



SUNOCO PIPELINE
An ENERGY TRANSFER Company

535 Fritztown Road
Sinking Spring, 19608

December 4, 2017

Mr. Edward J. Muzic, P.E.
Civil Engineer Manager, Hydraulic
Dam Safety, Waterways and Wetlands Section
Department of Environmental Protection
South-central Regional Office
909 Elmerton Ave | Harrisburg, PA 17110

**Response to DADEP Comments and Data Request
Revised Horizontal Directional Drill Analysis
Frankston Branch Juniata River Crossing
PA-BL-0122.0000-WX & PA-BL-0122.0000-WX -16 (SPLP HDD NO. S2-0140)
PADEP Section 105 PT No.: E07-459
Frankston Township, Blair County, PA**

Dear Mr. Muzic:

Sunoco Pipeline, L.P. (SPLP) provides the following information and attachments in response to your letter of December 1, 2017, which commented on SPLP's horizontal directional drill (HDD) re-evaluation referenced above.

Your requests contained in paragraph 2 & 3 of your letter have been incorporated into the revised HDD analysis.

Under the analysis section for Inadvertent Returns, the last paragraph now references Attachment 3, which contains SPLP's plans for controlling produced water.

The Conclusions section of the analysis now affirms that SPLP drilling and environmental managers will be on-site when this HDD advances to the elevation of potential development of return water, and the three days advance notice to your agency of the date when SPLP anticipates reaching this point in the profile.

SPLP appreciates your continued time and effort to review this information. With the submittal of this information, we request that DEP approves the revised plans for crossing the Frankston Branch of the Juniata River (HDD No. S2-0140) as soon as possible.

Sincerely,

Matthew Gordon
Project Director

**HORIZONTAL DIRECTIONAL DRILL ANALYSIS
FRANKSTOWN BRANCH JUNIATA RIVER CROSSING
PADEP SECTION 105 PERMIT NO.: E07-459
PA-BL-0122.0000-WX & PA-BL-0122.0000-WX -16
(SPLP HDD No. S2-0140)**

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PA-BL-0122.0000-WX & PA-BL-0122.0000-WX -16
(SPLP HDD No. S2-0140)

This reanalysis of the horizontal directional drill (HDD) installation of a 16-inch and 20-inch diameter pipeline crossing under the Juniata River has been completed in accordance with paragraphs 4 and 5 of the Stipulated Order (Order) issued under Environmental Hearing Board Docket No. 2017-009-L. This HDD is number 10 on the list of HDDs included on Exhibit 2 of the Order.

PIPE INFORMATION

20-Inch: 0.456 wall thickness; X-65

16-Inch: 0.438 wall thickness; X-70

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

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 20-INCH

- Horizontal length: 2,965 foot (ft)
- Entry/Exit angle: 10-18 degrees
- Maximum Depth of cover: 85 ft
- Depth below river: 46 ft
- Pipe design radius: 2,000 ft

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 16-INCH

- Horizontal length: 2,970 ft
- Entry/Exit angle: 10-18 degrees
- Maximum Depth of cover: 100 ft
- Depth below river: 46 ft
- Pipe design radius: 1,600 ft

GEOLOGIC AND HYDROGEOLOGIC ANALYSIS

Based upon publications by the Pennsylvania Bureau of Topographic and Geologic Survey (BTGS, 2001 and Sevon, 2000), the HDD location is in the Appalachian Mountain Section of the Ridge and Valley Physiographic Province of Pennsylvania, underlain by sedimentary rocks consisting of sandstone, siltstone, shale, limestone, and dolomite. Local topography is characterized by long narrow ridges and broad to narrow valleys, with some karst terrain. (Sevon, 2000).

Karst geology is present at this HDD location, and pursuant to the Stipulated Order the use of geophysical surveys should be considered in karst areas. The use of geophysical surveys during re-evaluation was considered but ultimately not implemented at the Juniata River HDD location because the results of geophysical surveys will not provide additional information that will reduce the risk of an IR. Based on recent geophysical assessments performed by SPLP at other HDD locations in karst formations, the range of quality data acquisition has varied from 20 – 60 ft below ground surface (bgs). As discussed below, this HDD has been redesigned and the profile is now 103 ft under the river bed, and is 100 ft or more below the ground surface for a majority of the HDD profile. Accordingly, no valuable data can be acquired that would provide further information for the planning of this HDD and prevention of IRs.

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

HYDROGEOLOGY, GROUND WATER, AND WELL PRODUCTION ZONES

Based on published geologic and hydrogeologic information, and evaluation of geotechnical borings from the site, the Juniata River HDD location is underlain by carbonate and sedimentary rocks of the Hamilton Group, Onondaga and Old Port Formations, Keyser and Tonoloway Formations, Wills Creek Formation, and Bloomsburg and Mifflintown Formations. The hydrogeologic setting is dominated by groundwater flow through secondary openings along geologic features including bedding planes, joints, faults, and fractures. The secondary openings may be enlarged or enhanced by dissolution in underlying carbonate rocks. This is supported by the observation of weathering, fractures, and joints in the geotechnical cores and may be indicative of the high yields reported from some nearby domestic and non-domestic wells. Well records indicate that water bearing zones in water wells close to the site are common to 350 feet bgs in the Hamilton Group, and to 300 feet bgs in the Onondaga and Old Port Formations.

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

INADVERTENT RETURN (IR) DISCUSSION

HDD specialists for Sunoco Pipeline, L.P. (SPLP) reviewed the original HDD designs summarized above, and determined that the design profiles for the 16 and 20-inch HDDs could fail at or before the crossing of the Juniata River. Therefore, as presented and discussed in the conclusions section below, the profile for both the 16 and 20-inch pipelines have been redesigned deeper, incorporating the maximum entry and exit angles allowed by the stress radius of the pipelines, which sharpens the pilot hole entry radius run down to horizontal depth and exit radius return to the land surface. The redesign increases the 20-inch profile depth below the river by 57 ft to a new depth of 103 ft below the river bottom, and increases the 16-inch depth by 48 ft to a new depth of 94 ft below the river bottom.

As shown on Figure 1 - Annular Pressure and Formation Pressure Capacity Curves in Attachment 2, the calculated drilling fluid pressures required for drilling of the pilot hole are below the bedrock fracture pressure for the entirety of the re-designed profile. The results of the geotech investigation evidence that competent rock having moderate integrity and strength commences at 30 ft bgs and improves consistently as the depth below ground increases.

A risk of an IR remains at the undercrossing of the first stream crossing (S-M32) due to the shallow depth of profile at this location and its proximity to the entry point of the HDD; however, this IR potential will be managed by the setting of casing into the profile extending past this feature.

Casing is heavy wall pipe welded into a segment of pre-determined length that is pushed into a pre-drilled hole until it is seated into the bedrock. Based upon the geotechnical core data results at this location, bedrock consisting of mudstone starts at 20 ft bgs. A good quality layer of mudstone is encountered at 30 ft bgs, approximately 60-80 ft into the HDD profile. Casing for the pilot hole will have an internal diameter (ID) 1-2 inches larger in diameter than the intended HDD pilot hole tool, thereby allowing pilot tool insertion and removal for the duration of the pilot hole drilling. The installation of casing at the HDD entry requires drilling a larger diameter pilot hole following the intended profile through the upper substrate materials and into good quality bedrock to establish a "toe" for the casing to be pushed into and achieve a seal against the bedrock face and hole sidewalls. It is not uncommon to inject a slug of loss control materials or grouting at the casing toe at the rock interface to effect a good seal.

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Installing casing can result in IR's. At the entry of this HDD, Stream M32 (ephemeral) occurs 49 ft east of the entry point and an IR into Stream M32 is likely during the casing installation. To mitigate an IR into this ephemeral stream, the stream can be flumed across the permanent easement to allow for continued flows if any exist, and sandbag dams set at both ends of the flume such that if an IR occurs within the permanent easement at this location these materials can be contained and removed. IRs outside the permanent easement will be contained, controlled, cleaned and restored in accordance with the SPLP Inadvertent Return Plan.

A unique feature of this HDD is the extreme differences in elevation between the HDD entry and exit point. The entry point is at an elevation of 894 ft, and the exit point is at elevation of 1,373 ft, a difference of 479 ft. Increased drilling pressures will be required to operate the drilling motor as the pilot hole advances upslope towards the exit point. These pressures will be internal to the drilling stem and will not be exhibited in the annulus of the drill or increase the risk of an IR; however, this elevation difference can create a "dry hole" situation in the annulus behind the drilling motor since gravity will induce an accelerated return of drilling fluids back to the entry point. To prevent this "dry hole" situation, drilling fluid characteristics, such as viscosity and cuttings suspension, will have to be monitored by the mud engineer as the pilot hole progresses.

ADJACENT FEATURES ANALYSIS

The crossing of the Juniata River is located in rural Blair County, approximately 4.9 miles east of Hollidaysburg, Pennsylvania. The pipeline route follows parallel to an existing, but out-of-service Lancer pipeline easement. The pipeline alignment re-joins the existing SPLP 8" easement approximately 0.35 miles east of the eastern end of the HDD alignment.

This HDD location is set within a small rural neighborhood and some agricultural land immediately west of the HDD alignment, and east of the river is within unmanaged deciduous woodlands within and surrounding State Game Land 147. The re-aligned profile for this HDD would cross under stream S-M32, wetland M24, wetland M29, the Juniata River (S-M31), and stream S-M38 (west to east). Both wetlands crossed by the HDD are exceptional value due to their proximity to Pennsylvania Fish and Boat Commission wild trout waters.

The reviewing geologists report that west of the Juniata River the groundwater incline is to the northwest. East of the river, groundwater would flow west following the topographic gradient downslope towards the river.

SPLP initiated direct contact by phone and in person with all landowners within 450 ft of the HDD profile. As a result of this effort, five (5) domestic (private) supply wells were identified within 450 ft of the proposed HDD. These wells occur at residences along Juniata Valley Road, and are west, southwest and northwest of the west HDD entry point, and all have had testing performed to establish background data on the water quality in each well. The nearest water well location is 383 ft northwest of the west HDD entry point. The owner of this well did not know the depth to water or total depth of the well. At two adjacent private wells, the static water level was 10 ft bgs, and 12 ft bgs. Neither of these owners knew the total depth of their wells. This HDD re-evaluation has been provided to each landowner within 450 feet of the HDD profile.

Typically, a good drilling mud program forms a "cake wall" around the diameter of the pilot or reamer during drilling process which seals fissures within the profile geology and limits the horizontal and vertical movement of drilling fluids. In addition, controlling the down hole mud weights and pressures should minimize the lateral movement of these materials through the geology. Lastly, as noted previously, casing will be installed down to competent rock into the entry profile to control the movement and returns of drilling fluids and cuttings. As a result an affect to nearby water wells is unlikely given their orientation to this HDD; however SPLP will monitor these wells during the HDD process in accordance with PADEP requirements.

During the entire HDD process, once the pilot hole has progressed east of the river, upslope towards the exit point and above 894 ft of elevation, significant quantities of groundwater could be produced that would flow back

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to the entry point. A large amount of this produced water will be utilized during the continued HDD process and will reduce or eliminate the need to import water. Excess produced water will have to be contained, controlled, filtered, and discharged, or collected in storage tanks and transported to the City of Altoona for treatment and disposal. Prior to achieving this elevation during the pilot hole phase, the contractor will have pre-prepared filtration structures and filtration bags in place to capture, filter, and discharge produced water. Portable storage tanks will be immediately available if the filtration system fails to clean the produced water sufficiently for discharge. Attachment 3 contains the water control and filtration details on the applicable section of the project's Erosion and Sediment Control Plans and a general discussion on the capture, control, filtration and discharge process.

ALTERNATIVES ANALYSIS

In accordance with state and federal guidance, SPLP has routed the Project to be co-located with existing pipeline and other utility corridors to avoid new "greenfield" routing alignments, to the maximum extent practical. This avoids and minimizes new and permanent impacts on previously undisturbed land, land use encumbrance, and site-specific and cumulative impacts on land, environmental, and community resources. The Juniata River HDD is co-located within an existing (but out-of-service) pipeline ROW and rerouting would cause new greenfield impacts.

The proposed HDD is an alternative plan of installation to a conventional open trench construction plan. Using the HDD method reduces the risk of new direct impacts to the river, streams, Chapter 93 Exceptional Value wetlands, and associated forested woodland and riparian habitats. Alteration of the current permitted route and plans for installation would not meaningfully reduce the risk of these impacts and would also require major modifications of the state Chapter 102 and Chapter 105 permits, and authorization issued by the U.S. Army Corps of Engineers.

The revised HDD profiles are 2,965 ft and 2,957 ft in horizontal length respectively and includes the crossing of the river, two (2) stream channels, and approximately 325 ft of emergent and forested wetlands.

Open-cut Analysis

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

The open cut crossing of the river would require using geotube dams upstream and downstream of the crossing location. Water flows in the river would have to be pumped around the dammed section using a series of 8-inch pumps while a trench across the river was excavated. While excavating the river crossing, any consolidated rock in the river bottom within the required depth of trench would have to be shattered using explosives, or if feasible, broken up for excavation using a rock hammer.

Due to the existing saturated ground conditions, a significant volume of produced groundwater would fill all the excavations during the open cut process. These water volumes can be pumped to a discharge filtration structure; however the current feasible filtration ability does not exceed 50 microns; therefore, cloudy water (from suspended fine clay and silt particles) would be discharged downstream regardless of all control methods employed for the entire duration of this crossing until completion.

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The crossing distance of the emergent and forested wetlands, which are the most expansive natural features crossed by the HDDs, is beyond the technical limits of a conventional auger bore. The river crossing is not possible by conventional bore due to the restraints of the topography on the east side of the river.

Re-Route Analysis

The pipeline route as currently permitted follows parallel to one (1) existing ROW, however, the pipeline is not in service. The route deviates from the existing SPLP 8" line in this location due to the engineering requirements for an HDD crossing with the larger pipe size in the project. Additionally, the properties where the SPLP 8" ROW is routed now have Land and Water Conservation Fund easements, which do not allow new pipelines to be installed. Rather than create a greenfield crossing through State Game Lands 147 and the remaining woodlands, SPLP took advantage of the break in topography and agricultural lands to co-locate with the Lancer pipeline ROW that is not currently in service. This allowed for the HDD crossing which would be less impactful to the Frankstown Branch Juniata River and associated wetlands. Additionally, the HDD crossing requires significantly less clearing efforts on the hillside on the west of the river and allows the vistas to remain intact. The reroute parallel to the existing SPLP 8" ROW has not had wetland delineations performed, but the river would still be crossed and an HDD would not likely be able to be performed due to the topography along that route and the limited open terrain on the west side of the HDD, adjacent to Juniata Valley Road.

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

HORIZONTAL DIRECTIONAL DRILL REDESIGN

Additional geologic investigations have been completed and utilized in the redesign of the planned HDDs. These redesigns adjust the HDD profile deeper to place the HDD pathway through bedrock having better structural integrity than a shallower profile and increase the overall length of the HDD due to pipe design requirements. A summary of the redesign factors is provided below. The original and redesigned HDD plan and profile drawings are provided in Attachment 4.

REVISED HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 20-INCH

- Horizontal length: 2,965 ft
- Entry/Exit angle: 12-20 degrees
- Maximum Depth of cover: 150 ft
- Depth below river: 103 ft
- Pipe design radius: 2,700 ft

REVISED HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 16-INCH

- Horizontal length: 2,957 ft
- Entry/Exit angle: 16-18 degrees
- Maximum Depth of cover: 140 ft
- Depth below river: 94 ft
- Pipe design radius: 2,100 ft

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As shown on Figure 2, the redesigned HDD profile for the 20-inch pipeline is the same length, with a maximum depth of cover increased by 65 ft from the permitted design. The entry/exit angles have been increased from 10-18 degrees to 16-20 degrees allowing for a sharper and quicker descent into competent rock. As shown on Figure 4 the redesigned HDD profile for the 16-inch pipeline is 13 ft shorter, with a depth of cover increased by 40 ft, and designed for a sharp and quick entry and exit from the horizontal depth.

CONCLUSION

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

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

- SPLP requires and enforces 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;
- The HDD entry point, which is west of the river, will have the first 60+ ft of the pilot hole cased to prevent an IR into the first designated stream, and to control drilling returns during drilling of the pilot hole phase;
- 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;
- During the reaming phase, the use of Loss Control Materials can be implemented if indications of a potential IR are noted or an IR is observed, and
- SPLP drilling and environmental managers will be onsite when the pilot phase for each HDD nears and passes the 894 ft of elevation, and SPLP will provide the DEP Southcentral Regional Office at least three (3) days advance notice of the date SPLP anticipates reaching this stage of the HDD.

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ATTACHMENT 1

GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT



We answer to you.

3020 Columbia Avenue, Lancaster, PA 17603 • Phone: (800) 738-8395
E-mail: rettew@rettew.com • Website: rettew.com

Engineers

Environmental
Consultants

Surveyors

Landscape
Architects

Safety
Consultants

October 20, 2017

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

RE: Sunoco Pipeline, L.P. Pipeline Project - Mariner East II
Juniata River Horizontal Directional Drill Location (S2-0140)
Hydrogeological Re-evaluation Report
Frankstown Township, Blair County, Pennsylvania
RETTEW Project No. 096302011

EXECUTIVE SUMMARY

1. The Stipulated Order dated August 8, 2017 requires a re-evaluation of the Juniata River Horizontal Directional Drill (HDD) location, including a geologic report.
2. The Juniata River HDD is underlain by carbonate and sedimentary rocks of the Devonian age Hamilton Group (Dh), Onondaga and Old Port Formations, undivided (Doo), Keyser and Tonoloway Formations, undivided (DSkt), the Silurian age Wills Creek Formation (Swc), and the Bloomsburg and Mifflintown Formations, undivided (Sbm).
3. Geologic mapping, published reports, and field mapping indicate steeply dipping beds with jointing and fracturing.
4. Water-bearing zones generally occur in secondary openings along bedding planes, joints, faults, fractures, and solution openings. Water-bearing zones in the Hamilton Group occur most frequently within 350 feet of the ground surface, and within 300 feet of the ground surface in the Onondaga and Old Port Formations.
5. To date, no HDD operations have started for the 16-inch or 20-inch pipeline.
6. Based on the hydro-structural characteristics of the underlying geology, and proposed HDD profile, the Juniata River HDD is susceptible to the inadvertent return (IR) of drilling fluids during HDD operations for the planned 16-inch and 20-inch drills. The revised HDD profile and HDD best management practices during drilling operations will be used to reduce the risk of an IR.

1.0 INTRODUCTION

The purpose of this report is to describe the geologic and hydrogeologic setting of the Juniata River (S2-0140) HDD location (the site) on the Sunoco Pipeline, L.P. (SPLP) Pennsylvania Pipeline Project - Mariner East II (PPP-ME2) Project. The Juniata River HDD is located in Frankstown Township, Blair County, Pennsylvania (refer to **Figure 1**). The HDD was designed to be drilled under the Juniata River, two small streams (S-M32 and S-M38), and two wetlands. This re-evaluation report is part of the response to the Stipulated Order dated August 8, 2017.

The proposed HDD profile was lengthened and deepened on July 11, 2017 to provide additional protective cover beneath the stream. The HDD entry on the western side of the profile is at an elevation of approximately 896 feet above mean sea level (AMSL) for the proposed 16-inch drill and 894 feet AMSL for the proposed 20-inch drill. The exit on the eastern side of the profile is at an elevation of approximately 1,357 feet AMSL for the proposed 16-inch drill and 1,373 feet AMSL for the proposed 20-inch drill. The inclination of the entry and exit angles has been increased to install the pipe through these protective soils, residual soils, and bedrock; and in closer proximity to the entry and exit points than the original, shallower profile.

Based on the annular pressure and formation pressure capacity curves provided by Directional Project Support (DPS) as part of the overall re-evaluation submittal, the weakest points in the profile are the HDD entry, exit and the crossing of the Juniata River. At the Juniata River crossing, the HDD profile is approximately 94 feet below the river for the proposed 16-inch drill and 103 feet for the proposed 20-inch drill. Copies of the revised HDD profiles are included in **Attachment 1**.

2.0 GEOLOGY AND SOILS

Based upon publications by the Pennsylvania Bureau of Topographic and Geologic Survey (BTGS, 2001 and Sevon, 2000), the site is in the Appalachian Mountain Section of the Ridge and Valley Physiographic Province of Pennsylvania, underlain by sedimentary rocks consisting of sandstone, siltstone, shale, conglomerate, limestone, and dolomite. Local topography is characterized by long narrow ridges and broad to narrow valleys, with some karst terrane. (Sevon, 2000).

According to the United States Department of Agriculture (USDA) Soil Surveys of Blair County, Pennsylvania, soils within approximately 450 feet of the drill path for HDD S2-0140 consist of 39 separate soil units. A USDA map that depicts the mapped area, along with the soil profile descriptions, is included as **Attachment 2**.

The site geology is mapped west to east as the Devonian age Hamilton Group, Onondaga and Old Port Formations, undivided, Keyser and Tonoloway Formations, undivided, the Silurian age Wills Creek Formation and the Bloomsburg and Mifflintown Formations, undivided, as shown on **Figure 2** (Berg and Dodge, 1981). The Juniata River HDD is located on the west limb of an anticline that has a strike trending northeast-southwest and dipping to the northwest.

The Hamilton Group includes the Mahantango Formation (Dmh) and the Marcellus Formation (Dmr). The Mahantango Formation consists of interbedded shale, siltstone, and sandstone. The Marcellus Formation consists of very dark to black, fissile shale. Joints are well developed, closely spaced, mostly open, and steeply dipping. Permeability is described as moderate. Joint and bedding plane openings provide a secondary porosity of low to moderate magnitude and moderate permeability. Excavation is described as moderately easy to difficult. Drilling rates are moderate to fast. Foundation stability is good when material is excavated to sound bedrock (Geyer and Wilshusen, 1982).

The Onondaga and Old Port Formations, undivided, consist of several rock types. The Onondaga Formation includes of limestone, calcareous shale, and claystone. The Old Port Formation includes sandstone, chert, shale, and limestone. Bedding features in these formations is described as well

bedded, with individual strata varying from flaggy to thick and massive. Bedrock fracturing is described as jointed with a blocky pattern that is moderately developed and moderately abundant. The joints are regularly spaced with a moderate distance between fractures that are open and steeply dipping. The joint, bedding and fracture-plane openings provide a secondary porosity of low magnitude and low permeability. Most joints within these units are blocky to seamy, moderately abundant, and open and vertical. Joints are moderately to closely spaced. These rocks are moderately weathered to a deep depth with deeper weathering in the shale units. Weathering results in small- to medium sized blocks. The overlying mantle is thin. From an engineering standpoint, excavation of these formations is difficult, but slope stability is good in the limestone member and fair in the shale member. Foundation stability is good, provided the excavation is to sound material and solution cavities are investigated and mitigated. Surface drainage is good. Secondary porosity of moderate magnitude is provided by joints and bedding plane fractures. Permeability is low to moderate. These rocks reportedly provide good foundation stability (Geyer and Wilshusen, 1982).

