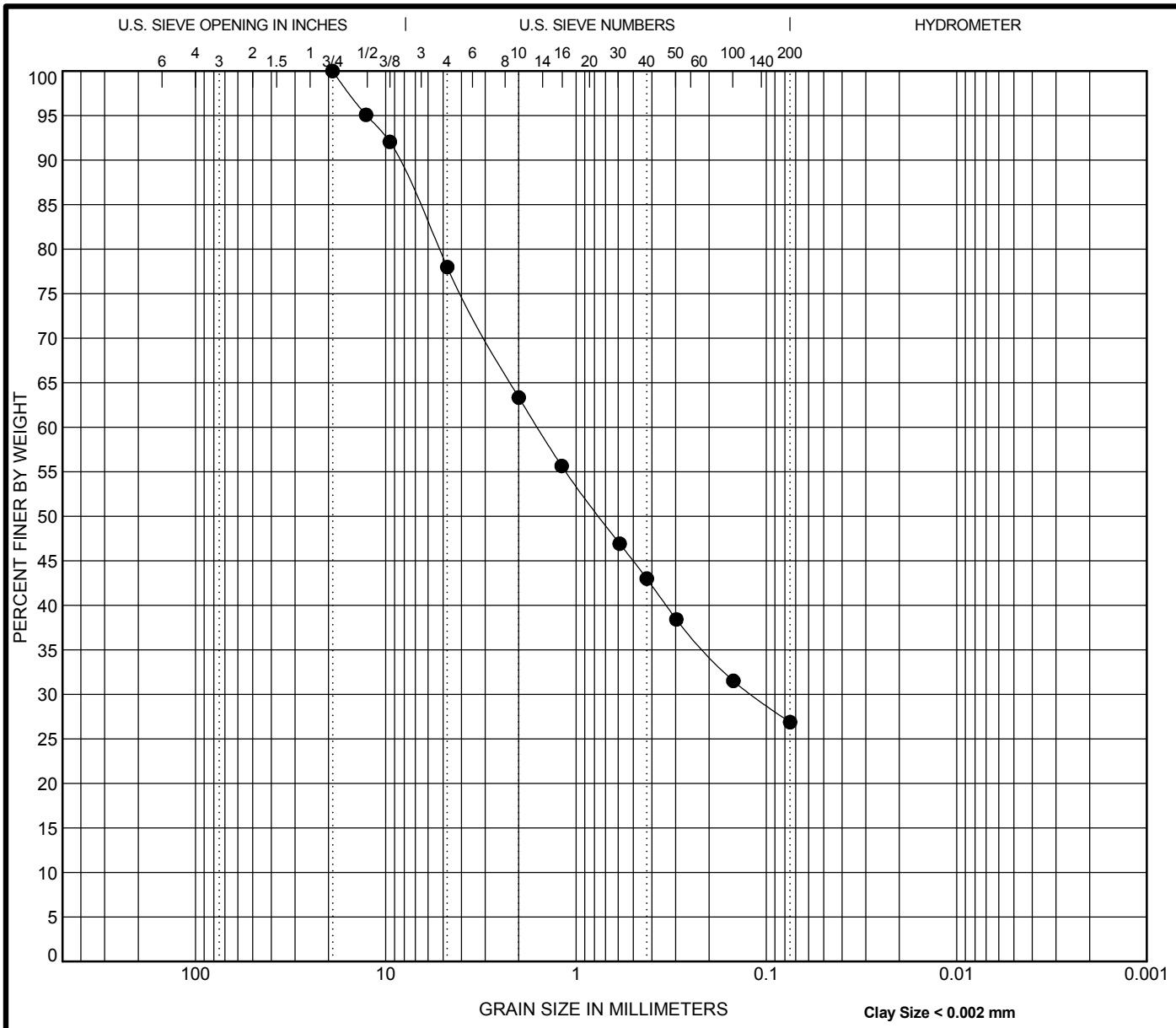
| MAJOR DIVISIONS | | | SYMBOLS | | TYPICAL DESCRIPTIONS |
|---|---|---|---|---|---|
| | | | GRAPH | LETTER | |
| COARSE GRAINED SOILS<br>MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE | GRAVEL AND GRAVELLY SOILS<br>MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE | CLEAN GRAVELS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

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

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

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




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY |
|---|---|---|---|---|---|---|
| | coarse | fine | coarse | medium | fine | |

