

**HORIZONTAL DIRECTIONAL DRILL ANALYSIS  
GRAHAM CREEK CROSSING  
PADEP SECTION 105 PERMIT NOS.: E21-449  
PA-CU-0062.0000-WX-16  
(SPLP HDD No. S2-0170-16)**

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This reevaluation of the horizontal directional drill (HDD) installation of a 16-inch diameter pipeline that traverses under Streams S-J37, S-J37B, and wetlands W-J35 and W-J36 in Lower Frankford Township, Cumberland County, Pennsylvania has been complete in accordance with Condition No. 3 of the Stipulated Order issued under Environmental Hearing Board Docket No. 2017-009-L. Condition No. 3 stipulates, for HDDs initiated after the temporary injunction issued by the Pennsylvania Department of Environmental Protection (PADEP) Environmental Hearing Board on July 25, 2017, a reanalysis must be performed on HDDs for which an inadvertent return (IR) occurs during the installation of one pipe (20-inch or 16-inch diameter) where a second pipe will thereafter be installed in the same right-of-way (ROW).

The HDD for the 20-inch pipeline installation was initiated before the issuance of the Order. Three (3) IRs occurred during the pilot hole phase of the HDD for installation of the 20-inch pipeline. All of these IR events were contained and remediated without further issue during completion of the pipeline installation.

### **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: 2,640 feet (ft.)
- Entry/Exit angle: 10 degrees
- Maximum Depth of cover: 57 ft.
- Depth below waters and wetlands: 49-57 ft
- Pipe design radius: 1,600 ft.

### **ROOT CAUSE ANALYSIS FOR THE 20-INCH PIPE INSTALLATION IR**

Based upon an analysis by the project geologists and HDD drilling specialists, the occurrence of the three IR events during the installation of the 20-inch pipeline was a result of the shallow depth of profile. The redesigned 16-inch HDD profile is designed to be below the installed 20-inch pipeline, with adjustments in the profile to maintain a flat horizontal run at maximum depth, and increased angles of entry into and out of bedrock. These changes will minimize the potential for IR's to occur during drilling of the 16-inch pipeline.

### **GEOLOGIC AND HYDROGEOLOGIC ANALYSIS**

The location of HDD S2-0170-16 is situated in the western portion of the Great Valley Section of the Ridge and Valley Physiographic Province. The geologic structure of the Ridge and Valley Physiographic Province is characterized by a series of alternating ridges formed on more resistant sandstones and quartzites and valleys underlain by more easily eroded shales and limestones. Two geologic units occur within a ½-mile radius of HDD, these units include the Martinsburg Formation, and the Greywacke and Shale Member of the Martinsburg Formation.

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

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**HYDROGEOLOGY, GROUND WATER, AND WELL PRODUCTION ZONES**

According to Becher and Root (1981), the Martinsburg Formation is the uppermost rock unit in the vicinity of HDD S2-0170-16. Groundwater flow paths within the clastic rocks of this formation have both local and regional components which are controlled by bedding, cleavage, and fractures in the rock. Locally, shallow groundwater discharges to the gaining portions of nearby streams such as Locust Creek, and deeper regional groundwater flow discharges toward points of regional groundwater discharge such as the Conodoguinet Creek and the Susquehanna River.

Based on the geotechnical report and boring logs, groundwater was encountered at 13 feet bgs in cores SB-01 and SB-02, which were drilled to 20.2 feet bgs and 18.7 feet bgs, respectively. Based on results of geotechnical drilling completed during November 2017, groundwater was measured in Boring B-01 at a depth of 19.6 feet bgs on November 14, 2017, and in Boring B-02 at 13.7 feet bgs on November 30, 2017.

Well records from the PA DCNR Pennsylvania Groundwater Information System (PaGWIS) database were reviewed to identify domestic water supply wells located within a ½-mile radius of the proposed HDD right-of-way (ROW) boundary (PaGWIS, 2017). Based on incomplete information in the PaGWIS database it appears that the majority of the identified wells were completed as 6-inch-diameter open-rock wells at depths ranging from 35 to 250 feet bgs. Based solely on the well inventory data provided by the PaGWIS database, the depth to bedrock ranges from 12 to 18 feet bgs, and well construction consists of 19 to 43 feet of steel casing with the open-rock portions of the wells extending from 19 to 250 feet bgs. Reported well yields range from 11 to 45 gpm. Seven static water level measurements were recorded and range from 2 to 25 feet bgs.

Attachment 1 provides an extensive discussion on the hydrogeology which informs this analysis.

**INADVERTENT RETURN (IR) DISCUSSION**

HDD specialists and geologists employed by SPLP have investigated the HDD design and subsurface geologic conditions during installation of the 20-inch pipeline. Based on the hydro-structural characteristics of the underlying geology compared to the permitted HDD profiles entry/exits, the original permitted design of the Graham Creek 16-inch HDD is susceptible to IRs of drilling fluids during future HDD operations.

A re-designed 16-inch HDD profile, and proactive implementation of drilling Best Management Practices (BMPs) during drilling operations will be used to reduce the risk of IRs. The 16-inch HDD profile has been re-designed to maintain a deeper depth of crossing beneath the Waters of the Commonwealth, and the inclination of the entry and exit angles has been increased in order to rapidly penetrate into and exit out of competent bedrock.

**ADJACENT FEATURES ANALYSIS**

This HDD is located in Lower Frankford Township, Cumberland County, approximately 2 miles (mi) west of the community of Bloserveille, Pennsylvania. The pipeline route follows parallel to an existing SPLP pipeline easement and crosses under Locust Creek approximately 0.4 mi north of the intersection of Old Mill Road and Wildwood Road.

This HDD passes under three segments of Locust Creek (streams S-J37A, S-J37B, and S-J36), stream S-J41, and one wetland (wetland J35). Locust Creek and stream S-J41 have a perennial flow regime but are not designated as high quality. Wetland J35 is comprised of emergent and forested vegetative cover types, and provides a buffer and is the riparian zone to Locust Creek. This HDD avoids surficial impacts to three segments of Locust Creek (streams S-J37A, S-J37B, and S-J36), stream S-J41, and wetland J35. Additionally, this HDD avoids surficial impacts to the floodway of Locust Creek, a Federal Emergency

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Management Agency (FEMA) 100-year floodplain (Chapter 106); forested wetland conversion, and existing underground gas pipelines laying parallel to and crossing perpendicular to the SPLP easement.

SPLP has identified all landowners with property located within 450 ft. of the HDD alignment. There are 8 individual landowners with properties located within 450 ft. of the HDD alignment. SPLP sent each of these landowners a notice letter via both certified and first-class mail on February 8, 2018, that included an offer to sample the landowner's private water supply/well in accordance with the terms of the Order and the Water Supply Assessment, Preparedness, Prevention and Contingency Plan. The letter also requested that each landowner contact the Right-of-Way agent for the local area and provide SPLP with information regarding: (1) whether the landowner has a well; (2) where that well is located, and its depth and size if known; and (3) whether the landowner would like to have the well sampled. In accordance with paragraph 10 of the Order, copies of the certified mail receipts for the letters sent to landowners have been provided to Karyn Yordy, Executive Assistant, Office of Programs at the Department's Central Office.

To date, SPLP has confirmed the presence of eight (8) private water supplies, of which one (1) is within 450 ft of the HDD profile. SPLP agents performed testing and monitoring of the adjacent water wells during the completion of the 20-inch HDD. No affects to water wells from the HDD have been documented by the monitoring and no complaints were received from the well owners.

To further avoid and mitigate any adverse effects from the HDD to private water wells, and in accordance with the requirements of the Stipulated Order, SPLP will transmit a copy of this HDD analysis to all landowners having a property line within 450 ft. of any direction of this HDD location.

The confirmed well locations are depicted on the well location map provided within the Hydrogeologic Report provided in Attachment 1.

## **ALTERNATIVES ANALYSIS**

As required by the Order, the reevaluation of HDD S2-0280 includes an analysis of open cut alternatives and potential re-routes. 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.

### **Open-cut Analysis**

Using a reduced construction corridor width of 50-ft, converting to an open cut trenched crossing method through this area would result in direct impacts to three crossing of Locust Creek and wetland J-35, including approximately 1.8 acres of emergent wetland impact, 1.0 acres of forested wetland impact, and 0.03 acres of impacts to state water bottoms. The HDD will avoid surface impacts to biological features and results in no surface impacts to streams and wetlands.

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Open cut impacts to these resources would require modification of the state and federal permits. Moreover, any produced groundwater in the open excavations would be pumped to a discharge filtration structure. The current feasible filtration ability, however, does not exceed 50 microns. Therefore, cloudy water (from suspended fine clay and silt particles) would be discharged downstream regardless of all control methods employed for the entire duration of the use of open cut construction techniques.

Finally, conventional auger bore is technically limited to less than 200 linear ft. at a time varying by the underlying substrate. Due extensive linear distance of continuous wetlands bisected by three crossings of Locust Creek there are no subset locations within this length of area to feasibly employ this type of installation method.

### **Re-Route Analysis**

The general route of the Mariner II Project in this area of the state is from west to east. The pipeline route as currently permitted follows parallel to existing SPLP and Buckeye pipeline easements that passes through an area of rural residential home sites and agricultural fields. There are no other established utility corridors north or south of the existing easements that would provide for an alternative alignment. As a result, any reroute to the north or south would establish a new greenfield utility corridor, and affect numerous previously unencumbered properties.

This re-route analysis conducted for the Graham Creek HDD confirms the conclusions reached in the previously submitted alternatives analysis.

### **HORIZONTAL DIRECTIONAL DRILL REDESIGN**

Additional geologic investigations have been completed and utilized in the redesign of the planned HDD. A summary of the redesign factors is provided below. The original and redesigned HDD plan and profile drawings are provided in Attachment 2.

#### **Revised Horizontal Directional Drill Design Summary: 16-inch**

- Horizontal length: 2,850 feet (ft.)
- Entry/Exit angle: 14-16 degrees
- Maximum Depth of cover: 128 ft.
- Depth below waters and wetlands: 54-128 ft
- Pipe design radius: 2,000 ft.

### **CONCLUSION**

The 16-inch HDD profile has been re-designed to allow for a deeper crossing beneath Locust Creek and adjacent wetlands. The inclination of the entry and exit angles has been increased in order to install the 16-inch pipe through protective soils, residual soils, and bedrock in closer proximity to the entry and exit points than the original shallower profile. As such, the revised profile greatly reduces the risk of IRs. Procedures established and documented in SPLP's revised IR Assessment, Preparedness, Prevention, and Contingency (PPC) Plan (April 2018 plan) across all ME II spreads have proven to be very effective in eliminating IRs and minimizing the extent of IRs. Additionally SPLP has engaged and requires proactive responses to Losses of Circulation which precede the occurrence of IRs.

The redesign of the HDD will not prevent all IRs. IR's are common on entry and exit of the drilling tool. In particular, upon the start of this HDD, Sunoco will employ the following HDD best management practices:

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- SPLP will provide the drilling crew and company inspectors the location(s) data on potential zones of higher risk for fluid loss and IRs, including the area related to previous IRs, and potential zones of fracture concentration identified by the fracture trace analysis, so that monitoring can be enhanced when drilling through these locations.
- SPLP will require and enforce the use of annular pressure (AP) monitoring during the drilling of the pilot holes, which assists in immediate identification of pressure changes indicative of loss of return flows or over pressurization of the annulus to manage development of pressures that can induce an IR;
- SPLP inspectors will ensure that an appropriate diameter pilot tool, relative to the diameter of the drilling pipe, is used to ensure adequate “annulus spacing” around the drilling pipe exits to allow good return flows during the pilot drilling;
- SPLP will implement short-tripping of the reaming tools as return flow monitoring indicates 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;
- Tool face pressure during pilot phase drilling will be used to identify specific locations, or zones, of geologic weakness within the annulus as potential locations for proactive treatment by grout injections to minimize the movement of drilling fluids outside of the borehole annulus, or stabilization of the annulus wall to minimize collapse of the surrounding geologic materials into the annulus;
- During all drilling phases, the use of Loss Control Materials (LCMs) will be considered if 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. The AP below that depth can exceed the effective stabilization capability of LCMs. The horizontal run of this HDD is below 70 ft of depth, accordingly, the preferred corrective action needed to address the presence of fractures or documented LOCs will be grouting of the HDD annulus. Two types of grouting will be utilized for corrective actions. 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. 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.

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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-valuation report will minimize the risk of IRs and impacts to public and private water supplies during the construction phases of the HDD.

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



Larry J. Gremminger, CWB  
Geotechnical Evaluation Leader  
Mariner East 2 Pipeline Project

2-11-2019

Date

Pertaining to the practice of geology



Douglas J. Hess, P.G.  
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Skelly and Loy, Inc.  
Director of Groundwater  
and Site Characterization  
Geo-Environmental Services

2/11/19

Date



Pertaining to the pipeline stress and HDD geometry



Jeffery A. Lowy, P.E.  
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Civil Engineer

2/19/19

Date



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**ATTACHMENT 1  
GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT**



February 6, 2019

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

Re: Sunoco PA Pipeline Project Mariner  
East II, Graham Creek HDD  
S2-0170, PA-CU-0062.0000-WX-16  
Hydrogeological Re-Evaluation  
Report  
Lower Frankford Township, Cumber-  
land County, Pennsylvania  
Rettew Project No. 096302011

## EXECUTIVE SUMMARY

1. This hydrogeologic re-evaluation is being prepared as a result of two inadvertent returns (IRs) that occurred as the Graham Creek horizontal directional drill (HDD) S2-0170 20-inch pilot hole was advanced near the HDD exit point. Also, during the 20-inch reaming phase of drilling, an additional IR occurred while the reamer bit was approximately 60 feet from the west entry pit.
2. The Graham Creek HDD is underlain by sedimentary rocks of the Ordovician-age Martinsburg Formation (Oml).
3. Geologic mapping, published reports, and field observations indicate a high degree of bedrock fracturing in the Martinsburg Formation characterized by irregularly spaced, generally open, highly developed joints with steeply dipping beds and dominant bedding-parallel fracture cleavage.
4. Water-bearing zones in the underlying geology generally occur in secondary openings along bedding planes, joints, faults, and fractures. Water-bearing zones in the Martinsburg Formation are reported to be distributed within the first 100 feet of the subsurface but occur as deep as 350 feet below ground surface (bgs).
5. The 20-inch HDD pipeline installation was completed on June 10, 2018. The HDD profile for the proposed 16-inch HDD has been redesigned to increase its depth below a buried utility and two streams (three stream crossings).
6. Based on the hydro-structural characteristics of the underlying geology and the IRs that occurred during installation of the 20-inch pilot drill, the proposed 16-inch Graham Creek HDD is susceptible to the inadvertent return of drilling fluids during HDD operations. A redesigned 16-inch HDD profile (Attachment 2, **Figure 2**) and Best Management Practices (BMPs) 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 hydrogeologic setting of the Graham Creek (S2-0170) HDD location. The Graham Creek HDD the site is located in Lower Frankford

Township, Cumberland County, Pennsylvania. The site is located approximately 7.6 miles northwest of Carlisle, approximately 1.7 miles northeast of Bloersville, and approximately 2.7 miles north of the Pennsylvania Turnpike (I-76). The HDD was designed to be drilled under an unnamed tributary (UNT S-J41) discharging to Locust Creek, Locust Creek (S-J37), the existing Buckeye Pipeline, and a second UNT (S-J36) discharging to Locust Creek (refer to **Figure 1**). This hydrogeologic report is part of the response to the Corrected Stipulated Order dated August 10, 2017, related to the potential for the inadvertent return of drilling fluids during proposed drilling operations for the 16-inch pipeline.

HDD S2-0170 is located within the Great Valley Section of the Ridge and Valley Physiographic Province (Pennsylvania Department of Conservation and Natural Resources [PA DCNR], 2000). The dominant topography in areas underlain by the Martinsburg Formation is typified by alternating ridges formed on more resistant sandstones and quartzites and valleys of low relief underlain by more easily eroded shales and limestones. Local relief is low to moderate and ranges in the vicinity of the site from approximately 505 feet above mean sea level (AMSL) to 531 feet AMSL (Google Earth, 2017). The site is drained by both shallow, unnamed tributary streams and Locust Creek which flows from northwest to southeast along the proposed east-west HDD path. The unnamed tributary flows to the south across the western half of the HDD trace where it ultimately discharges into Conodoguinet Creek. The area surrounding the HDD consists predominantly of rural residential and agricultural properties.

The proposed redesigned 16-inch HDD will cross under an UNT at 46 feet bgs, the existing Buckeye Pipeline at 126 feet bgs, Locust Creek at two locations (west to east) at 128 and 124 feet bgs, respectively, and a second UNT at 112 feet bgs. The proposed redesigned 16-inch HDD entry/exit point is at a surface elevation of 536 feet AMSL sloping gently downward toward the east to an elevation of 533 feet AMSL at the HDD entry/exit point. The proposed 16-inch HDD is approximately located between Stations 9551+00 and 9577+00 on the pipeline, for an overall horizontal length of 2,850 feet and a pipe length/bore path length of 2,884 feet. The existing 20-inch and the proposed 16-inch S2-0170 HDD locations are shown on **Figure 1**.

## 2.0 GEOLOGY AND SOILS

According to the PA DCNR (2000), the HDD S2-0170 site is situated in the western portion of the Great Valley Section of the Ridge and Valley Physiographic Province. The geologic structure of the Ridge and Valley Physiographic Province is characterized by a series of alternating ridges formed on more resistant sandstones and quartzites and valleys underlain by more easily eroded shales and limestones. The dominant topography in this area consists of a very broad valley with dissected uplands exhibiting low to moderate local relief. The general bedrock beneath the HDD S2-0170 site consists of shale and sandstone. The geologic structure consists of severe folds, thrust sheets, nappes, overturned folds, and steep faults. Many third- and fourth-order folds occur, and the drainage pattern is dendritic and trellis.

According to Google Earth, two geologic units occur within a ½-mile radius of HDD S2-0170. These units include the Martinsburg Formation, and the Greywacke and Shale Member of the Martinsburg Formation. The proposed HDD trace lies within the Martinsburg Formation. A geologic map showing the contact between these two Ordovician-age (443 to 485 million years old) units is included as **Figure 2**. Geyer and Wilshusen (1982) describe both units as consisting

of buff-weathering, dark gray shale, thin interbeds of siltstone metabentonite, and fine-grained sandstone; brown-weathering, medium-grained sandstone containing shale and siltstone interbeds in the middle of the formation; and a basal unit that grades into calcareous shale with platy weathering. These units are well-bedded; the sandstone is thick to massive, and the calcareous shale and shale are thin to fissile. Fracturing consists of dominant and highly developed cleavage; joints are also present and irregularly spaced, open, and nearly vertical. According to Geyer and Wilshusen (1982), fracturing in the Martinsburg Formation underlying the HDD S2-0170 site is typified by cleavage parallel to the bedding planes, however, irregularly spaced, naturally occurring fractures known as joints are also present. These joints are typically open and nearly vertical. The joint and bedding plane openings collectively provide a secondary porosity of low magnitude. The formation is moderately weathered to an approximate depth of 1 to 4 feet bgs. The topography is characterized as a valley of low relief dissected by ravines and small stream beds. The Martinsburg Formation (including the Greywacke and Shale units) is moderately weathered to a moderate depth; small to large platy fragments result; and the mantle is thick. Surface drainage is good, and the cleavage and joint-plane openings provide a secondary porosity of generally low magnitude and low permeability. The median-sustained groundwater yield is reported to be 32 gallons per minute (gpm), and the maximum well yield is reported as 200 gpm. Yielding zones are commonly less than 150 feet bgs in depth but can occur as deep as 400 feet bgs. The ease of excavation (and drilling) is classified as fairly easy in the shale, moderately difficult in the calcareous shale, and difficult in the sandstone. The drilling rate is reported to be fast.

According to the United States Department of Agriculture Soil Survey of Cumberland County, Pennsylvania, soils within approximately 600 feet of the drill path for HDD S2-0170 consist of nine soil types, primarily composed of channery silt loam (approximately 59%) and silt loam (approximately 41%). A site map showing the spatial distribution of the various soils along with the soil profile descriptions is included as **Attachment 1**.

### **3.0 HYDROGEOLOGY**

Bedrock geology ultimately influences the storage, transmission, and use of groundwater. Geologic factors such as rock type, intergranular porosity, rock strata inclination, faults, joints, bedding planes, and solution channels affect groundwater movement and availability. According to Becher and Root (1981), the Martinsburg Formation is the uppermost rock unit in the vicinity of HDD S2-0170. Groundwater flow paths within the clastic rocks have both local and regional components which are controlled by bedding, cleavage, and fractures in the rock. Locally, shallow groundwater discharges to the gaining portions of nearby streams such as Locust Creek and the UNT, and deeper regional groundwater flow discharges toward points of regional groundwater discharge such as the Conodoguinet Creek and the Susquehanna River. Based on the geotechnical report and boring logs included as **Attachment 2**, groundwater was encountered at 13 feet bgs in both SB-01 and SB-02, which were drilled to 20.2 feet bgs and 18.7 feet bgs, respectively. Based on results of geotechnical drilling completed during November 2017, groundwater was measured in Boring B-01 at a depth of 19.6 feet bgs on November 14, 2017, and in Boring B-02 at 13.7 feet bgs on November 30, 2017. The maximum reported well yield in the Martinsburg Formation is 200 gpm. Water-bearing zones are commonly less than 100 feet bgs but occur as deep as 350 feet bgs (Taylor and Werkheiser, 1984). According to Becher and Root (1981), the frequency of water-bearing zones declines gradually to 350 feet bgs. Cleavage is important in creating water-bearing openings, particularly in the Martinsburg Formation where it

provides numerous closely spaced, commonly minute openings which, individually, cannot provide much water to wells but, collectively, are capable of providing domestic supplies.