The undivided Keyser and Tonoloway Formations consist of dark gray, highly fossiliferous, crystalline to nodular limestone. These formations are well bedded, flaggy to thick, with some massive beds. The joints are platy and some have a blocky pattern. These units are moderately resistant to weathering. Joint and bedding plane openings and solution openings provide moderate secondary porosity. Permeability is described as low to moderate. Bedrock is described as difficult to excavate. Drilling rates are described as fast. Foundation stability is good, assuming an investigation for solution openings is performed, and when material is excavated to sound rock (Geyer and Wilshusen, 1982).

The Wills Creek Formation is an interbedded calcareous shale, siltstone, shaly limestone, and dolomite. The color range of this unit includes multicolored gray, grayish-red, yellowish-gray, and greenish-gray rocks. The formation is moderately well bedded, fissile to thin, moderately weathered and moderately resistant to weathering. Joints are well developed and highly abundant. Joint and bedding plane openings provide moderate secondary porosity. Permeability is described as low. Bedrock is reported to be moderately easy to excavate and drilling rates are reported as fast. Foundation stability is good when material is excavated to sound rock (Geyer and Wilshusen, 1982).

The Bloomsburg and Mifflintown Formations, undivided, are composed of red shale and siltstone with some sandstone and impure limestone. These formations are moderately well bedded and fissile to thin. They are highly weathered near the surface and only slightly resistant to weathering. Joint and bedding plane openings provide low to moderate secondary porosity. Permeability is described as moderate. Bedrock is reported to be moderately easy to excavate and drilling rates are reported to be relatively fast. Foundation stability is good when material is excavated to sound rock (Geyer and Wilshusen, 1982).

3.0 HYDROGEOLOGY

Groundwater at the site occurs in a fractured carbonate and sedimentary bedrock aquifer system within the geology described in Section 2.0. In these rock types of Blair County, water-bearing zones generally occur in the secondary openings along bedding planes, joints, faults and fractures. Most of the water-bearing zones penetrated by wells occur in individual fractures or groups of interconnected fractures that are sufficiently enlarged by solution that readily transport water (Taylor, 1982). In central Pennsylvania, many of the water-bearing rocks such as sandstone alternate with less permeable rocks such as shale. In areas with tilted rock strata or on the flank of an anticline, such as the Juniata HDD, water flows down dip in the permeable formations (Lohman, 1938). At this location, the HDD exit is at a

higher elevation and position on the limb of the anticline in contrast to the HDD entry which is at the base of the limb. As a result, it is assumed that primary groundwater flow is downdip and to the northwest.

The review of published data on water wells focused primarily on the Hamilton Group and Onondaga and Old Port Formations underlying the west side of the Juniata HDD, near the residential development along Juniata Valley Road. The depths of 243 domestic and non-domestic water supply wells in the Hamilton Group range from 10 to 685 feet below ground surface (bgs), with yields ranging from 1 to 380 gallons per minute (gpm). The median well depth for domestic wells is 173 feet bgs and 300 feet bgs for non-domestic wells. Median well yields are 12 gpm for domestic wells and 38 gpm for non-domestic wells. Water-bearing zones among 198 wells reported are relatively common to a depth of 350 feet, but are most frequent from 50 to 150 feet. The deepest water-bearing zone was reported at 635 feet bgs (Taylor, 1982).

The depths of 168 reported domestic and non-domestic water wells in the Onondaga and Old Port Formations range from 35 to 500 feet bgs, with yields ranging from 0 to 1,400 gpm. The median well depth for domestic wells is 141 feet and 215 feet for nondomestic wells. Median well yields are 10 gpm for domestic wells and 60 gpm for non-domestic wells. Water-bearing zones among the 88 wells reported are evenly distributed to a depth of 300 feet bgs, and the deepest water-bearing zone was reported at 460 feet bgs (Taylor, 1982).

Well records reviewed within a 0.5-mile radius of the HDD location were obtained from the Pennsylvania Groundwater Information System (PaGWIS). A total of two well records were available and are summarized below. The well locations are shown on **Figures 2 and 3**.

Well No.	Well Use	Casing Depth (feet)	Total Depth (feet)	Water Level (feet)	Yield (gpm)
58809	DOMESTIC	25	230	150	0.5
3686	DOMESTIC	28	198	18	6

4.0 FRACTURE TRACE ANALYSIS

Fracture traces underlying, or in close proximity to, the site were evaluated using historical aerial photographs from the years 1993 through 2016 (Google Earth, 2017), the Frankstown Quadrangle Geologic Maps (Berg and Dodge, 1981), and Plate 1 (Taylor, 1982). The photographs, publications and maps were reviewed to approximate the locations of natural linear fracture trace features or lineaments expressed on the ground surface. The linear features may be the surficial representation of deeper fractures, joints, faults or bedding planes within the subsurface which can transmit groundwater through the fractured bedrock aquifer at the site.

Figures 2 and 3 show the results of the fracture trace analysis overlain on the geologic map of the site and an aerial base map. Eight fracture traces were identified within close proximity to the Juniata HDD that are likely related to the primary geologic structure. Six of the fracture traces trend approximately northeast-southwest, parallel to geologic strike. Two perpendicular fracture traces trend southeast-northwest and may represent joint sets.

5.0 GEOTECHNICAL EVALUATION

Two geotechnical drilling evaluations were performed at the site; one in September and October of 2014 and the other in August of 2017. The 2014 test borings were advanced by hollow-stem augers and NQ-sized wireline rock coring techniques. The 2017 test borings were advanced using the mud rotary method. Soil, residual soil and weathered bedrock were sampled using split-spoon samplers. Geotechnical boring logs are included in **Attachment 1**.

Borings SB-01 and B3-2W were located near the HDD entry on the west side of the profile. Boring SB-03 was located approximately 600 feet east of the HDD entry and on the west bank of the Juniata River. Borings SB-02 and B3-2E were located near the HDD exit. The locations of the borings are depicted on **Figure 2** and **Figure 3**.

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

- Soil and residual soil depths vary from boring to boring; 6.5 feet at SB-01, 30 feet at SB-02, 14.5 feet at SB-03, 8 feet at B3-2W, and 23.5 feet at B3-2E. The residual soils are described as follows:
 - **Boring SB-01:** Sandy SILT (ML) with traces of gravel and weathered shale and fine SAND (SM) with highly weathered shale. Groundwater was observed at 16 feet bgs through the augers.
 - **Boring SB-02:** Sandy SILT (ML) with traces of gravel and weathered shale and fine SAND (SM) with highly weathered shale, and SILT and CLAY (ML/CL) with fine to medium sand and a trace of fine gravel. Groundwater was observed at 16.5 feet bgs through the augers. The boring was terminated at 30 feet bgs.
 - **Boring SB-03:** Augered to refusal at 14.5 feet bgs without sampling.
 - **Boring B3-2E:** Gravelly lean CLAY with sand (CL) and clayey GRAVEL (GC), trace sand with shale fragments. Groundwater was observed at 12.1, 12.0, and 16.0 feet bgs during the drilling process.
 - **Boring B3-2W:** Lean CLAY (CL). Groundwater was observed at 6.0 feet bgs.
- At depths of auger or split-spoon refusal and to total depth of the NQ cores, weathered bedrock and bedrock was encountered and is described as follows:
 - **Boring SB-03:** SB-03 was completed to a total depth of 34.5 feet. Alternating sequences of highly to very fractured gray limestone and calcareous shale were encountered. Rock recoveries were generally good to excellent (90% to 100%) in the core runs. Rock quality designations (RQDs) were very poor to fair (15% to 68%), and generally increased with depth.
 - **Boring B3-2E:** B3-2E was completed to a total depth of 586.8 feet. From 23.5 feet to 109.2 feet, weathered to completely weathered rock was observed in split spoon samples. Four alternating sequences of gray argillaceous limestone and gray and reddish brown to gray shale were encountered from 109.2 feet to the completion depth of 586.8 feet. The limestone is described as thin to medium bedded, with some shale interbeds having close to moderately close joint spacing. Primary joint sets in the limestone are high angle and secondary joint sets are low angle. RQDs in the limestone were fair to excellent (59% to 95%). The lowest RQDs in the limestone were reported from 109.2 feet to 116.8 feet, directly below the weathered to completely weathered rock. The shale is described as thinly bedded with some limestone interbeds and close to moderately close joint spacing. Primary joint sets in the shale are high angle and

secondary joint sets are low angle. RQDs in the limestone were poor to excellent (31% to 100%). The lowest RQDs were reported from 116.8 feet to 246 feet. Below 246 feet, RQDs were good to excellent (79% to 100%).

- o **Boring B3-2W:** B3-2W was completed to a depth of 120 feet. From 20 feet to 75 feet, slightly to moderately weathered mudstone was encountered. Less weathered, fresh mudstone was encountered from 75 feet to 120 feet. Joints are closely spaced, moderately dipping to near vertical and infilled with clay. RQDs were very poor to excellent (0% to 95%). There was not a strong correlation observed between depth and RQD.

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

Boring	Sample Depth (feet bgs)	Compressive Strength (psi)
SB-03	29.5	8,051
B3-2W	43.5	1,138
B3-2W	60	4,423
B3-2W	80	4,074
B3-2W	100	4,690
B3-2W	110	4,772
B2-2E	130	14,372
B2-2E	150	5,173
B2-2E	170	6,398
B2-2E	190	9,126
B2-2E	210	1,035
B2-2E	230	1,400
B2-2E	250	581
B2-2E	330	7,560
B2-2E	351	5,363
B2-2E	390	20,166
B2-2E	410	742
B2-2E	430	2,542
B2-2E	490	6,013
B2-2E	530	1,016

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

6.0 FIELD OBSERVATIONS

A field investigation was performed by a RETTEW geologist on October 3, 2017 to identify rock outcrops for fracture fabric analysis, possible ground-truthing of fracture traces identified during the desktop evaluation, and to identify potential sensitive receptors to IRs. A roadside outcrop was identified approximately 2.3 miles southwest of the HDD entry along geologic strike as shown on **Figure 2**. The outcrop consists of massive and nodular limestone with shale interbeds of the undivided Keyser and Tonoloway Formations. The average strike of bedding at this outcrop is 212° with an average dip of 44° NW. The strike of the primary joint set is 123° with a dip of 85° SW. A secondary joint set was identified and has a strike of 84° and a dip of 83° S. The field data is consistent with published geologic data, mapping, and fracture traces identified in Section 4.0. No additional sensitive receptors to IRs beyond the previously mapped streams and wetlands were identified during the site reconnaissance.

7.0 GEOPHYSICAL SURVEY CONSIDERATIONS

Karst geology is present at this HDD location, and pursuant to the Stipulated Order the use of geophysical surveys should be considered in karst areas. The use of geophysical surveys during re-evaluation was considered but ultimately not implemented at the Juniata River HDD location because the results of geophysical surveys would not likely provide additional information that would reduce the risk of an IR. In addition, results of geophysical surveys in karst terrains with the resolution necessary to image features that could affect the HDD are typically limited to the uppermost 20 to 50 feet of the ground surface. Based upon our experience working in karst geology, the predominant flaggy to thick and massively bedded limestone units of the Onondaga and Old Port Formations, and Keyser and Tonoloway Formations, are not as highly susceptible to the solution activity present in other more thickly-bedded carbonate geologic formations in Pennsylvania. In addition, the portion of the HDD profile extending through these formations ranges from approximately 50 feet bgs to 94 feet bgs beneath the Juniata River in the center of the profile. In our professional opinion, geophysical surveys would not provide additional information on the formational thickness, interbedded limestone and shale, and thin beds of limestone at depths greater than 50 feet bgs along the HDD profile. Geophysical survey data would not enhance the evaluation or reduce the risk of an IR.

8.0 CONCEPTUAL HYDROGEOLOGIC MODEL AND CONCLUSION

Based on published geologic and hydrogeologic information, and the evaluation of geotechnical borings from the site, the Juniata River HDD location is underlain by carbonate and sedimentary rocks of the Hamilton Group, Onondaga and Old Port Formations, Keyser and Tonoloway Formations, Wills Creek Formation, and Bloomsburg and Mifflintown Formations. The hydrogeologic setting is dominated by groundwater flow through secondary openings along geologic features including bedding planes, joints, faults, and fractures. The secondary openings may be enlarged or enhanced by dissolution in underlying carbonate rocks. This is supported by the observation of weathering, fractures, and joints in the

geotechnical cores and may be indicative of the high yields reported from some nearby domestic and non-domestic wells. In addition, field measurements of local geologic structure support the published information with regard to vertical and near vertical joint sets. Well records indicate that water-bearing zones in water wells close to the site are common to 350 feet bgs in the Hamilton Group and to 300 feet bgs in the Onondaga and Old Port Formations.

The originally proposed 16-inch and 20-inch HDD profiles were relatively shallow at the entry and exit points, and passed through both the unconsolidated overburden and fractured bedrock. The weakest point of the profile is beneath the first crossing of the Juniata River where the 16-inch pipe will be 94 feet, and the 20-inch pipe which will be 103, feet below the Juniata River. Based on the hydro-structural characteristics of the underlying geology described in this report and the proposed HDD profiles, the Juniata River HDD site is susceptible to the inadvertent return of drilling fluids during HDD operations. As a result, the HDD profile has been redesigned to allow for deeper crossings beneath the Juniata River. The inclination of the entry and exit angles has been increased to allow the pipe to be installed through the protective soils, residual soils, and bedrock to a deeper depth earlier on the entry trajectory and later along exit trajectory than the original, shallower profile. From a geologic perspective, the deeper profile, in conjunction with the proposed engineering controls and/or drilling best management practices will be used to reduce the risk of an IR.

9.0 REFERENCES

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- Google Earth Pro, 2017, Version 7.1.8.3036, September 20, 2017.
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- Sevon, D., 2000, Map 13, Physiographic Provinces of Pennsylvania, Pennsylvania Bureau of Topographic and Geologic Survey, Harrisburg, Pennsylvania.

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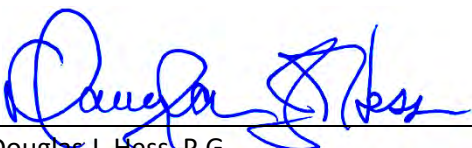
United States Department of Agriculture, 2017, Natural Resources Conservation Service, Published Soil Surveys for Pennsylvania, Blair County, Pennsylvania: website address:

<https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx>, accessed October 2, 2017.

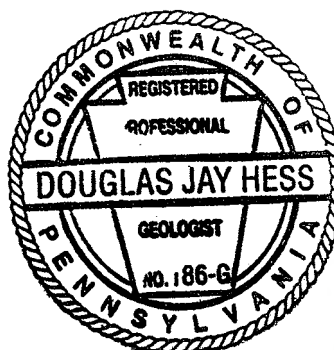
10.0 CERTIFICATION

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

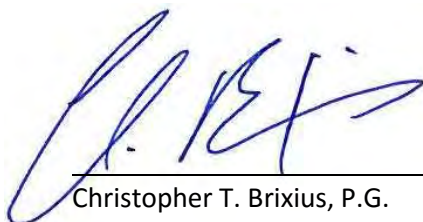
By affixing my seal to this document, I am certifying that, to my knowledge and belief, the information herein is true and correct. I further certify, that I am licensed to practice in the Commonwealth of Pennsylvania and that it is within my professional expertise to verify the correctness of the information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



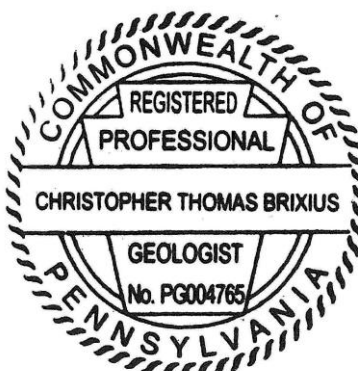
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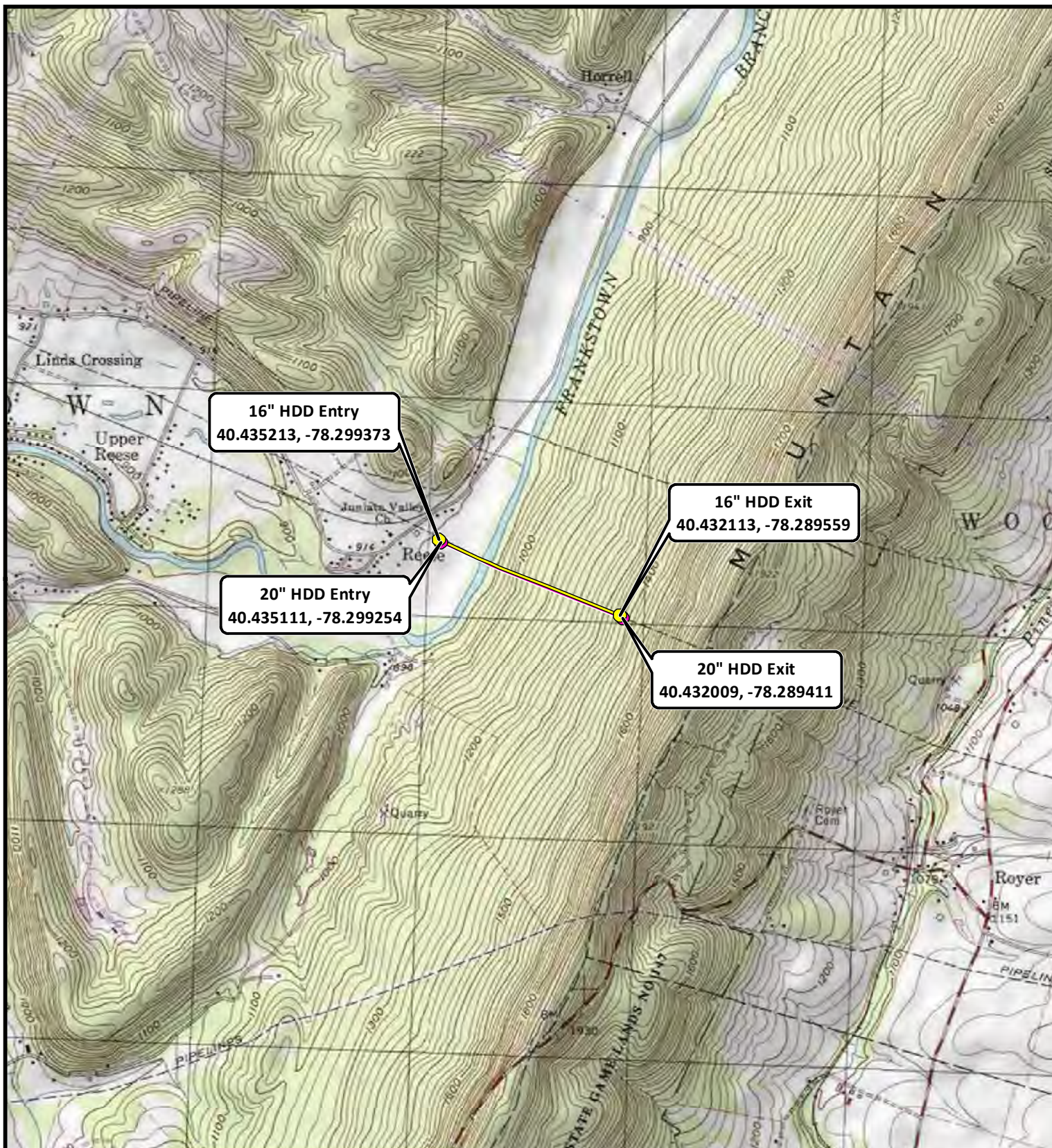
Ethan E. Prout, P.G.
License No. PG003884



Christopher T. Brixius, P.G.
License No. PG004765



FIGURES



- 16" HDD Entry/Exit
- 20" HDD Entry/Exit
- 16" HDD Profile
- 20" HDD Profile

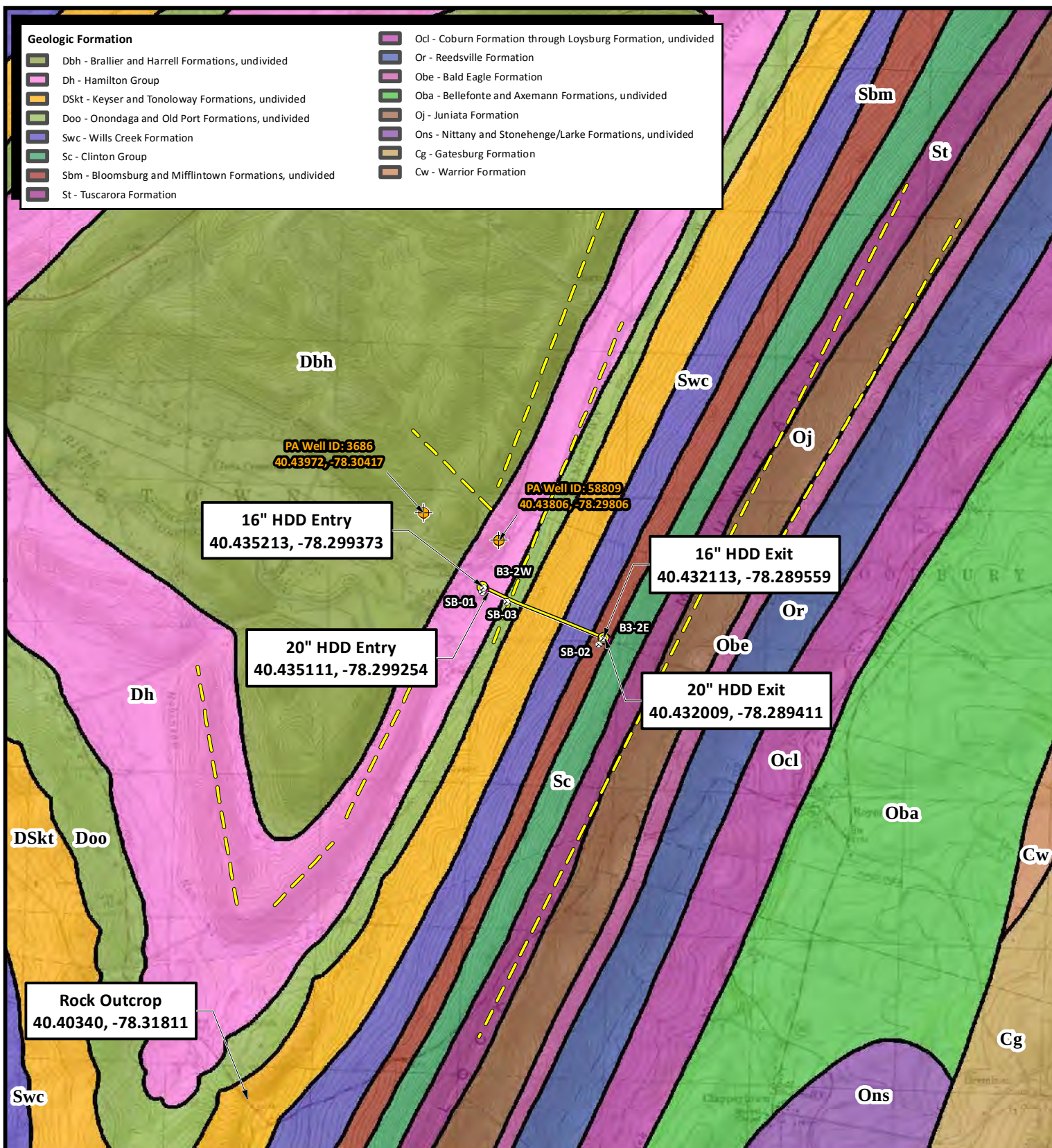
Sunoco Pipeline, L.P. Juniata River HDD Location