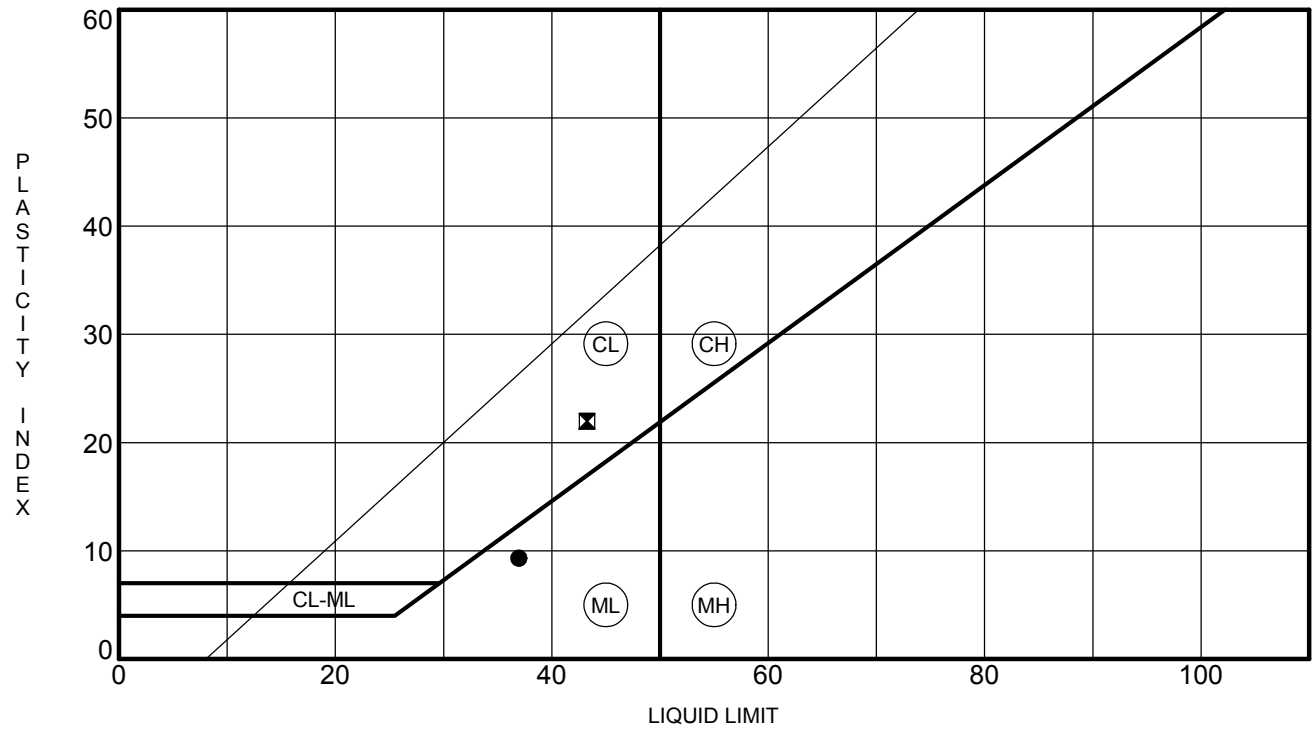
| Specimen Identification | | Classification | LL | PL | PI | Cc | Cu |
|---|---|---|---|---|---|---|---|
| ● **B-02** | **4.5** | **Clayey SAND with Gravel (SC)** | | | | | |

| Specimen Identification | | D100 | D60 | D30 | D10 | %Gravel | %Sand | %Silt | %Clay |
|---|---|---|---|---|---|---|---|---|---|
| ● **B-02** | **4.5** | **19.05** | **1.597** | **0.119** | | **22.0** | **51.1** | **26.9** | |

**Professional Service Industries, Inc.**
**1707 S. Cameron Street, Suite B**
**Harrisburg, PA 17104**
**Telephone: (717) 230-8622**
**Fax: (717) 230-8626**

## GRAIN SIZE DISTRIBUTION

Project: Energy Transfer HDD (DPS)
PSI Job No.: 04911465
Location: HWY 15 (PPP4)
Cumberland Co., PA




| | Boring | Depth (ft) | LL | PL | PI | Fines | Classification (*Visual) |
|---|---|---|---|---|---|---|---|
| ● | **B-01** | **6.0** | **37** | **28** | **9** | | **SILT with Sand (ML)** |
| ⊠ | **B-02** | **9.0** | **43** | **21** | **22** | | **Lean CLAY (CL)** |

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## ATTERBERG LIMIT RESULTS

PSI Job No.: 04911465
Project: Energy Transfer HDD (DPS)
Location: HWY 15 (PPP4)
Cumberland Co., PA