Well records from the PA DCNR Pennsylvania Groundwater Information System (PaGWIS) database were reviewed to identify domestic water supply wells located within a ½-mile radius of the proposed HDD right-of-way (ROW) boundary (PaGWIS, 2017). The search identified 10 wells within the ½-mile radius of the HDD. These wells consist of 9 private supply wells and one well whose use is listed as “other”. A map showing the well locations relative to the proposed HDD location is included as **Figure 3**. Given the rural nature of the surrounding area, presence of scattered residential dwellings, and limited information available in the PaGWIS database, it is likely that there are additional domestic supply wells within the ½-mile radius of the proposed HDD ROW. Well construction details were not reported for all of these wells. Based on incomplete information in the PaGWIS database (**Figure 3**), it appears that the majority of the identified wells were completed as 6-inch-diameter open-rock wells at depths ranging from 35 to 250 feet bgs. Based solely on the well inventory data provided by the PaGWIS database, the depth to bedrock ranges from 12 to 18 feet bgs, and well construction consists of 19 to 43 feet of steel casing with the open-rock portions of the wells extending from 19 to 250 feet bgs. Reported well yields range from 11 to 45 gpm. Seven static water level measurements were recorded and range from 2 to 25 feet bgs. Based on the geologic mapping available for the area, it appears that the majority of the wells identified above were completed in the Martinsburg Formation.

In January 2019, other Sunoco subcontractors researched private water supplies located within a 450-foot radius of the Graham Creek HDD. One additional water supply well was identified within the 450-foot radius and approximately 275 feet south of the western HDD entry/exit point. Additional supply wells were identified outside the 450-foot radius as shown on **Attachment 3**. While some information on the drilled well depth was reported for two of the wells, no information pertaining to the depth to water or well yield was reported.

#### **4.0 FRACTURE TRACE ANALYSIS**

Fracture traces are natural linear surficial features that are unaffected by local topographic relief and, as a result, are considered surface manifestations of concentrated high-angle bedrock fracturing. Fracture traces may be observed on aerial photographs as linear topographic features, straight stream segments, vegetation, or soil tonal variations. The Web-based Pennsylvania Imagery Navigator and Google Earth Pro were used to access, download, and view aerial imagery of the HDD site. Ten series of historical aerial photographs were analyzed that included photography dated April 1994, April 1999, April 2003, September 2005, March 2007, October 2008, September 2010, August 2012, September, 2013, and April 2016 (Pennsylvania Spatial Data Access [PASDA], 2017, and Google Earth Pro, 2017). Due to the lack of black-and-white photo quality stereo pairs in the Google Earth library, no fracture traces were discernible proximate to the HDD.

According to Becher and Root (1981), 11 fracture traces were previously identified within a ½-mile radius of the HDD site. Six of these mapped fracture traces trend approximately northeast-southwest (NE-SW) at locations north (N), northeast (NE), east (E), and southeast (SE) of the HDD profile. The other 5 fracture traces are mapped as trending northwest-southeast, with 4 situated within 2,200 feet southwest of the western entry/exit point of the HDD bore path and

another approximately 1,300 feet southeast of the eastern end entry/exit point of the HDD bore path. The mapped fracture traces are presented on both the Geology Map (**Figure 2**) and the Groundwater Well Location Map (**Figure 3**). The mapped fracture traces do not appear to correspond to observed surface features on the topographic map or aerial photographs. The general surface drainage patterns near the HDD site are characterized by the linear stream reaches of Locust Creek, Conodoguinet Creek, and several surface streams generally trending north to south reflecting the local geologic structure. It is Skelly and Loy's opinion that the numerous stream courses visible along the south-facing slope of Blue Mountain on both the topographic map and aerial photographs are suggestive of additional fracture traces proximate to the HDD bore path and are related to the primary geologic structure in the vicinity of the HDD site.

## 5.0 GEOTECHNICAL EVALUATION

Two geotechnical borings were completed on October 22 and 23, 2014, during the preliminary investigation of HDD S2-0170 and prior to initiating HDD operations. Boring SB-01 was located approximately 150 feet west of the western HDD entry/exit point along the south side of the HDD limit of disturbance (LOD). Boring SB-02 was located approximately 170 feet northwest of the eastern HDD entry/exit point along the north side of the LOD. The borings were completed to investigate soil, residual soil, and shallow weathered bedrock conditions using hollow-stem auger drilling methods. An NQ core barrel/bit was used for rock coring.

The generalized subsurface profile observed in these two borings completed at the HDD S2-0170 site can be described as follows.

- **SB-01:** Less than 1 inch of topsoil, overlying 8.5 feet of decomposed rock weathered to a mottled fine- to medium-grained SAND and CLAY, with a trace of fine GRAVEL; overlying 8.5 feet of decomposed rock weathered to a light gray to gray, fine- to coarse-grained SAND, and angular fine to coarse GRAVEL, with a little SILT; overlying 3.2 feet of weathered gray and dark-gray SHALE. Depth to bedrock was 17.0 feet. The underlying bedrock was described as partially weathered gray and dark gray SHALE. The total depth of this boring was 20.2 feet.
- **SB-02:** Approximately 2 inches of topsoil overlying 8 feet of decomposed shale weathered to brown and gray fine- to medium-grained SAND, some angular fine to coarse GRAVEL, and some SILT; overlying 9.0 feet of decomposed shale weathered to gray, fine- to coarse-grained SAND, and fine to coarse GRAVEL, with a little to some SILT. Depth to bedrock was 17.0 feet. The underlying bedrock was described as partially weathered gray SHALE. The total depth of the boring was 18.7 feet.

The boring logs indicate that the soil/weathered bedrock interface was encountered at 17.0 feet bgs in both SB-01 and SB-02. According to the Unified Soil Classification System (USCS), the soils consist of silty sand (SM) above silty gravel (GM) in SB-01. In SB-02, approximately 8.5 feet of clayey sand (SC) were present above 8.5 feet of silty sand (SM) and silty gravel (GM). Groundwater was encountered at 13 feet bgs in both SB-01 and SB-02. No geophysical

studies were performed at this location. The geotechnical report for S2-0170 is provided as **Attachment 2**.

Two additional borings were completed on November 10 to 14, 2017 (Geo Bore No. 1), and November 30, 2017 (Geo Bore No. 2). Geo Bore No. 1 was drilled approximately 600 feet west of the western HDD entry/exit point, and Geo Bore No. 2 was drilled approximately 100 feet east of the eastern HDD entry/exit point.

- **Geo Bore No. 1:** Geo Bore No. 1 was completed to a total depth of 155 feet with top of bedrock encountered at approximately 6 feet bgs. The bedrock consists of gray and dark gray, slightly to highly weathered, CARBONACEOUS SHALE. The rock coring logs describe the bedrock as ranging from highly weathered and broken to massive, with calcite veins. The Rock Quality Designation (RQD) ranged from very poor (0%) to excellent (92%). Groundwater was encountered at 19.6 feet bgs.
- **Geo Bore No. 2:** Geo Bore No. 2 was completed to a total depth of 130.2 feet bgs with the top of bedrock encountered at 15 feet. The bedrock consists of gray and dark gray, slightly to highly weathered, CARBONACEOUS SHALE. The rock coring logs describe the bedrock as ranging from highly weathered and broken to massive, with calcite veins. The RQD, ranged from poor (34%) to excellent (96%). Groundwater was encountered at 13.7 feet bgs.

The boring logs indicate that the soil/weathered bedrock interface was encountered at 6 feet bgs in Geo Bore No.1 and 15 feet bgs in Geo Bore No. 2. According to the USCS, the soils consist of 3 feet of silt and sand (ML) above 3 feet of clayey sand (SC) in Geo Bore No. 1. In Geo Bore No. 2, approximately 3.5 feet of clayey gravel (GC) were present above 9.5 feet of silty sand (SM) and 2.2 feet of silty gravel (GM). No geophysical studies were performed at this location. The boring logs and photographs of Geo Bore Nos. 1 and 2 are provided in **Attachment 2**.

Please note that Skelly and Loy or RETTEW did not oversee or direct the geotechnical drilling programs associated with HDD S2-0170 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 contractors. Skelly and Loy and RETTEW relied on these reports and incorporated their data into the general geologic and hydrogeologic framework of the analysis of HDD S2-0170 for this report.

## **6.0 FIELD OBSERVATIONS**

On September 25, 2017, a loss of returns (LOR) occurred during the 20-inch drill at a trajectory length of approximately 2,030 feet east of the HDD entry point and a depth of approximately 54 feet bgs. Drilling was immediately stopped and remedial measures taken (fiber was added to the drilling fluids) until full circulation was restored. A second LOR occurred on September 27, 2017, at a trajectory length of approximately 2,694 feet (east of the HDD entry point) and a depth of 30 feet bgs. Drilling was immediately stopped; however, an IR was

discovered as the rods were being removed to swab the bore and adjust the bore profile. The IR occurred approximately 1,850 feet from the entry point and 844 feet from the end of the bore. The IR resulted in the loss of approximately 500 gallons of drilling fluids impacting Wetland WL-J35 at the location identified on **Figures 2** and **3**. All drilling was suspended until the IR was contained and fully remediated. A second IR occurred on December 13, 2017, during drilling of the pilot hole. The second IR occurred within the permitted LOD and adjacent to the east end exit pit (**Figures 2** and **3**). The IR volume was estimated to be 25 gallons and occurred approximately 77 feet from the east-side entry/exit pit during drilling of the intercept pilot hole from the east side. This IR was considered to be associated with the “punching out” of the intercept pilot bit. Drilling immediately stopped upon discovery of the IR. The IR was contained within the ROW and LOD and within the erosion and sediment (E&S) controls. The IR was immediately cleaned up and drilling resumed. A third IR occurred on February 27, 2018, during the reaming phase (using a 20-inch-diameter reamer bit) and occurred while the reamer bit was approximately 60 feet from the west entry pit, within the unnamed tributary to Locust Creek (**Figures 2** and **3**). The IR was immediately detected and Flatirons immediately ceased drilling and began containment and clean-up activities. Clean-up activities included placing silt socks in the tributary immediately upstream of the IR discharge location and immediately downstream of the IR discharge location to prevent further downstream migration of drilling fluid. Any drilling fluid that had settled to the bottom of the tributary was collected using a vacuum truck. Following restart approval and permit approval to install a pump and hosing to divert streamflow around the IR discharge location, Flatirons resumed reaming of the 20-inch borehole on April 18, 2018. There were no subsequent IRs and the 20-inch pipe pull was completed on June 10, 2018.

A site reconnaissance was performed by a Skelly and Loy geologist on January 11, 2018, to identify rock outcrops for fracture fabric analysis, evaluation and ground-truthing of topographic expression related to fracture traces identified during the desktop assessment, and potential sensitive receptors to IRs. Readily accessible bedrock exposures were limited in the immediate vicinity of the HDD; however, structural geologic measurements consisting of bedding and jointing strike and dip were collected from a small outcrop exposed in a cutslope immediately north of the intersection of Wildwood and Run Roads approximately 1,500 feet south of the HDD entry point as shown on **Figures 2** and **3**. This bedrock exposure consists predominantly of interbedded dark to medium gray sandstone, siltstone, and shale characteristic of the Lower Member of the Martinsburg Formation. Field measurements along the cut slope exposure indicate that the average strike of bedding was N90°E with an average dip of 62°SE. The average strike of the joints identified at this outcrop was N2°W with an average near vertical dip of 81°NE. Jointing is also strongly influenced by bedding-parallel east-west trending cleavage. These field data are consistent with the published geologic data, mapping, and fracture traces identified in Section 4.0.

## **7.0 GEOPHYSICAL SURVEY CONSIDERATIONS**

According to published geologic mapping in the area of the HDD, no carbonate or karst geology is mapped as being present at this HDD location (Google Earth, 2017). The nearest limestone formation is mapped as the Ordovician age St. Paul Group, which at the closest point is more than two miles south of the Graham Creek HDD site. No carbonate bedrock was observed during the field reconnaissance. Although the Corrected Stipulated Order states that the use of geophysical surveys should be considered in karst areas, based on the lack of karst geologic features and extensively fractured bedrock, the use of geophysical surveys during re-evaluation

was considered but was ultimately not implemented at the Graham Creek HDD location because the results of geophysical surveys would not likely provide additional information that would reduce the risk of an IR. In addition, results of geophysical surveys in karst terrains with the resolution necessary to image features that could affect the HDD are typically limited to the upper 20 to 50 feet of the ground surface. Based on our experience working in karst geology, the lack of mapped karst geology along the HDD trace and lack of continuous thick-bedded limestone units, the Martinsburg Formation is not deemed susceptible to the solution activity present in other more thickly bedded carbonate geologic formations in Pennsylvania. In our professional opinion, geophysical surveys would not provide additional information on the formational thickness, interbedded siltstone, metabentonite, fine-grained sandstone, siltstones, and thinly bedded fissile shales at depths greater than 50 feet bgs along the HDD profile. Geophysical survey data would not enhance the evaluation of the HDD or reduce the risk of an IR.

## **8.0 CONCEPTUAL HYDROGEOLOGIC MODEL**

Groundwater occurring in the watershed occupied by the Graham Creek HDD originates as precipitation or snowmelt. The precipitation infiltrates through the overburden soils. As previously described (Section 3.0), shallow groundwater generally occurs under unconfined conditions within the upper portion of the bedrock. Based on site-specific geotechnical data (Section 5.0) and information obtained from the PaGWIS database (Section 3.0), the groundwater table occurs within the upper portion of the bedrock (2 to 25 feet bgs) proximate to the HDD path and contributes flow to local shallow groundwater discharge zones supporting the unnamed tributary and Locust Creek which cross the HDD profile. Based on these limited site-specific data, it appears that the groundwater table also occurs within the unconsolidated overburden near the soil/bedrock interface. The available data suggest that the groundwater table proximate to the HDD path is relatively shallow and may exist in some areas of the overburden soils that contribute flow to these local shallow groundwater discharge zones given that at least two unnamed tributaries flow above (across) the HDD profile where they discharge to Locust Creek. The thickness of the regolith and saturated regolith varies according to the underlying geohydrologic unit and topographic setting (Low, et. al, 2002).

Drilling logs of the four geotechnical borings completed from October 2014 through November 2017 indicate that the soil thickness near HDD S2-0170 ranges from approximately 6 to 17 feet and consists predominantly of silt, fine-grained sand, clay and weathered shale. Recorded descriptions of the bedrock core included slightly to highly weathered and massive shale. Data tabulated for supply wells found in the PaGWIS database (**Figure 3**) within a ½-mile radius of the HDD trace recorded measured water levels in the bedrock aquifer ranging from 2 to 25 feet bgs. Groundwater was encountered in all 4 geotechnical borings ranging in depth from 13 to 19.6 feet bgs.

This formation is highly anisotropic, with the predominant flow direction parallel to bedrock strike. The transport of groundwater in the fractured bedrock is generally greatest within highly permeable fractures, and the orientation of bedding planes and fractures primarily influence the direction of groundwater flow. Some site-specific evaluation of the bedrock has been completed in the area proximate to the geotechnical borings completed along this HDD profile and the identified bedrock outcrop located south of the southeastern LOD boundary (refer to **Figures 2**

and 3). No detailed characterization or groundwater flow modeling of the bedrock aquifer was performed as part of this hydrogeologic re-evaluation.

The groundwater flow direction in the overburden soils is presumed to mimic surface topography which slopes gently toward the unnamed tributaries and Locust Creek. The unnamed tributaries and Locust Creek are sustained by local shallow groundwater flow discharges. The geotechnical report and boring logs included as **Attachment 2** show that groundwater was present in the unconsolidated soils. Based on the PaGWIS database (Section 3.0), measured water levels in private supply wells located within ½-mile of the site reportedly range from 2 to 25 feet bgs. Based on this information, the uppermost groundwater table is presumed to occur within the uppermost bedrock or near the soil/bedrock interface under unconfined conditions.

## 9.0 CONCLUSIONS

Based on published geologic and hydrogeologic information, the S2-0170 Graham Creek HDD location is underlain by clastic sedimentary rocks (dark gray shale with thin interbeds of siltstone, metabentonite, and fine-grained sandstone) of the Martinsburg Formation. Groundwater movement within these rocks is primarily through a network of interconnected secondary openings (e.g., fractures, joints, and faults) that were developed by external forces following deposition of the beds. Geotechnical rock core observations confirm that the local bedrock is fractured and comprised of steeply dipping joints and bedding planes. All of the private water supply wells identified in the vicinity of the HDD are constructed in bedrock, indicating that none of the domestic wells relies on the shallow unconsolidated overburden as a source of groundwater supply. The uppermost portion of the bedrock aquifer, and potentially the unconsolidated soils and weathered bedrock, provide sustainable groundwater discharge to the unnamed tributaries and Conodoguinet Creek.

The proposed 16-inch HDD profile is relatively shallow when compared with the land surface, unnamed streams, existing Buckeye Pipeline, and Locust Creek and passes through both the unconsolidated overburden and fractured bedrock. The weakest point of the profile is beneath the first crossing of Locust Creek in the area of the identified northeast-southwest trending fracture trace. Based on the hydro-structural characteristics of the underlying geology described in this report and the known HDD profile through shallow soils and bedrock, the Graham Creek HDD site is susceptible to the inadvertent return of drilling fluids during HDD operations. The redesigned 16-inch HDD profile has been lengthened so that the western entry point is approximately 100 feet west of the originally proposed entry point location to allow for deeper crossings beneath the unnamed tributary stream (46 feet bgs vs. 11 feet bgs) and Locust Creek at two locations (128 feet bgs vs. 57 feet bgs; 124 feet bgs vs. 57 feet bgs), and the Buckeye pipeline (126 feet bgs vs. 53 feet bgs). Additionally, the redesigned 16-inch HDD profile is deeper than the as-built profile for the 20-inch HDD, although the original proposed 16-inch HDD profile was shallower than the as-built profile for the 20-inch HDD. The inclination of the entry and exit angles has been increased as a means to install the pipe through these protective residual soils and bedrock in closer proximity to the entry and exit points than the original, shorter profile. From a geologic perspective, the laterally adjusted, longer and deeper profile, in conjunction with the proposed engineering controls and/or drilling BMPs, will be used to reduce the risk of an IR. Drilling BMPs are described in the Horizontal Directional Drill Analysis component of the overall re-evaluation package.

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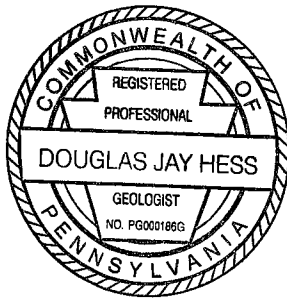
Mr. Matthew Gordon  
Sunoco Pipeline, L.P.  
RETTEW Project No. 096302011  
Page 11

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## 11.0 CERTIFICATION

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

By affixing my seal to this document, I am certifying that the information 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, P.G.  
License No. PG-000186-G

Sincerely yours,

SKELLY and LOY, Inc.

A handwritten signature in blue ink that reads "Douglas J. Hess".

