HORIZONTAL DIRECTIONAL DRILL ANALYSIS
NORFOLK SOUTHERN RAILROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E32-508
PA-IN-0019.0000-RR-16
(SPLP HDD# S2-0040-16)

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This reanalysis of the horizontal directional drill (HDD) installation of a 16-inch diameter pipeline that traverses the Norfolk Southern Railroad in Burrell Township, Indiana County, Pennsylvania, is in accordance with the Stipulated Order issued under Environmental Hearing Board Docket No. 2017-009-L for HDDs listed on Exhibit 3 of the Stipulated Order. This HDD is number 3 on the list of HDDs included on Exhibit 3 of the Order.

The installation of the 20-inch diameter pipeline using HDD was completed before the temporary injunction issued by the Pennsylvania Department of Environmental Protection (PADEP) Environmental Hearing Board on July 25, 2017. The first pipeline HDD had two inadvertent returns (IRs), which were remediated in conjunction with the installation of the 20-inch diameter pipeline.

The 16-inch pipeline HDD is referred to herein as HDD S2-0040-16.

PIPE INFORMATION

16-Inch: 0.438 wall thickness; X-70.

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

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 16-INCH

- Horizontal length: 780 feet (ft)
- Entry/Exit angle: 10-11 degrees
- Maximum depth of cover: 47 ft
- Pipe design radius: 1,600 ft

A copy of the original HDD plan and profile is included as Figure 1 in Attachment 2.

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

Drilling activities were initiated on the 20-inch HDD at this location on May 13, 2017, and completed on June 7, 2017. Two IRs were noted the first day of drilling. The first IR occurred in wetland W-J53 at approximately Station 6+54 on the HDD profile, and the second immediately upslope of stream S-J58, offset approximately 70 ft to the north of Station 4+70 on the HDD profile. Considering the orientation of wetland W-J53, it is possible that the second IR was part of the first IR. Drilling fluid could have followed the gradient of drainage in the wetland just beneath the land surface from the 1st location to the 2nd location. Both IRs were contained using a combination of silt fence and a pump to recover drilling fluids and there was no impact to stream S-J58. Drilling resumed using a higher viscosity drilling fluid with generally good returns for the remainder of the HDD.

At the time of the IRs the drill bit was less than 300 ft from the eastern entry/exit point. Soil boring SB-02 was installed at Station 7+45, approximately 90 ft east of the first IR, and is most representative of subsurface conditions at the IR locations. The log for geotechnical boring SB-02 shows 25.8 ft of unconsolidated overburden soil. Soil textures in the bottom 12 ft of SB-02 were logged as clayey silts with more decomposed sandstone rock content near the bottom of the boring.

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The pilot boring was approximately 16 ft below ground surface (bgs) at the Station 6+54 IR and approximately 25 ft bgs at the Station 4+70 IR, reflective of a relatively low entrance angle and shallow profile. Assuming SB-02 is representative of site conditions, the pilot drilling tool would not have been in competent bedrock under the location of the first IR. Therefore, the occurrence of the IRs in Wetland W-J53 during the installation of the 20-inch diameter pipeline at the Norfolk Southern Railroad Crossing likely resulted from a depth of cover on the HDD entry radius while proceeding through clayey silt with weathered sandstone bedrock that was too shallow under Wetland J-53 to contain drilling pressures.

GEOLOGIC AND HYDROGEOLOGIC ANALYSIS

HDD S2-0040-16 is located within the Pittsburgh Low Plateau Section of the Appalachian Plateaus Physiographic Province. The Pittsburgh Low Plateau Section consists of smooth to irregular, undulating surfaces; narrow, relatively shallow valleys with strip mines and reclaimed mine lands. Bedrock in the area belongs to the Pennsylvanian age Casselman Formation, part of the Conemaugh Group. The Casselman Formation is characterized by a few locally persistent red beds, calcareous claystone, freshwater limestones, thin sandstones, shales, siltstones, and generally thin, economically insignificant coal beds. Most of the shales overlying coals contain plant fossils, and several also contain freshwater fauna. Discontinuities in the form of joints, fractures, and faults are imprinted in the broadly folded bedrock in the region. These fractures and bedding plane partings can act as conduits for groundwater movement and/or represent areas of weakness in the rock.

Fracture trace analysis using high altitude aerial photography was performed in the vicinity of HDD S2-0040-16 to identify potential zones of bedrock weakness along drill paths. The proposed path of the revised profile transects a west-northwest trending fracture trace at approximately Station 2+00. Details regarding the fracture trace locations along the HDD alignment are provided in Section 2.2.4 of the Hydrogeologic Reevaluation Report in Attachment 1.

Karst geology is not present at this HDD location.

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

Coal Mining and Subsidence

A review of published mining and geological data indicate that mining of the Upper Freeport coal in the vicinity of HDD S2-0040-16 has been completed. The Penn State Mine Atlas (http://www.minemaps.psu.edu/) shows that HDD S2-0040-16 is within the limits of a room and pillar mine section of the Toms Run Mine operated by Rosebud Mining Company. The base of coal elevations below the revised HDD profile range from approximately 412 ft amsl at the western entry/exit to 445 ft amsl at the east entry/exit. The lowest elevation on the revised profile is 950 ft amsl, approximately 505 feet above the highest floor elevation of the mine. The coal is approximately 5-feet thick within the mine therefore the shortest distance from the mine roof to the revised profile is approximately 500 feet.

Kendorksi (2006) delineated estimated extents of four zones of fracturing above coal mines, based on the thickness of the extracted coal. From bottom to top these include the Caved Zone (with extensive fracturing and sizeable voids), Fracture Zone (with fracturing, without extensive dislocation of rocks or voids), Dilation Zone (small fractures), and the Constrained Zone (with no rock fracturing related to mine subsidence). The maximum estimated extent of the Dilation Zone above the Tom Run Mine is 300 feet and the lowest part of the revised profile is 500 feet above the mine therefore the profile is within the Constrained Zone. Accordingly, coal mining below the revised HDD profile does not represent an increased risk of IRs.

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HYDROGEOLOGY, GROUNDWATER, AND WELL PRODUCTION ZONES

Most groundwater in the area of HDD S2-0040-16 area occurs and moves within a fractured bedrock aquifer. Groundwater occurs within the secondary porosity created by fractures, bedding plan partings, and faults.

Groundwater was not encountered or measured in geotechnical boring SB-01, located near station 1+00 of the drill; but groundwater was encountered at 10 ft depth in geotechnical bore SB-02, located just south of station 7+45. Based on the results of the PaGWIS database search, yields from wells drilled within a mile of this HDD range from 5 to 25 gpm. The one well listed in PaGWIS within 1,000 ft of the HDD had a reported yield of 6 gpm.

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

INADVERTENT RETURN (IR) DISCUSSION

No IRs were reported along the alignment of the HDD S2-0040-16 drill on the list of IRs for ME I documented in the IR PPC Plan for Indiana County.

Two (2) additional geotechnical borings (B2-6E and B2-6W) were installed by Terracon in September 2017 in support of the HDD reevaluation.

Boring B2-6E was advanced on September 21, 2017, at the eastern entry/exit location on the original plan and profile to a depth of 84.6 ft bgs. Unconsolidated overburden comprised of clay with trace gravel occurred to 18.5 ft bgs. Weathered bedrock occurred from 18.5 to 28.6 ft bgs, prior to encountering competent bedrock. Bedrock cores were obtained from 28.6 to a total depth of 86.4 ft and contained shale, mudstone, and siltstone characteristic of the Casselman Formation. Core recoveries below 28.6 ft bgs, were high, ranging from 83 to 100 percent. A single water level measurement of 4.3 ft bgs was measured in B2-6E after the boring was completed.

Boring B2-6W, was advanced at the western entry/exit on the original profile for HDD S2-0040-16 to a depth of 91.5 ft bgs. Unconsolidated overburden was logged as 1.5 ft of clay with gravel above 8.6 ft of weathered bedrock to 10.1 ft bgs. The cored rock at B2-6W showed similar recoveries as B2-6E. A high-angled fracture was observed within shale at 24 ft bgs. Two (2) similar water level measurements were collected during the advance of the boring at 24.0 and 24.6 ft bgs.

In general, the 20-inch HDD IRs and other IRs on the ME II Project located in the Casselman Formation have been related to shallow overburden, coarse grained unconsolidated materials near the surface (such as alluvium and mine spoil), large elevation changes between entry/exits and the lowest elevation points along the profiles (sometimes creating soil plugs, elevated annular pressures, and loss of fluids), and the interconnectivity of open bedrock structural features that is difficult to predict.

ADJACENT FEATURES ANALYSIS

The crossing of the Norfolk Southern Railroad is located in Indiana County, approximately 2.4 miles northeast of the borough of Blairsville, Pennsylvania, and approximately 2.51 miles southwest of the community of Black Lick, Pennsylvania.

The pipeline alignment for HDD S2-0040-16 traverses from just west of the Norfolk Southern Railroad to just west of Kendall Road.

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This HDD location is set under the railroad as well as a wetland (W-J53) and stream S-J58. This HDD avoids surficial impacts to the stream and wetland, neither of which are designated as high quality or exceptional value.

SPLP performed a preconstruction survey of landowners within 450 ft and greater from the HDD alignment. No landowners responded positively to an offer to have their wells tested. The PaGWIS database reports no water supply wells within 450 ft of the ROW. During the well testing program in March 2017, a water sample was collected from one private well (Sample WL-03202017-520-01) at a parcel located 1,230 ft east of the original eastern entry/exit of HDD S2-0040-16 (see attached Well Location Map). The depth to water for this well was reported at 30 ft bgs. This well is plotted on Figure 6 in the Hydrogeologic Reevaluation Report provided in Attachment 1.

ALTERNATIVES ANALYSIS

As required by the Order, the reanalysis of S2-0040-16 includes an evaluation of open cut alternatives and a re-route analysis. As part of the PADEP Chapter 105 permit process for the Mariner II East Project, SPLP developed and submitted for review a project-wide Alternatives Analysis. During the development and siting of the project, SPLP considered a number of 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 that using the HDD method along the current route avoids direct impacts to stream S-J58, wetland W-J53, and their associated floodways and habitat.

Open-cut and Conventional Bore Analysis

The pipeline route follows parallel to an existing SPLP pipeline easement. SPLP specifications require a minimum of 48 inches of cover over the installed pipelines below ground and below the bottom of watercourses. To meet this cover requirement, construction through stream S-J58 and wetland W-J53 would require a minimum authorized open cut work space 75 ft in width to accommodate the 16-inch diameter pipeline, allowing for the pipeline to be installed with sufficient separation for integrity management and in consideration of the effects of trenching in open water on construction workspace. The assessed area of impact by this open cut plan would directly affect 360 square feet of state water bottoms, 0.278 acres of palustrine emergent wetlands, and 0.212 acre of floodway.

Re-Route Analysis

The pipeline route as currently permitted follows an existing SPLP easement and this HDD bypasses or avoids direct impacts to an emergent wetland and a stream.

No practicable re-route option lies to the north or south of the proposed route that would not transect the same stream and floodway. Shifting the pipeline route north would cross through forested habitat, stream S-J58, enter the FEMA 100-year floodplain (a state Chapter 106 area), and require new utility corridor. A shift south would cross the stream and would have be in close proximity to residential and commercial structures and utilities. A new utility corridor would require consent of newly-affected landowners or the use of eminent domain/condemnation, and would create a new land encumbrance on the private properties crossed. Given site conditions and features north and south of the proposed pipeline alignment, no practicable re-route exists that would result in less impacts to environmental resources.

In summary, due to the woodlands to the north and residential/commercial properties to the south of the proposed HDD, additional direct effects to infrastructure and creation of a new "greenfield" corridor for any shift north or south, there is no identifiable alternative route that would result in less impacts to aquatic and forested woodland resources and existing residences and associated infrastructure in the vicinity of the planned HDD.

This re-route analysis conducted for the Norfolk Southern Railroad HDD is consistent with the conclusions reached in the alternatives analysis previously submitted to the PADEP.

HORIZONTAL DIRECTIONAL DRILL REDESIGN

Additional geologic investigations have been completed and utilized in the redesign of the planned HDD. The overall length of the originally permitted HDD S2-0040-16 is 780 ft. The revised profile is 1,336 ft in length, an increase of 556 ft from the original design. The revised length of the HDD allows for a deeper profile that enters competent bedrock approximately 380 ft east of the eastern edge of wetland W-J53. On the revised profile the pilot boring will pass under the eastern edge of wetland W-J53 at a depth of 73 ft resulting in approximately 48 ft of competent rock above the profile at that location.

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: 1,336 ft
- Entry/Exit angle: 13-14 degrees
- Maximum depth of cover: 73 ft
- Pipe design radius: 2,000 ft

CONCLUSION

Based on the original and revised profiles for HDD S2-0040-16, the revised profile is deeper into bedrock than the original 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.

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

- 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 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. This HDD is marginally below 70 ft of depth in the horizontal run of the profile. Accordingly, the preferred corrective action needed to address the presence of fractures or unstable geology at greater depths below ground may require grouting of the HDD annulus. Two types of grouting will be utilized for corrective actions to seal fractures and stabilize zones of weak geology. 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 Geotechncial Evaluation Leader, Professional Geologists, Professional Engineers, and HDD specialists, the HDD Reevaluation Team's opinion is that the revised design of HDD S2-0040-16 and implementation of the management measures contained within this re-revaluation report will minimize the risk of IRs and impacts to public and private water supplies during the construction phases of the HDD.

12/11/2018

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

Pertaining to the practice of geology

12/11/18

Richard T. Wardrop, P.G. — Date
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Groundwater & Environmental Services, Inc.
Lead Hydrogeologist

COMMONWEALTH OF PENNSYLVANIA
REGISTERED PROFESSIONAL
RICHARD T. WARDROP
GEOLOGIST
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Pertaining to the pipeline stress and HDD geometry

12/11/18

Jeffery A. Lowy, P.E. — Date
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Rooney Engineering, Inc.
Civil Engineer

COMMONWEALTH OF PENNSYLVANIA
REGISTERED PROFESSIONAL
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12/11/18

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ATTACHMENT 1

GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT

HDD HYDROGEOLOGIC REEVALUATION REPORT

Mariner East II
Spread 2
HDD S2-0040-16
Norfolk Southern/Kendall Road
Burrell Township, Indiana County, Pennsylvania

Prepared for:

Sunoco Pipeline, L.P.

Prepared by:

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

December 2018

HDD HYDROGEOLOGIC REEVALUTION REPORT

Mariner East II
Spread 2
HDD S2-0040-16
Norfolk Southern Railroad Crossing
Burrell Township, Indiana County, Pennsylvania

December 2018

Prepared for:

Sunoco Pipeline, L.P.
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Prepared by:

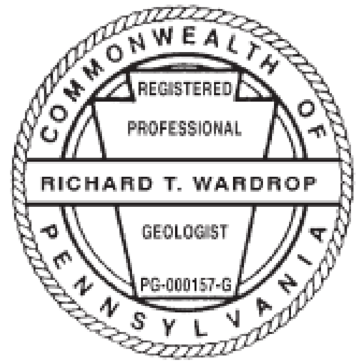
Jack Vasalani, P.G.
Principal Geologist

Reviewed b

Richard T. Wardrop, P.G.
Lead Hydrogeologist

Groundwater & Environmental Services, Inc.
440 Creamery Way, Suite 500
Exton, Pennsylvania 19341
(610) 458-1077

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



Richard T. Wardrop

December 11, 2018

Richard T. Wardrop, P. G. date

Lic. No. PG000157G

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FIGURES

ATTACHMENTS

1.0 INTRODUCTION

Sunoco Pipeline, L.P., (SPLP) retained Groundwater & Environmental Services, Inc. (GES) to prepare HDD Hydrogeologic Reevaluation Reports (HRRs) for horizontal directional drills (HDDs) listed on Exhibit 3 of the Stipulated Order EHB Docket No. 2017-009-L signed August 10, 2017. This report discusses the hydrogeologic reevaluation for HDD S2-0040-16 (the 16-inch HDD for this location). The planned alignment for HDD S2-0040-16 is located between Campbell's Mill Road (State Route 3011) and Kendall Road in Burrell Township, Indiana County, Pennsylvania. The discussion presented in this report is based on an alignment and profile developed by Tetra Tech/Rooney, revised on March 17, 2017 (original profile). GES has also been provided a proposed alternative profile for HDD S2-0040-16, revised November 13, 2018 (revised profile) (see **Attachment A**). The revised profile was developed to increase entry/exit angles, increase the radius and increase the depth of the profile by extending the east entry/exit point and making the HDD profile longer. The purpose of the revised profile is to minimize the risk of inadvertent returns (IRs) by installing the pipe deeper into competent bedrock. For the purpose of this assessment, GES utilized both HDD designs to evaluate the hydrogeologic conditions at HDD S2-0040-16. As the western entry/exit was not changed on the revised profile and stationing for both profiles begins at the western entry/exit, stationing relative to local land features and water resources is consistent between the two, except for additional stationing added to the east side of the HDD.