# Laboratory Summary Sheet



| Borehole | Approx. Depth | Liquid Limit | Plastic Limit | Plasticity Index | Qu (tsf) | %<#200 Sieve | Est. Specific Gravity | Water Content (%) | Dry Density (pcf) | Satur-ation (%) | Void Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B-01 | 1 | | | | | | | 22 | | | |
| B-01 | 6 | 37 | 28 | 9 | | | | 36 | | | |
| B-01 | 11 | | | | 495.04 | | | | | | |
| B-01 | 22.1 | | | | 552.79 | | | | | | |
| B-01 | 28.4 | | | | 1319.18 | | | | | | |
| B-01 | 34.9 | | | | 301.38 | | | | | | |
| B-01 | 40.6 | | | | 695.34 | | | | | | |
| B-01 | 57 | | | | 503.52 | | | | | | |
| B-01 | 67.4 | | | | 564.48 | | | | | | |
| B-01 | 78.2 | | | | 290.38 | | | | | | |
| B-02 | 1 | | | | | | | 23 | | | |
| B-02 | 4.5 | | | | | 26.9% | | 18 | | | |
| B-02 | 9 | 43 | 21 | 22 | | | | 45 | | | |
| B-02 | 10 | | | | | | | 38 | | | |
| B-02 | 11.1 | | | | 546.32 | | | | | | |
| B-02 | 21.5 | | | | 666.23 | | | | | | |
| B-02 | 31.7 | | | | 853.51 | | | | | | |
| B-02 | 40.8 | | | | 229.87 | | | | | | |
| B-02 | 47.5 | | | | 1336.64 | | | | | | |
| B-02 | 58.7 | | | | 992.64 | | | | | | |
| B-02 | 67.8 | | | | 578.50 | | | | | | |
| B-02 | 79.9 | | | | 513.45 | | | | | | |
| B-02 | 88.5 | | | | 668.55 | | | | | | |
| B-02 | 102.6 | | | | 791.47 | | | | | | |

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## Summary of Laboratory Results

PSI Job No.: 04911465
Project: Energy Transfer HDD (DPS)
Location: HWY 15 (PPP4)
Cumberland Co., PA
PA-CU-0176.0019-RD/PO#20170824-1

# ATTACHMENT 2
# SOIL RESOURCES MAP AND PROFILE DESCRIPTIONS

United States Department of Agriculture

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

# Custom Soil Resource Report for Cumberland County, Pennsylvania

## HWY 15 HDD


January 25, 2018

# Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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EdB—Edom silty clay loam, 3 to 8 percent slopes.....15
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HcB—Hagerstown silt loam, rocky, 3 to 8 percent slopes.....18
HcC—Hagerstown silt loam, rocky, 8 to 15 percent slopes.....19
Pe—Penlaw silt loam.....20
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# How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil

scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

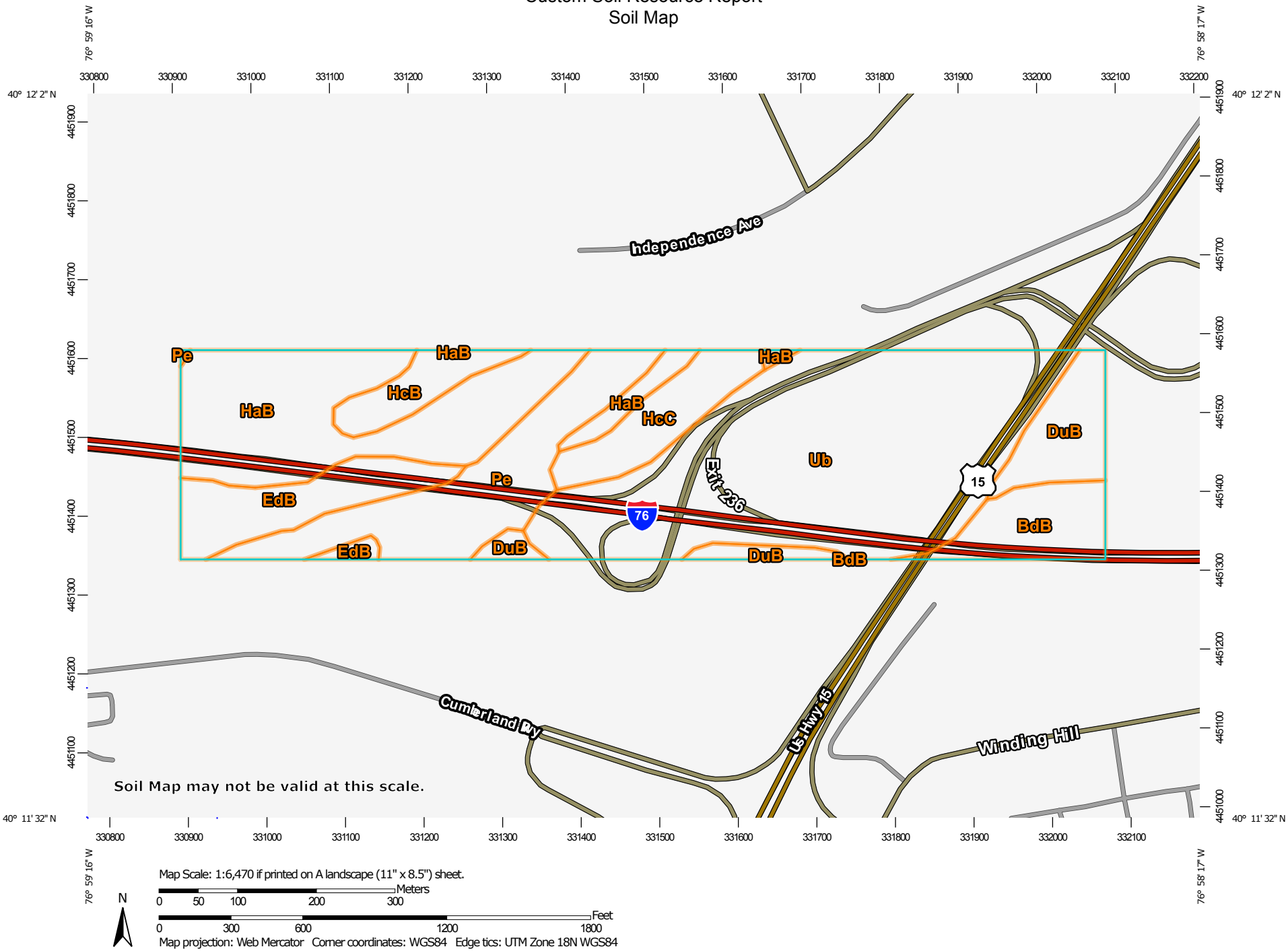
After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and

identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

# Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

# Custom Soil Resource Report
## Soil Map



## MAP LEGEND

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

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

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

**Special Line Features**

**Water Features**
- Streams and Canals

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

**Background**
- Aerial Photography

## MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

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

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

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

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

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

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

Soil Survey Area: Cumberland County, Pennsylvania
Survey Area Data: Version 11, Nov 27, 2017

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

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

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

# Map Unit Legend

| Map Unit Symbol | Map Unit Name | Acres in AOI | Percent of AOI |
|---|---|---|---|
| BdB | Bedington shaly silt loam, 3 to 8 percent slopes | 4.2 | 5.4% |
| DuB | Duffield silt loam, 3 to 8 percent slopes | 5.2 | 6.7% |
| EdB | Edom silty clay loam, 3 to 8 percent slopes | 5.7 | 7.3% |
| HaB | Hagerstown silt loam, 3 to 8 percent slopes | 15.7 | 20.3% |
| HcB | Hagerstown silt loam, rocky, 3 to 8 percent slopes | 2.6 | 3.4% |
| HcC | Hagerstown silt loam, rocky, 8 to 15 percent slopes | 4.3 | 5.6% |
| Pe | Penlaw silt loam | 9.9 | 12.8% |
| Ub | Urban land and Udorthents | 29.8 | 38.5% |
| **Totals for Area of Interest** | | **77.6** | **100.0%** |

# Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit

descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

# Cumberland County, Pennsylvania

## BdB—Bedington shaly silt loam, 3 to 8 percent slopes

### Map Unit Setting

*National map unit symbol:* r8tt
*Elevation:* 300 to 1,600 feet
*Mean annual precipitation:* 35 to 50 inches
*Mean annual air temperature:* 45 to 57 degrees F
*Frost-free period:* 120 to 214 days
*Farmland classification:* All areas are prime farmland

### Map Unit Composition

*Bedington and similar soils:* 85 percent
*Minor components:* 15 percent
*Estimates are based on observations, descriptions, and transects of the mapunit.*

### Description of Bedington

#### Setting

*Landform:* Hills
*Landform position (two-dimensional):* Summit
*Landform position (three-dimensional):* Interfluve, side slope
*Down-slope shape:* Linear
*Across-slope shape:* Concave
*Parent material:* Acid residuum weathered from sedimentary rock

#### Typical profile

*H1 - 0 to 9 inches:* channery silt loam
*H2 - 9 to 29 inches:* channery silty clay loam
*H3 - 29 to 72 inches:* very channery silt loam

#### Properties and qualities

*Slope:* 3 to 8 percent
*Depth to restrictive feature:* 60 to 80 inches to lithic bedrock
*Natural drainage class:* Well drained
*Runoff class:* Medium
*Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 2.00 in/hr)
*Depth to water table:* More than 80 inches
*Frequency of flooding:* None
*Frequency of ponding:* None
*Available water storage in profile:* Moderate (about 6.9 inches)

#### Interpretive groups

*Land capability classification (irrigated):* None specified
*Land capability classification (nonirrigated):* 2e
*Hydrologic Soil Group:* B
*Hydric soil rating:* No

### Minor Components

#### Comly

*Percent of map unit:* 7 percent
*Hydric soil rating:* No

**Berks**

*Percent of map unit:* 5 percent
*Landform:* Ridges, valleys
*Landform position (two-dimensional):* Backslope
*Landform position (three-dimensional):* Side slope
*Down-slope shape:* Convex, linear
*Across-slope shape:* Convex, linear
*Hydric soil rating:* No