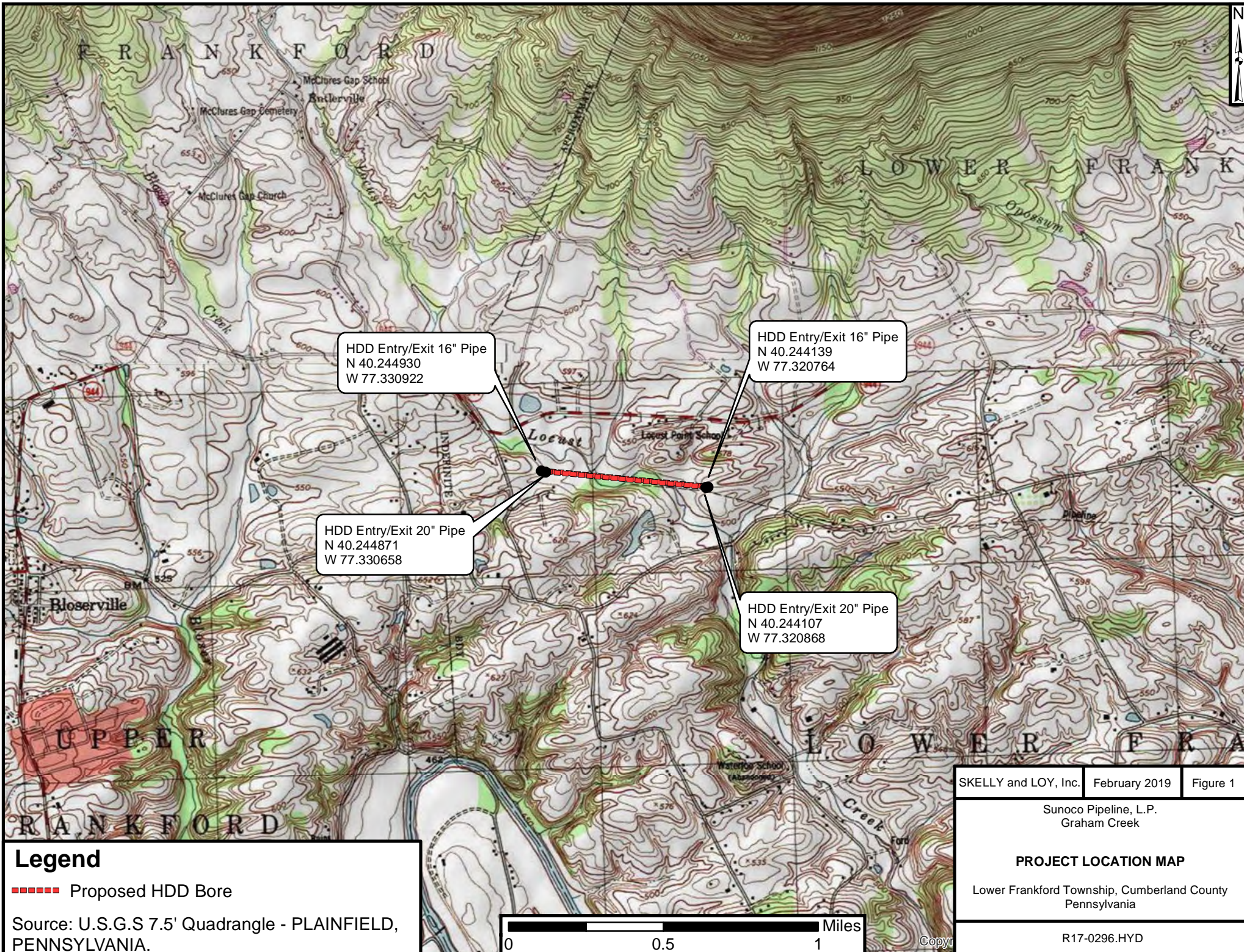
Douglas J. Hess, P.G.  
Director of Groundwater  
and Site Characterization  
Geo-Environmental Services

Enclosures

cc: R17-0296.HYD

File: HYDROGEOLOGIC\_REPORT- Graham Creek.docx

## **FIGURES**



HDD Entry/Exit 16" Pipe  
 N 40.244930  
 W 77.330922

HDD Entry/Exit 16" Pipe  
 N 40.244139  
 W 77.320764

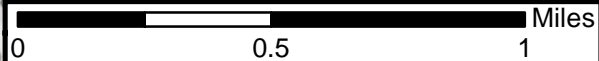
HDD Entry/Exit 20" Pipe  
 N 40.244871  
 W 77.330658

HDD Entry/Exit 20" Pipe  
 N 40.244107  
 W 77.320868

**Legend**

----- Proposed HDD Bore

Source: U.S.G.S 7.5' Quadrangle - PLAINFIELD, PENNSYLVANIA.



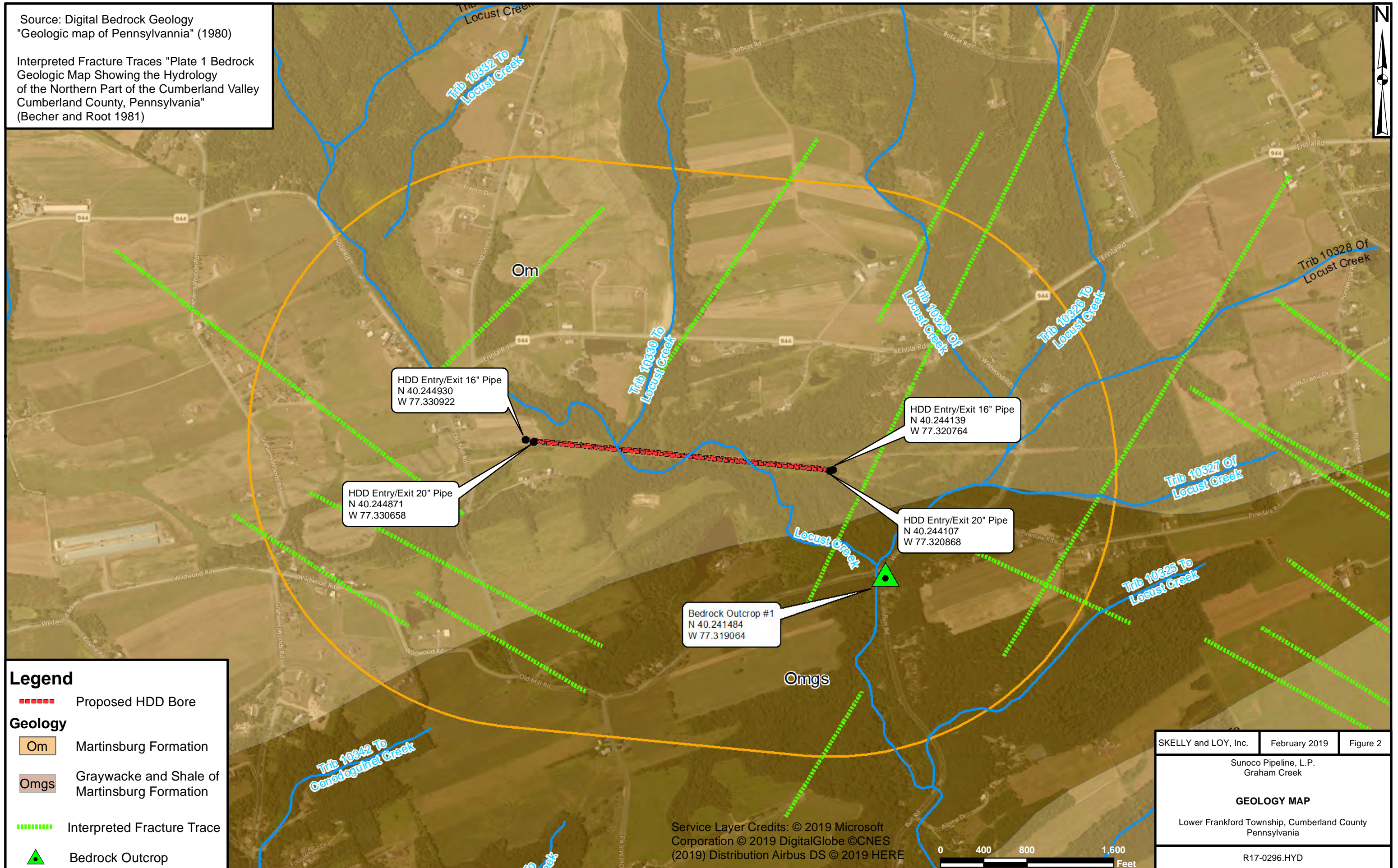
SKELLY and LOY, Inc. February 2019 Figure 1

Sunoco Pipeline, L.P.  
 Graham Creek  
**PROJECT LOCATION MAP**  
 Lower Frankford Township, Cumberland County  
 Pennsylvania

R17-0296.HYD

Source: Digital Bedrock Geology  
 "Geologic map of Pennsylvania" (1980)

Interpreted Fracture Traces "Plate 1 Bedrock  
 Geologic Map Showing the Hydrology  
 of the Northern Part of the Cumberland Valley  
 Cumberland County, Pennsylvania"  
 (Becher and Root 1981)

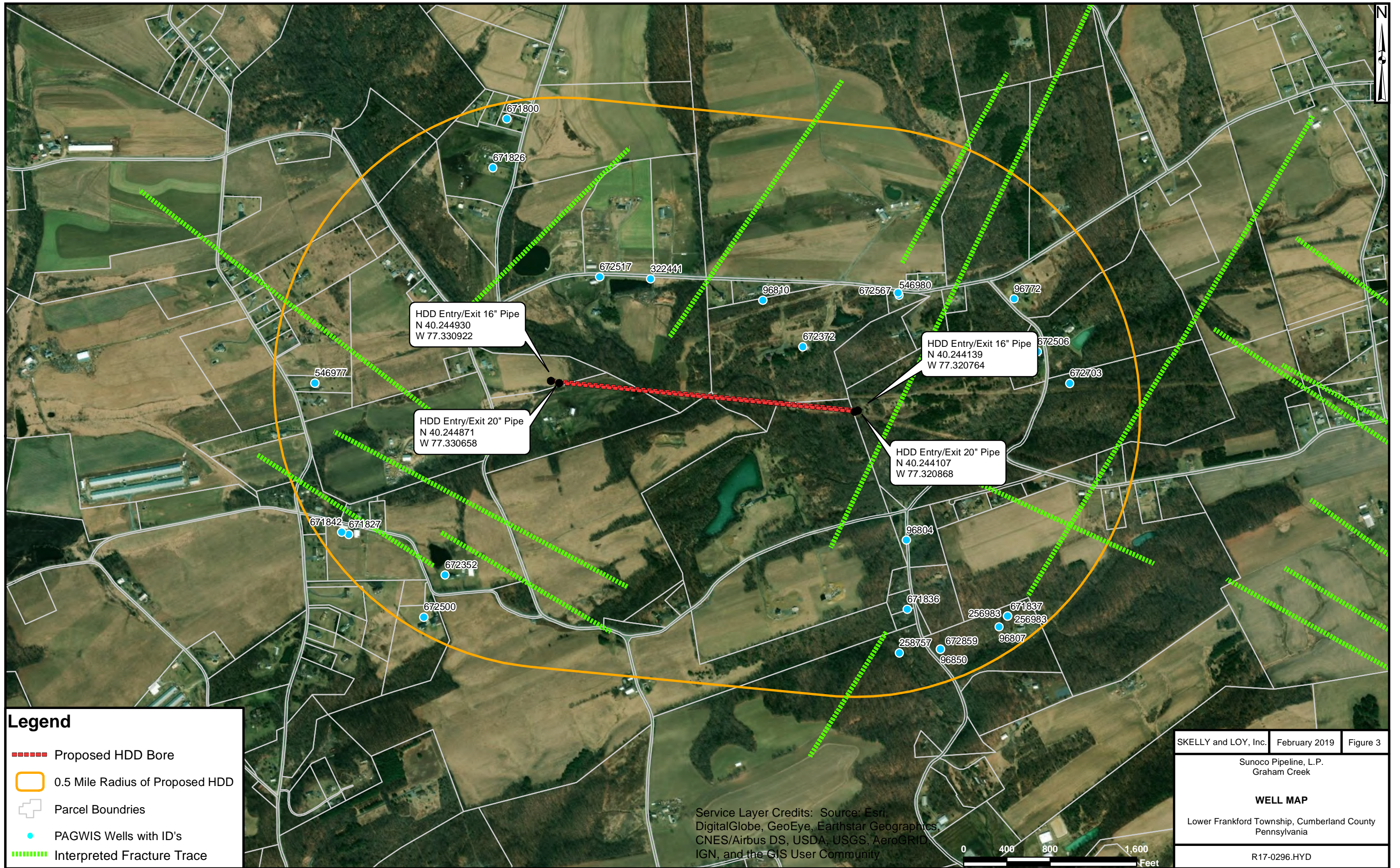


**Legend**

- - - - - Proposed HDD Bore
- Geology**
- Om Martinsburg Formation
- Omgs Graywacke and Shale of Martinsburg Formation
- - - - - Interpreted Fracture Trace
- ▲ Bedrock Outcrop

SKELLY and LOY, Inc.	February 2019	Figure 2
Sunoco Pipeline, L.P. Graham Creek		
<b>GEOLOGY MAP</b>		
Lower Frankford Township, Cumberland County Pennsylvania		
R17-0296.HYD		

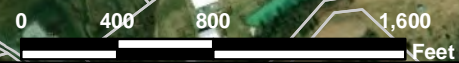
Service Layer Credits: © 2019 Microsoft Corporation © 2019 DigitalGlobe © CNES (2019) Distribution Airbus DS © 2019 HERE



**Legend**

- Proposed HDD Bore
- 0.5 Mile Radius of Proposed HDD
- Parcel Boundries
- PAGWIS Wells with ID's
- Interpreted Fracture Trace

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



SKELLY and LOY, Inc.	February 2019	Figure 3
Sunoco Pipeline, L.P. Graham Creek		
<b>WELL MAP</b>		
Lower Frankford Township, Cumberland County Pennsylvania		
R17-0296.HYD		

**ATTACHMENT 1**



United States  
Department of  
Agriculture

**NRCS**

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



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# How Soil Surveys Are Made

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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

## Custom Soil Resource Report

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

## Custom Soil Resource Report

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

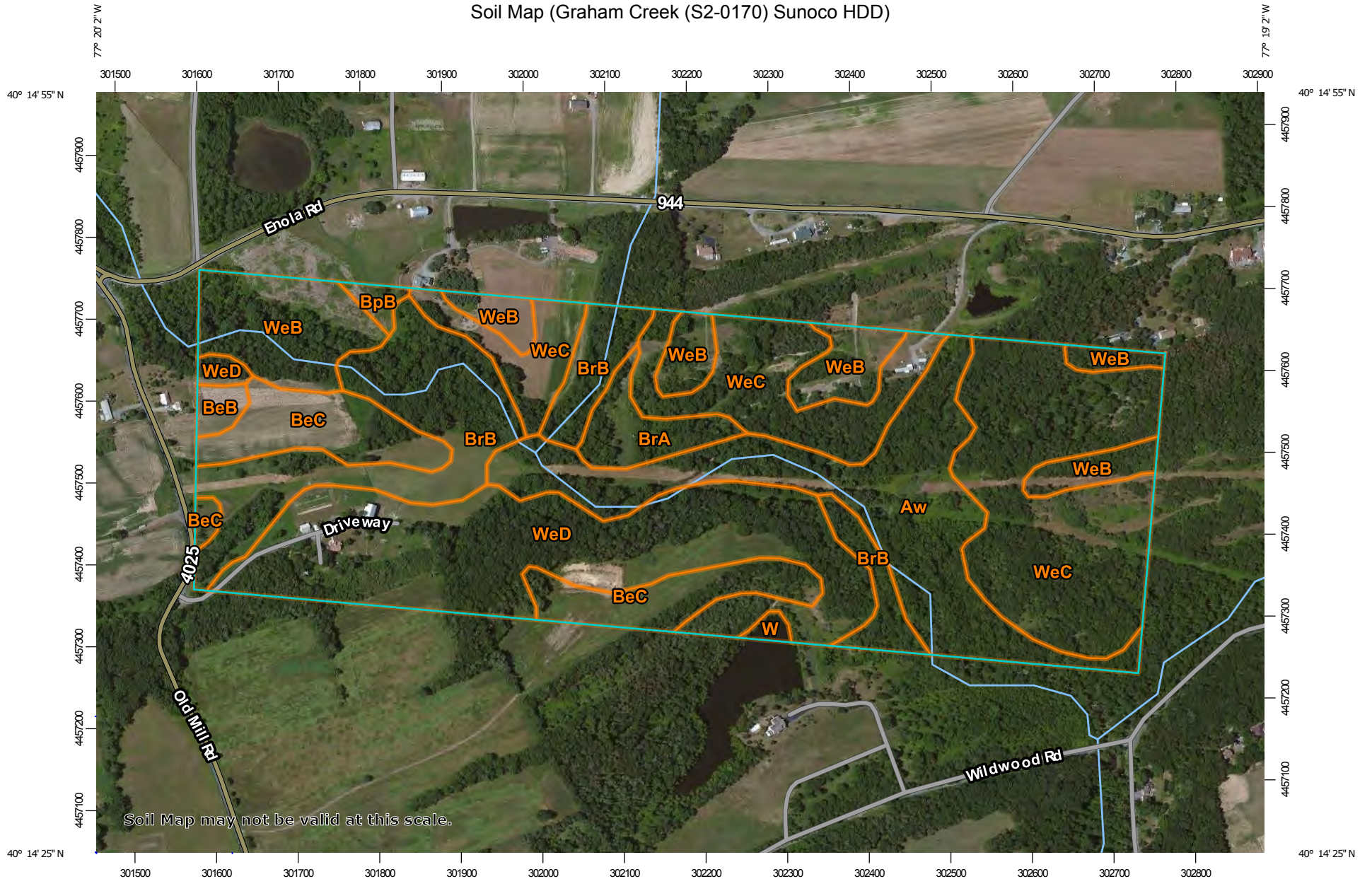
# Soil Map

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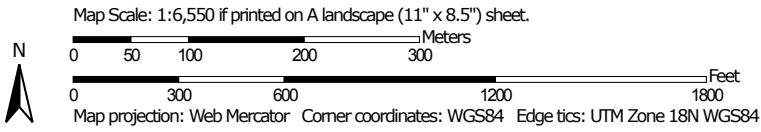
The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

# Custom Soil Resource Report





































## Soil Map (Graham Creek (S2-0170) Sunoco HDD)



Soil Map may not be valid at this scale.



### 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: Jun 18, 2010—Sep 25, 2010

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 (Graham Creek (S2-0170) Sunoco HDD)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Aw	Atkins silt loam	16.8	14.8%
BeB	Berks channery silt loam, 3 to 8 percent slopes	0.8	0.7%
BeC	Berks shaly silt loam, 8 to 15 percent slopes	9.7	8.5%
BpB	Blairton silt loam, 3 to 8 percent slopes	0.6	0.5%
BrA	Brinkerton silt loam, 0 to 3 percent slopes	2.9	2.6%
BrB	Brinkerton silt loam, 3 to 8 percent slopes	16.0	14.1%
W	Water	0.4	0.3%
WeB	Weikert very channery silt loam, 3 to 8 percent slopes	13.2	11.6%
WeC	Weikert very channery silt loam, 8 to 15 percent slopes	29.5	25.9%
WeD	Weikert very channery silt loam, 15 to 25 percent slopes	24.1	21.1%
<b>Totals for Area of Interest</b>		<b>114.0</b>	<b>100.0%</b>

## Map Unit Descriptions (Graham Creek (S2-0170) Sunoco HDD)

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

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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

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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

### Aw—Atkins silt loam

#### Map Unit Setting

*National map unit symbol:* r8tq  
*Elevation:* 200 to 3,000 feet  
*Mean annual precipitation:* 32 to 55 inches  
*Mean annual air temperature:* 46 to 59 degrees F  
*Frost-free period:* 120 to 214 days  
*Farmland classification:* Farmland of statewide importance

#### Map Unit Composition

*Atkins and similar soils:* 85 percent  
*Minor components:* 14 percent  
*Estimates are based on observations, descriptions, and transects of the mapunit.*

#### Description of Atkins

##### Setting

*Landform:* Flood plains  
*Landform position (two-dimensional):* Toeslope  
*Landform position (three-dimensional):* Base slope  
*Down-slope shape:* Linear  
*Across-slope shape:* Linear  
*Parent material:* Acid alluvium derived from sedimentary rock

##### Typical profile

*H1 - 0 to 10 inches:* silt loam  
*H2 - 10 to 30 inches:* silt loam  
*H3 - 30 to 60 inches:* gravelly silty clay loam

##### Properties and qualities

*Slope:* 0 to 3 percent  
*Depth to restrictive feature:* 60 to 99 inches to lithic bedrock  
*Natural drainage class:* Poorly drained  
*Runoff class:* Very high  
*Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to high  
(0.06 to 2.00 in/hr)  
*Depth to water table:* About 0 to 12 inches  
*Frequency of flooding:* Frequent  
*Frequency of ponding:* None  
*Available water storage in profile:* Moderate (about 8.9 inches)

##### Interpretive groups

*Land capability classification (irrigated):* None specified  
*Land capability classification (nonirrigated):* 3w  
*Hydrologic Soil Group:* B/D  
*Hydric soil rating:* Yes

#### Minor Components

##### Barbour

*Percent of map unit:* 6 percent  
*Hydric soil rating:* No

**Philo**

*Percent of map unit:* 6 percent  
*Hydric soil rating:* No

**Saprists**

*Percent of map unit:* 2 percent  
*Landform:* Depressions  
*Hydric soil rating:* Yes

**BeB—Berks channery silt loam, 3 to 8 percent slopes**

**Map Unit Setting**

*National map unit symbol:* 2sgb5  
*Elevation:* 320 to 3,570 feet  
*Mean annual precipitation:* 37 to 50 inches  
*Mean annual air temperature:* 47 to 56 degrees F  
*Frost-free period:* 148 to 192 days  
*Farmland classification:* Farmland of statewide importance

**Map Unit Composition**

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

**Description of Berks**

**Setting**

*Landform:* Ridges, mountain slopes  
*Landform position (two-dimensional):* Summit, shoulder, backslope  
*Landform position (three-dimensional):* Upper third of mountainflank, side slope  
*Down-slope shape:* Convex  
*Across-slope shape:* Convex, linear  
*Parent material:* Residuum weathered from shale and siltstone and/or fine grained sandstone