Figure 1 - Topographic Basemap
Frankstown Township, Blair County, PA
Project No. 096302011



0 1,000 2,000
Feet
1 inch = 2,000 feet

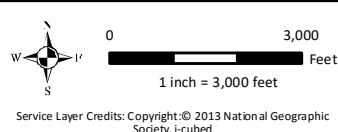


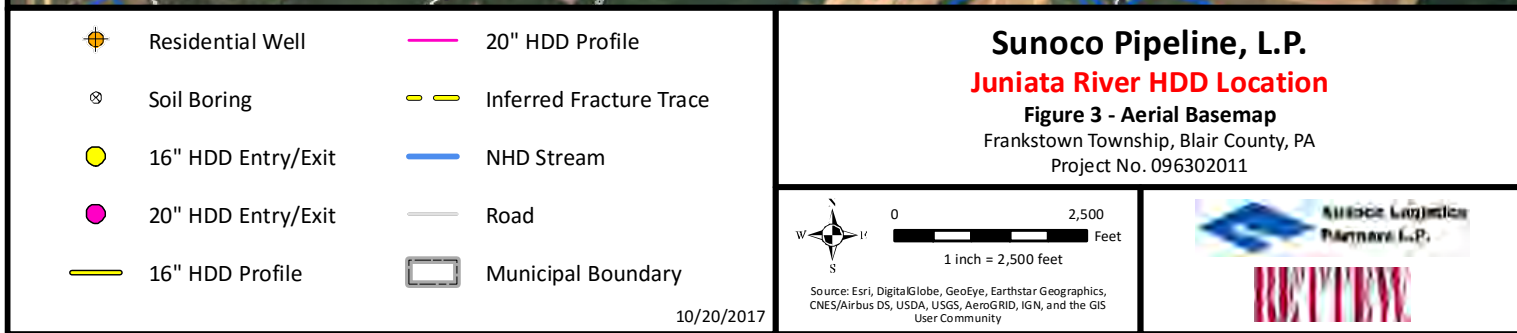


- Frankstown, PA USGS 7.5' Topographic Quadrangle
- 10/20/2017

Sunoco Pipeline, L.P. Juniata River HDD Location

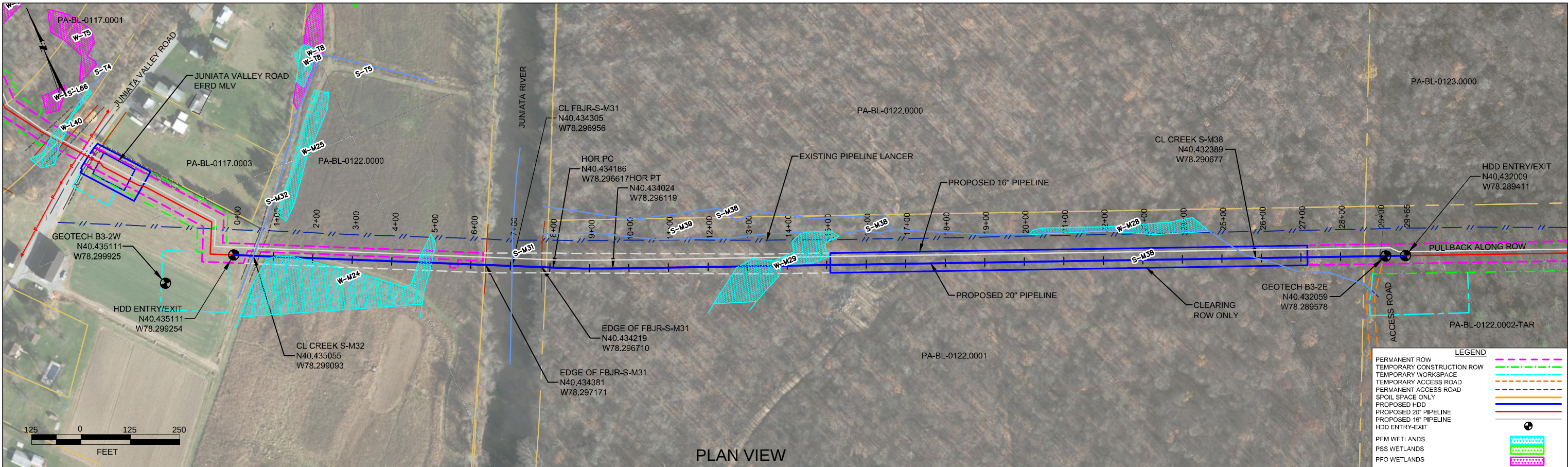
Figure 2 - Geologic Map
Frankstown Township, Blair County, PA
Project No. 096302011







ATTACHMENT 1
GEOTECHNICAL BORING LOGS



BLAIR COUNTY, PENNSYLVANIA - FRANKSTOWN TOWNSHIP
S2-0140

PROFILE VIEW

GEOTECH B3-2E

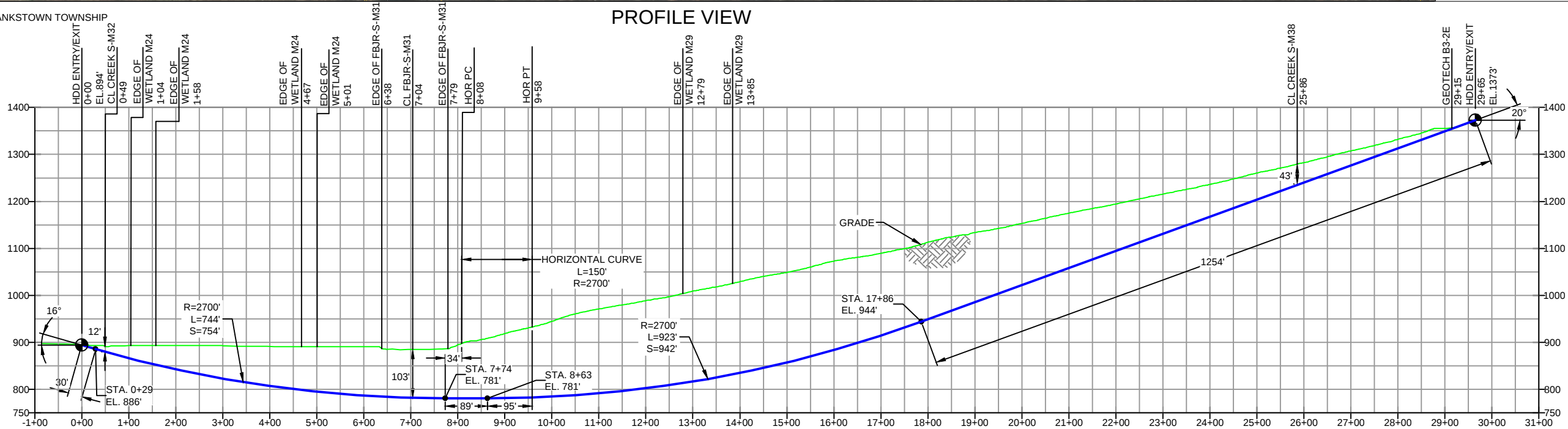
- NG EL. 1356'
- GRAVEL (0.0' - 0.7')
- GROUNDWATER (12.0')
- LEAN CLAY W/ SAND CL (0.7' - 13.5')
- GC (13.5' - 23.5')
- WEATHERED ROCK LIMESTONE (23.5' - 586.8')
- BORING TERMINATED EL.769'

NOTE: REFER TO TEST BORING LOG B3-2E TERRACON INC. PROJECT # J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B3-2W

- NG EL. 898'
- GROUNDWATER (6.0')
- LEAN CLAY CL (0.0' - 8.0')
- MUDSTONE (8.0' - 120.0')
- BORING TERMINATED EL.778'

NOTE: REFER TO TEST BORING LOG B3-2W TERRACON INC. PROJECT # J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:

- CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
- THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
- DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
- CROSSING PIPE SPECIFICATION:
HDD HORZ. LENGTH (L-): 2965'
HDD PIPE LENGTH (S-): 3067'
20" x 0.456" W.T., X-65, API5L PSL2, ERW, BFW
COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)

- INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
- INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
- PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
- CARRIER PIPE NOT ENCASED.
- PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
- CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
- SEE SUNCOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.

- SUNCOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
- SUNCOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.
- CONTRACTOR IS REQUIRED TO USE DRILLING FLUID / MUD WITH A UNIT WEIGHT OF 9.5 PPG OR LESS.

NOTES

- ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
- STATIONING IS BASED ON HORIZONTAL DISTANCES.
- ROONEY ENGINEERING, INC. AND SUNCOCO 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 SUNCOCO PIPELINE, LP, FOR ANY DAMAGES RESULTING FROM ERRORS OR OMISSIONS THEREIN.
- CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.
- SUNCOCO EMERGENCY HOTLINE NUMBER IS 811-800-786-7440.

REF. DRAWING

ES-3.51	TO	ES-3.53	EROSION & SEDIMENT PLAN
SHEET 33	TO	SHEET 34	AERIAL SITE PLAN
DWG NO		DWG NO	DESCRIPTION

REVISIONS

EP3	INCREASED VERTICAL CURVE RADIUS - DESIGN CHANGE PER MICHELS	MRS	10/19/17	RMB	10/19/17	CAG	10/19/17
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	09/30/16	RMB	09/30/16	AAW	09/30/16
EP1	REVISED PER PADEP COMMENTS	MRS	05/18/16	RMB	05/18/16	AAW	05/18/16
EP		MRS	03/15/16	RMB	03/15/16	AAW	03/15/16
C	ADDED GEOTECH INFO	MRS	09/04/15	RMB	09/04/15	AAW	09/04/15
B	ISSUED FOR BID	JAM	07/31/15	RMB	07/31/15	AAW	07/31/15
NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE

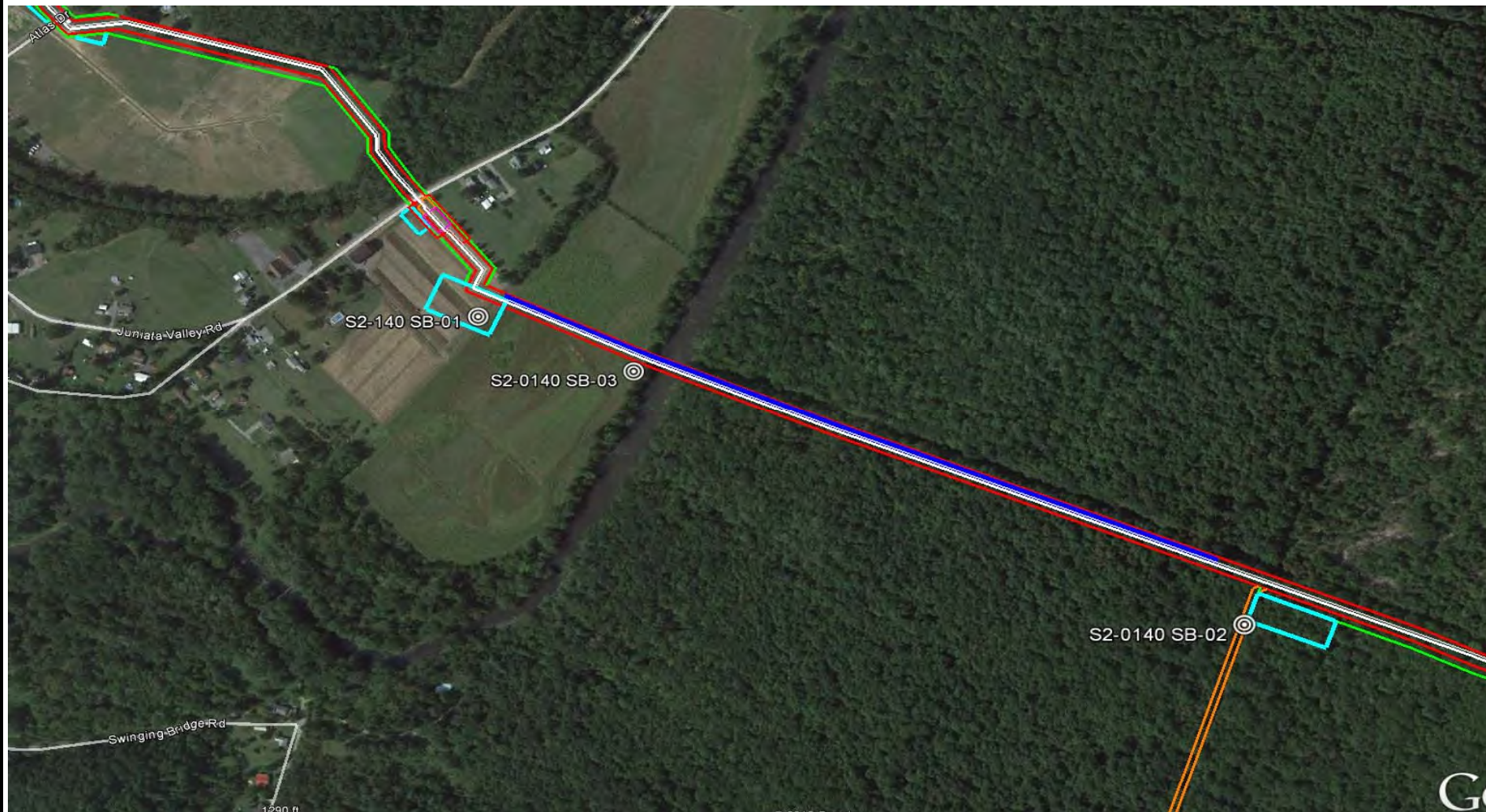


SUNCOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
JUNIATA RIVER
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250'

DWG. NUMBER: PA-BL-0122.0000-WX



LEGEND:

⊙ Geotechnical Soil Boring (SB) Locations



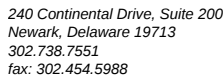
TETRA TECH

GEOTECHNICAL BORING LOCATIONS

HDD S2-0140

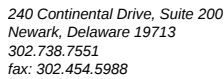
BLAIR COUNTY, FRANKSTOWN TOWNSHIP, PA

SUNOCO PENNSYLVANIA PIPELINE PROJECT



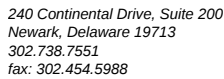
Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406
Project Location:	JUNIATA VALLEY ROAD, HOLLISDAYSBURG, PA			Page 1 of 1
HDD No.:	S2-0140	Dates(s) Drilled: 10-11-14	Inspector:	E. WATT
Boring No.:	SB-01	Drilling Method: SPT - ASTM D1586	Driller:	S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): 16.0	Total Depth (ft):	28.3
Boring Location Coordinates:	40°26'5.52"N		78°17'57.77"W	

Notes/Comments:	
<u>Pocket Pentrometer Testing</u>	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.	

[illegible]

S4: >4 TSF
S5: 3.0 TSF

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



Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406
Project Location:	JUNIATA VALLEY ROAD, HOLLISDAYSBURG, PA			Page 1 of 1
HDD No.:	S2-0140	Dates(s) Drilled: 09-25-15	Inspector:	E. WATT
Boring No.:	SB-03	Drilling Method: SPT - ASTM D1586	Driller:	K. KERSH
Drilling Contractor:	CONNELLY	Groundwater Depth (ft):	Total Depth (ft):	34.5
Boring Location Coordinates:	40° 26' 3.373" N		78° 17' 50.560" W	

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

**ROCK CORE DESCRIPTION SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S2-0140**

Location	Boring No.	Core Run	Core Depth (ft)		TCR (%)	SCR (%)	RQD (%)	Depth (ft)		Weathering	Classification	Bedding Thickness (ft)	Color	Discontinuity Data
			From	To				From	To					
S2-0140	SB-03	1	14.5	19.5	100	22	17	14.5	34.5	Moderate	Limestone	Massive	Gray	Fractures ranging from 6° to 56°, Avg. 31°; Occasional shaly cleavage to fractures
		2	19.5	24.5	100	20	15							
		3	24.5	29.5	90	49	43							
		4	29.5	34.5	100	68	68							

GEOTECHNICAL LABORATORY TESTING SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S2-0140

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, %	
S2-0140	SB-01	1	3.0	5.0	10.3	63.1	31	24	7	ML
		2	8.0	8.9	4.3	29.5	-	-	-	-
		4	18.0	18.7	5.9	15.4	-	-	-	-
		6	28.0	28.3	5.1	27.4	-	-	-	-
	SB-02	1	3.0	5.0	12.3	56.4	-	-	-	-
		3	13.0	15.0	16.5	33.1	33	22	11	SM
		4	18.0	20.0	14.5	86.3	-	-	-	-
		5	23.0	25.0	15.2	81.8	35	24	11	ML/CL
		6	28.0	30.0	14.3	91.6	-	-	-	-

Rock Core Testing Results				
Boring No.	Core Run	Approximate Depth (ft)	Compressive Strength (psi)	Unit Weight (pcf)
SB-03	4	29.5 - 30.0	8,050	163.1

Notes:

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

REGIONAL GEOLOGY SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S2-0140

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
S2-0140	Frankstown	SB-01	Hamilton Group - The Mahantango Formation and the underlying Marcellus Formation make up the Hamilton Group.	Ridge and Valley	Mahatango (aka Hamilton Group)	Shale-siltstone, laminated, fossiliferous			
		SB-02	Bloomsburg and Mifflintown Formations , undivided - The <u>Bloomsburg</u> Formation is predominantly red shale and siltstone. <u>Mifflintown</u> is Interbedded dark-gray shale and medium-gray fossiliferous limestone		Bloomsburg and Mifflintown Formations	predominantly red shale and siltstone.			
		SB-03	Onondaga and Old Port Formation (undivided) consists of two members - the upper Selinsgrove Limestone and the lower calcerous Needmore Shale.		Onondaga-Old Port	Limestone and calcareous shale with occasional chert	100-200	4-32	

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

FIELD DESCRIPTION AND LOGGING SYSTEM FOR SOIL EXPLORATION

GRANULAR SOILS

(Sand, Gravel & Combinations)

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

Relative Proportions

<u>Description Term</u>	<u>Percent</u>
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 No. 10 to No. 40 sieve (2.00mm – 0.425mm)
	(M)
	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)

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

Plasticity

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

ROCK

(Rock Cores)

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

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

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

UNIFIED SOIL CLASSIFICATION SYSTEM [Casagrande (1948)]

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

Major Divisions	Group Symbols	Typical Descriptions	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.	
Fine-grained soils (More than half of material is smaller than No. 200 sieve)	Sils 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
	Sils 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

A Line:
 $PI = 0.73(LL - 20)$

U Line:
 $PI = 0.9(LL - 8)$

Regions: CL or OL, CH or OH, MH or OH, ML or OL, CL-ML

(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.



Geotechnical Site Characterization

**Mariner East 2 Pipeline Project
Spread 3 – Juniata River
Commonwealth of Pennsylvania
Drawing #PA-BL-0122.0000-WX
PO #20170804-14**

October 9, 2017
Terracon Project No. J217P078

Prepared for:

Directional Project Support, Inc.
Magnolia, Texas

Prepared by:

Terracon Consultants, Inc.
Manchester, New Hampshire

terracon.com

Terracon

Environmental



Facilities



Geotechnical



Materials

October 9, 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 3 – Juniata River
Commonwealth of Pennsylvania
Drawing #PA-BL-0122.0000-WX
PO #20170804-14
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 Juniata River (Drawing #PA-BL-0122.0000-WX) 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 B3-2W and B3-2E, visual classification and photography of the rock core samples, and laboratory testing of representative rock samples.

Test borings, B3-2W and B3-2E were drilled between August 14 and 29, 2017 to depths of 120 and 586.8 feet, respectively as shown on the attached **Test Boring Location Plan**. Bedrock typically consisted of mudstone at B3-2W and interlayered sedimentary rock comprised of limestone and shale at B3-2E. 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.



Geotechnical Site Characterization

Mariner East 2 Pipeline – Spread 3 Juniata River ■ Pennsylvania

Drawing #PA-BL-0122.0000-WX / PO #20170804-14

October 9, 2017 ■ Terracon Project No. J217P078



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

Sincerely,

Terracon Consultants, Inc.