**Weikert**

*Percent of map unit:* 3 percent
*Hydric soil rating:* No

## DuB—Duffield silt loam, 3 to 8 percent slopes

**Map Unit Setting**

*National map unit symbol:* r8vp
*Elevation:* 300 to 1,500 feet
*Mean annual precipitation:* 34 to 50 inches
*Mean annual air temperature:* 46 to 57 degrees F
*Frost-free period:* 125 to 200 days
*Farmland classification:* All areas are prime farmland

**Map Unit Composition**

*Duffield and similar soils:* 85 percent
*Minor components:* 15 percent
*Estimates are based on observations, descriptions, and transects of the mapunit.*

**Description of Duffield**

**Setting**

*Landform:* Hills
*Landform position (two-dimensional):* Summit
*Landform position (three-dimensional):* Interfluve
*Down-slope shape:* Linear
*Across-slope shape:* Linear
*Parent material:* Residuum weathered from limestone

**Typical profile**

*H1 - 0 to 10 inches:* silt loam
*H2 - 10 to 56 inches:* silt loam
*H3 - 56 to 65 inches:* channery silt loam

**Properties and qualities**

*Slope:* 3 to 8 percent
*Depth to restrictive feature:* 60 to 80 inches to lithic bedrock
*Natural drainage class:* Well drained
*Runoff class:* Medium
*Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 2.00 in/hr)

*Depth to water table:* More than 80 inches
*Frequency of flooding:* None
*Frequency of ponding:* None
*Available water storage in profile:* High (about 10.4 inches)

**Interpretive groups**

*Land capability classification (irrigated):* None specified
*Land capability classification (nonirrigated):* 2e
*Hydrologic Soil Group:* B
*Hydric soil rating:* No

**Minor Components**

**Funkstown**

*Percent of map unit:* 8 percent
*Hydric soil rating:* No

**Clarksburg**

*Percent of map unit:* 5 percent
*Hydric soil rating:* No

**Dryrun**

*Percent of map unit:* 2 percent
*Hydric soil rating:* No

## EdB—Edom silty clay loam, 3 to 8 percent slopes

**Map Unit Setting**

*National map unit symbol:* rcp4
*Elevation:* 480 to 1,100 feet
*Mean annual precipitation:* 36 to 46 inches
*Mean annual air temperature:* 48 to 55 degrees F
*Frost-free period:* 150 to 210 days
*Farmland classification:* All areas are prime farmland

**Map Unit Composition**

*Edom and similar soils:* 100 percent
*Estimates are based on observations, descriptions, and transects of the mapunit.*

**Description of Edom**

**Setting**

*Landform:* Hillslopes, valleys
*Landform position (two-dimensional):* Backslope
*Landform position (three-dimensional):* Side slope
*Down-slope shape:* Convex
*Across-slope shape:* Convex
*Parent material:* Clayey residuum weathered from limestone and shale

**Typical profile**

*H1 - 0 to 8 inches:* silty clay loam
*H2 - 8 to 35 inches:* silty clay

*H3 - 35 to 67 inches:* channery silty clay
*H4 - 67 to 71 inches:* bedrock

**Properties and qualities**

*Slope:* 3 to 8 percent
*Depth to restrictive feature:* 40 to 72 inches to lithic bedrock
*Natural drainage class:* Well drained
*Runoff class:* Medium
*Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.20 to 2.00 in/hr)
*Depth to water table:* More than 80 inches
*Frequency of flooding:* None
*Frequency of ponding:* None
*Available water storage in profile:* Moderate (about 6.1 inches)

**Interpretive groups**

*Land capability classification (irrigated):* None specified
*Land capability classification (nonirrigated):* 2e
*Hydrologic Soil Group:* B
*Hydric soil rating:* No

## HaB—Hagerstown silt loam, 3 to 8 percent slopes

**Map Unit Setting**

*National map unit symbol:* 2rc98
*Elevation:* 600 to 1,750 feet
*Mean annual precipitation:* 37 to 45 inches
*Mean annual air temperature:* 45 to 55 degrees F
*Frost-free period:* 155 to 190 days
*Farmland classification:* All areas are prime farmland

**Map Unit Composition**

*Hagerstown and similar soils:* 85 percent
*Minor components:* 15 percent
*Estimates are based on observations, descriptions, and transects of the mapunit.*

**Description of Hagerstown**

**Setting**

*Landform:* Hills
*Landform position (two-dimensional):* Backslope, footslope, summit
*Landform position (three-dimensional):* Side slope, base slope, interfluve
*Down-slope shape:* Linear, concave
*Across-slope shape:* Linear, concave
*Parent material:* Clayey residuum weathered from limestone