As described in the Stipulated Order (pages 3 and 4), the HRRs will provide information to eliminate, reduce, or control the release or inadvertent return (IR) of HDD drilling fluids to the surface of the ground or impact to water supplies at the location during HDD operations. The HRRs are not intended to evaluate potential adverse effects of nearby man-made structures from HDD operations.

A map depicting the location of the HDD with topographic information for the surrounding area is presented as **Figure 1**.

This report presents the following information:

- Geologic and hydrogeologic characteristics in the area of HDD S2-0040-16;
- Summaries of studies performed pertinent to reevaluation, including fracture trace analysis and geotechnical borings;
- A site conceptual model; and
- A reevaluation summary with conclusions.

The contents of this report were developed from interpretation of published information, field observations, and related field studies. Site geotechnical boring programs were conducted by Tetra Tech in September 2014 and by Terracon Consultants, Inc. (Terracon) in September 2017, in support of the HDD S2-0040-16 design. Please note that GES did not oversee or direct either geotechnical drilling program, including, but not limited to, the selection of number and location of borings, determination of surface elevations, target depths, observations of rock cores during drilling operations, or preparation of boring logs. The geotechnical reports, boring logs, and any core photographs that resulted from these programs were generated by SPLP's contractors. GES relied on these reports and incorporated their data into the general geologic and hydrogeologic framework for this hydrogeologic reevaluation report.

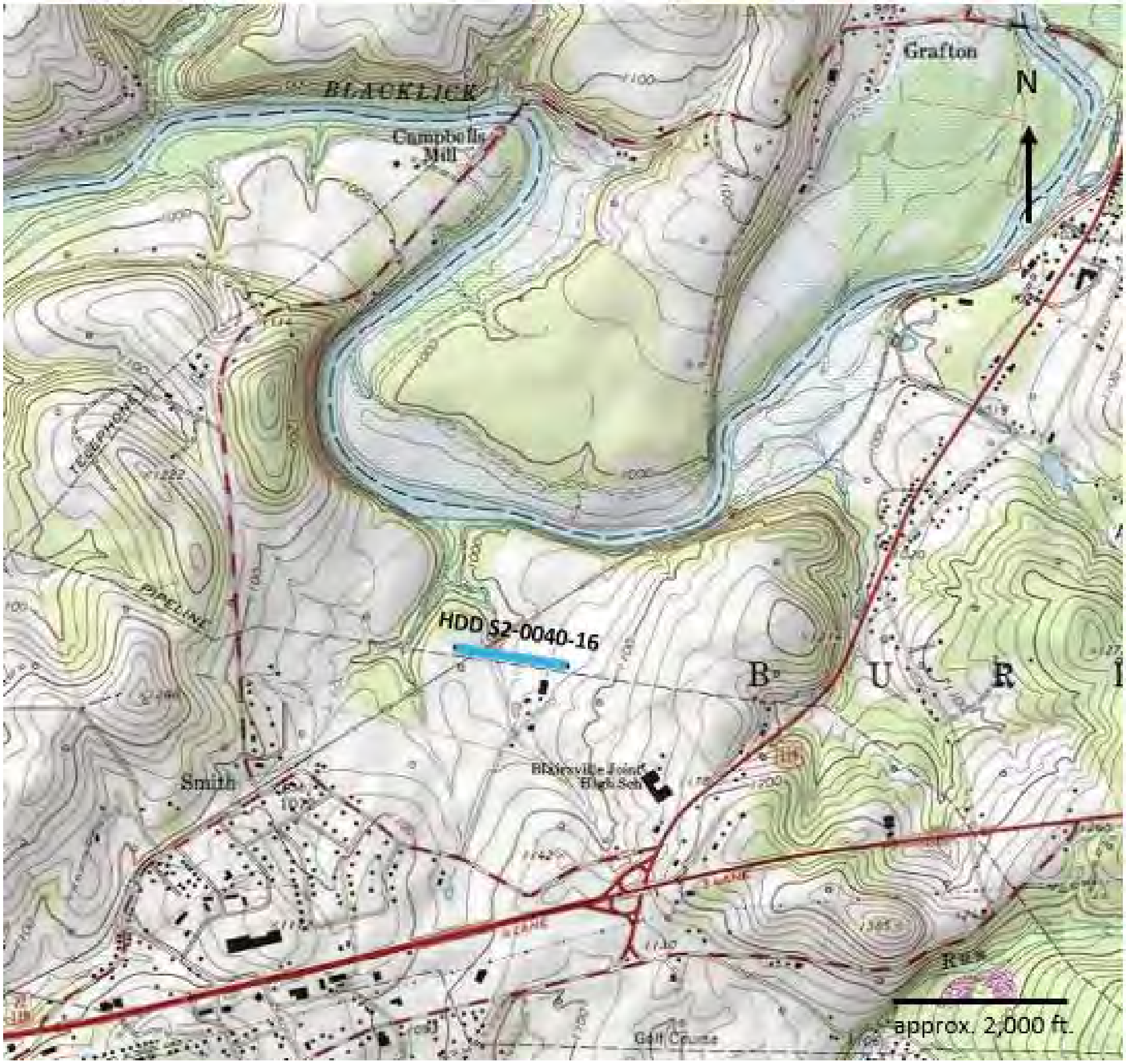


Figure 1. Site Location Map (modified from USGS Bolivar 1:24,000 Topo. Quad., rev. 1982)

2.0 HDD GEOLOGY / HYDROGEOLOGY

2.1 Physiography

HDD S2-0040-16 is located within the Pittsburgh Low Plateau Section of the Appalachian Plateaus Physiographic Province, which is characterized by smooth to irregular, undulating surface, narrow relatively shallow valleys, strip mines and reclaimed mine lands. Local relief between valley floors and the ridges typically range from 600 to 1,000 feet. Blacklick Creek is located 1,500 feet north of HDD S2-0040-16 and drains to the Conemaugh River Reservoir, which flows northwest. An unnamed tributary to Blacklick Creek (S-J58) is the only tributary that crosses the HDD S2-0040-16 drill path at Station 4+68.

2.1.1 Topography

The topography along the surface overlying HDD S2-0040-16 is relatively flat with subtle high points at the entry/exits and a depression at S-J58. The maximum difference in elevation over the revised profile is approximately 42 feet between the eastern entry/exit and S-J58. The surface elevation of the western entry/exit of HDD S2-0040-16 for both profiles is 1,030 feet above mean sea level (amsl) and is essentially flat to a railroad grade at Station 2+00 with a very gradual decline in the eastern direction to approximately 1,010 ft amsl at Stream S-J58 (Station 4+68). The topography gently rises to the eastern entry/exit on the original profile at Station 7+80, with a surface elevation of 1,027 ft amsl, but continues to Station 13+36 at elevation 1,052 ft amsl at the eastern entry/exit on the revised profile (see **Attachment A**).

2.1.2 Hydrology

The nearest surface water body to the HDD S2-0040-16 location is stream S-J58, a tributary to the Conemaugh River Reservoir that flows east to west, approximately 1,550 feet north of HDD S2-0040-16. The HDD passes under one wetland W-J53 that occurs between Stations 5+11 and 7+23. On original profile, the HDD would be approximately 5 feet below the wetland on the eastern extent and 25 feet at the western extent of the wetland. The revised profile shows the HDD will be approximately 73 feet deep at the eastern extent of W-J53 and approximately 60 feet deep at the western edge of W-J53.

2.2 Geology

2.2.1 Soils

Based on information obtained from the National Resource Conservation Service Web Soil Survey database ((USDA NRCS Web Soil Survey for Indiana County (http:\\websoilsurvey.nrcs.usda.gov)), soils along the path of HDD S2-0040-16 can range from 1.5 to greater than 7 feet thick. Overburden is primarily composed of fine-loamy alluvium and residuum from sedimentary rock, siltstone, and shale. These soils are somewhat poorly to well-drained and groundwater is at 0.5 to greater than 7 feet below ground surface (ft bgs), with shallower occurrences in the lowland.

2.2.2 Bedrock Lithology

Bedrock underlying the area of HDD S2-0040-16 belongs to the Pennsylvanian age Casselman Formation, part of the Conemaugh Group. **Figure 2** is a map depicting site bedrock geology for the area surrounding HDD S2-0040-16 (McElroy, 1998).

The Casselman Formation is characterized by a few locally persistent red beds, calcareous claystone, freshwater limestones, thin sandstones, shales, siltstones, and generally thin, economically insignificant coal beds. Most of the shales overlying coals contain plant fossils, and several also contain freshwater fauna.

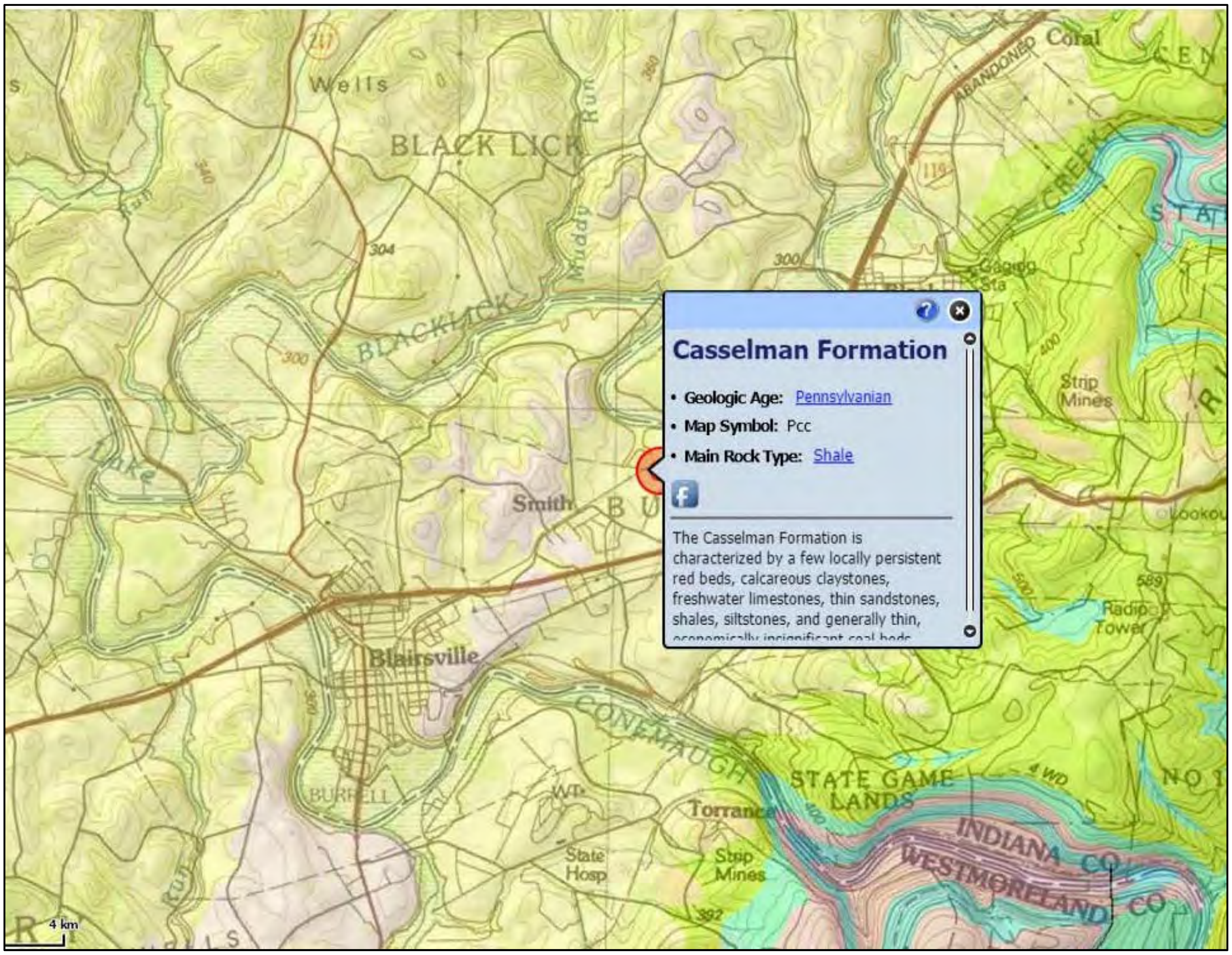


Figure 2. Site Geology Map (modified from PA DCNR Map Viewer: http://www.gis.dcnr.state.pa.us/maps/index.html)

2.2.3 Structure

Bragonier and Glover (1996) provide structure contour maps for the Upper Freeport coal beds in Indiana County. As shown on **Figure 3**, HDD S2-0040-16 is located within the east limb of the Latrobe Syncline. Here bedrock bedding is dipping gently WNW at approximately 1.2 degrees.

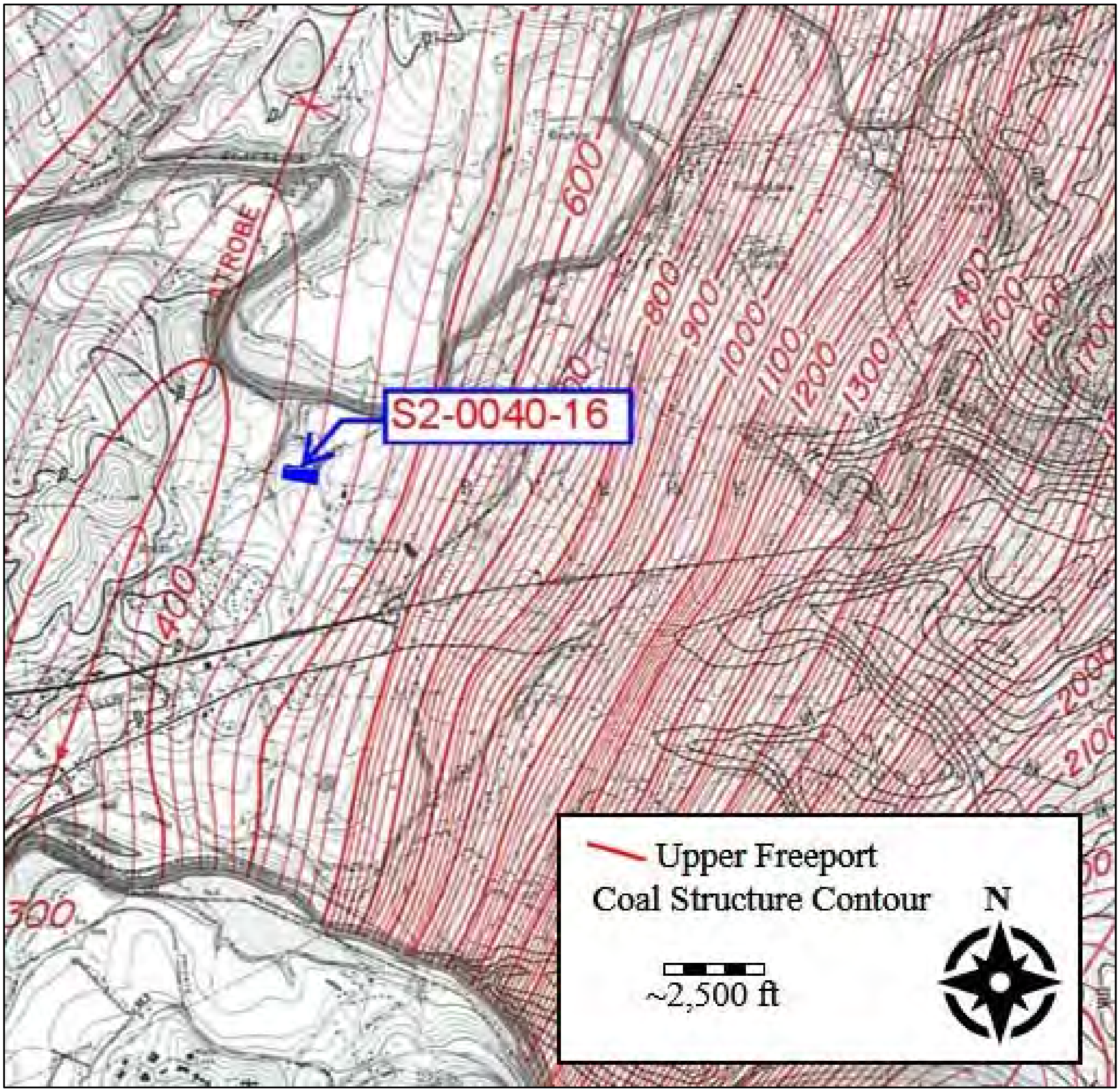


Figure 3. Structure Contour Map of the Upper Freeport Coal (mod. from Bragonier and Glover, 1996)

Discontinuities in the form of joints and faults are imprinted in the broadly folded bedrock in the region. These fractures can act as conduits for groundwater movement and/or represent areas of weakness in the rock. Fold axes can be areas of increased density of fracturing (McElroy, 1998). Nickelsen and Hough (1967) conducted regional mapping of joints in shale, coal and sandstone in the Appalachian Plateau. In the vicinity of HDD S2-0040-16, two systematic joint sets were mapped with approximate trends of west-northwest and northwest. Less frequent non-systematic joints were mapped approximately orthogonal to the systematic joints.