**Typical profile**

*Ap - 0 to 7 inches:* channery silt loam  
*Bw1 - 7 to 15 inches:* channery silt loam  
*Bw2 - 15 to 28 inches:* very channery silt loam  
*C - 28 to 36 inches:* extremely channery silt loam  
*R - 36 to 46 inches:* bedrock

**Properties and qualities**

*Slope:* 3 to 8 percent  
*Depth to restrictive feature:* 20 to 40 inches to lithic bedrock  
*Natural drainage class:* Well drained  
*Runoff class:* Medium  
*Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to high (0.06 to 5.95 in/hr)  
*Depth to water table:* More than 80 inches

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*Frequency of flooding:* None  
*Frequency of ponding:* None  
*Calcium carbonate, maximum in profile:* 1 percent  
*Gypsum, maximum in profile:* 1 percent  
*Salinity, maximum in profile:* Nonsaline (0.0 to 1.0 mmhos/cm)  
*Sodium adsorption ratio, maximum in profile:* 1.0  
*Available water storage in profile:* Very low (about 2.9 inches)

### Interpretive groups

*Land capability classification (irrigated):* None specified  
*Land capability classification (nonirrigated):* 2e  
*Hydrologic Soil Group:* B  
*Other vegetative classification:* Dry Uplands (DU2)  
*Hydric soil rating:* No

### Minor Components

#### Weikert

*Percent of map unit:* 10 percent  
*Landform:* Ridges  
*Landform position (two-dimensional):* Shoulder, backslope  
*Landform position (three-dimensional):* Side slope  
*Down-slope shape:* Linear  
*Across-slope shape:* Convex  
*Other vegetative classification:* Droughty Shales (SD2)  
*Hydric soil rating:* No

#### Brinkerton

*Percent of map unit:* 5 percent  
*Landform:* Ridges  
*Landform position (two-dimensional):* Footslope  
*Landform position (three-dimensional):* Base slope  
*Down-slope shape:* Concave, linear  
*Across-slope shape:* Linear, concave  
*Hydric soil rating:* Yes

## BeC—Berks shaly silt loam, 8 to 15 percent slopes

### Map Unit Setting

*National map unit symbol:* r8ty  
*Elevation:* 300 to 3,000 feet  
*Mean annual precipitation:* 30 to 65 inches  
*Mean annual air temperature:* 46 to 59 degrees F  
*Frost-free period:* 120 to 214 days  
*Farmland classification:* Farmland of statewide importance

### Map Unit Composition

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

## Description of Berks

### Setting

*Landform:* Hillslopes  
*Landform position (two-dimensional):* Shoulder  
*Landform position (three-dimensional):* Side slope  
*Down-slope shape:* Linear, convex  
*Across-slope shape:* Convex, linear  
*Parent material:* Acid silty residuum weathered from shale and siltstone

### Typical profile

*H1 - 0 to 7 inches:* channery silt loam  
*H2 - 7 to 29 inches:* very channery silt loam  
*H3 - 29 to 34 inches:* extremely channery silt loam  
*H4 - 34 to 38 inches:* bedrock

### Properties and qualities

*Slope:* 8 to 15 percent  
*Depth to restrictive feature:* 20 to 40 inches to lithic bedrock  
*Natural drainage class:* Well drained  
*Runoff class:* Low  
*Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 6.00 in/hr)  
*Depth to water table:* More than 80 inches  
*Frequency of flooding:* None  
*Frequency of ponding:* None  
*Available water storage in profile:* Very low (about 2.6 inches)

### Interpretive groups

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

## Minor Components

### Bedington

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

### Weikert

*Percent of map unit:* 4 percent  
*Hydric soil rating:* No

### Blairton

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

### Ernest

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

## **BpB—Blairton silt loam, 3 to 8 percent slopes**

### **Map Unit Setting**

*National map unit symbol:* r8v3

*Elevation:* 300 to 1,300 feet

*Mean annual precipitation:* 35 to 50 inches

*Mean annual air temperature:* 46 to 57 degrees F

*Frost-free period:* 120 to 214 days

*Farmland classification:* Farmland of statewide importance

### **Map Unit Composition**

*Blairton and similar soils:* 90 percent

*Minor components:* 5 percent

*Estimates are based on observations, descriptions, and transects of the mapunit.*

### **Description of Blairton**

#### **Setting**

*Landform:* Depressions

*Landform position (two-dimensional):* Summit

*Landform position (three-dimensional):* Head slope

*Down-slope shape:* Concave

*Across-slope shape:* Concave

*Parent material:* Local silty colluvium derived from shale and siltstone over acid silty residuum weathered from shale and siltstone

#### **Typical profile**

*H1 - 0 to 9 inches:* silt loam

*H2 - 9 to 22 inches:* channery silty clay loam

*H3 - 22 to 26 inches:* very channery loam

*H4 - 26 to 30 inches:* bedrock

#### **Properties and qualities**

*Slope:* 3 to 8 percent

*Depth to restrictive feature:* 20 to 40 inches to lithic bedrock

*Natural drainage class:* Somewhat poorly drained

*Runoff class:* High

*Capacity of the most limiting layer to transmit water (Ksat):* Moderately high (0.20 to 0.60 in/hr)

*Depth to water table:* About 6 to 36 inches

*Frequency of flooding:* None

*Frequency of ponding:* None

*Available water storage in profile:* Low (about 3.2 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**

**Brinkerton**

*Percent of map unit:* 5 percent  
*Landform:* Hills  
*Landform position (two-dimensional):* Footslope  
*Landform position (three-dimensional):* Base slope  
*Down-slope shape:* Concave  
*Across-slope shape:* Concave  
*Hydric soil rating:* Yes

**BrA—Brinkerton silt loam, 0 to 3 percent slopes**

**Map Unit Setting**

*National map unit symbol:* r8v4  
*Elevation:* 300 to 3,000 feet  
*Mean annual precipitation:* 35 to 55 inches  
*Mean annual air temperature:* 46 to 59 degrees F  
*Frost-free period:* 120 to 217 days  
*Farmland classification:* Not prime farmland

**Map Unit Composition**

*Brinkerton and similar soils:* 80 percent  
*Minor components:* 20 percent  
*Estimates are based on observations, descriptions, and transects of the mapunit.*

**Description of Brinkerton**

**Setting**

*Landform:* Depressions  
*Landform position (two-dimensional):* Toeslope  
*Landform position (three-dimensional):* Base slope  
*Down-slope shape:* Concave  
*Across-slope shape:* Concave  
*Parent material:* Local fine-silty colluvium derived from sedimentary rock

**Typical profile**

*H1 - 0 to 9 inches:* silt loam  
*H2 - 9 to 18 inches:* silty clay loam  
*H3 - 18 to 46 inches:* silty clay loam  
*H4 - 46 to 65 inches:* channery silt loam

**Properties and qualities**

*Slope:* 0 to 3 percent  
*Depth to restrictive feature:* 15 to 34 inches to fragipan  
*Natural drainage class:* 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 0 to 6 inches

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*Frequency of flooding:* None  
*Frequency of ponding:* None  
*Available water storage in profile:* Low (about 3.4 inches)

### Interpretive groups

*Land capability classification (irrigated):* None specified  
*Land capability classification (nonirrigated):* 4w  
*Hydrologic Soil Group:* D  
*Hydric soil rating:* Yes

### Minor Components

#### Atkins

*Percent of map unit:* 6 percent  
*Landform:* Flood plains  
*Landform position (three-dimensional):* Base slope  
*Down-slope shape:* Concave  
*Across-slope shape:* Concave  
*Hydric soil rating:* Yes

#### Laidig

*Percent of map unit:* 5 percent  
*Landform:* Mountains  
*Landform position (two-dimensional):* Footslope  
*Landform position (three-dimensional):* Lower third of mountainflank  
*Down-slope shape:* Concave  
*Across-slope shape:* Concave  
*Hydric soil rating:* No

#### Philo

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

#### Berks

*Percent of map unit:* 4 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

## BrB—Brinkerton silt loam, 3 to 8 percent slopes

### Map Unit Setting

*National map unit symbol:* r8v5  
*Elevation:* 300 to 3,000 feet  
*Mean annual precipitation:* 30 to 65 inches  
*Mean annual air temperature:* 46 to 59 degrees F  
*Frost-free period:* 120 to 217 days  
*Farmland classification:* Not prime farmland

**Map Unit Composition**

*Brinkerton and similar soils: 75 percent*

*Minor components: 25 percent*

*Estimates are based on observations, descriptions, and transects of the mapunit.*

**Description of Brinkerton**

**Setting**

*Landform: Depressions*

*Landform position (two-dimensional): Toeslope*

*Landform position (three-dimensional): Base slope*

*Down-slope shape: Concave*

*Across-slope shape: Concave*

*Parent material: Local fine-silty colluvium derived from sedimentary rock*

**Typical profile**

*H1 - 0 to 9 inches: silt loam*

*H2 - 9 to 18 inches: silty clay loam*

*H3 - 18 to 46 inches: silty clay loam*

*H4 - 46 to 65 inches: channery silt loam*

**Properties and qualities**

*Slope: 3 to 8 percent*

*Depth to restrictive feature: 15 to 34 inches to fragipan*

*Natural drainage class: 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 0 to 6 inches*

*Frequency of flooding: None*

*Frequency of ponding: None*

*Available water storage in profile: Low (about 3.4 inches)*

**Interpretive groups**

*Land capability classification (irrigated): None specified*

*Land capability classification (nonirrigated): 4w*

*Hydrologic Soil Group: D*

*Hydric soil rating: Yes*

**Minor Components**

**Ernest**

*Percent of map unit: 10 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*

**Laidig**

*Percent of map unit: 5 percent*

*Landform: Mountains*

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*Landform position (two-dimensional):* Foothlope

*Landform position (three-dimensional):* Lower third of mountainflank

*Down-slope shape:* Concave

*Across-slope shape:* Concave

*Hydric soil rating:* No

### **Atkins**

*Percent of map unit:* 3 percent

*Landform:* Flood plains

*Down-slope shape:* Concave

*Across-slope shape:* Concave

*Hydric soil rating:* Yes

### **Philo**

*Percent of map unit:* 2 percent

*Hydric soil rating:* No

## **W—Water**

### **Map Unit Setting**

*National map unit symbol:* r8yh

*Mean annual precipitation:* 36 to 50 inches

*Mean annual air temperature:* 46 to 59 degrees F

*Frost-free period:* 120 to 214 days

*Farmland classification:* Not prime farmland

### **Map Unit Composition**

*Water:* 100 percent

*Estimates are based on observations, descriptions, and transects of the mapunit.*

### **Description of Water**

#### **Setting**

*Parent material:* Rivers streams ponds

#### **Properties and qualities**

*Runoff class:* Negligible

*Frequency of ponding:* Frequent

## **WeB—Weikert very channery silt loam, 3 to 8 percent slopes**

### **Map Unit Setting**

*National map unit symbol:* 2v4vw

*Elevation:* 370 to 1,530 feet

*Mean annual precipitation:* 37 to 50 inches

*Mean annual air temperature:* 47 to 56 degrees F

*Frost-free period:* 148 to 192 days

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*Farmland classification:* Farmland of statewide importance

### Map Unit Composition

*Weikert and similar soils:* 85 percent

*Minor components:* 15 percent

*Estimates are based on observations, descriptions, and transects of the mapunit.*

### Description of Weikert

#### Setting

*Landform:* Ridges

*Landform position (two-dimensional):* Shoulder, backslope

*Landform position (three-dimensional):* Nose slope

*Down-slope shape:* Convex

*Across-slope shape:* Convex

*Parent material:* Gray and brown acid residuum weathered from shale and siltstone and/or fine grained sandstone

#### Typical profile

*A - 0 to 7 inches:* very channery silt loam

*Bw - 7 to 14 inches:* very channery silt loam

*C - 14 to 18 inches:* extremely channery silt loam

*R - 18 to 28 inches:* bedrock

#### Properties and qualities

*Slope:* 3 to 8 percent

*Depth to restrictive feature:* 10 to 20 inches to lithic bedrock

*Natural drainage class:* Somewhat excessively drained

*Runoff class:* Low

*Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to high  
(0.06 to 5.95 in/hr)

*Depth to water table:* More than 80 inches

*Frequency of flooding:* None

*Frequency of ponding:* None

*Salinity, maximum in profile:* Nonsaline (0.0 to 1.0 mmhos/cm)

*Available water storage in profile:* Very low (about 1.5 inches)

#### Interpretive groups

*Land capability classification (irrigated):* None specified

*Land capability classification (nonirrigated):* 4s

*Hydrologic Soil Group:* D

*Other vegetative classification:* Droughty Shales (SD2)

*Hydric soil rating:* No

### Minor Components

#### Berks

*Percent of map unit:* 6 percent

*Landform:* Ridges

*Landform position (two-dimensional):* Summit, shoulder, backslope

*Landform position (three-dimensional):* Side slope

*Down-slope shape:* Convex

*Across-slope shape:* Convex, linear

*Hydric soil rating:* No

#### Blairton

*Percent of map unit:* 3 percent

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*Landform:* Hillslopes  
*Landform position (two-dimensional):* Backslope  
*Landform position (three-dimensional):* Head slope  
*Down-slope shape:* Linear, concave  
*Across-slope shape:* Linear, concave  
*Hydric soil rating:* No

### **Brinkerton**

*Percent of map unit:* 3 percent  
*Landform:* Hillslopes  
*Landform position (two-dimensional):* Footslope  
*Landform position (three-dimensional):* Base slope  
*Down-slope shape:* Concave, linear  
*Across-slope shape:* Concave  
*Hydric soil rating:* Yes

### **Ernest**

*Percent of map unit:* 3 percent  
*Landform:* Hillslopes  
*Landform position (two-dimensional):* Footslope  
*Landform position (three-dimensional):* Base slope, head slope  
*Down-slope shape:* Concave  
*Across-slope shape:* Linear  
*Hydric soil rating:* No

## **WeC—Weikert very channery silt loam, 8 to 15 percent slopes**

### **Map Unit Setting**

*National map unit symbol:* 2v4vx  
*Elevation:* 370 to 1,530 feet  
*Mean annual precipitation:* 37 to 50 inches  
*Mean annual air temperature:* 47 to 56 degrees F  
*Frost-free period:* 148 to 192 days  
*Farmland classification:* Not prime farmland

### **Map Unit Composition**

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

### **Description of Weikert**

#### **Setting**

*Landform:* Ridges  
*Landform position (two-dimensional):* Shoulder, backslope  
*Landform position (three-dimensional):* Nose slope  
*Down-slope shape:* Convex  
*Across-slope shape:* Convex  
*Parent material:* Gray and brown acid residuum weathered from shale and siltstone and/or fine grained sandstone

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### Typical profile

*A - 0 to 7 inches:* very channery silt loam  
*Bw - 7 to 14 inches:* very channery silt loam  
*C - 14 to 18 inches:* extremely channery silt loam  
*R - 18 to 28 inches:* bedrock

### Properties and qualities

*Slope:* 8 to 15 percent  
*Depth to restrictive feature:* 10 to 20 inches to lithic bedrock  
*Natural drainage class:* Somewhat excessively drained  
*Runoff class:* Low  
*Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to high  
(0.06 to 5.95 in/hr)  
*Depth to water table:* More than 80 inches  
*Frequency of flooding:* None  
*Frequency of ponding:* None  
*Salinity, maximum in profile:* Nonsaline (0.0 to 1.0 mmhos/cm)  
*Available water storage in profile:* Very low (about 1.5 inches)

### Interpretive groups

*Land capability classification (irrigated):* None specified  
*Land capability classification (nonirrigated):* 4e  
*Hydrologic Soil Group:* D  
*Hydric soil rating:* No

### Minor Components

#### Berks

*Percent of map unit:* 7 percent  
*Landform:* Ridges  
*Landform position (two-dimensional):* Summit, shoulder, backslope  
*Landform position (three-dimensional):* Side slope  
*Down-slope shape:* Convex  
*Across-slope shape:* Convex, linear  
*Hydric soil rating:* No

#### Ernest

*Percent of map unit:* 5 percent  
*Landform:* Hillslopes  
*Landform position (two-dimensional):* Footslope  
*Landform position (three-dimensional):* Base slope, head slope  
*Down-slope shape:* Concave  
*Across-slope shape:* Linear  
*Hydric soil rating:* No

#### Brinkerton

*Percent of map unit:* 3 percent  
*Landform:* Hillslopes  
*Landform position (two-dimensional):* Footslope  
*Landform position (three-dimensional):* Base slope  
*Down-slope shape:* Concave, linear  
*Across-slope shape:* Concave  
*Hydric soil rating:* Yes

## **WeD—Weikert very channery silt loam, 15 to 25 percent slopes**

### **Map Unit Setting**

*National map unit symbol:* 2v4vy  
*Elevation:* 320 to 1,320 feet  
*Mean annual precipitation:* 37 to 50 inches  
*Mean annual air temperature:* 47 to 56 degrees F  
*Frost-free period:* 148 to 192 days  
*Farmland classification:* Not prime farmland

### **Map Unit Composition**

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

### **Description of Weikert**

#### **Setting**

*Landform:* Ridges  
*Landform position (two-dimensional):* Shoulder, backslope  
*Landform position (three-dimensional):* Side slope  
*Down-slope shape:* Convex, linear  
*Across-slope shape:* Convex, linear  
*Parent material:* Gray and brown acid residuum weathered from shale and siltstone and/or fine grained sandstone

#### **Typical profile**

*A - 0 to 2 inches:* very channery silt loam  
*Bw - 2 to 15 inches:* very channery silt loam  
*C - 15 to 18 inches:* extremely channery silt loam  
*R - 18 to 28 inches:* bedrock

#### **Properties and qualities**

*Slope:* 15 to 25 percent  
*Depth to restrictive feature:* 10 to 20 inches to lithic bedrock  
*Natural drainage class:* Well drained  
*Runoff class:* High  
*Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 5.95 in/hr)  
*Depth to water table:* More than 80 inches  
*Frequency of flooding:* None  
*Frequency of ponding:* None  
*Salinity, maximum in profile:* Nonsaline (0.0 to 1.0 mmhos/cm)  
*Available water storage in profile:* Very low (about 1.8 inches)

#### **Interpretive groups**

*Land capability classification (irrigated):* None specified  
*Land capability classification (nonirrigated):* 6e  
*Hydrologic Soil Group:* D  
*Hydric soil rating:* No

**Minor Components**

**Berks**

*Percent of map unit:* 6 percent

*Landform:* Ridges

*Landform position (two-dimensional):* Summit, shoulder, backslope

*Landform position (three-dimensional):* Side slope

*Down-slope shape:* Convex

*Across-slope shape:* Convex, linear

*Hydric soil rating:* No

**Blairton**

*Percent of map unit:* 6 percent

*Landform:* Hillslopes

*Landform position (two-dimensional):* Backslope

*Landform position (three-dimensional):* Head slope

*Down-slope shape:* Linear, concave

*Across-slope shape:* Linear, concave

*Hydric soil rating:* No

**Ernest**

*Percent of map unit:* 3 percent

*Landform:* Hillslopes

*Landform position (two-dimensional):* Footslope

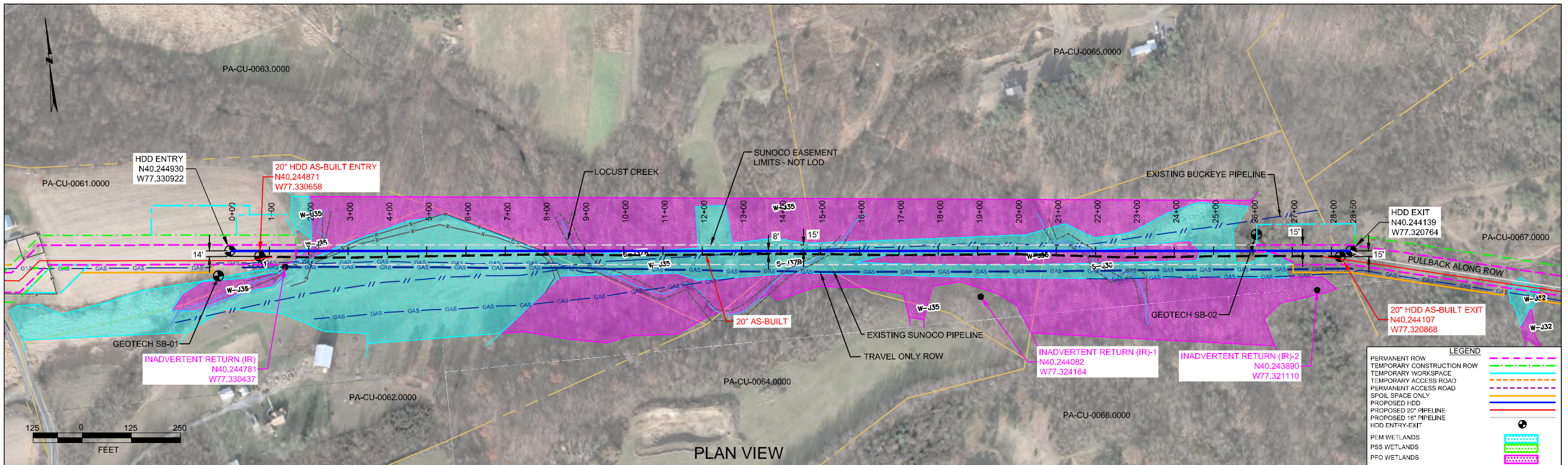
*Landform position (three-dimensional):* Base slope, head slope