**Typical profile**

*Ap - 0 to 10 inches:* silt loam
*Bt1 - 10 to 21 inches:* silty clay loam
*Bt2 - 21 to 56 inches:* silty clay
*C - 56 to 73 inches:* silty clay loam
*R - 73 to 83 inches:* bedrock

**Properties and qualities**

*Slope:* 3 to 8 percent
*Depth to restrictive feature:* 43 to 98 inches to lithic bedrock
*Natural drainage class:* Well drained
*Runoff class:* Medium
*Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 2.00 in/hr)
*Depth to water table:* More than 80 inches
*Frequency of flooding:* None
*Frequency of ponding:* None
*Available water storage in profile:* Moderate (about 8.7 inches)

**Interpretive groups**

*Land capability classification (irrigated):* None specified
*Land capability classification (nonirrigated):* 2e
*Hydrologic Soil Group:* B
*Hydric soil rating:* No

**Minor Components**

**Opequon**

*Percent of map unit:* 5 percent
*Landform:* Ridges
*Landform position (two-dimensional):* Shoulder, summit
*Landform position (three-dimensional):* Side slope, crest
*Down-slope shape:* Linear, convex
*Across-slope shape:* Convex, linear
*Hydric soil rating:* No

**Carbo**

*Percent of map unit:* 5 percent
*Landform:* Hills
*Landform position (two-dimensional):* Summit, backslope, shoulder
*Landform position (three-dimensional):* Side slope, crest
*Down-slope shape:* Linear, convex
*Across-slope shape:* Linear, convex
*Hydric soil rating:* No

**Funkstown**

*Percent of map unit:* 3 percent
*Landform:* Valley floors
*Landform position (two-dimensional):* Toeslope
*Landform position (three-dimensional):* Base slope
*Down-slope shape:* Concave
*Across-slope shape:* Concave, linear
*Hydric soil rating:* No

**Timberville**

*Percent of map unit:* 2 percent
*Landform:* Hills
*Landform position (two-dimensional):* Footslope
*Landform position (three-dimensional):* Head slope, base slope
*Down-slope shape:* Concave, linear
*Across-slope shape:* Convex, concave, linear
*Hydric soil rating:* No

## HcB—Hagerstown silt loam, rocky, 3 to 8 percent slopes

### Map Unit Setting

*National map unit symbol:* r8wn
*Elevation:* 460 to 1,500 feet
*Mean annual precipitation:* 30 to 45 inches
*Mean annual air temperature:* 45 to 57 degrees F
*Frost-free period:* 140 to 200 days
*Farmland classification:* Not prime farmland

### Map Unit Composition

*Hagerstown and similar soils:* 100 percent
*Estimates are based on observations, descriptions, and transects of the mapunit.*

### Description of Hagerstown

#### Setting

*Landform:* Ridges
*Landform position (two-dimensional):* Backslope
*Landform position (three-dimensional):* Side slope
*Down-slope shape:* Linear
*Across-slope shape:* Linear
*Parent material:* Clayey residuum weathered from argillaceous limestone

#### Typical profile

*H1 - 0 to 10 inches:* silt loam
*H2 - 10 to 19 inches:* clay
*H3 - 19 to 57 inches:* clay

#### Properties and qualities

*Slope:* 3 to 8 percent
*Depth to restrictive feature:* 40 to 84 inches to lithic bedrock
*Natural drainage class:* Well drained
*Runoff class:* Medium
*Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 2.00 in/hr)
*Depth to water table:* More than 80 inches
*Frequency of flooding:* None
*Frequency of ponding:* None
*Available water storage in profile:* High (about 10.0 inches)

#### Interpretive groups

*Land capability classification (irrigated):* None specified
*Land capability classification (nonirrigated):* 2s
*Hydrologic Soil Group:* B
*Hydric soil rating:* No

## HcC—Hagerstown silt loam, rocky, 8 to 15 percent slopes

### Map Unit Setting

*National map unit symbol:* r8wp
*Elevation:* 460 to 1,500 feet
*Mean annual precipitation:* 30 to 45 inches
*Mean annual air temperature:* 45 to 57 degrees F
*Frost-free period:* 140 to 200 days
*Farmland classification:* Not prime farmland

### Map Unit Composition

*Hagerstown and similar soils:* 100 percent
*Estimates are based on observations, descriptions, and transects of the mapunit.*

### Description of Hagerstown

#### Setting

*Landform:* Ridges
*Landform position (two-dimensional):* Backslope
*Landform position (three-dimensional):* Side slope
*Down-slope shape:* Linear
*Across-slope shape:* Linear
*Parent material:* Clayey residuum weathered from argillaceous limestone

#### Typical profile

*H1 - 0 to 10 inches:* silt loam
*H2 - 10 to 19 inches:* clay
*H3 - 19 to 57 inches:* clay