2.2.4 Fracture Trace Analysis

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

Figure 4 shows a fracture trace map prepared for this reevaluation. This mapping was performed using aerial stereographic pairs flown in the spring of 1939. As such, much of the land surface appears undeveloped and fracture traces are more easily seen. One of the fracture trace orientations generally matches the systematic joint alignments mapped by Nickelsen and Hough: a northwestern trending set. The majority of the mapped fracture traces for the area trend northeast and east-northeast, consistent with the non-systematic joint sets of Nickelsen and Hough. The proposed path of the revised profile is shown in red on **Figure 4** and transects a west-northwest trending fracture trace at approximately Station 2+00.

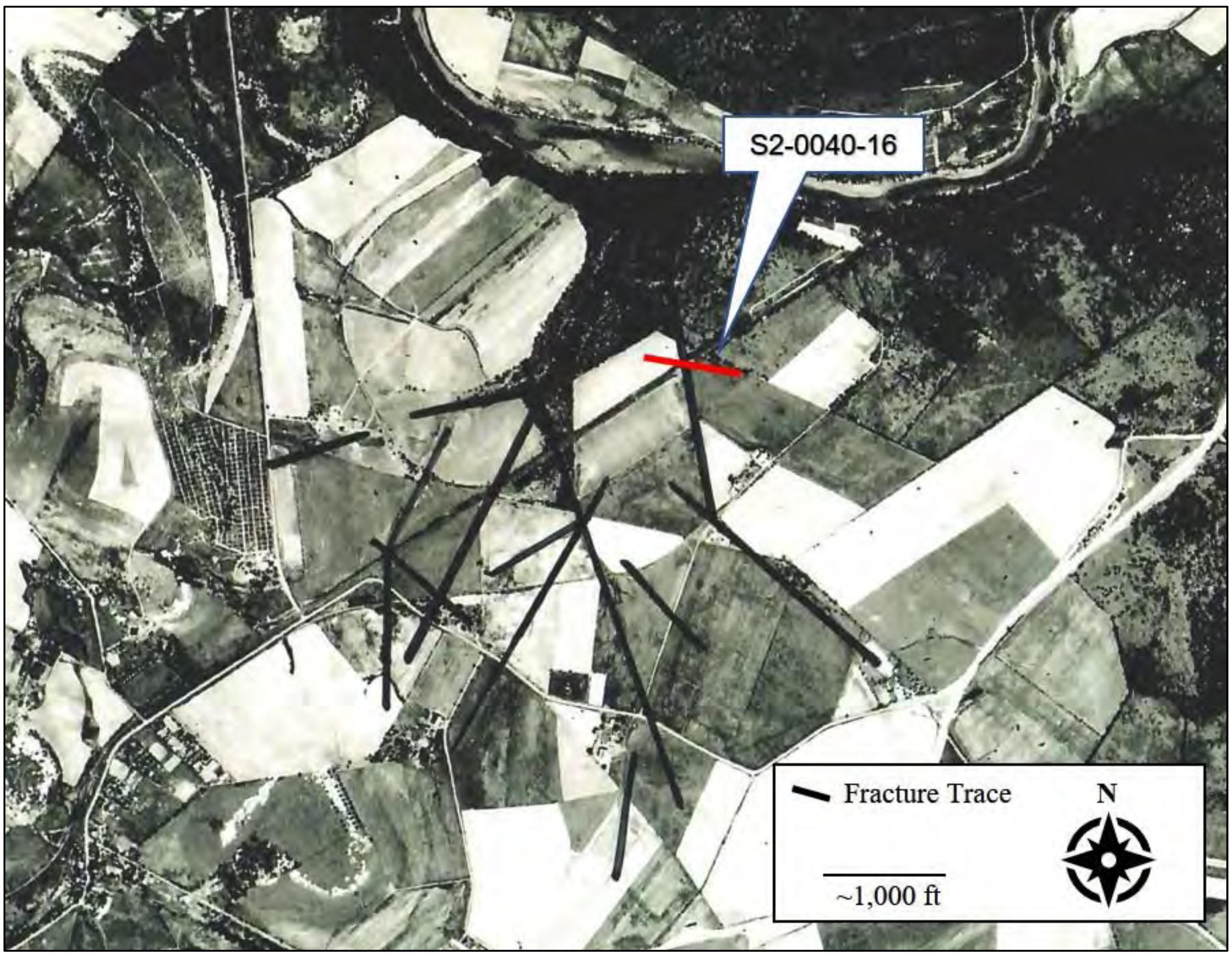


Figure 4. Fracture Trace Map

2.2.5 Karst

Based on published geologic data, no karst features are anticipated within the region of HDD S2-0040-16 as limestone units are relatively thin and discontinuous.

2.2.6 Mining

A review of published mining and geological data indicate that mining of the Upper Freeport coal in the vicinity of HDD S2-0040-16 has been completed as shown in **Figure 5**. The Penn State Mine Atlas (http://www.minemaps.psu.edu/) shows that HDD S2-0040-16 is within the limits of a room and pillar section of the Toms Run Mine operated by Rosebud Mining Company. Base of coal elevations below the revised HDD S2-0040-16 profile range from approximately 412 ft amsl at the western entry/exit to 445 ft amsl at the east entry/exit. The lowest elevation of HDD S2-0040-16 on the revised profile is 950 ft amsl at Station 6+81 as shown on the revised profile, approximately 505 feet above the highest floor elevation of the mine along the HDD S2-0040-16 drill path. The coal is approximately 5-feet thick within the mine; therefore, the shortest distance from the mine roof to the revised profile is approximately 500 feet.

Kendorksi (2006) delineated estimated extents of four zones above fracturing above deep mines, based on the thickness of the extracted coal. From bottom to top these include the Caved Zone (with extensive fracturing and sizeable voids), Fracture Zone (with fracturing, without extensive dislocation of rocks or voids), Dilation Zone (small fractures), and the Constrained Zone (with no rock fracturing related to mine subsidence). The maximum estimated extent of the Dilation Zone above the Tom Run Mine is 300 feet and the lowest part of the revised profile is 500 feet above the mine therefore the profile is within the Constrained Zone.

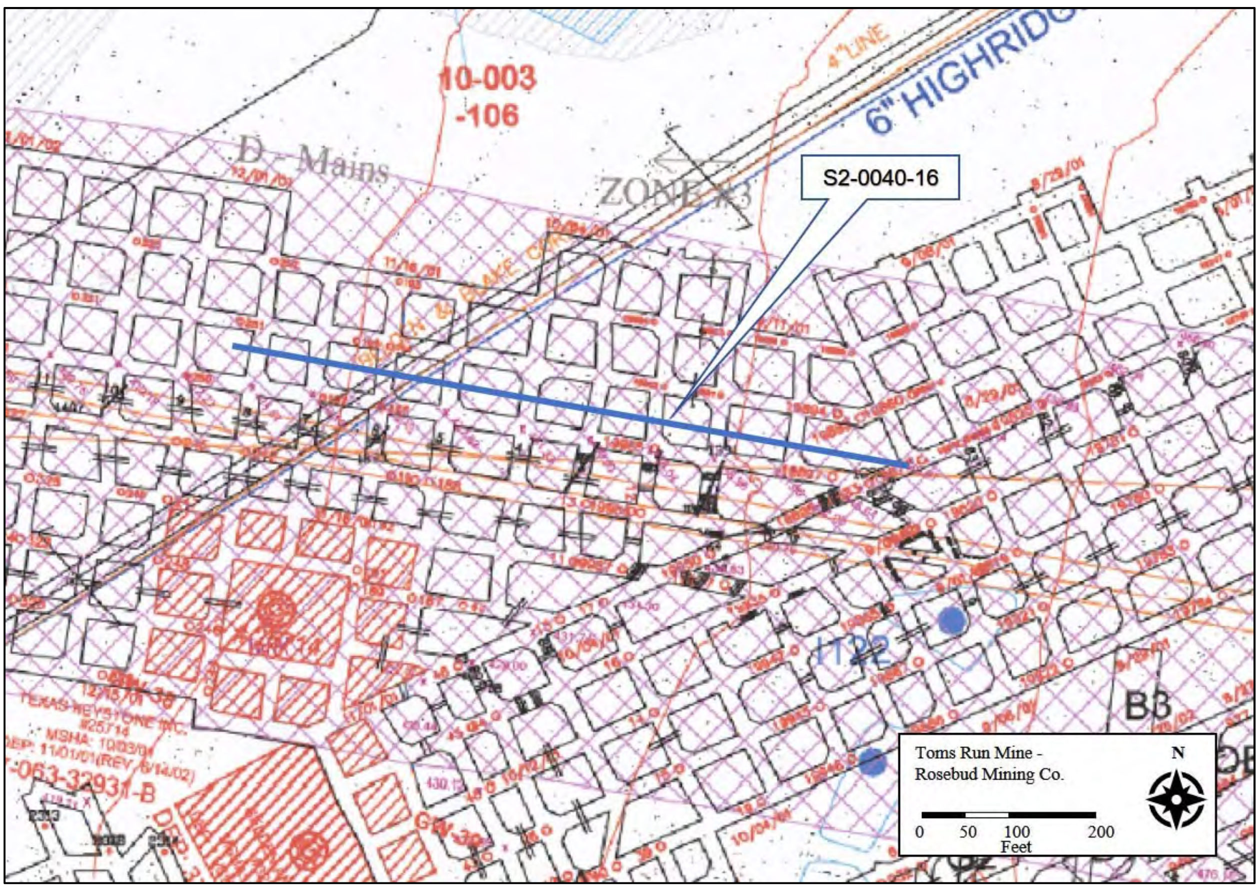


Figure 5. Limits of Upper Freeport Coal Seam Deep Mining Near HDD S2-0040-16 (modified from http://www.minemaps.psu.edu/)

2.2.7 Rock Engineering Properties

The Casselman Formation rock properties are as follows (Geyer and Wilshusen, 1982):

- Well-bedded; sandstone is thick bedded to massive; shale is thin and fissile; claystone bedding is very poor; limestone varies from nodular to well-bedded.
- Poor to moderately well-formed joints; open and vertical; moderately spaced and distributed.
- Moderate to fast drilling rate

2.2.8 Results of Geotechnical Borings

Original Borings
Two geotechnical borings (SB-01 and SB-02) were installed by Tetra Tech in September 2014 in support of the original HDD design. The locations for these borings are shown on both the original and revised plan and profiles in **Attachment A**. Boring SB-01 was augered to refusal at 11.5 ft bgs and is located at Station 1+00, 100 feet east of the western entry/exit point for the boring, with a surface elevation of approximately 1,032 ft amsl. Boring SB-02 was augered to refusal at 25.8 ft bgs and is located at Station 7+45, near the original eastern entry/exit location, with a surface elevation of approximately 1,025 ft amsl.

Unconsolidated overburden in both borings is comprised of silts and silty clayey soils. Weathered sandstone bedrock was encountered at the base of both borings. Groundwater was encountered in SB-02 at 10 ft bgs.

Recent Borings

Two additional geotechnical borings (B2-6E and B2-6W) were installed by Terracon in September 2017 in support of the HDD reevaluation.

.*B2-6E*
Boring B2-6E was advanced on September 21, 2017, at the eastern entry/exit location on the original plan and profile. This boring was located at a surface elevation of 1,026 ft amsl and installed to a depth of 84.6 ft bgs. Unconsolidated overburden was comprised of clay with trace gravel to 18.5 ft bgs. Weathered bedrock occurred from 18.5 to 28.6 ft bgs, prior to encountering competent bedrock. Bedrock cores were obtained from 28.6 to a total depth of 86.4 feet and contained shale, mudstone, and siltstone characteristic of the Casselman Formation. Core recoveries below 28.6 ft bgs, were high, ranging from 83 to 100 percent. Regarding rock quality index determination (RQD), core quality ranged from 30 to 100 percent, but did not necessarily increase with depth. Lower (less than 75 percent) RQD was observed from approximately 45 to 69 ft bgs where moderate to severe weathering was observed. A single water level measurement of 4.3 ft bgs was measured in B2-6E after the boring was completed.

B2-6W
Boring B2-6W, was advanced at the western entry/exit on the original profile for HDD S2-0040-16. This boring was located at an elevation of approximately 1,030 ft amsl and installed to a depth of 91.5 ft bgs. Unconsolidated overburden was logged as 1.5 feet of clay with gravel above 8.6 feet of weathered bedrock to 10.1 ft bgs. The cored rock at B2-6W showed similar recoveries and RQD values as B2-6E, with lower RQDs noted in intervals where moderate to severe weathering was observed. A high-angled fracture was observed within shale at 24 ft bgs. Two similar water level measurements collected during the advance of the boring at 24.0 and 24.6 ft bgs.

2.3 Hydrogeology

2.3.1 Occurrence of Groundwater
Groundwater in the bedrock aquifer below the land surface at HDD S2-0040-16 in Indiana County is stored and moves within a network of rock fractures and bedding plane partings. Regional systematic joints oriented northwest and west-northwest and may represent preferred pathways for groundwater flow.

Based on data contained in the geotechnical borings for HDD S2-0040-16, groundwater was encountered at approximately 24 ft bgs in boring B6-W near the west entry/exit, at approximately 4.3 ft bgs in boring B6-E near the east entry/exit (revised profile), and at 10 ft bgs in SB-02 at Station 7+45 near the eastern edge of wetland J-53. Perched groundwater, at or near the surface, was observed in wetland W-J53 from stream S-J58 east to Station 7+20 during the installation of the 20-inch pipe.

2.3.2 Groundwater Levels and HDD entry/exit elevations

The surface elevation of the west entry/exit for the both profiles is 1,030 ft amsl. The surface elevation of the eastern entry/exit on the original profile, at Station 7+80, is 1,027 ft amsl, whereas the surface elevation at the eastern entry/exit for the revised profile, over 550 feet to the east, is at approximately 1,052 ft amsl. If the water level elevations measured at the geotechnical borings are representative of local groundwater levels than the revised profile will be within groundwater for approximately 90 percent of the drill. Given the entry/exit elevations on the revised profile there is minimal risk of the HDD creating a groundwater discharge.

Pennsylvania Groundwater Information System (PaGWIS) reported five wells within a half mile of HDD S2-0040-16, but only one well is located within 1,000 feet of the revised profile. PA Well ID 117640 is a residential well located approximately 460 feet southeast of the eastern entry/exit on the original profile and is completed at 88 ft bgs. No static water level was reported for this well.