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

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

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

Attch:

TEST BORING LOCATION PLAN

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

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

TEST BORING LOCATION PLAN



**APPROXIMATE
BORING
LOCATION**

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

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

Terracon
Consulting Engineers & Scientists

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

TEST BORING LOCATION PLAN

Juniata River HDD Cores B3-2W and B3-2E
PA-BL-0122.0000-WX
Blair County, Pennsylvania

Exhibit

A-2

EXPLORATION RESULTS

BORING LOG NO. B3-2W Juniata River West

Page 1 of 4

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.435111° Longitude: -78.2999254° Approximate Surface Elev: 898 (Ft.) +/- ELEVATION (Ft.)								
	DEPTH								
	LEAN CLAY (CL) , olive-brown to orange and brown, soft			X	13	2-2-2 N=4			2.25
	Similar, red and brown, very stiff	5	▽	X	17	5-8-9 N=17			3.75
	8.0								
	Weathered rock with clay, grayish - brown, friable Advance roller bit to 20 feet to begin coring								
		10		X	3	50/3"			
		15		X	2	50/2"			
	20.0								
	Run 1, Soft, moderately weathered, grayish-black argillaceous MUDSTONE, moderately dipping close joints in-filled with clay				50		0	2.75 2.25 2.25 3.25 3.25	
	25.0								
	Run 2, Similar to above				46		27	2.75 2.25 2.25 2.5 2.75	
	30.0								
	Run 3, Medium hard, slightly weathered, grayish-black argillaceous MUDSTONE, moderately dipping close joints				60		70	2.5 2.5 2.5 2.5 2.5	
	35.0								

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

6' WD
0' AB

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/14/2017

Boring Completed: 8/15/2017

Drill Rig: CME-850

Driller: Terracon/Peter M.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2W Juniata River West

Page 2 of 4

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.435111° Longitude: -78.2999254° Approximate Surface Elev: 898 (Ft.) +/-								
	DEPTH	ELEVATION (Ft.)							
	Run 4, Similar to above				60		55	2.5 1.75 1.75 2.0 2.0	
40.0	858+/-	40							
	Run 5, Similar to above				51		60	3.0 3.5 3.75 3.5 3.75	
45.0	853+/-	45							
	Run 6, Similar to above				56		88	2.75 2.75 2.5 2.5 2.5	
50.0	848+/-	50							
	Run 7, Similar to above, moderately dipping to vertical joints				57		75	2.5 2.0 2.0 2.0 2.0	
55.0	843+/-	55							
	Run 8, Similar to above				57		83	2.0 2.0 2.0 2.0 2.25	
60.0	838+/-	60							
	Run 9, Similar to above, 64-65 feet : severely fractured zone				60		83	2.0 1.75 1.75 1.75 2.0	
65.0	833+/-	65							
	Run 10, Similar to above				60		95	2.0 2.25 2.25 2.0 2.0	
70.0	828+/-	70							

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

6' WD
0' AB

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/14/2017

Boring Completed: 8/15/2017

Drill Rig: CME-850

Driller: Terracon/Peter M.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2W Juniata River West

Page 3 of 4

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.435111° Longitude: -78.2999254° Approximate Surface Elev: 898 (Ft.) +/-								
	DEPTH ELEVATION (Ft.)								
	Run 11, Similar to above				60		95	2.0 2.0 2.0 2.0 2.25	
75.0	823+/-	75			60		91	2.0 2.0 2.0 2.0	
80.0	818+/-	80			53		45	3.0 3.25 3.25 3.0 3.25	
85.0	813+/-	85			60		83	3.0 3.5 3.5 3.25 3.25	
90.0	808+/-	90			60		62	3.0 2.75 2.75 2.75 2.5	
95.0	803+/-	95			60		52	3.0 3.25 5.0 4.5 3.5	
100.0	798+/-	100			50		43	2.75 2.75 2.75 2.75 2.5	
105.0	793+/-	105							

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

6' WD
0' AB

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/14/2017

Boring Completed: 8/15/2017

Drill Rig: CME-850

Driller: Terracon/Peter M.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2W Juniata River West

Page 4 of 4

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION Latitude: 40.435111° Longitude: -78.2999254° Approximate Surface Elev: 898 (Ft.) +/- DEPTH ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Run 18, Similar to above 110.0 788+/-	110			60		83	2.75 2.75 2.5 2.75 2.75	
	Run 19, Similar to above 115.0 783+/-	115			60		87	2.75 2.75 2.5 2.5 2.25	
	Run 20, Similar to above 120.0 778+/-	120			58		29	2.75 2.5 2.5 2.5 2.5	
	Boring Terminated at 120 Feet								

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

6' WD
0' AB

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/14/2017

Boring Completed: 8/15/2017

Drill Rig: CME-850

Driller: Terracon/Peter M.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

Page 1 of 20

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- ELEVATION (Ft.)								
	DEPTH								
	0.7 Gravel/cobbles 1355.5+/-								
	GRAVELLY LEAN CLAY WITH SAND (CL) , brown, very stiff								
		5							
				X	18	7-7-9 N=16			
		10							
				X	14	6-7-16 N=23			
		15							
	13.5 CLAYEY GRAVEL (GC) , trace sand, with shale fragments, medium dense 1342.5+/-								
				X	12	3-5-9 N=14			
		20							
				X	12	10-7-11 N=18			
		25							
	23.5 Brown to gray, very severely to completely weathered rock, friable, dense to very dense 1332.5+/-								
				X	12	13-24-35 N=59			
		30							
				X	14	19-27-38 N=65			

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017

Boring Completed: 8/29/2017

Drill Rig: Acker Renegade

Driller: Terracon/Willie D.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

Page 2 of 20

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- ELEVATION (Ft.)								
	DEPTH								
	Brown to gray, very severely to completely weathered rock, friable, dense to very dense (continued)								
		35		X	18	22-26-42 N=68			
		40		X	12	20-23-30 N=53			
		45		X	11	32-50/5"			
		50		X	15	24-38-42 N=80			
		55		X	15	20-28-36 N=64			
		60		X	10	34-50/4"			

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017

Boring Completed: 8/29/2017

Drill Rig: Acker Renegade

Driller: Terracon/Willie D.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL -J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

Page 3 of 20

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- ELEVATION (Ft.)								
	DEPTH								
	Brown to gray, very severely to completely weathered rock, friable, dense to very dense (<i>continued</i>)								
		65		X	15	32-44-50/5"			
		70		X	15	30-38-50/4"			
		75		X	13	40-36-42 N=78			
		80		X	13	13-23-26 N=49			
		85		X	16	15-26-37 N=63			
		90		X	10	14-24-13 N=37			

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

Hammer Type: Automatic

Advancement Method: Mud rotary with wireline	See Exhibit A-3 for description of field procedures. See Appendix B for description of laboratory procedures and additional data (if any).	Notes:	
Abandonment Method: Grouted to surface	See Appendix C for explanation of symbols and abbreviations.		
WATER LEVEL OBSERVATIONS	 201 Hammer Mill Rd Rocky Hill, CT	Boring Started: 8/21/2017	Boring Completed: 8/29/2017
▽ 16' 8/22/17		Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
▽ 12.1' 8/23/17		Project No.: J217P078	
▽ 12' 8/29/17			

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

Page 4 of 20

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- ELEVATION (Ft.)								
	DEPTH								
	Brown to gray, very severely to completely weathered rock, friable, dense to very dense (<i>continued</i>)								
		95			15	34-12-25 N=37			
	98.5	1257.5+/-			0	50/3"			
	Soft to moderately hard, very severely weathered, dark gray, carbonaceous LIMESTONE								
		100							
					3	50/3"			
		105							
					2	50/2"			
	109.2	1247+/-							
	Run 1, Hard, slightly weathered, gray, argillaceous LIMESTONE, thinly bedded, close to moderately close joint spacing, primary joint set: high angle, planar, fresh, slightly open				32		59	3.25 2.25	
	111.8	1244+/-							
	Run 2, Similar At 112.1 to 113.1 feet: high angle, slightly open, planar, iron stained joint				60		66	3.25 2.25 2 2.5 2.25	
		115							
	116.8	1239+/-							
					120			1.5 3.25	
		120							

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017

Boring Completed: 8/29/2017

Drill Rig: Acker Renegade

Driller: Terracon/Willie D.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

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PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- ELEVATION (Ft.)								
	DEPTH								
	Run 3, Moderately hard to hard, slightly weathered, dark gray, fine-grained, carbonaceous SHALE, very thinly bedded, primary joint set: high angle, close to moderately close, smooth, planar, fresh, slightly open At 117.8 feet: iron staining At 121.9 to 125.3 feet: high angle, clay filled joint (<i>continued</i>)	125			120		63	2 1.75 1.75 1.5 1.5 1.75 2 1.5	
	126.8 1229+/-								
	Run 4, Similar to 128.2 feet At 128.2 feet: Moderately hard to hard, slightly weathered, dark gray, fine grained SHALE, very thin bedding, interbedded with limestone, primary joint set: high angle, moderately close joint spacing, smooth, planar, fresh, slightly open; secondary joint set, low angle, close joint spacing, rough, planar, fresh, open At 132.6 to 133 feet: high angle iron-stained joint At 135.3 to 135.7 feet: high angle calcite filled joint	130 135			120		57	1.75 1.75 1.75 1.5 1.75 2.25 2.25 2.5 3.5 2	
	136.8 1219+/-								
	Run 5, Similar At 140.2 to 141.3 feet: low angle iron-stained joint	140 145			120		54	2 1.75 1.5 1.25 1.5 2.75 1.5 1.75 1.5 1.5	
	146.8 1209+/-								
	Run 6, Similar At 155.6 to 156.2 feet: high angle, open, iron-stained joint	150			120			1.75 1.25	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017

Boring Completed: 8/29/2017

Drill Rig: Acker Renegade

Driller: Terracon/Willie D.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

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PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- ELEVATION (Ft.)								
	Run 6, Similar At 155.6 to 156.2 feet: high angle, open, iron-stained joint (<i>continued</i>)	155			120		63	1.5 1.25 1.25 1.25 1.5 1.5 1.5 1.5	
	156.8 1199+/- Run 7, Similar At 159.0 to 159.3 feet: highly fractured zone	160			120		50	2 2 2.75 1.5 1.25 1.25 1.5 1.25 3 2.25	
	166.8 1189+/- Run 8, Similar	170			120		43	1.5 1.25 2 1.5 2.75 2 2.5 2 3.5 2.75	
	176.8 1179+/- Run 9, Similar At 178.7 to 179.2 feet: high angle, clay-filled joint	180			120			2.5 1.25	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017

Boring Completed: 8/29/2017

Drill Rig: Acker Renegade

Driller: Terracon/Willie D.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

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PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- ELEVATION (Ft.)								
	Run 9, Similar At 178.7 to 179.2 feet: high angle, clay-filled joint (<i>continued</i>)	185			120		62	1.75 2.25 1.5 1.5 2 1.75 1.5 1.25	
	Run 10, Similar	190			120		31	1.5 2 2.5 1.5 2.5 1.75 2 2.5 1.5 1.5	
	Run 11, Similar	200			120		63	1.75 2.5 1.5 1.5 2 1.75 2.25 2 2.5 1.75	
	Run 12, Similar At 209.0 to 209.7 feet: broken zone	210			120			2 1.75	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017

Boring Completed: 8/29/2017

Drill Rig: Acker Renegade

Driller: Terracon/Willie D.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

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PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- ELEVATION (Ft.)								
	DEPTH								
	Run 12, Similar At 209.0 to 209.7 feet: broken zone (<i>continued</i>)	215			120		71	1.25 2 1.75 1 1.5 1.75 1.75 2	
	216.8 1139+/-								
	Run 13, Similar	220			120		73	2 2 1.5 1.5 2 1.5 1.5 2 1.75 1.75	
	226.8 1129+/-								
	Run 14, Similar At 223.7 to 228.1 feet: broken zone At 233.8 to 238.4 feet: broken zone	230			120		80	1.5 2 2 1.5 1.25 1.5 1.5 1.75 1.5 2	
	236.8 1119+/-								
	Run 15, Moderately hard to hard, slightly weathered, dark gray, fine-grained SHALE, very thin bedding, interbedded with limestone, primary joint set: high angle, moderately close joint spacing, smooth, planar, fresh, slightly open	240			120			1.5 1.25	

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

Hammer Type: Automatic

Advancement Method: Mud rotary with wireline	See Exhibit A-3 for description of field procedures. See Appendix B for description of laboratory procedures and additional data (if any).	Notes:
Abandonment Method: Grouted to surface	See Appendix C for explanation of symbols and abbreviations.	
WATER LEVEL OBSERVATIONS	Terracon 201 Hammer Mill Rd Rocky Hill, CT	Boring Started: 8/21/2017 Boring Completed: 8/29/2017
16' 8/22/17		Drill Rig: Acker Renegade Driller: Terracon/Willie D.
12.1' 8/23/17		
12' 8/29/17		Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

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PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- ELEVATION (Ft.)								
	Run 15, Moderately hard to hard, slightly weathered, dark gray, fine-grained SHALE, very thin bedding, interbedded with limestone, primary joint set: high angle, moderately close joint spacing, smooth, planar, fresh, slightly open (<i>continued</i>)	245			120		61	1.25 2 1.5 1.25 1.75 1.75 1.5 1.5	
246.8		1109+/-							
	Run 16, Moderately hard to hard, fresh, dark gray, fine-grained, carbonaceous SHALE, very thin bedding, interbedded with siltstone/limestone, primary joint set: high angle, close to moderately close joint spacing, rough, planar, fresh, slightly open; secondary joint set: low angle, moderately close, rough, planar, fresh, open	250			115		90	1.75 1.5 1.25 1.25 1.5 1.25 1.5 1.5 1.5	
256.8		1099+/-							
	Run 17, Similar	260			120		100	1.25 1.25 1.5 1.25 1.25 1.25 1 1.25 1.25	
266.8		1089+/-							
	Run 18, Similar	270			120			1.5 1.25	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017

Boring Completed: 8/29/2017

Drill Rig: Acker Renegade

Driller: Terracon/Willie D.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

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PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- ELEVATION (Ft.)								
	Run 18, Similar (<i>continued</i>)	275			120		90	1.25 1.25 1.75 1.75 1.25 1.5 1.5 1.5	
	Run 19, Similar	280			120		90	1.75 1.25 1.5 1.25 1.25 1.5 1.75 1.5 1.75	
	Run 20, Similar	290			120		100	2.25 1.25 1.75 1.25 1.5 1.5 1.75 1.75 1.5	
	Run 21, Similar	300			120			4.25 2	
	At 297.4 to 297.7 feet: clay-filled zone								

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

Hammer Type: Automatic

Advancement Method: Mud rotary with wireline	See Exhibit A-3 for description of field procedures. See Appendix B for description of laboratory procedures and additional data (if any).	Notes:	
Abandonment Method: Grouted to surface	See Appendix C for explanation of symbols and abbreviations.		
WATER LEVEL OBSERVATIONS	 201 Hammer Mill Rd Rocky Hill, CT	Boring Started: 8/21/2017	Boring Completed: 8/29/2017
16' 8/22/17		Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
12.1' 8/23/17		Project No.: J217P078	
12' 8/29/17			

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

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PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- ELEVATION (Ft.)								
	Run 21, Similar At 297.4 to 297.7 feet: clay-filled zone (continued)	305			120		79	2 2 2 1.75 2 2.5 2.5 2.5	
	306.8 1049+/- Run 22, Similar	310			120		98	1.75 2 1.75 1.25 1.25 2.25 2.25 2.25 2.25	
	316.8 1039+/- Run 23, Similar	320			120		94	1.75 1 1.25 1.25 1.5 1.25 1.5 1.5 1.5	
	326.8 1029+/- Run 24, Similar At 327.8 to 329.1 feet: calcareous zone	330			120			1.75 1	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017

Boring Completed: 8/29/2017

Drill Rig: Acker Renegade

Driller: Terracon/Willie D.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

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PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- ELEVATION (Ft.)								
	DEPTH								
	Run 24, Similar At 327.8 to 329.1 feet: calcareous zone (continued)	335			120		98	1.25 1.25 1.5 1.25 1.5 1.25 1.5 1.5	
	336.8 1019+/-								
	Run 25, Similar	340			120		93	1.75 1.5 1.5 1.25 1.5 1.5 1.25 1.5 1.5	
	346.8 1009+/-								
	Run 26, Similar At 356.4 to 356.8 feet: lost recovery	350			117		94	1.5 2 2 1.5 1.75 1.75 1.75 1.5 1.5 1.5	
	356.8 999+/-								
	Run 27, Similar	360			120			1.5 1.75	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017

Boring Completed: 8/29/2017

Drill Rig: Acker Renegade

Driller: Terracon/Willie D.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

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PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- DEPTH ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Run 27, Similar (continued)	365			120		97	2 1.5 1.75 1.5 1.5 1.5 1	
	Run 28, Similar At 367.9 to 368.2 feet: high angle slickensided joints	370			120		92	1.5 1.25 1.75 2 1.5 1.25 1.75 1.5 2 2.25	
	Run 29, Similar to 386.2 feet At 386.2 feet: Hard, fresh, gray, argillaceous LIMESTONE, thin to medium bedding, interbedded with shale, primary joint set: high angle, moderately close, rough, planar, fresh, slightly open; secondary joint set: low angle, moderately close, smooth, planar, fresh	380			120		95	2.75 2 1.5 1.75 1.5 1.25 1.25 1.25 1.25	
	Run 30, Similar from 386.2 feet	390			120			2.75 1.75	

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

Hammer Type: Automatic

Advancement Method: Mud rotary with wireline	See Exhibit A-3 for description of field procedures. See Appendix B for description of laboratory procedures and additional data (if any).	Notes:
Abandonment Method: Grouted to surface	See Appendix C for explanation of symbols and abbreviations.	
WATER LEVEL OBSERVATIONS		Boring Started: 8/21/2017 Boring Completed: 8/29/2017
 16' 8/22/17	201 Hammer Mill Rd Rocky Hill, CT	Drill Rig: Acker Renegade Driller: Terracon/Willie D.
 12.1' 8/23/17		Project No.: J217P078
 12' 8/29/17		

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

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PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- DEPTH ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Run 30, Similar from 386.2 feet (continued)	395			120		90	1.5 1.25 1.75 1.25 1.75 2.5 3	
	Run 31, Similar	400			120		90	1.75 1.5 1.75 2 1.75 1.75 2.25 2.75 3 2.75	
	Run 32, Similar	410			120		88	1.75 1.5 2.5 2 2.5 2.5 2.5 2.5 2	
		420			120			1.75 1.75	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017

Boring Completed: 8/29/2017

Drill Rig: Acker Renegade

Driller: Terracon/Willie D.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

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PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/-								
	DEPTH ELEVATION (Ft.)								
	Run 33, Similar to 422.3 feet At 422.3 feet: Soft to moderately hard, slightly to moderately weathered, reddish brown to gray SHALE, interbedded with siltstone, occasional calcareous nodules, very thinly bedded, primary joint set: high angle, planar, rough, fresh, slightly open; secondary joint set: low angle, planar, smooth, fresh, slightly open (continued)	425			120		93	2 1.5 2 2.5 2.5 2 2.5 2	
	426.8 929+/-								
	Run 34, Similar At 431.6 to 432.4 feet: calcareous zone	430			120		89	1.75 1.5 2 1.25 3.5 1.5 1.75 1.25 2.5 3.5	
	436.8 919+/-								
	Run 35, Similar At 443.6 to 447.1 feet: calcareous zone	440			120		92	3.25 2.5 2.5 3.25 2 2.25 2.5 2 1.75 1.75	
446.8 909+/-									
	Run 36, Similar	450			120			2 2.5	
Stratification lines are approximate. In-situ, the transition may be gradual. Hammer Type: Automatic									
Advancement Method: Mud rotary with wireline		See Exhibit A-3 for description of field procedures. See Appendix B for description of laboratory procedures and additional data (if any).			Notes:				
Abandonment Method: Grouted to surface		See Appendix C for explanation of symbols and abbreviations.							
WATER LEVEL OBSERVATIONS		 201 Hammer Mill Rd Rocky Hill, CT			Boring Started: 8/21/2017		Boring Completed: 8/29/2017		
16' 8/22/17					Drill Rig: Acker Renegade		Driller: Terracon/Willie D.		
12.1' 8/23/17					Project No.: J217P078				
12' 8/29/17									

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

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PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- ELEVATION (Ft.)								
	Run 36, Similar (continued)	455			120		86	2.75 2.75 2.75 2.25 2.5 2.5 2.5 2.5	
	456.8 899+/-								
	Run 37, Similar	460			120		98	2.25 2.25 2.25 2.25 2.25 1.75 2.25 2.5	
	At 463.8 to 464.2 feet: calcareous zone	465							
	466.8 889+/-								
	Run 38, Similar	470			120		98	2.25 3 2.75 2.75 2.5 3 2.5 1.75 2 3	
	476.8 879+/-	475							
	Run 39, Similar	480			120			2.25 2.75	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017

Boring Completed: 8/29/2017

Drill Rig: Acker Renegade

Driller: Terracon/Willie D.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

Page 17 of 20

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- DEPTH ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Run 39, Similar (continued)	485			120		94	2.5 1.75 2 2 1.75 2.25 2.5 2.75	
	Run 40, Similar At 493.2 to 494 feet: calcareous zone	490			120		80	3 2 2 2 2 2.25 2 2.5 3 3	
	Run 41, Similar	500			120		97	2.5 2.25 2.5 1.75 2.25 2.25 2.5 2.25 1.75 2.25	
	Run 42, Similar At 515.0 to 521.8 feet: calcareous zone	510			120			2.25 2.75	

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

Hammer Type: Automatic

Advancement Method: Mud rotary with wireline	See Exhibit A-3 for description of field procedures. See Appendix B for description of laboratory procedures and additional data (if any).	Notes:
Abandonment Method: Grouted to surface	See Appendix C for explanation of symbols and abbreviations.	
WATER LEVEL OBSERVATIONS		Boring Started: 8/21/2017 Boring Completed: 8/29/2017
 16' 8/22/17	201 Hammer Mill Rd Rocky Hill, CT	Drill Rig: Acker Renegade Driller: Terracon/Willie D.
 12.1' 8/23/17		
 12' 8/29/17		Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

Page 18 of 20

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- ELEVATION (Ft.)								
	Run 42, Similar At 515.0 to 521.8 feet: calcareous zone (continued)	515			120		100	2.5 2.25 1.75 2.5 2.25 1.75 2 2.5	
	Run 43, Similar	520			120		100	2.25 1.75 2.25 2 2 2 1.5 1.75 2 2.5	
	Run 44, Similar	530			120		93	2.25 2.25 2 2.25 2.5 2 2 1.5 1.75 2	
	Run 45, Similar At 540.4 to 540.9 feet: calcareous zone	540			120			2 2.25	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017

Boring Completed: 8/29/2017

Drill Rig: Acker Renegade

Driller: Terracon/Willie D.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

Page 19 of 20

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- DEPTH ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Run 45, Similar At 540.4 to 540.9 feet: calcareous zone (continued)	545			120		95	2.75 2 2 1.75 1.75 2.75 3.75	
	546.8 809+/-								
	Run 46, Similar At 546.8 to 547.8 feet: calcareous zone	550			120		95	3.25 2.75 2.5 2.75 2 2.25 3 3 2.5 2.75	
	556.8 799+/-								
	Run 47, Similar	560			120		98	1.75 1.75 2 2.75 2.5 2.5 2.75 2.25 2.5 3.5	
	566.8 789+/-								
	Run 48, Similar	570			120			2 2.25	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017

Boring Completed: 8/29/2017

Drill Rig: Acker Renegade

Driller: Terracon/Willie D.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

BORING LOG NO. B3-2E Juniata River East

Page 20 of 20

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.432059° Longitude: -78.289578° Approximate Surface Elev: 1356 (Ft.) +/- ELEVATION (Ft.)								
	Run 48, Similar (continued)	575			120		100	2.75 2 2.25 2.25 2.75 2 2 2.25	
	576.8 779+/-								
	Run 49, Similar At 577.3 to 578.1 feet: calcareous zone	580			120		98	2.25 2.5 2.25 1.75 2 2 2 1.75 2.25 2.25	
	586.8 769+/-								
	Boring Terminated at 586.8 Feet								
Stratification lines are approximate. In-situ, the transition may be gradual. Hammer Type: Automatic									
Advancement Method: Mud rotary with wireline			See Exhibit A-3 for description of field procedures. See Appendix B for description of laboratory procedures and additional data (if any). See Appendix C for explanation of symbols and abbreviations.			Notes:			
Abandonment Method: Grouted to surface									
WATER LEVEL OBSERVATIONS			 201 Hammer Mill Rd Rocky Hill, CT			Boring Started: 8/21/2017		Boring Completed: 8/29/2017	
16' 8/22/17						Drill Rig: Acker Renegade		Driller: Terracon/Willie D.	
12.1' 8/23/17						Project No.: J217P078			
12' 8/29/17									

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 3.GPJ

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

Boring No.: B3-2W
 Sample No.: 1
 Sample Depth: 43.5 feet
 Sampling Date: 8/14/17

Lithology : Mudstone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 1 min

Diameter: 1.97 in
 Length: 4.47 in
 L/D: 2.27
 End Area: 3.05 in²

Maximum Axial Load at Failure: 3,470 lb
 Compressive Strength: 1,138 psi
 Compressive Strength: 7.85 Mpa
 Unit Weight 161 pcf

Photograph before the test mistakenly shows 42 feet

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 3
Client :	Directional Project Support Inc.

Terracon
 77 Sundial Ave., Suite 401 W
 Manchester, New Hampshire

Performed by:	W. Shedd
Test Date:	10/7/2017
Reviewed By :	L.Dwyer
Review Date :	10/9/2017

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

Boring No.: B3-2W
 Sample No.: 2
 Sample Depth: 60 feet
 Sampling Date: 8/14/17

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

Diameter: 1.93 in
 Length: 3.47 in
 L/D: 1.80
 End Area: 2.93 in²

Maximum Axial Load at Failure: 12,940 lb
 Compressive Strength: 4,423 psi
 Compressive Strength: 30.50 Mpa
 Unit Weight 166 pcf

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

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 3
Client :	Directional Project Support Inc.

Terracon
 77 Sundial Ave., Suite 401 W
 Manchester, New Hampshire

Performed by:	A.Suprunenko
Test Date:	10/3/2017
Reviewed By :	L.Dwyer
Review Date :	10/9/2017

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

Boring No.: B3-2W
 Sample No.: 3
 Sample Depth: 80 feet
 Sampling Date: 8/14/17

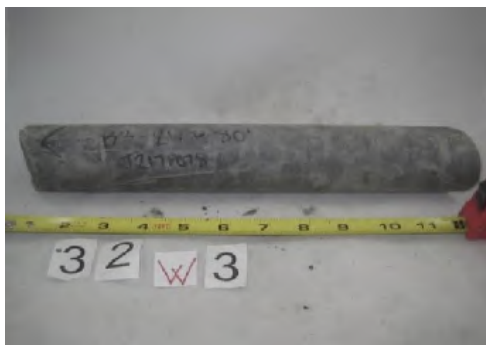
Lithology : Mudstone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 4 min

Diameter: 1.93 in
 Length: 3.78 in
 L/D: 1.96
 End Area: 2.93 in²

Maximum Axial Load at Failure: 11,920 lb
 Compressive Strength: 4,074 psi
 Compressive Strength: 28.09 Mpa
 Unit Weight 63 pcf

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

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2W
 Sample No.: 4
 Sample Depth: 100 feet
 Sampling Date: 8/14/17

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

Diameter: 1.93 in
 Length: 4.49 in
 L/D: 2.33
 End Area: 2.93 in²

Maximum Axial Load at Failure: 13,720 lb
 Compressive Strength: 4,690 psi
 Compressive Strength: 32.33 Mpa
 Unit Weight 167 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 3
Client :	Directional Project Support Inc.

Terracon
 77 Sundial Ave., Suite 401 W
 Manchester, New Hampshire

Performed by:	A.Suprunenko
Test Date:	10/3/2017
Reviewed By :	L.Dwyer
Review Date :	10/9/2017

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

Boring No.: B3-2W
 Sample No.: 5
 Sample Depth: 110 feet
 Sampling Date: 8/14/17

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

Diameter: 1.93 in
 Length: 4.00 in
 L/D: 2.07
 End Area: 2.93 in²

Maximum Axial Load at Failure: 13,960 lb
 Compressive Strength: 4,772 psi
 Compressive Strength: 32.90 Mpa
 Unit Weight 165 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2W
 Sample No.: 6
 Sample Depth: 119 feet
 Sampling Date: 8/14/17

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

Diameter: N/A in
 Length: N/A in
 L/D: N/A
 End Area: N/A in²

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

Specimen broke during preparation

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 3
Client :	Directional Project Support Inc.

Terracon
 77 Sundial Ave., Suite 401 W
 Manchester, New Hampshire

Performed by:	H. Whitford
Test Date:	10/9/2017
Reviewed By :	L.Dwyer
Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 1
 Sample Depth: 130 feet
 Sampling Date: 8/21/17

Lithology : Shale
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 14 min

Diameter: 1.99 in
 Length: 4.67 in
 L/D: 2.35
 End Area: 3.11 in²

Maximum Axial Load at Failure: 44,700 lb
 Compressive Strength: 14,372 psi
 Compressive Strength: 99.09 Mpa
 Unit Weight 169 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

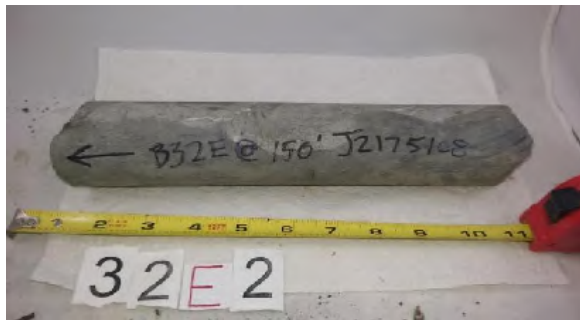
Boring No.: B3-2E
 Sample No.: 2
 Sample Depth: 150 feet
 Sampling Date: 8/21/17

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

Diameter: 1.99 in
 Length: 4.54 in
 L/D: 2.28
 End Area: 3.11 in²

Maximum Axial Load at Failure: 16,090 lb
 Compressive Strength: 5,173 psi
 Compressive Strength: 35.67 Mpa
 Unit Weight 170 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 3
Client :	Directional Project Support Inc.

Terracon
 77 Sundial Ave., Suite 401 W
 Manchester, New Hampshire

Performed by:	A.Suprunenko
Test Date:	10/3/2017
Reviewed By :	L.Dwyer
Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 3
 Sample Depth: 170 feet
 Sampling Date: 8/21/17

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

Diameter: 1.98 in
 Length: 4.20 in
 L/D: 2.12
 End Area: 3.08 in²

Maximum Axial Load at Failure: 19,700 lb
 Compressive Strength: 6,398 psi
 Compressive Strength: 44.11 Mpa
 Unit Weight 74 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 4
 Sample Depth: 190 feet
 Sampling Date: 8/21/17

Lithology : Shale
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 9 min

Diameter: 1.98 in
 Length: 4.56 in
 L/D: 2.30
 End Area: 3.08 in²

Maximum Axial Load at Failure: 28,100 lb
 Compressive Strength: 9,126 psi
 Compressive Strength: 62.92 Mpa
 Unit Weight 167 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 5
 Sample Depth: 210 feet
 Sampling Date: 8/21/17

Lithology : Shale
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 1 min

Diameter: 1.99 in
 Length: 4.50 in
 L/D: 2.26
 End Area: 3.11 in²

Maximum Axial Load at Failure: 3,220 lb
 Compressive Strength: 1,035 psi
 Compressive Strength: 7.14 Mpa
 Unit Weight 167 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

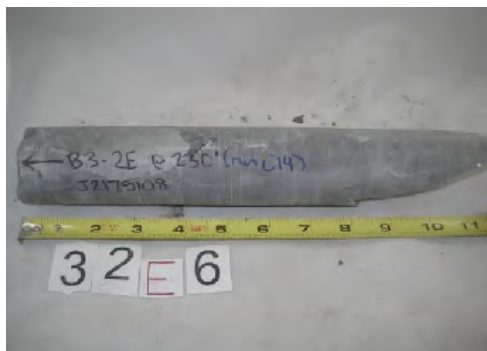
Boring No.: B3-2E
 Sample No.: 6
 Sample Depth: 230 feet
 Sampling Date: 8/21/17

Lithology : Shale
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 1 min

Diameter: 1.98 in
 Length: 4.48 in
 L/D: 2.26
 End Area: 3.08 in²

Maximum Axial Load at Failure: 4,310 lb
 Compressive Strength: 1,400 psi
 Compressive Strength: 9.65 Mpa
 Unit Weight 168 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 6
 Sample Depth: 230 feet
 Sampling Date: 8/21/17

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

Diameter: 1.98 in
 Length: 4.05 in
 L/D: 2.05
 End Area: 3.08 in²

Maximum Axial Load at Failure: 13,230 lb
 Compressive Strength: 4,297 psi
 Compressive Strength: 29.62 Mpa
 Unit Weight 165 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 3
Client :	Directional Project Support Inc.

Terracon
 77 Sundial Ave., Suite 401 W
 Manchester, New Hampshire

Performed by:	W. Shedd
Test Date:	10/7/2017
Reviewed By :	L.Dwyer
Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 7
 Sample Depth: 250 feet
 Sampling Date: 8/21/17

Lithology : Shale
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 1 min

Diameter: 1.98 in
 Length: 4.40 in
 L/D: 2.22
 End Area: 3.08 in²

Maximum Axial Load at Failure: 1,790 lb
 Compressive Strength: 581 psi
 Compressive Strength: 4.01 Mpa
 Unit Weight 170 pcf

Before the Test

Photograph before the test is not available

After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 8
 Sample Depth: 270 feet
 Sampling Date: 8/21/17

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

Diameter: N/A in
 Length: N/A in
 L/D: N/A
 End Area: N/A in²

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

Specimen broke during preparation. Target depth range is too fractured to assign second test.

Before the Test



After the Test

Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 9
 Sample Depth: 287 feet
 Sampling Date: 8/21/17

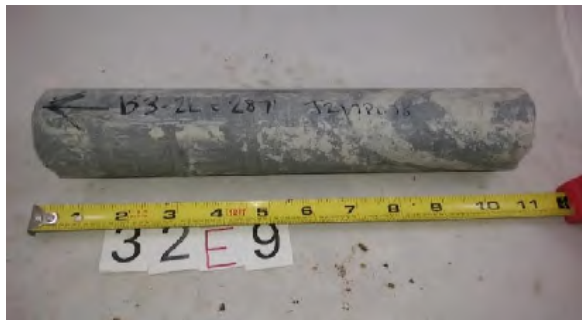
Lithology : Shale
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 2 min

Diameter: 1.99 in
 Length: 3.00 in
 L/D: 1.51
 End Area: 3.11 in²

Maximum Axial Load at Failure: 7,490 lb
 Compressive Strength: 2,408 psi
 Compressive Strength: 16.60 Mpa
 Unit Weight 168 pcf

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

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 10
 Sample Depth: 310 feet
 Sampling Date: 8/21/17

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

Diameter: N/A in
 Length: N/A in
 L/D: N/A
 End Area: N/A in²

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

Specimen broke during preparation

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 11
 Sample Depth: 330 feet
 Sampling Date: 8/21/17

Lithology : Shale
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 7 min

Diameter: 2.00 in
 Length: 4.30 in
 L/D: 2.15
 End Area: 3.14 in²

Maximum Axial Load at Failure: 23,750 lb
 Compressive Strength: 7,560 psi
 Compressive Strength: 52.12 Mpa
 Unit Weight 169 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 12
 Sample Depth: 351 feet
 Sampling Date: 8/21/17

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

Diameter: 1.99 in
 Length: 4.27 in
 L/D: 2.15
 End Area: 3.11 in²

Maximum Axial Load at Failure: 16,680 lb
 Compressive Strength: 5,363 psi
 Compressive Strength: 36.98 Mpa
 Unit Weight 172 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 3
Client :	Directional Project Support Inc.

Terracon
 77 Sundial Ave., Suite 401 W
 Manchester, New Hampshire

Performed by:	H. Whitford
Test Date:	10/9/2017
Reviewed By :	L.Dwyer
Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 13
 Sample Depth: 370 feet
 Sampling Date: 8/21/17

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

Diameter: N/A in
 Length: N/A in
 L/D: N/A
 End Area: N/A in²

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

Specimen broke during preparation

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 14
 Sample Depth: 390 feet
 Sampling Date: 8/21/17

Lithology : Limestone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 18 min

Diameter: 1.91 in
 Length: 4.40 in
 L/D: 2.30
 End Area: 2.87 in²

Maximum Axial Load at Failure: 57,780 lb
 Compressive Strength: 20,166 psi
 Compressive Strength: 139.04 Mpa
 Unit Weight 193 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 3
Client :	Directional Project Support Inc.

Terracon
 77 Sundial Ave., Suite 401 W
 Manchester, New Hampshire

Performed by:	A.Suprunenko
Test Date:	10/3/2017
Reviewed By :	L.Dwyer
Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 15
 Sample Depth: 410 feet
 Sampling Date: 8/21/17

Lithology : Limestone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 1 min

Diameter: 2.00 in
 Length: 4.32 in
 L/D: 2.16
 End Area: 3.14 in²

Maximum Axial Load at Failure: 2,330 lb
 Compressive Strength: 742 psi
 Compressive Strength: 5.11 Mpa
 Unit Weight 168 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 3
Client :	Directional Project Support Inc.

Terracon
 77 Sundial Ave., Suite 401 W
 Manchester, New Hampshire

Performed by:	A.Suprunenko
Test Date:	10/3/2017
Reviewed By :	L.Dwyer
Review Date :	10/9/2017

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

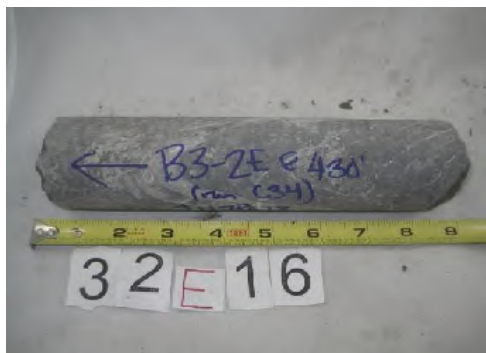
Boring No.: B3-2E
 Sample No.: 16
 Sample Depth: 430 feet
 Sampling Date: 8/21/17

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

Diameter: 2.00 in
 Length: 4.37 in
 L/D: 2.19
 End Area: 3.14 in²

Maximum Axial Load at Failure: 7,930 lb
 Compressive Strength: 2,524 psi
 Compressive Strength: 17.40 Mpa
 Unit Weight 169 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 17
 Sample Depth: 450 feet
 Sampling Date: 8/21/17

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

Diameter: N/A in
 Length: N/A in
 L/D: N/A
 End Area: N/A in²

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

Specimen broke during preparation

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 3
Client :	Directional Project Support Inc.

Terracon
 77 Sundial Ave., Suite 401 W
 Manchester, New Hampshire

Performed by:	A.Suprunenko
Test Date:	10/3/2017
Reviewed By :	L.Dwyer
Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 18
 Sample Depth: 472 feet
 Sampling Date: 8/21/17

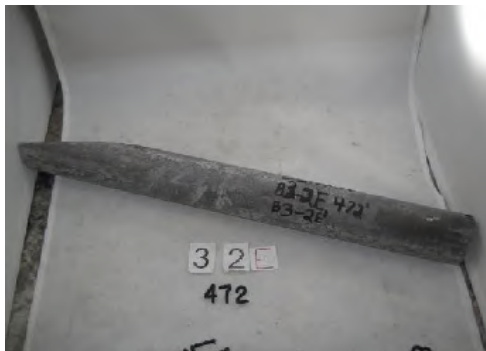
Lithology : Shale
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 2 min

Diameter: 1.99 in
 Length: 3.17 in
 L/D: 1.59
 End Area: 3.11 in²

Maximum Axial Load at Failure: 5,390 lb
 Compressive Strength: 1,733 psi
 Compressive Strength: 11.95 Mpa
 Unit Weight 171 pcf

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

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	H. Whitford
Project No.	J217P078		Test Date:	10/9/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

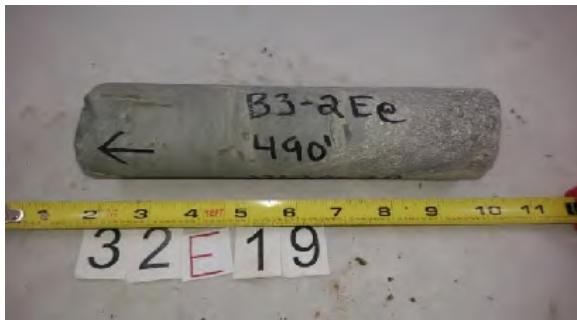
Boring No.: B3-2E
 Sample No.: 19
 Sample Depth: 490 feet
 Sampling Date: 8/21/17

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

Diameter: 2.00 in
 Length: 4.58 in
 L/D: 2.29
 End Area: 3.14 in²

Maximum Axial Load at Failure: 18,890 lb
 Compressive Strength: 6,013 psi
 Compressive Strength: 41.46 Mpa
 Unit Weight 172 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 20
 Sample Depth: 510 feet
 Sampling Date: 8/21/17

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

Diameter: 1.91 in
 Length: 3.61 in
 L/D: 1.89
 End Area: 2.87 in²

Maximum Axial Load at Failure: 380 lb
 Compressive Strength: 133 psi
 Compressive Strength: 0.91 Mpa
 Unit Weight 209 pcf

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

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 21
 Sample Depth: 530 feet
 Sampling Date: 8/21/17

Lithology : Shale
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 1 min

Diameter: 1.99 in
 Length: 4.51 in
 L/D: 2.27
 End Area: 3.11 in²

Maximum Axial Load at Failure: 3,160 lb
 Compressive Strength: 1,016 psi
 Compressive Strength: 7.01 Mpa
 Unit Weight 172 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 22
 Sample Depth: 550 feet
 Sampling Date: 8/21/17

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

Diameter: N/A in
 Length: N/A in
 L/D: N/A
 End Area: N/A in²

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

Specimen broke during preparation

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 3
Client :	Directional Project Support Inc.

Terracon
 77 Sundial Ave., Suite 401 W
 Manchester, New Hampshire

Performed by:	A.Suprunenko
Test Date:	10/3/2017
Reviewed By :	L.Dwyer
Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 23
 Sample Depth: 565 feet
 Sampling Date: 8/21/17

Lithology : Shale
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 1 min

Diameter: 1.99 in
 Length: 4.45 in
 L/D: 2.24
 End Area: 3.11 in²

Maximum Axial Load at Failure: 4,020 lb
 Compressive Strength: 1,292 psi
 Compressive Strength: 8.91 Mpa
 Unit Weight 172 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 24
 Sample Depth: 575 feet
 Sampling Date: 8/21/17

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

Diameter: 2.00 in
 Length: 4.53 in
 L/D: 2.27
 End Area: 3.14 in²

Maximum Axial Load at Failure: 1,440 lb
 Compressive Strength: 458 psi
 Compressive Strength: 3.16 Mpa
 Unit Weight 171 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

Boring No.: B3-2E
 Sample No.: 25
 Sample Depth: 585 feet
 Sampling Date: 8/21/17

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

Diameter: 1.99 in
 Length: 4.49 in
 L/D: 2.26
 End Area: 3.11 in²

Maximum Axial Load at Failure: 12,990 lb
 Compressive Strength: 4,176 psi
 Compressive Strength: 28.80 Mpa
 Unit Weight 172 pcf

Before the Test



After the Test



Drawing # : PA-BL-0122.0000-WX
 PO # : 20170804-14
 Crossing : Juniata River
 Spread : Spread 3

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 3
Client :	Directional Project Support Inc.

Terracon
 77 Sundial Ave., Suite 401 W
 Manchester, New Hampshire

Performed by:	A.Suprunenko
Test Date:	10/3/2017
Reviewed By :	L.Dwyer
Review Date :	10/9/2017

The information contained in this report may not be reproduced except in its entirety without the express written consent of Terracon, Inc. Reports are relevant only to the items tested and may not be attributed to other work. Testing was performed in general accordance with the stated ASTM test method.



Photograph 1: B3-2W, Samples C-1 to C-4 (20 to 40 feet)



Photograph 2: B3-2W, Samples C-5 to C-8 (40 to 60 feet)



Photograph 3: B3-2W, Samples C-9 to C-12 (60 to 80 feet)



Photograph 4: B3-2W, Samples C-13 to C-16 (80 to 100 feet)



Photograph 5: B3-2W, Samples C-17 to C-20 (100 to 120 feet)



Photograph 1: B3-2E, Samples C-1 to C-3 (109.2 to 126.8 feet)



Photograph 2: B3-2E, Samples C-4 to C-5 (126.8 to 146.8 feet)



Photograph 3: B3-2E, Samples C-6 to C-7 (146.8 to 166.8 feet)



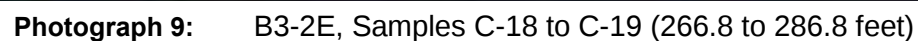
Photograph 4: B3-2E, Samples C-8 to C-9 (166.8 to 186.8 feet)



Photograph 5: B3-2E, Samples C-10 to C-11 (186.8 to 206.8 feet)

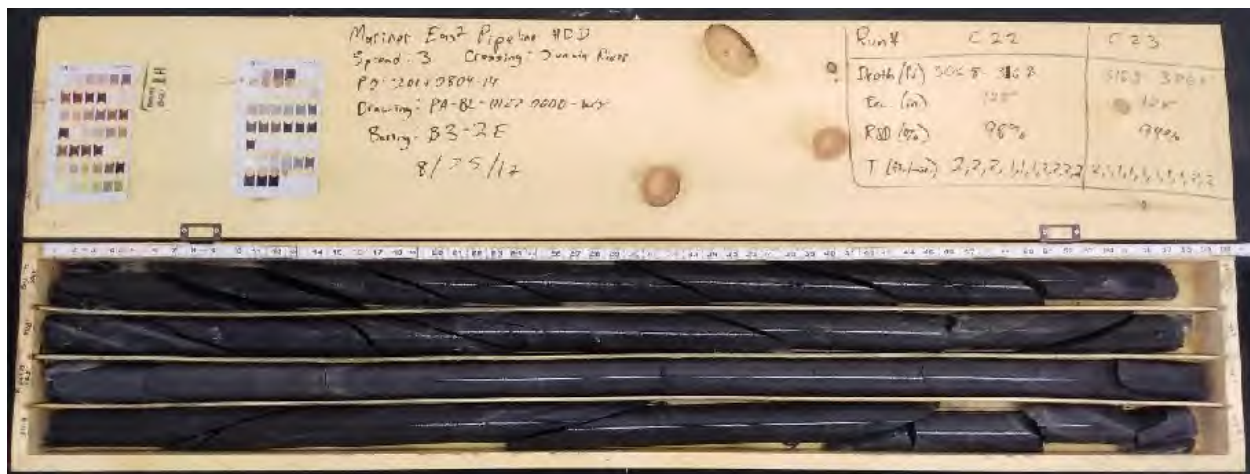


Photograph 6: B3-2E, Samples C-12 to C-13 (206.8 to 226.8 feet)

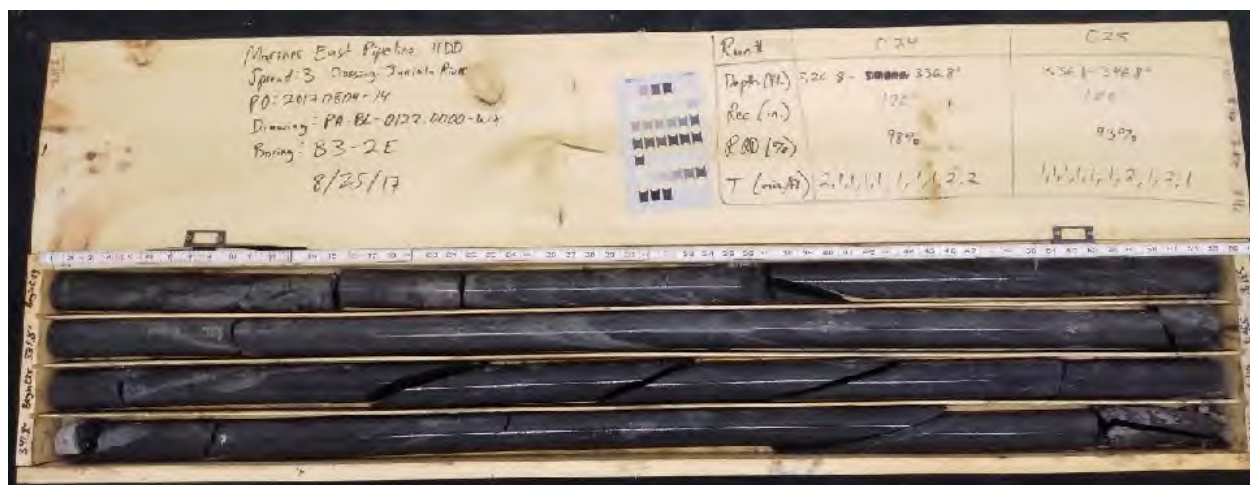




Photograph 10: B3-2E, Samples C-20 to C-21 (286.8 to 306.8 feet)



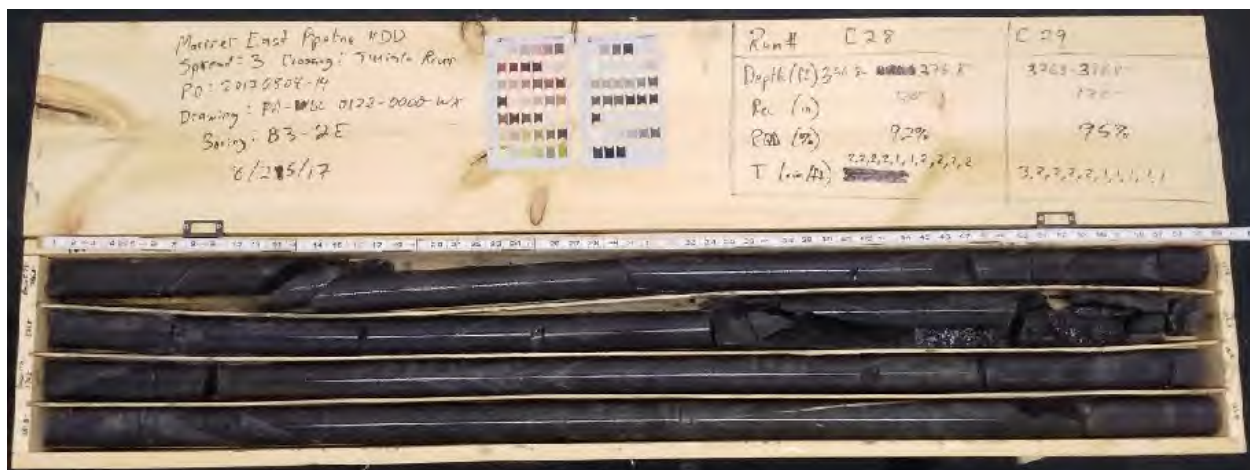
Photograph 11: B3-2E, Samples C-22 to C-23 (306.8 to 326.8 feet)



Photograph 12: B2-3E, Samples C-24 to C-25 (326.8 to 346.8 feet)



Photograph 13: B3-2E, Samples C-26 to C-27 (346.8 to 366.8 feet)



Photograph 14: B3-2E, Samples C-28 to C-29 (366.8 to 386.8 feet)



Photograph 15: B3-2E, C-30 to C-31 (386.8 to 406.8 feet)



Photograph 16: B3-2E, Samples C-32 to C-33 (406.8 to 426.8 feet)



Photograph 17: B3-2E, Samples C-34 to C-35 (426.8 to 446.8 feet)



Photograph 18: B3-2E, Samples C-36 to C-37 (446.8 to 466.8 feet)



Photograph 19: B3-2E, Samples C-38 to C-39 (466.8 to 486.8 feet)



Photograph 20: B3-2E, Samples C-40 to C-41 (486.8 to 506.8 feet)



Photograph 21: B3-2E, Samples C-42 to C-43 (506.8 to 526.8 feet)



SUPPORTING INFORMATION

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests ^A					Soil Classification	
					Group Symbol	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:	Cu ³ 4 and 1 ≤ Cc ≤ 3 ^E		GW	Well-graded gravel ^F
		Less than 5% fines ^C	Cu < 4 and/or 1 > Cc > 3 ^E		GP	Poorly graded gravel ^F
		Gravels with Fines:	Fines classify as ML or MH		GM	Silty gravel ^{F,G,H}
		More than 12% fines ^C	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:	Cu ³ 6 and 1 ≤ Cc ≤ 3 ^E		SW	Well-graded sand ^I
		Less than 5% fines ^D	Cu < 6 and/or 1 > Cc > 3 ^E		SP	Poorly graded sand ^I
		Sands with Fines:	Fines classify as ML or MH		SM	Silty sand ^{G,H,I}
		More than 12% fines ^D	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

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

^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.

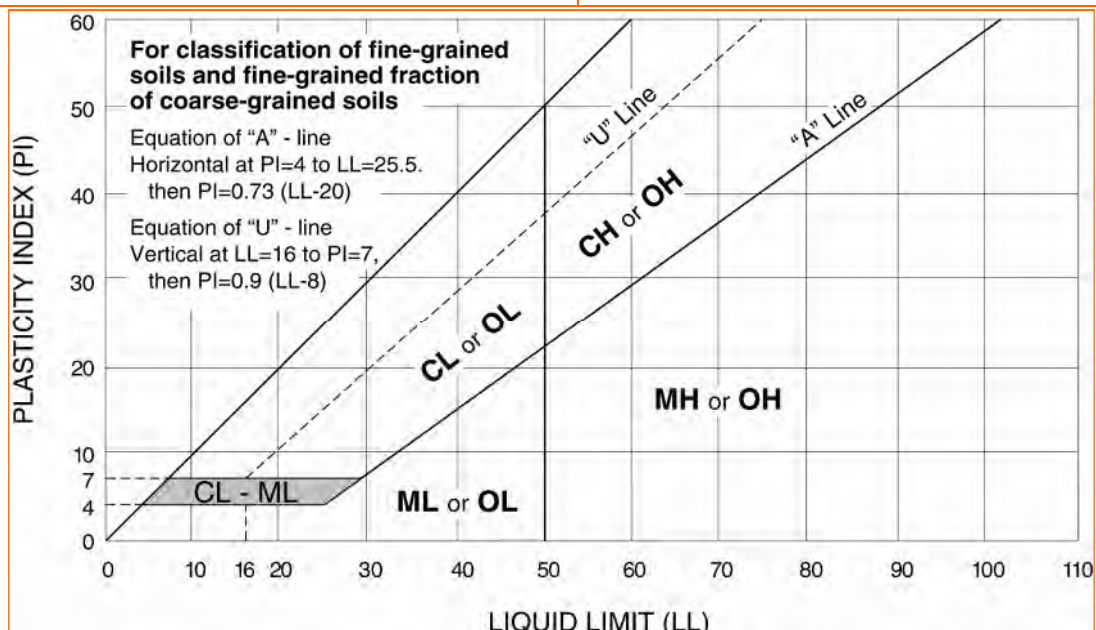
^M If soil contains ³ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

^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

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

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

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

ATTACHMENT 2
SOIL RESOURCES MAP AND PROFILE DESCRIPTIONS

Soil Map

Map Scale: 1:15,700 if printed on A landscape (11" x 8.5") sheet.

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84



United States
Department of
Agriculture



Natural
Resources
Conservation
Service

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

Custom Soil Resource Report for **Blair County, Pennsylvania**



Custom Soil Resource Report

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Unit Polygons

 Soil Map Unit Lines

 Soil Map Unit Points

Special Point Features

 Blowout
 Borrow Pit
 Clay Spot
 Closed Depression
 Gravel Pit
 Gravelly Spot
 Landfill
 Lava Flow
 Marsh or swamp
 Mine or Quarry
 Miscellaneous Water
 Perennial Water
 Rock Outcrop
 Saline Spot
 Sandy Spot
 Severely Eroded Spot
 Sinkhole
 Slide or Slip
 Sodic Spot

 Spoil Area
 Stony Spot
 Very Stony Spot
 Wet Spot
 Other
 Special Line Features

Water Features

 Streams and Canals

Transportation

 Rails
 Interstate Highways
 US Routes
 Major Roads
 Local Roads

Background

 Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

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

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL:

Coordinate System: Web Mercator (EPSG:3857)

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

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

Soil Survey Area: Blair County, Pennsylvania

Survey Area Data: Version 10, Sep 19, 2016

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

Date(s) aerial images were photographed: Oct 6, 2011—Oct 17, 2011

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

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
AbB	Albrights gravelly silt loam, 3 to 8 percent slopes	3.7	0.5%
AbC	Albrights gravelly silt loam, 8 to 15 percent slopes	3.2	0.4%
Ba	Basher soils	57.8	7.2%
BmF	Berks-Weikert channery silt loams, 25 to 70 percent slopes	15.9	2.0%
BrB	Brinkerton silt loam, 3 to 8 percent slopes	2.6	0.3%
BuB	Buchanan gravelly silt loam, 3 to 8 percent slopes	3.5	0.4%
BuC	Buchanan gravelly silt loam, 8 to 15 percent slopes	0.1	0.0%
BxB	Buchanan extremely stony silt loam, 3 to 8 percent slopes	28.0	3.5%
BxD	Buchanan extremely stony silt loam, 8 to 25 percent slopes	118.3	14.8%
CbB	Clarksburg silt loam, 3 to 8 percent slopes	6.0	0.7%
CbC	Clarksburg silt loam, 8 to 15 percent slopes	0.8	0.1%
DR	Dystrochrepts-Rubble land complex	55.7	7.0%
EdC	Edom silty clay loam, 8 to 15 percent slopes	4.6	0.6%
ErB	Ernest silt loam, 3 to 8 percent slopes	4.6	0.6%
ErC	Ernest silt loam, 8 to 15 percent slopes	5.5	0.7%
HeD	Hagerstown-Rock outcrop complex, 8 to 25 percent slopes	0.3	0.0%
HhC	Hazleton very stony sandy loam, 8 to 15 percent slopes	11.5	1.4%
HhF	Hazleton channery sandy loam, 25 to 70 percent slopes, extremely stony	66.4	8.3%
Ho	Holly silt loam	8.7	1.1%
HuB	Hublersburg cherty silt loam, 3 to 8 percent slopes	0.1	0.0%
HuC	Hublersburg cherty silt loam, 8 to 15 percent slopes	0.7	0.1%

Custom Soil Resource Report

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
HxD2	Hublersburg cherty silty clay loam, 15 to 25 percent slopes, eroded	0.7	0.1%
LaD	Laidig channery loam, 15 to 25 percent slopes	2.4	0.3%
LeD	Laidig extremely stony loam, 8 to 25 percent slopes	71.0	8.9%
LeF	Laidig extremely stony loam, 25 to 45 percent slopes	96.3	12.1%
LLF	Leck kill channery silt loam, very steep	32.3	4.0%
LnD	Lehew very stony loam, 8 to 25 percent slopes	14.6	1.8%
Lo	Linden soils	1.9	0.2%
MeC	Meckesville gravelly silt loam, 8 to 15 percent slopes	17.3	2.2%
MkD	Meckesville very stony silt loam, 8 to 25 percent slopes	34.8	4.4%
MoB	Monongahela silt loam, 3 to 8 percent slopes	4.3	0.5%
MuB	Murrill gravelly silt loam, 3 to 8 percent slopes	7.8	1.0%
MuC	Murrill gravelly silt loam, 8 to 15 percent slopes	15.6	2.0%
MuD	Murrill gravelly silt loam, 15 to 25 percent slopes	6.2	0.8%
MxD	Murrill extremely stony silt loam, 8 to 25 percent slopes	37.0	4.6%
OuC	Opequon silty clay loam, 8 to 15 percent slopes	0.8	0.1%
OuD	Opequon silty clay loam, 15 to 25 percent slopes	11.6	1.4%
OxF	Opequon-Hagerstown-Rock outcrop complex, 25 to 50 percent slopes	8.8	1.1%
Pt	Pits-Dumps complex	2.5	0.3%
Pu	Purdy silt loam	2.4	0.3%
Qu	Quarries-Dumps complex	15.7	2.0%
UD	Udifuvents-Dystrochrepts complex	9.1	1.1%
W	Water	8.0	1.0%
Totals for Area of Interest		798.8	100.0%

**FRANKSTOWN BRANCH JUNIATA RIVER CROSSING
PADEP SECTION 105 PERMIT NO.: E07-459
PA-BL-0122.0000-WX & PA-BL-0122.0000-WX -16
(SPLP HDD No. S2-0140)**

ATTACHMENT 2

ANNULAR PRESSURE AND FRACTURE PRESSURE CALCULATIONS



HORIZONTAL DIRECTIONAL CONCEPTUAL DRILL DESIGN

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

CROSSING: JUNIATA RIVER HDD
20-INCH STEEL PIPE

ISSUE: APC/FPC DESIGN

Contents:

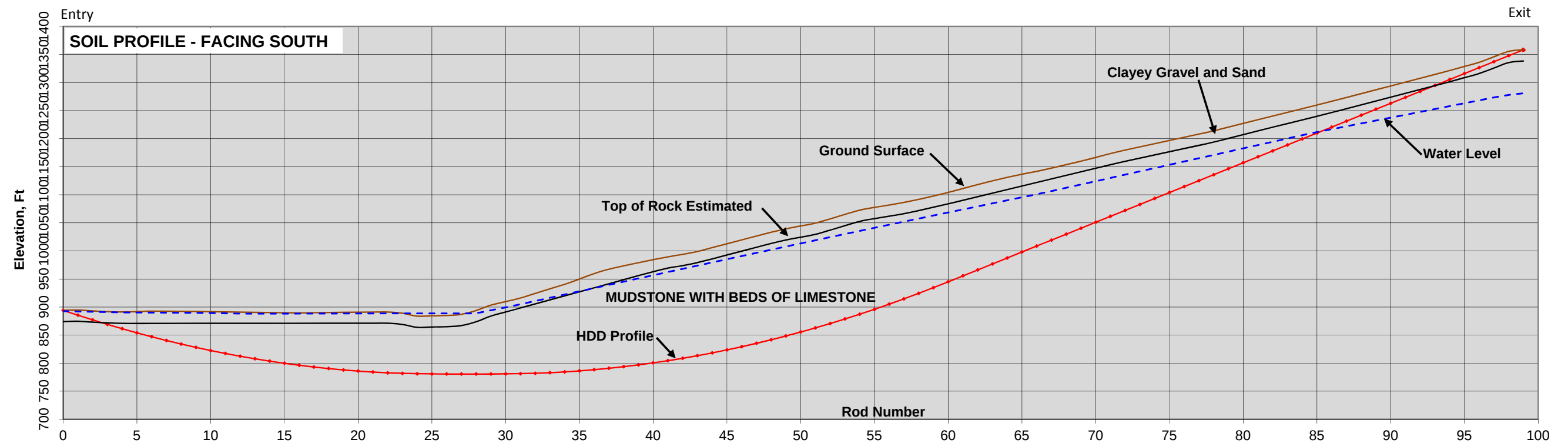
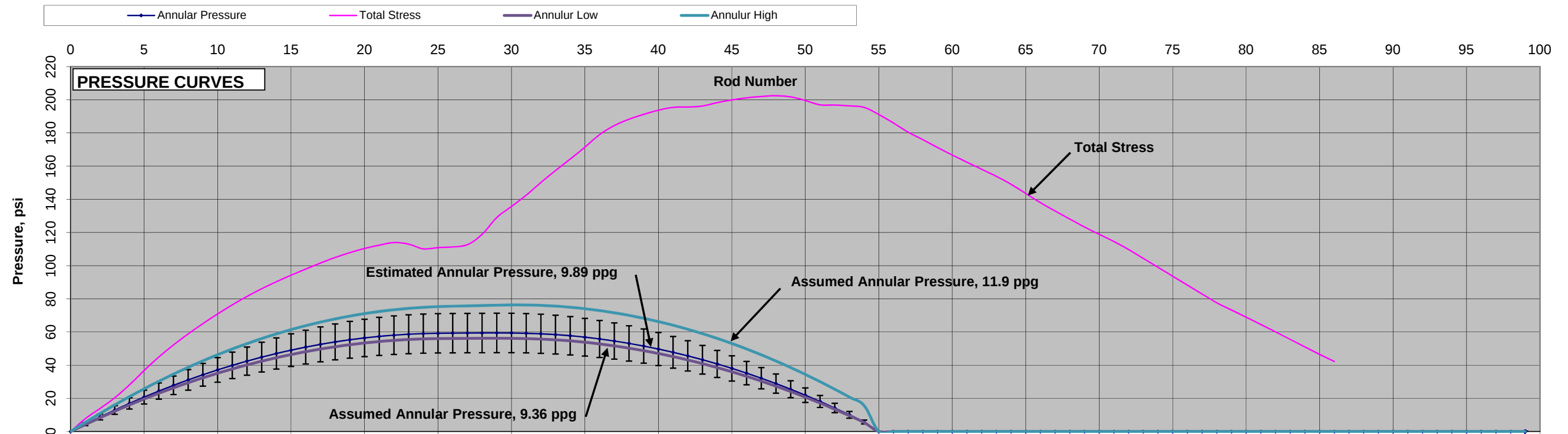
	Figure 1 - Annular Pressure and Formation Pressure Capacity Curves
	Table 1 - Design Summary, Assumptions, Conditions
	Table 2 - Design Drill Path Calculation
	Table 3 - Estimated Annular Pressure Curve Example Calculation
	Table 4 - Estimated Formation Pressure Curve Example Calculation

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

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

Project No: 0
Print Date: 5-Oct-2017

Revision	ID	DESCRIPTION	BY
10/5/2017	0	APC/FPC Design	BCD



Notes:

1. Geology is interpreted from project data
2. Rod length: 31 feet
3. The error bars are at 20 %
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report, Properties are interpreted from field and laboratory data as presented in Table 3.

Basis of annular pressure calculations

12.31 in	Pilot Hole Diameter
74.0 pcf	Unit Weight Drill Fluid
300 gal/min	Pump Rate
6.63 in	Drill Rod Diameter
31	Ft per rod
20%	for APC curve

ISSUED: APC/FPC DESIGN



33311 Lois Lane, Suite A
Magnolia, Texas 77354
59.7819 (O) 617.510.80

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

**ANNULAR PRESSURE AND
FORMATION PRESSURE CURVES
JUNIATA RIVER HDD**

Revision 0

Print Date ; 10/5/2017 17:31

FIGURE 1

C:\Users\jdundert\Documents\DPSP\Pennington\Area 1\Pennington\APC Design\Spread 3\32-0400-Juniata River\32-0400_20_10-5-17-APC-08-011-Comments

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	29+65.47	FT
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)		
East	North	Elevation
Entry 1815553.1404	401864.4720	894.00 ft
Horizontal Curve PI 1816391.3314	401473.2105	896.00 ft
Exit 1818285.4442	400714.2943	1,358.33 ft
Depth to Mudline 14.00 ft	Clearance Depth =	99.25 ft
Measured Plan Length at ties =	2965.4689 ft	
Coordinate Length =	2965.4689 ft	
OK-HORIZONTAL CURVE		

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End				Length	Radius	Angle
	Station	Easting	Northing	Station	Easting	Northing	Azimuth			
Tangent	0+00.00	1815553.1404	401864.4720	8+49.87	1816323.2428	401504.9938	E 334.97717 N	849.87		
Curve	8+49.87	1816323.2428	401504.9938	10+00.12	1816461.0824	401445.2633	E 338.16545 N	150.24	2700.00	3.188 deg.
Tangent	10+00.12	1816461.0824	401445.2633	29+65.47	1818285.4442	400714.2943	E 338.16545 N	1965.35		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment	Horizontal Curve Segment	Exit Tangent Segment	Check Delta 0.0000 0.0000 OK CALC Exit Station 29+65.47 OK STA
Plan Length, ft. 849.87	Input Radius, ft. 2700.00	Plan Length, ft. 1965.35	
Entry Azimuth, deg. ⁵ E 334.97717 N	Curve, deg. 3.188 deg.	Exit Azimuth, deg. ⁵ E 338.16545 N	
Entry Azimuth, rad. ⁵ 5.84645	Curve, rad. 0.05565	Exit Azimuth, rad. ⁵ 5.90210	
Calculate PCH	Calculate PTH	Calculate Exit	
Chord Length, ft. 150.22	Easting 1818285.4442	Easting 1818285.4442	
PCH Easting 1816323.2428	Arc Length, ft. 150.24	Northing 400714.2943	
PCH Northing 401504.9938	Chord Azimuth, deg. 336.5713		
PI Easting = 1816391.3314	PI Northing = 401473.2105		
PTH Easting = 1816461.0824	PTH Northing = 401445.2633		
Cum Plan Length 849.87	Cum Plan Length 1000.12	Cum Plan Length 2965.468906	

Pull Geometry

Pipe Entry	EXIT		Enter the pipe entry location into the hole: Entry/Exit				Path Length	Curve Radius
	Elevations		Vertical Angle, (-) = Clockwise					
Segment	Start	End	Start	End	Δ Angle			
Entry Tangent	1358.33 ft	943.58 ft	20.00 deg	20.00 deg	0.00 deg	1212.65 ft	0.00 ft	
Entry Curve	943.58 ft	780.75 ft	20.00 deg	0.00 deg	-20.00 deg	942.48 ft	2700.00 ft	
Bottom Tangent	780.75 ft	780.75 ft	0.00 deg	0.00 deg	0.00 deg	128.10 ft	0.00 ft	
Exit Curve	780.75 ft	885.34 ft	0.00 deg	-16.00 deg	-16.00 deg	753.98 ft	2700.00 ft	
Exit Tangent	885.34 ft	894.00 ft	-16.00 deg	-16.00 deg	0.00 deg	31.39 ft	0.00 ft	
Total Check =						3068.60 ft	OK	

Compound Curve Assessment

	Vert. Plan	Horiz. Plan	
Entry	774.40	849.87	No, Horiz > Entry V(Tan+Curve)
Exit	2062.97	1965.35	Yes, Horiz < Exit V(Tan+Curve)

VERTICLE PATH DESIGN CALCULATIONS (FT)

Entry Tangent Segment 1	Entry Vert. Curve Segment 2	Middle Tangent Segment 3	Exit Vert. Curve Segment 4	Exit Tangent Segment 5
Entry Angle -16.000 deg.	Vertical Radius 2700.00	Rod Length 128.09857	Radius 2700.00	Exit Elevation 1358.33
Entry Angle, rad. -0.2793 rad	Vert. Curve, deg. 16.000 deg.	Inclined Bottom Tan NO	Design Exit Angle 20.000 deg.	
Rod/Path Length 31.39	Vert. Curve, rad. 0.2793 rad		Vert. Curve, rad. 0.3491 rad	
Calculate Vertical PCV	Calculate Vertical PTV	Calculate Vertical PCV	Calculate Vertical PTV	Calculate Exit
Plan Length 30.18	Plan Length 744.22	Plan Length 128.0985726	Vert. Curve, deg. 20.000 deg.	Plan Length 1139.52
Path Length 31.39	Arc Path Length 753.98	Path Length 128.10	Vert. Curve, rad. 0.34906585	Path Length 1212.65
Tangent Depth -8.65	Curve Vert Depth -104.59	End Elevation 780.75	Plan Length 923.45	Elevation 1358.33
End Elevation 885.34	End Elevation 780.75	Rise/drop 0.00	Path Arc Length 942.48	Rise/drop 414.75
	Lowest Elevation 780.75		Lowest Elevation 780.75	
	End Vert Angle 0.000 deg.	End Vert Angle 0.000 deg.	Elevation 943.58	
	End Vert Angle, rad 0.0000 rad	End Vert Angle, rad 0.0000 rad	Curve Vert Depth 162.83	Prop. Plan Length 2965.468906

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station 0+00.00	Start Station 0+30.18	Start Station 7+74.40	Start Station 9+02.50	Start Station 18+25.95	Start Station 18+25.95
PVC Station 0+30.18	PTV Station 7+74.40	PCV Station 9+02.50	PTV Station 18+25.95	Exit Station 29+65.469	
Cum Plan Length 30.18	Cum Plan Length 774.40	Cum Plan Length 902.50 ft	Cum Plan Length 1825.95	Cum Plan Length 2965.468906	
Cum Path Length 31.39	Cum Path Length 785.38	Cum Path Length 913.48 ft	Cum Path Length 1855.95	Cum Path Length 3068.601501	
Cum Depth -8.65	Cum Depth -113.25	Cum Depth -113.25 ft	Cum Depth 49.58	Cum Depth 464.33	

Summary of Drill Calculations

Entry to Exit Elevation Change =	464.33 ft
Minimum Design Elevation =	780.75 ft
Invert Depth below exit =	577.58 ft
Invert Depth below entry =	113.25 ft
Path Length =	3,068.60 ft
Plan Length =	2,965.47 ft
Minimum Plan Length (No Tangent) =	2,837.37 ft
Entry Angle =	-16.00 deg
Exit Angle =	20.00 deg
Compound Curve at Entry =	NO
Compound Curve at Exit =	1,909 ft

Stationing Check

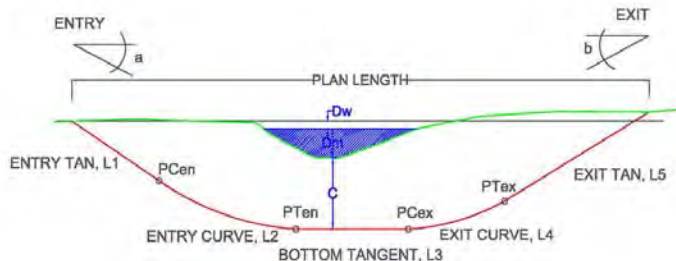
OK STATIONING

Plan Length Check

OK CALCULATION

NOTES:

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



Indicates inputs
Indicates status on internal design checks

ISSUE: APC/FPC DESIGN



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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
JUNIATA RIVER HDD
20-INCH STEEL PIPE

Revision 0

10/5/2017

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



JUNIATA RIVER HDD
20-INCH STEEL PIPE
INPUT

1. Drill path data

	Measured Distance	Elevations	Angles	Lengths	Angle Change
Drill Entry	0.000 ft	893.997	-16	Entry to PC	31.395 ft
PC	31.395 ft			PC to PT	753.982 ft -0.021 deg/ft
PT	785.377 ft			Invert Tangent	128.099 ft
PC	913.476 ft			PC to PT	942.478 ft 0.021 deg/ft
PT	1855.953 ft			PT to Exit	1212.648 ft
Drill Exit	3068.602 ft	1358.33 ft	20		3068.602 ft
					Length Ck OK

2. Drill Fluid Hydraulic Assumptions

	Assumed	Low	High
Density, γ_f =	74 9.89 lb/gal	70 9.36 lb/gal	89 11.90 lb/gal
Dynamic annulus pressure P_d =	0.0014 psi/ft	0.0013 psi/ft	0.0068 psi/ft
Drill fluid viscosity, μ_p =	2 cp	6 cp	13 cp
Yield point of drill fluid, YP =	41	19	5

3. Drill Data Assumptions

Assumed Drill Size:	DD660
Avg Rod length =	31.0 feet
Diameter of hole, D_h =	12.31125
Drill Rod Tube Diameter, D_r =	6.625 in
Drilling Pump rate, gpm =	300 gal/min
Max Rig Pump =	1200 gpm
Number of drill rods =	99
Estimated annular pilot uphole drill fluid velocity, V_{ha} =	68.29 ft/min

4. Calculate Annular Pressure, P

Method A - (API RP) 13D

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

Method B - HDD Good Practices Cavity Expansion Annular Pressure

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

Start Station	0+00.00	1						
Drill Path			Assumed Return Density		Low Return Density		High Return Density	
			Density, γ_{fE} = 74		Density, γ_{fL} = 70		Density, γ_{fH} = 89	
Rod Measured Distance MD	Station X	Elevation Y	Annular Fluid Pressure P_A	Annular Fluid Pressure P_B	Annular Fluid Pressure P_A	Annular Fluid Pressure P_B	Annular Fluid Pressure P_A	Annular Fluid Pressure P_B
ft	ft	ft	psi	psi	psi	psi	psi	psi
0.00	0+00.00	894.00	0.00	0.00	0.00	0.00	0.00	0.00
31.00	0+29.80	885.45	4.43	5.51	4.19	4.68	5.49	5.43
62.00	0+59.65	877.08	8.78	10.93	8.30	9.27	10.88	10.76
93.00	0+89.59	869.04	12.95	16.18	12.25	13.70	16.06	15.88
124.00	1+19.62	861.35	16.94	21.26	16.03	17.97	21.03	20.78
155.00	1+49.74	854.01	20.76	26.15	19.64	22.06	25.78	25.47
186.00	1+79.93	847.01	24.40	30.87	23.08	25.99	30.32	29.95
217.00	2+10.21	840.36	27.86	35.40	26.35	29.74	34.64	34.21
248.00	2+40.56	834.05	31.14	39.76	29.46	33.33	38.75	38.25
279.00	2+70.99	828.10	34.24	43.94	32.39	36.75	42.64	42.08
310.00	3+01.48	822.49	37.16	47.94	35.16	40.00	46.32	45.70
341.00	3+32.03	817.24	39.91	51.76	37.75	43.08	49.78	49.10

TABLE 4
ESTIMATED FORMATION PRESSURE CURVE (FPC) EXAMPLE CALCULATION

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

JUNIATA RIVER HDD
 20-INCH STEEL PIPE
 INPUT



1. Drill path data from vertical path calculations

	Measured Distance	Elevations	Angles	Lengths	Angle Change
Entry	0.000 ft	893.997	-16	Entry to PC	31.395 ft
PC	31.395 ft			PC to PT	753.982 ft -0.021 deg/ft
PT	785.377 ft		0	Invert Tangent	128.099 ft
PC	913.476 ft			PC to PT	942.478 ft 0.021 deg/ft
PT	1855.953 ft			PT to Exit	1212.648 ft
Exit	3068.602 ft	1358.33 ft	20	3068.602 ft	Length Ck OK

2. Drill Fluid Hydraulic Data for Estimated Drill Fluid

Dynamic annulus pressure =	0.00135 psi/LF	
Uphole Drill Fluid Density =	74	9.9 lb/gal
Drill fluid viscosity, cp =	2 cp	
Up hole drill fluid velocity, ft/sec =	68.29 ft/sec	
Pump rate, gpm =	300 gal/min	
Diameter of hole D _H , in =	12.31125	
Diameter of Drill Rod D _R , in =	6.625	
Yield point of drill fluid, lb/100 ft ² =	41.00 Lb/100FT ²	

Radius

R _H =	6.156 in
R _R =	3.313 in

3. Soil Profile Data

Technical approach to generate data as no testing available

Material Layer	Dry Density γ (pcf)	Moisture Content %	Insitu Saturated Density (pcf)	Effective UW (pcf)	Phi, Φ	Undrained Cohesion c, psf	Poisson Ratio μ	Slow Shear Modulus, G psf	OCR Cohesive (Use 0 if non- cohesive)	Model Material Layer Description	Cohesive
1	110	15.0%	126.5	47.60 pcf	10	2000	0.3	67,613	1	Clay	Y
2	150	5.0%	157.5	87.60 pcf	75	0.01	0.3	526,858	1	Mudstone	N
3								0			
4								0			
5								0			
6								0			
7								0			
8								0			
9								0			
10								0			
Water	62.4			62.40 pcf							

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

Dynamic Shear Modulus, $G_{max} = (\gamma/g) * V_s^2$

Extended Strain Shear Modulus G is typically between 5% and 20% of G_{max}

g = acceleration of gravity = 32.2 ft/s²

Select Reduction Factor, RF = 15% Ref 1

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

Joint = 9

Away Distance from Entry = 270.99 ft

Depth of Cover = 63.90 ft

Layers	Surface 1-2	Surface 2-3	Surface 3-4	Surface 4-5	Surface 5-6	Surface 6-7	Surface 7-8	Surface 8-9	Surface 9-10	TOTAL	
Soil Type in Layer =	1	2	2								
Dry Density in Layer, γ_d =	110.00 pcf	150.00 pcf	150.00 pcf								
Insitu Density in Layer, γ_s =	126.50 pcf	157.50 pcf	157.50 pcf								
Effective Weight in Layer, γ'_e =	47.60 pcf	87.60 pcf	87.60 pcf								
Total Layer Thickness over drill, h_s =	21.08 ft	42.82 ft	0.00 ft							63.90 ft	Total CK
Saturated Thickness over drill, h_{sat} =	18.74 ft	42.82 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	61.56 ft	
Dry Thickness over drill, h_{dry} =	2.34 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	2.34 ft	
Contribution Effective Stress, σ' =	1,458.74 psf	4,071.97 psf	0.00 psf								
Contribution Total Stress, $\sigma = h_s \cdot \gamma_s$	2,628.02 psf	6,743.79 psf	0.00 psf								
Shear Modulus, G =	67,613 psf	526,858 psf	526,858 psf								

Height of Water above Soil Surface, h_w = 0.00 ft

Total soil and water height above drill path, H_T = 63.90 ft

Total water height above drill path, H_W = 61.56 ft

Properties At Drill Depth for Selected Joint

R_H =	0.51 ft	Radius of drill hole
$R_{max} = h_s / FS_D$ =	42.60 ft	Maximum allowable radius of plastic zone = Height of soil above Drill Path (h_s) divided by Delft & Queens Equation FS_D
	2	Soil Layer At Drill Depth
G_w =	526,858 psf	Large Strain Shear Modulus at drill depth
$S_u = c = q_u / 2$	0 psf	Cohesive material: cohesion c = unconfined compressive strength (q_u) divided by 2
ϕ =	75 deg	1.3090 rad
H_W =	61.56 ft	Total water height above drill path
FS_D =	1.5	Factor of Safety for Delft & Queens Equation soil type: Use 1.5 for Sand and 2 for Clay at Drill Depth - Apply to R_{max} and P_{max}
μ =	0.3	Poisson ration (Granular Soil: Angle of internal friction of layer at drill path depth)
OCR =	1	Over Consolidation Ratio
K_o =	0.429	Coefficient of lateral earth pressure at rest. For OCR = 1 use relation $K_o = \mu / (1 - \mu)$; For OCR > 1 use $K_o = (K_{onormally\ consolidated}) * OCR^{-1/2}$
σ_o =	9,372 psf	Total Stress at drill depth, $\sigma = \gamma_d(\text{above water}) * h_{dry} + \gamma_s(\text{saturated}) * h_{sat}$
u =	3,841 psf	Water pressure at drill depth, $u = \gamma_w * H_W$
σ' =	5,531 psf	Effective Stress at drill depth, $\sigma' = \sigma - u$

5. Method A - Total Stress Method (Conservative)

Calculate Allowable Controlling Formation Pressure Capacity

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

P_{maxA} =	9,372 psf	65.08 psi
	65.08 psi	Check Calculation

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

Calculate Allowable Controlling Formation Pressure Capacity

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

P_{maxB}	30,013 psf	208.42 psi
	208.42 psi	Check Calculation

Based on Mohr-Coulomb

$$\text{Strength} = c + \sigma' \cdot \tan(\phi)$$

20,641 psf	143.34 psi
------------	------------

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

$$P_{\max} = \mu + [p'_f + c * \cot \phi] * \{[R_o/R_{p\max}]^2 + [(\sigma'_o * \sin \phi + c * \cos \phi) / G]\}^{-\sin \phi / (1 + \sin \phi)} - c * \cot(\phi)$$

Sin(φ) =	0.96592583
Cos(φ) =	0.25881905
Cot(φ) =	0.26794919

$$\mu = 3,841 \text{ psf} \quad \text{Initial Pore Pressure, } \mu = \gamma_w * H_w$$

$$\sigma'_o = 5,531 \text{ psf} \quad \text{Effective Stress, } \sigma'_o = \Sigma [\gamma_d * h_d + \gamma' * h_s]$$

$$p'_f = 10,873 \text{ psf} \quad p'_f =$$

$$P_{\max} = 106,885 \text{ psf} \quad 742.26 \text{ psi} \quad P_{\max} = \mu + A * (B + C)^D - E$$

$$P_{\text{allc}} = 71,257 \text{ psf} \quad 494.84 \text{ psi} \quad P_{\text{all}} = P_{\max} / \text{FS}$$

$$A = 10872.96243 \quad A = p'_f + c * \cot \phi$$

$$B = 0.000145007 \quad B = [R_o/R_{p\max}]^2$$

$$C = 0.010139841 \quad C = (\sigma'_o * \sin \phi + c * \cos \phi) / G$$

$$D = -0.49133381 \quad D = -\sin \phi / (1 + \sin \phi)$$

$$E = 0.002679492 \quad E = c * \cot \phi$$

$$\sigma' = 5,530.71 \quad \text{check Calculation}$$

$$106,885 \text{ psf} \quad \text{check Calculation}$$

Checks
10872.96243
0.000145006
0.010139841
-0.49133381
0.002679492

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

(Assumes undrained properties)

$$K_o < 1 \quad P_i = S_u + (1/2) * (3K_o - 1) * \sigma'_o - S_u * \ln[(R_o/R_{p\max})^2 + (S_u/G)]$$

$$K_o > 1 \quad P_i = S_u + (1/2) * (3 - K_o) * \sigma'_o - S_u * \ln[(R_o/R_{p\max})^2 + S_u/G]$$

To Determine if hydraulic fracturing or blowout occurs

(<2Su) indicates hydraulic fracturing; (>2Su) indicates blowout

$$K_o < 1 \quad F_1(K_o, \sigma'_o, S_u) = (3 * K_o - 1) * \sigma'_o$$

$$K_o > 1 \quad F_1(K_o, \sigma'_o, S_u) = (3 - K_o) * \sigma'_o$$

$$K_o = 0.429$$

$$P_i = 1,339 \text{ psf} \quad 9.30 \text{ psi}$$

$$F_1 = \text{Expect Blowout}$$

$$9.30 \text{ psi} \quad \text{check Calculation}$$

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

(See Annular Pressure Calculations for joint by joint calculations)

Method A - (API RP) 13D

Method B - HDD Good Practices Cavity Expansion Annular Pressure

$$P_{\text{annularA}} = 34.24 \text{ psi} \quad P_A = [\gamma_f (Y_{\text{entry}} - Y) / 144] + (P_d) / (\text{MD})$$

$$P_{\text{annularB}} = 43.94 \text{ psi} \quad P_B = [\gamma_f * (Y_{\text{entry}} - Y) / 144] + \text{MD} * [\mu_p * V_{\text{ha}} / (1000 * (D_h - D_r)^2)] + \text{YP} / [200 * (D_h - D_r)]$$

$$\text{Method A} \quad 65.08 \text{ psi} \quad \text{FS} = 1 \quad \text{Total Stress}$$

$$\text{Method B} \quad 208.42 \text{ psi} \quad \text{FS} = 1 \quad \text{Total Stress + Strength}$$

$$\text{Method C} \quad 494.84 \text{ psi} \quad \text{At FS}_D = 1.5 \quad \text{Delft Equation}$$

$$\text{Method D} \quad 9.30 \text{ psi} \quad \text{At FS}_D = 1.5 \quad \text{Queens Equation}$$

Comparative Factor of Safety against Drill Fluid Loss at Critical Joint

$$\text{Critical Joint} = 9$$

$$\text{Depth of Cover} = 63.9 \text{ ft}$$

Confining Pressure Calculation Method	Method A	Method B	Method C	Method D
Method (X)/P _{annularA}	1.90	6.09	14.45	0.27
Method (X)/P _{annularB}	1.48	4.74	11.26	0.21

Acceptable if Factor of Safety >=1.0

Drill Path			Assumed Return Density		Low Return Density		High Return Density	
			Density, $\gamma_{FE} = 74$		Density, $\gamma_{FL} = 70$		Density, $\gamma_{FH} = 89$	
Rod Measured Distance MD	Station X	Elevation Y	Annular Fluid Pressure P_A	Annular Fluid Pressure P_B	Annular Fluid Pressure P_A	Annular Fluid Pressure P_B	Annular Fluid Pressure P_A	Annular Fluid Pressure P_B
ft	ft	ft	psi	psi	psi	psi	psi	psi
372.00	3+62.64	812.33	42.47	55.40	40.17	45.99	53.02	52.28
403.00	3+93.30	807.78	44.85	58.86	42.43	48.72	56.05	55.24
434.00	4+24.02	803.58	47.05	62.14	44.51	51.29	58.85	57.99
465.00	4+54.78	799.74	49.07	65.24	46.42	53.68	61.44	60.52
496.00	4+85.58	796.24	50.90	68.15	48.16	55.90	63.81	62.82
527.00	5+16.42	793.10	52.56	70.88	49.72	57.96	65.97	64.92
558.00	5+47.29	790.32	54.03	73.43	51.11	59.83	67.90	66.79
589.00	5+78.20	787.89	55.32	75.80	52.34	61.54	69.61	68.44
620.00	6+09.13	785.81	56.43	77.99	53.38	63.07	71.11	69.87
651.00	6+40.08	784.09	57.36	79.99	54.26	64.43	72.38	71.09
682.00	6+71.05	782.73	58.10	81.81	54.96	65.62	73.44	72.08
713.00	7+02.04	781.72	58.66	83.45	55.49	66.63	74.28	72.85
744.00	7+33.03	781.07	59.04	84.91	55.85	67.47	74.89	73.41
775.00	7+64.03	780.77	59.23	86.18	56.03	68.14	75.29	73.74
806.00	7+95.03	780.71	59.30	87.33	56.10	68.70	75.54	73.93
837.00	8+26.03	780.71	59.35	88.45	56.14	69.22	75.75	74.08
868.00	8+57.03	780.71	59.39	89.57	56.18	69.74	75.96	74.23
899.00	8+88.03	780.71	59.43	90.69	56.22	70.27	76.17	74.38
930.00	9+19.03	780.81	59.42	91.76	56.22	70.75	76.33	74.47
961.00	9+50.02	781.17	59.28	92.69	56.08	71.09	76.31	74.40
992.00	9+81.02	781.90	58.95	93.44	55.77	71.26	76.08	74.10
1023.00	10+12.00	782.98	58.43	94.00	55.28	71.26	75.62	73.58
1054.00	10+42.96	784.41	57.74	94.39	54.62	71.09	74.95	72.85
1085.00	10+73.91	786.20	56.86	94.59	53.79	70.74	74.05	71.89
1116.00	11+04.84	788.35	55.80	94.60	52.79	70.23	72.94	70.71
1147.00	11+35.74	790.85	54.56	94.44	51.61	69.53	71.61	69.32
1178.00	11+66.61	793.70	53.13	94.09	50.26	68.67	70.05	67.70
1209.00	11+97.44	796.91	51.52	93.56	48.74	67.63	68.28	65.87
1240.00	12+28.23	800.48	49.73	92.85	47.05	66.43	66.29	63.82
1271.00	12+58.98	804.39	47.76	91.96	45.19	65.05	64.09	61.55
1302.00	12+89.69	808.66	45.61	90.88	43.15	63.50	61.66	59.06
1333.00	13+20.34	813.28	43.28	89.63	40.95	61.77	59.02	56.36
1364.00	13+50.94	818.26	40.76	88.19	38.57	59.88	56.15	53.43
1395.00	13+81.48	823.58	38.07	86.58	36.02	57.82	53.08	50.29
1426.00	14+11.96	829.26	35.20	84.78	33.30	55.58	49.78	46.94
1457.00	14+42.37	835.28	32.14	82.80	30.41	53.18	46.27	43.36
1488.00	14+72.70	841.65	28.91	80.65	27.35	50.60	42.54	39.58
1519.00	15+02.97	848.37	25.50	78.32	24.13	47.86	38.60	35.57
1550.00	15+33.15	855.44	21.91	75.80	20.73	44.95	34.45	31.35
1581.00	15+63.25	862.85	18.14	73.11	17.17	41.87	30.08	26.92
1612.00	15+93.26	870.61	14.19	70.25	13.44	38.62	25.49	22.28
1643.00	16+23.19	878.72	10.07	67.20	9.54	35.21	20.70	17.42
1674.00	16+53.01	887.16	5.77	63.98	5.47	31.63	15.69	12.35
1705.00	16+82.74	895.95	0.00	0.00	0.00	0.00	0.00	0.00
1736.00	17+12.37	905.08	0.00	0.00	0.00	0.00	0.00	0.00
1767.00	17+41.89	914.55	0.00	0.00	0.00	0.00	0.00	0.00
1798.00	17+71.29	924.35	0.00	0.00	0.00	0.00	0.00	0.00
1829.00	18+00.59	934.49	0.00	0.00	0.00	0.00	0.00	0.00
1860.00	18+29.77	944.95	0.00	0.00	0.00	0.00	0.00	0.00
1891.00	18+58.90	955.55	0.00	0.00	0.00	0.00	0.00	0.00
1922.00	18+88.03	966.16	0.00	0.00	0.00	0.00	0.00	0.00
1953.00	19+17.16	976.76	0.00	0.00	0.00	0.00	0.00	0.00
1984.00	19+46.29	987.36	0.00	0.00	0.00	0.00	0.00	0.00
2015.00	19+75.42	997.97	0.00	0.00	0.00	0.00	0.00	0.00
2046.00	20+04.55	1,008.57	0.00	0.00	0.00	0.00	0.00	0.00

Drill Path			Assumed Return Density		Low Return Density		High Return Density	
			Density, $\gamma_{FE} = 74$		Density, $\gamma_{FL} = 70$		Density, $\gamma_{FH} = 89$	
Rod Measured Distance MD	Station X	Elevation Y	Annular Fluid Pressure P_A	Annular Fluid Pressure P_B	Annular Fluid Pressure P_A	Annular Fluid Pressure P_B	Annular Fluid Pressure P_A	Annular Fluid Pressure P_B
ft	ft	ft	psi	psi	psi	psi	psi	psi
2077.00	20+33.68	1,019.17	0.00	0.00	0.00	0.00	0.00	0.00
2108.00	20+62.82	1,029.77	0.00	0.00	0.00	0.00	0.00	0.00
2139.00	20+91.95	1,040.38	0.00	0.00	0.00	0.00	0.00	0.00
2170.00	21+21.08	1,050.98	0.00	0.00	0.00	0.00	0.00	0.00
2201.00	21+50.21	1,061.58	0.00	0.00	0.00	0.00	0.00	0.00
2232.00	21+79.34	1,072.18	0.00	0.00	0.00	0.00	0.00	0.00
2263.00	22+08.47	1,082.79	0.00	0.00	0.00	0.00	0.00	0.00
2294.00	22+37.60	1,093.39	0.00	0.00	0.00	0.00	0.00	0.00
2325.00	22+66.73	1,103.99	0.00	0.00	0.00	0.00	0.00	0.00
2356.00	22+95.86	1,114.59	0.00	0.00	0.00	0.00	0.00	0.00
2387.00	23+24.99	1,125.20	0.00	0.00	0.00	0.00	0.00	0.00
2418.00	23+54.12	1,135.80	0.00	0.00	0.00	0.00	0.00	0.00
2449.00	23+83.25	1,146.40	0.00	0.00	0.00	0.00	0.00	0.00
2480.00	24+12.38	1,157.00	0.00	0.00	0.00	0.00	0.00	0.00
2511.00	24+41.51	1,167.61	0.00	0.00	0.00	0.00	0.00	0.00
2542.00	24+70.64	1,178.21	0.00	0.00	0.00	0.00	0.00	0.00
2573.00	24+99.77	1,188.81	0.00	0.00	0.00	0.00	0.00	0.00
2604.00	25+28.90	1,199.42	0.00	0.00	0.00	0.00	0.00	0.00
2635.00	25+58.03	1,210.02	0.00	0.00	0.00	0.00	0.00	0.00
2666.00	25+87.16	1,220.62	0.00	0.00	0.00	0.00	0.00	0.00
2697.00	26+16.29	1,231.22	0.00	0.00	0.00	0.00	0.00	0.00
2728.00	26+45.42	1,241.83	0.00	0.00	0.00	0.00	0.00	0.00
2759.00	26+74.56	1,252.43	0.00	0.00	0.00	0.00	0.00	0.00
2790.00	27+03.69	1,263.03	0.00	0.00	0.00	0.00	0.00	0.00
2821.00	27+32.82	1,273.63	0.00	0.00	0.00	0.00	0.00	0.00
2852.00	27+61.95	1,284.24	0.00	0.00	0.00	0.00	0.00	0.00
2883.00	27+91.08	1,294.84	0.00	0.00	0.00	0.00	0.00	0.00
2914.00	28+20.21	1,305.44	0.00	0.00	0.00	0.00	0.00	0.00
2945.00	28+49.34	1,316.04	0.00	0.00	0.00	0.00	0.00	0.00
2976.00	28+78.47	1,326.65	0.00	0.00	0.00	0.00	0.00	0.00
3007.00	29+07.60	1,337.25	0.00	0.00	0.00	0.00	0.00	0.00
3038.00	29+36.73	1,347.85	0.00	0.00	0.00	0.00	0.00	0.00
3068.00	29+65.49	1,358.32	0.00	0.00	0.00	0.00	0.00	0.00

**FRANKSTOWN BRANCH JUNIATA RIVER CROSSING
PADEP SECTION 105 PERMIT NO.: E07-459
PA-BL-0122.0000-WX & PA-BL-0122.0000-WX -16
(SPLP HDD No. S2-0140)**

ATTACHMENT 3

PRODUCED WATER CONTAINMENT, CONTROL, AND FILTRATION



BioStar Guidelines for Treating Turbid Water

Water should be above 40 degrees Fahrenheit and have a pH value between 6.5 and 8.5.

Supplies Needed: BioStar Floc 500 polymer string, PVC tube to house polymer string, 40 to 50 feet of discharge hose, dewatering bag, and other dewatering structure requirements.

The BioStar Floc 500 polymer string consists of 6 packets of polymer. The string should be presoaked in water for 30 minutes prior to placing in service. Secure the BioStar 500 inside the PVC tube with zip tie or string. Secure pump discharge hose to PVC tube. Add an additional 40 to 50 feet of discharge hose to outlet of PVC tube. The end of the discharge hose shall be secured into a settling tank, sediment basin or dewatering bag. The dewatering bag must be sized to the capacity of the pump.

The BioStar polymer creates a charge on the small sediment causing them to stick together and create flocs. These flocs can be seen visually in the water samples. The flocs get heavier and settle out or get caught within the sediment bag.

Pumping rate should not exceed 300 GPM. If pumping rate is greater than 300 GPM, increase # of PVC tubes and Biostar to match pumping rate. For instance, if you are using a 900 GPM pump, you would need to split the discharge flow to 3 lines. Then you would have 3 strings of BioStar within 3 PVC tubes attached to the 3 discharge hoses and 3 dewatering bags.

Troubleshooting:

If at the discharge point, flocs are not formed and visible:

Make sure the bag is in good contact with the water flow.

Flowrate may exceed bag treatment capacity of water may have higher turbidity levels.

Water is colder than 40 degrees Fahrenheit.

In either case add an additional bags until visual results are achieved.

The BioStar 500 can be used and reused until all the material in the bag is depleted. Generally, a bag will last about 6 to 24 hours under continuous 300 GPM flow.

For further information, contact Michels Environmental or go to www.biostar-ch.com.



Biostar-CH™ Floc 500 Product Specifications

This specification sheet describes the characteristics of the Biostar-CH™ Floc 500

Floc 500 Bag Description:

The Floc 500 treatment bag is constructed with six individual units bound together in-line to form a semi-solid unit.

The bag is constructed of a dark green, high strength, water permeable material allowing for consistent flow through capacity and dependable dosing at approximately 2.5 ppm. Each bag contains a pre-determined amount of Biostar-CH to treat various turbidity levels and flow rates. (refer to separate flow/turbidity chart and usage guideline publication.)



(Floc 500 shown with PVC housing unit)

Dimensions:

Length – 5.0 ft.

Width – 5.0 inches

Weight – 1.5 -2 lbs.

The Floc 500 bag will stretch when in an active flow to 5.5-6 feet in length.

Construction Material Specifications:

Bag material – tear resistant, non-clogging, high velocity flow-through fabric.

Connecting points - self tapping teeth grommets connected together with high strength double lock cable ties providing 30 percent stronger joint unions

End securing ties – two eight inch mounting ties rated at 550 pound break strength.

Ingredients:

Biostar-CH™ Floc 500 contains a proprietary water treatment grade of chitosan (a natural biopolymer) and lactic acid

Biostar-CH™ is an all natural class 55 water clarifier. It is non-toxic and non-hazardous material which naturally breaks down into carbon dioxide and water within two to three weeks of application. No special handling or safety precautions are required.

There are no additional additives for any reason.

- **Viscosity:** 150 mpa.s (cps) Determination Method – 1% Biostar-CH™ chitosan lactate flake dissolved in 1% lactic acid solution at 20 degrees C
- **pH (1% solution):** 3.0 – 5.0
- **Solids Content:** ≤1.5%
- **Turbidity:** 10 NTU or less
- **Solubility:** Water soluble
- **Purity:** Free of visible foreign matter.

Biostar Floc 500B contains a 50/50 blend of chitosan and an anionic bridger which creates larger heavier flocs with high shear strength.

Biostar Floc 500 APD contains 100% anionic bridger.

Usage and Application - Floc 500/250 Bag Treatment

Proper Dose Rate Determination:

- **The Floc 500 bag will release an average dose rate of approximately 2.5 ppm or mg/L in a continuous flow of water up to 300 gpm.**

- Under continuous flow, each bag will deliver the dose rate and treat about 125,000 gallons for the Floc 500 and 62,500 for the Floc 250. The dose rate for the Floc 250 will be approximately 1.2 ppm or mg/L. *(results will vary depending on turbidity and gpm flow rate)*

Adjust the number of bags and/or the volume of water to administer the appropriate dose. (See floc bag dose rate chart)

Troubleshooting:

If at the discharge point flocs are not formed and visible:

Make sure the bag is in good contact with the water flow.

Flow rate may exceed bag treatment capacity or water may have higher turbidity levels. In either case add an additional bags until visual results are achieved.

The bags can be used and re-used until all the material in the bag is depleted. Generally, a bag will last about 6-24 hours under continuous 300 gpm flow.

For some applications, bags can be pre-soaked in water for 15 minutes prior to deployment to ensure product hydration and immediate dose release.

The use of Biostar-CH™ and application techniques are fully supported and documented.

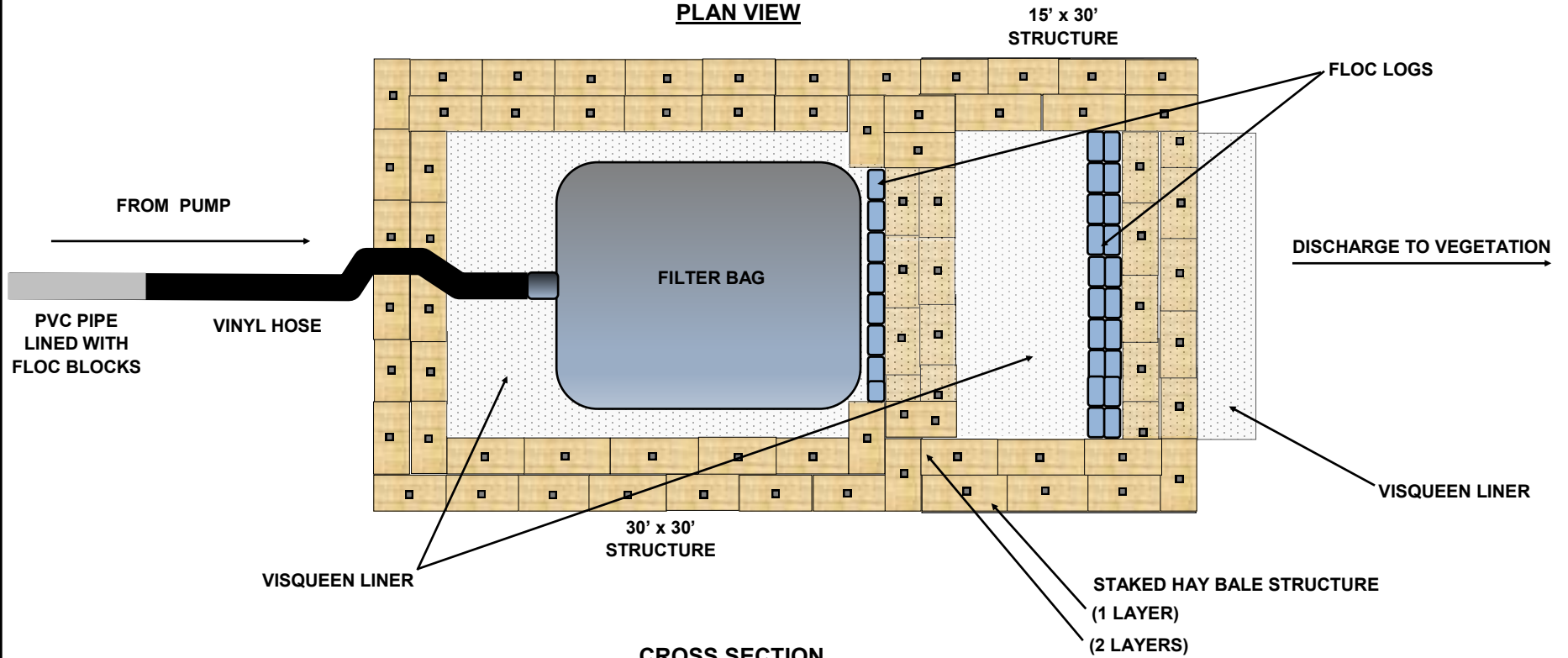
Stormwater Wastewater

Biostar-CH™ is marketed through a network of local distributors.

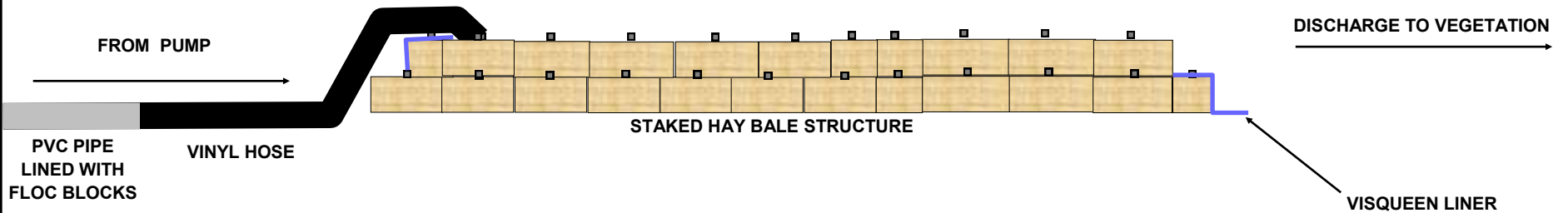
Biostar, Inc. **P.O. Box 523** **Stillwater, MN** **55082**
ph: 715.426.5131 email: sales@biostar-ch.com www.biostar-ch.com

The facts stated and the recommendations made herein are accurate to the best of our knowledge. Biostar-CH™ is a trademark of Biostar, Inc.
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PLAN VIEW



CROSS SECTION



Prepared By:

MICHELS

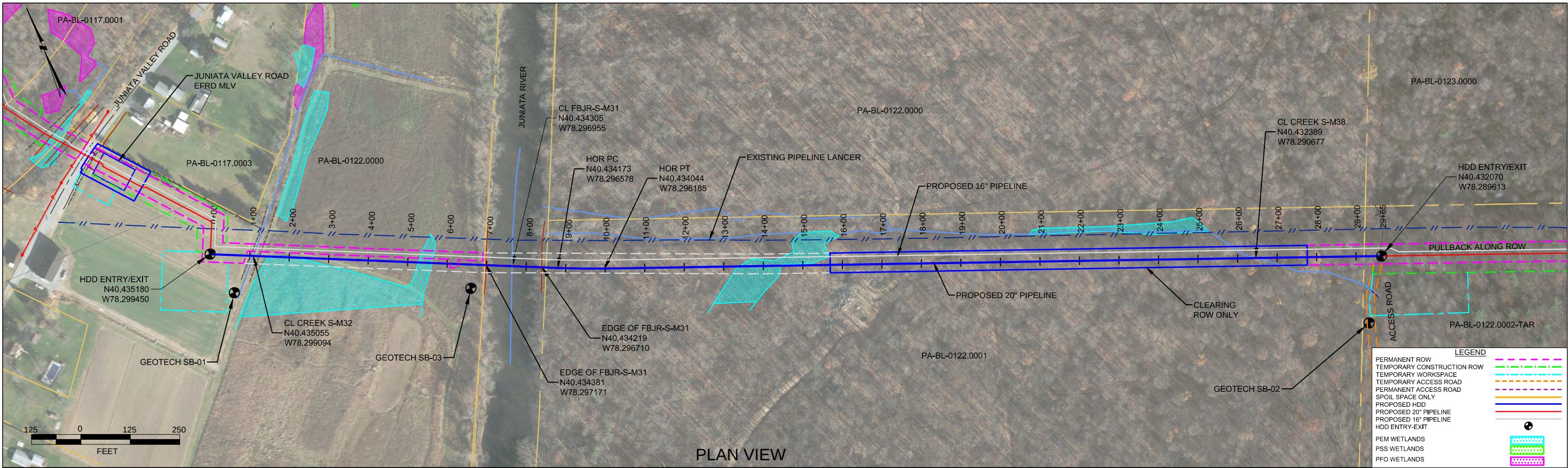
MICHELS PIPELINE CONSTRUCTION

**PROPOSED
DEWATERING FLOC TREATMENT TYPICAL**

**FRANKSTOWN BRANCH JUNIATA RIVER CROSSING
PADEP SECTION 105 PERMIT NO.: E07-459
PA-BL-0122.0000-WX & PA-BL-0122.0000-WX -16
(SPLP HDD No. S2-0140)**

ATTACHMENT 4

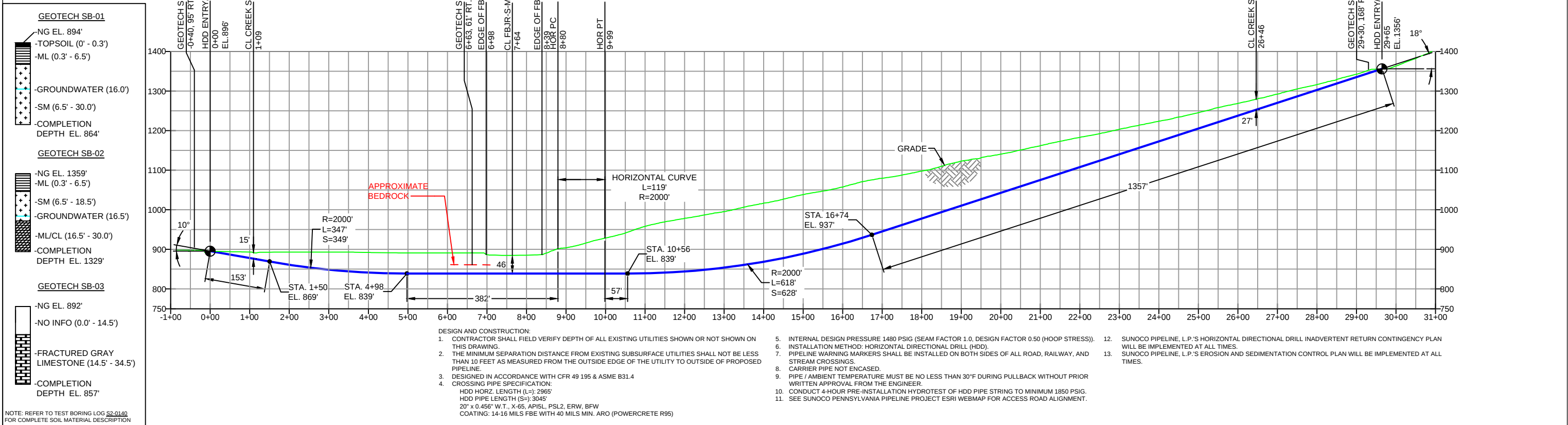
ORIGINAL AND REVISED HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES



PLAN VIEW

BLAIR COUNTY, PENNSYLVANIA - FRANKSTOWN TOWNSHIP
S2-0140

PROFILE VIEW



NOTES

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

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
4	REVISED PROFILE WITH 2017 LIDAR	MRS	03/21/17	RMB	03/21/17	CAG	03/21/17
3	REVISED PER ENGINEERING COMMENTS	DLM	08/26/16	RMB	08/26/16	AAW	08/26/16
2	MLV NAME UPDATED	DLM	04/07/16	RMB	04/07/16	AAW	04/07/16
1	ADDED "CLEARING ROW ONLY" ANNOTATION	MRS	03/28/16	RMB	03/28/16	AAW	03/28/16
0	ISSUED FOR CONSTRUCTION	MRS	12/22/15	RMB	12/22/15	AAW	12/22/15

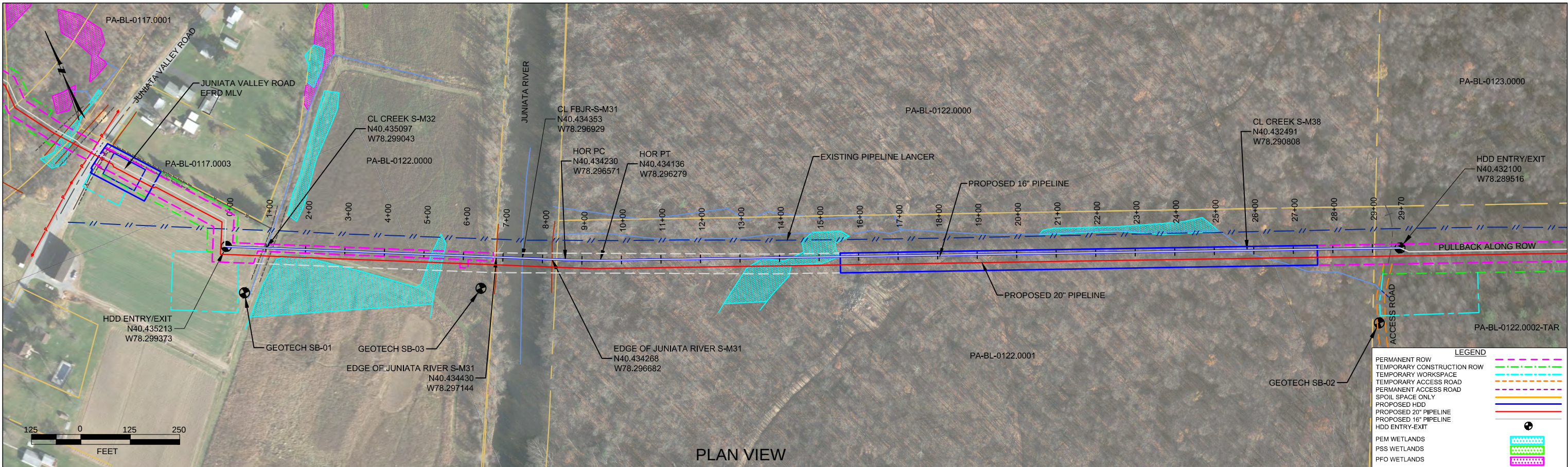


SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
JUNIATA RIVER
PENNSYLVANIA PIPELINE PROJECT

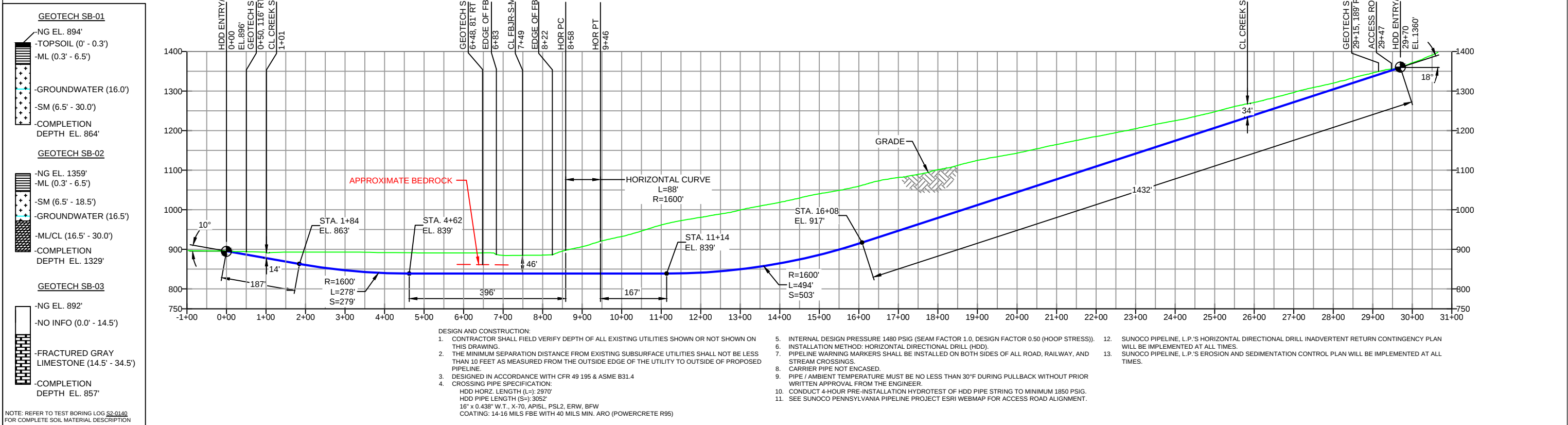
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DWG. NUMBER: PA-BL-0122.0000-WX



BLAIR COUNTY, PENNSYLVANIA - FRANKSTOWN TOWNSHIP
S2-0140-16

PROFILE VIEW



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SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
JUNIATA RIVER
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250'

DWG. NO: PA-BL-0122.0000-WX-16