*Down-slope shape:* Concave

*Across-slope shape:* Linear

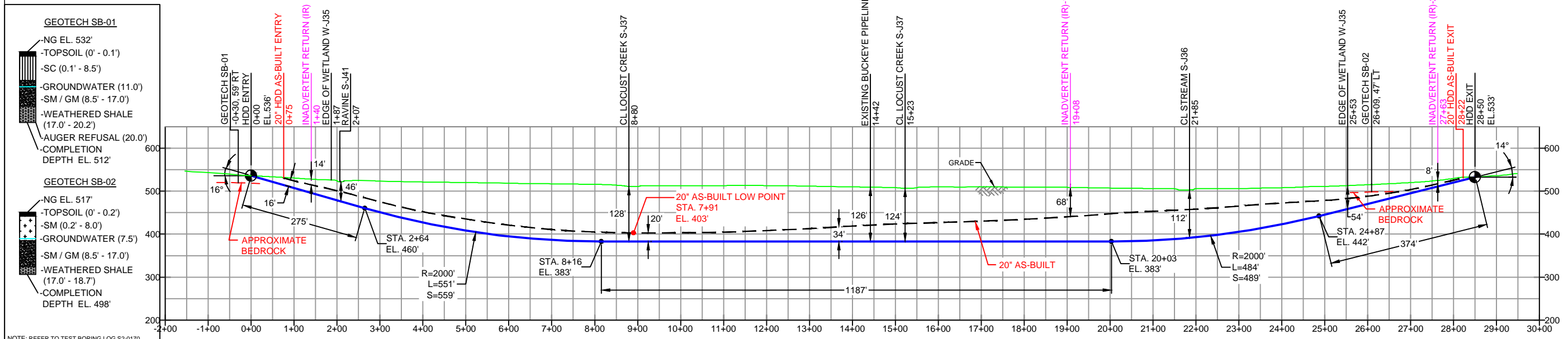
*Hydric soil rating:* No

**ATTACHMENT 2**



PLAN VIEW  
PROFILE VIEW

CUMBERLAND COUNTY, PENNSYLVANIA, LOWER FRANKFORD TOWNSHIP  
S2-0170-16



NOTE: REFER TO TEST BORING LOG S2-0170 FOR COMPLETE SOIL MATERIAL DESCRIPTION

DESIGN AND CONSTRUCTION:

- CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
- THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
- DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
- CROSSING PIPE SPECIFICATION:  
HDD HORZ. LENGTH (L<sub>H</sub>): 2850'  
HDD PIPE LENGTH (S<sub>H</sub>): 2884'  
16" x 0.438" W.T., X-70, API 5L, PSL2, ERW, BFW  
COATINGS: 14-16 MILS OF 3M SCOTCHKOTE TM 6233 FBE WITH 40 MILS MIN. DFT (POWERCRETE R95 OR ENGINEER APPROVED EQUAL)
- INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50).
- INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
- PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
- CARRIER PIPE NOT ENCASED.
- PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
- CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
- SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
- SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
- SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

NOTES

- ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
- STATIONING IS BASED ON HORIZONTAL DISTANCES.
- 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.
- CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.
- SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REF. DRAWING		REVISIONS	
ES-4.24	TO ES-4.26	NO.	DESCRIPTION
SHEET 16	SHEET 17	EP3	DESIGN CHANGE - INCREASED DEPTH OF DRILL
		EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16
		EP1	REVISED PER PADEP COMMENTS
		EP	
		A	ISSUED FOR BID

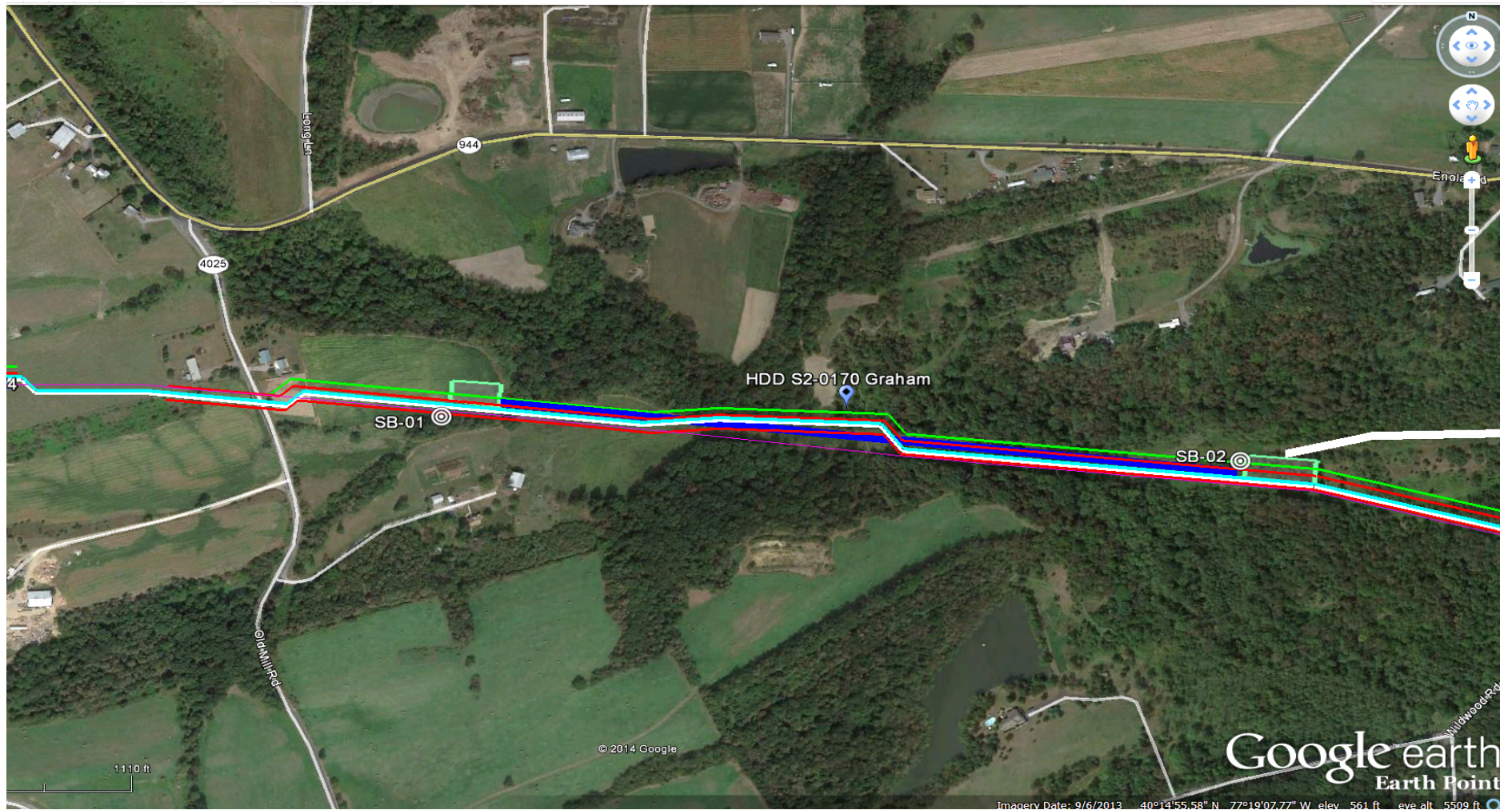
**Sunoco Logistics Partners L.P.**

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

**SUNOCO PIPELINE, L.P.**

HORIZONTAL DIRECTIONAL DRILL  
GRAHAM CREEK  
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250' DWG. NO. PA-CU-0062.0000-WX-16



**LEGEND:**

⊙ Geotechnical Soil Boring (SB) Locations



GEOTECHNICAL BORING LOCATIONS

HDD S2-0170

CUMBERLAND COUNTY, LOWER FRANKFORD TOWNSHIP, PA

SUNOCO PENNSYLVANIA PIPELINE PROJECT





**GEOTECHNICAL LABORATORY TESTING SUMMARY  
SUNOCO PENNSYLVANIA PIPELINE PROJECT  
HDD S2-0170**

HDD No.	Test Boring No.	Sample No.	Depth of Sample (ft.)		Water Content, % (ASTM D2216)	Percent Silts/Clays, % (ASTM D1140)	Atterburg Limits (ASTM D4318)			USCS Classif. (ASTM D2487)
			From	To			Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	
S2-0170	SB-01	1	3.0	5.0	20.0	39.0	33	22	11	SC
		2	8.0	9.4	5.9	15.4	-	-	-	-
		3	13.0	15.0	7.6	8.1	-	-	-	-
		4	18.0	18.3	6.3	9.6	-	-	-	-
		5	20.0	20.2	8.2	18.4	-	-	-	-
	SB-02	1	3.0	4.3	8.6	26.4	-	-	-	-
		2	8.0	9.4	12.8	23.7	-	-	-	-
		3	13.0	14.3	11.6	19.9	-	-	-	-
		4	18.0	18.4	4.6	11.9	-	-	-	-

Notes:

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

**REGIONAL GEOLOGY SUMMARY  
SUNOCO PENNSYLVANIA PIPELINE PROJECT  
HDD S2-0170**

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
S2-0170	Graham	SB-01	<b>Martinsburg Fm</b> - buff-weathering, dark-gray to purple shale and slate with thin interbeds of siltstone, metabentonite, and fine-grained sandstone.	Gently sloping, valley	Martinsburg Fm	Shale and slate with interbedded siltstone		12-18	
		SB-02							

*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)

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

### 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)

### Relative Proportions

<u>Description Term</u>	<u>Percent</u>
Trace	1 - 10
Little	11 - 20
Some	21 - 35
And	36 - 50

## COHESIVE SOILS

(Silt, Clay & Combinations)

<u>Consistency</u>	<u>N (blows)*</u>
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

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

## ROCK

(Rock Cores)

<u>Rock Quality Designation (RQD), %</u>	<u>Rock Quality Description</u>
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)]**

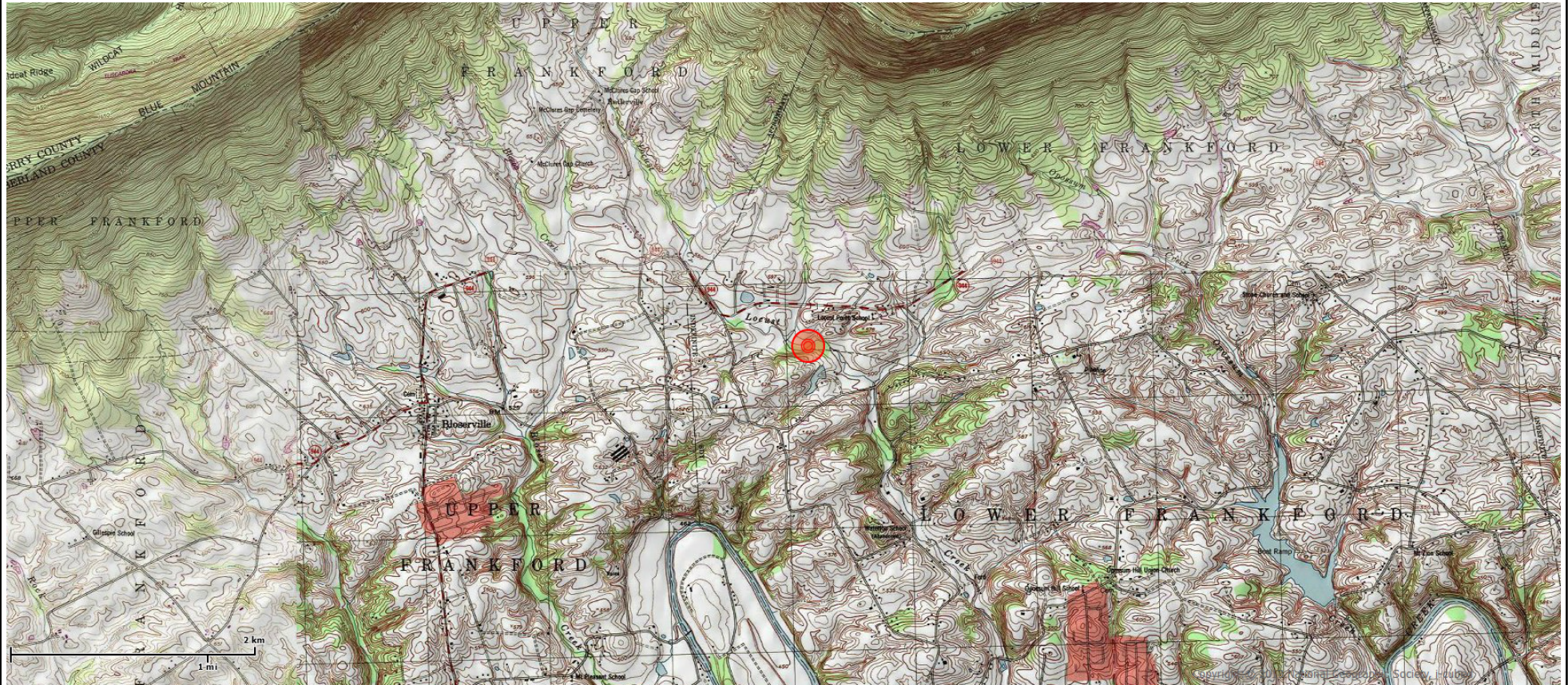
Major Divisions		Group Symbols	Typical Descriptions	Laboratory Classifications				
Coarse Grained Soils (More than half of material is larger than No. 200 sieve)	Gravels (More than half of coarse fraction is larger than No. 4 sieve size)	Clean gravel (Little or no fines)	GW Well-graded gravels, gravel-sand 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 <sup>(1)</sup>	$C_u = \frac{D_{60}}{D_{10}}$ 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, gravelly 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			
						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 $\pm 2$ percent.		
		Fine-grained soils (More than half of material is smaller than No. 200 sieve)	Silt 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								
Silt 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							

(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.

**Figure 1: Site Vicinity Map**

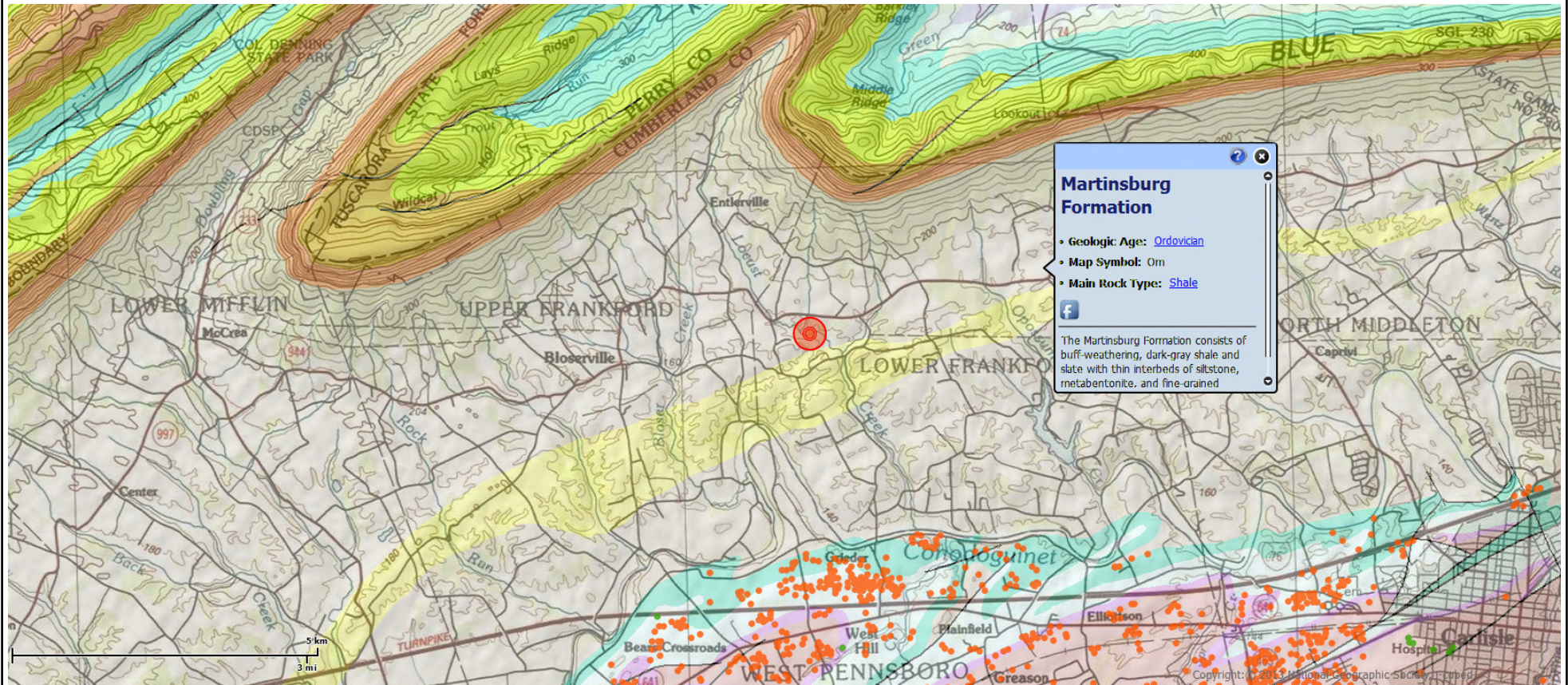
Make online reservations at  
[www.visitPAparks.com](http://www.visitPAparks.com)  
or call toll-free 888-PA-PARKS

Visit us at <http://www.dcnr.state.pa.us>



**Figure 3: Site Geology Map**

Visit us at <http://www.dcnr.state.pa.us>



DATE STARTED: 11/10/17  
 DATE COMPLETED: 11/14/17  
 COMPLETION DEPTH: 155.0 ft  
 BENCHMARK: N/A  
 ELEVATION: N/A  
 LATITUDE: n/a°  
 LONGITUDE: n/a°  
 STATION: N/A    OFFSET: N/A  
 REMARKS:

DRILL COMPANY: Eichelbergers  
 DRILLER: L. Trimble    LOGGED BY: Lehman/Ebersole  
 DRILL RIG: Diedrich D-50  
 DRILLING METHOD: Hollow Stem Auger  
 SAMPLING METHOD: 2-in SS2.000-in Core  
 HAMMER TYPE: Automatic  
 EFFICIENCY: N/A  
 REVIEWED BY: F. Hoffman

# BORING B-1

<b>Water</b>	▽ Pre-Core (11/13/17)	Not Enc.
	▼ 11/14/17 @ 7:30 a.m.	19.6 feet
	▼ 11/14/17 @ 2:15 p.m.	18.2 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 ⊕	STRENGTH, tsf ▲ Qu    * Qp	Additional Remarks
0				S-1	24	<b>RESIDUUM</b> -Very Stiff, Light gray-brown, Gravelly SILT with Sand, moist	ML	5-10-15-25 N=25	14	⊙		
5				S-2	24	<b>RESIDUUM</b> -Medium Dense, Light gray-brown, Clayey SAND, trace Gravel, moist	SC	6-13-15-20 N=28	14	⊙ ⊠ ⊕		LL = 31 PL = 22 Fines=42.1%
						Auger refusal encountered at approximately 6 feet						4 min.
				R-1	0	<b>Completely Weathered Carbonaceous SHALE</b> -No recovery from rock coring operations within this stratum		RQD=0 Rec=0%				4 min.
				R-2	24	<b>Carbonaceous SHALE</b> -Light gray-brown to dark gray-brown, Weathered to Highly Weathered, very broken to slightly broken, moderately hard, laminated to thinly bedded, sheer dip, bedding joint, narrowly to medium spaced discontinuity, shallow to sheer dip, calcite veins		RQD=0 Rec=100%				4 min.
				R-3	60			RQD=0 Rec=100%				4 min.
				R-4	53	<b>Carbonaceous SHALE</b> -Gray to dark gray, Weathered, very broken to massive, moderately hard, laminated to thinly bedded, sheer dip, bedding joint, narrowly to medium spaced discontinuity, shallow to sheer dip, calcite veins		RQD=10 Rec=88%				4 min.
				R-5	60	Weathered/Highly Weathered layer @ 25 feet (~ 2-1/2 inches thick)		RQD=10 Rec=100%				4 min.
				R-6	42			RQD=0				4 min.