2.3.3 Well Yields

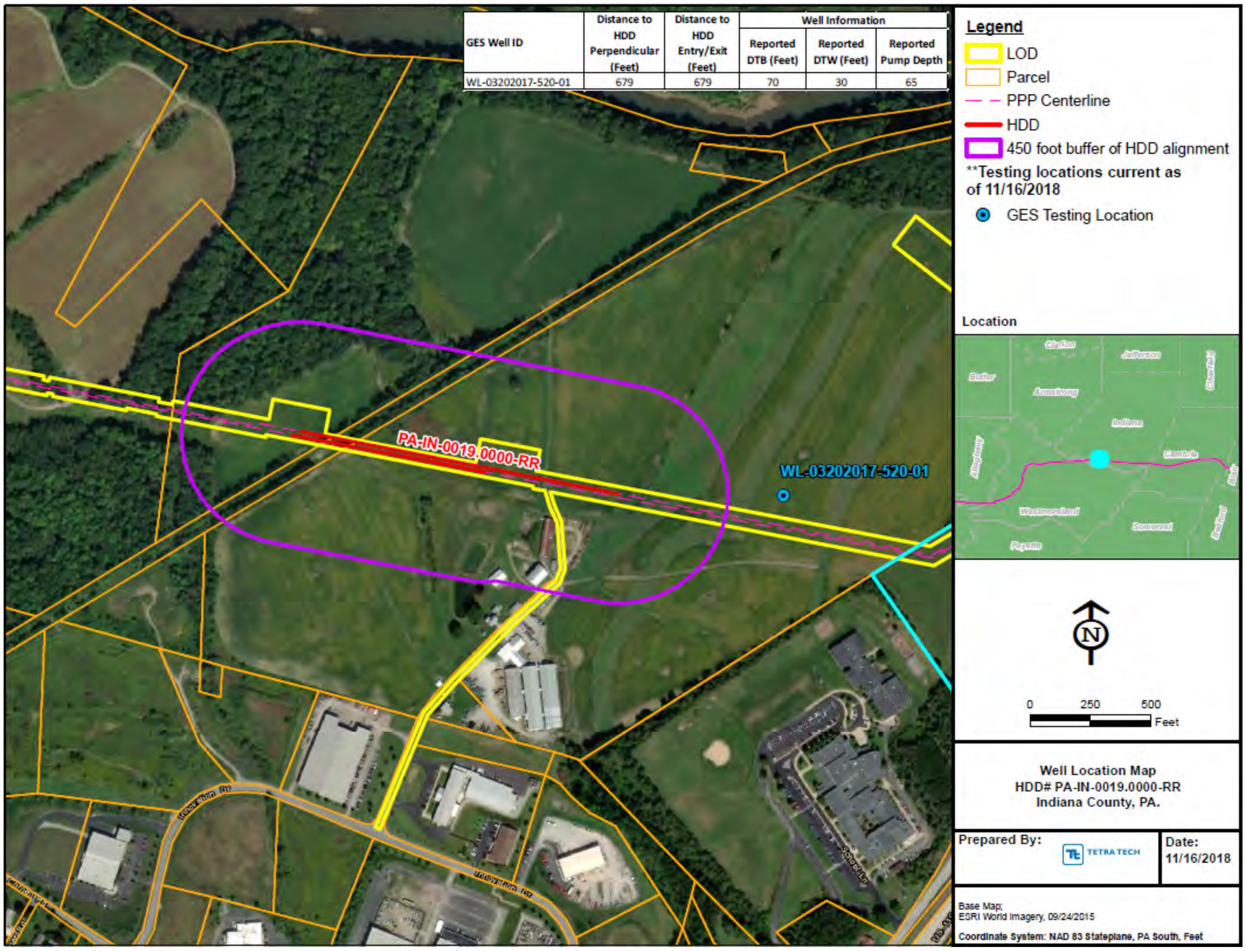
Published median well yields (Geyer and Wilshusen 1982) are highly variable depending on local effective porosity in the Conemaugh Group and have ranged from 1 to 357 gallons per minute (gpm). Based on the results of the PaGWIS database search, yields from wells drilled within a mile of HDD S2-0040-16 range from 5 to 25 gpm. The one well listed in PaGWIS within 1,000 feet of the HDD had a reported yield of 6 gpm. McElroy (1998) notes that the median yield for wells drilled into the Casselman formation is 10 gal/min with a range from 0 to 32 gal/min.

2.3.4 SPLP Water Supply Surveys

SPLP performed a survey of land owners within 450 feet of the ROW for the revised profile and no land owners responded positively to an offer to have their wells tested (see **Figure 6**). The PaGWIS database reports no water supply wells within 450 feet of the ROW (see **Section 2.3.3**). During the well testing program in March 2017, a water sample was collected from one private well (Sample WL-03202017-520-01) at a parcel located 1,230 feet east of the original eastern entry/exit of HDD S2-0040-16. The depth to water for this well was reported at 30 ft bgs.

2.4 Summary of Geophysical Studies

No geophysical studies were conducted for this reevaluation as there is no indication of karst development in the area and the Toms Run Upper Freeport deep coal mine is 500 feet and greater below the revised profile.



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-03202017-520-01	679	679	70	30	65

Figure 6. Water Supply Wells Sampled within 450 feet of ROW

3.0 OBSERVATIONS TO DATE

3.1 On This HDD Alignment

3.1.1 ME I

No IRs were reported along the alignment of the HDD S2-0040-16 drill on the list of IRs for ME I documented in the IR PPC Plan for Indiana County.

3.1.2 ME II

Drilling activities were initiated at HDD S2-0040-20 (the 20-inch HDD for this location) as part of the ME II pipeline installation on May 13, 2017 and completed on June 7, 2017. Two IRs were noted the first day of drilling, the first in wetland W-J53 along the drill path for HDD S2-0040-20, at approximately Station 6+54, and the second immediately upslope of stream S-J58, offset approximately 70 feet to the north of Station 4+70. Considering the orientation of wetland W-J53, it is possible that the second IR was part of the first IR. Drilling fluid could have followed the gradient of drainage in the wetland just beneath the land surface from the 1st IR to the 2nd IR (see **Figure 7**). Both IRs were contained using a combination of silt fence and a pump to recover drilling fluids and there was no impact to stream S-J58. Drilling resumed to completion using a higher viscosity drilling fluid with generally good returns for the remainder of the boring and there was no impact to stream S-J58.

At the time of the IRs the drill bit was less than 300 feet from the eastern entry/exit point. Soil boring SB-02 was installed at Station 7+45, approximately 90 feet east of the first IR, and is most representative of subsurface conditions at the IR locations. The log for geotechnical boring SB-02 shows 25.8 feet of unconsolidated overburden soil. Soil textures in the bottom 12 feet of SB-02 were logged as clayey silts with more decomposed rock content near the bottom of the boring.

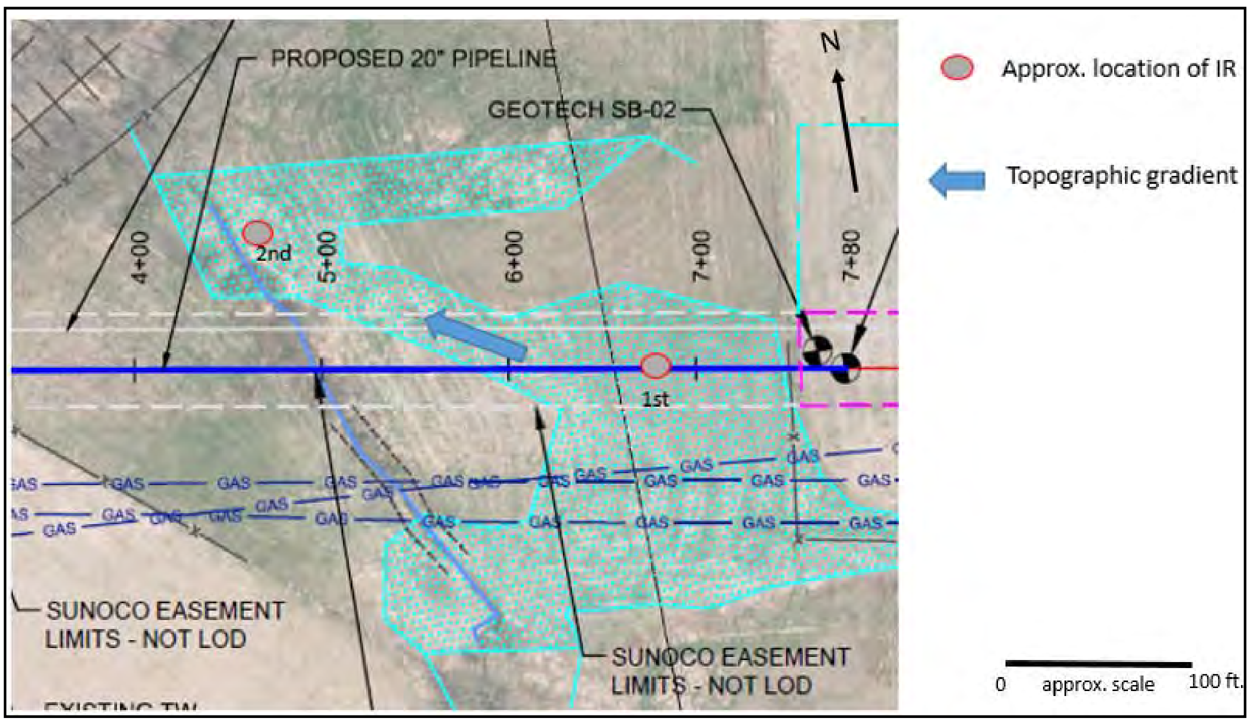


Figure 7. Location of Inadvertent Returns, ME II 20-inch HDD

The pilot boring was approximately 16 ft bgs at the Station 6+54 IR and approximately 25 ft bgs at the Station 4+70 IR, reflective of a relatively low entrance angle and shallow profile. Assuming SB-02 is representative of site conditions, the pilot boring would not have been in competent bedrock under the location of the 1st IR at Station 6+54. Therefore, the occurrence of the IRs in Wetland W-J53 during the installation of the 20-inch diameter pipeline at the Norfolk Southern Railroad/Kendall Rd. Crossing likely resulted from a depth of cover on the HDD entry radius that was too shallow while proceeding through clayey silt with weathered sandstone bedrock under the wetland.

3.2 On Other HDD Alignments in Similar Hydrogeologic Settings

3.2.1 ME I

No IRs were reported on the list of IRs for ME I documented in the IR PPC Plan for site underlain by Casselman Formation bedrock.

3.2.2 ME II

All of the IRs to date in Spreads 1 and 2 for the ME II pipeline have occurred while drilling through the cyclic sequences of sandstone, shale, limestone, clays seams and coal present within western Pennsylvania bedrock formations, including the Allegheny Group, Casselman Formation, Glenshaw Formation, Monongahela Group, and Waynesburg Formation. Entries and exits pass through alluvium, colluvium and soils developed on top weathered bedrock and mine spoils. In general, the IRs have been related to shallow overburden, coarse grained unconsolidated materials near the surface (such as alluvium and mine spoil), large elevation changes between entry/exits and the lowest elevation points along the profiles (sometimes creating soil plugs, elevated annular pressures and loss of fluids), and the interconnectivity of open bedrock structural features that is difficult to predict.

4.0 SUMMARY AND CONCLUSIONS

4.1 HDD Site Conceptual Model

Two IRs occurred during the drilling of the pilot bore for the 20-inch line. These occurred because the profile was shallow and the east entry/exit was at the eastern edge of wetland W-J53. The boring logs for SB-02 and B2-6E indicate that the pilot bore for the 20-inch line traveled over 150 feet under the wetland area before competent bedrock was encountered (see **Attachment A**). The original profile for the 16-inch line is similar to the as-built profile for the 20-inch line. The revised profile for HDD S2-0040-16 is relatively symmetric with entry/exits points located on elevated ground west and east of the flood plain of Stream S-J58 and wetland W-J53, central to the alignment. The angles of entry and exit on the original profile (10 and 11 degrees) are increased (13 and 14 degrees) on the revised profile. This revised profile shows a horizontal distance of 1,336 feet which represents an increase of 556 feet from the original profile. All of the additional proposed footage is east of the east entry/exit for the original profile. This allows for a deeper profile that encounters competent bedrock approximately 380 feet east of the eastern edge of wetland W-J53. On the revised profile the pilot boring will pass under the eastern edge of wetland W-J53 at a depth of 73 feet allowing for approximately 48 feet of competent rock above the profile at that location.

There is variability in bedrock strength below the weathered bedrock/competent bedrock horizon, which occurs approximately 30 feet bgs. Bedrock cores from geotechnical borings B2-6E and B2-6E were similar, containing shale, mudstone, and siltstone characteristic of the Casselman Formation. Core recoveries below the weathered bedrock horizon were high, ranging from 83 to 100 percent. Core RQDs ranged from 30 to 100 percent, but an increase in RQD with depth was not demonstrated. Less than 75 percent RQD was observed in weathered bedrock zones in each boring. A facture trace trending west-northwest was mapped transecting the alignment at approximately Station 2+00. Fracture traces represent potential zones of fracture concentration where weaker bedrock may be encountered. The Toms Run Upper Freeport deep coal mine is 500 feet and greater below the revised profile, placing the revised profile within the Constrained Zone, as defined by Kendorski (2006), with no additional bedrock fracturing caused by mine subsidence. HDD drilling methods should account for the demonstrated variability in bedrock strength. That said, the two IRs that occurred during the pilot bore for the 20-inch HDD were easily sealed by adjusting the weight of the drilling mud with no additional loss of fluids or IR activity throughout installation of the HDD.

A relatively high water table occurs close to land surface in the central part of the revised profile in the area of wetland W-J53 and stream S-J58 and it is anticipated that approximately 90 percent of the drill will be below the water table; however, elevated entry/exit points at both ends of the profile represent a very low risk of the HDD creating a groundwater discharge.

No domestic supply wells have been identified within 450-feet of the revised alignment, greatly reducing any risk of a water quality impact from the HDD.

4.2 Conclusions and Recommendations

The proposed revised profile for HDD S2-0040-16 represents several safeguards to reduce the risk of IRs similar to those that occurred during the pilot hole for the 20-inch HDD at this location. The entrance and exit angles are steeper, the profile is longer and deeper, and the pilot hole will be well within competent rock when it passes beneath wetland W-J53 and stream S-J58. Drilling procedures should account for the variability in bedrock strength. This includes the immediate suspension of drilling activity and assessment at the initial signs for fluid loss that was implemented by the ME II HDD program in the summer of 2018. There is very little risk to private and public water supplies from implementing the revised profile for HDD S2-0040-16 given the distance from the HDD to any of these supplies.

5.0 REFERENCES

Bragonier and Glover, A. D, (1996), *Coal Resources of Indiana County, Pennsylvania – Part 1, Coal Crop Lines, Mined Out Areas, and Structure Contours*. Pa. Geol. Surv., 4th. Ser., M-98.

Geyer, A. R. and J. P. Wilshusen, (rev. 1982) *Engineering Characteristics of the Rocks of Pennsylvania.* PaDER, ORM, Pa Geol. Surv., 4th ser., EGR-1.

Kendorski, F. S. (2006) Effect of Full-Extraction Underground Mining on Ground and Surface Waters a 25-Year Retrospective, 25th International Conference on Ground Control Mining, Morgantown WV 2006.

McElroy, T. A. (1998), *Groundwater resources of Cambria County, Pennsylvania*, Pa. Geol. Surv., 4th. Ser., W67.

McElroy, T. A. (1998), *Geological Map of Cambria County, Pennsylvania, Showing the Locations of Selected Wells and Springs, in Groundwater Resources of Cambria County, Pennsylvania*, Pa. Geol. Surv., 4th. Ser., W67.

Nickelsen, R. P. and Hough, V. D. (1967) *Jointing in the Appalachian Plateau of Pennsylvania*, GSA Bull. v. 78, p. 609-630.

PA DCNR (Department of Conservation and Natural Resources) Map Viewer (http://www.gis.dcnr.state.pa.us/maps/index.html).

PAGWIS, Pennsylvania Groundwater Information System (http://dcnr.state.pa.us/topogeo/groundwater/pagwis/records/index.htm).