#### Properties and qualities

*Slope:* 8 to 15 percent
*Depth to restrictive feature:* 40 to 84 inches to lithic bedrock
*Natural drainage class:* Well drained
*Runoff class:* Medium
*Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 2.00 in/hr)
*Depth to water table:* More than 80 inches
*Frequency of flooding:* None
*Frequency of ponding:* None
*Available water storage in profile:* High (about 10.0 inches)

#### Interpretive groups

*Land capability classification (irrigated):* None specified
*Land capability classification (nonirrigated):* 3s
*Hydrologic Soil Group:* B
*Hydric soil rating:* No

## Pe—Penlaw silt loam

### Map Unit Setting

*National map unit symbol:* r8y8
*Elevation:* 300 to 1,500 feet
*Mean annual precipitation:* 34 to 50 inches
*Mean annual air temperature:* 48 to 57 degrees F
*Frost-free period:* 140 to 205 days
*Farmland classification:* Farmland of statewide importance

### Map Unit Composition

*Penlaw and similar soils:* 90 percent
*Minor components:* 10 percent
*Estimates are based on observations, descriptions, and transects of the mapunit.*

### Description of Penlaw

#### Setting

*Landform:* Swales
*Landform position (two-dimensional):* Toeslope, footslope
*Landform position (three-dimensional):* Base slope
*Down-slope shape:* Concave
*Across-slope shape:* Concave
*Parent material:* Colluvium derived from limestone, sandstone, and shale

#### Typical profile

*H1 - 0 to 11 inches:* silt loam
*H2 - 11 to 30 inches:* silty clay loam
*H3 - 30 to 45 inches:* silty clay loam
*H4 - 45 to 69 inches:* silty clay

#### Properties and qualities

*Slope:* 0 to 3 percent
*Depth to restrictive feature:* 15 to 30 inches to fragipan; 40 to 72 inches to lithic bedrock
*Natural drainage class:* Somewhat poorly drained
*Runoff class:* Very high
*Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.20 in/hr)
*Depth to water table:* About 6 to 18 inches
*Frequency of flooding:* None
*Frequency of ponding:* None
*Available water storage in profile:* Low (about 5.4 inches)

#### Interpretive groups

*Land capability classification (irrigated):* None specified
*Land capability classification (nonirrigated):* 3w
*Hydrologic Soil Group:* C/D
*Hydric soil rating:* No

**Minor Components**

**Clarksburg**

*Percent of map unit:* 5 percent
*Landform:* Swales
*Landform position (two-dimensional):* Toeslope
*Landform position (three-dimensional):* Base slope
*Down-slope shape:* Concave
*Across-slope shape:* Concave
*Hydric soil rating:* No

**Melvin**

*Percent of map unit:* 5 percent
*Landform:* Flood plains
*Down-slope shape:* Concave
*Across-slope shape:* Concave
*Hydric soil rating:* Yes

## Ub—Urban land and Udorthents

**Map Unit Setting**

*National map unit symbol:* r8yg
*Mean annual precipitation:* 36 to 50 inches
*Mean annual air temperature:* 46 to 59 degrees F
*Frost-free period:* 120 to 215 days
*Farmland classification:* Not prime farmland

**Map Unit Composition**

*Urban land:* 90 percent
*Minor components:* 10 percent
*Estimates are based on observations, descriptions, and transects of the mapunit.*

**Description of Urban Land**

**Setting**

*Down-slope shape:* Linear
*Across-slope shape:* Linear
*Parent material:* Pavement, buildings and other artifically covered areas

**Properties and qualities**

*Slope:* 0 to 8 percent
*Depth to restrictive feature:* 10 inches to densic material
*Runoff class:* Very high

**Interpretive groups**

*Land capability classification (irrigated):* None specified
*Land capability classification (nonirrigated):* 8s
*Hydric soil rating:* No

**Minor Components**

**Udorthents, steep**

*Percent of map unit:* 10 percent
*Landform:* Mountains
*Landform position (two-dimensional):* Summit, backslope
*Landform position (three-dimensional):* Mountaintop
*Down-slope shape:* Convex
*Across-slope shape:* Convex
*Hydric soil rating:* No

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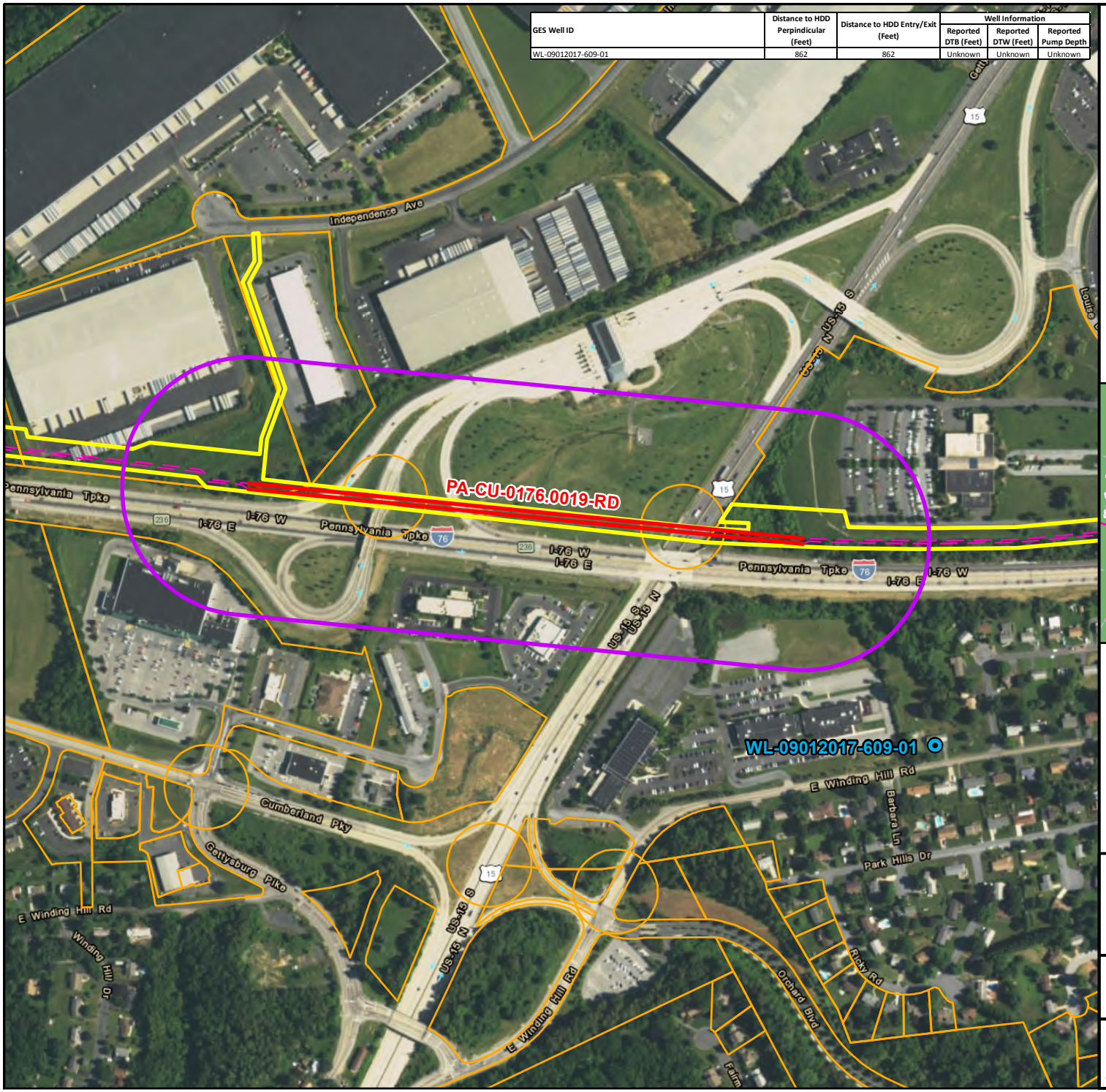
RETTEW

# ATTACHMENT 3
# 450-FOOT WELL SURVEY




| GES Well ID | Distance to HDD Perpindicular (Feet) | Distance to HDD Entry/Exit (Feet) | Well Information | | |
|---|---|---|---|---|---|
| | | | Reported DTB (Feet) | Reported DTW (Feet) | Reported Pump Depth |
| WL-09012017-609-01 | 862 | 862 | Unknown | Unknown | Unknown |

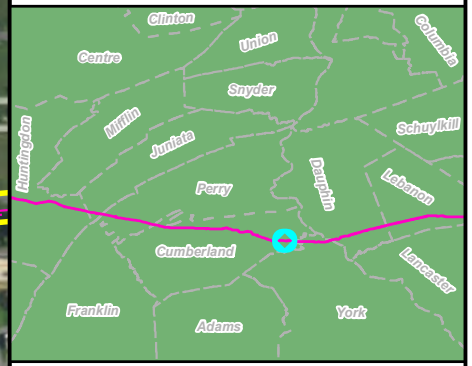
## Legend

- LOD
- Parcel
- PPP Centerline
- HDD
- 450 foot buffer of HDD alignment

****Testing locations current as of 12/11/2017**

- GES Testing Location

**Location**




0 250 500 Feet

**Well Location Map**
**HDD# PA-CU-0176.0019-RD**
**Cumberland County, PA.**

**Prepared By:** TETRA TECH

**Date:** 12/12/2017

Base Map;
ESRI World Imagery, 09/24/2015

**Coordinate System: NAD 83 Stateplane, PA South, Feet**

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