Continued Next Page



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

PROJECT NO.: 04911514  
 PROJECT: Energy Transfer HDD (DPS)  
 LOCATION: Graham Creek (PPP4)  
 Cumberland Co., PA

PA-CU-0062.0000-WX-16/DPS PO# 20171108

**DATE STARTED:** 11/10/17 **DRILL COMPANY:** Eichelbergers  
**DATE COMPLETED:** 11/14/17 **DRILLER:** L. Trimble **LOGGED BY:** Lehman/Ebersole  
**COMPLETION DEPTH:** 155.0 ft **DRILL RIG:** Diedrich D-50  
**BENCHMARK:** N/A **DRILLING METHOD:** Hollow Stem Auger  
**ELEVATION:** N/A **SAMPLING METHOD:** 2-in SS2.000-in Core  
**LATITUDE:** n/a° **HAMMER TYPE:** Automatic  
**LONGITUDE:** n/a° **EFFICIENCY:** N/A  
**STATION:** N/A **OFFSET:** N/A **REVIEWED BY:** F. Hoffman  
**REMARKS:**

# BORING B-1

**Water**  Pre-Core (11/13/17) Not Enc.  
 11/14/17 @ 7:30 a.m. 19.6 feet  
 11/14/17 @ 2:15 p.m. 18.2 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, %	STRENGTH, tsf	Additional Remarks
30						<b>Carbonaceous SHALE</b> -Gray to dark gray, Weathered, very broken to massive, moderately hard, laminated to thinly bedded, sheer dip, bedding joint, narrowly to medium spaced discontinuity, shallow to sheer dip, calcite veins		Rec=100%			3 min.
				R-7	41			RQD=0 Rec=68%			3 min. 2 min.
						Highly Weathered layer @ 36 feet (~ 6 inches thick)					4 min. 5 min.
				R-8	54			RQD=22 Rec=90%			5 min. 6 min. 5 min.
						Weathered/broken layer @ 40.5 feet (~ 8 inches thick)					>> 5 min. Q <sub>u</sub> = 86.0 tsf
				R-9	58	<b>Carbonaceous SHALE</b> -Gray to dark gray, Weathered to Slightly Weathered, very broken to massive, moderately hard, laminated to thinly bedded, sheer dip, bedding joint, narrowly to medium spaced discontinuity, shallow to sheer dip, calcite veins		RQD=44 Rec=96%			5 min. 6 min.
						Weathered/Highly Weathered layer @ 43.2 feet (~ 6-1/4 inches thick)					3 min. 3 min.
						Weathered/Highly Weathered layer @ 46.5 feet (~ 7-1/2 inches thick)					>> 3 min. Q <sub>u</sub> = 142.7 tsf
				R-10	50	Weathered/Highly Weathered layer from 48 to 51.5 feet.		RQD=18 Rec=84%			3 min. 4 min.
						Weathered/broken layer @ 53 feet (~ 3-1/4 inches thick)					5 min. 5 min.
				R-11	60			RQD=38 Rec=100%			6 min. 6 min.
						Broken/very broken layer @ 56.5 feet (~ 3-1/4 inches thick)					5 min.
						Weathered/Highly Weathered layer @ 57.6 feet (~ 13-1/2 inches thick)					4 min.
				R-12	60			RQD=40 Rec=100%			3 min. 4 min.

Continued Next Page



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

**PROJECT NO.:** 04911514  
**PROJECT:** Energy Transfer HDD (DPS)  
**LOCATION:** Graham Creek (PPP4)  
 Cumberland Co., PA

PA-CU-0062.0000-WX-16/DPS PO# 20171108

**DATE STARTED:** 11/10/17 **DRILL COMPANY:** Eichelbergers  
**DATE COMPLETED:** 11/14/17 **DRILLER:** L. Trimble **LOGGED BY:** Eshman/Ebersole  
**COMPLETION DEPTH:** 155.0 ft **DRILL RIG:** Diedrich D-50  
**BENCHMARK:** N/A **DRILLING METHOD:** Hollow Stem Auger  
**ELEVATION:** N/A **SAMPLING METHOD:** 2-in SS2.000-in Core  
**LATITUDE:** n/a° **HAMMER TYPE:** Automatic  
**LONGITUDE:** n/a° **EFFICIENCY:** N/A  
**STATION:** N/A **OFFSET:** N/A **REVIEWED BY:** F. Hoffman  
**REMARKS:**

# BORING B-1

**Water**  
 ▽ Pre-Core (11/13/17) Not Enc.  
 ▼ 11/14/17 @ 7:30 a.m. 19.6 feet  
 ▼ 11/14/17 @ 2:15 p.m. 18.2 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, %	STRENGTH, tsf	Additional Remarks
60						Weathered/Highly Weathered layer @ 60.1 feet (~ 4-1/4 inches thick)					4 min. >> $Q_u = 119.2$ tsf
						Weathered/broken layer @ 61.5 feet (~ 14-1/2 inches thick)					4 min.
				R-13	60	<b>Carbonaceous SHALE</b> -Gray to dark gray, Slightly Weathered, broken to massive, moderately hard, laminated to thinly bedded, shear dip, bedding joint, narrowly to medium spaced discontinuity, shallow to shear dip, calcite veins		RQD=54 Rec=100%			2 min.
											3 min.
											3 min.
				R-14	56			RQD=66 Rec=94%			3 min.
						Weathered/Highly Weathered layer from 70.3 to 71.5 feet.					3 min.
											3 min.
				R-15	60			RQD=42 Rec=100%			3 min.
						Weathered layer @ 75.6 feet (~ 4-3/4 inches thick)					4 min.
											4 min.
											1 min.
											1 min.
				R-16	58			RQD=60 Rec=96%			2 min.
											2 min.
											2 min.
											2 min.
											2 min.
				R-17	60	Broken layer @ 82.4 feet (~ 2-1/4 inches thick)		RQD=74 Rec=100%			2 min. >> $Q_u = 198.5$ tsf
											2 min.
											2 min.
											2 min.
											2 min.
											2 min.
											2 min.
											2 min.
											2 min.
				R-18	60	Weathered layer @ 84.6 feet (~ 2 inches thick)		RQD=58 Rec=100%			2 min. >> $Q_u = 102.7$ tsf
											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.:** 04911514  
**PROJECT:** Energy Transfer HDD (DPS)  
**LOCATION:** Graham Creek (PPP4)  
 Cumberland Co., PA

PA-CU-0062.0000-WX-16/DPS PO# 20171108

DATE STARTED: 11/10/17  
 DATE COMPLETED: 11/14/17  
 COMPLETION DEPTH: 155.0 ft  
 BENCHMARK: N/A  
 ELEVATION: N/A  
 LATITUDE: n/a°  
 LONGITUDE: n/a°  
 STATION: N/A    OFFSET: N/A  
 REMARKS:

DRILL COMPANY: Eichelbergers  
 DRILLER: L. Trimble    LOGGED BY: Lehman/Ebersole  
 DRILL RIG: Diedrich D-50  
 DRILLING METHOD: Hollow Stem Auger  
 SAMPLING METHOD: 2-in SS2.000-in Core  
 HAMMER TYPE: Automatic  
 EFFICIENCY: N/A  
 REVIEWED BY: F. Hoffman

# BORING B-1

Water	▽	Pre-Core (11/13/17)	Not Enc.
	▼	11/14/17 @ 7:30 a.m.	19.6 feet
	▽	11/14/17 @ 2:15 p.m.	18.2 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, %	STRENGTH, tsf	Additional Remarks
90				R-19	60	<b>Carbonaceous SHALE</b> -Gray to dark gray, Slightly Weathered, broken to massive, moderately hard, laminated to thinly bedded, sheer dip, bedding joint, narrowly to medium spaced discontinuity, shallow to sheer dip, calcite veins Weathered layer @ 90.1 feet (~ 1-3/4 inches thick)		RQD=92 Rec=100%			2 min. 2 min. 2 min. 2 min. 2 min.
95				R-20	26	Highly Weathered/very broken layer @ 98.1 feet (~ 2-1/2 inches thick)		RQD=45 Rec=100%			3 min. 3 min. 1 min.
100				R-21	60	<b>Carbonaceous SHALE</b> -Dark gray, Weathered to Slightly Weathered, very broken to massive, moderately hard, laminated to thinly bedded, sheer dip, bedding joint, narrowly to medium spaced discontinuity, shallow to sheer dip, calcite veins		RQD=36 Rec=100%			>> $Q_u = 64.7$ tsf 3 min. 5 min. 4 min. 4 min. 5 min.
105				R-22	60	Weathered/Highly Weathered layer @ 105.2 feet (~ 5-3/4 inches thick)		RQD=50 Rec=100%			4 min. 5 min. 3 min. 3 min.
110				R-23	60	Broken/very broken layer @ 109.2 feet (~ 4 inches thick) Highly Weathered layer from 111.4 to 112.4 feet.		RQD=28 Rec=100%			5 min. 3 min. 3 min.
115				R-24	60	<b>Carbonaceous SHALE</b> -Dark gray, Slightly Weathered, very broken to massive, moderately hard, laminated to thinly bedded, sheer dip, bedding joint, narrowly to medium spaced discontinuity, shallow to sheer dip, calcite veins Very broken layer @ 116.9 feet (~ 2-1/4 inches thick) Weathered/Highly Weathered/very broken layer @ 117.7 feet (~ 17-1/2 inches thick)		RQD=44 Rec=100%			>> $Q_u = 52.9$ tsf 3 min. 3 min. 3 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.: 04911514  
 PROJECT: Energy Transfer HDD (DPS)  
 LOCATION: Graham Creek (PPP4)  
 Cumberland Co., PA

PA-CU-0062.0000-WX-16/DPS PO# 20171108

**DATE STARTED:** 11/10/17 **DRILL COMPANY:** Eichelbergers  
**DATE COMPLETED:** 11/14/17 **DRILLER:** L. Trimble **LOGGED BY:** Eshman/Ebersole  
**COMPLETION DEPTH:** 155.0 ft **DRILL RIG:** Diedrich D-50  
**BENCHMARK:** N/A **DRILLING METHOD:** Hollow Stem Auger  
**ELEVATION:** N/A **SAMPLING METHOD:** 2-in SS2.000-in Core  
**LATITUDE:** n/a° **HAMMER TYPE:** Automatic  
**LONGITUDE:** n/a° **EFFICIENCY:** N/A  
**STATION:** N/A **OFFSET:** N/A **REVIEWED BY:** F. Hoffman  
**REMARKS:**

# BORING B-1

**Water** ▽ Pre-Core (11/13/17) Not Enc.  
 ▼ 11/14/17 @ 7:30 a.m. 19.6 feet  
 ▼ 11/14/17 @ 2:15 p.m. 18.2 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, %	STRENGTH, tsf	Additional Remarks
120				R-25	55	<b>Carbonaceous SHALE</b> -Dark gray, Slightly Weathered, very broken to massive, moderately hard, laminated to thinly bedded, shear dip, bedding joint, narrowly to medium spaced discontinuity, shallow to shear dip, calcite veins		RQD=78 Rec=92%			3 min. ● Q <sub>u</sub> = 113.4 tsf 3 min.
125				R-26	60	Broken/very broken layer @ 126 feet (~ 3-1/4 inches thick)  Weathered layer from 127.5 to 128.7 feet. Highly Weathered layer @ 128.1 feet (~ 4-1/4 inches thick)		RQD=52 Rec=100%			3 min. 3 min. 3 min. 3 min.
130				R-27	60	Weathered layer with soil @ 133.1 feet (~ 3-1/2 inches thick)		RQD=88 Rec=100%			2 min. ● Q <sub>u</sub> = 181.7 tsf 2 min. 2 min. 3 min. 3 min.
135				R-28	60			RQD=90 Rec=100%			3 min. 3 min. 2 min. 3 min.
140				R-29	60			RQD=78 Rec=100%			2 min. ● Q <sub>u</sub> = 588.0 tsf 2 min. 2 min. 2 min.
145				R-30	48			RQD=62 Rec=80%			2 min. 3 min. 3 min. 3 min. 3 min. ● Q <sub>u</sub> = 153.5 tsf 3 min.

Continued Next Page



Professional Service Industries, Inc.  
 1707 S. Cameron Street, Suite B  
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**PROJECT NO.:** 04911514  
**PROJECT:** Energy Transfer HDD (DPS)  
**LOCATION:** Graham Creek (PPP4)  
 Cumberland Co., PA

PA-CU-0062.0000-WX-16/DPS PO# 20171108

DATE STARTED: 11/10/17  
 DATE COMPLETED: 11/14/17  
 COMPLETION DEPTH: 155.0 ft  
 BENCHMARK: N/A  
 ELEVATION: N/A  
 LATITUDE: n/a°  
 LONGITUDE: n/a°  
 STATION: N/A    OFFSET: N/A  
 REMARKS:

DRILL COMPANY: Eichelbergers  
 DRILLER: L. Trimble    LOGGED BY: Lehman/Ebersole  
 DRILL RIG: Diedrich D-50  
 DRILLING METHOD: Hollow Stem Auger  
 SAMPLING METHOD: 2-in SS2.000-in Core  
 HAMMER TYPE: Automatic  
 EFFICIENCY: N/A  
 REVIEWED BY: F. Hoffman

# BORING B-1

<b>Water</b>	▽ Pre-Core (11/13/17)	Not Enc.
	▼ 11/14/17 @ 7:30 a.m.	19.6 feet
	▼ 11/14/17 @ 2:15 p.m.	18.2 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, %	STRENGTH, tsf	Additional Remarks
150			R-31	60	60	<b>Carbonaceous SHALE</b> -Dark gray, Slightly Weathered, very broken to massive, moderately hard, laminated to thinly bedded, sheer dip, bedding joint, narrowly to medium spaced discontinuity, shallow to shear dip, calcite veins Weathered/Highly Weathered layer with soil @ 153 feet (~ 11-1/2 inches thick)		RQD=76 Rec=100%	0 25 50 X Moisture    PL + LL	0 2.0 4.0 ▲ Qu            * Qp	2 min.
			R-32	14	14			RQD=0 Rec=92%			
155						Test boring terminated @ 155 feet					2 min.



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PROJECT NO.: 04911514  
 PROJECT: Energy Transfer HDD (DPS)  
 LOCATION: Graham Creek (PPP4)  
 Cumberland Co., PA

PA-CU-0062.0000-WX-16/DPS PO# 20171108

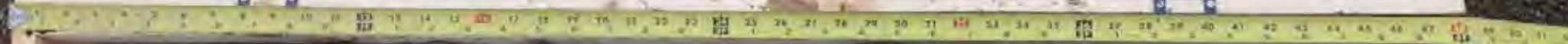
OMAI-1514  
Graham Creek  
PPH  
B-1  
Box 1 of 1  
11/10/12

Run	Depth	R <sub>100</sub>	R <sub>200</sub>
R-1	6.0-11.0	0.0	0.0
R-2	11.0-13.0	2.0	0.0
R-3	13.0-18.0	5.0	0.0
R-4	18.0-23.0	4.4	0.5
R-5	23.0-28.0	5.0	0.5



D991-1514  
 Graham Creek  
 PDP1  
 B-1  
 Box 2 of -  
 11/10/17

Run	Depth	Rec.	RSD
R-5 (cont)	23.0-28.0	5.0	0.5
R-6	28.0-31.5	3.5	0.0
R-7	31.5-36.5	3.4	0.0
R-8	36.5-41.5	4.5	1.1



28.0

0.8

SK

36.5

41.5

BORING B-1 DATE 11/15/17 BOX 3  
 DEPTH 41.5 FT. TO 56.5 FT. SPREAD PPP # 4  
 HDD Graham Creek PSI # 04911514  
 Tetra Tech Drawing PA-CU-0062.0000 - WX-16

RUN	DEPTH	REC	ROD
R-9	41.5' - 46.5'	4.8'	2.2'
R-10	46.5' - 51.5'	4.2'	0.9'
R-11	51.5' - 56.5'	5.0'	1.9'



BORING B-1 DATE 11/13/17 BOX 4

DEPTH 56.5 FT TO 70.3 FT. SPREAD PPP 4

HDD Graham Creek PSE # 04911514

Tetra Tech Drawing PA-CU-0062.0000-WX-16

RUN	DEPTH	REC	ROD
R-12	56.5' - 61.5'	5.0'	2.0'
R-13	61.5' - 66.5'	5.0'	2.7'
R-14	66.5' - 71.5'	<del>5.0'</del> 4.7'	3.3'

56.5

61.5

66.5

70.3

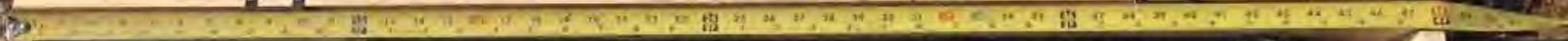
BORING B-1 DATE 11/10/17 BOX 5

DEPTH 70.3 FT D 84.8 FT SPREAD PPP 4

HDD Graham Creek PSI # 04911514

Tetra Tech Drawing PA-CU-0062.0000-WX-16

RUN	DEPTH	REC	RQD
R-14	66.5' - 71.5'	4.7'	3.3'
R-15	71.5' - 76.5'	5.0'	2.1'
R-16	76.5' - 81.5'	4.8'	3.0'
R-17	81.5' - 86.5'	5.0'	3.7'



BORING B-1 DATE 11/13/17 BOX 6

DEPTH 84.8 FT. TO 98.7 FT. SPREAD PFP 4

HDD Graham Creek PSI # 04911514

Tetra Tech Drawing PA-CU-0062.0000-WX-16

RUN	DEPTH	REC	RAB
R-17	81.5' - 86.5'	5.0'	3.7'
R-18	86.5' - 91.5'	5.0'	2.9'
R-19	91.5' - 96.5'	5.0'	4.6'
R-20	96.5' - 98.7'	2.2'	1.0'



BORING B-1 DATE 11/14/17 BOX 7  
 DEPTH 98.7 FT. TO 112.4 FT. SPREAD PPP 4  
 HDD Graham Creek PSI # 04911514  
 Tetra Tech Drawing PA-CU-0062.0000-WX-16

RUN	DEPTH	REC	RQD
R-21	<del>98.7 - 103.7</del> 98.7 - 103.7	5.0'	1.8'
R-22	<del>103.7 - 108.7</del> 103.7 - 108.7	5.0'	2.5'
R-23	108.7 - 113.7	5.0'	1.4'



BORING B-1 DATE 11/14/17 Box 8

DEPTH 112.4 FT. TO 127.5 FT. SPREAD FPP 4

HDD Graham Creek PSI # 04911514

Tetra Tech Drawing PA-CU-0062.0000 - WX-K6

RUN	DEPTH	REC	RQD
R-23	108.7' - 113.7'	5.0'	1.4'
R-24	113.7' - 118.7'	5.0'	2.2'
R-25	118.7' - 123.7'	4.6'	3.9'
R-26	123.7' - 128.7'	5.0'	2.6'

112.4'

113.7'

118.7'

127.5'



BORING B-1 DATE 11/19/17 BOX 9

DEPTH 127.5 FT. TO 141.9 FT. SPREAD PPP 4

HDD Graham Creek PSI # 04911514

Extra Tech Drawing PA-CU-0062-0000-WK-16

RUN	DEPTH	REC	ROD
R-26	123.7 - 128.7'	5.0'	2.6'
R-27	128.7 - 133.7'	5.0'	4.4'
R-28	133.7 - 138.7'	5.0'	4.5'
R-29	138.7 - 143.7'	5.0'	3.9'



BORING B-1 DATE 11/14/17 Box 10

DEPTH 141.9 FT. TO 155.0 FT. SPREAD APP 4

HDD Graham Creek PSI # 04911514

Tetra Tech Drawing PA-CU-0062.0000-WX-16

RUN	DEPTH	REC	RECD
R-29	138.7 - 143.7	5.0'	3.9'
R-30	143.7 - 148.7	4.0'	3.1'
R-31	148.7 - 153.7	5.0'	3.8'
R-32	153.7 - 155.0	1.2'	0.0'

141.9

143.7




148.7

155.0

153.7

**DATE STARTED:** 11/30/17 **DRILL COMPANY:** Eichelbergers  
**DATE COMPLETED:** 11/30/17 **DRILLER:** L. Spicher **LOGGED BY:** K. Ebersole  
**COMPLETION DEPTH:** 130.2 ft **DRILL RIG:** CME 55 Track  
**BENCHMARK:** N/A **DRILLING METHOD:** Hollow Stem Auger  
**ELEVATION:** N/A **SAMPLING METHOD:** 2-in SS2.000-in Core  
**LATITUDE:** n/a° **HAMMER TYPE:** Automatic  
**LONGITUDE:** n/a° **EFFICIENCY:** N/A  
**STATION:** N/A **OFFSET:** N/A **REVIEWED BY:** F. Hoffman  
**REMARKS:**