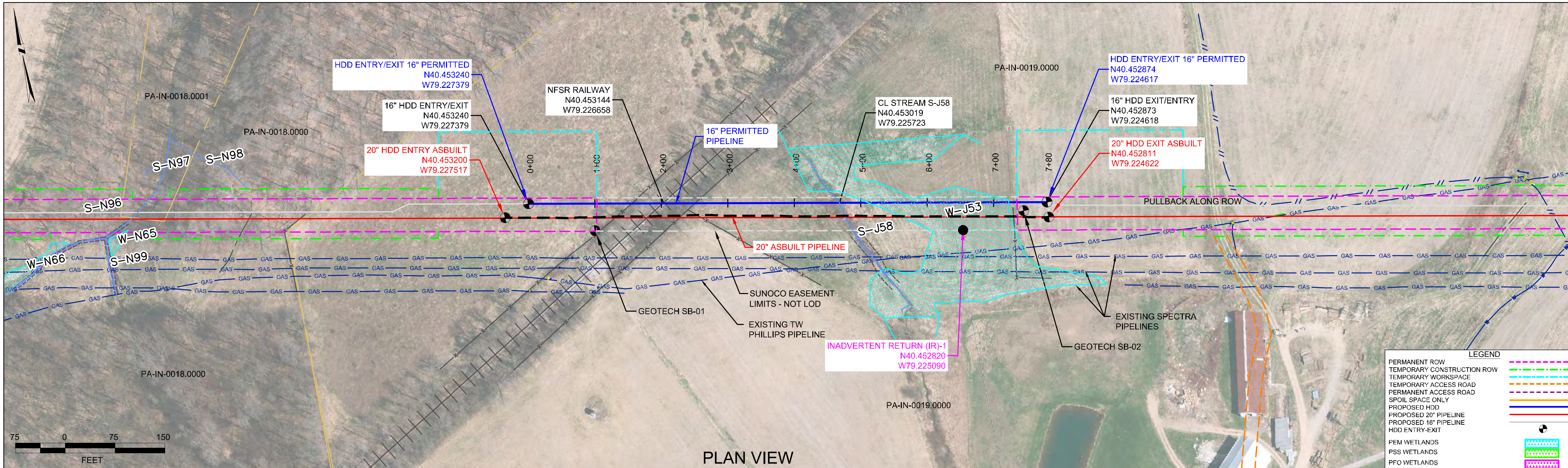
Penn State Mine Atlas (http://www.minemaps.psu.edu).

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

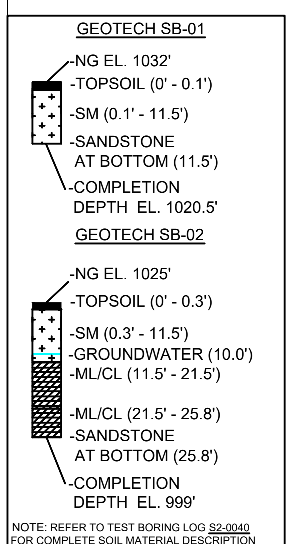
USGS (United States Geological Survey), Bolivar, Pennsylvania, 1:24,000 topographic quadrangle map, rev. 1982.

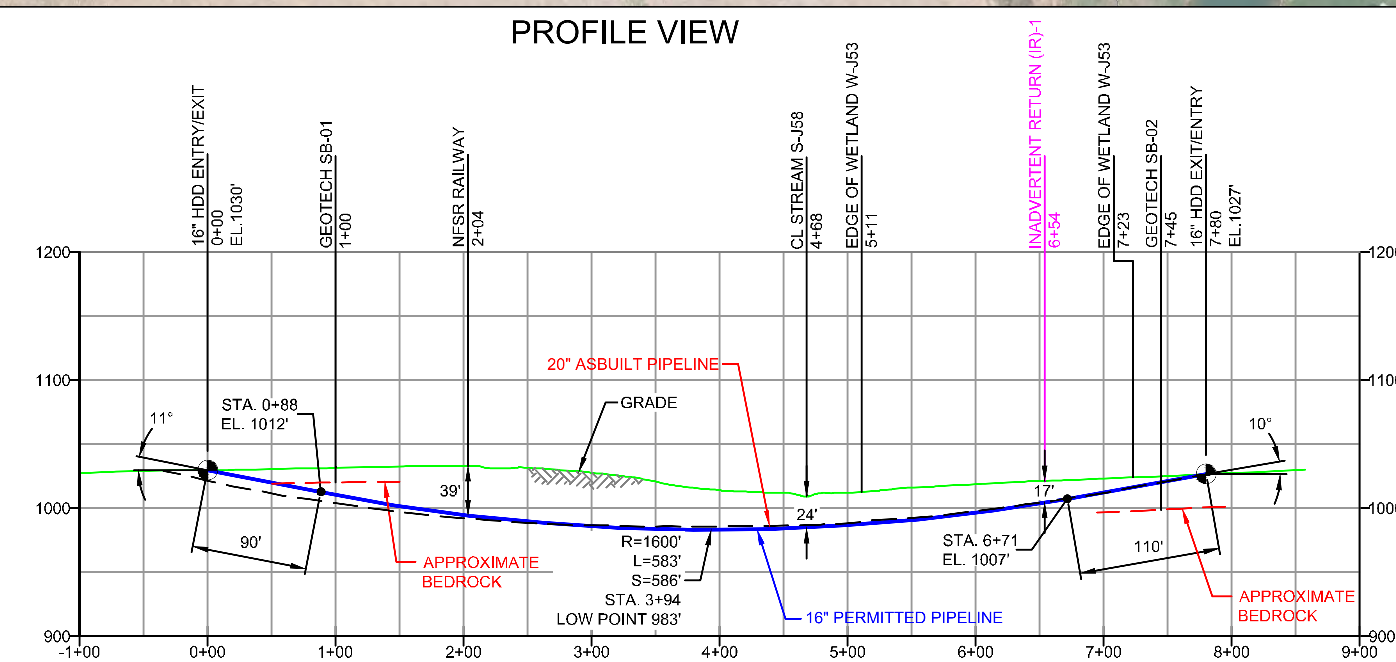
Attachment A

Original and Revised Plans and Profiles



INDIANA COUNTY, PENNSYLVANIA - BURRELL TOWNSHIP
S2-0040-16





DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):780'
   HDD PIPE LENGTH (S=):786'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. PIPELINE AND CROSSING TO BE INSTALLED AND MAINTAINED IN ACCORDANCE WITH LAST APPROVED AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION SPECIFICATIONS FOR PIPELINES CONVEYING FLAMMABLE AND NON-FLAMMABLE SUBSTANCES.
12. BLASTING NOT PERMITTED.
13. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.

PRELIMINARY EXHIBIT 3 IR HDD

NOTES

1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
2. STATIONING IS BASED ON HORIZONTAL DISTANCES.
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5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
3	REVISED PROFILE WITH 2017 LIDAR	MRS	03/17/17	RMB	03/17/17	CAG	03/17/17
2	REVISED PER ENGINEERING COMMENTS	MRS	08/26/16	RMB	08/26/16	AAW	08/26/16
1	REDESIGN	MRS	03/03/16	RMB	03/03/16	AAW	03/03/16
0	ISSUED FOR CONSTRUCTION	MRS	12/21/15	RMB	12/21/15	AAW	12/21/15

Sunoco Logistics Partners L.P.

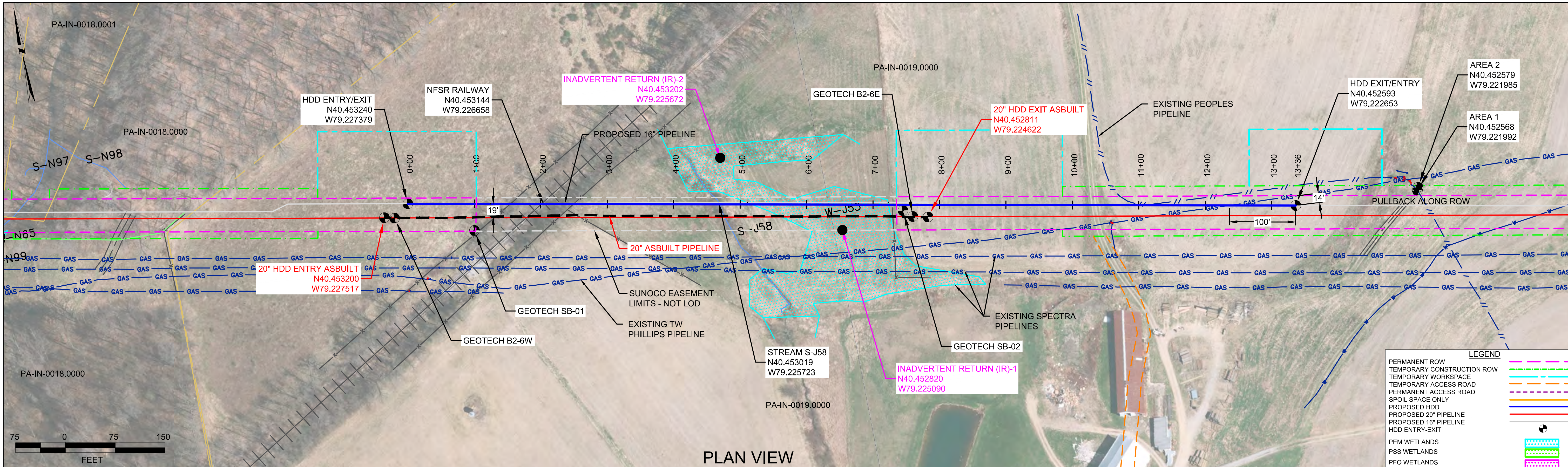
TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
NORFOLK SOUTHERN RAILROAD
PENNSYLVANIA PIPELINE PROJECT

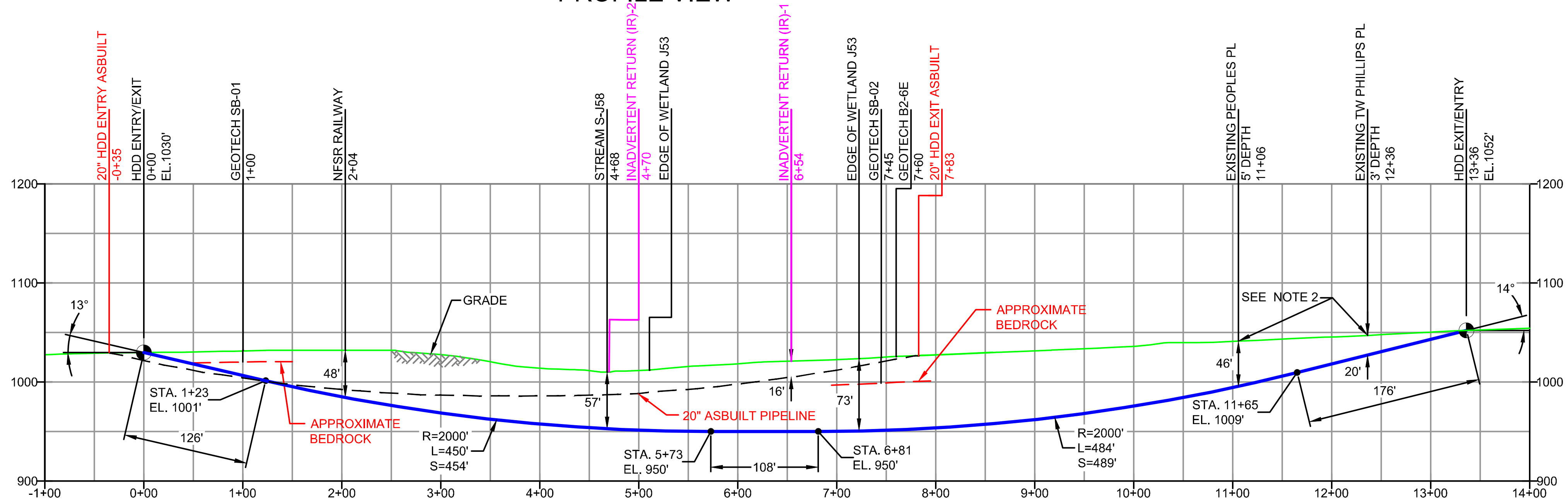
SCALE: 1"=150'

DWG. NUMBER: PA-IN-0019.0000-RR-16 IR EXH



INDIANA COUNTY, PENNSYLVANIA - BURRELL TOWNSHIP
S2-0040-16

PROFILE VIEW



GEOTECH SB-01

- NG EL. 1032'
- TOPSOIL (0' - 0.1')
- SM (0.1' - 11.5')
- SANDSTONE AT BOTTOM (11.5')
- COMPLETION DEPTH EL. 1020.5'

GEOTECH SB-02

- NG EL. 1025'
- TOPSOIL (0' - 0.3')
- SM (0.3' - 11.5')
- GROUNDWATER (10.0')
- ML/CL (11.5' - 21.5')
- ML/CL (21.5' - 25.8')
- SANDSTONE AT BOTTOM (25.8')
- COMPLETION DEPTH EL. 999'

NOTE: REFER TO TEST BORING LOG S2-0040 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B2-6W

- NG EL. 1030'
- SANDY LEAN CLAY CL (0.0' - 1.5')
- GROUNDWATER (24.6')
- SHALE/MUDSTONE /SANDSTONE (1.5' - 91.5')
- BORING TERMINATED EL.938.5'

NOTE: REFER TO TEST BORING LOG B2-6W TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B2-6E

- NG EL. 1026'
- GROUNDWATER (4.3')
- SANDY LEAN CLAY CL (0.0' - 13.5')
- LEAN CLAY CL (13.5' - 18.5')
- SHALE/MUDSTONE /SANDSTONE (1.5' - 86.4')
- BORING TERMINATED EL.939.6'

NOTE: REFER TO TEST BORING LOG B2-6E TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

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3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):1336'
   HDD PIPE LENGTH (S=):1353'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 2100 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 2625 PSIG.
11. PIPELINE AND CROSSING TO BE INSTALLED AND MAINTAINED IN ACCORDANCE WITH LAST APPROVED AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION SPECIFICATIONS FOR PIPELINES CONVEYING FLAMMABLE AND NON-FLAMMABLE SUBSTANCES.
12. BLASTING NOT PERMITTED.
13. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.

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

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-2.13	TO	ES-2.14	EROSION & SEDIMENT PLAN
SHEET 9	TO	SHEET 9	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	EXTENDED DRILL DESIGN LENGTH	MRS	11/13/18	RMB	11/13/18	CAG	11/13/18
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	JTW	05/06/16	RMB	05/06/16	AAW	05/06/16
EP		DLM	03/15/16	RMB	03/15/16	AAW	03/15/16
B	ADDED GEOTECH INFO	MRS	09/07/15	RMB	09/07/15	AAW	09/07/15
A	ISSUED FOR REVIEW	DLM	08/14/15	RMB	08/14/15	AAW	08/14/15

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

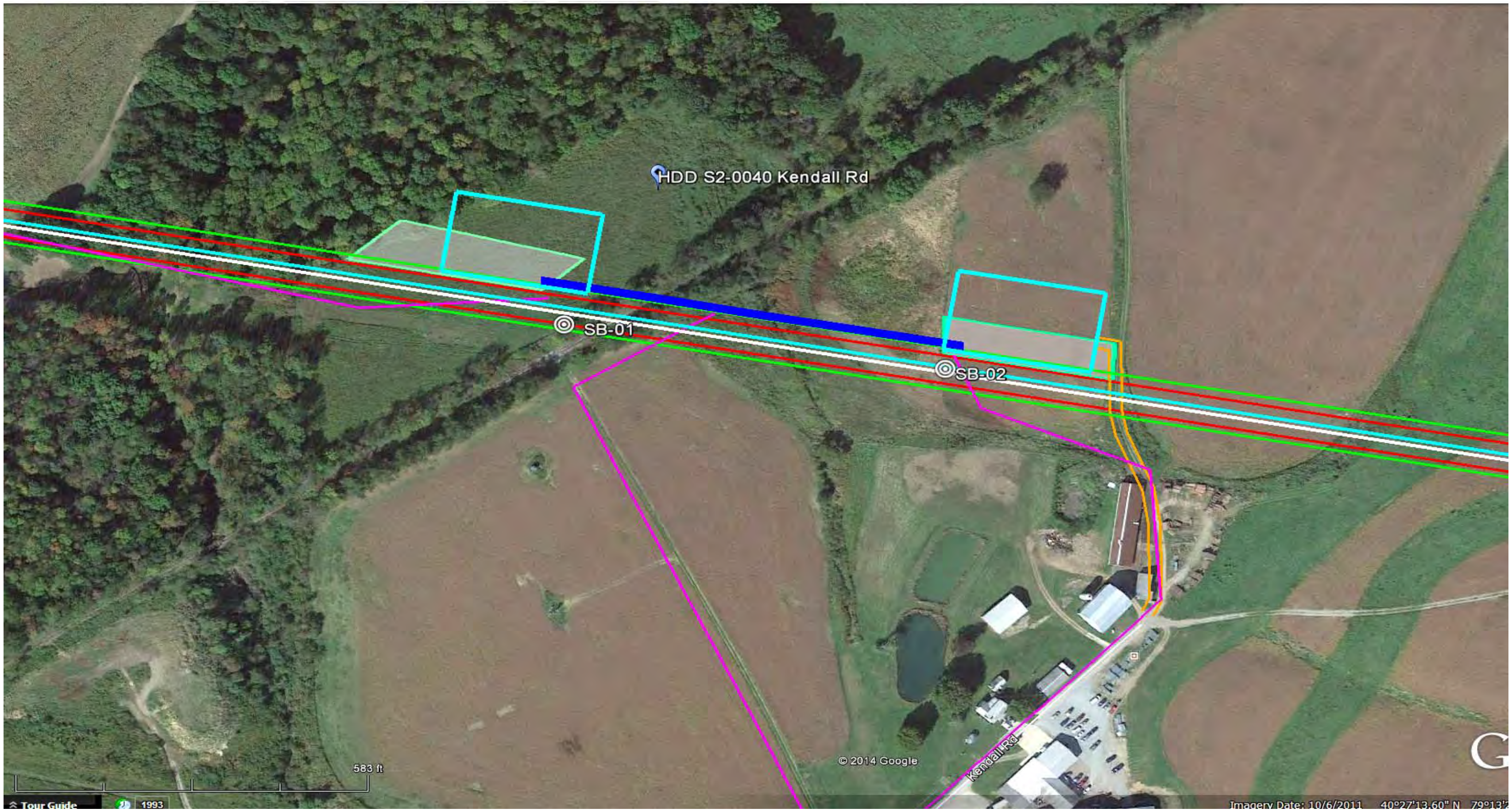
16-INCH HORIZONTAL DIRECTIONAL DRILL
NORFOLK SOUTHERN RAILROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=150'

DWG. NO: PA-IN-0019.0000-RR-16

Attachment B

Geotechnical Reports



LEGEND:

Geotechnical Soil Boring (SB) Locations

TETRA TECH

GEOTECHNICAL BORING LOCATIONS
HDD S2-0040
INDIANA COUNTY, BURRELL TOWNSHIP, PA
SUNOCO PENNSYLVANIA PIPELINE PROJECT

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

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406	
Project Location:	KENDALL ROAD, BLAIRSVILLE, PA			Page 1 of 1	
HDD No.:	S2-0040	Dates(s) Drilled: 09-25-14		Inspector:	E. WATT
Boring No.:	SB-01	Drilling Method: SPT - ASTM D1586		Driller:	S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED		Total Depth (ft):	11.5

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.1			TOPSOIL (1").					
1	3.0	3.9	0.1		8	SM	LIGHT BROWN FINE TO MEDIUM SAND WITH SOME SILT, AND A LITTLE	2	50/5"			**>50**
							F-C SANDSTONE GRAVEL.					
2	8.0	8.8			7		LIGHT BROWN FINE TO MEDIUM SAND WITH A LITTLE SILT, AND SOME	3	50/4"			**>50**
							F-C SANDSTONE GRAVEL.					
3	10.0	10.6			6		LIGHT BROWN FINE TO MEDIUM SAND WITH A LITTLE SILT, AND SOME	3	50/2"			**>50**
				11.5			F-C SANDSTONE GRAVEL.					
							AUGUR REFUSAL AT 11'. AUGURED OFF-SET BORING TO AUGER					
							REFUSAL AT 11.5'.					
							CAVED AND DRY AT 9'.					
							PLACED CONCRETE PLUGS.					

Notes/Comments:

Pocket Pentrometer Testing

DR: DECOMPOSED ROCK

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

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

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

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406	
Project Location:	KENDALL ROAD, BLAIRSVILLE, PA			Page 1 of 1	
HDD No.:	S2-0040	Dates(s) Drilled: 10-08-14		Inspector:	E. WATT
Boring No.:	SB-02	Drilling Method: SPT - ASTM D1586		Driller:	S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): 10.0		Total Depth (ft):	25.8

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.3			TOPSOIL (4").					
1	3.0	5.0	0.3		4	SM	ORANGE BROWN FINE SAND WITH SOME SILT AND SOME FINE	2	11	12	14	**23**
							TO COARSE SANDSTONE GRAVEL.					
2	8.0	10.0			24		DR WEATHERED TO A ORANGE BROWN FINE TO MEDIUM SAND, WITH	4	7	9	7	**16**
				11.5			SOME SILTY CLAY, AND A LITTLE FINE SANDSTONE GRAVEL.					
3	13.0	15.0	11.5		13	ML/CL	MOTTLED (ORANGE BROWN, BROWN, GRAY) CLAYEY SILT.	2	4	5	9	**9**
4	18.0	20.0			24		DR WEATHERED TO A MOTTLED (VARI-COLORED) CLAYEY SILT	1	7	20	50	**27**
				21.5			(USCS: ML/CL).					
5	23.0	24.3	21.5		17	ML/CL	DR WEATHERED TO A REDDISH BROWN CLAYEY SILT.	2	35	50/4"		**>50**
6	25.0	25.8		25.8	5		DR WEATHERED TO A REDDISH BROWN CLAYEY SILT.	2	50/4"			**>50**
							AUGER REFUSAL AT 25'.					
							WET ON SPOON AT 16'					
							WATER LEVEL THRU AUGERS AT 10'					
							CAVED AT 25'					
							WATER LEVEL ON TOP OF CAVE AT 10'.					
							PLACED CONCRETE PLUG.					

Notes/Comments:

Pocket Pentrometer Testing
S4: 2.5 TSF
S3: 1.75 TSF

DR: DECOMPOSED ROCK

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

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

GEOTECHNICAL LABORATORY TESTING SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S2-0040

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, %	
S2-0040	SB-01	1	3.0	3.9	6.0	21.4	-	-	-	-
		2	8.0	8.8	5.8	14.2	-	-	-	-
		3	10.0	10.6	4.2	10.6	-	-	-	-
	SB-02	1	3.0	5.0	8.7	27.7	-	-	-	-
		2	8.0	10.0	15.4	25.9	-	-	-	-
		3	13.0	15.0	19.0	98.2	-	-	-	-
		4	18.0	20.0	20.0	94.8	33	24	9	ML/CL
		5	23.0	24.3	13.1	95.5	-	-	-	-

Notes:

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

REGIONAL GEOLOGY SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S2-0040

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
S2-0040	Kendall Road	SB-01	**Casselman Formation** - Cyclic sequences of shale, siltstone, sandstone, red beds, thin, impure limestone, and thin, nonpersistent coal; red beds are associated with landslides; base is at top of Ames limestone.	Upland to mid-ridge	Casselman	Shale-siltstone, sandstone; clastic; limestone; coal	236-525	5-30	
		SB-02							

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

FIELD DESCRIPTION AND LOGGING SYSTEM FOR SOIL EXPLORATION

GRANULAR SOILS

(Sand, Gravel & Combinations)

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

Relative Proportions

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

Particle Size Identification

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

COHESIVE SOILS

(Silt, Clay & Combinations)

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

Plasticity

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

ROCK

(Rock Cores)

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

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

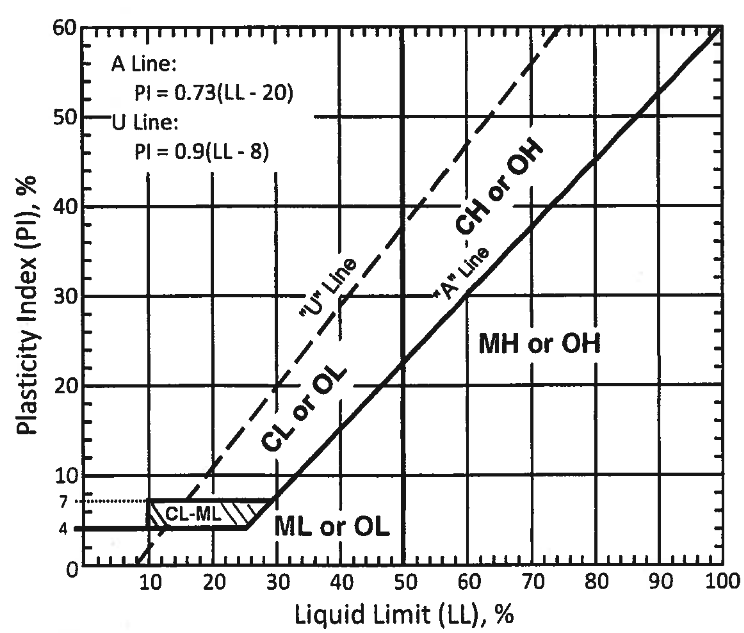
Groundwater observations were made at the times indicated. Groundwater elevations fluctuate throughout a given year, depending on actual field porosity and variations in seasonal and annual precipitation.

UNIFIED SOIL CLASSIFICATION SYSTEM [Casagrande (1948)]

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

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

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



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

October 17, 2017

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

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

Re: Geotechnical Site Characterization
Mariner East 2 Pipeline Project
Spread 2 – Norfolk Southern RR
Commonwealth of Pennsylvania
Drawing # PA-IN-0019.0000RR
PO # 20170912-1
Terracon Project No. J217P078

Dear Mr. Sessions:

This letter provides a summary of the bedrock characterization for the Mariner East 2 Pipeline Project crossing to be located at Norfolk Southern RR (Drawing # PA-IN-0019.0000RR) in the Commonwealth of Pennsylvania. Our services were performed in general accordance with our proposal number PJ2175108 dated July 28, 2017. Our scope of services included advancing two borings, designated as B2-6W and B2-6E, visual classification and photography of the rock core samples, and laboratory testing of representative rock samples.

Test borings, B2-6W and B2-6E were drilled between September 19 and 22, 2017 to depths of 91.5 and 86.4 feet, respectively as shown on the attached **Test Boring Location Plan**. Bedrock typically consisted of interlayered sedimentary rock comprised of sandstone, siltstone, mudstone, and shale. Final test boring logs documenting overburden soil and bedrock conditions as well as photographs of the rock core samples are attached.

Rock compressive strength testing was performed on samples from approximately 20-foot intervals within the bedrock strata at each boring location. Unconfined compressive strength test results are shown on the attached reports.

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

Sincerely,
Terracon Consultants, Inc.

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

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

Attch:

TEST BORING LOCATION PLAN
EXPLORATION RESULTS (Boring Logs, Laboratory Data, Rock Core Photographs)
SUPPORTING INFORMATION (Unified Soil Classification System, Description of Rock Properties)

TEST BORING LOCATION PLAN

N

APPROXIMATE BORING LOCATION

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

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

Terracon
Consulting Engineers & Scientists
201 Hammer Mill Road Rocky Hill, Ct 06067
PH. (860) 721-1900 FAX. (860) 721-1939

TEST BORING LOCATION PLAN

Norfolk Southern RR HDD Cores B2-6W and B2-6E

PA-IN-0019.0000RR

Indiana County, Pennsylvania

Exhibit

A-2

EXPLORATION RESULTS

BORING LOG NO. B2-6W Norfolk Southern RR West

PROJECT: Mariner East Pipeline Borings

SITE: Spread 2

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

LOCATION PA-IN-0019.0000RR
20170912-1
Latitude: 40.453191° Longitude: -79.227463°

Approximate Surface Elev: 1030 (Ft.) +/-

DEPTH	DESCRIPTION	ELEVATION (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
1.5	**SANDY LEAN CLAY (CL)**, with gravel, brown	1028.5+/-							
10.1	Weathered rock, gray to brown, very dense	1020+/-			12	17-30-50/3"			
					1	50/1"			
11.5	Run 1, Moderately hard, slightly weathered, gray, fine to medium-grained SANDSTONE, thin bedding, primary joint set, low angle, very close spacing, slightly open, planar, rough, iron-stained; secondary joint set, moderately dipping, close spacing, slightly open, planar, rough, iron-stained	1018.5+/-			16		0	0.75 0.5	
16.5	Run 2, Similar to 12 feet At 12 feet: Moderately hard, fresh, gray, fine to medium-grained, micaceous SANDSTONE, thin bedding, primary joint set, low angle, very close to close spacing, slightly open, planar, rough, fresh	1013.5+/-			60		58	0.25 0.25 0.5 0.5 0.5	
21.5	Run 3, Similar	1008.5+/-			60		73	0.5 0.5 0.5 0.5 0.5	
26.5	Run 4, Similar to 23.5 feet From 23.5 to 26.1 feet: Moderately hard, slightly weathered, gray, SHALE interbedded with siltstone, very thin bedding, primary joint set, low angle, close to very close spacing, slightly open, planar, rough, fresh From 24.1 to 24.5 feet: High angle, rough, healed, iron-stained joint	1003.5+/-			60		50	0.25 0.5 0.75 0.75 1	
	At 26.1 feet: Moderately hard, fresh, gray, fine to medium-grained, micaceous SANDSTONE, thin bedding, primary joint set, low angle, close to moderately close spacing, slightly open, planar, rough, fresh Run 5, Similar				60		84	0.5 0.5 0.25 0.5	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS

Not encountered on 9/20/17
24' on 9/21/17
24.6' AB

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-19-2017	Boring Completed: 09-21-2017
Drill Rig: Diedrich D-50	Driller: Terra Testing, Inc.
Project No.: J217P078	Exhibit: A-1

BORING LOG NO. B2-6W Norfolk Southern RR West

PROJECT: Mariner East Pipeline Borings

SITE: Spread 2

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

LOCATION PA-IN-0019.0000RR 20170912-1
Latitude: 40.453191° Longitude: -79.227463°

Approximate Surface Elev: 1030 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
31.5	Run 5, Similar *(continued)*	998.5+/-				60			0.5	
36.5	Run 6, Similar From 32.7 to 33.6 feet: Argillaceous, carbonaceous zone	993.5+/-	35			60		78	0.5 0.5 0.5 0.5 0.5	
41.5	Run 7, Similar	988.5+/-	40			60		85	0.75 1 0.5 0.25 0.5	
46.5	Run 8, Similar to 41.7 feet At 41.7 feet: Soft to moderately hard, moderately weathered, gray, MUDSTONE with occasional calcareous nodules, very thin bedding, primary joint set, moderately dipping, close spacing, planar, tight, slickensided	983.5+/-	45			60		60	0.5 0.75 1 1.5 1.75	
51.5	Run 9, Similar	978.5+/-	50			60		53	1.75 1.25 2.25 1.25 1.25	
56.5	Run 10, Similar	973.5+/-	55			60		66	1.5 1.75 1.75 1.5 2	
	Run 11, Similar to 59.8 feet At 59.8 feet: Moderately hard, fresh, gray SHALE interbedded with siltstone, very thin bedding, primary joint set, low angle, moderately close spacing, slightly open, planar, smooth, fresh		60			60		57	2 1.5 2 2	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS

Not encountered on 9/20/17

24' on 9/21/17

24.6' AB

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-19-2017	Boring Completed: 09-21-2017
Drill Rig: Diedrich D-50	Driller: Terra Testing, Inc.
Project No.: J217P078	Exhibit: A-1

BORING LOG NO. B2-6W Norfolk Southern RR West

PROJECT: Mariner East Pipeline Borings

SITE: Spread 2

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

LOCATION PA-IN-0019.0000RR 20170912-1
Latitude: 40.453191° Longitude: -79.227463°

Approximate Surface Elev: 1030 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
61.5		968.5+/-	60			1.5	
66.5	Run 12, Similar	963.5+/-	60		100	1.5 1 1.25 1.25 1.25	
71.5	Run 13, Similar	958.5+/-	60		95	1 1.25 0.75 1 1.25	
76.5	Run 14, Similar to 73.7 feet, moderately dipping joint at 71.7 feet At 73.7 feet: Soft, severely weathered, reddish brown to gray MUDSTONE interbedded with shale with occasional calcareous nodules, very thin bedding, primary joint set, moderately dipping, moderately close spacing, tight, planar, fresh, slickensided; secondary joint set, low angle, close to very close spacing, slightly open, planar, rough	953.5+/-	52		50	1.25 1.25 1.75 1.75 1.75	
81.5	Run 15, Similar	948.5+/-	55		32	1.25 1.25 2 2 1.75	
86.5	Run 16, Similar	943.5+/-	60		72	1 1 1.25 1.5 1.75	
	Run 17, Similar From 87.4 to 88.8 feet: Calcareous conglomeratic zone, moderately hard		53		35	1.25 1.25 1.75 1.75	

Depth scale (Ft.): 65, 70, 75, 80, 85, 90

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS
Not encountered on 9/20/17
24' on 9/21/17
24.6' AB

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-19-2017	Boring Completed: 09-21-2017
Drill Rig: Diedrich D-50	Driller: Terra Testing, Inc.
Project No.: J217P078	Exhibit: A-1

BORING LOG NO. B2-6W Norfolk Southern RR West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

SITE: Spread 2

LOCATION PA-IN-0019.0000RR
20170912-1
Latitude: 40.453191° Longitude: -79.227463°

Approximate Surface Elev: 1030 (Ft.) +/-

GRAPHIC LOG	DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	91.5	938.5+/-				53			2	

Boring Terminated at 91.5 Feet

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS

Not encountered on 9/20/17

24' on 9/21/17

24.6' AB

201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-19-2017	Boring Completed: 09-21-2017
Drill Rig: Diedrich D-50	Driller: Terra Testing, Inc.
Project No.: J217P078	Exhibit: A-1

BORING LOG NO. B2-6E Norfolk Southern RR East

PROJECT: Mariner East Pipeline Borings

SITE: Spread 2

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

LOCATION PA-IN-0019.0000RR
20170912-1
Latitude: 40.452824° Longitude: -79.224702°

Approximate Surface Elev: 1026 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)
0 - 13.5	**SANDY LEAN CLAY (CL)**, trace gravel, brown, very soft	1012.5+/-
13.5 - 18.5	**LEAN CLAY (CL)**, trace gravel, brown, medium stiff	1007.5+/-
18.5 - 28.6	Weathered rock, reddish brown to gray, dense to very dense	997.5+/-

DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
3.5 - 5	▽	X	11	woh-1-1 N=2			0.25
8.5 - 10		X	18	1-1-1 N=2			0.25
12.5 - 14		X	10	3-3-5 N=8			1.25
18.5 - 20		X	12	11-17-20 N=37			NA
22.5 - 24		X	18	26-26-42 N=68			NA
28.6 - 30			2	50/2"			NA
			30			0.75	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS

▽ *4.3' AB*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-21-2017	Boring Completed: 09-22-2017
Drill Rig: Diedrich D-50	Driller: Terra Testing, Inc.
Project No.: J217P078	Exhibit: A-2

BORING LOG NO. B2-6E Norfolk Southern RR East

PROJECT: Mariner East Pipeline Borings

SITE: Spread 2

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

LOCATION PA-IN-0019.0000RR 20170912-1

Latitude: 40.452824° Longitude: -79.224702°

Approximate Surface Elev: 1026 (Ft.) +/-

GRAPHIC LOG	DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Run 1, Soft, severely weathered, gray to reddish brown MUDSTONE with occasional calcareous nodules, very thin bedding, primary joint set, low angle, very close spacing, planar, rough, tight, clay-filled 31.4	994.5+/-				30		56	0.75 0.75	
	At 29.7 feet: Moderately hard, slightly weathered, gray SHALE interbedded with siltstone and sandstone, very thin bedding, primary joint set, low angle, moderately close to close spacing, slightly open, planar, smooth, fresh *(continued)* Run 2, Similar 36.4	989.5+/-	35			60		100	0.75 0.5 0.75 1 1.25	
	Run 3, Similar 41.4	984.5+/-	40			60		100	1.25 1 1.25 1 1	
	Run 4, Similar to 45.3 feet At 45.3 feet: Soft to moderately hard, moderately severely weathered, reddish brown to gray MUDSTONE with occasional calcareous nodules, very thin bedding, primary joint set, moderately dipping, close spacing, tight, planar, slickensided, fresh; secondary joint set, low angle, close to very close spacing, tight to slightly open, planar, rough, fresh 46.4	979.5+/-	45			54		67	1 1.25 1 1 1.5	
	Run 5, Similar From 48.3 to 49.4 feet: Hard, calcareous zone 51.4	974.5+/-	50			54		38	1.25 1.75 1.25 0.75 1.5	
	Run 6, Similar 56.4	969.5+/-	55			60		58	1.5 1 1.75 1.5 1.75	
	Run 7, Similar		60			56		30	1.5 1.25 1.25 1.75	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS

4.3' AB

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-21-2017	Boring Completed: 09-22-2017
Drill Rig: Diedrich D-50	Driller: Terra Testing, Inc.
Project No.: J217P078	Exhibit: A-2

BORING LOG NO. B2-6E Norfolk Southern RR East

PROJECT: Mariner East Pipeline Borings

SITE: Spread 2

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

LOCATION PA-IN-0019.0000RR 20170912-1
Latitude: 40.452824° Longitude: -79.224702°

Approximate Surface Elev: 1026 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description	DEPTH (Ft.)	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
61.4	964.5+/-	Run 7, Similar *(continued)*		56		2.5
66.4	959.5+/-	Run 8, Similar From 63.7 to 65.3 feet: Hard, calcareous zone	65	60	32	2.25 2.25 2.25 1.75 1.5
71.4	954.5+/-	Run 9, Similar to 69.4 feet At 69.4 feet: Moderately hard, fresh, gray SILTSTONE interbedded with sandstone and shale, thin bedding, primary joint set, low angle, close to moderately close spacing, slightly open, planar, rough, fresh	70	50	35	2.5 2.25 2.5 1.75 1.5
76.4	949.5+/-	Run 10, Similar	75	60	98	1.75 1 1.25 1 0.75
81.4	944.5+/-	Run 11, Similar From 78.6 to 79.2 feet: Carbonaceous, argillaceous zone	80	60	92	1.5 1.5 1.25 1.25 1.25
86.4	939.5+/-	Run 12, Similar From 85.5 to 86.1 feet: Carbonaceous, argillaceous zone	85	57	92	1.25 1.25 1 0.75 0.75

Boring Terminated at 86.4 Feet

Column headings: GRAPHIC LOG; WATER LEVEL OBSERVATIONS; SAMPLE TYPE; FIELD TEST RESULTS; Penetrometer Test (tsf)

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS

4.3' AB

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-21-2017	Boring Completed: 09-22-2017
Drill Rig: Diedrich D-50	Driller: Terra Testing, Inc.
Project No.: J217P078	Exhibit: A-2

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

Boring No.:	B2-6W	Lithology :	Sandstone
Sample No.:	4	Moisture Content :	As received
Sample Depth:	22 feet	Lab Temperature :	70° F
Sampling Date:	9/19/17	Loading Rate:	55 psi/s
		Time to Failure:	9 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	29,750 lb
Length:	4.91 in	Compressive Strength:	9,565 psi
L/D:	2.47	Compressive Strength:	65.95 Mpa
End Area:	3.11 in^2	Unit Weight	161 pcf

Before the Test

After the Test

Drawing # : PA-IN-0019.0000RR
PO # : 20170912-1
Crossing : Norfolk Southern RR
Spread : Spread 2

Project:	Mariner East Pipeline	Terracon	Performed by:	D. Savage
Project No	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/16/2017
Location:	Spread 2	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/16/2017

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

Boring No.: B2-6W
Sample No.: 6
Sample Depth: 33 feet
Sampling Date: 9/19/17

Lithology : Sandstone
Moisture Content : As received
Lab Temperature : 70° F
Loading Rate: 55 psi/s
Time to Failure: 8 min

Diameter: 1.99 in
Length: 4.99 in
L/D: 2.51
End Area: 3.11 in^2

Maximum Axial Load at Failure: 26,200 lb
Compressive Strength: 8,424 psi
Compressive Strength: 58.08 Mpa
Unit Weight 158 pcf

Before the Test

After the Test

Drawing # : PA-IN-0019.0000RR
PO # : 20170912-1
Crossing : Norfolk Southern RR
Spread : Spread 2

Project:	Mariner East Pipeline	Terracon	Performed by:	D. Savage
Project No	J217P078		Test Date:	10/16/2017
Location:	Spread 2	77 Sundial Ave., Suite 401 W	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	Manchester, New Hampshire	Review Date :	10/16/2017

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

Boring No.:	B2-6W	Lithology :	Sandstone
Sample No.:	7	Moisture Content :	As received
Sample Depth:	38 feet	Lab Temperature :	70° F
Sampling Date:	9/19/17	Loading Rate:	55 psi/s
		Time to Failure:	15 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	50,880 lb
Length:	4.77 in	Compressive Strength:	16,359 psi
L/D:	2.40	Compressive Strength:	112.79 Mpa
End Area:	3.11 in^2	Unit Weight	160 pcf

Before the Test

After the Test

Drawing # : PA-IN-0019.0000RR
PO # : 20170912-1
Crossing : Norfolk Southern RR
Spread : Spread 2

Project:	Mariner East Pipeline	Terracon	Performed by:	D. Savage
Project No	J217P078		Test Date:	10/16/2017
Location:	Spread 2	77 Sundial Ave., Suite 401 W	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	Manchester, New Hampshire	Review Date :	10/16/2017

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

Boring No.:	B2-6W	Lithology :	Shale
Sample No.:	11	Moisture Content :	As received
Sample Depth:	60 feet	Lab Temperature :	70° F
Sampling Date:	9/19/17	Loading Rate:	55 psi/s
		Time to Failure:	8 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	27,780 lb
Length:	4.73 in	Compressive Strength:	8,932 psi
L/D:	2.38	Compressive Strength:	61.58 Mpa
End Area:	3.11 in^2	Unit Weight	168 pcf

Before the Test

After the Test

Drawing # : PA-IN-0019.0000RR
PO # : 20170912-1
Crossing : Norfolk Southern RR
Spread : Spread 2

Project:	Mariner East Pipeline	Terracon	Performed by:	D. Savage
Project No	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/16/2017
Location:	Spread 2	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/16/2017

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

Boring No.:	B2-6E	Lithology :	Shale
Sample No.:	1	Moisture Content :	As received
Sample Depth:	30 feet	Lab Temperature :	70° F
Sampling Date:	9/21/17	Loading Rate:	55 psi/s
		Time to Failure:	0 min

Diameter:	N/A in	Maximum Axial Load at Failure:	N/A lb
Length:	N/A in	Compressive Strength:	N/A psi
L/D:	N/A	Compressive Strength:	N/A Mpa
End Area:	N/A in^2	Unit Weight	N/A pcf

Specimen broke during preparation

Before the Test

After the Test

Drawing # : PA-IN-0019.0000RR
PO # : 20170912-1
Crossing : Norfolk Southern RR
Spread : Spread 2

Project:	Mariner East Pipeline	Terracon	Performed by:	D. Savage
Project No	J217P078		Test Date:	10/16/2017
Location:	Spread 2	77 Sundial Ave., Suite 401 W	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	Manchester, New Hampshire	Review Date :	10/16/2017

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

Boring No.:	B2-6E	Lithology :	Shale
Sample No.:	3	Moisture Content :	As received
Sample Depth:	31 feet	Lab Temperature :	70° F
Sampling Date:	9/21/17	Loading Rate:	55 psi/s
		Time to Failure:	7 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	22,820 lb
Length:	4.50 in	Compressive Strength:	7,337 psi
L/D:	2.26	Compressive Strength:	50.59 Mpa
End Area:	3.11 in^2	Unit Weight	171 pcf

Before the Test

After the Test

Drawing # : PA-IN-0019.0000RR
PO # : 20170912-1
Crossing : Norfolk Southern RR
Spread : Spread 2

Project:	Mariner East Pipeline	Terracon	Performed by:	D. Savage
Project No	J217P078		Test Date:	10/16/2017
Location:	Spread 2		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/16/2017

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

Boring No.:	B2-6E	Lithology :	Mudstone
Sample No.:	6	Moisture Content :	As received
Sample Depth:	55 feet	Lab Temperature :	70° F
Sampling Date:	9/21/17	Loading Rate:	55 psi/s
		Time to Failure:	4 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	13,510 lb
Length:	4.05 in	Compressive Strength:	4,388 psi
L/D:	2.05	Compressive Strength:	30.25 Mpa
End Area:	3.08 in^2	Unit Weight	168 pcf

Before the Test

After the Test

Drawing # : PA-IN-0019.0000RR
PO # : 20170912-1
Crossing : Norfolk Southern RR
Spread : Spread 2

Project:	Mariner East Pipeline	Terracon	Performed by:	D. Savage
Project No	J217P078		Test Date:	10/16/2017
Location:	Spread 2	77 Sundial Ave., Suite 401 W	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	Manchester, New Hampshire	Review Date :	10/16/2017

Photograph 1: B2-6W, Samples C-1 to C-4 (10.1 to 26.5 feet)

Photograph 2: B2-6W, Samples C-5 to C-8 (26.5 to 46.5 feet)

Photograph 3: B2-6W, Samples C-9 to C-12 (46.5 to 66.5 feet)

Photograph 4: B2-6W, Samples C-13 to C-16 (66.5 to 86.5 feet)

Photograph 5: B2-6W, Sample C-17 (86.5 to 91.5 feet)

Photograph 1: B2-6E, Samples C-1 to C-4 (28.6 to 46.4 feet)

Photograph 2: B2-6E, Samples C-5 to C-8 (46.4 to 66.4 feet)

Photograph 3: B2-6E, Samples C-9 to C-12 (66.4 to 86.4 feet)

SUPPORTING INFORMATION

UNIFIED SOIL CLASSIFICATION SYSTEM

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

[A] Based on the material passing the 3-inch (75-mm) sieve

[B] If field sample contained cobbles or boulders, or both, add “with cobbles or boulders, or both” to group name.

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

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

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

[F] If soil contains ³ 15% sand, add “with sand” to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add “with organic fines” to group name.

[I] If soil contains ³ 15% gravel, add “with gravel” to group name.

[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add “with sand” or “with gravel,” whichever is predominant.

[L] If soil contains ³ 30% plus No. 200 predominantly sand, add “sandy” to group name.

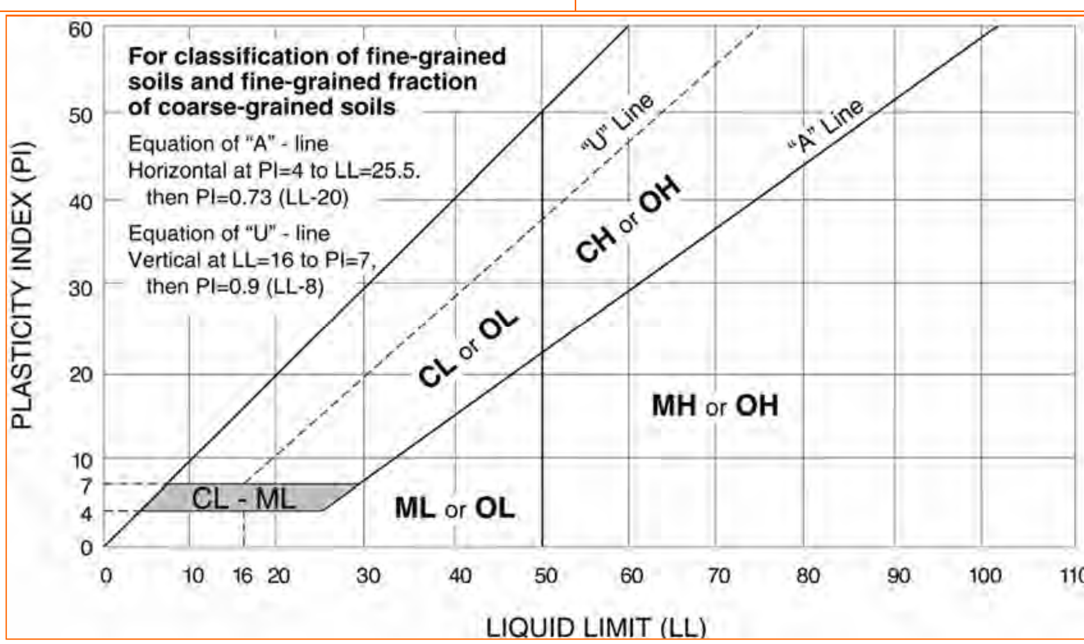
[M] If soil contains ³ 30% plus No. 200, predominantly gravel, add “gravelly” to group name.

[N] PI ³ 4 and plots on or above “A” line.

[O] PI < 4 or plots below “A” line.

[P] PI plots on or above “A” line.

[Q] PI plots below “A” line.



DESCRIPTION OF ROCK PROPERTIES

Terracon GeoReport

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

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

Joint, Bedding, and Foliation Spacing in Rock [1]

Spacing	Joints	Bedding/Foliation
Less than 2 in.	Very close	Very thin
2 in. – 1 ft.	Close	Thin
1 ft. – 3 ft.	Moderately close	Medium
3 ft. – 10 ft.	Wide	Thick
More than 10 ft.	Very wide	Very thick

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

Rock Quality Designator (RQD) [1]

RQD, as a percentage	Diagnostic description
Exceeding 90	Excellent
90 – 75	Good
75 – 50	Fair
50 – 25	Poor
Less than 25	Very poor

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

Joint Openness Descriptors

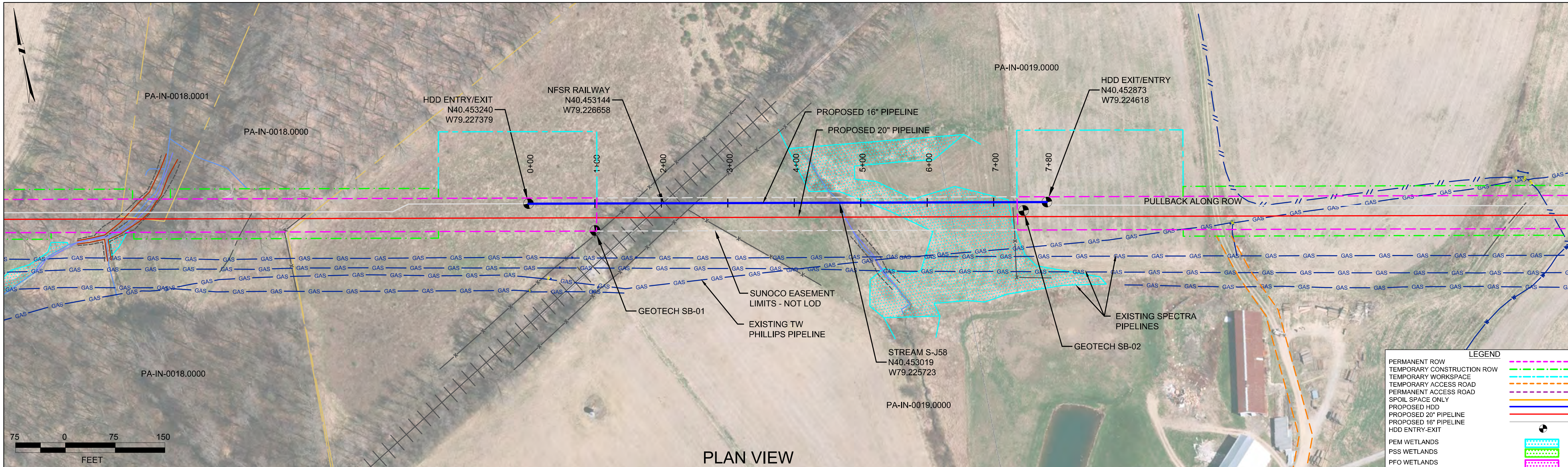
Openness	Descriptor
No Visible Separation	Tight
Less than 1/32 in.	Slightly Open
1/32 to 1/8 in.	Moderately Open
1/8 to 3/8 in.	Open
3/8 in. to 0.1 ft.	Moderately Wide
Greater than 0.1 ft.	Wide

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

HORIZONTAL DIRECTIONAL DRILL ANALYSIS
NORFOLK SOUTHERN RAILROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E32-508
PA-IN-0019.0000-RR-16
(SPLP HDD# S2-0040-16)

ATTACHMENT 2

HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES



PLAN VIEW

INDIANA COUNTY, PENNSYLVANIA - BURRELL TOWNSHIP
S2-0040-16

PROFILE VIEW

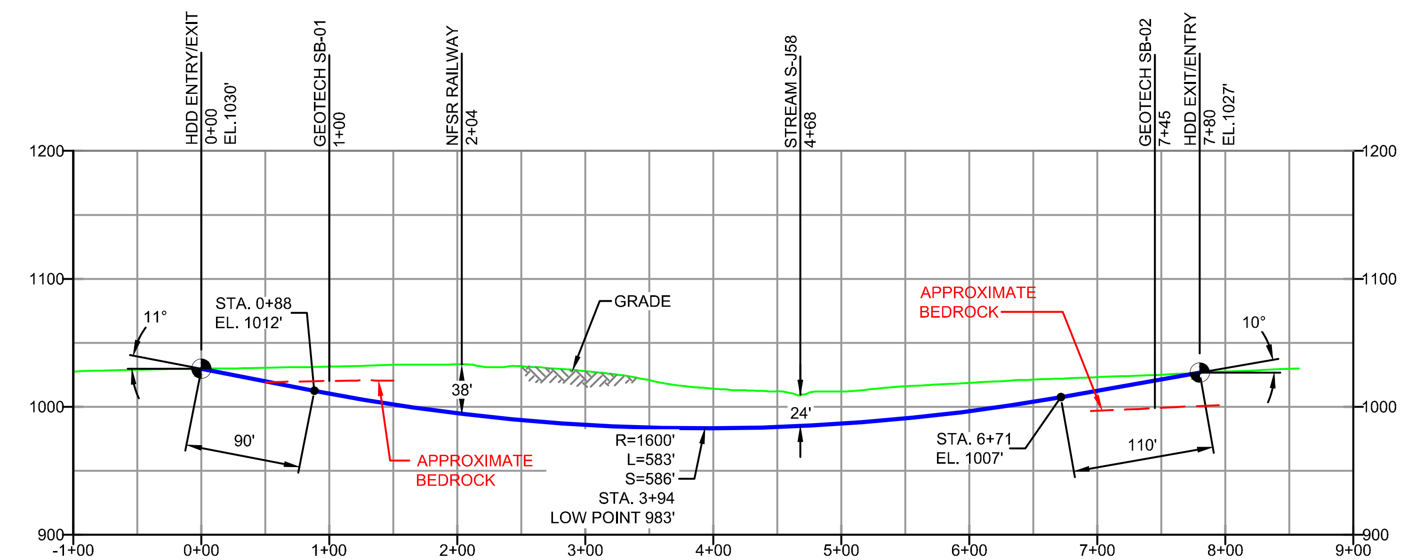
GEOTECH SB-01

- NG EL. 1032'
- TOPSOIL (0' - 0.1')
- SM (0.1' - 11.5')
- SANDSTONE AT BOTTOM (11.5')
- COMPLETION DEPTH EL. 1020.5'

GEOTECH SB-02

- NG EL. 1025'
- TOPSOIL (0' - 0.3')
- SM (0.3' - 11.5')
- GROUNDWATER (10.0')
- ML/CL (11.5' - 21.5')
- ML/CL (21.5' - 25.8')
- SANDSTONE AT BOTTOM (25.8')
- COMPLETION DEPTH EL. 999'

NOTE: REFER TO TEST BORING LOG S2-0040 FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):780'
   HDD PIPE LENGTH (S=):786'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. PIPELINE AND CROSSING TO BE INSTALLED AND MAINTAINED IN ACCORDANCE WITH LAST APPROVED AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION SPECIFICATIONS FOR PIPELINES CONVEYING FLAMMABLE AND NON-FLAMMABLE SUBSTANCES.
12. BLASTING NOT PERMITTED.
13. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.

Figure 1: Original 16-Inch HDD Plan and Profile

NOTES

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

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
3	REVISED PROFILE WITH 2017 LIDAR	MRS	03/17/17	RMB	03/17/17	CAG	03/17/17
2	REVISED PER ENGINEERING COMMENTS	MRS	08/26/16	RMB	08/26/16	AAW	08/26/16
1	REDESIGN	MRS	03/03/16	RMB	03/03/16	AAW	03/03/16
0	ISSUED FOR CONSTRUCTION	MRS	12/21/15	RMB	12/21/15	AAW	12/21/15

Sunoco Logistics Partners L.P.

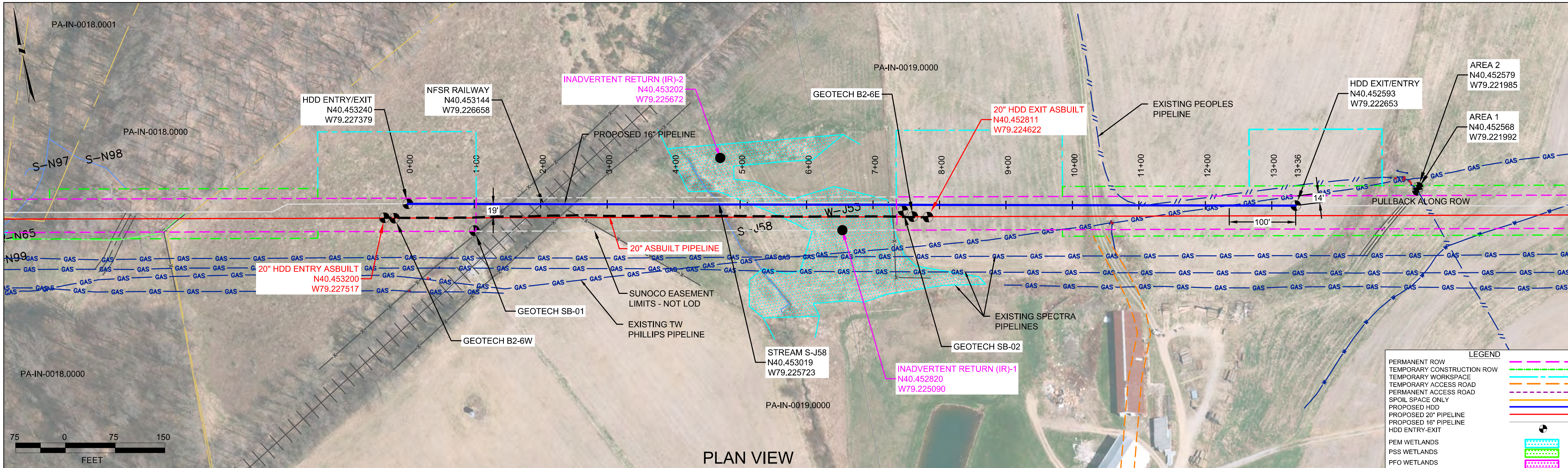
TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

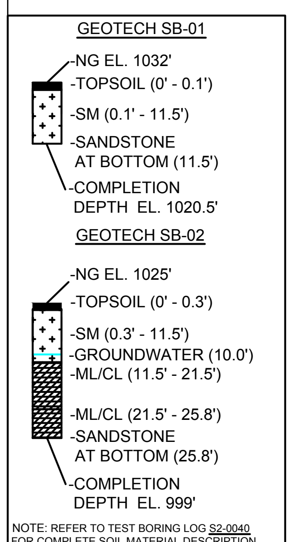
HORIZONTAL DIRECTIONAL DRILL
NORFOLK SOUTHERN RAILROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=150'

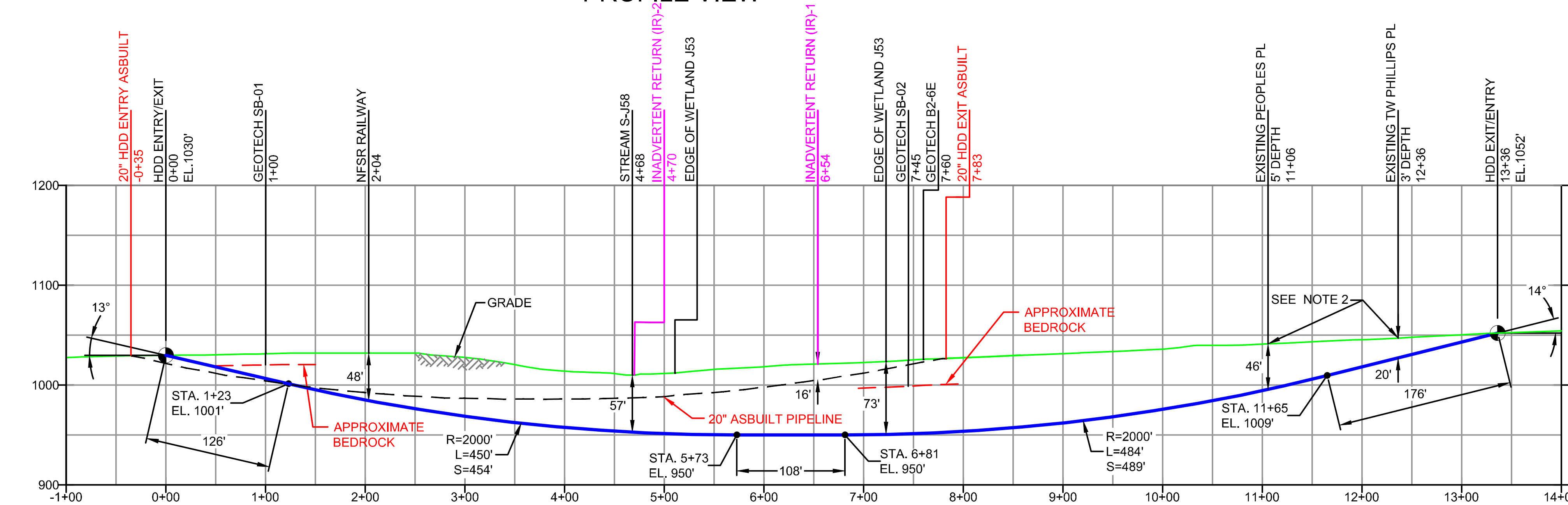
DWG. NUMBER: PA-IN-0019.0000-RR-16

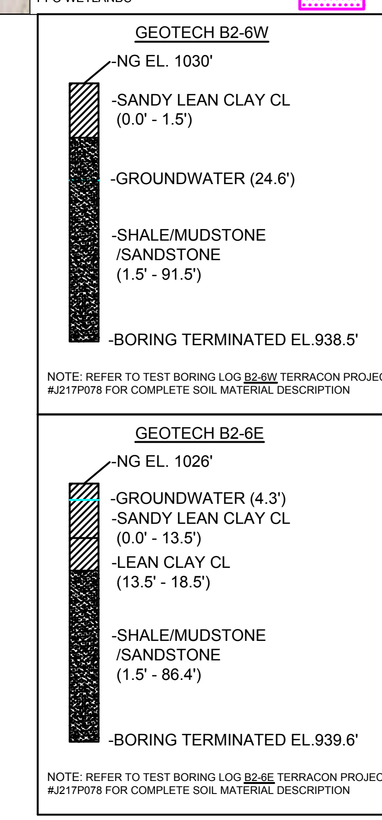


INDIANA COUNTY, PENNSYLVANIA - BURRELL TOWNSHIP
S2-0040-16



PROFILE VIEW





DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXITING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):1336'
   HDD PIPE LENGTH (S=):1353'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 2100 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 2625 PSIG.
11. PIPELINE AND CROSSING TO BE INSTALLED AND MAINTAINED IN ACCORDANCE WITH LAST APPROVED AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION SPECIFICATIONS FOR PIPELINES CONVEYING FLAMMABLE AND NON-FLAMMABLE SUBSTANCES.
12. BLASTING NOT PERMITTED.
13. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.

Figure 2. Revised 16-Inch HDD Plan and Profile

NOTES

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

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-2.13	TO	ES-2.14	EROSION & SEDIMENT PLAN
SHEET 9	TO	SHEET 9	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	EXTENDED DRILL DESIGN LENGTH	MRS	11/13/18	RMB	11/13/18	CAG	11/13/18
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	JTW	05/06/16	RMB	05/06/16	AAW	05/06/16
EP		DLM	03/15/16	RMB	03/15/16	AAW	03/15/16
B	ADDED GEOTECH INFO	MRS	09/07/15	RMB	09/07/15	AAW	09/07/15
A	ISSUED FOR REVIEW	DLM	08/14/15	RMB	08/14/15	AAW	08/14/15

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SUNOCO PIPELINE, L.P.

16-INCH HORIZONTAL DIRECTIONAL DRILL
NORFOLK SOUTHERN RAILROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=150' DWG. NO: PA-IN-0019.0000-RR-16