## BORING B-2

**Water**  Pre-Core (11/30/17) 12.8 feet  
 11/30/17 @ 4:00 p.m. 13.7 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 © X Moisture PL LL STRENGTH, tsf ▲ Qu * Qp	Additional Remarks
0				S-1	22	Possible RESIDUUM-Medium Dense, Gray-brown, Clayey GRAVEL with Sand, moist	GC	7-10-9-11 N=19	11	X ©	
5				S-2	10	Highly Weathered SHALE Sampled As:-Very Dense, Gray-brown, Silty SAND with Gravel, moist	SM	33-50/3"	8	X	Fines=16.2%
10				S-3	16	Trace clay inclusions from 10 to 11.2 feet.		29-35-50/3"	9	X	Fines=12.7%
15				S-4	1	Highly Weathered SHALE Sampled As:-Very Dense, Gray-brown, Silty GRAVEL with Sand, dry/moist Auger refusal @ 15.2 feet	GM	50/2"	5	X	
20				R-1	59	Carbonaceous SHALE-Gray to dark gray, Weathered to Slightly Weathered, very broken to massive, moderately hard, laminated to thin bedding, mineral veining (calcite), moderate to very steep, occasional shear, shallow to very steep, narrowly to widely spaced discontinuities, bedding joints, tight to open joints		RQD=34 Rec=98%			>>▲ Q <sub>u</sub> = 424.8 tsf 166.6 pcf
25				R-2	59	Carbonaceous SHALE-Gray to dark gray, Slightly Weathered, very broken to massive, moderately hard, laminated to thin bedding, mineral veining (calcite), moderate to very steep, occasional shear, shallow to very steep, narrowly to widely spaced discontinuities, bedding joints, tight to open joints Broken layer @ 23.3 feet (~ 3 inches thick)		RQD=70 Rec=98%			
30				R-3	60			RQD=96 Rec=100%			2 min. >>▲ 3 min. Q <sub>u</sub> = 672.3 tsf 168.0 pcf 3 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.:** 04911514  
**PROJECT:** Energy Transfer HDD (DPS)  
**LOCATION:** Graham Creek (PPP4)  
 Cumberland Co., PA

PA-CU-0062.0000-WX-16/DPS PO# 20171108



**DATE STARTED:** 11/30/17 **DRILL COMPANY:** Eichelbergers  
**DATE COMPLETED:** 11/30/17 **DRILLER:** L. Spicher **LOGGED BY:** K. Ebersole  
**COMPLETION DEPTH:** 130.2 ft **DRILL RIG:** CME 55 Track  
**BENCHMARK:** N/A **DRILLING METHOD:** Hollow Stem Auger  
**ELEVATION:** N/A **SAMPLING METHOD:** 2-in SS2.000-in Core  
**LATITUDE:** n/a° **HAMMER TYPE:** Automatic  
**LONGITUDE:** n/a° **EFFICIENCY:** N/A  
**STATION:** N/A **OFFSET:** N/A **REVIEWED BY:** F. Hoffman  
**REMARKS:**

## BORING B-2

**Water** ▽ Pre-Core (11/30/17) 12.8 feet  
 ▽ 11/30/17 @ 4:00 p.m. 13.7 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 © X Moisture    ▣ PL + LL STRENGTH, tsf ▲ Qu            * Qp	Additional Remarks	
60						<b>Carbonaceous SHALE</b> -Gray to dark gray, Slightly Weathered, very broken to massive, moderately hard, laminated to thin bedding, mineral veining (calcite), moderate to very steep, occasional shear, shallow to very steep, narrowly to widely spaced discontinuities, bedding joints, tight to open joints					3 min.	
			R-10	60		Weathered layer @ 65 feet (~ 6 inches thick)		RQD=94 Rec=100%				3 min.
65												3 min.
			R-11	59				RQD=90 Rec=98%			>> Q <sub>u</sub> = 369.5 tsf 168.6 pcf	3 min.
70												3 min.
			R-12	60				RQD=96 Rec=100%				3 min.
75												3 min.
			R-13	54		Broken layer @ 78 feet (~ 13-1/2 inches thick)		RQD=38 Rec=90%			>> Q <sub>u</sub> = 446.7 tsf 167.8 pcf	3 min.
80						Highly Weathered/very broken layer @ 80.4 feet (~ 7-1/4 inches thick)						3 min.
			R-14	60				RQD=82 Rec=100%				3 min.
85												3 min.
			R-15	59		Broken layer @ 88.1 feet (~ 1-3/4 inches thick)		RQD=84 Rec=98%			>> Q <sub>u</sub> = 455.8 tsf 168.4 pcf	3 min.
90												3 min.

Continued Next Page



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**PROJECT NO.:** 04911514  
**PROJECT:** Energy Transfer HDD (DPS)  
**LOCATION:** Graham Creek (PPP4)  
 Cumberland Co., PA

PA-CU-0062.0000-WX-16/DPS PO# 20171108



**DATE STARTED:** 11/30/17 **DRILL COMPANY:** Eichelbergers  
**DATE COMPLETED:** 11/30/17 **DRILLER:** L. Spicher **LOGGED BY:** K. Ebersole  
**COMPLETION DEPTH:** 130.2 ft **DRILL RIG:** CME 55 Track  
**BENCHMARK:** N/A **DRILLING METHOD:** Hollow Stem Auger  
**ELEVATION:** N/A **SAMPLING METHOD:** 2-in SS2.000-in Core  
**LATITUDE:** n/a° **HAMMER TYPE:** Automatic  
**LONGITUDE:** n/a° **EFFICIENCY:** N/A  
**STATION:** N/A **OFFSET:** N/A **REVIEWED BY:** F. Hoffman  
**REMARKS:**

## BORING B-2

<b>Water</b>	▽	Pre-Core (11/30/17)	12.8 feet
	▼	11/30/17 @ 4:00 p.m.	13.7 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 ©	Additional Remarks
120		[Graphic Log]	R-22	60	60	<b>Carbonaceous SHALE</b> -Gray to dark gray, Slightly Weathered, very broken to massive, moderately hard, laminated to thin bedding, mineral veining (calcite), moderate to very steep, occasional shear, shallow to very steep, narrowly to widely spaced discontinuities, bedding joints, tight to open joints		RQD=96 Rec=100%		X Moisture      PL LL 0                    25                    50	3 min.
125			R-23	56	56	Weathered/broken layer @ 126.7 feet (~ 2 inches thick)		RQD=66 Rec=94%		STRENGTH, tsf ▲ Qu                    * Qp 0                    2.0                    4.0	3 min. 3 min. 3 min. 3 min. 3 min. 3 min. 2 min. >> 14.1 tsf 167.7 pcf 2 min. 2 min. 3 min.
130						Test boring terminated @ 130.2 feet					



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**PROJECT NO.:** 04911514  
**PROJECT:** Energy Transfer HDD (DPS)  
**LOCATION:** Graham Creek (PPP4)  
 Cumberland Co., PA

PA-CU-0062.0000-WX-16/DPS PO# 20171108

BORING B-2 DATE 11/29/17 BOX 2 of 8

DEPTH 28.2 FT. TO 43.0 FT SPREAD PPP 4

HDD Graham Creek PSI # 04911514

Tetra

BORING B-2 DATE 11/29/17 BOX 1 of 8

DEPTH 0.0 FT. TO 28.2 FT. SPREAD PPP 4

HDD Graham Creek PSI # 04911514

Tetra Tech Drawing PA-CU-0062.0000-WX-16

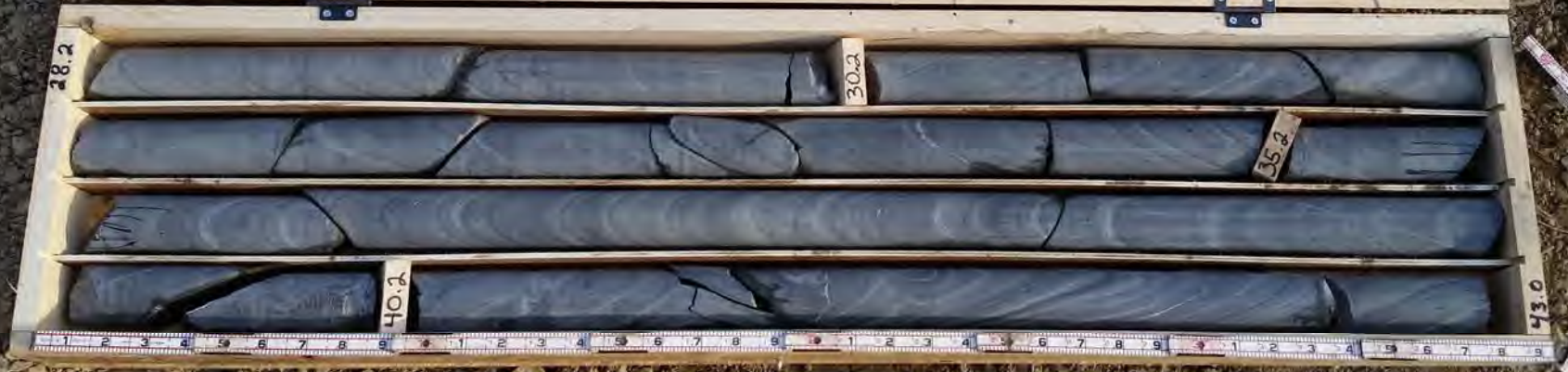
RUN	DEPTH	REC	RQD
R-1	15.2 - 20.2	4.9	1.7
R-2	20.2 - 25.2	4.9	3.5
R-3	25.2 - 30.2	5.0	4.8
R-4	8-		



B. 2 11/29/17 Box 3 of 8  
DEPTH 43.0 TO 57.6 PSI # 04911514  
DPS 2017 1103 PA-CU-0062.0000 - WK-16  
Graham Creek PPP-4

BORING B-2 DATE 11/29/17 BOX 2 of 8  
DEPTH 28.2 FT. TO 43.0 FT. SPREAD PPP 4  
HDD Graham Creek PSI # 04911514  
Tetra Tech Drawing PA-CU-0062.0000 - WK-16

RUN	DEPTH	REC	ROD
R-3	25.2 - 30.2	5.0	4.8
R-4	30.2 - 35.2	5.0	4.3
R-5	35.2 - 40.2	5.0	4.1
R-6	40.2 - 45.2	4.6	4.0



PPP-4  
Graham Creek

BOX 4 OF 8

76 to 78.3 PSI # 04911514

2017 11 03 PA-CU-0062-0000-WX-16

Creek

B-2 11/29/17 Box 3 of 8 PPP-4  
Depth 43.0 to 57.6 PSI # 04911514  
DPS 2017 11 03 PA-CU-0062-0000-WX-16  
Graham Creek

Run	Depth		Rec	RAD
R-6	40.2	-45.2	4.6	4.0
R-7	45.2	-50.2	5.0	3.5
R-8	50.2	-55.2	5.0	5.0
R-9	55.2	-60.2	5.0	4.5
<del>R-10</del>				



11/29/17 Box 6 of 8 PPP-4  
Depth 86.9 to 91.9 PSI # 04911514  
PA-CU-0062-0000-WX-16  
Graham Creek

B2 11/29/17 BOX 5 OF 8  
Depth 72.3 to 86.9 PSI # 04911514

DP B2 11/29/17 BOX 4 OF 8 PPP-4  
GRC Depth 57.6 to 72.3 PSI # 04911514

DPS 2017 11 03  
PA-CU-0062-0000-WX-16  
Graham Creek

Run	Depth	Rec	RQD
R-9	55.2 - 60.2	5.0	4.5
R-10	60.2 - 65.2	5.0	4.7
R-11	65.2 - 70.2	4.9	4.5
R-12	70.2 - 75.2	5.0	4.8



11/29/17 BOX 7 OF 8 PPP-4  
 PSI# 04911514  
 CU-0062-0000-WX-16 Graham Creek

B2 11/29/17 BOX 6 OF 8  
 Depth 86.9 to 101.5 PSI# 04911514  
 DPS 2017 11 03  
 PA-CU-0062-0000-WX-16  
 Graham Creek

Run	Depth	Rec	RQD
R-12	70.2 - 75.2	5.0	4.8
R-13	75.2 - 80.2	4.5	1.9
R-14	80.2 - 85.2	5.0	4.1
R-15	85.2 - 90.2	4.9	4.2
<del>R-16</del>			



72.3

75.2

80.2

85.2

86.9

DEPTH ~~101.5~~ ~~101.5~~ PSI # 04911514  
 DPS 2017 11 03  
 PA-CU-0062-0000-WX-16  
 Graham Creek

R-17	105.2 - 110.2	4.5	3.4
R-20	110.2 - 115.2	4.5	4.0
R-21	115.2 - 120.2	5.0	4.8

B2 11/29/17 BOX 6 OF 8 PPP-4  
 Depth ~~86.9~~ to 101.5 PSI # 04911514  
 DPS 2017 11 03  
 PA-CU-0062-0000 - WX-16  
 Graham Creek

Run	Depth	Rec	RQD
R-15	85.2 - 90.2	4.9	4.2
R-16	90.2 - 95.2	5.0	3.0
R-17	95.2 - 100.2	5.0	4.5
R-18	100.2 - 105.2	4.8	2.2

86.9

90.2

95.2

100.2

101.5



B2 11/29/17 BOX 1 OF 8 PPP-4  
Depth 101.5 to 117.0 PSI # 04911514  
DPS 2017 11 03  
PA-CU-0062-0000-WX-16  
Graham Creek

Run	Depth	Rec	ROD
R-18	100.2 - 105.2	4.8	2.2
R-19	105.2 - 110.2	4.5	3.4
R-20	110.2 - 115.2	4.5	4.0
R-21	115.2 - 120.2	5.0	4.8



BORING B-2 DATE 11/29/17 Box 1 OF 8

DEPTH 0.0 FT. TO 28.2 FT. SPREAD PPP 4

D Graham C  
a Tech Drawing

B2 11/29/17 Box 8 OF 8 PPP-4  
Depth 117.0 to 130.2 PSI# 04911514  
DPS 2017 11 03  
PA-CU-0062.0000-WX-16  
Graham Creek

Run	Depth	Rec	RQD
R-21	115.2 - 120.2	5.0	4.8
R-22	120.2 - 125.2	5.0	4.8
R-23	125.2 - 130.2	4.7	3.3
EOB ~			



**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.    | ☒ SS: Split-Spoon - 1 3/8" I.D., 2" O.D., except where noted. |
| HSA: Hollow Stem Auger - typically 3¼" or 4¼ I.D. openings, except where noted. | ■ ST: Shelby Tube - 3" O.D., except where noted.              |
| M.R.: Mud Rotary - Uses a rotary head with Bentonite or Polymer Slurry          | ▮ RC: Rock Core   |
| R.C.: Diamond Bit Core Sampler  | ⬇ TC: Texas Cone  |
| H.A.: Hand Auger  | ☞ BS: Bulk Sample   |
| P.A.: Power Auger - Handheld motorized auger                                    | ☒ 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<sub>60</sub>: A "N" penetration value corrected to an equivalent 60% hammer energy transfer efficiency (ETR)  
 Q<sub>u</sub>: Unconfined compressive strength, TSF  
 Q<sub>p</sub>: 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    ANGULARITY OF COARSE-GRAINED PARTICLES**

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

<u>Description</u>	<u>Criteria</u>
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**

<u>Component</u>	<u>Size Range</u>
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**

<u>Description</u>	<u>Criteria</u>
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**

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

**GENERAL NOTES**

(Continued)

**CONSISTENCY OF FINE-GRAINED SOILS**

<u>Q<sub>u</sub> - TSF</u>	<u>N - Blows/foot</u>	<u>Consistency</u>
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**

<u>Description</u>	<u>Criteria</u>
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**

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

**STRUCTURE DESCRIPTION**

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

<u>Q<sub>u</sub> - TSF</u>	<u>Consistency</u>
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**

<u>Description</u>	<u>Criteria</u>
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**

<u>Voids</u>	<u>Void Diameter</u>
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)

<u>Component</u>	<u>Size Range</u>
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**

<u>Rock Mass Description</u>	<u>RQD Value</u>
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.

**Degree of Brokenness**

<u>Characteristic</u>	<u>Description</u>
Less than 1 inch	Very Broken
1 inch to 3 inches	Broken
3 inches to 6 inches	Slightly Broken
Greater than 6 inches	Massive

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.

**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.

Bedding/ Discontinuity Dip (Abbrev.)	Description
Flat Dip ( <b>Fld</b> )	Beds/Discontinuities dipping < 5 degrees
Shallow Dip ( <b>Sld</b> )	Beds/Discontinuities dipping from 5 to 15 degrees
Moderate Dip ( <b>Mdd</b> )	Beds/Discontinuities dipping from 15 to 30 degrees
Steep Dip ( <b>Std</b> )	Beds/Discontinuities dipping from 30 to 45 degrees
Very Steep Dip ( <b>Vsd</b> )	Beds/Discontinuities dipping from 45 to 60 degrees
Sheer Dip ( <b>Srd</b> )	Beds/Discontinuities dipping > 60 degrees

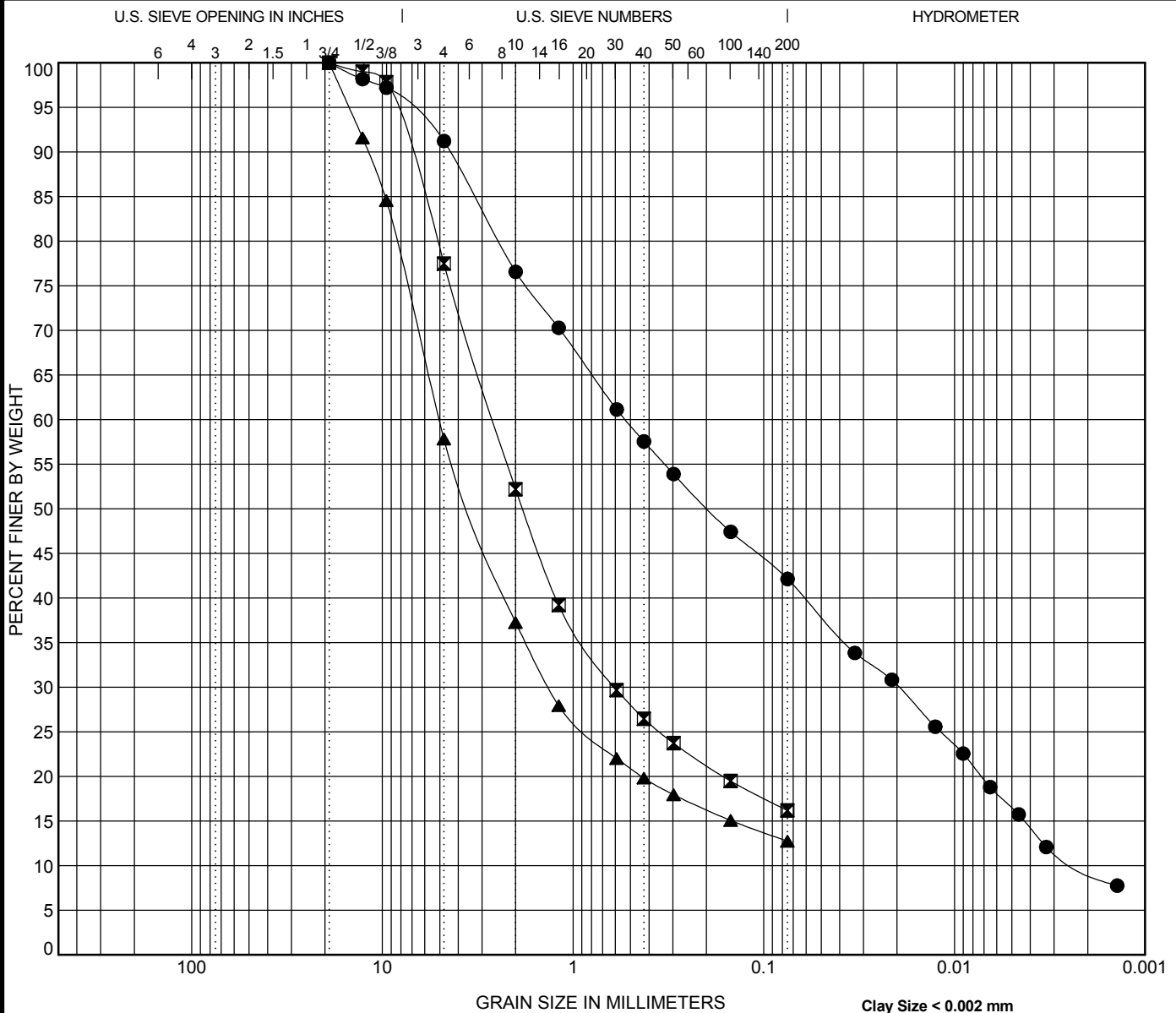
Table 29 - Bedding/Discontinuity Dip Descriptors

From PADOT Publication 222 "Geotechnical Investigations Manual"

# SOIL CLASSIFICATION CHART

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

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



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification	Classification	LL	PL	PI	Cc	Cu
● B-1 5.0	Clayey SAND (SC)	31	22	9	0.33	243.69
⊠ B-2 5.5	Silty SAND with Gravel (SM)					
▲ B-2 10.5	Silty SAND with Gravel (SM)					

Specimen Identification	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● B-1 5.0	19.05	0.532	0.02	0.002	8.8	49.1	32.6	9.6
⊠ B-2 5.5	19.05	2.613	0.604		22.5	61.3	16.2	
▲ B-2 10.5	19.05	5.028	1.336		42.2	45.1	12.7	

 Professional Service Industries, Inc. 1707 S. Cameron Street, Suite B Harrisburg, PA 17104 Telephone: (717) 230-8622 Fax: (717) 230-8626	<h3>GRAIN SIZE DISTRIBUTION</h3>	
	Project: Energy Transfer HDD (DPS) PSI Job No.: 04911514 Location: Graham Creek (PPP4) Cumberland Co., PA	



# Laboratory Summary Sheet

Sheet 1 of 1

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-1	1							14			
B-1	5	31	22	9		42.1%		14			
B-1	38.6				86.01						
B-1	45.2				142.71						
B-1	60.8				119.24						
B-1	69.2				237.33						
B-1	80				198.53						
B-1	87.6				102.65						
B-1	99.6				364.68						
B-1	114.1				52.92						
B-1	121.1				113.42						
B-1	130.3				181.66						
B-1	139.7				587.97						
B-1	149.1				153.48						
B-2	1							11			
B-2	5.5					16.2%		8			
B-2	10.5					12.7%		9			
B-2	15							5			
B-2	17.8				424.80						
B-2	27.5				672.32						
B-2	35.6				285.30						
B-2	45.6				411.87						
B-2	56				353.57						
B-2	68				369.46						
B-2	77				446.74						
B-2	86.4				455.76						
B-2	97				557.64						
B-2	108.2				287.54						
B-2	116.4				339.59						
B-2	127.2				514.14						

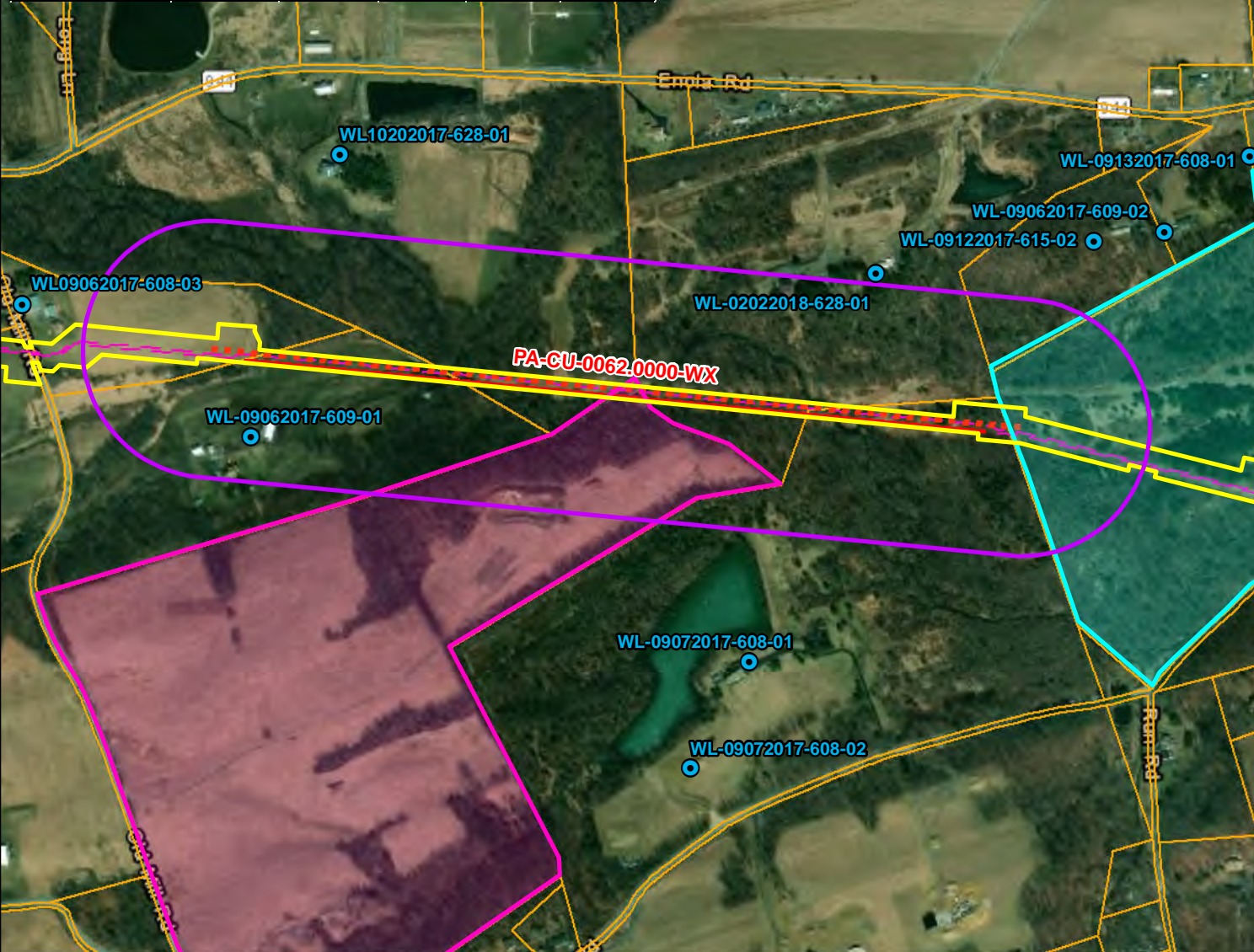

**Professional Service Industries**  
 1707 S. Cameron Street, Suite B  
 Harrisburg, PA 17104  
 Telephone: (717) 230-8622  
 Fax: (717) 230-8626

**Summary of Laboratory Results**

PSI Job No.: 04911514  
 Project: Energy Transfer HDD (DPS)  
 Location: Graham Creek (PPP4)  
 Cumberland Co., PA  
 PA-CU-0062.0000-WX-16/DPS PO# 20171103

**ATTACHMENT 3**

GES Well ID	Distance to HDD Perpendicular (Feet)	Distance to HDD Entry/Exit (Feet)	Well Information		
			Reported DTB (Feet)	Reported DTW (Feet)	Reported Pump Depth
WL-10202017-628-01	722	791	Unknown	Unknown	Unknown
WL-09062017-609-01	268	272	Unknown	Unknown	Unknown
WL-09072017-608-01	885	1,153	Unknown	Unknown	Unknown
WL-09072017-608-02	1,276	1,566	125	Unknown	Unknown
WL-09122017-615-02	697	697	Unknown	Unknown	Unknown
WL-09132017-608-01	1,242	1,242	200-300	Unknown	Unknown
WL-09062017-609-02	849	849	Unknown	Unknown	Unknown
WL-09062017-608-03	381	681	Unknown	Unknown	Unknown
WL-02022018-628-01	485	666	Unknown	Unknown	Unknown



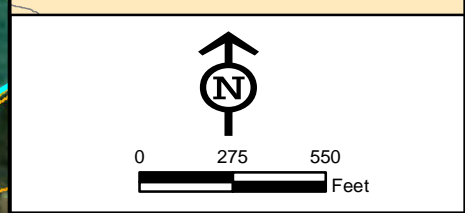
### Legend

- LOD
- Parcel
- PPP Centerline
- PPP 1 HDD
- Proposed PPP 2 HDD Redesign
- 450 Foot Buffer of HDD Alignment
- Public Water Supply/Landowner Confirmed No Well
- Testing Refused

**\*\*Testing locations current as of 02/01/2019**

- GES Testing Location

**Location**



**Well Location Map**  
HDD# PA-CU-0062.0000-WX  
Cumberland County, PA.

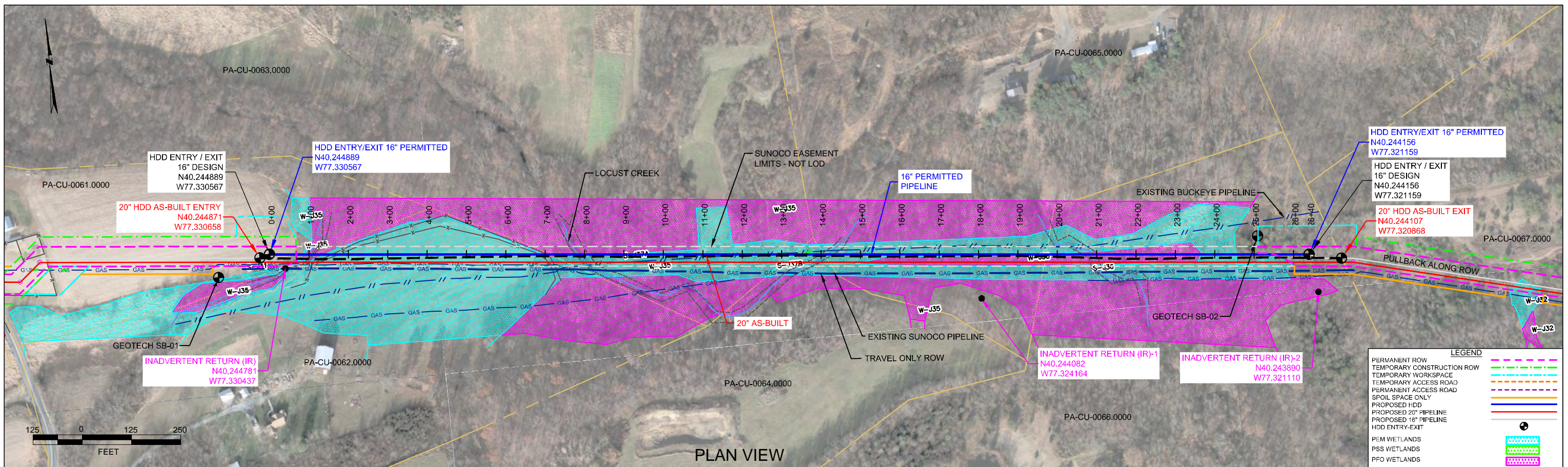
Prepared By:	Date: 2/1/2019
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Base Map:  
ESRI World Imagery, 09/24/2015  
Coordinate System: NAD 83 Stateplane, PA South, Feet

C:\GIS\workspace\Tetra\Projects\PA-CU\WellLocations\WellLocations\_PA\_CU\_DWG2\_10000.mxd

**GRAHAM CREEK CROSSING  
PADEP SECTION 105 PERMIT NOS.: E21-449  
PA-CU-0062.0000-WX-16  
(SPLP HDD No. S2-0170-16)**

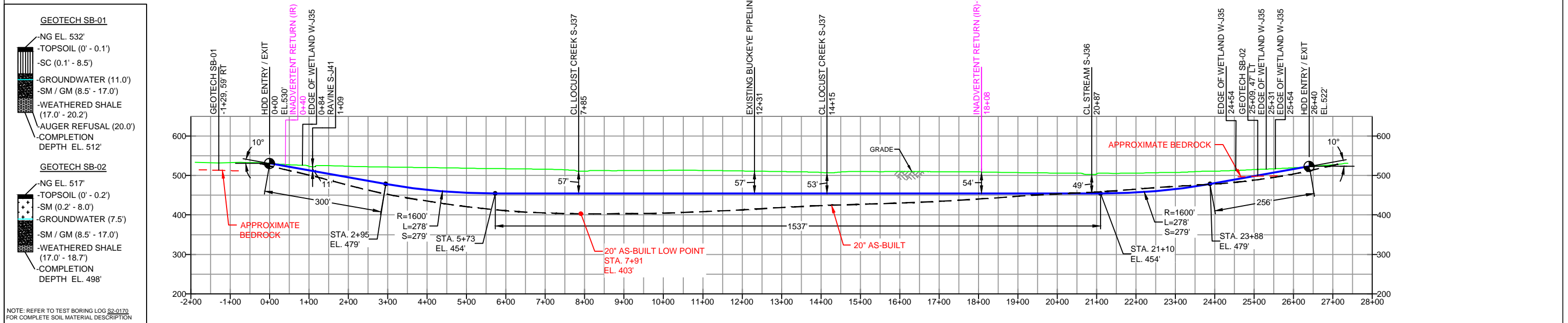
**ATTACHMENT 2  
HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES**



PLAN VIEW

CUMBERLAND COUNTY, PENNSYLVANIA, LOWER FRANKFORD TOWNSHIP  
S2-0170-16

PROFILE VIEW



- GEOTECH SB-01**
- NG EL. 532'
  - TOPSOIL (0' - 0.1')
  - SC (0.1' - 8.5')
  - GROUNDWATER (11.0')
  - SM / GM (8.5' - 17.0')
  - WEATHERED SHALE (17.0' - 20.2')
  - AUGER REFUSAL (20.0')
  - COMPLETION DEPTH EL. 512'
- GEOTECH SB-02**
- NG EL. 517'
  - TOPSOIL (0' - 0.2')
  - SM (0.2' - 8.0')
  - GROUNDWATER (7.5')
  - SM / GM (8.5' - 17.0')
  - WEATHERED SHALE (17.0' - 18.7')
  - COMPLETION DEPTH EL. 498'

- DESIGN AND CONSTRUCTION:
- CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
  - THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
  - DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
  - CROSSING PIPE SPECIFICATION:  
HDD HORZ. LENGTH (L<sub>H</sub>): 2640'  
HDD PIPE LENGTH (S<sub>H</sub>): 2652'  
16" x 0.438" W.T., X-70, API 5L, PSL2, ERW, BFW  
COATINGS: 14-16 MILS OF 3M SCOTCHKOTE TM 6233 FBE WITH 40 MILS MIN. DFT (POWERCRETE R95 OR ENGINEER APPROVED EQUAL)
  - INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50).
  - INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
  - PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
  - CARRIER PIPE NOT ENCASED.
  - PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
  - CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
  - SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
  - SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
  - SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

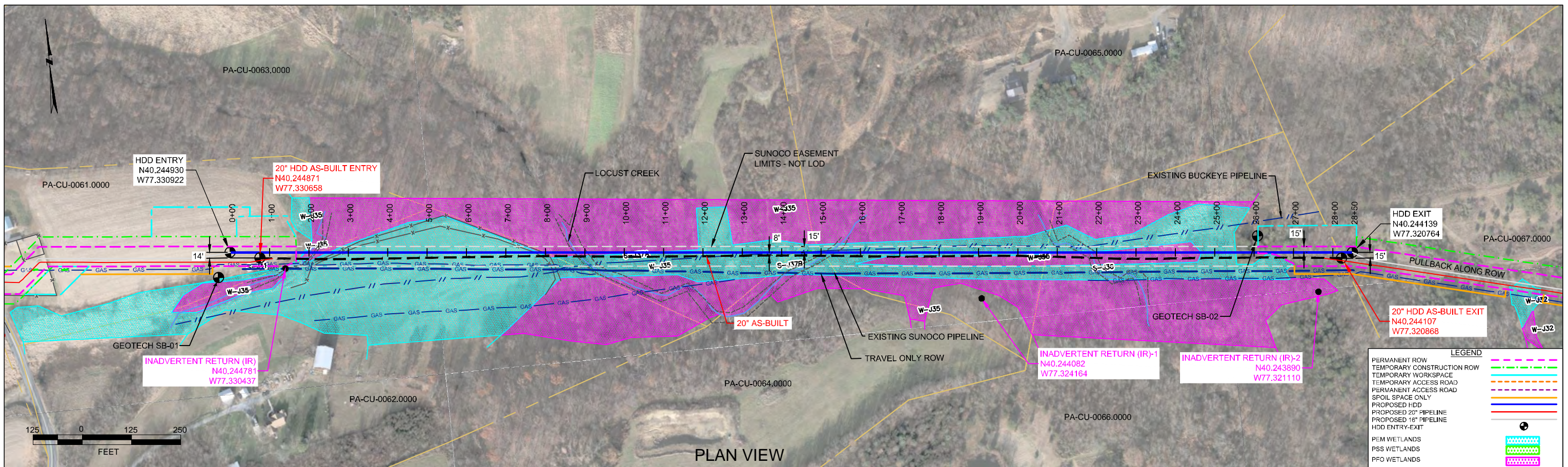
**HDD IR OVERLAY**

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

NOTES		REF. DRAWING		REVISIONS						SUNOCO PIPELINE, L.P.			
1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83 2. STATIONING IS BASED ON HORIZONTAL DISTANCES. 3. ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP ARE NOT RESPONSIBLE FOR LOCATION OF FOREIGN UTILITIES SHOWN IN PLOT PLAN OR PROFILE. THE INFORMATION SHOWN HEREON IS FURNISHED WITHOUT LIABILITY ON THE PART OF ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP. FOR ANY DAMAGES RESULTING FROM ERRORS OR OMISSIONS THEREIN. 4. CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING. 5. SUNOCO EMERGENCY HOTLINE NUMBER IS 811-800-786-7440.		ES-4.24	TO	ES-4.26	EROSION & SEDIMENT PLAN						HORIZONTAL DIRECTIONAL DRILL GRAHAM CREEK PENNSYLVANIA PIPELINE PROJECT		
		SHEET 16	TO	SHEET 17	AERIAL SITE PLAN						SCALE: 1"=250'	DWG. NO. PA-CU-0062.0000-WX-16	
						EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	MRS	10/04/16	RMB	10/04/16	AAW	10/04/16
						EP1	REVISED PER PADEP COMMENTS	MRS	05/17/16	RMB	05/17/16	AAW	05/17/16
						EP		JTW	02/26/16	RMB	02/26/16	AAW	02/26/16
						A	ISSUED FOR BID	MRS	08/31/15	RMB	08/31/15	AAW	08/31/15
		DWG NO		DWG NO	DESCRIPTION	NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE

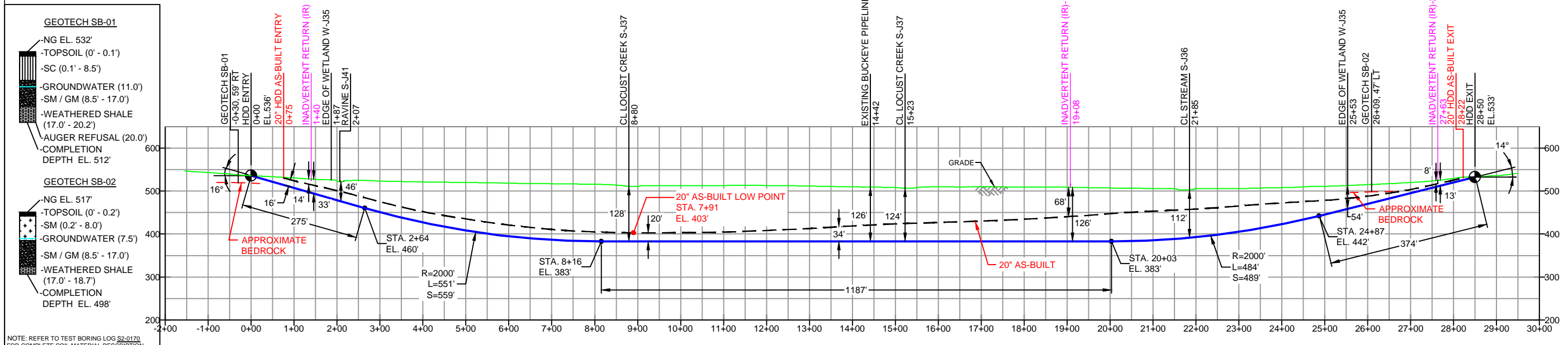
**Sunoco Logistics Partners L.P.**

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



CUMBERLAND COUNTY, PENNSYLVANIA, LOWER FRANKFORD TOWNSHIP  
S2-0170-16

PLAN VIEW  
PROFILE VIEW



- DESIGN AND CONSTRUCTION:
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  - THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
  - DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
  - CROSSING PIPE SPECIFICATION:  
HDD HORZ. LENGTH (L<sub>H</sub>): 2850'  
HDD PIPE LENGTH (S<sub>H</sub>): 2884'  
16" x 0.438" W.T., X-70, API 5L, PSL2, ERW, BFW  
COATINGS: 14-16 MILS OF 3M SCOTCHKOTE TM 6233 FBE WITH 40 MILS MIN. DFT (POWERCRETE R95 OR ENGINEER APPROVED EQUAL)
  - INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50).
  - INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
  - PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
  - CARRIER PIPE NOT ENCASED.
  - PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
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  - SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
  - SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
  - SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

Figure 2. Redesigned 16-Inch HDD Plan and Profile

NOTES		REF. DRAWING		REVISIONS						Sunoco Logistics Partners L.P.			SUNOCO PIPELINE, L.P.	
1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83 2. STATIONING IS BASED ON HORIZONTAL DISTANCES. 3. ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP ARE NOT RESPONSIBLE FOR LOCATION OF FOREIGN UTILITIES SHOWN IN PLOT PLAN OR PROFILE. THE INFORMATION SHOWN HEREON IS FURNISHED WITHOUT LIABILITY ON THE PART OF ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP. FOR ANY DAMAGES RESULTING FROM ERRORS OR OMISSIONS THEREIN. 4. CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING. 5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.		ES-4.24	TO	ES-4.26	EROSION & SEDIMENT PLAN								HORIZONTAL DIRECTIONAL DRILL GRAHAM CREEK PENNSYLVANIA PIPELINE PROJECT	
		SHEET 16	TO	SHEET 17	AERIAL SITE PLAN	EP3	DESIGN CHANGE - INCREASED DEPTH OF DRILL	MRS	12/11/18	RMB	12/11/18	AMC	12/11/18	SCALE: 1"=250' DWG. NO. PA-CU-0062.0000-WX-16
						EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	MRS	10/04/16	RMB	10/04/16	AAW	10/04/16	
						EP1	REVISED PER PADEP COMMENTS	MRS	05/17/16	RMB	05/17/16	AAW	05/17/16	
						EP	ISSUED FOR BID	JTW	02/26/16	RMB	02/26/16	AAW	02/26/16	
		DWG NO		DWG NO	DESCRIPTION	NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE	