HDD Design Report
Pohopoco Creek (Beltzville Lake) / Wild Creek HDD Crossing

PennEast Pipeline Project

December 17, 2018

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1 Introduction

Mott MacDonald has prepared this HDD design report at the request of PennEast Pipeline Company, LLC (PennEast), for their proposed HDD crossing of Pohopoco Creek (Beltzville Lake) and Wild Creek, part of the larger PennEast Pipeline Project. The proposed Project consists of 115 miles of 36-inch diameter (NPS 36) high pressure, natural gas pipeline from Luzerne County, Pennsylvania to Mercer County, New Jersey.

Specifically, this report summarizes Mott MacDonald's evaluation of the design elements and risk discussions (as determined in the information provided), and presents recommendations for enhancing the success of the Beltzville Lake HDD Crossing.

The drawings and design elements have been prepared and evaluated with the aid of a completed geotechnical subsurface investigation performed by Mott MacDonald, and laboratory assessment and testing analysis completed by Craig Test Boring Co., Inc (CTB). The soil and rock samples were obtained during the geotechnical investigation program, and sent to CTB laboratory for testing. Discussions on the geotechnical aspects in this design report have been extracted from the information presented in the site-specific Geological Data Report (GDR).

1.1 Crossing Description

The proposed plan and profile is provided in Appendix A. The horizontal length of the proposed HDD is approximately 6,100 feet (with a true length of approximately 6,161 feet). The eastern HDD entry point is located approximately 1,790 feet east of the eastern bank of Pohopoco Creek, and the western HDD entry point is located approximately 1,590 feet west of the western bank of Wild Creek. An elevation difference of approximately 16 feet exists between the east and west HDD entry locations, with the east HDD entry location at the lower elevation.

The pipe staging area for the drag section is located on the western side of the crossing. It is envisioned that, due to limited workspace, this pipe string will be fabricated into four sections prior to pullback operations.

This crossing has been designed to utilize the drill and intersect method to complete the pilot bore phase of the installation. To accommodate the drill and intersect method, a flat horizontal tangent of 2,850 feet has been incorporated into the design profile between STA 2299+81 and 2328+32 as shown on the crossing drawing in Appendix A.

2 Anticipated Geotechnical Conditions

The following discussions on the anticipated geotechnical conditions are based on the information provided by the site-specific geotechnical investigation program. Borehole logs for completed borings to support the design of the crossings by HDD methods are provided in Appendix B.

The objective of these discussions is to provide an explanation of the various construction risks identified in subsequent sections related to the geotechnical conditions.

2.1 Subsurface Investigations

A total of nine (9) borings were completed as part of the geotechnical investigation program, to support the evaluation and design of the Beltzville Lake HDD Crossing. Two (2) boreholes, designated as B-10 and B-11, were drilled west of Wild Creek to 125 feet (EL 645) and 185 feet (EL 500) below the ground surface, respectively. Five (5) boreholes, designated as B-12, B-13, B-14, B-15, and B-Poh-1, were drilled between Wild Creek and Pohopoco Creek, to depths ranging between 100 feet to 230 feet below ground surface (between EL 475 and EL 450). On the east side of Pohopoco Creek, two (2) boreholes, designated as B-16 and B-17, were drilled to 175 feet (EL 461) and 120 feet (EL 598) below ground surface, respectively. More detailed discussions can be found in the site-specific GDR.

Vibration monitoring was also completed to at the request of Bethlehem Authority for borings B-15 and B-16 during drilling activities to monitor the potential vibration impact to nearby infrastructure items. More detailed discussions can be found in the Vibra-Tech report in Attachment F of the site-specific GDR.

A summary of the subsurface materials encountered at the site is provided below.

2.2 Geotechnical Observations

2.2.1 Geotechnical Observations West of Wild Creek

The HDD installation on the west side of Wild Creek is anticipated to encounter soils overlying bedrock materials. Based on Boring B-10, the site soils are anticipated to include the following:

- Loose clayey gravel from the ground surface to a depth of 3.5 feet (from Elev. 774 to 770.5 feet).
- Very dense possible gravel to a depth of 15 feet (to Elev. 759 feet). No material was recovered from a depth of 3.5 feet to 15 feet (Elev. 770.5 to 759 feet). Drilling indicates possible gravel within this zone.
- Slightly weathered to fresh, weak to very strong shale to a termination depth of 125 feet (to Elev. 624 feet). RQD values ranged between 33 to 100 percent (avg. 81 percent) with RQD increasing with depth. Recovery values ranged between 90 to 100 percent (avg. 99 percent).

Based on Boring B-11, the site soils are anticipated to include the following:

- Loose gravel from the ground surface to a depth of 3.5 feet (from Elev. 688 to 684.5 feet).
- Very dense gravel with clay to a depth of 13 feet (to Elev. 675 feet).
- Slightly weathered to fresh, weak to very strong shale to a termination depth of 185 feet (to Elev. 503 feet). RQD values ranged between 0 to 100 percent (avg. 77 percent) with RQD increasing with depth. Recovery values ranged between 75 to 100 percent (avg. 98 percent).

The bedrock materials are anticipated to include predominantly slightly weathered to fresh, weak to very strong shale based on information collected from Borings B-10 and B-11. The strength of the shale appears to be weakest at the soil/rock interface and increases with depth. Isolated areas of highly weathered and weak shale were also encountered at various depths. Along the proposed HDD alignment, the bedrock on the west side of Wild Creek appears to be of very poor to excellent quality, with RQD

values ranging from 0 to 100 percent, and an average value of 79 percent. The core recovery values ranged from 75 to 100 percent, with an average value of 98 percent.

Laboratory testing results on the shale within this area show an unconfined compressive strength (UCS) ranging from 4,289 to 5,428 psi with an average value of 4,790 psi. The axial point load UCS ranged from 3,371 psi to 19,105 psi with an average of 13,498 psi. The diametral point load UCS ranged from 925 psi to 12,373 psi with an average of 5,708 psi. The splitting tensile strength ranged from 628 psi to 1,821 psi with an average 1,046 psi.

2.2.2 Geotechnical Observations East of Wild Creek

The HDD installation on the east side of the Wild Creek is anticipated to be entirely within bedrock. It is not expected that the HDD will encounter the soils that overlie bedrock materials in this area. Based on Boring B-12, the site soils are anticipated to include the following:

- Loose to very dense clayey sand with decomposed sandstone fragments from the ground surface to a depth of 18.5 feet (from Elev. 703 feet to Elev. 684.5 feet).
- Very dense decomposed shale fragments to a depth of 35 feet (to Elev. 668 feet). Possible boulders identified within layer.
- Slightly weathered to fresh, weak to strong shale to a depth of 65 feet (to Elev. 638 feet). RQD values ranged between 0 to 82 percent (avg. 36 percent). Recovery values ranged between 90 to 100 percent (avg. 96 percent).
- Fresh, strong shale to a termination depth of 225 feet (to Elev. 478 feet). RQD values ranged between 65 to 100 percent (avg. 93 percent). Recovery values ranged between 93 to 100 percent (avg. 99 percent).

Based on Boring B-13, the site soils are anticipated to include the following:

- Medium stiff to stiff clay from the ground surface to a depth of 8.5 feet (from Elev. 706 feet to Elev. 697.5 feet).
- Very dense decomposed sandstone with clay to a depth of 35.3 feet (to Elev. 670.7 feet).
- Moderately weathered to fresh, weak to strong shale to a depth of 95 feet (to Elev. 611 feet). RQD values ranged between 0 to 97 percent (avg. 93 percent). Recovery values ranged between 88 to 100 percent (avg. 99 percent).
- Fresh, strong shale to a termination depth of 230 feet (to Elev. 476 feet). RQD values ranged between 53 to 100 percent (avg. 92 percent). Recovery values ranged between 95 to 100 percent (avg. 100 percent).

Overall, the slate east of Wild Creek appears to be of fair to excellent quality, with RQD values ranging from 53 to 100 percent, and an average value of 93 percent. The core recovery values ranged from 93 to 100 percent, with an average value of 100 percent. The shale appears to be of very poor to excellent quality, with RQD values ranging from 0 to 97 percent, with an average value of 42 percent. The core recovery values ranged from 88 to 100 percent, with an average value of 96 percent.

Laboratory testing results on the slate within this area show an unconfined compressive strength ranging from 736 to 6,680 psi, with an average value of 2,599 psi. The axial point load UCS ranged from 1,628 psi to 8,065 psi with an average of 3,917 psi. The diametral point load UCS ranged from 4,216 psi to 12,401 psi with an average of 8,568 psi. The splitting tensile strength ranged from 501 psi to 807 psi with an average 656 psi.

No samples of shale were tested within this area.

2.2.3 Geotechnical Observations West of Pohopoco Creek

The HDD installation on the western side of the Pohopoco Creek is anticipated to be entirely within bedrock. Based on Boring B-14, the site soils are anticipated to include the following:

- Medium stiff silt with gravel from the ground surface to a depth of 3.5 feet (from Elev. 700 feet to Elev. 696.5 feet).
- Very stiff clay with gravel to a depth of 7.5 feet (to Elev. 692.5 feet).
- Hard silt with gravel to a depth of 13.5 feet (to Elev. 686.5 feet).
- Very dense decomposed shale fragments to a depth of 19.3 feet (to Elev. 680.7 feet).
- Slightly weathered to fresh, very weak to weak shale to a termination depth of 100 feet (to Elev. 600 feet). RQD values ranged between 14 to 93 percent (avg. 64 percent). Recovery values ranged between 90 to 100 percent (avg. 98 percent).

Based on Boring B-POH-1, the site soils are anticipated to include the following:

- Very soft to hard clay with decomposed shale fragments from the ground surface to a depth of 8.5 feet (from Elev. 695 feet to Elev. 689.5 feet).
- Hard clayey silt with decomposed shale fragments to a depth of 18.5 feet (to Elev. 679.5 feet).
- Very dense decomposed shale fragments with clay to a depth of 32 feet (to Elev. 663 feet).
- Moderately weathered to fresh, strong shale to a depth of 75 feet (to Elev. 620 feet). RQD values ranged between 25 to 90 percent (avg. 70 percent) and recovery values of 100 percent.
- Moderately weathered to fresh, medium strong to strong slate to a termination depth of 225 feet (to Elev. 470 feet). RQD values ranged between 53 to 100 percent (avg. 85 percent). Recovery values ranged between 92 to 100 percent (avg. 99 percent).

Based on Boring B-15, the site soils are anticipated to include the following:

- Very stiff clayey silt with decomposed shale fragments from the ground surface to a depth of 9.5 feet (from Elev. 654 feet to 644.5 feet).
- Very dense decomposed shale fragments with silt to a depth of 18 feet (to Elev. 636 feet).
- Fresh, medium strong to strong slate to a termination depth of 175 feet (to Elev. 479 feet). RQD values ranged between 0 to 100 percent (avg. 81 percent). Recovery values ranged between 87 to 100 percent (avg. 99 percent).

The HDD installation on the western side of the Pohopoco Creek is anticipated to be entirely within bedrock. It is not expected that the HDD will encounter the soils that overlie bedrock materials in this area. Based on Borings B-14, B-Poh-1, and B-15, the surficial soils consist of clay and silt overlying decomposed shale fragments.

Overall, the slate west of Pohopoco Creek appears to be of very poor to excellent quality, with RQD values ranging from 0 to 100 percent, and an average value of 83 percent. The core recovery values ranged from 87 to 100 percent, with an average value of 99 percent. The shale appears to be of very poor to excellent quality, with RQD values ranging from 14 to 93 percent, with an average value of 66 percent. The core recovery values ranged from 90 to 100 percent, with an average value of 99 percent.

It is anticipated that the HDD alignment will only encounter the slate in the area west of Pohopoco Creek. Along the horizontal tangent in this area, the RQD values are anticipated to range from 57 to 100 percent, with an average value of 85 percent. The core recovery values are anticipated to be 100 percent.

Laboratory testing results on the slate within this area show an unconfined compressive strength ranging from 1,284 to 3,135 psi, with an average value of 2,308 psi. The axial point load UCS ranged from 5,008 psi to 5,502 psi with an average of 5,255 psi. The diametral point load UCS ranged from 3,323 psi to 9,854 psi with an average of 6,893 psi. The splitting tensile strength ranged from 745 psi to 1,542 psi with an average 1,200 psi.

Laboratory testing results on shale within this area shows an unconfined compressive strength of 2,526 psi. The axial point load UCS was tested as 7,959 psi and the diametral point load UCS was 4,046 psi. The splitting tensile strength ranged from 566 psi to 921 psi with an average 744 psi.

2.2.4 Geotechnical Observations East of Pohopoco Creek

The HDD installation on the east side of Pohopoco Creek is anticipated to encounter residual soils overlying bedrock materials. Based on Boring B-16, the site soils are anticipated to include the following:

- Very soft silt from the ground surface to a depth of 2.5 feet (from Elev. 638 feet to Elev. 635.5 feet).
- Very dense decomposed shale to a depth of 15 feet (to Elev. 623 feet).
- Slightly weathered to fresh, weak to medium strong shale to a depth of 115 feet (to Elev. 523 feet). RQD values ranged between 7 to 100 percent (avg. 70 percent). Recovery values ranged between 82 to 100 percent (avg. 98 percent).
- Fresh, medium strong to strong slate to a termination depth of 175 feet (to Elev. 463 feet). RQD values ranged between 77 to 100 percent (avg. 98 percent). Recovery values ranged between 98 to 100 percent (avg. 100 percent).

Based on Boring B-17, the site soils are anticipated to include the following:

- Dense to very dense decomposed shale fragments with clay from the ground surface to a depth of 15 feet (from Elev. 720 feet to 705 feet).
- Moderately weathered to fresh, weak to strong shale to a depth of 95 feet (to Elev. 625 feet). RQD values ranged between 0 to 100 percent (avg. 52 percent). Recovery values ranged between 65 to 100 percent (avg. 97 percent).
- Fresh, strong slate to a termination depth of 120 feet (to Elev. 600 feet). RQD values ranged between 85 to 100 percent (avg. 97 percent). Recovery values ranged between 90 to 100 percent (avg. 98 percent).

The bedrock materials are anticipated to include moderately weathered to fresh, weak to strong shale overlying fresh, medium strong to strong slate at depth based on information collected from Borings B-16 and B-17. Isolated areas of highly weathered and weak bedrock were encountered at various depths.

Along the proposed HDD alignment, the shale on the east side of Pohopoco Creek appears to be of very poor to excellent quality, with RQD values ranging from 0 to 100 percent, and an average value of 62 percent. The core recovery values of the shale ranged from 65 to 100 percent, with an average value of 97 percent. The slate on the east side of Pohopoco Creek appears to be of good to excellent quality, with RQD values ranging from 0 to 100 percent, and an average value of 98 percent. The core recovery values of the slate ranged from 90 to 100 percent, with an average value of 99 percent.

Laboratory testing results on the slate within this area show an unconfined compressive strength ranging from 4,163 to 7,388 psi, with an average value of 5,776 psi. The axial point load UCS was tested as 6,593 psi. The diametral point load UCS ranged from 9,758 psi to 11,755 psi with an average of 10,757 psi. The splitting tensile strength ranged from 876 psi to 942 psi with an average 909 psi.

Laboratory testing results on the shale within this area show an unconfined compressive strength ranging from 8,618 to 13,030 psi with an average value of 10,824 psi. The axial point load UCS ranged from 6,862 psi to 11,590 psi with an average of 9,226 psi. The diametral point load UCS ranged from 9,473 psi to 11,825 psi with an average of 10,649 psi. The splitting tensile strength ranged from 1,024 psi to 1,047 psi with an average 1,036 psi.

2.3 Groundwater Observations

Ground water was recorded at 34 feet below ground surface in boring B-10. East of Wild Creek, in Borings B-12 and B-13, groundwater was observed between 18 and 39 feet below ground surface (Elev. 687 and 665 feet). West of Pohopoco Creek, groundwater was only observed in Boring B-15 at 7 feet below ground surface (Elev. 647 feet). East of Pohopoco Creek, groundwater was only observed in Boring B-16 at 5 feet below ground surface (Elev. 635 feet). See the site-specific GDR for additional information on ground water.

An artesian condition was observed in Boring B-15, west of Pohopoco Creek, at 128.5 feet below ground surface (Elev. 525.5 feet). A TROLL 500 Data Logger was placed in the boring at a depth of 133 feet to measure real-time gauge pressure for 48 hours. The measured artesian pressure in Boring B-15 was between 63.3 and 64.3 psi. The corresponding elevation of the artesian condition is approximately 669 feet, or 15 feet above the ground surface.

2.4 Vibration Monitoring

At the request of Bethlehem Authority, vibration monitoring was conducted by Vibra-Tech, where geotechnical drilling activities occurred in close proximity to Bethlehem Authority's Wild Creek Water Transmission lines. Industry standard requirements set boundary limits for vibration and ground motion frequency, to limit the damage to sensitive structures and critical resources. Typically, the limits are set at 0.75 inches per second for frequencies less than 40 Hz, and 2 inches per second for frequencies greater than 40 Hz. The more stringent limit of 0.75 inches per second, regardless of ground frequency, was set as the vibration limit and was not exceeded at any point during the geotechnical drilling activities. More detailed discussions can be found in the Vibra-Tech report in Attachment F of the site-specific GDR.

2.5 Karst Formations and Abandoned Mines

A review of the available geologic resources and historic subsurface feature records has been completed for the area of the Beltzville Lake HDD Crossing. No Karst features or abandoned mines have been mapped on either side of Wild Creek or Pohopoco Creek in the vicinity of the HDD crossing.

3 Beltzville Lake Crossing

3.1 HDD Bore Geometry and Alignment Considerations

3.1.1 Entry and Exit Angles

HDD operations are typically designed with entry angles between 8° and 16°, although steeper entry angles have been used where insufficient setback distance or steeply sloping ground exists for a given alignment. Exit angles are typically lower than the entry angle, as consideration must be given to the pipe diameter, the equipment necessary to transition the pipe into the bore, and the stresses induced as the pipe is forced over the break-over location as it enters the HDD bore.

For the Beltzville Lake Crossing, the east entry and west entry angles have been set at 16° and 12° respectively, relative to the horizontal.

3.1.2 Vertical and Horizontal Curvature

Vertical curvature is inherent to all HDD installations. The need for horizontal curvature is dependent on the restrictions specific to a single crossing. While horizontal curvature is feasible, it greatly increases the complexity of the scope of design and construction when required. It also increases the stress, and therefore the risk, to the pipe and the overall installation. Steering in both planes is not a standard industry practice, and can lead to complex radii and a reduction in the overall bending radius that the pipe will be subjected to. A straight alignment has been selected for this HDD crossing, thereby eliminating the risks associated with horizontal curvature.

The proposed vertical curve radius of 3,600 feet shown in Appendix A is consistent with the HDD industry standard of 1,200 times the 3 foot outer diameter of the pipe. This radius has been taken as the design radius for the crossing.

3.1.3 HDD Installation Depth

The depth of cover for a given HDD installation is dependent on several factors, including but not limited to:

- The anticipated geotechnical materials
- The presence of preferential flow pathways
- The design bending radius
- The presence of existing utilities and/or structures
- Installation length

Of these, the most important factors are the properties of the overlying geotechnical material, and the resistance these materials provide against the required installation-induced bore fluid pressures necessary to remove the cuttings.

Another important factor in establishing the proper installation depth is the ability to maintain bore stability over the course of the installation. This is accomplished by placing the HDD bore through geotechnical materials that are favorable to HDD operations.

As shown in Appendix A, the minimum depth of cover beneath the bottom of Wild Creek, Pohopoco Creek, and the Bethlehem Authority Wild Creek Transmission lines is approximately 124 feet, 125 feet, and 164 feet respectively.

3.1.4 Bore Diameter

The diameter of the HDD bore needs to be greater than the outer diameter of the pipe. This larger bore is required to facilitate the flow of drilling fluids around the pipe, reduce the frictional force acting on the pipe as it is installed, and to help the pipe negotiate curves in the alignment.

The acceptable industry standard for the final bore diameter is generally 1.5 times larger than the pipe outer diameter for small diameter pipe (less than 24 inches), and 12 inches larger than the outer diameter for large diameter installations. However, the actual diameter of the bore is typically dependent upon the geotechnical conditions and the required bore geometry. Hence, it may be necessary to increase the diameter beyond the typical industry standard to facilitate the installation process. To increase the likelihood of success, it is highly recommended that the final bore diameter be selected by the HDD Contractor, based on their experiences with similar geotechnical materials, pipe diameters, and installation lengths, and to suit their means and methods.

Based on typical HDD industry standards, the anticipated bore diameter for the NPS 36 pipe is 48 inches.

3.2 Line and Grade Accuracy

The horizontal and vertical position of the bottom hole assembly is tracked using a downhole survey tool, consisting of a probe that utilizes Earth's gravitational and magnetic fields. These tools have a nominal accuracy of approximately:

- Inclination: ± 0.1°
- Azimuth: ± 0.3° to 0.5°
- Tool-face: ± 0.1°

The accuracy of these tools can be enhanced by using a surface wire/coil loop established over the alignment. Inducing an electrical current through the wire creates a localized magnetic field that the probe can then use to determine its location relative to the surveyed coil and magnetic field.

These enhanced guidance systems include TruTracker and ParaTrack systems. The TruTracker guidance system relies on a closed loop surveyed wire layout that is at least as wide as the depth of the HDD installation. For highways and water body crossings, individual coils are often established on each side of the crossing feature. A ParaTrack system relies on a single wire placed directly over the HDD alignment centerline, with a return wire offset several hundred feet from the alignment to form a closed loop system. When augmented with a surface coil, the lateral and vertical position of the survey probe is plus or minus two (2) percent of the depth separating the location of the probe and the surface coil. Greater inaccuracies may occur if site constraints prevent the use of an energized wire grid on the ground surface.

Fiber-optic gyroscopic guidance systems have also been used to track downhole tooling. This type of system relies on an inertial measurement unit to calculate the position of the bottom hole assembly and is not affected by magnetic interference. This tool is very effective in accurately locating the surface tool position during pilot bore drilling.

With all of these methods, survey readings can be taken at the end of each drilled joint or every half of a joint. Stand-alone surveys can be completed where the surface coils are established. Here the inaccuracy is a function of the specific depth of cover at the location in question. Where the surface coils cannot be established such as across a highway or beneath a river, the position of the bottom hole assembly is determined based on the calculated position of the previous measurement. In this manner, any inaccuracy built into the measured position is additive as the drill length increases. However, as the bottom hole assembly re-encounters the surface coil on the opposite side of the highway or river, the inaccuracy is once again a function of a stand-alone measurement based on the specific depth of cover at the location in question.

Mott MacDonald recommends the use of a gyroscopic guidance system for the Beltzville Lake Crossing to mitigate concerns associated with laying a surface coil along the proposed alignment and across the waterways. If a ParaTrack system is proposed by the HDD Contractor, the HDD Contractor must assure adequate coverage of surveying with no gaps in coverage with a surface coil and/or beacon.

3.3 Required Workspace and Staging Areas

For the proposed HDD installation, the staging area for the eastern side of the crossing has been established at 250 feet by 250 feet, and the staging area for the western side of the crossing has been established at 250 feet by 250 feet (to accommodate use of the drill and intersect strategy). This area is required to stage equipment necessary for the installation, which includes the drill rig, stacks of drill pipe, operator control cabin, tooling trailers, crane or excavator, separation plant, mud tanks, mud pumps, Baker storage tanks, office trailer, and support trailers. The eastern construction pad will require earthwork to either level a construction pad or provide benches to stage equipment properly on this side of the crossing.

In addition to the entry and exit staging areas, a staging area of 75 feet wide by the length of the pipe string (greater width is required where multiple drag sections are required) is also required for welding sections of the pipe string, and preferably the entire pipe string when possible, prior to installation. The proposed staging area for the drag section is located on the western side of the crossing. The available length of the staging area is approximately 2,400 feet, resulting in the need for fabricating the pipe string into three (3) drag sections and the need for three (3) intermediate welds during pullback operations. The HDD Contractor will need to minimize delays during intermediate welding operations. For the proposed crossing, the staging area width is 125 feet for the majority of the pipe staging area with 100 feet width in the vicinity of an existing septic tank. The staging area crosses two roads. This provided width is sufficient to stage the multiple pipe strings.

3.4 Requirement for Temporary Surface Casing

During the geotechnical investigation, layers of gravel and decomposed rock fragments were observed with thicknesses of 13 to 15 feet on both sides of the Beltzville Lake Crossing. These soils represent a significant risk to the overall bore stability, raveling of gravel into the bore, potential damage to the pipe string, and increased pullback loads/stresses. To support these soils and mitigate the risks associated with such deposits, a temporary conductor casing is recommended on both sides of the HDD installation. The approximate casing length required on the western side of the proposed HDD installation is 110 feet and, 210 feet on the eastern side of the installation, depending on where the soil/bedrock interface is encountered with the HDD alignment.

The minimum conductor casing diameter is recommended to be 56 inches to allow for the free passage of the 48-inch reamer assembly. Any required casing pipe shall be removed once pullback operations have been completed.

The requirement for temporary conductor casings on each end of the proposed HDD installation will require a drill and intersect installation strategy for this crossing. This method involves drilling independent pilot bores from each side of the installation, meeting within a target intersection location along the alignment. For the proposed profile, the intersection location is envisioned to occur along the 2,850-foot long horizontal tangent between STA 2299+81 and 2328+32 as shown on the crossing drawing in Appendix A.

3.5 Drilling Fluid Make-Up Water and Source

HDD operations require a continuous source of water to support construction activities. It is typical for contractors to make use of an onsite source or have water delivered from a nearby source. In each case, the contractor should verify that the water source is suitable for HDD operations, or treat it (filtration, pH, etc.) so that it is suitable for use.

For the proposed crossing, no on-site source of fresh water has been identified as a potential source to support construction activities. Estimates of fresh water requirements are a function of maintaining drilling fluid flow within the bore during the HDD installation, water requirements to adjust for hole volume, minor losses to processed spoil and surrounding geotechnical materials, wash water, etc. Daily fresh water usage typically ranges from 2,650 to 5,300 ft^3, depending on the process and storage capabilities of the Contractor.

Total fresh water requirements can be estimated as a function of the final reamed diameter. Factors of between two (2) and seven (7) times the final reamed diameter have been used to estimate the fresh water requirements necessary to support HDD operations. Based on a factor of four (4), the estimated total water usage (assuming no loss in circulation) is approximately 2,293,700 gallons (306,623 ft^3). This volume estimate assumes good HDD industry practices and procedures are followed, and that no significant fluid losses occur during the installation. This volume also includes fresh water required for buoyancy control during the HDD installation, estimated at approximately 193,531 gallons.

3.6 Disposal of Excess Drilling Fluid and Processed Spoils

Excess drilling fluids and processed spoils will need to be disposed of during the installation. The direct area around the HDD is not expected to be suitable for permanent disposal of drilling fluid or processed solids (based on local, state, and federal regulations). Local temporary storage will be required either in above ground tanks or a lined burrow pit. A suitable offsite disposal site should be located for disposal of drilling fluid and processed spoil, per the local, state, and federal guidelines.

Disposal volumes of excess drilling fluid and spoil are estimated at approximately 1,785,000 gallons (8,838 yd^3) and 109,508 ft^3 (4,056 yd^3) respectively. During pullback operations, the estimated displaced fluid volume is approximately 322,551 gallons (1,597 yd^3).

3.7 Schedule

The duration of the HDD installation is conservatively estimated to take a total of 180 shifts, as shown in Table 1. This estimate is based on a 12-hour shift, regardless of whether 24-hour operations are conducted to complete the crossing. No provisions have been included for pad construction and erection and tear-down of a shelter (if used) in these durations. In addition, no contingency has been provided for adverse weather or harder drilling conditions.

Table 1: Estimated schedule duration for the HDD crossing

Activity	Duration (Shifts)
Mobilization	3
Rig Up / Equipment Setup	5
Casing Installation	10
Pilot Bore Drilling	25
Reaming	120
Swab Pass	3
Product Pipe Pullback	4
Casing Removal	5
Rig Down / Demobilization	5
Total Number of Shifts	**180**

4 HDD Engineering Evaluation

4.1 Pipeline Properties

The pipeline properties used for the evaluation of the Beltzville Lake Crossing have been provided by PennEast, and are summarized in Table 2 below:

Table 2: Pipeline properties and input parameters for the HDD evaluation

Evaluation Parameter	Value
Pipe Size	NPS 36
Outer Diameter	36 in
Wall Thickness	0.762 in
Pipe Grade	X-70
Maximum Allowable Operating Pressure	1,480 psig
Minimum Operating Temperature	45°F
Maximum Operating Temperature	120°F
Poisson's Ratio	0.30
Elastic Modulus	29,200,000 psi
Coefficient of Thermal Expansion	6.5 x 10^{-6} in/in/°F
Design Factor	0.5

4.2 Design and Minimum Allowable Bend Radii

The minimum ultimate bend radius is a function of the maximum allowable operating pressure, pipe diameter, wall thickness, design factor, location factor, and specified minimum yield strength of the pipe material. Determination of the ultimate minimum bend radius is based on determining the hoop and longitudinal stresses under operating pressure and then determining the available magnitude of stress that the product pipe can accommodate in an alignment bend/curve.

The minimum ultimate bending radius evaluation is completed in accordance with:

- ASCE Manual of Practice No. 108 Pipeline Design for Installation by Horizontal Directional Drilling
- 49 CFR 192 Transportation of Natural and Other Gas by Pipeline- Minimum Federal Safety Standards
- ASME B31.8 Gas Transmission Distribution and Piping Systems
- ASME B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids

Using the pipe properties provided in Table 2, the ultimate minimum bending radius is calculated for the pipe and pressure conditions. This radius represents the lowest radius that could be drilled without overstressing the pipe for the identified pipe properties and in-service loading. Based on the pipe properties provided in Table 2 and a design factor of 0.5, the ultimate minimum bending radius is approximately 2,500 feet.

The minimum allowable bending radius is the minimum radius that the HDD contractor is permitted to drill during their pilot bore to maintain the design alignment and profile. This radius is established above the calculated ultimate minimum bending radius to not overstress the pipe during the HDD installation process, and sufficiently below the design radius provided on the construction drawings. Based on an ultimate minimum bending radius of 2,500 feet, the minimum allowable bending radius has been established at 2,600 feet.

The design radius is the radius selected to develop the HDD plan and profile. This radius is greater than the minimum allowable bending radius given to the HDD contractor to complete the construction of the crossing. The design bending radius for developing the Beltzville Lake profile has been established at 3,600 feet, which is consistent with the HDD industry standard of 1,200 times the outer diameter of the NPS 36 pipe.

4.3 Operating Stress Evaluation

Evaluation of operating loads for pipelines installed by HDD methods is generally similar to the evaluation for pipelines installed by open-cut construction methods. The main difference between the two scenarios is that the condition of elastic bending (as a result of the curved HDD alignment profile) must be considered for the HDD installation. Elastic bending stresses occur as the pipe takes on the final shape of the HDD bore. As a rule, the bending stresses induced are not a critical stress condition on their own, but must be considered in a combined loading condition with other stress conditions such as hoop stress and longitudinal stress.

An operating stress evaluation has been completed in compliance with the American Society of Mechanical Engineers B31.4 and B31.8. The input parameters for this analysis are provided in Table 2. The results of the evaluation are provided in Table 3 below, and are based on the minimum allowable bending radius of 2,600 feet (the allowable bend radius provided to the HDD contractor). As observed in Table 3, the operating stresses are below the maximum allowable limits. Hence, the pipe properties (wall thickness and grade) are sufficient to meet the operating stresses within the HDD alignment.

Table 3: Summary of operating stress evaluation

Stress Condition	Estimated Stress (psi)	Percent of SMYS[1] (%)	Maximum Allowable Percent of SMYS[1] (%)
Longitudinal Bending Stress	16,846	24.1	--
Hoop Stress	34,961	49.9	50[2]
Longitudinal Tensile Stress from Hoop Stress	10,488	15.0	--
Longitudinal Stress from Thermal Expansion	-14,235	20.3	90[3]
Net Longitudinal Stress (Compression Side of the Curve)	-20,593	29.4	90[4]
Net Longitudinal Stress (Tension Side of the Curve)	13,099	18.7	90[4]
Maximum Shear Stress	27,777	39.7	45
Combined Biaxial Stress	55,553	79.4	90[4]

Notes: [1] Specified Minimum Yield Stress
[2] Limited by design factor
[3] Limited by ASME B31.4
[4] Limited by ASME B31.8

4.4 HDD Installation Load and Stress Evaluation

A total of six (6) pull load evaluations were completed for the HDD bore profile. These calculations are based on the installation load calculation method provided in the American Society of Civil Engineer MREP 108 (2015), and the Pipeline Research Committee at the American Gas Association publication, entitled “Installation of Pipelines by Horizontal Directional Drilling, an Engineering Guide.”

The pull load evaluation includes assumptions for final bore diameter, soil, and pipe roller friction coefficients, drilling fluid yield point, plastic viscosity, drilling fluid pumping rate, and other installation parameters such as buoyancy control measures (i.e. whether or not the pipe will be filled with water during pullback operations). In addition, the evaluation accounts for the capstan effect induced by curves in the alignment, fluidic drag, buoyancy of the pipe string within the bore, and the weight of the tail string at start-up and throughout the installation process.

Six (6) installation evaluations have been completed to investigate the effects of varying mud weights and buoyancy control measures during the installation of the pipe. The six (6) scenarios evaluated include:

- Case 1: Drilling Fluid Weight — 10 ppg (Specific Gravity of 1.20)
  Pipe — No buoyancy control (pipe empty of water)
- Case 2: Drilling Fluid Weight — 10 ppg (Specific Gravity of 1.20)
  Pipe — Full buoyancy control (pipe full of water)
- Case 3: Drilling Fluid Weight — 11 ppg (Specific Gravity of 1.32)
  Pipe — No buoyancy control (pipe empty of water)
- Case 4: Drilling Fluid Weight — 11 ppg (Specific Gravity of 1.32)
  Pipe — Full buoyancy control (pipe full of water)
- Case 5: Drilling Fluid Weight — 12 ppg (Specific Gravity of 1.44)
  Pipe — No buoyancy control (pipe empty of water)
- Case 6: Drilling Fluid Weight — 12 ppg (Specific Gravity of 1.44)
  Pipe — Full buoyancy control (pipe full of water)

A summary of the maximum anticipated pull load for each case scenario is provided in Table 4 below. Detailed calculations are provided in Appendix C. The anticipated installation loads shown in Table 4 are well below the ultimate allowable load of the pipe of approximately 3,542,953 lbs, based on a tensile stress equivalent to 60 percent of the yield stress for the given wall thickness and pipe grade provided in Table 2. It is important to note the difference in pull loads when buoyancy control measures are implemented and water is added to the pipe during pullback, as the estimated installation loads are typically lower when buoyancy control measures are used. Mott MacDonald recommends the use of buoyancy control measures to lower the overall installation loads and stresses for this installation, as installation loads may exceed the capacity of industry standard equipment in the absence of buoyancy control.

A start-up factor of 1.5 has been applied to the estimated pullback forces to replicate the higher installation loads observed during stoppages and recommencing of pullback operations. This is referred to as the initial start-up pullback force in Table 4.

Table 4: Summary of anticipated pullback loads

Drilling Fluid Weight (ppg)	Product Pipe Buoyancy Condition	Estimated Pullback Force (lbs)	Initial Start-Up Force String 1 (lbs)	Initial Start-Up Force String 2 (lbs)	Initial Start-Up Force String 3 (lbs)
10 (Case 1)	Empty	1,030,000	62,949	529,979	1,038,827
10 (Case 2)	Full	573,061	62,949	260,515	631,775
11 (Case 3)	Empty	1,197,118	62,949	592,398	1,185,386
11 (Case 4)	Full	445,588	62,949	245,649	536,003
12 (Case 5)	Empty	1,373,080	62,949	654,736	1,343,706
12 (Case 6)	Full	363,936	62,949	230,760	442,103

Results of the corresponding installation stresses (based on the design bending radius of 3,600 feet) are summarized in Table 5.

Table 5: Summary of installation stress evaluation

Stress Condition	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Maximum Tensile Stress (Percent of Allowable)	12,315 psi (17.6%)	7,489 psi (10.7%)	14,191 psi (20.3%)	6,354 psi (9.1%)	16,277 psi (23.3%)	5,241 psi (7.5%)
Maximum Bending Stress (Percent of Allowable)	12,083 psi (17.3%)	12,083 psi (17.3%)	12,083 psi (17.3%)	12,083 psi (17.3%)	12,083 psi (17.3%)	12,083 psi (17.3%)
Maximum Hoop Stress (Percent of Allowable)	3,626 psi (5.2%)	601 psi (0.9%)	3,988 psi (5.7%)	964 psi (1.4%)	4,351 psi (6.2%)	1,326 psi (1.9%)
Maximum Unity Check – Tensile and Bending	0.48	0.38	0.52	0.36	0.55	0.35
Maximum Unity Check – Tensile, Bending, and Hoop	0.46	0.12	0.54	0.13	0.63	0.14

As observed in this Table, the results of the HDD installation stress evaluation are within the allowable limits for all cases.

4.5 Hydraulic Fracture Evaluation

The hydraulic fracture evaluation for this crossing has been completed in general accordance with the Delft Geotechnics Method outlined in Appendix B of the Army Corps of Engineers 1998 Report CPAR-GL-98 and 2002 Report ERDC/GSL TR-02-9 (Guidelines for Installation of Utilities Beneath Corp of Engineers Levees Using Horizontal Directional Drilling). This method is used to estimate the maximum effective pressure (i.e. drilling fluid pressure) that can be induced during an HDD operation within a particular soil horizon. This pressure is then compared with the fluid pressure required to induce slurry flow within the HDD bore to determine the potential for a hydraulic fracture for a given HDD alignment. The required fluid pressure for an HDD installation is governed by the drilling fluid weight (commonly referred to as the mud weight), installation length and depth, and drilling fluid flow properties (plastic viscosity, yield point, etc.).

The hydraulic fracture evaluation method described above and used in the HDD industry was developed for soil installations. Currently, no accepted method is available to model/predict the maximum allowable drilling fluid pressure within bedrock materials. While bedrock tensile strength and unconfined compressive strength evaluations have been used to estimate the allowable drilling fluid pressure within bedrock materials, these methods tend to provide results that are not considered suitably conservative, and greatly over-predict the true maximum allowable drilling fluid pressures. These over-predictions are a result of laboratory testing on sound or high-quality bedrock samples that are not representative of the strengths of the weaker bedrock materials that contain natural fractures/joints that are washed out or impacted by the geotechnical coring process. Hence, for bedrock hydraulic fracture evaluation, Mott MacDonald has elected to model the shale and slate bedrock materials as strong soils. This conservative approach has been used by Mott MacDonald to successfully complete several HDD installations in similar bedrock materials.

The Delft Geotechnics Method assumes a uniform column of soil above any point of interest along the alignment. Where an increased risk of hydraulic fracture is identified, it does not necessarily mean that a hydraulic fracture will occur. A proper HDD execution plan, based on HDD industry standard construction practices, can reduce the risk of a hydraulic fracture from occurring.

In order to complete the hydraulic fracture evaluation, it is necessary to make several assumptions relative to the bore diameter, drilling fluid pumping rate, and drilling fluid properties. Parameters used in Mott MacDonald's evaluation are provided in Table 6 below. These parameters have been selected based on Mott MacDonald's experience in drilling within similar anticipated geotechnical materials.

Table 6: Assumptions used for hydraulic fracture evaluation

Evaluation Parameter	Value
Pilot Bore Diameter	12-¼ in
Drill Pipe Diameter	6-⅝ in
Drilling Fluid Pumping Rate	750 gal/min
Drilling Fluid Weight (Specific Gravity)	10.5 ppg (1.26)
Yield Point	18 lb./100 ft^2
Plastic Viscosity	12 cP

In addition to the assumptions provided in Table 6, assumptions are also required for the anticipated soil formation(s) and their properties including, but not limited to, geotechnical material strength, unit weight, cohesion, friction angle, and shear modulus. These assumptions are provided in Tables 7 through 9 for the varied subsurface materials that are anticipated for this crossing. For this evaluation, Mott MacDonald assumes that the encountered subsurface material will be similar to that described in Section 2, namely, gravel overlying shale and slate bedrock. For this evaluation, it has also been assumed that the Drill and Intersect method will be used to complete the pilot bore.

Table 7: Material property assumptions for the gravel

Evaluation Parameter	Value
Soil Unit Weight Above / Below Water Table	130 lb./ft^3 / 140 lb./ft^3
Effective Cohesion	0 psf
Internal Friction Angle	30°
Young's Modulus	522,136 psf
Poisson's Ratio	0.33

Table 8: Material property assumptions for the shale bedrock

Evaluation Parameter	Value
Soil Unit Weight Above / Below Water Table	145 lb./ft^3 / 150 lb./ft^3
Effective Cohesion	7,500 psf
Internal Friction Angle	11°
Young's Modulus	1,357,553 psf
Poisson's Ratio	0.33

Table 9: Material property assumptions for the slate bedrock

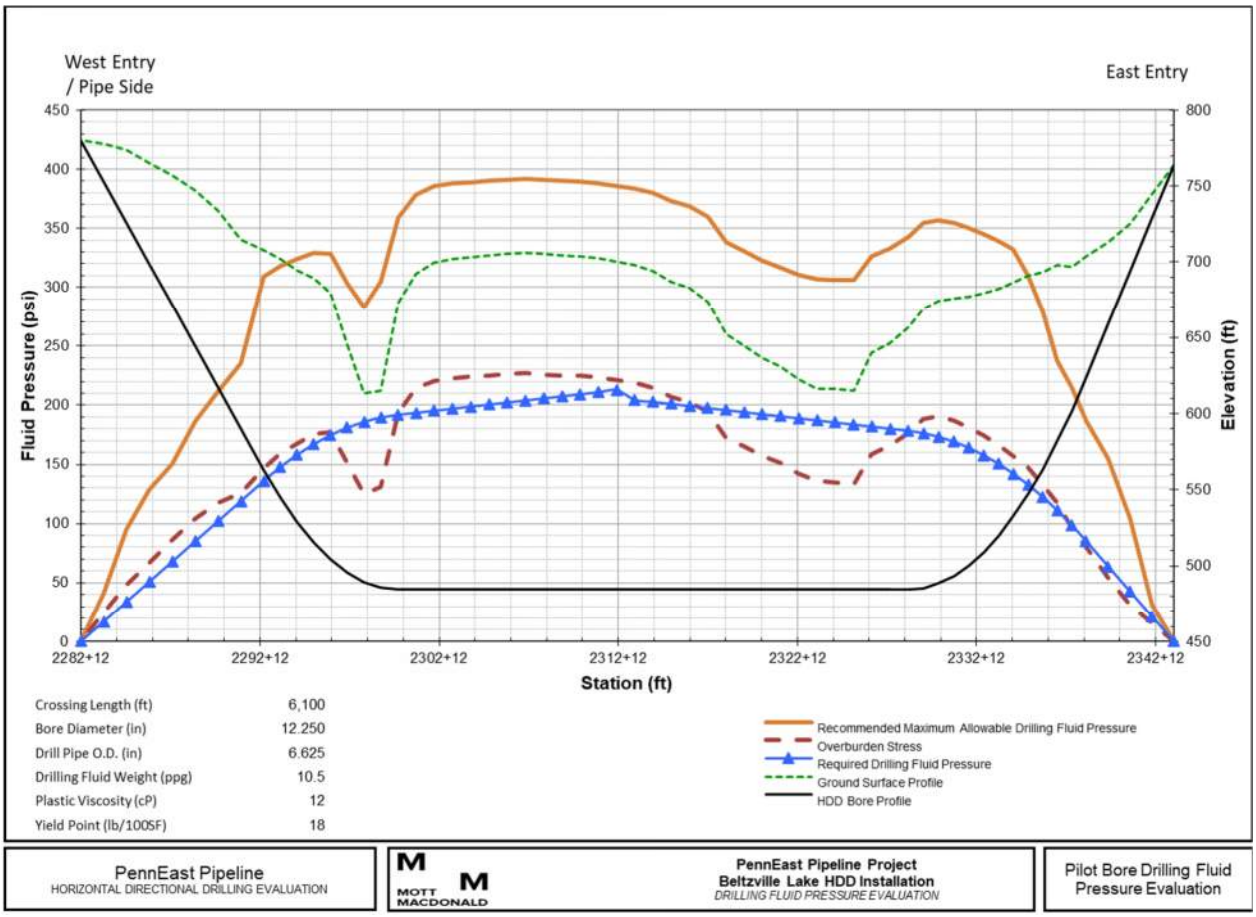
Evaluation Parameter	Value
Soil Unit Weight Above / Below Water Table	150 lb./ft^3 / 155 lb./ft^3
Effective Cohesion	7,500 psf
Internal Friction Angle	11°
Young's Modulus	1,670,834 psf
Poisson's Ratio	0.33

The results of the preliminary hydraulic fracture evaluation for the proposed crossing are provided in Figure 1 for the pilot bore phase of the installation process. More detailed results are provided in Appendix D. A safety factor has been incorporated into the hydraulic fracture evaluation for the allowable bore pressure within the bedrock, to account for assumptions incorporated into the design and heterogeneity of the geotechnical materials. The graph also displays the total soil/bedrock overburden stress representing the equivalent unit weight of the overlying soil without consideration of any soil strength. Mott MacDonald recommends holding discussions with the HDD contactor if the actual bore pressures trend higher than those values estimated in Appendix D during actual construction, especially if the observed bore pressures spike during the installation.

As shown in the graph, the required bore pressure to facilitate the installation process is well below the allowable bore pressure for the installation.

Once the pilot bore is completed, the hydraulic fracture risk associated with the reaming, swab, and pullback phase of the installation typically decreases, assuming the bore is reamed to its full extent and a subsequent swab pass is completed through the bore prior to installing the pipe. However, it is important to note that although the hydraulic fracture potential is significantly reduced, a hydraulic fracture event may still occur during the reaming pass if the bore becomes plugged or blocked such that the required drilling fluid pressure increases in magnitude to the point where it exceeds the estimated allowable mud pressure for the overlying soils. HDD industry standard construction practices, such as pumping sufficient drilling fluids, maintaining drilling fluid returns, monitoring and maintaining drilling fluid and returning slurry properties, etc., should reduce any potential loss of drilling fluids.

Figure 1: Calculated, Recommended, and Allowable Drilling Fluid Pressures



5 HDD Risk Discussions

5.1 HDD Risk Characterization

Risk identification and mitigation is paramount to successfully completing the Beltzville Lake Crossing. Discussions of the general risks associated with these crossings are presented below.

5.2 HDD Industry – State of Practice

Mott MacDonald maintains an up-to-date database of successfully completed HDD installations based on pipeline diameter and installation length, as shown in Table 10 below. This database is used to quickly and uniquely assess the achievable installation length for a given pipeline diameter. The green shaded cells indicate the common range of HDD industry experience/capability, and was established with the requirement that several contractors have successfully completed similar installation lengths at the specific diameter. The yellow shaded cells identify the installation lengths and diameters that are considered feasible with an experienced contractor in favorable ground conditions. The red shaded cells are considered to be at the limits of, or beyond, the current state-of-the-practice for the HDD industry.

Table 10: State of the HDD Industry

	Installation Length												
Product Pipe Diameter	1,000 m	1,200 m	1,400 m	1,600 m	1,800 m	2,000 m	2,200 m	2,400 m	2,600 m	2,800 m	3,000 m	3,500 m	3,750 m
	3,281 ft	3,937 ft	4,593 ft	5,249 ft	5,905 ft	6,562 ft	7,218 ft	7,874 ft	8,530 ft	9,186 ft	9,842 ft	11,483 ft	12,303 ft
200 mm (8 inch)	16	9	14	4	5	10	5	0	0	0	1	0	1
250 mm (10 inch)	9	9	4	11	1	0	3	1	0	0	0	0	0
300 mm (12 inch)	14	10	9	4	3	1	0	1	1	0	0	1	0
350 mm (14 inch)	3	5	3	0	1	0	0	0	0	0	0	0	0
400 mm (16 inch)	9	4	4	6	4	1	3	0	0	0	2	0	0
450 mm (18 inch)	0	0	0	2	0	0	0	0	0	0	0	0	1
500 mm (20 inch)	8	10	9	1	0	1	2	1	0	0	0	0	0
600 mm (24 inch)	29	30	9	12	9	4	1	2	0	0	1	0	0
750 mm (30 inch)	23	10	10	11	8	3	1	3	0	0	1	0	0
900 mm (36 inch)	23	21	21	6	2	1	2	0	1	0	0	0	0
1050 mm (42 inch)	29	21	11	5	1	1	0	0	0	0	0	0	0
1200 mm (48 inch)	1	2	1	0	0	0	0	0	0	0	0	0	0

Colour Coding:

- Within typical capabilities of industry. Multiple experienced contractors.
- Zone of limited industry application. Considered feasible with an experienced contractor and favourable ground conditions.
- Exceeds current capabilities of industry. Considered risky even with an experienced contractor and favourable ground conditions.

NOTE: Current State of the HDD Industry shown above is based solely on the reported installation lengths and diameters. Site-specific geotechnical and installation based risks have not been considered in developing this chart.

It is very important to note that the state of the HDD industry shown above includes crossings with similar elevations between HDD entry/exit locations and the crossing feature, good soils/bedrock materials, and adequate staging area for fabricating the pipe string. These completed projects mostly reflect those with low risk profiles (especially for larger and longer HDD installations). As such, when comparing a specific crossing to those completed projects within the HDD industry, the site-specific geotechnical and crossing risks need to be thoroughly considered and evaluated to verify the completed project listings are comparable and deemed to be adequate. If the current proposed crossing carries a low risk profile, then the comparison can serve as a guide to what has been successfully completed within the HDD industry. However, if the current proposed crossing carries a high risk profile, then the comparison to the completed projects may not be applicable.

As observed in Table 10, a few HDD installations have been successfully completed at or close to a diameter of NPS 36 for lengths longer than the horizontal installation length of approximately 6,094 feet, with a true pipe length of approximately 6,148 feet, required for the Beltzville Lake Crossing. Therefore, from a constructability standpoint, the Beltzville Lake Crossing falls within the zone of limited experience of what has been accomplished to date within the HDD industry.

5.3 Geotechnical Risk Discussions

Sands, silts, and clays typically present no significant challenge to an HDD installation. These materials are often described as good to excellent materials in terms of feasibility. However, when these soils exist in a soft or loose state, they may not provide sufficient strength to resist the required fluid pressures necessary to complete an HDD installation. Within these materials, the required drilling fluid pressures can exceed their strength, resulting in the formation of a hydraulic fracture through the overlying soils and ponding of drilling fluids at the ground surface. This risk can only be mitigated by placing the HDD bore within more favorable geotechnical materials that provide greater resistance to induced drilling fluid pressures, or through the use of conductor casings to provide an open pathway for drilling fluid flow.

Soils containing gravels and larger size particles (cobbles) range from marginally acceptable to unacceptable in terms of feasibility, depending upon the percentage of gravels by weight and particle size. Only those particles that can be suspended within the drilling fluid can be removed from the bore. Generally speaking, gravel-sized particles from approximately 0.5 to 0.75 inches can be removed from the bore, provided good HDD practices are followed. Particles greater in size typically cannot be suspended by the drilling fluid, and tend to settle out and accumulate along the bottom of the bore. The risks associated with accumulation of larger particles within the bore increase with greater bore diameter, due to the greater exposed soil materials in the crown of a larger bore.

To mitigate risks associated with the anticipated soils, temporary conductor casings have been incorporated into the design of the profile at each end of the installation.

Controlling and maintaining fluid flow within the bore is critical to the success of an HDD installation. Installation risks significantly increase when slurry circulation is not maintained within the HDD bore. The flow of drilling fluid follows the path of least resistance. As long as the bore is located within favorable geotechnical materials at a sufficient installation depth and properly drilled by the HDD contractor, a stable flow pathway can be created between the drill bit and the HDD entry or exit locations, and maintaining drilling fluid flow within the bore should not be an issue. As observed in the hydraulic fracture evaluation, loss of drilling fluids through the overlying soil is not anticipated for this crossing. However, as an added precautionary measure, emergency spill kits and turbidity curtains will be placed as shown in Appendix A.

The drill and intersect method was chosen to mitigate the risks associated with the geotechnical data provided during the investigation, such as drilling through gravel and decomposed rock fragments at the entry and exit points, and hydraulic fracture through the overburden materials above the alignment. However, drill and intersect method adds a level of complexity and technical proficiency to the drilling process. Mott MacDonald recommends that an intersection plan be discussed with the contractor and that they demonstrate that they are technically proficient using the drill and intersect method.

Bedrock can be highly variable and can be classified as being excellent to unacceptable with respect to HDD feasibility. Competent bedrock is well suited for HDD as the bore tends to remain open for extended periods of time. However, heavily weathered, jointed, fractured or fissured bedrock can present challenges with respect to bore stability. In fact, poor quality bedrock can present the same challenges as coarse granular (gravel) deposits where fracturing and jointing is extensive, and present an unacceptable risk in terms of constructability to an HDD installation. The risk associated with these materials arises from the inability to support and maintain stability within the bore.

This risk increases with RQD ratings below 60 percent. For the Beltzville Lake Crossing, the bedrock exhibits a wide range of ratings, with an average of 77.7 percent overall, and occasional isolated areas below 60 percent. The areas of lower rock quality are not anticipated to significantly increase risks associated with this installation.

The strength of the bedrock can impact construction duration, with higher strength leading to more frequent trips out of the bore to replace worn tooling. The laboratory tests completed to date on the shale bedrock indicate unconfined compressive strengths ranging from 2,526 to 13,030 psi, with an average value of 6,424 psi. The unconfined compressive strength of the slate bedrock ranged from 736 to 7,388 psi, with an average value of 3,118 psi.

High-angle fractures were frequently observed throughout the geotechnical borings, which increases the risk to bore stability, as the vertical and intersecting fracture planes will be less likely to bridge the crown of the bore and maintain an open annular space for fluid flow. Bore collapse that occurs during the pilot bore and reaming phases of the installation can lead to spikes in drilling fluid pressure, lost circulation and hydraulic fracture, increased force on the downhole tooling, decreased steering control, and loss or damage of downhole tooling. A swab pass is recommended to determine the condition of each bore prior to pullback operations. If areas of higher drill rig effort (torque or thrust/pullback) are experienced, the HDD Contractor should complete additional passes with a hole opener to clear the bore of any debris within the bore.

Preferential flow pathways may occur where heavily weathered, jointed, fractured or fissured bedrock exists. If interconnected, preferential flow pathways may exist for drilling fluid losses into the rock mass or upwards towards the ground surface. Fortunately, the presence of the drilling fluid slurry within the bore is often capable of sealing fractures and/or joints as drilling fluids migrate into these features, resulting in low potential for inadvertent returns of drilling fluids at the ground surface.

Based on the anticipated geotechnical materials, the HDD installation has been designed within favorable geotechnical materials to the extent possible.

5.4 Crossing-Specific Risk Discussions

The length of the pipe staging area for the proposed crossing is insufficient to fabricate the pipe into a single string prior to pullback operations, and intermediate welds will be required. Intermediate welds will require stoppage of pullback operations each time a new pipe segment is welded on. These stoppages represent a significant risk to the installation because the bore is required to remain open much longer than would be required for the installation of a single pipe string. Stoppages for the intermediate welds also provide downtime, while welding occurs, that allows the drilling fluids to “gel” and making it harder to resume pullback operations due to the increased friction between the gelled fluids and the pipe. Start-up loads will increase each time pullback operations are resumed. In some cases, the gel strength of the fluids is too great and the resulting loads lead to damage to the pipe, or the pipe may become stuck at its current position in the bore. This risk increases with each additional intermediate weld. Prior to pullback operations, a swab pass should be completed to gauge whether the bore has been conditioned to accept the pipe.

Areas of high torque and/or pull force should be re-reamed to lower the drill rig effort to pass tools through this portion of the bore. The pipe should be installed with the shortest sections of pipe first and the longest pipe section last to decrease the startup loads on the pipe required to resume drilling operations.

Artesian groundwater conditions were noted in Boring B-15 at a depth of approximately 128.5 feet below ground surface corresponding to an elevation of approximately 525.5 feet. The water pressure was measured at 64.2 psi by a pressure meter placed at a depth of 133 feet corresponding to a pressure head equivalent to an elevation of 699 feet (15 feet above the ground surface).

While artesian conditions can present challenges to an HDD installation associated with washing out any filter cake and degrading required drilling fluid properties, the drilling fluid pressure from the column of drilling fluid in the HDD bore is anticipated to be at least 81 psi at the depth in question. The higher mud pressure will exert a counterbalancing pressure against this artesian condition decreasing risks associated with the condition.

6 Summary

For the Beltzville Lake Crossing, geotechnical risks have been acknowledged, but no fatal deterrents have been identified within the alignment. Based on the required installation length and diameter, the HDD contracting community in North America has successfully completed a number of HDD installations of similar lengths.

While not anticipated, if an attempted HDD installation is unsuccessful, the proposed HDD alignment could be modified using the same HDD entry/exit locations to accommodate an additional HDD attempt, depending on the condition that resulted in the HDD failure. Prior to attempting a second HDD crossing, a risk mitigation workshop should be held with all parties to determine the cause of the initial failure and any mitigation measures that could be adopted to reduce the risk(s) during the second HDD attempt.

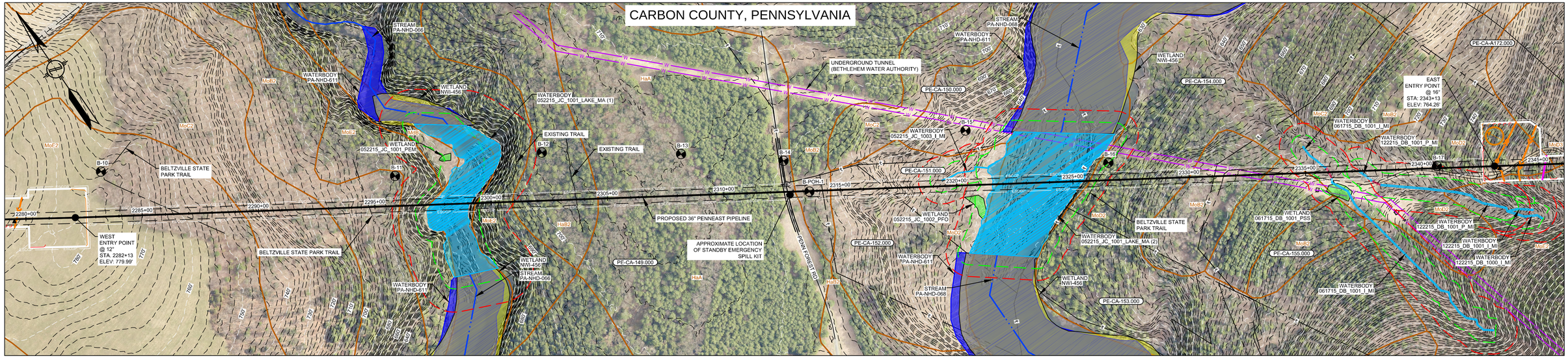
7 Limitations

This report is intended to be used in its entirety. The data, interpretations, conclusions, and recommendations contained within this report are provided for informational purposes for PennEast, and pertain specifically to the Beltzville Lake Crossing. The data and conclusions presented herein do not and should not be applied to any other project site or HDD installation. Interpretations of the subsurface conditions are based on the information obtained from the geotechnical borings. The subsurface conditions presented between the geotechnical borings are interpretations and may vary from the actual conditions encountered.

It is recommended that Mott MacDonald provide construction monitoring services to verify the subsurface conditions encountered during construction, provide field design services, and evaluate contractor performance in accordance with the contract and the approved contractor supplied work plan.

Appendix A

HDD Plan and Profile



POHOPOCO CREEK (BELTZVILLE LAKE)/ WILD CREEK HDD PLAN VIEW

SCALE: 1" = 200'

GRAPHIC SCALE

200' 100' 0' 200'

CROSSING SPECIFIC HDD NOTES:

1. ALL DIMENSIONS AND ELEVATIONS ARE IN FEET, UNLESS OTHERWISE SPECIFIED.
2. ALL CHAINAGES ARE HORIZONTAL.
3. CONTRACTOR SHALL DETERMINE FINAL LOCATIONS AND DIMENSIONS OF ALL MUD PITS NECESSARY TO ACCOMMODATE THEIR MEANS AND METHODS.
4. CONTRACTOR TO STAGE ALL PERSONNEL AND EQUIPMENT WITHIN THE PERMITTED LIMIT OF DISTURBANCE AS DEPICTED ON THIS DRAWING, UNLESS OTHERWISE AUTHORIZED BY THE CLIENT.
5. CONTRACTOR SHALL DETERMINE DIAMETER, GRADE, WALL THICKNESS AND ADDITIONAL LENGTH OF TEMPORARY CONDUCTOR CASINGS IF DEEMED NECESSARY BY THE CONTRACTOR. ANY INSTALLED TEMPORARY CONDUCTOR CASING SHALL BE FULLY REMOVED UPON COMPLETION OF PULLBACK OPERATIONS.
6. THE MINIMUM ALLOWABLE DRILLING RADIUS SHALL BE 2,600 FEET BASED ON A 3-JOINT AVERAGE.
7. EXISTING UTILITY LOCATIONS AND DEPTHS, INCLUDING PRIVATE SERVICES, ARE APPROXIMATE AND SHALL BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO ANY CONSTRUCTION OPERATIONS. PENNSYLVANIA LAW REQUIRES AT LEAST 48 HOURS AND NO MORE THAN TEN (10) WORKING DAYS NOTICE BEFORE EXCAVATION OR DEMOLITION.
8. HDD OPERATIONS SHALL BE CONDUCTED IN ACCORDANCE WITH ALL PERMIT REQUIREMENTS.
9. DOWNHOLE ANNULAR DRILLING FLUID PRESSURES SHALL BE MONITORED AT ALL TIMES DURING THE PILOT BORE DRILLING PROCESS. LOCATION OF MONITORING SHALL BE AS CLOSE TO THE DRILL BIT AS POSSIBLE.
10. HDD CONTRACTOR SHALL BE PREPARED TO PUMP A CEMENT GROUT DOWNHOLE TO HELP SEAL LARGE PREFERENTIAL FLOW PATHWAYS AND RESTORE DRILLING FLUID FLOW WITHIN THE HDD BORE IN THE EVENT HISTORIC MINE WORKINGS ARE ENCOUNTERED AND EXCESSIVE DRILLING FLUID LOSSES OCCUR.
11. PILOT BORE SHALL BE CONTINUOUSLY TRACKED AT ALL TIMES. CONTRACTOR SHALL USE A GYROSCOPIC GUIDANCE SYSTEM TO COMPLETE THE PILOT BORE INSTALLATION. NO BLIND SECTIONS SHALL BE PERMITTED, EVEN WHEN THE DRILL BIT IS UNDER WATER.
12. IF THE CONTRACTOR ENCOUNTERS AN OBSTRUCTION THAT PREVENTS THE INSTALLATION ACCORDING TO THE PROJECT SPECIFICATIONS, THE CONTRACTOR SHALL PLACE A CEMENT BASED GROUT WITHIN THE BORE. WORK SHALL NOT RESUME UNTIL REVISED PLANS AND PROCEDURES HAVE BEEN SUBMITTED TO AND ACCEPTED BY THE OWNER.
13. PILOT BORE DRILLING TOLERANCES SHALL BE AS FOLLOWS:

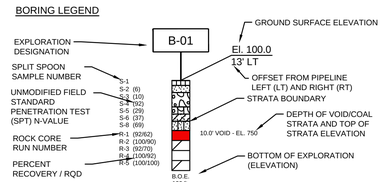
Item	Tolerance
Pilot entry angle	Increase angle up to 3° (steeper), but no decrease in angle allowed.
Pilot entry location	As staked by Owner. No changes without Owner approval.
Pilot exit angle	Decrease angle up to 2° (flatter), but no increases in exit angle allowed.
Pilot exit location	Up to ten (10) feet shorter or longer.
Pilot depth	Up to three (3) feet shallower depth allowed. Up to ten (10) feet increase in pipe design depth (deeper) allowed.
Pilot alignment	Up to ten (10) feet left or right of the Owner survey centerline but not within five (5) feet of the right-of-way/easement boundary or any below ground utility or structure.

14. CROSS SECTIONS PRESENTS SUMMARY BOREHOLE LOG GRAPHICS, SEE FULL BOREHOLE LOG FOR DETAILS.

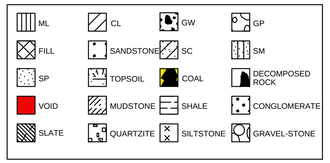
Wild Creek	Pohopoco Creek
10 year flow: 1870 cfs	10 year flow: 4470 cfs
Max stream depth: 15 feet	Max stream depth: 18 feet
Approximate cross section area: 1800 sq. ft.	Approximate cross section area: 3950 sq. ft.
Approximate linear flow rate: 1.04 fps	Approximate linear flow rate: 1.13 fps

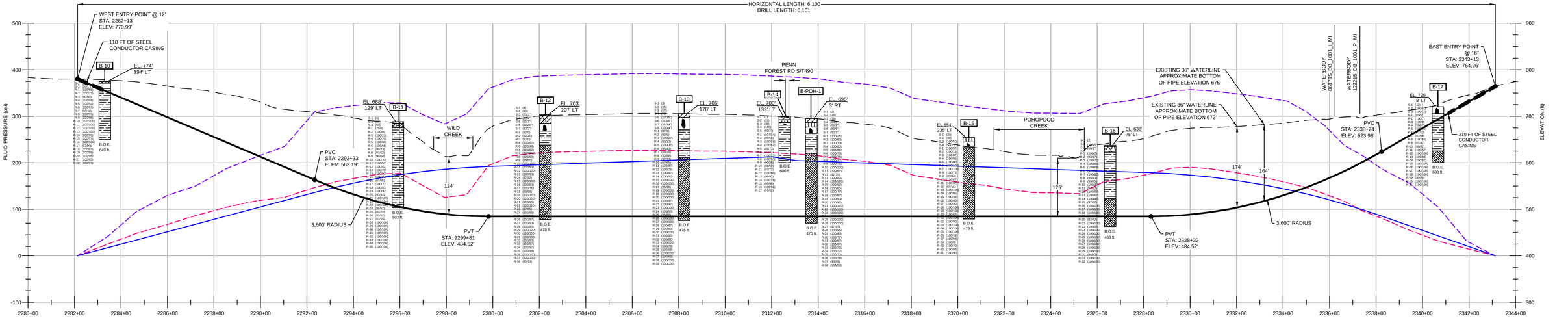
COMMONWEALTH OF PENNSYLVANIA — MICHAEL A. WILCOX — ENGINEER — 12/17/18

BORING LEGEND



SOIL AND ROCK STRATAGRAPHIC LEGEND:





REQUIRED DRILLING FLUID PRESSURE
RECOMMENDED MAXIMUM ALLOWABLE DRILLING FLUID PRESSURE
OVERBURDEN STRESS
HDD BORE PROFILE
GROUND SURFACE PROFILE

POHOPOCO CREEK (BELTZVILLE LAKE)/ WILD CREEK HDD PROFILE

HORIZONTAL SCALE: 1" = 200'

VERTICAL SCALE: 1" = 100'

GRAPHIC SCALE

HORIZ SCALE: 200' 100' 0' 200'

VERT SCALE: 100' 50' 0' 100'

NOTES:

1. THE CONTOURS AND IMAGERY SHOWN WERE PROVIDED BY PICTOMETRY, 2015. ADDITIONAL CONTOURS AND IMAGERY SUPPLEMENTED FROM PASDA.
2. EXISTING FEATURE SURVEYED PERFORMED BY MOTT MACDONALD 2015 THRU 2018. ADDITIONAL FEATURES DIGITIZED FROM IMAGERY. ALL LOCATIONS ARE APPROXIMATE AND SHALL BE VERIFIED BY CONTRACTOR.
3. PROPERTY LINES DEPICTED ON THIS PLAN ARE BASED ON GIS TAX MAP DATA AND RECTIFIED PROPERTY LINES AND ARE NOT THE RESULT OF A BOUNDARY SURVEY.
4. WATERBODY INFORMATION PROVIDED BY AECOM 2015 THRU 2018.

REFERENCE DRAWINGS

DWG. NO.	TITLE
000-03-01-087	ALIGNMENT SHEET
000-03-01-088	ALIGNMENT SHEET
000-03-01-089	ALIGNMENT SHEET

REVISIONS

	REVISIONS	DATE	DRAWN	CK	APPR
A	ISSUED FOR PADEP	10/2018	JL (MM)	AJD (MM)	MJD (MM)

APPROVALS

DRAWN BY	DATE
RJP (MM)	10/15/2018
CHECKED BY	DATE
CAF (MM)	10/15/2018
ENG. APPROVAL	DATE
MDN (MM)	10/15/2018
P.M. APPROVAL	DATE
MAW (MM)	10/15/2018

CLIENT APPROVAL

DATE

PREPARED FOR

PennEast PIPELINE

PENNEAST PIPELINE PROJECT

SOIL EROSION AND SEDIMENT CONTROL PLAN
PROPOSED 36" PIPELINE
HDD EXHIBIT PLAN AND PROFILE
POHOPOCO CREEK (BELTZVILLE LAKE)
WILD CREEK HDD
CARBON COUNTY, PENNSYLVANIA

SCALE	DRAWING NO.	REVISION
AS SHOWN	000-03-07-002	A

G:\PENNEAST\353754_PENNEAST_PIPELINE_EPCM\DATA\PROD_STATE_PERMIT\WORK\PAD\RAFT\NC\EROSION_SEDIMENT_CONTROL_PLAN\HDD_DETAILS\000-03-07-002.DWG DJM64749

Appendix B

Geotechnical Boring Logs

MOTT MACDONALD

SOIL/ROCK BORING LOG LEGEND

USCS Group Symbol

UNIFIED SOIL CLASSIFICATION SYSTEM AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			FINE-GRAINED SOILS (more than 50% of material is smaller than No. 200 sieve size.)		
Gravels More than 50% of coarse fraction larger than N.4 sieve size	Clean Gravels (Less than 5% fines)		**SILTS AND CLAYS** Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey of clayey fine sands or clayey silts with slight plasticity
	GW	Well-graded gravels, gravel-sand mixtures, little or no fines		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines		OL	Organic silts and organic silty clays of low plasticity
	Gravels with fines (more than 12% fines)		**SILTS AND CLAYS** Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	GM	Silty gravels, gravel-sand-silt mixtures		CH	Inorganic clays of high plasticity, fats clays
	GC	Clayey gravels, gravel-sand-clay mixtures		OH	Organic clays of medium to high plasticity, organic silts
Sands More than 50% of coarse fraction larger than N.4 sieve size	Clean Sands (Less than 5% fines)		**HIGHLY ORGANIC SOILS**	PT	Peat and other highly organic soils
	SW	Well-graded sands, gravelly sands, little or no fines	Determine percentages of sand and Gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:		
	SP	Poorly-graded sands, gravelly sands, little or no fines			
	Sands with fines (More than 12% fines)				
	SM	Silty sands, sand-silt mixtures	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		
	SC	Clayey sands, sand-clay mixtures			

Minor Components

Description	Criteria
20 – 30%	some
10 – 20%	little
1 – 10%	trace

Infilling

Description	Symbol
Clay	CL
Silt	ML
Sand	SD
Calcite	CA
Carbonate	C
Dolomite	DO
Gypsum/Tale	GY
Hematite	HE
Limonite	L
Quartz	QZ
Chlorite	CH
Pyrite	PY
Iron Oxide Staining	FE
Stylolite	ST
Not Determined	X
None	N
Healed	H

Weathering of Rock Mass

Description	Symbol	Criteria	Grade
Fresh (Unweathered)	FR	No visible sign of rock material weathering, except slight discoloration on major discontinuity surfaces.	I
Slightly Weathered	SL	Discoloration indicates weathering of rock material and discontinuity surfaces. All rock material may be discolored by weathering and may be somewhat weaker than externally than in its fresh condition.	II
Moderately Weathered	M	Less than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as a continuous framework or as corestones.	III
Highly Weathered	H	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones.	IV
Completely Weathered	C	All rock material is decomposed and/or disintegrated to soil. The original mass structure remains largely intact.	V
Residual Soil	RS	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

Discontinuity Spacing

Description	Symbol	Spacing (in.)
Extremely Close	EC	< 0.75
Very Close	VC	0.75 – 2.5
Close	C	2.5 – 8.0
Moderate	M	8 – 24
Wide	W	24 – 80
Very Wide	VW	80 – 240
Extremely Wide	EW	> 240

Spacing Type

Description	Symbol	Spacing (in.)
Joint	J	A natural fracture along which no displacement has occurred. May occur in parallel groups called sets.
Shear	S	A natural fracture along which differential movement has occurred. May be slickensided or striated.
Fault	F	A natural fracture along which displacement has occurred. Usually lined with gouge and slickensides.
Vein	V	A thin, sheet-like igneous intrusion into a fissure.
Bedding Joint	B	Joints that occur along bedding planes.
Foliation Joint	FJ	Joints that occur parallel to the foliation of a rock mass.
Shear Zone	SZ	Zone of fractured rock and gouge bordering the displacement plane.

Field Strength

Description	Criteria	Grade	Approx. Range of Uniaxial Compressive Strength (psi)
Extremely Weak	Indented by thumbnail.	R0	40 – 150
Very Weak	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife.	R1	150 – 700
Weak	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer.	R2	700 – 4,000
Medium Strong	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of geological hammer.	R3	4,000 – 7,000
Strong	Specimen requires more than one blow of geological hammer to fracture it.	R4	7,000 – 15,000
Very Strong	Specimen requires many blows of geological hammer to fracture it.	R5	15,000 – 36,000
Extremely Strong	Specimen can only be chipped with geological hammer.	R6	>36,000

Roughness

Intermediate Scale	Symbol	Small Scale	Symbol
Stepped	S	Rough	R
Undulating	U	Smooth	Sm
Planar	P	Slickensided	K
Not Determined	X	Wavy	Wa
		Not Determined	X

Weathering/Alteration of Discontinuity Surfaces

Description	Symbol	Criteria
Fresh	FR	No visible sign of weathering on the rock discontinuity surfaces.
Discolored	DS	Discoloration of rock material discontinuity surfaces. Degree of discoloration and specific discolored mineral constituents (if applicable) indicated.
Disintegrated	DG	Discontinuity surface rock material is weathered to a soil with the rock material fabric intact. Rock material is friable, but the mineral grains are not decomposed.
Decomposed	DE	Discontinuity surface rock material is weathered to a soil with the rock material fabric intact and with some or all mineral grains decomposed.

Aperture

Description	Symbol	Aperture (in.)	
Very Tight	VT	< 0.004	"Closed" Features
Tight*	T	0.004 – 0.010	
Partly Open	PO	0.01 – 0.02	
Open**	O	0.02 – 0.10	"Gapped" Features
Moderately Wide	MW	0.1 – 0.4	
Wide	W	> 0.4	
Very Wide	VW	0.4 – 4.0	"Open" Features
Extremely Wide	EW	4.0 – 40.0	
Cavernous	CA	> 40	

MOTT MACDONALD

BOREHOLE LOG GRAPHIC LEGEND

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Delaware River Crossing, NJ/ PA	**Project Manager:**	Vatsal Shah
Client:	PennEast Pipeline	**Project Director:**	Michael Wilcox

Soil Log Graphic Legend


CH: USCS High Plasticity Clay


CL: USCS Low Plasticity Clay


CL-ML: USCS Low Plasticity Silty Clay


DECOMPOSED ROCK: Decomposed Rock


DOLOMITE: Dolomite


FILL: Miscellaneous and Manmade Fill


GM: USCS Silty Gravel


GP: USCS Poorly-graded Gravel


GP-GM: USCS Poorly-graded Gravel with Silt


GRAVEL-STONE: Gravel or Crushed Stone


ML: USCS Silt


QUARTZITE: Quartz and Quartzite


SC: USCS Sandy Clay to Clayey Sand


SM: USCS Silty Sand


SP: USCS Poorly-graded Sand


SP-SM: USCS Poorly-graded Sand with Silt


SW-SM: USCS Well-graded Sand with Silt


TOPSOIL: Topsoil


VOID: Underground Void

Rock Log Graphic Legend


DOLEMITE - OBSELETE: USE DOLOMITE


DOLOMITE - Dolomite


GNEISS - Gneiss


LIMESTONE - Limestone


SILTSTONE - Siltstone

▽ Ground Water Level
(Note that due to drilling process disturbance the ground water levels obtained during drilling are not as representative as those obtained from monitoring wells)

This legend reports all soil and rock graphics which have been used in the logs of this project only.

MOTT MACDONALD

SOIL BORING LOG

BORING NO.: **B-10**
Page **1** of **1**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Rhan Flatin
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	July 7, 2015 at 8:00 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	July 8, 2015 at 2:00 pm

Elevation: 774 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off DCNR trail. **Coord.:** **N:** 40.889053 **E:** -75.565341 **Horizontal Datum:** NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	5	2	5
Inside Dia. (in.)	4	1.375	2.0
Hammer Wt. (lb.)	140	140	-
Hammer Fall (in.)	30	30	-

Rig Make & Model: CME-750X

☐ Truck ☐ Tripod ☐ Cat-Head
☑ ATV ☐ Geoprobe ☑ Winch
☐ Track ☐ Air Track ☑ Roller Bit
☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut ☑ Automatic ☐ _____

Drilling Fluid: ☐ Bentonite ☐ Polymer ☑ Water ☐ None

Drill Rod Size:

Casing Advance: Mud Rotary

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Group Symbol	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks
	S-1 0.0'- 2.0'	14	2 2 3 4		GC	0.2 2" TOPSOIL Loose, Clayey GRAVEL (GC)	-	-	-	-	
						3.5 No Recovery					
770 5	S-2 5.0'- 7.0'	15	23 41 55 59				-	-	-	-	Possible Gravel.
10	S-3 10.0'- 12.0'	0	50/2"			No Recovery	-	-	-	-	Possible Gravel.
760 15						15.0 Top of Rock at 15 feet BGS. See Rock Coring Log.					

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water

Sample Type

O Open End Rod
T Thin-Wall Tube
U Undisturbed Sample
S Split Spoon Sample
G Geoprobe

Notes:

PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-10**

Field Test Legend:
Dilatancy: N - None S - Slow R - Rapid
Toughness: L - Low M - Medium H - High
Plasticity: NP - Non-Plastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Medium H - High VH - Very High

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD

CORE BORING LOG

BORING NO.: **B-10**
Page **1** of **5**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Rhan Flatin
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	July 7, 2015 at 8:00 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	July 8, 2015 at 2:00 pm

Elevation: 774 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off DCNR trail. **Coord.: N:** 40.889053 **E:** -75.565341

Item	Casing	Core Barrel	Core Bit
Type	HW	NQ2	Imp. Diamond
Length (ft)	5	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Horizontal Datum: NAD 1983 **Rig Make & Model:** CME-750X **Drilling Method:** Wireline

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec (in. / %)	RQD (in / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
									SEE TEST BORING LOG FOR OVERBURDEN DETAILS		(See Legend for Rock Description System)						
	2.00	15.0							SHALE, dark gray, fine grain, slightly weathered, weak, extremely close to close spaced discontinuities with iron stains, vuggy spots	15.18	J	20	S,R	DS	T	N	Several small vugs with fossil impressions. Less than 5% core light brown Shale.
	1.50																
	1.75		R-1	60 100%	35 58%	R2	SL			16.85	J	40	S,R	DS	PO	CL	
										17.58	J	30	U,Sm	FR	T	N	
	1.75									17.90	J	40	S,Sm	DS	T	N	
	2.00	20.0															
20	1.50	20.0							SHALE, dark gray, very fine grain, slightly weathered, weak, extremely close to close spaced discontinuities								Has fossil vugs. 10% light brown Shale.
	1.00								21.45' - 22.1' Highly weathered zone	21.20	J	55	S,R	FR	T	N	
	1.50		R-2	60 100%	20 33%	R2	SL			22.63	J	35	S,R	DS	T	CL	
										23.00	J	60	S,R	DS	PO	CL	
	1.50									23.25	J	26	U,Sm	DS	T	N	
750	2.00	25.0															
25	2.50	25.0							SHALE, dark gray, very fine grain, slightly weathered, weak, extremely close to close spaced discontinuities, vuggy spots								10% light brown Shale.
										25.65	J	70	U,Sm	DS	PO	N	
	2.50									26.25	J	40	U,Sm	DS	T	CL	
	3.25		R-3	54 90%	30 50%	R2	SL			27.10	J	10	S,R	DS	T	CL	
										27.63	J	52	U,Sm	DS	T	CL	
										28.10	J	55	S,Sm	DS	PO	CL	
	3.00									28.60	J	50	S,R	DS	PO	CL	
	2.75	30.0															
30	2.00	30.0							SHALE, dark gray, very fine grain, slightly weathered, weak, extremely close to moderately spaced discontinuities, vuggy spots								45% light brown Shale.
										30.53	J	18	U,Sm	DS	T	CL	
										30.80	J	32	P,Sm	DS	PO	CL	
	1.25									31.72	J	25	S,R	DS	T	N	
	2.50		R-4	60 100%	29 48%	R2	SL			32.45	J	10	P,Sm	DS	PO	N	
	2.25									33.25	J	65	U,Sm	DS	PO	CL	
										33.50	J	55	S,R	DS	PO	CL	
740	2.50	35.0								34.70	J	60	S,R	DS	PO	N	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
		-			

Notes:

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	0.25	35.0							SHALE, dark gray, very fine grain, slightly weathered, weak, extremely close to close spaced discontinuities 35' - 35.5' Highly fractured zone								50% light brown Clay. Vugs continue.
	2.00																
	2.00		R-5	60 100%	32 53%	R2	SL			37.00 37.45	J J	41 15	U,Sm P,Sm	DS DS	T PO	CL CL	
	2.25									38.60	J	20	U,Sm	DS	T	Ca	
	2.25	40.0							39' - 40' Highly fractured zone								
40	1.75	40.0							SHALE, dark gray, very fine grain, slightly weathered, weak, extremely close to moderately spaced discontinuities								10% light brown Clay. Pyrite on core.
	1.50									41.10 41.30	J J	17 70	U,R U,R	DS DS	T T	Fe Fe	
	2.25		R-6	60 100%	40 67%	R2	SL			41.65 41.80	J J	65 50	U,R S,R	DS DS	T T	Fe N	
	1.75									43.30	J	48	S,R	DS	T	Fe	
730										43.83	J	13	P,Sm	DS	T	N	
	2.00	45.0								44.27 44.60	J J	16 75	U,R S,R	FR FR	T T	Ca Py	
45	1.50	45.0							SHALE, dark gray, very fine grain, slightly weathered, weak, extremely close to moderately spaced discontinuities	45.43 45.75	J J	35 55	S,R U,Sm	DS DS	T T	Fe Fe	Less than 5% light brown Clay. Pyrite on core.
	1.25									46.28 46.65	J J	15 15	S,R U,R	DS DS	T PO	Fe CL	
	2.00		R-7	59 98%	25 42%	R2	SL			48.00	J	30	S,R	FR	T	Py	
	2.25									48.80	J	80	S,R	DS	PO	CL	
	1.75	50.0															
50	1.25	50.0							SHALE, dark gray, very fine grain, slightly weathered, medium strong, extremely close to moderately spaced disconinuities	50.23 50.77	J J	40 40	S,R P,R	FR DS	T T	Py Fe	Pyrite on core.
	1.50								51.5' - 51.75' Moderately weathered SHALE with 20% Clay	51.17 51.73	J J	10 30	U,Sm U,R	DS DG	PO PO	CL CL	
	2.00		R-8	60 100%	44 73%	R3	SL			52.15	J	42	P,Sm	DS	T	Py	
	1.25									53.43 53.77	J J	18 38	U,Sm S,R	DS DS	PO PO	CL CL	
720	1.75	55.0								54.23 54.63	J J	33 15	S,R U,R	DS FR	PO T	CL N	
55	1.75	55.0							SHALE, dark gray, very fine gain, fresh, very strong, very close to moderately spaced discontinuities	55.40	J	30	U,Sm	DS	T	N	No water return after 55 feet.
	1.25									56.05	J	22	U,R	DS	PO	CL	
	1.75		R-9	60 100%	59 98%	R5	FR										
	1.50																
	1.25	60.0								59.45 59.55	J J	15 20	U,R U,Sm	DS DS	T T	CL N	
60		60.0															

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	1.25									60.50	J	53	P,Sm	FR	T	Ca	
	1.25								SHALE, dark gray, very fine grain, fresh, very strong, close to moderately spaced discontinuities	61.55	J	35	U,Sm	FR	T	Py	Pyrite on core (<1% surface).
	1.50		R-10	60 100%	60 100%	R5	FR			62.30	J	30	P,Sm	FR	T	Py	
	1.75									63.50	J	35	P,Sm	FR	T	N	
710	1.50	65.0								64.50	J	45	U,Sm	DS	T	CL	
65	1.50	65.0							SHALE, dark gray, very fine grain, fresh, very strong, moderately to wide spaced discontinuities	65.30	J	37	U,Sm	FR	PO	Ca	
	1.25																
	1.50		R-11	60 100%	60 100%	R5	FR			67.85	J	55	U,Sm	FR	T	Py	
	1.75																
	1.75	70.0															
70	1.25	70.0							SHALE, dark gray, very fine grain, fresh, very strong, very close to wide spaced discontinuities	70.55	J	30	P,Sm	FR	PO	Ca	
	1.75																
	1.50		R-12	60 100%	60 100%	R5	FR			73.15	J	20	U,Sm	DS	PO	N	
	2.50									73.40	J	60	U,Sm	FR	T	Ca	
700										73.55	J	30	U,Sm	DS	T	N	
	2.25	75.0								74.00	J	25	S,R	FR	PO	Ca	
75	2.50	75.0							SHALE, dark gray, very fine grain, fresh, very strong, close to wide spaced discontinuities	75.50	J	47	P,Sm	FR	T	Ca	Used up to 2,000 Gallons.
	2.00																
	1.50		R-13	60 100%	60 100%	R5	FR			76.80	J	40	P,Sm	FR	T	Ca	
	1.75																
	1.50	80.0															
80	1.50	80.0							SHALE, dark gray, very fine grain, fresh, very strong, moderately to wide spaced discontinuities								Used up to 300 Gallons for R13/R14.
	1.00																
	1.00		R-14	60 100%	56 93%	R5	FR			82.25	J	10	U,Sm	DS	T	Ca	
	1.00									82.45	J	18	U,Sm	DS	T	Ca	
690	1.25	85.0															
85	0.75	85.0							SHALE, dark gray, very fine grain, fresh, very strong, close to wide spaced discontinuities	85.55	J	52	S,R	DS	PO	N	Used up to 300 Gallons for R15/R16.

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	1.50																
	1.00		R-15	60 100%	58 97%	R5	FR			87.75	J	85	S,R	DS	PO	N	
	1.25																
	1.25	90.0															
90																	
	0.75	90.0							SHALE, dark gray, very fine grain, fresh, very strong, close to wide spaced discontinuities	90.50	J	23	U,R	FR	T	N	
	1.00																
	1.00		R-16	60 100%	60 100%	R5	FR										
	1.00																
680																	
	1.00	95.0															
95																	
	1.00	95.0							SHALE, dark gray, very fine grain, fresh, very strong, very close to wide spaced discontinuities								Used up to 300 Gallons for R17/R18 (1/2).
	1.25																
	1.00		R-17	58 97%	54 90%	R5	FR			97.55	J	45	U,Sm	FR	T	Py	
										97.65	J	35	U,R	DS	T	Ca	
	1.25									98.20	J	48	U,R	FR	T	Ca	
	1.00	100.0															
100																	
	1.00	100.0							SHALE, dark gray, very fine grain, fresh, very strong, extremely close to moderately spaced discontinuities								Used up to 300 Gallons for R18 (1/2) /R19.
	1.00									100.62	J	35	U,R	FR	T	Ca	
	1.00		R-18	60 100%	55 92%	R5	FR			102.00	J	8	P,R	DS	T	Ca	
	1.00																
670										103.80	J	65	U,Sm	DS	PO	N	
	1.25	105.0								104.00	J	30	S,Sm	DS	T	N	
105																	
	1.00	105.0								105.80	J	5	U,Sm	DS	PO	N	
	1.00									106.57	J	25	U,Sm	DS	T	N	
	1.00		R-19	60 100%	57 95%	R5	FR										
	1.00									107.90	J	8	S,Sm	DS	PO	Ca	
	1.00	110.0															
110																	
	1.50	110.0							SHALE, dark gray, very fine grain, fresh, very strong, moderately to wide spaced discontinuities								Used up to 300 Gallons for R20/R21/R22.
	1.00																

MOTT MACDONALD

CORE BORING LOG
(continued)

BORING NO.: **B-10**
Page **5** of **5**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	1.00																
	1.00		R-20	60 100%	57 95%	R5	FR										
	1.25																
660	1.25	115.0								113.97	J	10	U,R	FR	T	Py	
115	1.00	115.0							SHALE, dark gray, very fine grained, fresh, very strong, close to wide spaced discontinuities	115.38	J	33	S,R	FR	T	Py	
	1.00																
	1.00		R-21	60 100%	56 93%	R5	FR										
	1.00																
	1.50	120.0															
120	1.00	120.0							SHALE, dark gray, very fine grain, fresh, very strong, extremely close to wide spaced discontinuities								
	1.00																
										121.71	J	50	S,Sm	FR	T	Py	
	1.00		R-22	60 100%	58 97%	R5	FR			122.10	J	34	U,Sm	FR	T	Py	
	1.00																
650	1.25	125.0															
125									125.0 End of Boring at 125 feet BGS. Borehole grouted with cement and bentonite hole plug.								Note: Water level in hole at 34.6 feet according to driller's measurement.
130																	
640																	
135																	

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-10**

Figure B-10.1
B-10 Box 1 Runs 1-4 Dry

Figure B-10.2
B-10 Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-10

Figure B-10.3
B-10 Box 2 Runs 5-8 Dry

Figure B-10.4
B-10 Box 2 Runs 5-8 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-10

Figure B-10.5
B-10 Box 4 Runs 13-16 Wet (Left side)

Figure B-10.6
B-10 Box 4 Runs 13-16 Wet (Right side)

MOTT MACDONALD	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-10

Figure B-10.7
B-10 Box 6 Runs 21-22 Dry

Figure B-10.8
B-10 Box 6 Runs 21-22 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-10

MOTT MACDONALD

SOIL BORING LOG

BORING NO.: **B-11**
Page **1** of **1**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Rhan Flatin
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	July 9, 2015 at 7:00 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	July 13, 2015 at 3:30 pm

Elevation: 688 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off DCNR trail. **Coord.:** **N:** 40.887232 **E:** -75.561533 **Horizontal Datum:** NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	5	2	5
Inside Dia. (in.)	4	1.375	2.0
Hammer Wt. (lb.)	140	140	-
Hammer Fall (in.)	30	30	-

Rig Make & Model: CME-750X

☐ Truck ☐ Tripod ☐ Cat-Head
☑ ATV ☐ Geoprobe ☑ Winch
☐ Track ☐ Air Track ☑ Roller Bit
☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type
☐ Safety
☐ Doughnut
☑ Automatic
☐ _____

Drilling Fluid
☐ Bentonite
☑ Polymer
☑ Water
☐ None

Drill Rod Size:
Casing Advance
Mud Rotary

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Group Symbol	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks
	S-1 0.0'- 2.0'	2	1/12" 3 3		GP	0.1 Topsoil Loose, Fine GRAVEL (GP)	-	-	-	-	
						3.5					
5 680	S-2 5.0'- 7.0'	15	44 45 42 32		GC	Very dense, GRAVEL with Clay, trace Sand (GC)	-	-	-	-	
10	S-3 10.0'- 12.0'	15	21 21 72 74		GC	Very dense, GRAVEL with Clay (GC)	-	-	-	-	
						13.0 Top of Rock at 13 feet BGS. See Rock Coring Log.					
15 670											

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water

Sample Type

O Open End Rod
T Thin-Wall Tube
U Undisturbed Sample
S Split Spoon Sample
G Geoprobe

Notes:
PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-11**

Field Test Legend:
Dilatancy: N - None S - Slow R - Rapid
Toughness: L - Low M - Medium H - High
Plasticity: NP - Non-Plastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Medium H - High VH - Very High

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

CORE BORING LOG

BORING NO.: **B-11**
Page **1** of **7**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Rhan Flatin
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	July 9, 2015 at 7:00 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	July 13, 2015 at 3:30 pm

Elevation: 688 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off DCNR trail. **Coord.: N:** 40.887232 **E:** -75.561533

Item	Casing	Core Barrel	Core Bit
Type	HW	NQ2	Imp. Diamond
Length (ft)	5	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Horizontal Datum: NAD 1983 **Rig Make & Model:** CME-750X **Drilling Method:** Wireline

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec (in. / %)	RQD (in / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
									SEE TEST BORING LOG FOR OVERBURDEN DETAILS		(See Legend for Rock Description System)						
		13.0							13' - 15' SHALE fragments with Clay, Dark gray, very fine grain, slightly weathered, extremely close to close spaced discontinuities Largest core pieces 3.5"								No joints.
			R-1	18 75%	0 0%	R2	SL										
		15.0															
15		15.0							SHALE with Clay, Dark gray, very fine grain, slightly weathered, weak, extremely close to close spaced discontinuities								No joints.
	1.50																
	1.50																
	2.00		R-2	60 100%	0 0%	R2	SL										
670	1.75																
	2.75	20.0															
20	1.75	20.0							SHALE with Clay, Dark gray, very fine grain, slightly weathered, weak, extremely close to close spaced discontinuities								
	1.50																
	1.50									21.63	J	30	P,Sm	DS	T	CL	
			R-3	60 100%	15 25%	R2	SL										
	1.25									22.80	J	12	S,R	DS	PO	N	
	1.25									23.95	J	40	P,Sm	DS	PO	CL	
										24.12	J	37	S,R	DS	T	Fe	
										24.33	J	33	P,Sm	DS	T	Fe	
		25.0								24.65	J	44	P,Sm	DS	T	Fe	
25	1.50	25.0							SHALE wih Clay, Dark gray, very fine grain, slighly weathered, weak, extremely close to close spaced discontinuities								
	1.50																
	1.50		R-4	60 100%	42 70%	R2	SL			27.50	J	40	P,Sm	DS	T	Fe	
660	1.75																
	1.75	30.0															
30	2.25	30.0							SHALE with Clay, Dark gray, very fine grain, slightly weathered, weak, extremely close to close spaced discontinuities	30.35	J	34	S,Sm	FR	T	N	
	1.75									31.65	J	25	P,Sm	DS	PO	CL	
										32.01	J	20	S,R	FR	T	N	
	1.50		R-5	60 100%	36 60%	R2	SL			32.50	J	35	P,R	FR	T	N	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
		-			

Notes:

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	1.75									33.33	J	26	P,Sm	DS	T	CL	
	1.75	35.0								34.45	J	28	S,R	FR	T	N	
35	1.50	35.0							SHALE with Clay, Dark gray, very fine grain, slightly weathered, weak, very close to moderately spaced discontinuities	34.93	J	10	S,R	DS	T	CL	
	1.75									35.80	J	70	S,R	DS	T	CL	
	2.00		R-6	60 100%	39 65%	R2	SL			36.60	J	18	S,R	DS	PO	CL	
650	2.00									37.75	J	30	U,Sm	DS	T	CL	
	2.00	40.0								38.30	J	84	U,Sm	DS	T	Fe	
40	1.75	40.0							SHALE, Dark gray, very fine grain, slightly weathered, weak, very close to moderately spaced discontinuities	39.67	J	15	P,Sm	DS	T	CL	
	1.50									41.35	J	50	S,R	DS	PO	CL	
	1.75		R-7	59 98%	44 73%	R2	SL			41.75	J	45	U,Sm	DS	T	CL	
	1.75									42.50	J	30	S,R	DS	T	N	
	1.75	45.0								43.33 43.40 43.77 44.05	J J J J	30 70 30 36	S,R U,R U,Sm P,Sm	DG DS DS DS	PO T PO PO	CL CL N CL	
45	1.50	45.0							SHALE, Dark gray, very fine grain, slightly weathered, medium strong, very close to moderately spaced discontinuities								Used up to 300 Gallons.
	1.75																
	1.50		R-8	58 97%	37 62%	R3	SL			47.05	J	35	S,R	DS	PO	CL	
640	1.75									47.80	J	45	U,Sm	DG	PO	CL	
	1.75	50.0								48.60 49.25 49.75	J J J	60 35 35 67	U,R S,R S,R S,R	DS DS DS DS	T T T T	Fe N N CL	
50	1.75	50.0							SHALE, Dark gray, very fine grain, slightly weathered, weak, extremely close to moderately spaced discontinuities	50.80	J	33	S,R	DS	PO	N	
	1.25									51.25	J	48	S,R	DS	PO	CL	
	1.50		R-9	59 98%	36 60%	R2	SL										
	1.25									53.35	J	40	S,R	DS	PO	N	
		55.0								54.15 54.50	J J	48 20	U,R S,R	DS DS	T PO	CL CL	
55	1.50	55.0							SHALE, Dark gray, very fine grain, slightly weathered, strong, extremely close to moderately spaced discontinuities	55.45	J	43	U,Sm	DS	T	CL	
	1.25									56.26	J	45	U,Sm	DS	T	CL	
	1.25		R-10	60 100%	42 70%	R4	SL			57.00	J	34	U,Sm	DS	PO	CL	
630	2.25									57.87	J	42	U,Sm	DS	T	N	

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.25																
	1.50	60.0								59.20	J	60	S,R	DS	T	Fe	
										59.76	J	52	U,Sm	DS	T	N	
60	1.50	60.0							SHALE, Dark gray, very fine grain, fresh, strong, extremely close to moderately spaced discontinuities	60.35	J	32	P,Sm	DS	T	CL	
	1.25									61.35	J	70	S,Sm	DS	T	CL	
	1.50		R-11	60 100%	34 57%	R4	FR										
	1.75									63.30	J	35	S,Sm	DG	PO	CL	
										63.65	J	42	S,R	DS	PO	CL	
	1.75	65.0								64.00	J	60	U,Sm	DS	PO	CL	
										64.65	J	45	U,Sm	DS	PO	CL	
65	1.50	65.0							SHALE, Dark gray, very fine grain, fresh, medium strong, extremely close to moderately spaced discontinuities	65.50	J	52	U,Sm	FR	T	Ca	
	1.75									66.00	J	68	U,Sm	DS	T	Ca	
										66.60	J	74	U,R	DS	T	CL	
	1.50		R-12	60 100%	37 62%	R3	FR			67.25	J	5	S,R	DS	PO	CL	
620										67.80	J	28	P,Sm	DG	PO	CL	Used up to 300 Gallons.
	1.75																
	1.75	70.0								69.50	J	85	U,R	FR	T	Ca	
70		70.0							SHALE, Dark gray, very fine grain, fresh, strong, close to moderately spaced discontinuities								
	1.25									70.65	J	30	U,R	DS	PO	CL	
										70.90	J	39	P,R	DS	T	Fe	
	1.50									71.75	J	8	S,Sm	DS	T	N	
	2.00		R-13	60 100%	42 70%	R4	FR										
										72.85	J	36	P,Sm	DS	PO	N	
	1.50									73.33	J	33	P,Sm	FR	T	N	
										73.80	J	37	P,Sm	DS	T	N	
	1.50	75.0								74.60	J	70	U,Sm	DS	T	Fe	
75		75.0							SHALE, Dark gray, very fine grain, fresh, strong, close to moderately spaced discontinuities								
	1.25									75.73	J	40	P,Sm	DS	PO	Fe	
	1.75									76.53	J	36	P,Sm	DS	T	CL	
										76.85	J	35	P,Sm	DS	PO	CL	
	1.50		R-14	60 100%	55 92%	R4	FR			77.64	J	35	P,Sm	DS	T	CL	
610										78.03	J	35	P,Sm	DS	PO	CL	
	1.75									78.55	J	38	U,Sm	DS	T	N	
										78.82	J	62	U,Sm	FR	PO	N	
	1.50	80.0								79.19	J	36	P,Sm	DS	T	CL	
80		80.0							SHALE, Dark gray, very fine grain, fresh, strong, close to moderately spaced discontinuities								
	1.25									80.60	J	35	P,Sm	DS	T	N	
	1.50									81.40	J	35	P,Sm	DS	T	N	
	1.75		R-15	60 100%	50 83%	R4	FR		82.1' - 82.25' Shale fragments with Clay, highly weathered zone								
										82.87	J	35	U,Sm	DS	PO	N	
	1.50									83.38	J	37	P,Sm	DS	T	N	

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	1.45	85.0															
85		85.0							SHALE, Dark gray, very fine grain, fresh, strong, close to moderately spaced discontinuities								
	1.75									85.45	J	40	P,Sm	DS	PO	N	
										85.70	J	35	P,Sm	DS	PO	N	
	1.50																
										86.75	J	32	U,Sm	DS	T	N	
	1.75		R-16	58 97%	51 85%	R4	FR										
600																	
	1.50									88.38	J	27	U,Sm	FR	T	N	
										88.85	J	20	U,Sm	DS	PO	N	
	1.50	90.0															
90		90.0							SHALE, Dark gray, very fine grain, fresh, strong, very close to moderately spaced discontinuities								
	1.25																
										90.92	J	38	P,Sm	DS	T	N	
	1.50																
										91.60	J	35	U,Sm	FR	PO	N	
										92.00	J	37	P,Sm	FR	PO	N	
	1.50		R-17	60 100%	46 77%	R4	FR										
	1.75																
										93.78	J	36	P,Sm	DS	T	N	
										94.00	J	35	P,R	DS	T	N	
	1.25	95.0															
95		95.0							SHALE, Dark gray, very fine grain, fresh, strong, extremely close to wide spaced discontinuities								
	1.50																
	1.50																
										97.15	J	40	P,Sm	FR	T	N	
	1.50		R-18	60 100%	50 83%	R4	FR										
590										97.88	J	55	S,Sm	DS	T	N	
	1.50																
										99.15	J	50	P,Sm	FR	T	Py	
	1.75	100.0								99.45	J	63	U,Sm	FR	T	N	
100		100.0							SHALE, Dark gray, very fine grain, fresh, strong, extremely close to wide spaced discontinuities								
	1.00																
										101.28	J	30	P,Sm	FR	PO	N	
	1.00																
	1.25		R-19	60 100%	55 92%	R4	FR										
	1.50																
										103.67	J	32	P,Sm	FR	PO	N	
										104.15	J	8	P,Sm	FR	T	N	
	1.50	105.0															
105		105.0							SHALE, Dark gray, very fine grain, fresh, very strong, wide spaced discontinuities								Mechanical breaks (MB) as worked on core. No joints.
	1.25																
	1.25																
	1.25		R-20	56 93%	56 93%	R5	FR										
580																	
	1.25																
	1.25																

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
110	1.25	110.0															
	1.25	110.0							SHALE, Dark gray, very fine grain, fresh, very strong, wide spaced discontinuities								Mechanical breaks only. No joints.
	1.50																
	1.25		R-21	60 100%	60 100%	R5	FR										
	1.25																
	1.50	115.0															
115		115.0							SHALE, Dark gray, very fine grain, fresh, very strong, wide spaced discontinuities								Mechanical breaks only. No joints.
	1.50																
	1.50																
	1.50		R-22	60 100%	60 100%	R5	FR										
570	1.50																
	1.50	120.0															
120		120.0							SHALE, Dark gray, very fine grain, fresh, very strong, wide spaced discontinuities								Mechanical breaks only. No joints.
	1.25																
	1.50																
	1.50		R-23	60 100%	60 100%	R5	FR										
	1.50																
	1.50	125.0															
125		125.0							SHALE, Dark gray, very fine grain, fresh, very strong, wide spaced discontinuities								Mechanical breaks only. No joints.
	1.50																
	1.50																
	1.50		R-24	57 95%	58 97%	R5	FR										
560	1.50																
	1.50	130.0															
130		130.0							SHALE, Dark gray, very fine grain, fresh, very strong, very close to wide spaced discontinuities								Used up to 300 Gallons at 130 feet.
	1.25																
	1.00																
	1.00		R-25	49 82%	47 78%	R5	FR										
	1.25									133.55	J	55	U,Sm	FR	T	N	
	1.25									133.90	J	60	U,Sm	FR		N	
135		135.0															

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	1.50	135.0							SHALE, Dark gray, very fine grain, fresh, very strong, extremely close to wide spaced discontinuities								
	2.00																
	2.00		R-26	56 93%	55 92%	R5	FR										
550	2.00									138.19	J	8	P,Sm	FR	T	N	
										138.25	J	10	U,Sm	FR	T	Py	
	2.00	140.0															
140	1.75	140.0							SHALE, Dark gray, very fine grain, fresh, very strong, extremely close to moderately spaced discontinuities	140.40	J	65	P,Sm	FR	T	N	Used up to 300 Gallons.
	2.00									141.55	J	60	P,Sm	FR	T	N	
	1.75		R-27	52 87%	33 55%	R5	FR										
	2.00																
	2.00	145.0															
145	1.75	145.0							SHALE, Dark gray, very fine grain, fresh, very strong, wide spaced discontinuities								
	1.25									146.40	J	7	U,Sm	FR	T	N	
	1.50		R-28	60 100%	60 100%	R5	FR										
540	1.25																
	1.25	150.0															
150	1.50	150.0							SHALE, Dark gray, very fine grain, fresh, very strong, wide spaced discontinuities								No joints.
	1.25																
	1.25		R-29	60 100%	60 100%	R5	FR										
	1.50																
	1.50	155.0															
155	1.25	155.0							SHALE, Dark gray, very fine grain, very strong, wide spaced discontinuities								No joints.
	1.75																
	2.00		R-30	60 100%	60 100%	R5	FR										
530	2.00																
	1.25	160.0															
160	1.50	160.0							SHALE, Dark gray, very fine grain, very strong, wide spaced discontinuities								No joints.

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-11**
Page **7** of **7**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	1.50																
	1.50		R-31	60 100%	60 100%	R5	FR										
	1.50																
	1.50	165.0															
165		165.0							SHALE, Dark gray, very fine grain, very strong, wide spaced discontinuities								Used up to 300 Gallons. No joints.
	1.50																
	1.50																
	1.50		R-32	60 100%	60 100%	R5	FR										
520	1.50																
	1.50	170.0															
170		170.0							SHALE, Dark gray, very fine grain, very strong, wide spaced discontinuities								No joints.
	1.50																
	1.50																
	1.50		R-33	60 100%	60 100%	R5	FR										
	1.50																
	1.50	175.0															
175		175.0							SHALE, Dark gray, very fine grain, very strong, wide spaced discontinuities								No joints.
	1.50																
	1.75																
	1.50		R-34	60 100%	60 100%	R5	FR										
510	1.50																
	1.50	180.0															
180		180.0							SHALE, Dark gray, very fine grain, fresh, very strong, wide spaced discontinuities								Mechanical breaks only. No joints.
	1.50																
	1.50																
	1.25		R-35	60 100%	60 100%	R5	FR										
	1.50																
	1.50	185.0															
185									185.0 End of Boring at 185 feet BGS. Borehole grouted wih cement and bentonite hole plug. Offset Borehole 40 feet North of the staked location.								Used up to 300 Gallons.

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-11**

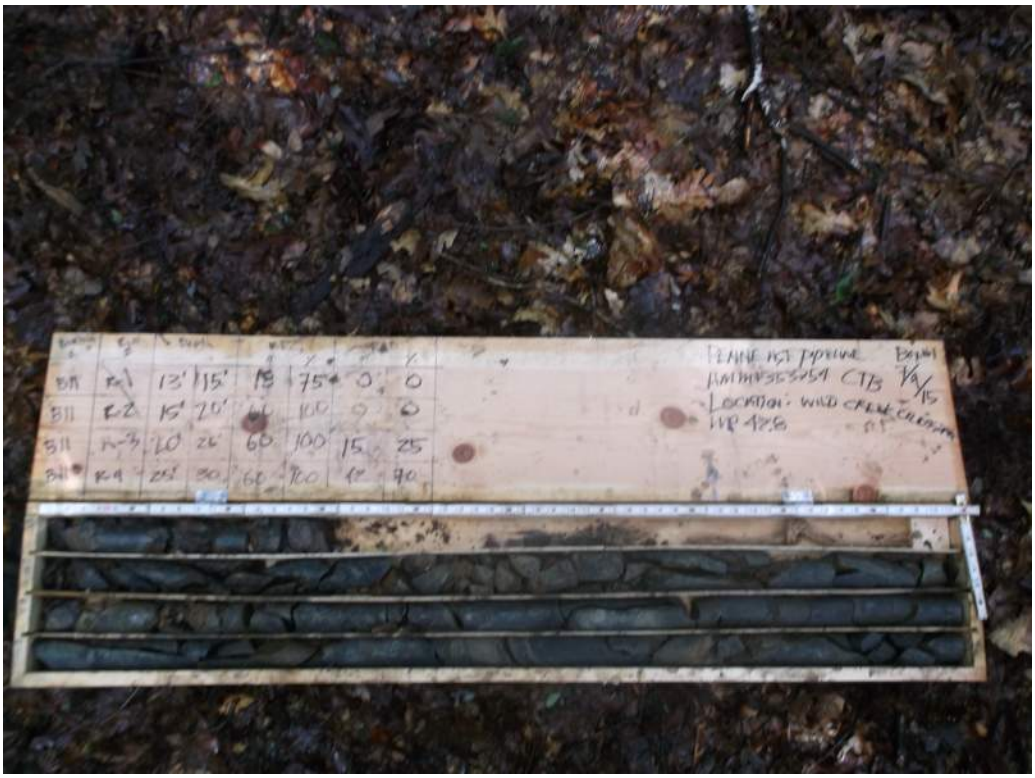


Figure B-11.1
B-11 Box 1 Runs 1-4 Dry

Figure B-11.2
B-11 Box 2 Runs 5-8 Dry

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-11

Figure B-11.3
B-11 Box 3 Runs 9-12 Dry

Figure B-11.4
B-11 Box 4 Runs 13-16 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-11

Figure B-11.5
B-11 Box 5 Runs 17-20 Dry

Figure B-11.6
B-11 Box 6 Runs 21-24 Dry

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-11

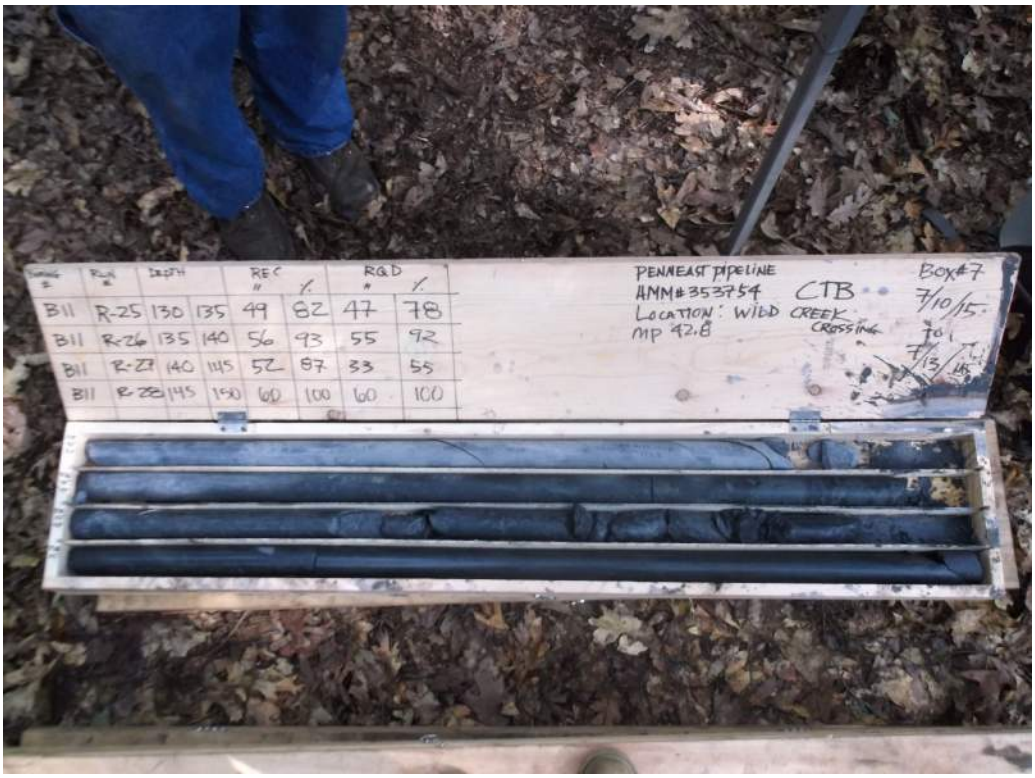


Figure B-11.7
B-11 Box 7 Runs 25-28 Dry

Figure B-11.8
B-11 Box 8 Runs 29-32 Dry

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-11

Figure B-11.9
B-11 Box 8 Runs 29-32 Wet

Figure B-11.10
B-11 Box 9 Runs 33-35 Dry

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-11

Figure B-11.11
B-11 Box 9 Runs 33-35 Wet

MOTT MACDONALD

SOIL BORING LOG

BORING NO.: **B-12**
Page **1** of **2**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler/Bernard Cortes
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	January 21, 2016 at 10:20 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	January 27, 2016 at 9:00 am

Elevation: 703 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** 12 feet East of marker post. **Coord.:** **N:** 40.886271 **E:** -75.559407 **Horizontal Datum:** NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	5	2	5
Inside Dia. (in.)	4	1.375	2.0
Hammer Wt. (lb.)	140	140	-
Hammer Fall (in.)	30	30	-

Rig Make & Model: CME-750X

☐ Truck ☐ Tripod ☐ Cat-Head
☑ ATV ☐ Geoprobe ☑ Winch
☐ Track ☐ Air Track ☑ Roller Bit
☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut ☑ Automatic ☐ _____

Drilling Fluid: ☐ Bentonite ☐ Polymer ☑ Water ☐ None

Drill Rod Size:

Casing Advance: Mud Rotary

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Group Symbol	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks
	S-1 0.0'- 2.0'	11	2 2 2 3		OH	Black, TOPSOIL	N	-	NP	N	
						0.6					
					SC	Loose, Orange-brown Clayey SAND, dry (SC)					
700											
5	S-2 5.0'- 7.0'	19	8 6 7 12		SC	Medium dense, Orange-brown Clayey SAND, trace Gravel, moist (SC)	N	-	NP	N	
	8.0'-'						-	-	-	-	Rollerbit grinding on Gravel layer at 8 feet BGS.
10	S-3 10.0'- 12.0'	24	24 70/3"		SC	Very dense, Orange-brown Clayey SAND with Decomposed Sandstone fragments, moist (SC)	N	-	NP	N	
690											
15	S-4 15.0'- 17.0'	24	80/4"		SC	Very dense, Orange-brown Clayey SAND with Decomposed Sandstone fragments, moist (SC) 16' - 17' Possible Boulder	N	-	NP	N	
						18.5					

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
1/22/16	7:20	16:00	30.0	65.0	39
1/26/16	8:00	84:00	30.0	135.0	46.5

Sample Type

O Open End Rod
T Thin-Wall Tube
U Undisturbed Sample
S Split Spoon Sample
G Geoprobe

Notes:
PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-12**

Field Test Legend:
Dilatancy: N - None S - Slow R - Rapid
Toughness: L - Low M - Medium H - High
Plasticity: NP - Non-Plastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Medium H - High VH - Very High

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

SOIL BORING LOG
(continued)

BORING NO.: **B-12**
Page **2** of **2**

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Symbol Group	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks*
	S-5 20.0'- 20.1'	1	50/1"			Very dense, Reddish brown DECOMPOSED SANDSTONE fragments, moist (Possible Boulder)	N	-	NP	N	
680											
25	S-6 25.0'- 25.0'	0	100/0"			No Recovery 25' - 28' Boulder encountered	N	-	NP	N	
	28.0'-'					28' - 30' Soft Clay layer	-	-	-	-	Drilled quickly from 28 to 30 feet.
30	S-7 30.0'- 30.2'	2	80/2"			Very dense, Light gray to dark gray DECOMPOSED SHALE fragments, moist, Clay layers present within rock	N	-	NP	N	
670											
35						35.0 Top of Rock at 35 feet BGS. See Rock Coring Log.					
40											
660											
45											

NOTES:

PROJECT NO.: **353754**

BORING NO.: **B-12**

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

CORE BORING LOG

BORING NO.: **B-12**
Page **1** of **8**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler/Bernard Cortes
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	January 21, 2016 at 10:20 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	January 27, 2016 at 9:00 am

Elevation: 703 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** 12 feet East of marker post. **Coord.: N:** 40.886271 **E:** -75.559407

Item	Casing	Core Barrel	Core Bit
Type	HW	NQ2	Imp. Diamond
Length (ft)	5	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Horizontal Datum: NAD 1983 **Drilling Method:** Wireline
Rig Make & Model: CME-750X

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec (in. / %)	RQD (in / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
									SEE TEST BORING LOG FOR OVERBURDEN DETAILS		(See Legend for Rock Description System)						
	2.00	35.0							SHALE, Dark to light gray, very fine grained, slightly weathered, weak, extremely close spaced discontinuities 35' - 40' Highly fractured zone								Used up to 40 Gallons for R1.
	2.50																
	4.00		R-1	55 92%	0 0%	R2	SL										
	3.00																
	3.00	40.0															
40																	
	3.00	40.0							SHALE, Dark to light gray, very fine grained, slightly weathered, weak, very close spaced discontinuities 40' - 45' Highly fractured zone								Used up to 40 Gallons for R2.
	3.50																
	3.50		R-2	60 100%	0 0%	R2	SL										
660																	
	3.50																
	3.50	45.0															
45																	
	3.00	45.0							45' - 51.1' SHALE, Dark gray, very fine grained, slightly weathered, weak, very close spaced discontinuities 45' - 50' Highly fractured zone								Used up to 40 Gallons for R3.
	3.00																
	3.00		R-3	54 90%	0 0%	R2	SL										
	3.00																
	3.00	50.0															
50																	
	3.00	50.0															
	3.00								51.1' - 55' SHALE, Dark gray, very fine grained, slightly weathered, medium strong, close spaced discontinuities 50' - 51.2' Highly fractured zone	51.90 52.00	J J	60 60	P,Sm P,Sm	FR FR	VT VT	N N	Used up to 40 Gallons for R4.
	3.00		R-4	60 100%	37 62%	R3	SL										
650									53.7' - 55' Highly fractured zone	52.90	J	30	P,R	FR	T	N	
	3.00																
	3.00	55.0															

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
1/22/16	7:20	16:00	30.0	65.0	39.0
1/26/16	8:00	84:00	30.0	135.0	46.5

Notes:

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-12**
Page **2** of **8**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00	55.0							SHALE, Dark gray, very fine grained, fresh, strong, very close to moderately spaced discontinuities 55' - 55.7' Highly fractured zone								Used up to 40 Gallons for R5.
	3.00									56.40	J	30	P,R	FR	T	N	
										56.70	J	80	P,Sm	FR	VT	N	
	3.00		R-5	60 100%	29 48%	R4	FR		57.6' - 59' Highly fractured zone								
	3.00																
	3.00	60.0															
60		60.0							SHALE, Dark gray, very fine grained, fresh, strong, very close to moderately spaced discontinuities								Used up to 40 Gallons for R6.
	3.00									60.80	B	50	P,R	FR	VT	N	
	3.20																
	3.20		R-6	60 100%	49 82%	R4	FR			62.30	B	40	P,R	FR	VT	N	
640									62.7' - 63.9' Highly fractured zone								
	3.20																
	3.20	65.0															
65		65.0							65.0 SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Used up to 50 Gallons for R7.
	2.50																
	2.50									66.50	B	60	P,R	FR	VT	N	
	2.50		R-7	60 100%	60 100%	R4	FR										
	3.00									68.60	B	60	P,Sm	FR	T	N	
	3.00	70.0															
70		70.0							SLATE, Dark gray, very fine grained, fresh, strong, wide to moderately spaced discontinuities								Used up to 50 Gallons for R8.
	3.00									70.80	B	50	P,Sm	FR	T	N	
	3.00									71.30	B	60	P,Sm	FR	T	N	
										71.90	J	70	P,R	FR	T	N	
	3.00		R-8	60 100%	56 93%	R4	FR										
630																	
	3.50																
	3.50	75.0															
75		75.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								Used up to 50 Gallons for R9.
	3.20									75.50	B	40	P,Sm	FR	VT	Py	
										75.80	B	40	P,Sm	FR	VT	N	
	3.20																
										76.70	B	40	P,Sm	FR	VT	N	
	3.20		R-9	59 98%	54 90%	R4	FR										
	3.20									78.10	B	50	P,Sm	FR	VT	N	
	3.30	80.0															
80		80.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Used up to 50 Gallons for R10.

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-12**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.50									81.00	B	75	P,Sm	FR	T	Ca	
	2.40																
	2.40		R-10	60 100%	60 100%	R4	FR										
620	2.30																
	2.30	85.0															
85	2.00	85.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities	85.70	J	30	P,Sm	FR	VT	N	Used up to 50 Gallons for R11.
										85.90	J	30	P,Sm	FR	VT	N	
	2.00									86.40	J	30	P,Sm	FR	T	N	
	2.00		R-11	60 100%	56 93%	R4	FR										
	2.00																
	2.00	90.0								89.50	J	60	P,R	FR	T	N	
90	2.50	90.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Used up to 270 Gallons for R12.
	2.50																
	2.50		R-12	60 100%	60 100%	R4	FR										
610	2.50									93.40	J	30	P,Sm	DS	PO	Fe	
	2.50	95.0															
95	2.50	95.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Used up to 200 Gallons for R13.
	2.50																
	2.50		R-13	60 100%	56 93%	R4	FR										
	2.50									98.40	J	30	P,Sm	FR	T	N	
	2.50	100.0								99.50	J	60	P,Sm	DS	O	Fe	
100	2.50	100.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities	100.30	J	10	P,R	FR	PO	N	Used up to 100 Gallons for R14.
	2.50																
	3.00		R-14	58 97%	49 82%	R4	FR										
600	3.00																
	3.00	105.0							104' - 105' Mechanical damage								
105	2.00	105.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								No discontinuities. Used up to 100 Gallons for R15.

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.30																
	2.30		R-15	60 100%	60 100%	R4	FR										
	2.30																
	2.30	110.0															
110	2.00	110.0							SLATE, Dark gray, very fine grained, fresh, strong, moderate to close spaced discontinuities								Used up to 100 Gallons for R16.
	2.00									110.90	B	60	P,Sm	FR	VT	N	
	2.00									111.50	B	60	P,Sm	FR	VT	N	
	2.50		R-16	60 100%	50 83%	R4	FR			112.30	J	30	P,Sm	FR	VT	N	
590										112.80	J	30	P,Sm	FR	VT	N	
	2.50									113.40	J	10	P,R	FR	PO	N	
	2.50	115.0															
115	2.00	115.0							SLATE, Dark gray, very fine grained, fresh, strong, very close to moderately spaced discontinuities								Used up to 80 Gallons for R17.
	2.00									116.20	B	40	P,R	DS	PO	N	
										116.40	J	10	P,R	FR	T	N	
	2.00		R-17	60 100%	45 75%	R4	FR										
	2.00									117.70	B	40	P,R	DS	PO	N	
										118.10	B	30	P,R	FR	PO	N	
										118.50	J	40	P,Sm	FR	T	N	
	2.00	120.0															
120	2.40	120.0							SLATE, Dark gray, very fine grained, fresh, strong, moderate to wide spaced discontinuities								Used up to 80 Gallons for R18.
	2.40									121.00	J	5	P,R	FR	PO	N	
	2.40		R-18	59 98%	59 98%	R4	FR			122.60	B	30	P,R	FR	T	N	
580	2.40																
	2.40	125.0								124.70	J	70	P,R	FR	PO	N	
125	2.20	125.0							SLATE, Dark gray, very fine grained, fresh, strong to very strong, wide spaced discontinuities								No discontinuities. Used up to 100 Gallons for R19.
	2.20																
	2.20		R-19	60 100%	60 100%	R4	FR										
	2.20																
	2.20	130.0															
130	2.30	130.0							SLATE, Dark gray, very fine grained, fresh, strong to very strong, moderate to wide spaced discontinuities								Used up to 100 Gallons for R20.
	2.30									131.30	B	40	P,Sm	FR	T	N	

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.30																
	2.30		R-20	60 100%	60 100%	R4	FR			132.40	B	50	P,Sm	FR	VT	N	
570	2.30																
	2.30	135.0															
135	2.00	135.0							SLATE, Dark gray, very fine grained, fresh, strong, moderately spaced discontinuities								Used up to 275 Gallons for R21.
	2.30									135.90	J	50	U,Sm	FR	T	N	
	2.50		R-21	60 100%	57 95%	R4	FR			137.20	J	50	U,Sm	FR	VT	N	
	2.60									138.20	J	50	P,R	FR	T	N	
	3.00	140.0															
140	2.40	140.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Used up to 275 Gallons for R22.
	2.50									140.50	J	70	P,Sm	FR	VT	N	
	2.50		R-22	60 100%	60 100%	R4	FR										
560	2.50									143.20	J	70	P,R	FR	VT	N	
	2.50	145.0															
145	2.20	145.0							SLATE, Dark gray, very fine grained, fresh, strong, very close to wide spaced discontinuities								Used up to 275 Gallons for R23.
	2.60									145.40	J	40	P,R	FR	T	N	
	2.40		R-23	58 97%	39 65%	R4	FR										
	2.30									148.30	J	40	U,R	FR	O	N	
	2.40	150.0							148.6' - 150' Highly fractured zone								
150	1.50	150.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities 150.7' -150.9' Highly fractured zone with Pyrite infill								Used up to 275 Gallons for R24.
	2.00																
	2.00		R-24	60 100%	57 95%	R4	FR			151.90	J	40	P,R	FR	VT	N	
550										152.70	J	40	P,R	FR	VT	N	
	2.50									153.00	J	50	P,R	FR	VT	N	
	3.00	155.0								153.70	J	50	P,R	DS	O	N	
155	1.00	155.0							SLATE, Dark gray, very fine grained, fresh, strong, extremely close to wide spaced discontinuities	154.80	J	40	P,R	FR	PO	Py	Used up to 275 Gallons for R25.
										155.50	J	30	P,R	FR	T	N	
	1.00									155.70	J	30	P,R	FR	VT	N	
									156.6' - 157' Highly fractured zone								

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	1.00		R-25	60 100%	52 87%	R4	FR										
	1.50									158.50	J	20	P,Sm	FR	T	N	
	2.00	160.0								159.40	J	35	P,Sm	FR	O	N	
160	2.25	160.0							SLATE, Dark gray, fine grained, fresh, medium strong, extremely close to wide spaced discontinuities								Used up to 275 Gallons for R26.
	2.00								160.7' - 160.9' Highly fractured zone	161.00	J	30	S,R	FR	PO	N	
	2.50		R-26	60 100%	52 87%	R3	FR			162.50	J	20	S,R	FR	PO	Py	
540	1.50									162.80	J	25	S,R	FR	PO	N	
	2.50	165.0															
165	1.50	165.0							SLATE, Dark gray, fine grained, fresh, strong, extremely close to wide spaced discontinuities								Used up to 275 Gallons for R27.
	1.50								165' - 165.5' Highly fractured zone	165.50	J	50	P,Sm	FR	VT	N	
	1.50									165.80	J	45	P,Sm	FR	VT	N	
	1.50		R-27	60 100%	56 93%	R4	FR										
	1.50									168.60	MB						
	2.50	170.0								169.00	MB						
170	1.50	170.0							SLATE, Dark gray, fine grained, fresh, strong, extremely close spaced discontinuities	169.50	J	40	P,R	FR	VT	N	Used up to 275 Gallons for R28.
	1.75								170' - 170.4' Highly fractured zone	170.90	J	10	P,R	FR	VT	N	
	2.00		R-28	60 100%	50 83%	R4	FR										
530	1.50									173.20	MB					Py	
	2.00	175.0								173.70	J	60	P,R	FR	VT	N	
175	1.50	175.0							174.8' - 175' Highly fractured zone SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities	174.50	J	50	U,R	FR	VT	N	Used up to 275 Gallons for R29.
	1.50																
	1.50		R-29	60 100%	60 100%	R4	FR										
	1.50																
	1.50	180.0								179.30	J	20	S,R	FR	O	N	
180	1.50	180.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Used up to 275 Gallons for R30.
	1.50									181.50	J	50	P,R	FR	VT	N	
	1.50		R-30	60	60	R4	FR										

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
				100%	100%												
520	1.50																
	1.50																
	1.50	185.0								184.10	J	50	P,R	FR	VT	N	
185		185.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								Used up to 275 Gallons for R31.
	1.50																
	1.50									186.60	J	50	P,R	FR	VT	N	
	1.50		R-31	60 100%	60 100%	R4	FR										
	1.50									188.30	J	50	P,R	FR	VT	N	
	1.50	190.0															
190		190.0							SLATE, Dark gray, very fine grained, fresh, strong, extremely close to wide spaced discontinuities								Used up to 275 Gallons for R32.
	1.50																
	1.50								191.3' - 193.8' Highly fractured zone with Pyrite infilling								
	1.50		R-32	60 100%	56 93%	R4	FR										
510	1.50																
	1.50	195.0															
195		195.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								Used up to 275 Gallons for R33. Broken with hammer to fit into the box.
	1.50									195.50	J	50	P,R	FR	O	N	
	1.50																
	1.50		R-33	60 100%	58 97%	R4	FR										
	1.50									198.50	J			FR	O	N	
	2.00	200.0															
200		200.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								Used up to 275 Gallons for R34. Broken with hammer to fit into the box.
	1.50																
	1.50																
	1.50		R-34	60 100%	58 97%	R4	FR										
500	1.50									203.30	J	30	P,Sm	FR	T	N	
	1.50	205.0															
205		205.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								Used up to 275 Gallons for R35.
	1.50																
	1.50																
	1.50		R-35	60 100%	59 98%	R4	FR			207.70	J	50	U,Sm	FR	VT	N	

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-12**
Page **8** of **8**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	1.50																
	1.50																
	1.50	210.0								209.50	J	20	U,R	FR	VT	N	
210		210.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								Used up to 275 Gallons for R36.
	1.50																
	1.50									211.00	J	30	P,Sm	FR	VT	Ca	
	1.75		R-36	60 100%	60 100%	R4	FR										
490																	
	1.50																
	2.00	215.0															
215		215.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Used up to 275 Gallons for R37.
	1.50																
	1.25																
	1.50		R-37	60 100%	60 100%	R4	FR										
	1.50																
	1.50	220.0								219.20	J	20	S,R	FR	VT	N	
220		220.0							SLATE, Dark gray, very fine grained, fresh, strong, extremely close to wide spaced discontinuities								Used up to 275 Gallons for R38.
	1.50																
	1.50																
	1.50		R-38	56 93%	56 93%	R4	FR			222.00	J	50	P,Sm	FR	VT	N	
480																	
	1.50									223.30	J	30	P,Sm	FR	T	N	
	1.50	225.0															
225									225.0 End of Boring at 225 feet BGS. Borehole grouted with cement and bentonite hole plug.								
230																	
470																	

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-12**

Figure B-12.1
B-12 Box 1 Runs 1-4 Dry

Figure B-12.2
B-12 Box 1 Runs 1-4 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-12

Figure B-12.3
B-12 Box 2 Runs 5-8 Dry

Figure B-12.4
B-12 Box 2 Runs 5-8 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-12

Figure B-12.5
B-12 Box 3 Runs 9-12 Dry

Figure B-12.6
B-12 Box 3 Runs 9-12 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-12

Figure B-12.7
B-12 Box 4 Runs 13-16 Dry

Figure B-12.8
B-12 Box 4 Runs 13-16 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-12

Figure B-12.9
B-12 Box 5 Runs 17-20 Dry

Figure B-12.10
B-12 Box 5 Runs 17-20 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-12

Figure B-12.11
B-12 Box 6 Runs 21-24 Dry

Figure B-12.12
B-12 Box 6 Runs 21-24 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-12

Figure B-12.13
B-12 Box 7 Runs 25-28 Dry

Figure B-12.14
B-12 Box 7 Runs 25-28 Wet

Figure B-12.15
B-12 Box 8 Runs 29-32 Dry

Figure B-12.16
B-12 Box 8 Runs 29-32 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-12

Figure B-12.17
B-12 Box 9 Runs 33-36 Dry

Figure B-12.18
B-12 Box 9 Runs 33-36 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-12

Figure B-12.19
B-12 Box 10 Runs 37-38 Dry

Figure B-12.20
B-12 Box 10 Runs 37-38 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-12

MOTT MACDONALD

SOIL BORING LOG

BORING NO.: **B-13**
Page **1** of **2**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	January 14, 2016 at 12:55 pm
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	January 20, 2016 at 12:00 pm

Elevation: 706 ft. **Vertical Datum:** NAVD 1988

Boring Location: In the woods, off the Bethlehem Authority Right of Way.

Coord.: **N:** 40.885355 **E:** -75.55758

Horizontal Datum: NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	5	2	5
Inside Dia. (in.)	4	1.375	2.0
Hammer Wt. (lb.)	140	140	-
Hammer Fall (in.)	30	30	-

Rig Make & Model: CME-750X

☐ Truck ☐ Tripod ☐ Cat-Head
☑ ATV ☐ Geoprobe ☑ Winch
☐ Track ☐ Air Track ☑ Roller Bit
☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type
☐ Safety
☐ Doughnut
☑ Automatic
☐ _____

Drilling Fluid
☐ Bentonite
☐ Polymer
☑ Water
☐ None

Drill Rod Size:

Casing Advance
Mud Rotary

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Group Symbol	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks
	S-1 0.0'- 2.0'	20	1 1 2 5		CL	Medium stiff, Light brown CLAY, trace Sand, moist (CL)	N	-	M	N	
5 700	S-2 5.0'- 7.0'	22	14 8 7 7		CL	Stiff, Light brown to orange CLAY, trace Sand, moist (CL)	N	-	M	N	
						8.5					
10	S-3 10.0'- 12.0'	13	16 20 37 32			Very dense, Orange to reddish brown DECOMPOSED SANDSTONE with Clay and Sand, moist	N	-	NP	N	
15 690	S-4 15.0'- 17.0'	18	25 31 47 50/3"			Very dense, Black to orange DECOMPOSED SHALE with Clay, moist	N	-	NP	N	Litho relics structure present.

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
1/15/16	7:30	-		60.0	18.2
1/18/16	8:30	-		115.0	19.5
1/19/16	9:00	-		170.0	24.5
1/20/16	0:00	-		210.0	24

Sample Type

O Open End Rod
T Thin-Wall Tube
U Undisturbed Sample
S Split Spoon Sample
G Geoprobe

Notes:

PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-13**

Field Test Legend:
Dilatancy: N - None S - Slow R - Rapid
Toughness: L - Low M - Medium H - High
Plasticity: NP - Non-Plastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Medium H - High VH - Very High

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

SOIL BORING LOG
(continued)

BORING NO.: **B-13**
Page **2** of **2**

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Symbol Group	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks*
	S-5 20.0'-20.5'	5	120/6" 120/5"			Very dense, Black to orange-brown DECOMPOSED SHALE with Clay, dry	N	-	NP	N	
25	S-6 25.0'-25.5'	5	115/6"			Very dense, Black DECOMPOSED SHALE with Light brown Clay, moist	N	-	NP	N	
680											
30	S-7 30.0'-30.3'	4	110/4"			Very dense, Black DECOMPOSED SHALE with Light brown Clay, moist	N	-	NP	N	
35	S-8 35.0'-35.3'	4	100/4"			35.3	N	-	NP	N	
670						Top of Rock at 35 feet BGS. See Rock Coring Log.					
40											
45											
660											

NOTES:

PROJECT NO.: **353754**

BORING NO.: **B-13**

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

CORE BORING LOG

BORING NO.: **B-13**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	January 14, 2016 at 12:55 pm
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	January 20, 2016 at 12:00 pm

Elevation: 706 ft. **Vertical Datum:** NAVD 1988

Item	**Casing**	**Core Barrel**	**Core Bit**
Type	HW	NQ2	Imp. Diamond
Length (ft)	5	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Boring Location: In the woods, off the Bethlehem Authority Right of Way.

Horizontal Datum: NAD 1983

Rig Make & Model: CME-750X

Coord.: N: 40.885355 **E:** -75.55758

Drilling Method: Wireline

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec (in. / %)	RQD (in / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
									SEE TEST BORING LOG FOR OVERBURDEN DETAILS								
	2.50	35.0							SHALE, Dark gray and light brown, very fine grained, moderately weathered, weak, very close spaced discontinuities 35' - 40' Highly fractured zone								
670	2.50																
	3.00		R-1	58 97%	5 8%	R2	M										
	3.00																
	3.00	40.0															
40																	
	3.00	40.0							41' - 42' SHALE, Dark gray and light brown, very fine grained, moderately weathered, weak very close spaced discontinuities 40' - 45' Highly fractured zone								
	3.00																
	4.00		R-2	55 92%	0 0%	R2	M		42' - 45' SHALE, Gray and brown, very fine grained, highly weathered, very weak, extremely close spaced discontinuities								
	4.00																
	4.00	45.0															
45																	
	3.50	45.0							SHALE, Dark gray, very fine grained, weak, close to very close spaced discontinuitie Occasional thin Quartz vein 45' - 50' Highly fractured zone								
660	3.50																
	3.50		R-3	60 100%	16 27%	R2	M										
	3.50																
	3.50	50.0															
50																	
	4.00	50.0							SHALE, Dark gray, very fine grained, slightly weathered, weak, close to very close spaced discontinuities Occasional thin Quartz vein								
	4.50																
	5.00		R-4	56 93%	13 22%	R2	SL										
	5.00																
	5.00	55.0															

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
1/15/16	7:30	-		60.0	18.2
1/18/16	8:30	-		115.0	19.5
1/19/16	9:00	-		170.0	24.5
1/20/16	0:00	-		210.0	24.0

Notes:

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00	55.0							SHALE, Dark gray, very fine grained, fresh, medium strong, close to very close spaced discontinuities 55' - 60' Highly fractured zone								Used up to 270 Gallons for R1 through R5.
650	3.00																
	4.00		R-5	60 100%	19 32%	R3	FR										
	4.00																
	4.50	60.0															
60	3.00	60.0							SHALE, Dark gray, very fine grained, fresh, medium strong, close spaced discontinuities	60.70 60.80	B J	30 60	P,R P,R	FR FR	T T	N N	
	3.00								61.2' - 61.8' Highly fractured zone								
	3.00		R-6	57 95%	26 43%	R3	FR			62.20 62.80	B J	25 70	S,R S,R	DG FR	PO T	N N	
	3.50								63.3' - 64' Highly fractured zone								
	4.50	65.0															
65	3.00	65.0							SHALE, Dark gray, very fine grained, fresh, medium strong, close spaced discontinuities 65' - 70' Highly fractured zone								
640	3.00																
	3.00		R-7	53 88%	21 35%	R3	FR										
	3.50																
	3.50	70.0															
70	3.50	70.0							SHALE, Dark gray, very fine grained, fresh, medium strong to strong, moderately spaced discontinuities								Used up to 270 Gallons for R6/R7/R8.
	3.50																
	3.50		R-8	54 90%	53 88%	R3	FR			72.20 72.70	J B	60 0	P,Sm P,Sm	FR FR	VT T	N N	
	3.50																
	3.50	75.0								74.50	J	60	P,Sm	FR	T	N	
75	3.00	75.0							SHALE, Dark gray, very fine grained, fresh, medium strong to strong, moderately space discontinuities								Used up to 270 Gallons for R9.
630	3.50									76.20	J	60	P,Sm	FR	PO	N	
	3.50		R-9	58 97%	44 73%	R3	FR			77.30	J	55	P,Sm	FR	VT	N	
	3.50																
	3.50	80.0															
80		80.0							SHALE, Dark gray, very fine grained, fresh, medium strong to strong, close to moderately spaced								Used up to 270 Gallons for R10.

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00								discontinuities								
	3.50									81.40	J	55	P,Sm	FR	VT	N	
										81.50	J	55	P,Sm	FR	VT	N	
	3.50		R-10	58 97%	39 65%	R3	FR										
										82.70	J	60	P,R	DS	PO	N	
	3.50									83.30	J	60	P,Sm	FR	VT	N	
										83.90	J	60	P,Sm	FR	VT	N	
	4.00	85.0								84.40	B	40	P,R	DS	O	N	
85		85.0							SHALE, Dark gray, very fine grained, fresh, strong, moderate to wide spaced discontinuities								Used up to 270 Gallons for R11.
620	3.00																
	3.00																
			R-11	60 100%	58 97%	R4	FR			87.00	J	60	P,Sm	FR	VT	N	
	3.00																
	2.80																
										89.00	J	60	P,Sm	FR	VT	N	
	2.80	90.0															
90		90.0							SHALE, Dark gray, very fine grained, fresh, strong, moderately spaced discontinuities								Used up to 400 Gallons for R12.
	3.00									90.50	B	12	P,Sm	FR	T	N	
									91' - 92.1' Highly fractured zone								
	3.00																
	3.00		R-12	60 100%	45 75%	R4	FR										
										93.00	J	60	P,Sm	FR	VT	N	
	3.00																
										93.70	J	60	P,Sm	FR	VT	N	
										93.80	B	30	P,R	DS	PO	N	
	3.00	95.0								94.40	B	40	P,R	DS	O	N	
95		95.0							95.0 SLATE, Dark gray, fine grained, fresh, strong, moderately spaced discontinuities								Used up to 300 Gallons for R13.
610	3.00																
										96.00	J	60	P,Sm	FR	VT	N	
	2.50																
	2.50		R-13	60 100%	52 87%	R4	FR		97.4' - 98' Highly fractured zone								
	2.50																
	3.00	100.0															
100		100.0							SLATE, Dark gray, fine grained, fresh, strong, wide spaced discontinuities								Used up to 400 Gallons for R14.
	2.50																
	2.50									101.50	J	60	P,Sm	FR	VT	N	
	2.50		R-14	60 100%	55 92%	R4	FR		102.5' - 102.9' Highly fractured zone								
	2.50																
	3.00	105.0															
105		105.0							SLATE, Dark gray, fine grained, fresh, strong, wide spaced discontinuities								Used up to 270 Gallons for R15.
	3.00																

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00									106.50	J	5	P,Sm	FR	VT	N	
	3.50		R-15	60 100%	60 100%	R4	FR			107.50	J	5	P,Sm	FR	VT	N	
	3.50																
	3.50	110.0															
110	3.00	110.0							SLATE, Dark gray, fine grained, fresh, strong, wide spaced discontinuities								Used up to 270 Gallons for R16.
	3.00									111.00	J	60	S,R	FR	VT	N	
	2.50		R-16	60 100%	60 100%	R4	FR			112.50	J	0	P,Sm	FR	PO	N	
	2.50																
	3.00	115.0															
115	2.90	115.0							SLATE, Dark gray, fine grained, fresh, strong, wide spaced discontinuities								Used up to 250 Gallons for R17.
590	3.00																
	3.00		R-17	57 95%	57 95%	R4	FR										
	3.50																
	4.00	120.0															
120	3.00	120.0							SLATE, Dark gray, fine grained, fresh, strong, wide spaced discontinuities								Used up to 250 Gallons for R18.
	3.00									120.90	J	60	P,R	FR	VT	N	
	3.00		R-18	60 100%	60 100%	R4	FR										
	3.00																
	3.00	125.0															
125	3.00	125.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								Used up to 120 Gallons for R19.
580										125.60	J	5	P,R	DG	PO	N	
	3.00									126.10	J	25	P,R	DG	PO	N	
	3.00		R-19	60 100%	60 100%	R4	FR										
	3.00									127.80	J	40	P,R	DG	PO	N	
	3.00																
	3.00	130.0															
130	3.00	130.0							SLATE, Dark gray, very fine grained, fresh, strong, moderate to wide spaced discontinuities								Used up to 120 Gallons for R20.
	3.00									131.00	B	60	P,Sm	FR	VT	N	

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00								131.5' - 132' Calcite and Quartz veins encountered								
	3.00		R-20	60 100%	60 100%	R4	FR			132.40	B	60	P,Sm	FR	VT	N	
	3.00									133.80	B	60	P,Sm	FR	VT	N	
	3.50	135.0															
135		135.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								Used up to 120 Gallons for R21.
570									137' - 138' Calcite and Quartz veins encountered								
			R-21	60 100%	58 97%	R4	FR			137.90	B	60	P,Sm	FR	VT	N	
		140.0															
140		140.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								Used up to 270 Gallons for R22.
			R-22	60 100%	58 97%	R4	FR			141.80	B	60	P,Sm	FR	VT	N	
										143.40	B	60	P,Sm	FR	VT	N	
										144.10	B	60	P,Sm	FR	VT	N	
		145.0							144.5' and below Rapid water loss	144.50	J	0	P,R	FR	O	N	
145		145.0							Minor Pyrite deposits encountered SLATE, Dark gray, very fine grained, fresh, strong, moderate to wide spaced discontinuities								Used up to 270 Gallons for R23.
560	3.00									145.80	B	60	P,Sm	FR	VT	N	
	3.00		R-23	60 100%	60 100%	R4	FR										
	3.00									148.20	B	60	P,Sm	FR	VT	N	
	3.00	150.0															
150	2.80	150.0							SLATE, Dark gray, very fine grained, fresh, strong, very close to moderately spaced discontinuities								Used up to 270 Gallons for R24.
	2.80									150.50	B	60	P,Sm	FR	VT	N	
	2.80		R-24	60 100%	32 53%	R4	FR		152' - 154' Highly fractured zone								
	2.80																
	2.80	155.0								154.40	B	60	P,Sm	FR	VT	N	
155		155.0							154.7' - 155' Highly fractured zone SLATE, Dark gray, very fine grained, fresh, strong, very close to moderately spaced discontinuities								Used up to 270 Gallons for R25.
550	3.00									155.60	J	40	P,R	FR	T	N	
										155.70	B	60	P,Sm	FR	VT	N	
	3.00									156.70	B	60	P,Sm	FR	VT	N	

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00		R-25	57 95%	48 80%	R4	FR			157.30	B	60	P,Sm	FR	VT	N	
	3.00									158.00	B	60	P,R	FR	VT	N	
	3.00	160.0															
160	2.50	160.0							SLATE, Dark gray, very fine grained, fresh, strong, moderate to wide spaced discontinuities								Used up to 270 Gallons for R26.
										160.60	B	50	P,Sm	FR	VT	N	
	2.50									161.10	B	60	P,Sm	FR	VT	N	
	3.00		R-26	60 100%	60 100%	R4	FR										
	3.00									163.50	B	60	P,Sm	FR	VT	N	
	3.00	165.0															
165	3.00	165.0							SLATE, Dark gray, very fine grained, fresh, strong, moderate to wide spaced discontinuities 166.5' - 167.0' Quartz veins encountered								Used up to 270 Gallons for R27.
540										165.60	B	60	P,Sm	FR	VT	N	
	2.50									166.50	B	60	P,Sm	FR	VT	N	
	2.50		R-27	60 100%	60 100%	R4	FR										
	2.50																
	3.00	170.0								168.80 169.00	B B	60 60	P,Sm P,Sm	FR FR	VT VT	N N	
170	3.50	170.0							SLATE, Dark gray, very fine grained, fresh, strong, very close to wide spaced discontinuities								Used up to 270 Gallons for R28.
	3.50																
	3.50		R-28	60 100%	52 87%	R4	FR		172.6' 0.25" CLAY layer								
	3.50																
	3.50	175.0								174.20	B	60	P,R	FR	VT	N	
175	3.00	175.0							SLATE, Dark gray, very fine grained, fresh, strong, very close to wide spaced discontinuities								Used up to 270 Gallons for R29.
530	2.80								176.1' - 176.9' Highly fractured zone								
	2.80		R-29	60 100%	50 83%	R4	FR										
	2.80																
	2.80	180.0															
180	2.50	180.0							180' - 182.8' CALCAREOUS SLATE, Dark gray mottled light gray, very fine grained, fresh, strong, wide spaced discontinuities								Used up to 190 Gallons for R30.
	2.50																
	2.50		R-30	60	60	R4	FR										

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-13**

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.50			100%	100%				182.8' - 185' SLATE, Dark gray, very fine grained, fresh, strong, moderate to wide spaced discontinuities	182.90	B	60	P,Sm	FR	VT	N	
	2.50																
	2.50	185.0															
185	3.00	185.0							SLATE, Dark gray, very fine grained, fresh, strong, moderate to wide spaced discontinuities								Used up to 260 Gallons for R31.
520	3.50									185.90	B	60	P,Sm	FR	VT	N	
	3.50		R-31	60 100%	57 95%	R4	FR										
	3.50									188.20	J	60	P,Sm	FR	VT	N	
										188.40	J	60	P,Sm	FR	VT	N	
	4.00	190.0								189.30	V	5	P,R	FR	VT	Ca	
190		190.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								Used up to 250 Gallons for R32.
	2.50																
	2.50									191.60	J	70	P,Sm	FR	VT	N	
	2.50		R-32	60 100%	49 82%	R4	FR		192.1' - 192.9' Highly fractured zone								
	2.50																
	2.50	195.0															
195	3.00	195.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								No discontinuities. Used up to 270 Gallons for R33.
510	3.00																
	3.00		R-33	60 100%	60 100%	R4	FR										
	3.00																
	3.00	200.0															
200	3.00	200.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities 200' - 201.5' Highly fractured zone								Used up to 270 Gallons for R34.
	3.00																
	3.50		R-34	60 100%	44 73%	R4	FR										
	3.50																
	3.50	205.0															
205	3.00	205.0							SLATE, Dark gray, very fine grained, fresh, strong, moderate to wide spaced discontinuities								Used up to 270 Gallons for R35.
500	3.00								206' Calcite nodule encountered	206.00	V	0	P,R	FR	O	Ca	
										206.10	J	70	P,Sm	FR	VT	N	
	3.00		R-35	60 100%	59 98%	R4	FR										

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-13**
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Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00																
	3.00																
	3.00	210.0															
210		210.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								No discontinuities. Used up to 270 Gallons for R36.
	3.00																
	3.00																
	3.50		R-36	60 100%	60 100%	R4	FR										
	3.50																
	3.50	215.0															
215		215.0							SLATE, Dark gray, very fine grained, fresh, strong, very close to moderately spaced discontinuities 215' - 216.8' Highly fractured zone								Used up to 200 Gallons for R37.
	3.00																
490																	
	3.00																216.5' Some Slickensided fractures, possibly minor faults.
	3.50		R-37	60 100%	38 63%	R4	FR										
	3.50								218' - 218.4' Veins of Calcite with some small Quartz veins and occasional Pyrite	218.40	J	60	P,R	FR	T	N	
										218.70	J	20	P,R	FR	T	N	
	3.50																
	3.50	220.0															
220		220.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								No discontinuities. Used up to 200 Gallons for R38.
	2.50																
	2.50																
	3.00		R-38	60 100%	60 100%	R4	FR										
	3.00																
	3.00	225.0															
225		225.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	3.00																
480																	
	3.00																
	3.00		R-39	60 100%	60 100%	R4	FR										
	3.00									228.50	J	25	P,Sm	FR	T	N	
	3.00	230.0															
230									230.0 End of Boring at 230 feet BGS. Borehole grouted with cement and bentonite hole plug.								

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-13**

Figure B-13.1
B-13 Box 1 Runs 1-4 Dry

Figure B-13.2
B-13 Box 1 Runs 1-4 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-13

Figure B-13.3
B-13 Box 2 Runs 5-8 Dry

Figure B-13.4
B-13 Box 2 Runs 5-8 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-13

Figure B-13.5
B-13 Box 3 Runs 9-12 Dry

Figure B-13.6
B-13 Box 3 Runs 9-12 Wet

Figure B-13.7
B-13 Box 4 Runs 13-16 Dry

Figure B-13.8
B-13 Box 4 Runs 13-16 Wet

Figure B-13.9
B-13 Box 5 Runs 17-20 Dry

Figure B-13.10
B-13 Box 5 Runs 17-20 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-13

Figure B-13.11
B-13 Box 6 Runs 21-24 Dry

Figure B-13.12
B-13 Box 6 Runs 21-24 Wet

Figure B-13.13
B-13 Box 7 Runs 25-28 Dry

Figure B-13.14
B-13 Box 7 Runs 25-28 Wet

Figure B-13.15
B-13 Box 8 Runs 29-32 Dry

Figure B-13.16
B-13 Box 8 Runs 29-32 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-13

Figure B-13.17
B-13 Box 9 Runs 33-36 Dry

Figure B-13.18
B-13 Box 9 Runs 33-36 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-13

Figure B-13.19
B-13 Box 10 Runs 37-39 Dry

Figure B-13.20
B-13 Box 10 Runs 37-39 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-13

MOTT MACDONALD

SOIL BORING LOG

BORING NO.: **B-14**
Page **1** of **1**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Pohopoco Stream Crossing, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Jonathan Nelson
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	June 16, 2015 at 8:30 am
Driller/Helper:	Mike Gorski /Mark	**Date/Time Finished:**	June 22, 2015 at 2:00 pm

Elevation: 700 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off Penn Forest Road South **Coord.:** **N:** 40.884655 **E:** -75.556491 **Horizontal Datum:** NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	5	2	5
Inside Dia. (in.)	4	1.375	2.0
Hammer Wt. (lb.)	140	140	-
Hammer Fall (in.)	30	30	-

Rig Make & Model: CME-75

☑ Truck ☐ Tripod ☐ Cat-Head
☐ ATV ☐ Geoprobe ☑ Winch
☐ Track ☐ Air Track ☑ Roller Bit
☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut ☑ Automatic ☐ _____

Drilling Fluid: ☐ Bentonite ☐ Polymer ☑ Water ☐ None

Drill Rod Size: **Casing Advance:** Mud Rotary

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Group Symbol	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks
700	S-1 0.0'- 2.0'	7	2 4 3 2		ML	0.3 3" TOPSOIL Medium stiff, Dark brown SILT with Gravel, moist (ML)	N	-	NP	N	
						3.5					
	4.0'-'						-	-	-	-	Groundwater possibly encountered at 4.0 feet BGS.
5	S-2 5.0'- 7.0'	9.5	5 5 14 23		CL	Very stiff, Brownish yellow Lean CLAY with Gravel, wet (CL)	N	M	M	L	PP = 2.7 tsf. TV = 0.34 tsf.
						7.5					
10 690	S-3 10.0'- 12.0'	16	19 13 25 32		ML	Hard, Brownish yellow SILT with Gravel, trace Clay, moist (ML)	N	-	NP	L	PP = 3.8 tsf. TV = 0.14 tsf.
						13.5					
15	S-4 15.0'- 17.0'	18	45 49 61			Very dense, Dark gray to brown, Decomposed SHALE fragments, trace Silt, moist	N	M	M	N	
	S-5 19.0'-	3	50/1"			19.3 Very dense, Dark gray, SHALE fragments, wet Top of Rock at 19.3 feet BGS. See Rock Coring Log.	N	-	NP	N	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water

Sample Type

O Open End Rod
T Thin-Wall Tube
U Undisturbed Sample
S Split Spoon Sample
G Geoprobe

Notes:
PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-14**

Field Test Legend:
Dilatancy: N - None S - Slow R - Rapid
Toughness: L - Low M - Medium H - High
Plasticity: NP - Non-Plastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Medium H - High VH - Very High

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

CORE BORING LOG

BORING NO.: **B-14**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Pohopoco Stream Crossing, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Jonathan Nelson
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	June 16, 2015 at 8:30 am
Driller/Helper:	Mike Gorski /Mark	**Date/Time Finished:**	June 22, 2015 at 2:00 pm

Elevation: 700 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off Penn Forest Road South **Coord.: N:** 40.884655 **E:** -75.556491

Item	Casing	Core Barrel	Core Bit
Type	HW	NQ2	Imp. Diamond
Length (ft)	5	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Horizontal Datum: NAD 1983 **Rig Make & Model:** CME-75 **Drilling Method:** Wireline

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec (in. / %)	RQD (in / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
									SEE TEST BORING LOG FOR OVERBURDEN DETAILS								
20 680	16.62	19.3							SHALE, dark gray to black, fine grain, slightly weathered, very weak, extremely close spaced discontinuities								
										20.30	MB						
	15.33									20.70	J	50	P,Sm	DS	T	Fe	
	13.90		R-1	59 107%	8 14%	R1	SL										2nd to 3rd gear at 21.6 feet.
	9.75																3rd to 4th gear at 22.6 feet.
										22.90	J	44	P,Sm	DS	T	Fe	
	6.50	23.9								23.25	J	50	P,Sm	DS	T	Fe	
		23.9							SHALE, dark gray, fine grain, slightly weathered, weak, extremely close spaced discontinuities	23.90	J	54	P,Sm	DS	T	Fe	Loss of water 24.0 to 24.3 feet.
	7.08		R-2	13 98%	9 68%	R2	SL			24.40	J	54	P,Sm	DS	T	Fe	
25		25.0															
	6.85	25.0							SHALE, dark gray, fine grain, slightly weathered, very weak, extremly close spaced discontinuities								Loss of water 25.5 to 27.0 feet.
	6.28																
	6.28		R-3	60 100%	11 18%	R1	SL			27.70	J	50	P,Sm	DS	T	N	
										28.25	MB						
	6.67									28.40	J	50	P,Sm	DS	PO	N	
										28.80	MB						
	7.4	30.0															
30 670		30.0							SHALE, dark gray, fine grain, slightly weathered, weak, very close spaced discontinuities	30.00	J	51	P,Sm	DS	PO		
	7.00									30.50	MB						
										30.75	J	54	P,R	DS	T	CL	
	7.06									31.00	MB						
										31.55	J	44	S,Sm	FR	T		
										31.85	J	60	P,Sm	DS	T		
	7.40		R-4	60 100%	37 61%	R2	SL			32.10	MB						
	5.67									33.50	J	38	P,Sm	DS	T		
										33.95	MB						
	6.33	35.0															
35		35.0							SHALE dark gray, fine grain, fresh, weak, very close spaced discontinuities with iron stains	34.65	J	50	S,Sm	DS	O		
	5.75									35.15	MB						
										35.45	J	65	S,Sm	FR	T	N	
										36.10	J	76	P,Sm	FR	T	N	
	4.85									36.20	J	57	P,R	FR	T	N	
										36.70	J	60	P,R	FR	PO	N	
	6.22		R-5	59 98%	44 73%	R2	FR			36.75	J	55	P,Sm	FR	T	N	
										37.75	J	80	S,R	FR	PO	N	
										38.00	J	60	P,Sm	FR	T	N	
	5.00									38.55	J	60	P,Sm	FR	PO	N	
	5.85									38.90	J	50	P,Sm	FR	T	N	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
		-			

Notes:

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	5.85	40.0								39.75	MB						
40 660	5.17	40.0							SHALE, black, fine grain, fresh, weak, extremely close spaced discontinuities	40.15	J	65	X,Wa	DS	T	N	
										40.60	MB						
	6.90									41.70	J	60	P,R	FR	T	N	
	7.00		R-6	58 97%	26 43%	R2	FR			42.15	J	60	P,Sm	FR	T	N	
										42.85	J	52	P,R	FR	T	N	
	6.00																
	5.62	45.0								44.44	MB						
45	4.50	45.0							SHALE, black, fine grain, fresh, weak, extremely close spaced discontinuities	45.00	J	51	P,Sm	FR	T	N	
										45.60	MB						
	4.08									46.60	J	62	P,Wa	FR	T	N	
	3.70		R-7	60 100%	46 77%	R2	FR			47.60	J	59	P,Sm	FR	T	N	
	4.60																
	4.35	50.0							49.15' - 50' Highly fractured zone	49.15	MB						
50 650	4.50	50.0							SHALE, black, fine grain, fresh, weak, extremely close spaced discontinuities								Water loss at 50.7 feet.
	4.20									51.05	J	35	P,Wa	FR	T	N	
										51.60	J	56	S,Sm	FR	T	N	
										51.85	J	52	P,Sm	FR	T	N	
	5.33		R-8	60 100%	38 63%	R2	FR			52.25	J	60	P,Wa	FR	T	N	
	4.80									53.50	J	59	P,Sm	FR	PO	N	
										54.10	MB						
	4.25	55.0								54.45	J	47	P,Wa	FR	T	N	
55	2.50	55.0							SHALE, black, fine grain, slightly weathered, weak, extremely close spaced discontinuities								
										56.00	MB						
	2.50									56.55	J	25	P,Sm	FR	T	N	
	3.25		R-9	54 90%	16 26%	R2	SL										
	4.28									58.25	J	50	P,Wa	FR	T	N	
										58.65	J	51	P,Wa	FR	T	N	
										58.85	J	53	P,Wa	FR	T	N	
	5.17	60.0								59.20	J	51	P,Wa	FR	T	N	
60 640	3.35	60.0							SHALE, black, fine grain, fresh, weak, extremely close spaced discontinuities	60.00	J	64	P,Sm	FR	T	N	
	3.67									61.55	MB						
	3.50		R-10	59 98%	30 50%	R2	FR			62.20	MB						
										62.55	J	70	U,Wa	FR	T	N	
	3.08									63.60	J	47	P,Wa	FR	T	N	
	3.90									64.20	J	44	P,Wa	FR	T	N	
										64.45	J	24	P,Wa	FR	T	N	

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
		65.0															
65		65.0							SHALE, black, fine grain, fresh, weak, extremely close spaced discontinuities	64.90	MB						
	3.75									65.80	MB						
	3.33									66.35	J	63	P,Sm	FR	T	N	
	3.22		R-11	58 97%	44 73%	R2	FR										
	3.17									68.45	J	76	P,Sm	FR	T	N	
	3.22	70.0								69.75	J	51	P,Wa	FR	T	N	
70 630		70.0							SHALE, black, fine grain, fresh, weak, extremely close spaced discontinuities	70.10	MB						
	4.00									70.50	J	50	P,Sm	FR	PO	CL	
										70.85	J	57	P,Wa	FR	T	N	
	3.32									72.05	J	54	P,Sm	FR	T	N	
	3.20		R-12	60 100%	53 88%	R2	FR			72.20	J	59	P,Sm	FR	T	N	
	3.30																
	3.10	75.0															
75		75.0							SHALE, black, fine grain, fresh, weak, extremely close spaced discontinuities	75.00	J	55	S,Wa	FR	T	N	
	3.50																
	3.60									76.70	J	55	P,Sm	FR	T	N	
	3.50		R-13	58 96%	56 93%	R2	FR										
	3.60									78.75	J	39	S,R	FR	T	N	
	3.75	80.0								79.75	J	50	U,R	FR	T	N	
80 620		80.0							SHALE, black, fine grain, fresh, weak, extremely close spaced discontinuities	80.20	J	48	P,Sm	FR	T	N	
	3.33																
	3.25									82.05	MB						
	3.50		R-14	60 100%	47 78%	R2	FR			82.20	J	67	P,Sm	FR	T	N	
	3.35																
	3.90	85.0								84.30	J	72	P,R	FR	T	N	
85		85.0							SHALE, black, fine grain, fresh, weak, exremely close spaced discontinuities	85.10	J	54	P,Sm	FR	T	N	
	3.87									85.45	J	34	S,Sm	FR	T	N	
	3.83									86.50	MB						
	3.17		R-15	59 99%	48 80%	R2	FR			87.47	J	52	P,Sm	FR	T	N	
	3.15									88.70	J	46	S,Sm	FR	T	N	
	2.50	90.0								89.35	MB						
90 610		90.0								89.85 90.00	J MB	51	P,Sm	FR	T	N	

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-14**
Page **4** of **4**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.25								SHALE, black, fine grain, fresh, weak, extremely close spaced discontinuities								
	4.30																
	3.83		R-16	60 100%	55 92%	R2	FR			92.00	J	61	U,R	FR	T	N	
										92.35	J	52	S,Sm	FR	T	N	
	4.35																
	4.57	95.0															
95																	
	3.55	95.0							SHALE, black, fine grain, fresh, weak, exremely close spaced discontinuities	95.00	J	55	U,Sm	FR	T	N	
										95.75	J	56	S,Sm	FR	T	N	
	3.67																
	4.00		R-17	55 91%	50 83%	R2	FR										
	3.75																
	3.17	100.0								99.35	J	60	U,Wa	FR	T	N	
100 600									100.0 End of Boring at 100 feet BGS. Borehole grouted with cement and bentonite hole plug.								
105																	
110 590																	
115																	

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-14**

Figure B-14.1
B-14 Box 1 Run 1-5 Dry

Figure B-14.2
B-14 Box 1 Run 1-5 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-14

Figure B-14.3
B-14 Box 2 Run 5-9 Dry

Figure B-14.4
B-14 Box 2 Run 5-9 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-14

Figure B-14.5
B-14 Box 3 Run 9-12 Dry

Figure B-14.6
B-14 Box 3 Run 9-12 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-14

Figure B-14.7
B-14 Box 4 Run 13-16 Dry

Figure B-14.8
B-14 Box 4 Run 13-16 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-14

Figure B-14.9
B-14 Box 5 Run 17 Dry

Figure B-14.10
B-14 Box 5 Run 17 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-14

MOTT MACDONALD

SOIL BORING LOG

BORING NO.: **B-15**
Page **1** of **1**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Bernard Cortes
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	January 28, 2016 at 7:45 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	February 1, 2016 at 3:00 pm

Elevation: 654 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off Bethlehem Authority ROW. **Coord.:** **N:** 40.883806 **E:** -75.553972 **Horizontal Datum:** NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	5	2	5
Inside Dia. (in.)	4	1.375	2.0
Hammer Wt. (lb.)	140	140	-
Hammer Fall (in.)	30	30	-

Rig Make & Model: CME-750X

☐ Truck ☐ Tripod ☐ Cat-Head
☑ ATV ☐ Geoprobe ☑ Winch
☐ Track ☐ Air Track ☑ Roller Bit
☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut ☑ Automatic ☐ _____

Drilling Fluid: ☐ Bentonite ☐ Polymer ☑ Water ☐ None

Drill Rod Size:

Casing Advance: Mud Rotary

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Group Symbol	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks
					ML	Hand Augured to 5 feet BGS					
650											
5	S-1 5.0'- 7.0'	24	6 13 25 12		ML	Very stiff, Light brown SILT with Decomposed Shale fragments, dry to wet (ML)	N	-	NP	N	TV = 0.75 tsf
	S-2 7.0'- 9.0'	24	6 13 25 12		ML	Very stiff, Light brown Clayey SILT with Decomposed Shale fragments, dry (ML)	N	L	L	L	TV = 0.75 tsf Advanced casing to 10 feet BGS.
						9.5					
10	S-3 10.0'- 10.4'	5	100/5"			Very dense, Dark gray DECOMPOSED SHALE fragments with Clayey Silt, dry	N	L	L	N	
640	S-4 14.0'- 14.2'	2	50/2"			Very dense, Dark gray DECOMPOSED SHALE fragments with Silt, moist	N	-	NP	N	
15						18.0					
						No Recovery. Top of Rock at 18 feet BGS. See Rock Coring Log.					

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
1/29/16	7:30	-			7.3
2/4/16	0:00	0:00	30.0	175.0	-15.3

Sample Type

O Open End Rod
T Thin-Wall Tube
U Undisturbed Sample
S Split Spoon Sample
G Geoprobe

Notes:

PP = Pocket Penetrometer
TV = Torvane
Upon completion of drilling a pressure data logger was installed at 133ft below ground surface for 48 hours, the borehole top was sealed and the pressure rose to 64.3psi by the end of monitoring, indicating an artesian condition of 15.3ft above ground surface. It is noted that the pressure curve had not fully stabilized at time of measurement termination and it is approximated that pressures may have rose to 17ft above ground surface.

Boring No.: **B-15**

Field Test Legend:
Dilatancy: N - None S - Slow R - Rapid
Toughness: L - Low M - Medium H - High
Plasticity: NP - Non-Plastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Medium H - High VH - Very High

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

CORE BORING LOG

BORING NO.: **B-15**
Page **1** of **7**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Bernard Cortes
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	January 28, 2016 at 7:45 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	February 1, 2016 at 3:00 pm

Elevation: 654 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off Bethlehem Authority ROW. **Coord.:** **N:** 40.883806 **E:** -75.553972

Item	**Casing**	**Core Barrel**	**Core Bit**
Type	HW	NQ2	Imp. Diamond
Length (ft)	5	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Horizontal Datum: NAD 1983
Rig Make & Model: CME-750X
Drilling Method: Wireline

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec (in. / %)	RQD (in / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
									SEE TEST BORING LOG FOR OVERBURDEN DETAILS								
	2.50	20.0							SLATE, Dark gray, very fine grained, fresh, strong, extremely close to moderately spaced discontinuities	20.30	MB						
	2.50									21.20	J	60	P,Sm	FR	VT	N	
										21.50	J	40	P,Sm	FR	VT	N	
										21.90	J	65	P,Sm	FR	VT	N	
	2.25		R-1	60 100%	34 57%	R4	FR			22.50	J	60	P,Sm	FR	VT	N	
	4.00								23.3' - 25' Highly fractured zone								
630	1.00	25.0															
25	2.00	25.0							SLATE, Dark gray, very fine grained, fresh, strong, extremely close to close spaced discontinuities 25.6' - 25.5' Highly fractured zone								
	2.00									26.50	J	55	P,R	FR	VT	Ca	
										26.90	J	60	X,R	FR	PO	Ca	
	3.00		R-2	60 100%	11 18%	R4	FR			27.40	J	50	P,R	FR	T	N	
										28.00	J	50	P,Sm	FR	VT	N	
	3.00								28.8' - 29.1' Highly fractured zone								
	2.00	30.0															
30	2.00	30.0							SLATE, Dark gray, very fine grained, fresh, medium strong, extremely close to wide spaced discontinuities	30.50	J	90	P,R	FR	VT	Ca	
	2.00																
										31.80	J	40	P,R	FR	VT	Ca	
	2.00		R-3	60 100%	52 87%	R3	FR			32.00	J	70	P,R	FR	VT	Ca	
										32.90	J	50	P,R	FR	T	N	
	2.00																
620	2.00	35.0															
35	2.00	35.0							SLATE, Dark gray, very fine grained, fresh, medium strong, extremely close to wide spaced discontinuities								
	2.00									36.10	J	40	P,R	FR	PO	N	
	2.50		R-4	60 100%	57 95%	R3	FR			37.10	J	40	P,R	FR	VT	N	
	2.00									38.60	J	40	P,Sm	FR	VT	N	
	2.00	40.0															

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
1/29/16	7:30	-			7.3
2/4/16	0:00	0:00	30.0	175.0	-15.3

Notes:

SEE TEST BORING LOG FOR OVERBURDEN DETAILS

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-15**
Page **2** of **7**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
		40.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	2.00																
	2.00																
	2.00		R-5	60 100%	54 90%	R4	FR										
	2.00																
610																	
	2.00									44.10	J		X,R	DE	O	N	
		45.0								44.60	J	30	P,R	FR	T	N	
45		45.0							SLATE, Dark gray, very fine grained, fresh, medium strong, close to wide spaced discontinuities								
	2.50																
	2.50									46.30	J	40	P,Sm	FR	VT	N	
										46.60	J	80	P,R	DE	T	N	
	2.50		R-6	60 100%	60 100%	R3	FR										
										48.00	J		X,R	DE	O	N	
	3.00									48.60	J		X,R	DE	O	N	
	3.00	50.0															
50		50.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	2.00																
	2.00									51.10	J	60	P,R	FR	VT	N	
										52.00	J	50	P,R	FR	T	N	
	2.50		R-7	60 100%	60 100%	R4	FR										
	2.50									53.50	J	40	P,R	FR	PO	N	
600																	
	2.00	55.0								54.70	MB						
55		55.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								
	2.00									55.70	MB						
	2.00									56.20	J		X,R	FR	O	N	
	2.00		R-8	60 100%	45 75%	R4	FR										
	2.50																
	2.50									58.80	J	70	P,R	FR	O	N	
		60.0															
60		60.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	2.25																
	2.50																
	2.25		R-9	52 87%	50 83%	R4	FR			62.10	J	70	P,R	FR	T	N	
	2.50																
590																	
	2.50								64.2' Highly fractured zone	64.20	J	30	P,R	FR	T	N	
		65.0															
65		65.0							SLATE, Dark gray, very fine grained, fresh, strong,								

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-15**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-15**
Page **3** of **7**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.50								close to wide spaced discontinuities	65.60	J	66.7	P,R	FR	T	N	
	2.50																
	2.50		R-10	60 100%	52 87%	R4	FR										
	2.50																
	2.50	70.0															
70		70.0							SLATE, Dark gray, very fine grained, fresh, strong, extremely close to wide spaced discontinuities	70.20	J	30	P,Sm	FR	VT	N	
	2.00																
	2.00																
	2.00		R-11	60 100%	52 87%	R4	FR			72.00	J	30	P,R	FR	O	N	
	2.00									73.40	J	40	P,Sm	FR	VT	N	
580																	
	2.50	75.0								74.40	J	60	P,R	FR	VT	N	
75		75.0								74.70	J	40	P,R	FR	T	N	
	5.00								SLATE, Dark gray, very fine grained, fresh, medium strong, extremely close to close spaced discontinuities 75' - 80' Highly fractured zone								
	2.00																
	2.00		R-12	52 87%	9 15%	R3	FR										
	2.00																
	2.00									78.90	J	50	P,R	DS	PO	Fe	
	2.00	80.0								79.20	J	40	P,R	DS	PO	Fe	
80		80.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	2.50																
	2.00									81.40	J	30	P,R	DE	PO	Ca	
	2.50		R-13	60 100%	60 100%	R4	FR										
	2.50																
570																	
	2.50	85.0															
85		85.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	2.00																
	2.00									85.80	MB						
	2.00		R-14	60 100%	57 95%	R4	FR										
	4.00																
	4.00	90.0								89.30	J	50	P,R	FR	VT	N	
90		90.0							SLATE, Dark gray, very fine grained, fresh, strong, extremely close to wide spaced discontinuities 90' - 96.9' Highly fractured zone								
	4.00																

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-15**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-15**
Page **4** of **7**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.00																
	3.00		R-15	60 100%	29 48%	R4	FR			92.40	J	30	P,Sm	FR	VT	N	
										92.90	MB						
	3.00									93.60	MB						
560	3.50	95.0								94.50	MB						
95	3.50	95.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities 95' - 95.8' Highly fractured zone								
	3.00																
	3.00		R-16	60 100%	48 80%	R4	FR										
	3.00																
	3.50	100.0															
100	3.00	100.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	3.00									101.50	J	70	P,R	FR	VT	N	
										101.90	J	40	P,R	FR	VT	N	
	3.00		R-17	60 100%	54 90%	R4	FR			102.40	J	50	P,R	FR	VT	N	
	3.50									103.20	J	25	P,R	FR	VT	N	
550	3.50	105.0															
105	3.00	105.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	3.50																
	3.50		R-18	60 100%	60 100%	R4	FR										
										108.00	J	40	P,K	FR	VT	N	
	3.50																
	3.50	110.0															
110	3.00	110.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	3.00																
	3.00		R-19	60 100%	60 100%	R4	FR										
	3.00																
540										113.70	MB						
	3.00	115.0								114.50	MB						
115	3.00	115.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Used up to 275 Gallons for R1 through R20.

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-15**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-15**
Page **5** of **7**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00																
	3.00																
	3.00		R-20	60 100%	52 87%	R4	FR										
	3.25																
	3.25	120.0								119.30	J	50	P,R	DS	T	Ca	
										119.40	J	60	P,R	DS	T	Ca	
120																	
	3.00	120.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	3.00																
	3.00		R-21	60 100%	60 100%	R4	FR										
	3.00																
530																	
	3.00	125.0								124.70	MB						
125																	
	3.00	125.0							SLATE, Dark gray, very fine grained, fresh, strong extremely close to wide spaced discontinuities								
	3.00																
	3.00		R-22	60 100%	48 80%	R4	FR										
	3.00																
	3.00	130.0															Possible Artesian Condition at 128.5 feet.
130																	
	2.50	130.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontiniuties								Possible Artesian Condition.
	2.50																
	2.50		R-23	60 100%	60 100%	R4	FR										
	2.50																
520																	
	2.50	135.0															
135																	
	2.50	135.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Used up to 275 Gallons for R21/R22/R23/R24. Possible Artesian Condition.
	2.50																
	2.50		R-24	60 100%	60 100%	R4	FR										
	2.50																
	7.50	140.0								139.10	J	75	P,R	FR	PO	N	
140																	
	3.00	140.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	3.00																

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-15**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-15**
Page **6** of **7**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00																
	3.00		R-25	60 100%	60 100%	R4	FR										
	3.00																
510	2.50	145.0															
145	5.00	145.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Possible Artesian Condition.
	3.00																
	3.00		R-26	60 100%	56 93%	R4	FR										
	3.00									148.60	J	50	P,R	DS	PO	QZ	
										148.70	J		X,R	DS	PO	QZ	
	3.00	150.0															
150	3.00	150.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Possible Artesian Condition.
	3.00																
	3.00		R-27	60 100%	56 93%	R4	FR			151.90	J	40	P,R	DS	PO	QZ	
	3.00																
500	3.00	155.0								153.90	J	80	P,R	FR	T	QZ	
155	3.00	155.0							SLATE, Dark gray, very fine grained, fresh, strong, extremely close to close spaced discontinuities								Possible Artesian Condition.
										155.60	MB						
	3.00									156.00	J	30	P,Sm	DG	PO	N	
	3.00								156.3' - 156.7' Highly fractured zone								
	3.00		R-28	60 100%	0 0%	R4	FR			157.00	J	30	P,Sm	DS	T	N	
									157.5' - 159.7' Highly fractured zone								
	3.00																
	3.00	160.0															
160	3.00	160.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								Changed Core Bit.
										160.30	MB						
	3.00																
	3.00		R-29	60 100%	42 70%	R4	FR										
	3.00									163.10	J	50	P,Sm	FR	T	N	
490	3.00	165.0								164.30	J	50	P,Sm	DG	MW	N	
										164.60	J	90	P,R	DG	PO	N	
165	3.00	165.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	3.00																

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-15**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-15**
Page **7** of **7**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00		R-30	60 100%	56 93%	R4	FR										
	3.00									168.30	J	60	P,Sm	FR	VT	N	
	3.00	170.0								169.60	J	70	P,R	DG	VW	N	
170		170.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	3.00																
	3.00																
	3.00		R-31	60 100%	54 90%	R4	FR			172.30	J	40	P,Sm	FR	T	N	
	3.00																
480	3.00	175.0							175.0								
175									End of Boring at 175 feet BGS. Borehole grouted with cement and bentonite hole plug.								
180																	
470																	
185																	
190																	

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-15**

Figure B-15.1
B-15 Box 1 Runs 1-4 Dry

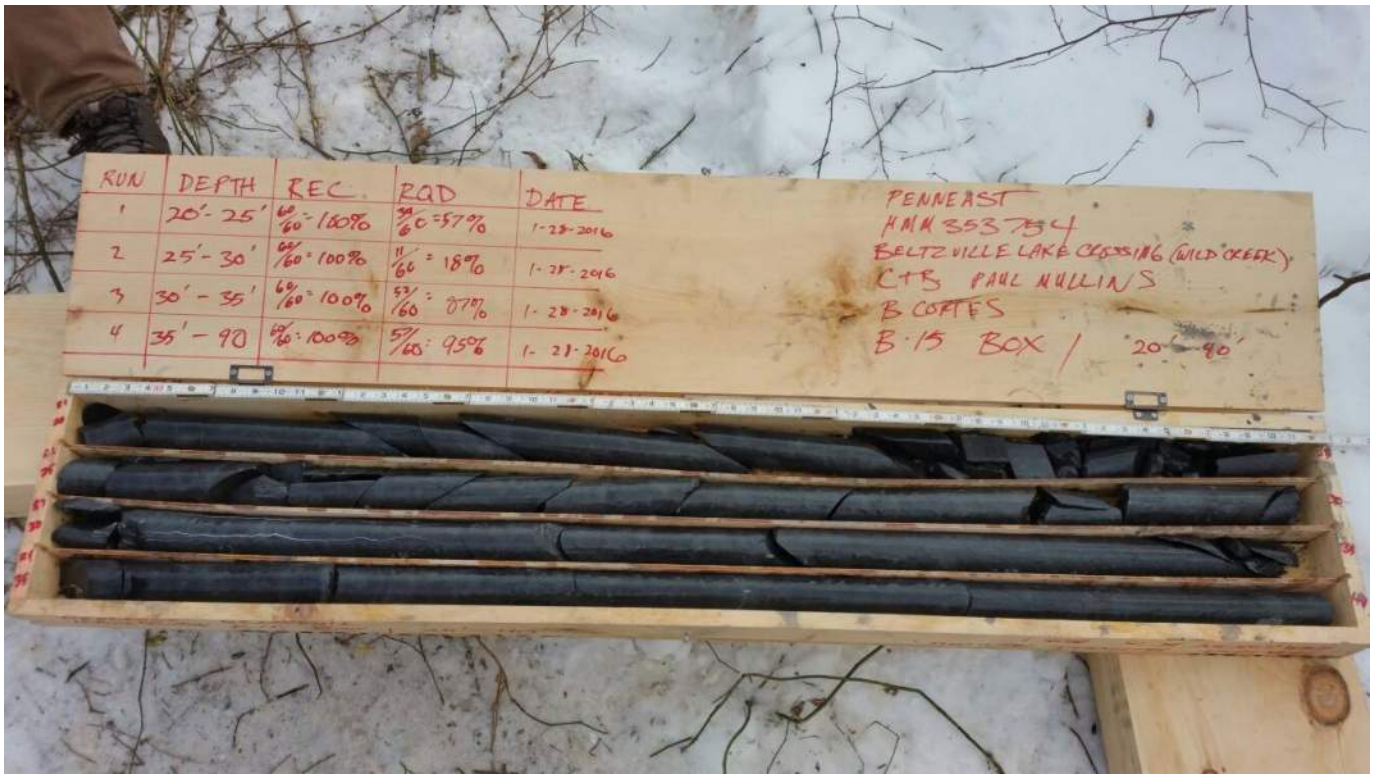

Figure B-15.2
B-15 Box 1 Runs 1-4 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-15

Figure B-15.3
B-15 Box 2 Runs 5-8 Dry

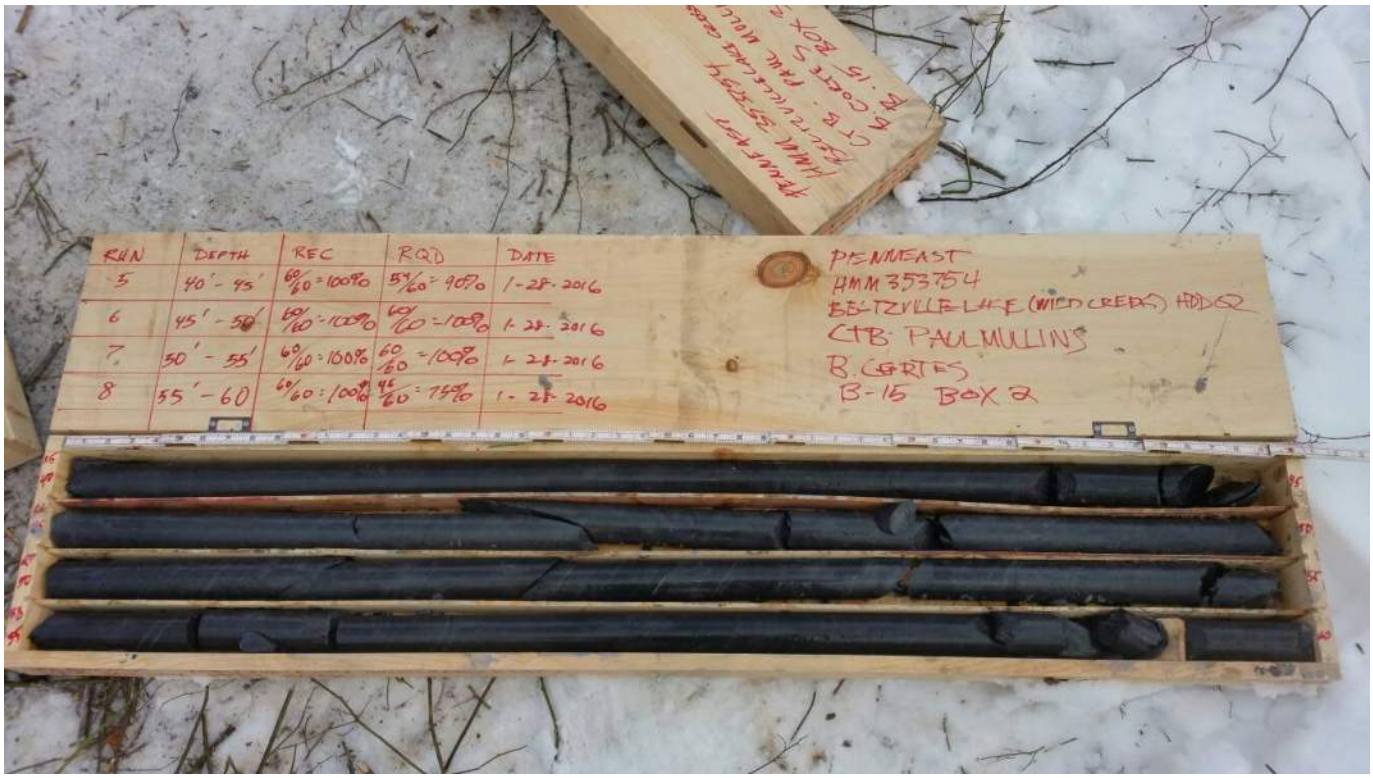

Figure B-15.4
B-15 Box 2 Runs 5-8 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-15

Figure B-15.5
B-15 Box 3 Runs 9-12 Dry

Figure B-15.6
B-15 Box 3 Runs 9-12 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-15

Figure B-15.7
B-15 Box 4 Runs 13-16 Dry

Figure B-15.8
B-15 Box 4 Runs 13-16 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-15

Figure B-15.9
B-15 Box 5 Runs 17-20 Dry

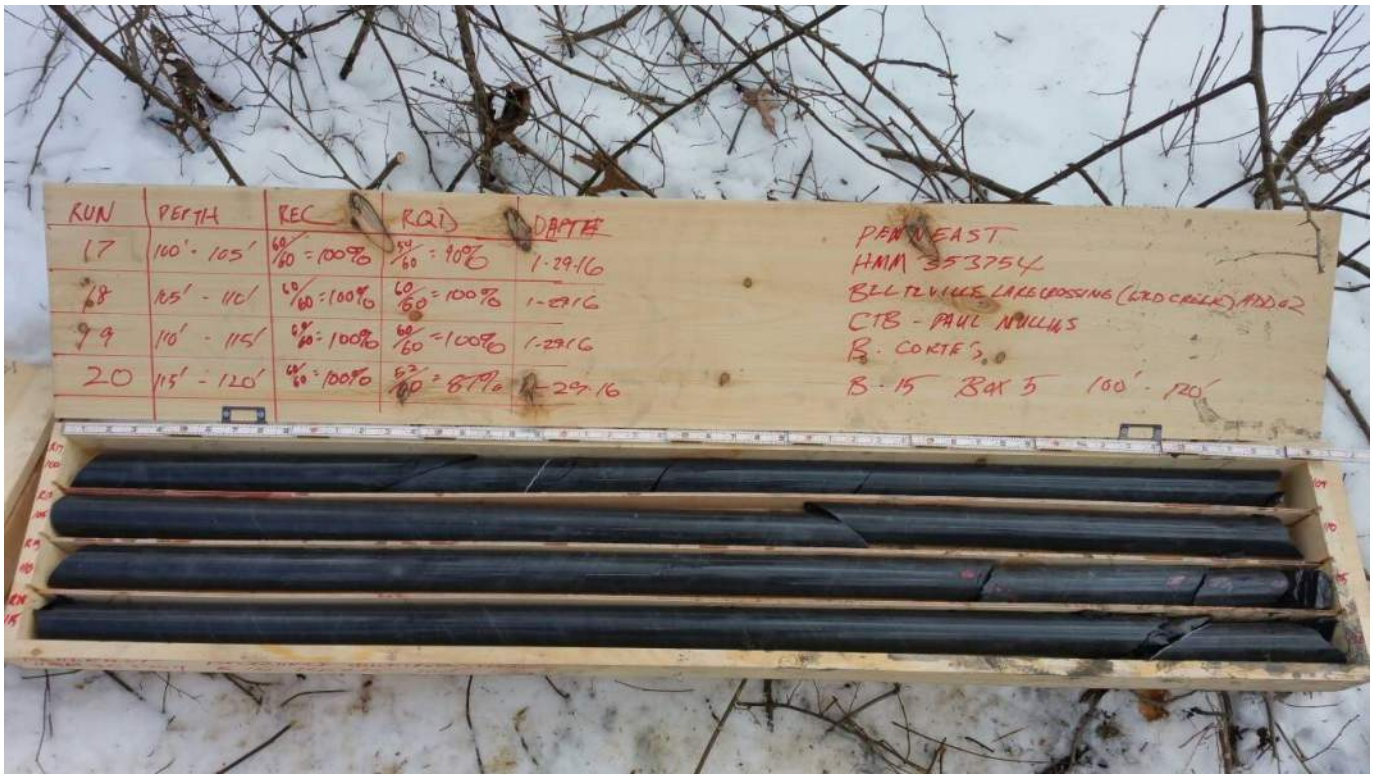

Figure B-15.10
B-15 Box 5 Runs 17-20 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-15

Figure B-15.11
B-15 Box 6 Runs 21-24 Dry

Figure B-15.12
B-15 Box 6 Runs 21-24 Wet

	PennEast Pipeline Project **Rock Core Photographs**	**BORING NO.:** B-15

Figure B-15.13
B-15 Box 7 Runs 25-28 Dry

Figure B-15.14
B-15 Box 7 Runs 25-28 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-15

Figure B-15.15
B-15 Box 8 Runs 29-31 Dry

Figure B-15.16
B-15 Box 8 Runs 29-31 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-15

MOTT MACDONALD

SOIL BORING LOG

BORING NO.: **B-16**
Page **1** of **1**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	January 6, 2016 at 11:15 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	January 11, 2016 at 3:15 pm

Elevation: 638 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** 45' West of Pipe, in the woods. **Coord.:** **N:** 40.882499 **E:** -75.552343 **Horizontal Datum:** NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	5	2	5
Inside Dia. (in.)	4	1.375	2.0
Hammer Wt. (lb.)	140	140	-
Hammer Fall (in.)	30	30	-

Rig Make & Model: CME-750X

☐ Truck ☐ Tripod ☐ Cat-Head
☑ ATV ☐ Geoprobe ☑ Winch
☐ Track ☐ Air Track ☑ Roller Bit
☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type
☐ Safety
☐ Doughnut
☑ Automatic
☐ _____

Drilling Fluid
☐ Bentonite
☐ Polymer
☑ Water
☐ None

Drill Rod Size:

Casing Advance
Mud Rotary

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Group Symbol	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks
	S-1 0.0'- 2.0'	6	1 1 1 1		OL	Very soft, Brown Organic SILT, roots and other plant matter	-	-	-	-	
						2.5					
	3.0'-'						-	-	-	-	Difficult driving casing at 3 feet BGS.
5	S-2 5.0'- 6.0'	10	95 135		GP	Very dense, Black DECOMPOSED SHALE fragments, wet	-	-	-	-	
630											
10	S-3 10.0'- 10.5'	4	105/5"		GP	Very dense, Black DECOMPOSED SHALE fragments, wet	-	-	-	-	
						15.0					
15	S-4 15.0'- 15.1'		50/1"			No Recovery Top of Rock at 15 feet BGS. See Rock Coring Log.	-	-	-	-	
620											

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
1/6/16	11:15	-	3.0	45.0	5
1/11/16	7:30	-		160.0	10.8

Sample Type

O Open End Rod
T Thin-Wall Tube
U Undisturbed Sample
S Split Spoon Sample
G Geoprobe

Notes:

Groundwater at Lake Level = 5 feet BGS
PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-16**

Field Test Legend:
Dilatancy: N - None S - Slow R - Rapid
Toughness: L - Low M - Medium H - High
Plasticity: NP - Non-Plastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Medium H - High VH - Very High

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

CORE BORING LOG

BORING NO.: **B-16**
Page **1** of **7**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	January 6, 2016 at 11:15 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	January 11, 2016 at 3:15 pm

Elevation: 638 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** 45' West of Pipe, in the woods. **Coord.: N:** 40.882499 **E:** -75.552343

Item	Casing	Core Barrel	Core Bit
Type	HW	NQ2	Imp. Diamond
Length (ft)	5	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Horizontal Datum: NAD 1983
Rig Make & Model: CME-750X
Drilling Method: Wireline

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec (in. / %)	RQD (in / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
									SEE TEST BORING LOG FOR OVERBURDEN DETAILS		(See Legend for Rock Description System)						
	3.00	15.0							SHALE, Dark gray, very fine grained, slightly weathered, weak, very close spaced discontinuities 15' - 18.5' Highly fractured zone								
	1.60																
	1.80		R-1	60 100%	4 7%	R2	SL										
620	2.00									18.50	J	60	P,Sm	DS	VT	N	
	2.00									19.00	B	20	P,R	DS	T	N	
		20.0															
20		20.0							SHALE, Dark gray, very fine grained, slightly weathered, weak, very close spaced discontinuities								
	3.00									20.50	J	50	P,Sm	DS	T	N	
	4.00								21' - 23.2' Highly fractured zone								
	3.00		R-2	56 93%	22 37%	R2	SL										
	3.00									23.40	J	50	P,Sm	DS	T	N	
	3.00									24.00 24.20	J J J	50 50	P,Sm P,Sm	DS FR	T VT	N N	
		25.0															
25		25.0							SHALE, Dark gray, very fine grained, slightly weathered, weak, close spaced discontinuities	25.00 25.10	J B	60 40	P,Sm P,Sm	DS DS	VT VT	N N	
	3.00									25.80 26.00	B B	30 60	P,Sm P,Sm	FR FR	VT VT	N N	
	2.00									26.50	B	65	P,Sm	FR	VT	N	
	3.00		R-3	60 100%	42 70%	R2	SL			27.20	B	60	P,Sm	FR	VT	N	
610										28.00	B	60	P,Sm	FR	VT	N	
	3.00									28.30 28.40	B B	60 20	P,Sm P,Sm	FR FR	VT VT	N N	
	3.00									29.20	B	45	P,Sm	FR	VT	N	
		30.0								29.60	B	60	P,Sm	FR	VT	N	
30		30.0							SHALE, Dark gray, very fine grained, slightly weathered, weak, close spaced discontinuities								
	2.00																
	2.00									31.50 31.60	B B	70 30	P,Sm P,Sm	FR FR	VT VT	N N	
	2.00		R-4	60 100%	38 63%	R2	SL										
	2.00									33.00	B	30	P,Sm	FR	VT	N	
	2.00									33.50	B	30	P,Sm	FR	VT	N	
										33.90	B	30	P,Sm	FR	VT	N	
		35.0							34' - 35' Highly fractured zone								

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
1/6/16	11:15	-	3.0	45.0	5.0
1/11/16	7:30	-		160.0	10.8

Notes:

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.00	35.0							SHALE, Dark gray, very fine grained, slightly weathered, weak, close spaced discontinuities	35.50	B	40	P,Sm	FR	VT	N	
	3.00									36.20	B	40	P,Sm	FR	VT	N	
	2.00		R-5	60 100%	53 88%	R2	SL		37.4' - 38' Highly fractured zone	37.40	J	20	P,Sm	FR	VT	N	
600	2.00									38.00	B	20	P,Sm	FR	VT	N	
	2.00									38.50	J	30	P,Sm	FR	VT	N	
	2.00	40.0								39.30	B	31	P,Sm	FR	VT	N	
40		40.0								39.50	J	60	P,Sm	FR	VT	N	
	2.00								SHALE, Dark gray, very fine grained, fresh, weak, moderately spaced discontinuities								
	3.00																
	2.00		R-6	58 97%	57 95%	R2	FR										
	2.00									43.80	B	40	P,Sm	FR	VT	N	
	3.00	45.0								44.80	J	40	P,Sm	FR	VT	N	
45		45.0							SHALE, Dark gray, very fine grained, fresh, weak, moderately spaced discontinuities								
	4.00																
	3.00																
	2.50		R-7	60 100%	55 92%	R2	FR										
590	3.00									47.80	B	40	P,R	FR	VT	N	
	3.50	50.0								49.50	MB						
50		50.0							SHALE, Dark gray, very fine grained, fresh, weak, moderately spaced discontinuities								
	2.00									50.50	MB						
	3.00									51.40	MB						
	2.50		R-8	57 95%	56 93%	R2	FR			52.00	MB						
	2.50																
	2.50	55.0															
55		55.0							SHALE, Dark gray, very fine grained, fresh, weak, moderately spaced discontinuities								
	2.50																
	3.00																
	2.50		R-9	56 93%	45 75%	R2	FR		57.5' - 58.3' Highly fractured zone								
580	3.00																
	3.50	60.0								59.10	B	40	P,R	FR	T	N	
60		60.0							SHALE, Dark gray, very fine grained, fresh, weak, moderately spaced discontinuities								

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.50									60.50	B	30	S,R	FR	VT	N	
	3.50																
	3.00		R-10	60 100%	22 37%	R2	FR		61.9' Firm, Black CLAY, organic odor (2" thick) 62.1' - 70' Highly Fractured Zone	61.90	B	0	S,R	DE	VW	CL	
	3.00																
	3.00	65.0															
65		65.0							SHALE, Dark gray, very fine grained, fresh, weak, very close to close spaced discontinuities								Majority of discontinuities are bedding fractures. Occasional Pyrite crystal precipitation on bedding joint surfaces. Occasional Clay infill on joints.
	3.50																
	3.50																
	4.00		R-11	58 97%	37 62%	R2	FR										
570	3.00																
	3.50	70.0															
70		70.0							SHALE, Dark gray, very fine grained, fresh, weak, moderately spaced discontinuities								
	3.00																
	3.50																
	3.00		R-12	60 100%	40 67%	R2	SL										
	3.00								73.5' - 85' Highly fractured zone 73.5' - 73.6' Brown Clay infill	73.50	B	20	P,R	DS	O	Ca	
	4.00	75.0															
75		75.0							SHALE, Dark gray, very fine grained, slightly weathered, weak, close spaced discontinuities								All fractures are along bedding planes.
	2.50																
	2.50																
	3.50		R-13	60 100%	37 62%	R2	SL										
560	3.50																
	3.00	80.0															
80		80.0							SHALE, Dark gray, very fine grained, slightly weathered, weak, close spaced discontinuities								
	3.50																
	3.70									81.00	J	75	P,R	DS	O	QZ	
	5.00		R-14	60 100%	27 45%	R2	SL										
	5.50																
	5.00	85.0															
85		85.0							SHALE, Dark gray, very fine grained, slightly weathered, weak, close spaced discontinuities								
	4.00																

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-16**
Page **4** of **7**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.50																
	4.50		R-15	58 97%	18 30%	R2	SL		87' - 87.5' 0.75" Quartz vein. 1" eitherside, SHALE is Leached to Light gray	87.00	V	30	P,R	DG	MW	QZ	
550	4.50																
	5.50	90.0															
90	2.30	90.0							SHALE, Dark gray, very fine grained, fresh, medium strong, wide spaced discontinuities								No discontinuities.
	3.00																
	4.00		R-16	60 100%	60 100%	R3	FR										
	3.00																
	3.00	95.0															
95	3.00	95.0							SHALE, Dark gray, very fine grained, fresh, medium strong, very wide to wide spaced discontinuities								No discontinuities.
	2.50																
	2.50		R-17	60 100%	60 100%	R3	FR										
540	2.80																
	3.00	100.0															
100	3.50	100.0							SHALE, Dark gray, very fine grained, fresh, medium strong, very wide to wide spaced discontinuities								Occasional fine Quartz vein No discontinuities.
	3.50																
	3.50		R-18	60 100%	60 100%	R3	FR										
	3.50																
	3.50	105.0															
105	3.50	105.0							SHALE, Dark gray, very fine grained, fresh, medium strong, very wide to wide spaced discontinuities								
	3.50																
	3.50		R-19	60 100%	60 100%	R3	FR										
530	4.00									108.00	V	30	P,Sm	FR	VT	QZ	
	3.50	110.0															108.5' - 110' Core dropped out of barrel. Redrilled, core was solid now broken.
110	4.00	110.0							SHALE, Dark gray, very fine grained, fresh, medium strong, wide spaced discontinuities								RQD likely 100% in the ground, mechanical breaks
	3.50									110.90	B	30	P,R	FR	VT	N	Used up to 1,200 Gallons for R7

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-16**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.50																through R20.
	5.00		R-20	49 82%	43 72%	R3	FR										
	5.00																
	6.00	115.0							115.0								
115	5.00	115.0							SLATE, Dark gray, very fine grained, fresh, medium strong, wide spaced discontinuities								No discontinuities.
	5.50																
	5.50		R-21	60 100%	60 100%	R3	FR										
520	5.00																
	5.00	120.0															
120	4.50	120.0							SLATE, Dark gray, very fine grained, fresh, medium strong, wide spaced discontinuities	120.60	B	35	P,R	FR	VT	N	
	4.00																
	3.50		R-22	60 100%	57 95%	R3	FR										
	4.00																
	4.00	125.0								124.00	J	60	P,R	FR	VT	N	
125	4.00	125.0							SLATE, Dark gray, very fine grained, fresh, medium strong, wide spaced discontinuities								
	4.00																
	4.00		R-23	60 100%	60 100%	R3	FR										
510	4.00									128.50	B	35	P,R	FR	VT	N	
	4.00	130.0								129.30	B	35	P,R	FR	VT	N	
130	3.00	130.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								No discontinuities.
	4.00																
	3.50		R-24	60 100%	60 100%	R4	FR										
	3.50																
	3.50	135.0															
135	3.50	135.0							SLATE, Gray, very fine grained, fresh, strong, wide spaced discontinuities								No discontinuities.
	3.50																

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
500	3.00		R-25	60 100%	60 100%	R4	FR										
	3.00																
	3.00	140.0															
140	3.00	140.0							SLATE, Gray, very fine grained, fresh, strong, wide spaced discontinuities								No discontinuities Rock core was stuck in shoe causing many mechanical breaks.
	3.00																
	3.00		R-26	60 100%	60 100%	R4	FR										
	3.50																
	3.50	145.0															
145	3.00	145.0							SLATE, Gray, very fine grained, fresh, strong, wide spaced discontinuities								Rock core was stuck in shoe causing mechanical breaks.
	3.00									146.60	B	30	P,R	FR	VT	N	
	3.00		R-27	60 100%	60 100%	R4	FR										
490	3.00																
	3.50	150.0															
150	3.00	150.0							SLATE, Gray, very fine grained, fresh, strong, wide spaced discontinuities								No discontinuities.
	3.00																
	3.00		R-28	60 100%	60 100%	R4	FR										
	3.00																
	3.00	155.0															
155	3.00	155.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	3.00									156.70	B	30	P,R	FR	VT	N	
	3.00		R-29	60 100%	60 100%	R4	FR										
480	3.00																
	3.50	160.0															
160	3.00	160.0							SLATE, Dark gray, very fine grained, fresh, strong, moderately spaced discontinuities 160' - 16.3' Fractured zone with Pyrite								
	4.00																
	4.00		R-30	59	46	R4	FR		161.9' - 162.7' Fractured zone with Pyrite								Significant water loss

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-16**
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Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath.	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.00			98%	77%												Used up to 275 Gallons for R30.
	4.00																
	4.00	165.0															
165		165.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Used up to 275 Gallons for R31.
	4.00																
	3.00																
	3.00		R-31	60 100%	60 100%	R4	FR										
470																	
	3.00																
	3.00	170.0															
170		170.0							SLATE, Dark gray, very fine grained, fresh, strong, moderately spaced discontinuities	169.80	MB						
	3.00																
	3.00									171.80	J	60	P,R	FR	VT	N	
	4.00		R-32	60 100%	60 100%	R4	FR			172.70	B	30	P,R	FR	VT	N	
	3.00									173.40	J	40	P,R	FR	VT	N	
	4.00	175.0								174.50	B	35	P,R	DS	VT	N	
175									175.0 End of Boring at 175 feet BGS. Borehole grouted with cement and bentonite hole plug.								
460																	
180																	
185																	

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-16**

Figure B-16.1
B-16 Box 1 Runs 1-4 Dry

Figure B-16.2
B-16 Box 1 Runs 1-4 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-16

Figure B-16.3
B-16 Box 2 Runs 5-8 Dry

Figure B-16.4
B-16 Box 2 Runs 5-8 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-16

Figure B-16.5
B-16 Box 3 Runs 9-12 Dry

Figure B-16.6
B-16 Box 3 Runs 9-12 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-16

Figure B-16.7
B-16 Box 4 Runs 13-16 Dry

Figure B-16.8
B-16 Box 4 Runs 13-16 Wet

Figure B-16.9
B-16 Box 5 Runs 17-20 Dry

Figure B-16.10
B-16 Box 5 Runs 17-20 Wet

Figure B-16.11
B-16 Box 6 Runs 21-24 Dry

Figure B-16.12
B-16 Box 6 Runs 21-24 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-16

Figure B-16.13
B-16 Box 7 Runs 25-28 Dry

Figure B-16.14
B-16 Box 7 Runs 25-28 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-16

Figure B-16.15
B-16 Box 8 Runs 29-32 Dry

Figure B-16.16
B-16 Box 8 Runs 29-32 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-16

MOTT MACDONALD

SOIL BORING LOG

BORING NO.: **B-17**
Page **1** of **1**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	January 12, 2016 at 7:35 am
Driller/Helper:	Craig Test Boring Co., Inc. /Nick Beehler	**Date/Time Finished:**	January 14, 2016 at 9:00 am

Elevation: 720 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** East of the access to the right of way. **Coord.:** **N:** 40.88035 **E:** -75.548164 **Horizontal Datum:** NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	5	2	5
Inside Dia. (in.)	4	1.375	2.0
Hammer Wt. (lb.)	140	140	-
Hammer Fall (in.)	30	30	-

Rig Make & Model: CME-750X

☐ Truck ☐ Tripod ☐ Cat-Head
☑ ATV ☐ Geoprobe ☑ Winch
☐ Track ☐ Air Track ☑ Roller Bit
☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type
☐ Safety
☐ Doughnut
☑ Automatic
☐ _____

Drilling Fluid
☐ Bentonite
☐ Polymer
☑ Water
☐ None

Drill Rod Size:

Casing Advance
Mud Rotary

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Group Symbol	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks
720	0.0'-'					Loose, Gray DECOMPOSED SHALE fragments	-	-	-	-	0" - 7" Hand cleared
5	S-1 5.0'- 7.0'	22	10 19 23 26			Dense, Gray and brown DECOMPOSED SHALE fragments with Silt and Sand, dry	N	-	NP	N	
10 710	S-2 10.0'- 10.4'	4	100/5"			Very dense, Gray DECOMPOSED SHALE fragments with Clay, moist	N	-	NP	N	
						15.0					
15	S-3 15.0'- 15.1'	0	100/1"			No Recovery Top of Rock at 15 feet BGS. See Rock Coring Log.	N	-	NP	N	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water

Sample Type

O Open End Rod
T Thin-Wall Tube
U Undisturbed Sample
S Split Spoon Sample
G Geoprobe

Notes:

PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-17**

Field Test Legend:
Dilatancy: N - None S - Slow R - Rapid
Toughness: L - Low M - Medium H - High
Plasticity: NP - Non-Plastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Medium H - High VH - Very High

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD

CORE BORING LOG

BORING NO.: **B-17**
Page **1** of **5**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	January 12, 2016 at 7:35 am
Driller/Helper:	Craig Test Boring Co., Inc. /Nick Beehler	**Date/Time Finished:**	January 14, 2016 at 9:00 am

Elevation: 720 ft. **Vertical Datum:** NAVD 1988

Boring Location: East of the access to the right of way.

Coord.: N: 40.88035 **E:** -75.548164

Item	Casing	Core Barrel	Core Bit
Type	HW	NQ2	Imp. Diamond
Length (ft)	5	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Horizontal Datum: NAD 1983
Rig Make & Model: CME-750X

Drilling Method: Wireline

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec (in. / %)	RQD (in / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
									SEE TEST BORING LOG FOR OVERBURDEN DETAILS								
	5.00	15.0							SHALE, Dark gray, very fine grained, moderately weathered, weak, highly fractured 15' - 20' Highly fractured zone, has discoloration of joint and Clay infill								
	5.00																
	5.00		R-1	39 65%	0 0%	R2	M										
	5.00																
	5.00	20.0															
20 700	4.00	20.0							SHALE, Dark gray and brown, very fine grained, moderately weathered, weak, highly fractured 20' - 25' Highly fractured zone, discolored joints and Clay infill								
	4.00																
	4.00		R-2	60 100%	4 7%	R2	M										
	4.00																
	4.00	25.0															
25	4.00	25.0							SHALE, Dark gray and brown, very fine grained, moderately weathered, weak, highly fractured 25' - 30' Highly fractured zone, discolored joints and Clay infill								
	4.00																
	4.00		R-3	60 100%	0 0%	R2	M										
	4.00																
	4.00	30.0															
30 690	4.00	30.0							SHALE, Dark gray and brown, very fine grained, moderately weathered, weak, highly fractured 30' - 35' Highly fractured zone Discoloration is around fractures Joints have minor Clay infill								
	4.00																
	4.00		R-4	60 100%	4 7%	R2	M										
	4.00																
	5.00	35.0															

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
		-			

Notes:

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00	35.0							SHALE, Dark gray, very fine grained, moderately weathered, weak, highly fractured 35' - 41.5' Highly fractured zone								
	3.00																
	4.00		R-5	60 100%	8 13%	R2	M										
	4.00								38' - 41.5' SHALE, Dark gray, very fine grained, slightly weathered, weak, very close spaced discontinuities								
	4.00	40.0															
40 680	4.00	40.0															
	4.00																
	4.00		R-6	58 97%	32 53%	R3	FR		41.5' - 45' SHALE, Dark gray, very fine grained, fresh, medium strong, medium spaced discontinuities Fossils noted in descrete layers Small coral and foraminifera								Used up 270 Gallons for R1 through R6. No fossils.
	5.00																
	5.00	45.0								44.20	B	30	P,R	FR	VT	N	
45																	
	4.00	45.0							SHALE, Dark gray, very fine grained, fresh, medium strong, moderately spaced discontinuities								
	4.00									46.50	B	30	P,R	DE	VW	CL	
	4.00		R-7	58 97%	54 90%	R3	FR										
	4.00																
	5.00	50.0								49.00	B	30	P,R	FR	VT	N	
50 670																	
	4.00	50.0							SHALE, Dark gray, very fine grained, discolored weathering, medium strong, very close spaced discontinuities								
	4.00								51' - 53' Highly fractured zone								
	4.00		R-8	60 100%	38 63%	R3	FR										
	4.00								SHALE, Dark gray, very fine grained, discolored weathering, medium strong, wide spaced discontinuities	53.50	B	30	P,R	FR	VT	N	
	5.00	55.0							53.9' Shell fossil encountered	54.00	B	30	P,R	FR	VT	N	
55																	
	4.00	55.0							55' - 56.9' SHALE, Dark gray, very fine grained, fresh, medium strong, moderately spaced discontinuities								Used up to 270 Gallons for R7/R8/R9.
	4.00																
	5.00		R-9	58 97%	22 37%	R3	FR		56.9' - 60' SHALE, Dark gray, very fine grained, slightly weathered, highly fractured 56.9' - 60' Highly fractured zone								
	5.00																
	5.00	60.0															
60 660		60.0							SHALE, Dark gray, very fine grained, fresh, medium strong, moderate to close spaced discontinuities								

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00								60.5' - 62.3' Highly fractured zone 60.5' - 62' Vertical fracture								
	3.00																
	3.50		R-10	59 98%	37 62%	R3	FR										
	3.50																
	4.00	65.0								64.30	B	35	P,R	FR	T	N	
65	5.00	65.0							SHALE, Dark gray, very fine grained, fresh, medium strong, moderate to close spaced discontinuities 65' - 65.6' Highly fractured zone								Used up to 540 Gallons for R10/R11.
	5.00									66.50	B	50	P,R	FR	T	N	
										66.90	B	30	P,R	FR	T	N	
	5.00		R-11	60 100%	34 57%	R3	FR			67.70	J	50	P,R	DS	PO	CL	
										68.10	B	30	P,R	FR	VT	N	
	5.00									68.50	J	90	P,R	FR	T	N	
	5.00	70.0								69.10	B	70	P,R	DG	PO	C	
70 650	4.00	70.0							SHALE, Dark gray, very fine grained, fresh, strong, wide spaced discontintuities								No discontinuities. Used up to 270 Gallons for R12.
	4.00																
	4.00		R-12	60 100%	60 100%	R4	FR										
	4.00																
	4.00	75.0							74.5' Bed of fossilized shells								
75	4.00	75.0							SHALE, Dark gray, very fine grained, fresh, strong, close spaced discontinuities	75.30	B	60	P,R	FR	T	N	Used up to 270 Gallons for R13.
	4.00									76.00	J	60	S,R	FR	T	N	
										77.00	J	60	P,R	FR	T	N	
	4.00		R-13	60 100%	50 83%	R4	FR			77.60	J	60	P,R	FR	VT	N	
	4.00								78.5' Fossilized shells								
	4.00	80.0															
80 640	4.00	80.0							80' - 81' SHALE, Dark gray, very fine grained, weak, slightly weathered, close spaced discontinuities	79.80	B	30	P,R	DS	T	CL	
	4.00								81' - 82' Firm, Brown CLAY								
	4.00		R-14	60 100%	37 62%	R4	FR		82' - 85' SHALE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	3.00																
	4.00	85.0															
85	4.00	85.0							SHALE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Mechanical breaks only. Used up to 270 Gallons for R15.

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.00																
	3.00		R-15	60 100%	60 100%	R4	FR										
	4.00																
	4.00	90.0															
90 630	3.00	90.0							SHALE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Used up to 270 Gallons for R16.
	3.00																
	3.00		R-16	60 100%	60 100%	R4	FR										
	4.00									93.10	B	35	P,R	FR	T	N	
	4.00	95.0							95.0								
95	3.00	95.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities	95.30	J	70	P,R	FR	T	N	Used up to 270 Gallons for R17.
	3.00																
	3.00		R-17	60 100%	60 100%	R4	FR										
	3.00									98.20	B	15	P,R	FR	PO	N	
	4.00	100.0															
100 620	3.00	100.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								No discontinuities. Used up to 270 Gallons for R18.
	3.00																
	3.00		R-18	60 100%	60 100%	R4	FR										
	3.00																
	3.00	105.0															
105	3.00	105.0							SLATE, Dark gray, very fine grained, fresh, strong, moderately spaced discontinuities								Used up to 270 Gallons for R19.
	3.00																
	3.00		R-19	54 90%	51 85%	R4	FR										
	3.50																
	3.50	110.0							109.3' - 110' Highly fractured zone, possibly mechanical breaks								
110 610	3.00	110.0							SLATE, Dark gray, very fine grained, fresh, strong, moderate to wide spaced discontinuities								No discontinuities, mechanical breaks only. Used up to 270 Gallons for R20.
	3.00																

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-17**
Page **5** of **5**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00																
	3.00		R-20	60 100%	60 100%	R4	FR										
	3.50																
	3.50	115.0															
115		115.0							SLATE, Dark gray, very fine grained, fresh, strong, moderate to wide spaced discontinuities								Used up to 200 Gallons for R21.
	3.00																
	3.00																
	3.00		R-21	60 100%	60 100%	R4	FR										
	3.00																
	3.50	120.0							120.0								
120 600									End of Boring at 120 feet BGS. Borehole grouted with cement and bentonite hole plug.								
125																	
130 590																	
135																	

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-17**

Figure B-17.1
B-17 Box 1 Runs 1-4 Dry

Figure B-17.2
B-17 Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-17

Figure B-17.3
B-17 Box 2 Runs 5-8 Dry

Figure B-17.4
B-17 Box 2 Runs 5-8 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-17

Figure B-17.5
B-17 Box 3 Runs 9-12 Dry

Figure B-17.6
B-17 Box 3 Runs 9-12 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-17

Figure B-17.7
B-17 Box 4 Runs 13-16 Dry

Figure B-17.8
B-17 Box 4 Runs 13-16 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-17

Figure B-17.9
B-17 Box 5 Runs 17-20 Dry

Figure B-17.10
B-17 Box 5 Runs 17-20 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-17

Figure B-17.11
B-17 Box 6 Run 21 Dry

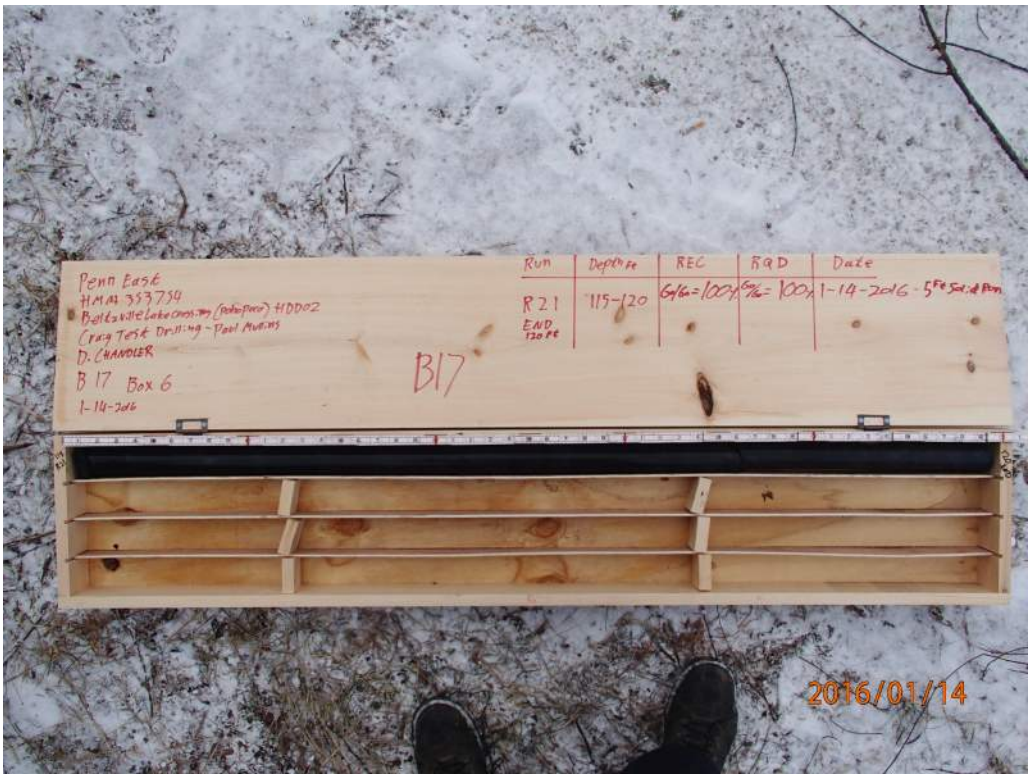


Figure B-17.12
B-17 Box 6 Run 21 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-17

MOTT MACDONALD M M

SOIL BORING LOG

BORING NO.: **B-Poh-1**
Page **1** of **2**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Bernard Cortes
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	February 5, 2016 at 7:45 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	February 10, 2016 at 10:45 am

Elevation: 695 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off Penn Forest Road South. **Coord.:** **N:** 40.88418 **E:** -75.556409 **Horizontal Datum:** NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	5	2	5
Inside Dia. (in.)	4	1.375	2.0
Hammer Wt. (lb.)	140	140	-
Hammer Fall (in.)	30	30	-

Rig Make & Model: CME-750X

☐ Truck ☐ Tripod ☐ Cat-Head
☑ ATV ☐ Geoprobe ☑ Winch
☐ Track ☐ Air Track ☑ Roller Bit
☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type
☐ Safety
☐ Doughnut
☑ Automatic
☐ _____

Drilling Fluid
☑ Bentonite
☐ Polymer
☑ Water
☐ None

Drill Rod Size:
Casing Advance
Mud Rotary

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Group Symbol	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks
	S-1 0.0'- 2.0'	24	4 1 1 1		CL	Very soft, Brownish yellow Lean CLAY (CL)	N	-	M	N	
5 690	S-2 5.0'- 7.0'	12	5 16 18 22		CL	Hard, Brownish yellow to yellowish red Lean CLAY with Decomposed Shale fragments, moist (CL)	N	L	M	N	
						8.5					
10	S-3 10.0'- 12.0'	24	13 17 22 32		ML	Hard, Brownish yellow to reddish brown Clayey SILT with Decomposed Shale fragments, moist (ML)	N	L	L	N	
15 680	S-4 15.0'- 17.0'	3	60/3"		ML	Hard, Yellowish brown Clayey SILT with Decomposed Shale fragments, moist (ML)	N	-	NP	N	
						18.5					

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water

Sample Type

O Open End Rod
T Thin-Wall Tube
U Undisturbed Sample
S Split Spoon Sample
G Geoprobe

Notes:

PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-Poh-1**

Field Test Legend:
Dilatancy: N - None S - Slow R - Rapid
Toughness: L - Low M - Medium H - High
Plasticity: NP - Non-Plastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Medium H - High VH - Very High

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

SOIL BORING LOG
(continued)

BORING NO.: **B-Poh-1**
Page **2** of **2**

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Symbol Group	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks*
	S-5 20.0'-22.0'	2	50/2"			Very dense, Black DECOMPOSED SHALE fragments with Clay, wet	N	L	L	N	
25 670	S-6 25.0'-27.0'	6	80/6"			Very dense, Black DECOMPOSED SHALE fragments with Clay, wet	N	L	L	N	
30	S-7 30.0'-32.0'	1	50/1"			Very dense, Black DECOMPOSED SHALE fragments with Clay, wet	N	L	L	N	
						32.0 Top of Rock at 32 feet BGS. See Rock Coring Log.					
35 660											
40											
45 650											

NOTES:

PROJECT NO.: **353754**

BORING NO.: **B-Poh-1**

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD

CORE BORING LOG

BORING NO.: **B-Poh-1**
Page **1** of **8**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Beltzville Lake Crossing, Lehighton, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Bernard Cortes
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	February 5, 2016 at 7:45 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	February 10, 2016 at 10:45 am

Elevation: 695 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off Penn Forest Road South. **Coord.: N:** 40.88418 **E:** -75.556409

Item	Casing	Core Barrel	Core Bit
Type	HW	NQ2	Imp. Diamond
Length (ft)	5	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Horizontal Datum: NAD 1983 **Rig Make & Model:** CME-750X **Drilling Method:** Wireline

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec (in. / %)	RQD (in / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
660									SEE TEST BORING LOG FOR OVERBURDEN DETAILS								
	2.50	35.0							SHALE, Dark gray, very fine grained, moderately weathered, strong, extremely close to close spaced discontinuities	35.70	J	60	P,R	FR	T	N	
										35.90	J	-	X,R	DS	O	CL	
	2.00									36.40	J	60	P,Sm	DG	O	N	
										36.70	J	60	P,Sm	DG	O	N	
	2.00		R-1	60 100%	15 25%	R4	M		37.1' - 38.2' Highly fractured zone								
	3.00									38.40	J	70	P,Sm	DG	T	N	
										38.70	J	70	P,R	DG	O	CL	
	5.00	40.0								38.90	J	70	P,Sm	DS	PO	CL	
40		40.0							SHALE, Dark gray, very fine grained, fresh, strong, extremely close to close spaced discontinuities	40.20	J	60	P,Sm	FR	T	N	Used up to 275 Gallons (R1 to R2).
	3.00									41.30	J	60	P,Sm	DG	T	N	
	3.00									41.40	J	60	P,R	DG	T	N	
	3.50		R-2	60 100%	48 80%	R4	FR			42.70	J	70	P,R	FR	O	N	
	3.00									43.60	J	-	X,R	FR	VT	N	
	3.00	45.0															
45 650		45.0							SHALE, Dark gray, very fine grained, fresh, strong, extremely close to wide spaced discontinuities								
	3.00									45.50	J	70	P,Sm	FR	T	N	
										45.90	J	60	P,Sm	FR	PO	N	
	3.50									46.60	J	70	P,Sm	FR	PO	N	
	3.50		R-3	60 100%	44 73%	R4	FR			47.20	J	60	P,Sm	FR	T	N	
										47.90	J	-	X,R	FR	O	N	
	3.50																
	3.50	50.0								49.20	J	65	P,R	DG	PO	N	
50		50.0							SHALE, Dark gray, very fine grained, moderately weathered, strong, extremely close to wide spaced discontinuities	50.60	J	70	P,Sm	FR	T	N	
	3.00																
	3.00								51.7' - 52.4' Highly fractured zone								
	3.00		R-4	60 100%	36 60%	R4	M										
	4.00									52.90	J	70	P,Sm	FR	T	N	
	4.00	55.0															

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
		-			

Notes:

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
640		55.0							SHALE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								Loss of water.
	3.50									55.60	J	65	P,Sm	FR	T	N	
	2.50																
	3.00		R-5	60 100%	54 90%	R4	FR										
	3.00																
	3.00	60.0															
60		60.0							SHALE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								Used up to 275 Gallons (R3 to R6).
	2.50									60.60	J	80	P,R	FR	T	N	
										60.80	J	80	P,Sm	FR	T	N	
	3.00																
	3.50		R-6	60 100%	45 75%	R4	FR										
	3.00																
	3.00	65.0								64.10	J	-	X,R	FR	PO	N	
65 630		65.0							SHALE, Dark gray, very fine grained, fresh, strong, extremely close to close spaced discontinuities								
	3.50									65.30	J	50	P,R	FR	T	N	
										65.80	J	10	P,R	FR	PO	N	
	3.50									66.20	MB						
										66.90	J	50	P,Sm	FR	T	N	
	3.00		R-7	60 100%	47 78%	R4	FR			67.00	J	50	P,Sm	FR	VT	N	
										67.80	J	50	P,R	FR	T	N	
	3.50									68.50	J	60	P,Sm	FR	PO	N	
	3.50	70.0															
70		70.0							SHALE, Dark gray, very fine grained, fresh, strong, extremely close to close spaced discontinuities								
	3.50									70.70	J	60	P,R	FR	T	N	
										71.00	J	-	X,R	DS	O	QZ	
	3.00									71.10	J	50	P,R	FR	PO	N	
	2.50		R-8	60 100%	46 77%	R4	FR			72.00	J	60	P,Sm	FR	T	N	
	3.00									73.30	J	10	P,R	FR	O	N	
										73.40	J	40	P,Sm	FR	T	N	
	3.00	75.0								74.40	J	40	P,Sm	FR	T	N	
75 620		75.0							75.0 SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								
	3.50									75.70	J	60	P,Sm	FR	VT	N	
										75.80	J	60	P,Sm	FR	VT	N	
	3.50									76.00	J	60	P,Sm	FR	VT	N	
										76.50	J	60	P,Sm	FR	T	N	
	3.50		R-9	60 100%	45 75%	R4	FR			77.40	J	60	P,Sm	FR	T	N	
	3.00									78.30	J	60	P,Sm	FR	VT	N	
	3.00	80.0								79.50	J	60	P,Sm	FR	PO	N	
80		80.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								Loss of water at 80 feet BGS.

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00																
	3.00									81.10	J	50	P,K	FR	VT	N	
	3.00		R-10	60 100%	60 100%	R4	FR										
										82.60	J	70	P,Sm	FR	VT	N	
	3.50									83.40	J	60	P,Sm	FR	T	N	
	3.00	85.0								84.40	MB						
85 610		85.0							SLATE, Dark gray, very fine grained, fresh, strong, extremely close to wide spaced discontinuities								
	3.00									85.70	J	60	P,Sm	FR	T	N	
	3.00									86.70	J	10	P,Sm	FR	T	N	
	3.00		R-11	60 100%	52 87%	R4	FR										
	3.50								87.9' - 88.1' Highly fractured zone								
	3.00	90.0								89.50	J	-	X,R	DG	O	N	Lost all water at 89.4 feet BGS.
90		90.0							SLATE, Dark gray, very fine grained, fresh, strong, extremely close wide spaced discontinuities 90.4' - 90.6' Highly fractured zone								
	3.00									91.00	J	60	P,Sm	FR	VT	N	
	3.50		R-12	55 92%	42 70%	R4	FR			92.00	J	65	P,R	FR	VT	N	
	3.50									93.70	J	60	P,Sm	FR	VT	N	
	4.00	95.0															
95 600		95.0							SLATE, Dark gray, very fine grained, fresh, medium strong, extremely close to wide spaced discontinuities								
	3.50									95.20	J	50	P,Sm	FR	VT	N	Used up to 275 Gallons (R7 to R13).
										95.70	J		X,R	FR	O	N	
	3.00									96.30	J	-	P,Sm	FR	VT	N	
	3.50		R-13	60 100%	48 80%	R3	FR			97.00 97.20 97.30	J MB J	90 70	P,Sm P,Sm	FR FR	T O	N N	
	3.00																
	5.00	100.0								99.30	J	15	P,R	DG	O	N	
100		100.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	3.00									100.70	J	60	P,Sm	FR	VT	N	
	3.00																
	3.50		R-14	60 100%	60 100%	R4	FR										
	3.00																
	3.00	105.0															
105 590		105.0							SLATE, Dark gray, very fine grained, fresh, strong, extremely close to wide spaced discontinuities								Used up to 275 Gallons (R14 to R15).
	3.00									105.60	J	60	P,K	FR	VT	N	

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00									106.20	J	20	P,Sm	FR	T	N	
										106.80	J	60	P,Sm	FR	VT	N	
	3.00		R-15	60 100%	55 92%	R4	FR			107.30	J	60	P,R	FR	T	N	
	3.00																
	3.00	110.0															
110	3.50	110.0							SLATE, Dark gray, fine grained, fresh, strong, close to wide spaced discontinuities								
	3.50									111.10	J	60	P,K	FR	VT	N	
	3.50		R-16	60 100%	54 90%	R4	FR			112.30	J	60	P,Sm	FR	PO	N	
	3.50																
	3.50	115.0								114.60	J	60	P,Sm	FR	VT	N	
115 580										114.70	MB						
	3.00	115.0							SLATE, Dark gray, very fine grained, slightly weathered, strong, extremely close to wide spaced discontinuities Calcite infilling encountered.								
	3.00																
	3.50		R-17	60 100%	46 77%	R4	SL		117.8' - 118.7' Highly fractured zone	117.40	J	70	P,Sm	FR	T	N	
	3.50																
	3.50	120.0															
120	3.50	120.0							SLATE, Dark gray, very fine grained, slightly weathered, strong, close to wide spaced discontinuities								Used up to 275 Gallons (R16 to R18).
										120.50	J	60	P,Sm	FR	VT	N	
										121.00	J	10	P,Sm	FR	T	N	
	3.50									121.40	J	-	X,R	DS	O	Py	
	3.50		R-18	60 100%	52 87%	R4	SL										
	3.50																
	4.50	125.0															
125 570	3.00	125.0							SLATE, Dark gray, very fine grained, slightly weathered, strong, extremely close to wide spaced discontinuities								
	3.00																
	3.00		R-19	60 100%	50 83%	R4	SL										
										128.00	J	30	P,R	FR	PO	Py	
	3.00									128.50	J	60	P,Sm	FR	VT	N	
										129.10	J	60	P,R	DG	PO	N	
	3.00	130.0								129.50	J	60	P,R	DG	O	N	
130	4.00	130.0							SLATE, Dark gray, very fine grained, fresh, extremely close to wide spaced discontinuities								
	3.50																

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.50																
	4.00		R-20	60 100%	55 92%	R4	FR										
	4.00									133.70	J	20	X,R	DG	O	N	
										133.90	J	-	X,R	DG	O	CL	
	5.00	135.0								134.10	J	60	P,Sm	DG	T	N	
135 560	4.00	135.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Used up to 275 Gallons (R19 to R21).
	4.00																
	4.50		R-21	60 100%	60 100%	R4	FR										
	5.00									138.30	J	40	P,Wa	FR	T	N	
	5.00	140.0															
140	3.00	140.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
										140.60	J	70	P,Sm	FR	VT	N	
	3.00									140.80	MB						
	2.00		R-22	60 100%	60 100%	R4	FR										
	2.50																
	2.50	145.0															
145 550	5.00	145.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
										145.90	MB						
	3.00																
	4.00		R-23	60 100%	60 100%	R4	FR										
	4.00																
	4.50	150.0								149.10	J	40	P,R	DG	O	N	
										149.40	MB						
150	3.50	150.0							SLATE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								Used up to 275 Gallons (R22 to R24). Lossing water more rapid.
	3.50																
										151.70	J	50	P,R	DG	O	N	
	5.00		R-24	60 100%	60 100%	R4	FR										
	4.00																
	5.00	155.0								154.60	MB						
155 540	3.00	155.0							SLATE, Dark gray, very fine grained, fresh, strong, wide to very wide spaced discontinuities	155.00	MB						No discontinuities.
	3.00																

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	5.00		R-25	60 100%	60 100%	R4	FR										
	5.00																
	4.00	160.0															
160	3.50	160.0							SLATE, Dark gray, very fine grained, fresh, strong, wide to very wide spaced discontinuities								No discontinuities. Used up to 275 Gallons (R24 to R26).
	3.50																
	3.50		R-26	60 100%	60 100%	R4	FR										
	4.00																
	5.00	165.0															
165 530	4.00	165.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								Used up to 275 Gallons for R27.
	4.00																
	4.00		R-27	58 97%	58 97%	R4	FR			167.00	J	60	P,R	FR	VT	N	
	4.50									168.60	J	60	P,Sm	FR	VT	N	
	5.00	170.0								169.00 169.30	J MB	10	P,R	DG	PO	N	
170	3.00	170.0							SLATE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								
	3.50																
	4.50		R-28	60 100%	57 95%	R4	FR			171.70	J	60	P,R	FR	PO	N	
	4.50									173.10	J	60	P,Sm	FR	T	N	
	4.00	175.0								174.00	J	50	P,Sm	FR	T	N	
175 520	3.50	175.0							SLATE, Dark gray, very fine grained, slightly weathered, strong, extremely close to moderately spaced discontinuities								
	4.50									176.20	J	50	P,Sm	FR	VT	N	
	4.00		R-29	60 100%	51 85%	R4	SL			177.80 177.90	J J	60 30	P,Sm P,Sm	FR FR	VT T	N N	
	4.00									179.30	J	50	P,R	FR	T	N	
	4.00	180.0															
180	3.50	180.0							SLATE, Dark gray, very fine grained, slightly weathered, strong, extremely close to close spaced discontinuities Pyrite infilling encountered	180.60 180.80	J J	20 70	P,Wa P,Sm	FR FR	T T	N N	Used up to 275 Gallons (R29 to R30).
	4.50									181.40	MB						
	4.00		R-30	60	46	R4	SL			182.30	J	40	P,Sm	DG	PO	Py	

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.00			100%	77%												
	4.00								183.4' - 184.5' Highly fractured zone with Calcite infill								
	3.50	185.0															
185 510	3.25	185.0							SLATE, Dark gray, very fine grained, slightly weathered, strong, extremely close to moderately spaced discontinuities	185.30	MB						Lossing water more rapid.
	3.00									186.50	J	40	P,Sm	FR	T	N	
	3.50		R-31	60 100%	52 87%	R4	FR			187.70	J	60	P,Sm	FR	T	N	
	3.50									188.30	J	40	P,Sm	FR	T	N	
										188.50	J	40	P,Sm	FR	T	N	
	3.50	190.0								189.10	J	40	P,Sm	FR	PO	N	
190	3.00	190.0							SLATE, Dark gray, fine grained, fresh, strong, extremely close to moderately spaced discontinuities 190.4' - 192.2' Highly fractured zone								Used up to 275 Gallons (R31 to R32).
	3.00																
	3.50		R-32	60 100%	34 57%	R4	FR			192.70	J	30	P,Sm	FR	PO	N	
	3.50																
	3.50	195.0								194.40	J	40	P,Sm	FR	T	N	
195 500										194.60	J	40	P,R	FR	T	N	
	3.00	195.0							SLATE, Dark gray, very fine grained, fresh, medium strong, close to moderately spaced discontinuities	195.80	J	40	P,R	FR	O	N	
	3.00									196.40	J	90	P,Sm	DG	VT	N	
	3.00		R-33	60 100%	42 70%	R3	FR			197.30	J	40	P,Sm	FR	VT	N	
	3.00									197.90	J	40	P,Sm	FR	VT	N	
										198.00	J	30	P,R	FR	VT	N	
										198.30	J	40	P,Sm	FR	VT	N	
										198.70	J	40	P,Sm	FR	VT	N	
	3.00	200.0								199.00	J	40	P,Sm	FR	VT	N	
										199.40	MB						
200										199.80	MB						
	4.00	200.0							SLATE, Dark gray, very fine grained, moderately weathered, medium strong, extremely close to close spaced discontinuities								Used up to 275 Gallons (R33 to R34).
										200.80	J	40	P,Sm	FR	VT	N	
	3.50									201.50	J	40	P,R	DG	PO	N	
										201.70	J	40	P,R	FR	T	N	
	3.50		R-34	60 100%	43 72%	R3	M			202.10	J	40	P,Sm	FR	VT	N	
										202.30	J	40	P,Sm	FR	VT	N	
									202.8' - 203.4' Highly fractured zone								
	3.00									203.60	J	40	P,R	DG	PO	QZ	
										203.90	J	40	P,Sm	FR	VT	N	
	3.50	205.0								204.10	J	40	P,R	DG	T	N	
205 490		205.0															
	4.50								SLATE, Dark gray, very fine grained, moderately weathered, medium strong, extremely close to moderately spaced discontinuities	205.20	J	40	P,R	DG	PO	N	
	4.00									206.20	J	40	P,Sm	FR	T	N	
									206.6' - 207.1' Highly fractured zone with Quartz infill	206.30	MB						
	4.00		R-35	60 100%	42 70%	R3	M			207.80	J	40	X,R	DE	T	N	

NOTES:

PROJECT NO.: **353754**

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.50																
	4.50									208.40	J	40	P,Sm	FR	T	N	
	4.00	210.0								209.50	J	40	P,Sm	DS	T	QZ	
210		210.0							SLATE, Dark gray, very fine grained, slightly weathered, medium strong, extremely close to close spaced discontinuities								
	4.00									210.80	J	10	P,R	DG	T	N	
	4.00									211.40	J	20	P,R	DS	T	QZ	
										211.90	J	30	P,R	DS	T	QZ	
	4.00		R-36	60 100%	47 78%	R3	SL		212.5' - 212.9' Highly fractured zone	212.30	J	30	P,R	FR	T	N	
	4.00									213.40	J	20	P,R	FR	O	N	
	4.50	215.0							214.4' - 215' Highly fractured zone								
215 480		215.0							SLATE, Dark gray, very fine grained, moderately weathered, medium strong, extremely close to close spaced discontinuities								
	4.00									215.50	MB						
	4.00								216' - 216.7' Highly fractured zone								
										217.00	J	20	P,Sm	FR	T	N	
	4.00		R-37	57 95%	39 65%	R3	M			217.20	J	70	P,Sm	FR	VT	N	
										217.40	J	15	P,Sm	FR	VT	N	
										217.90	J	30	P,Sm	DS	T	N	
	4.00									218.20	J	30	P,R	FR	T	N	
										218.40	J	20	P,Sm	FR	T	N	
	4.00	220.0								219.20	J	20	P,Sm	FR	T	N	
220		220.0							SLATE, Dark gray, very fine grained, moderately weathered, extremely close to moderately spaced discontinuities								
	4.00									220.30	J	30	P,Sm	DS	PO	Ca	
	4.00									221.50	J	50	P,R	DG	PO	Ca	
										221.90	J	50	P,Sm	FR	VT	N	
										222.00	J	50	P,R	FR	VT	N	
	4.00		R-38	60 100%	32 53%	R3	M			222.30	J	40	P,Sm	FR	PO	N	
	4.00								222.7' - 225' Highly fractured zone with Calcite infill								
	4.00	225.0															
225 470									225.0 End of Boring at 225 feet BGS. Borehole grouted with cement and bentonite hole plug.								
230																	

Figure B-Poh-1.1
B-Poh-1 Box 1 Runs 1-4 Dry

Figure B-Poh-1.2
B-Poh-1 Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-Poh-1

Figure B-Poh-1.3
B-Poh-1 Box 2 Runs 5-8 Dry

Figure B-Poh-1.4
B-Poh-1 Box 2 Runs 5-8 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-Poh-1

Figure B-Poh-1.5
B-Poh-1 Box 3 Runs 9-12 Dry

Figure B-Poh-1.6
B-Poh-1 Box 3 Runs 9-12 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-Poh-1

Figure B-Poh-1.7
B-Poh-1 Box 4 Runs 13-16 Dry

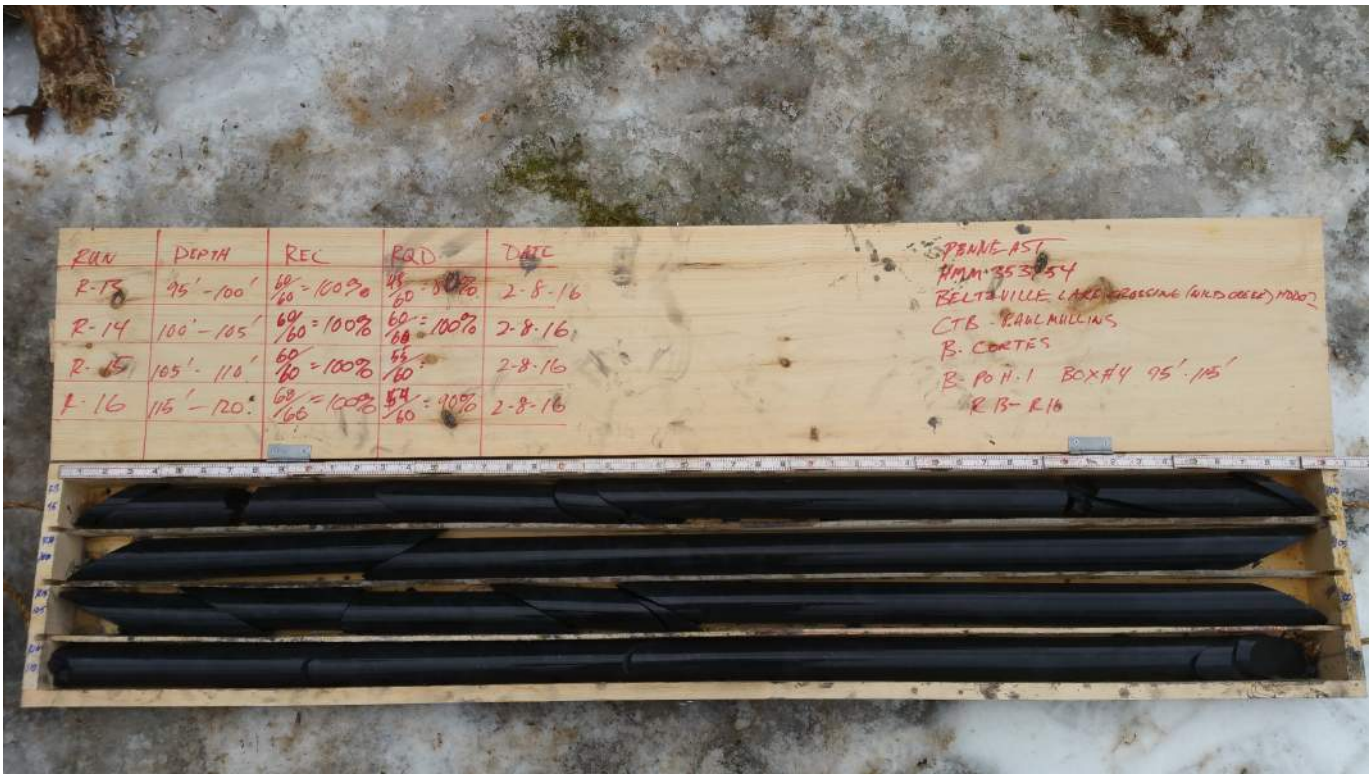


Figure B-Poh-1.8
B-Poh-1 Box 4 Runs 13-16 Wet

Figure B-Poh-1.9
B-Poh-1 Box 5 Runs 17-20 Dry

Figure B-Poh-1.10
B-Poh-1 Box 5 Runs 17-20 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-Poh-1

Figure B-Poh-1.11
B-Poh-1 Box 6 Runs 21-24 Dry

Figure B-Poh-1.12
B-Poh-1 Box 6 Runs 21-24 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-Poh-1

Figure B-Poh-1.13
B-Poh-1 Box 7 Runs 25-28 Dry

Figure B-Poh-1.14
B-Poh-1 Box 7 Runs 25-28 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-Poh-1

Figure B-Poh-1.15
B-Poh-1 Box 8 Runs 29-32 Dry

Figure B-Poh-1.16
B-Poh-1 Box 8 Runs 29-32 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-Poh-1

Figure B-Poh-1.17
B-Poh-1 Box 9 Runs 33-36 Dry

Figure B-Poh-1.18
B-Poh-1 Box 9 Runs 33-36 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-Poh-1

Figure B-Poh-1.19
B-Poh-1 Box 10 Runs 37-38 Dry

Figure B-Poh-1.20
B-Poh-1 Box 10 Runs 37-38 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-Poh-1

Appendix C

Installation Load and Stress Evaluation

MOTT MACDONALD

Horizontal Directional Drilling
Minimum Radius Calculations - MAOP Based

Project Name: PennEast Pipeline
Project No: 353754
HDD Name: Beltzville Lake
Location: Carbon County, PA

By: S. Crouse
Checked: G. Duyvestyn
Owner: PennEast Pipeline
Date: 10/27/2015

References:

1. ASME/ANSI B31.4 section 402.3.2
2. ASME/ANSI B31.8 section 833.3
3. ASME/ANSI B31.8 section 833.4
4. ASME/ANSI B31.4 section 402.3.1

Design Parameters

Pipe Diameter	36	inches
Wall Thickness	0.762	inches
D/t Ratio	47	
MAOP	1,480	psi
SMYS	70,000	psi
Modulus of Elasticity	2.92E+07	psi
Design Factor	0.5	

Hoop Stress Calculation

Hoop Stress = (MAOP * Pipe Diameter) / (2 * Wall Thickness)
Calculated Hoop Stress 34,961 psi

Longitudinal Stress Calculation

Longitudinal Stress = Hoop Stress / 2
Calculated Longitudinal Stress 17,480 psi

Allowable Stress Calculation

Allowable Stress = Design Factor * SMYS
Calculated Allowable Stress 35,000 psi

Bending Stress Calculation

Bending Stress = Allowable Stress - Longitudinal Stress
Calculated Bending Stress 17,520 psi

Minimum Bend Radius Calculation

Minimum Radius = (Modulus of Elasticity * Pipe Diameter) / (2 * Bending Stress)
Calculated Minimum Radius 2,500 feet

MOTT MACDONALD

Horizontal Directional Drilling
Operating Stress Analysis - MAOP Based

Project Name: PennEast Pipeline
Project No: 353754
HDD Name: Beltzville Lake
Location: Carbon County, PA

By: S. Crouse
Checked: G. Duyvestyn
Owner: PennEast Pipeline
Date: 10/27/2015

References:

1. ASME/ANSI B31.4 section 402.3.2
2. ASME/ANSI B31.8 section 833.3
3. ASME/ANSI B31.8 section 833.4
4. ASME/ANSI B31.4 section 402.3.1

Design Parameters

Pipe Diameter	36	inches
Wall Thickness	0.762	inches
D/t Ratio	47	
MAOP	1,480	psi
SMYS	70,000	psi
Modulus of Elasticity	2.92E+07	psi
Combined Design Factor	0.5	
Poisson's Ratio	0.30	
Minimum Radius of Curvature	2,500	feet
Radius of Curvature Factor	104%	
Design Minimum Allowable Radius of Curvature	2,600	feet
Coefficient of Thermal Expansion	6.50E-06	in/in/°F
Assumed Installation Temperature	45	°F
Assumed Operating Temperature	120	°F

Longitudinal Stress from Bending

Longitudinal Stress from Bending		16,846	psi
	Percent SMYS	24.1%	

Hoop Stress

Calculated Hoop Stress		34,961	psi	Should be less than Design Factor x SMYS of 35,000 psi
	Percent SMYS	49.9%		Limited by Design Factor according to 49 CFR 192.11

Longitudinal Tensile Stress from Hoop Stress

Longitudinal Tensile Stress from Hoop Stress		10,488	psi	
	Percent SMYS	15.0%		

Longitudinal Stress from Thermal Expansion

Longitudinal Stress from Thermal Expansion		-14,235	psi	
	Percent SMYS	20.3%		Limited by 90% SMYS by ASME/ANSI B31.4 section 402.3.2

Net Longitudinal Stress (Compression Side of Curve)

Net Longitudinal Stress (Compression Side of Curve)		-20,593	psi	
	Percent SMYS	29.4%		Limited by 90% SMYS by ASME/ANSI B31.8 section 833.3

Net Longitudinal Stress Tension Side of Curve)

Net Longitudinal Stress (Tesion Side of Curve)		13,099	psi	
	Percent SMYS	18.7%		Limited by 90% SMYS by ASME/ANSI B31.8 section 833.3

Maximum Shear Stress

Maximum Shear Stress		27,777	psi	
	Percent SMYS	39.7%		Limited by 45% SMYS by ASME/ANSI B31.4 section 402.3.1

Combined Biaxial Stress Check

Combined Biaxial Stress Check		55,553	psi	
	Percent SMYS	79.4%		Limited to 90% SMYS by ASME/ANSI B31.8 section 833.4

MOTT MACDONALD

Horizontal Directional Drilling
Calculation of Pull Loads and Stresses during Pipe Installation

Calculated by: S. Crouse
Checked by: G. Duyvestyn
Date: 2/13/2017
Project No: 353754

PROJECT: PennEast Pipeline

HDD CROSSING LOCATION: Pohopoco Creek (Beltzville Lake) / Wild Creek

Reference:
1. **Installation of Pipelines by Horizontal Directional Drilling, an Engineering Guide, PRCI Publication 2015**
2. **Pipeline Design for Installation by Horizontal Directional Drilling, Manual of Practice, ASCE MREP 108, 2005**

HDD Installation Load Analysis

Segment Type	Type of Curve	Bore Stationing		Installed Length		Bore Elevation		Bore Diameter		Geotechnical Friction Factor	TOTAL PULL LOADS		
		feet	metres	feet	metres	feet	metres	inch	mm				
Pipe Entry Location		7+88	0+240	0.0	0.0	780.0	237.7	--	--		62,949	lb	**31.5** tons
straight		9+15	0+279	130.3	39.7	752.9	229.5	48.0	1219.2	0.3	77,554	lb	**38.8** tons
straight		10+43	0+318	260.7	79.5	725.8	221.2	48.0	1219.2	0.3	92,158	lb	**46.1** tons
straight		11+70	0+357	391.0	119.2	698.7	213.0	48.0	1219.2	0.3	106,763	lb	**53.4** tons
straight		12+98	0+396	521.4	158.9	671.6	204.7	48.0	1219.2	0.3	121,367	lb	**60.7** tons
straight		14+25	0+434	651.7	198.7	644.5	196.4	48.0	1219.2	0.3	135,972	lb	**68.0** tons
straight		15+53	0+473	782.1	238.4	617.4	188.2	48.0	1219.2	0.3	150,577	lb	**75.3** tons
straight		16+80	0+512	912.4	278.1	590.3	179.9	48.0	1219.2	0.3	165,181	lb	**82.6** tons
straight		18+08	0+551	1,042.8	317.8	563.2	171.7	48.0	1219.2	0.3	179,786	lb	**89.9** tons
curve	vertical	19+00	0+579	1,137.0	346.6	544.8	166.1	48.0	1219.2	0.3	221,439	lb	**110.7** tons
curve	vertical	19+93	0+607	1,231.3	375.3	528.8	161.2	48.0	1219.2	0.3	220,515	lb	**110.3** tons
curve	vertical	20+86	0+636	1,325.5	404.0	515.3	157.1	48.0	1219.2	0.3	228,370	lb	**114.2** tons
curve	vertical	21+80	0+664	1,419.8	432.8	504.2	153.7	48.0	1219.2	0.3	237,946	lb	**119.0** tons
curve	vertical	22+74	0+693	1,514.0	461.5	495.6	151.1	48.0	1219.2	0.3	529,979	lb	**265.0** tons
curve	vertical	23+68	0+722	1,608.3	490.2	489.5	149.2	48.0	1219.2	0.3	363,297	lb	**181.6** tons
curve	vertical	24+62	0+750	1,702.5	518.9	485.8	148.1	48.0	1219.2	0.3	372,825	lb	**186.4** tons
curve	vertical	25+56	0+779	1,796.8	547.7	484.5	147.7	48.0	1219.2	0.3	381,811	lb	**190.9** tons
straight		26+58	0+810	1,898.5	578.7	484.5	147.7	48.0	1219.2	0.3	388,261	lb	**194.1** tons
straight		27+60	0+841	2,000.3	609.7	484.5	147.7	48.0	1219.2	0.3	394,712	lb	**197.4** tons
straight		28+61	0+872	2,102.1	640.7	484.5	147.7	48.0	1219.2	0.3	401,162	lb	**200.6** tons
straight		29+63	0+903	2,203.9	671.7	484.5	147.7	48.0	1219.2	0.3	407,612	lb	**203.8** tons
straight		30+65	0+934	2,305.6	702.8	484.5	147.7	48.0	1219.2	0.3	414,063	lb	**207.0** tons
straight		31+67	0+965	2,407.4	733.8	484.5	147.7	48.0	1219.2	0.3	420,513	lb	**210.3** tons
straight		32+69	0+996	2,509.2	764.8	484.5	147.7	48.0	1219.2	0.3	426,963	lb	**213.5** tons
straight		33+70	1+027	2,611.0	795.8	484.5	147.7	48.0	1219.2	0.3	433,414	lb	**216.7** tons
straight		34+72	1+058	2,712.7	826.9	484.5	147.7	48.0	1219.2	0.3	445,398	lb	**222.7** tons
straight		35+74	1+089	2,814.5	857.9	484.5	147.7	48.0	1219.2	0.3	457,383	lb	**228.7** tons
straight		36+76	1+120	2,916.3	888.9	484.5	147.7	48.0	1219.2	0.3	469,368	lb	**234.7** tons
straight		37+77	1+151	3,018.1	919.9	484.5	147.7	48.0	1219.2	0.3	481,353	lb	**240.7** tons
straight		38+79	1+182	3,119.8	950.9	484.5	147.7	48.0	1219.2	0.3	493,337	lb	**246.7** tons
straight		39+81	1+213	3,221.6	982.0	484.5	147.7	48.0	1219.2	0.3	505,322	lb	**252.7** tons
straight		40+83	1+244	3,323.4	1,013.0	484.5	147.7	48.0	1219.2	0.3	517,307	lb	**258.7** tons
straight		41+85	1+275	3,425.2	1,044.0	484.5	147.7	48.0	1219.2	0.3	529,292	lb	**264.6** tons
straight		42+86	1+306	3,526.9	1,075.0	484.5	147.7	48.0	1219.2	0.3	541,276	lb	**270.6** tons
straight		43+88	1+338	3,628.7	1,106.0	484.5	147.7	48.0	1219.2	0.3	553,261	lb	**276.6** tons
straight		44+90	1+369	3,730.5	1,137.1	484.5	147.7	48.0	1219.2	0.3	565,246	lb	**282.6** tons
straight		45+92	1+400	3,832.3	1,168.1	484.5	147.7	48.0	1219.2	0.3	577,231	lb	**288.6** tons
straight		46+93	1+431	3,934.0	1,199.1	484.5	147.7	48.0	1219.2	0.3	1,038,827	lb	**519.4** tons
straight		47+95	1+462	4,035.8	1,230.1	484.5	147.7	48.0	1219.2	0.3	704,536	lb	**352.3** tons
straight		48+97	1+493	4,137.6	1,261.2	484.5	147.7	48.0	1219.2	0.3	716,521	lb	**358.3** tons
straight		49+99	1+524	4,239.4	1,292.2	484.5	147.7	48.0	1219.2	0.3	728,506	lb	**364.3** tons
straight		51+01	1+555	4,341.3	1,323.2	484.5	147.7	48.0	1219.2	0.3	740,509	lb	**370.3** tons
straight		52+03	1+586	4,443.2	1,354.3	484.5	147.7	48.0	1219.2	0.3	752,513	lb	**376.3** tons
straight		53+05	1+617	4,545.2	1,385.4	484.5	147.7	48.0	1219.2	0.3	764,517	lb	**382.3** tons
straight		54+07	1+648	4,647.1	1,416.5	484.5	147.7	48.0	1219.2	0.3	776,521	lb	**388.3** tons
curve	vertical	54+91	1+674	4,731.9	1,442.3	485.5	148.0	48.0	1219.2	0.3	854,222	lb	**427.1** tons
curve	vertical	55+76	1+700	4,816.8	1,468.2	488.5	148.9	48.0	1219.2	0.3	849,379	lb	**424.7** tons
curve	vertical	56+61	1+725	4,901.6	1,494.0	493.5	150.4	48.0	1219.2	0.3	861,852	lb	**430.9** tons
curve	vertical	57+45	1+751	4,986.4	1,519.9	500.5	152.6	48.0	1219.2	0.3	877,932	lb	**439.0** tons
curve	vertical	58+28	1+776	5,069.7	1,545.3	509.3	155.2	48.0	1219.2	0.3	894,614	lb	**447.3** tons
curve	vertical	59+11	1+802	5,152.9	1,570.6	520.0	158.5	48.0	1219.2	0.3	911,405	lb	**455.7** tons
curve	vertical	59+93	1+827	5,236.2	1,596.0	532.6	162.3	48.0	1219.2	0.3	928,030	lb	**464.0** tons
curve	vertical	60+75	1+852	5,319.4	1,621.4	547.1	166.8	48.0	1219.2	0.3	944,385	lb	**472.2** tons
curve	vertical	61+57	1+877	5,402.7	1,646.8	563.5	171.8	48.0	1219.2	0.3	960,424	lb	**480.2** tons
curve	vertical	62+38	1+901	5,485.9	1,672.1	581.8	177.3	48.0	1219.2	0.3	976,128	lb	**488.1** tons
curve	vertical	63+19	1+926	5,569.2	1,697.5	602.0	183.5	48.0	1219.2	0.3	991,481	lb	**495.7** tons
curve	vertical	63+99	1+950	5,652.4	1,722.9	624.0	190.2	48.0	1219.2	0.3	1,006,474	lb	**503.2** tons
straight		65+21	1+988	5,779.7	1,761.7	659.0	200.9	48.0	1219.2	0.3	1,012,355	lb	**506.2** tons
straight		66+43	2+025	5,906.9	1,800.4	694.1	211.6	48.0	1219.2	0.3	1,018,237	lb	**509.1** tons
straight		67+66	2+062	6,034.1	1,839.2	729.2	222.3	48.0	1219.2	0.3	1,024,118	lb	**512.1** tons
HDD Rig Location		68+88	2+099	6,161.4	1,878.0	764.3	233.0	48.0	1219.2	0.3	1,030,000	lb	**515.0** tons

HDD Installation Stress Analysis

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	CombinedTensile and Bending <1.0	Combined Tensile, Bending and Hoop Factor	Combined Tensile, Bending and Hoop <1.0
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS				
746	5.15	1.07%	0	0.00	0.00%	0	0.00	0.00%	0.01	Yes	0.00	Yes
919	6.34	1.31%	0	0.00	0.00%	333	2.29	0.48%	0.02	Yes	0.00	Yes
1,092	7.53	1.56%	0	0.00	0.00%	665	4.59	0.95%	0.02	Yes	0.01	Yes
1,266	8.73	1.81%	0	0.00	0.00%	998	6.88	1.43%	0.02	Yes	0.02	Yes
1,439	9.92	2.06%	0	0.00	0.00%	1,330	9.17	1.90%	0.03	Yes	0.03	Yes
1,612	11.11	2.30%	0	0.00	0.00%	1,663	11.46	2.38%	0.03	Yes	0.05	Yes
1,785	12.31	2.55%	0	0.00	0.00%	1,995	13.76	2.85%	0.03	Yes	0.07	Yes
1,958	13.50	2.80%	0	0.00	0.00%	2,328	16.05	3.33%	0.03	Yes	0.10	Yes
2,131	14.69	3.04%	0	0.00	0.00%	2,660	18.34	3.80%	0.04	Yes	0.13	Yes
2,625	18.10	3.75%	12,083	83.31	17.26%	2,886	19.90	4.12%	0.32	Yes	0.25	Yes
2,614	18.02	3.73%	12,083	83.31	17.26%	3,082	21.25	4.40%	0.32	Yes	0.28	Yes
2,707	18.67	3.87%	12,083	83.31	17.26%	3,248	22.39	4.64%	0.32	Yes	0.30	Yes
2,821	19.45	4.03%	12,083	83.31	17.26%	3,384	23.33	4.83%	0.32	Yes	0.32	Yes
6,283	43.32	8.98%	12,083	83.31	17.26%	3,489	24.06	4.98%	0.38	Yes	0.38	Yes
4,307	29.69	6.15%	12,083	83.31	17.26%	3,565	24.58	5.09%	0.35	Yes	0.36	Yes
4,420	30.47	6.31%	12,083	83.31	17.26%	3,610	24.89	5.16%	0.35	Yes	0.37	Yes
4,526	31.21	6.47%	12,083	83.31	17.26%	3,626	25.00	5.18%	0.35	Yes	0.37	Yes
4,603	31.73	6.58%	0	0.00	0.00%	3,626	25.00	5.18%	0.08	Yes	0.24	Yes
4,679	32.26	6.68%	0	0.00	0.00%	3,626	25.00	5.18%	0.08	Yes	0.24	Yes
4,756	32.79	6.79%	0	0.00	0.00%	3,626	25.00	5.18%	0.08	Yes	0.24	Yes
4,832	33.32	6.90%	0	0.00	0.00%	3,626	25.00	5.18%	0.09	Yes	0.24	Yes
4,909	33.84	7.01%	0	0.00	0.00%	3,626	25.00	5.18%	0.09	Yes	0.25	Yes
4,985	34.37	7.12%	0	0.00	0.00%	3,626	25.00	5.18%	0.09	Yes	0.25	Yes
5,061	34.90	7.23%	0	0.00	0.00%	3,626	25.00	5.18%	0.09	Yes	0.25	Yes
5,138	35.42	7.34%	0	0.00	0.00%	3,626	25.00	5.18%	0.09	Yes	0.25	Yes
5,280	36.40	7.54%	0	0.00	0.00%	3,433	23.67	4.90%	0.09	Yes	0.25	Yes
5,422	37.38	7.75%	0	0.00	0.00%	3,433	23.67	4.90%	0.10	Yes	0.25	Yes
5,564	38.36	7.95%	0	0.00	0.00%	3,433	23.67	4.90%	0.10	Yes	0.25	Yes
5,706	39.34	8.15%	0	0.00	0.00%	3,433	23.67	4.90%	0.10	Yes	0.25	Yes
5,848	40.32	8.35%	0	0.00	0.00%	3,433	23.67	4.90%	0.10	Yes	0.25	Yes
5,990	41.30	8.56%	0	0.00	0.00%	3,433	23.67	4.90%	0.11	Yes	0.25	Yes
6,132	42.28	8.76%	0	0.00	0.00%	3,433	23.67	4.90%	0.11	Yes	0.25	Yes
6,274	43.26	8.96%	0	0.00	0.00%	3,433	23.67	4.90%	0.11	Yes	0.26	Yes
6,417	44.24	9.17%	0	0.00	0.00%	3,433	23.67	4.90%	0.11	Yes	0.26	Yes
6,559	45.22	9.37%	0	0.00	0.00%	3,433	23.67	4.90%	0.12	Yes	0.26	Yes
6,701	46.20	9.57%	0	0.00	0.00%	3,433	23.67	4.90%	0.12	Yes	0.26	Yes
6,843	47.18	9.78%	0	0.00	0.00%	3,433	23.67	4.90%	0.12	Yes	0.26	Yes
12,315	84.91	17.59%	0	0.00	0.00%	3,433	23.67	4.90%	0.22	Yes	0.31	Yes
8,352	57.58	11.93%	0	0.00	0.00%	3,433	23.67	4.90%	0.15	Yes	0.27	Yes
8,494	58.56	12.13%	0	0.00	0.00%	3,433	23.67	4.90%	0.15	Yes	0.27	Yes
8,636	59.54	12.34%	0	0.00	0.00%	3,433	23.67	4.90%	0.15	Yes	0.28	Yes
8,778	60.52	12.54%	0	0.00	0.00%	3,433	23.67	4.90%	0.16	Yes	0.28	Yes
8,921	61.51	12.74%	0	0.00	0.00%	3,433	23.67	4.90%	0.16	Yes	0.28	Yes
9,063	62.49	12.95%	0	0.00	0.00%	3,433	23.67	4.90%	0.16	Yes	0.28	Yes
9,205	63.47	13.15%	0	0.00	0.00%	3,433	23.67	4.90%	0.16	Yes	0.28	Yes
10,126	69.82	14.47%	12,083	83.31	17.26%	3,420	23.58	4.89%	0.45	Yes	0.46	Yes
10,069	69.42	14.38%	12,083	83.31	17.26%	3,384	23.33	4.83%	0.45	Yes	0.45	Yes
10,217	70.44	14.60%	12,083	83.31	17.26%	3,322	22.91	4.75%	0.45	Yes	0.45	Yes
10,407	71.76	14.87%	12,083	83.31	17.26%	3,236	22.31	4.62%	0.46	Yes	0.44	Yes
10,605	73.12	15.15%	12,083	83.31	17.26%	3,129	21.57	4.47%	0.46	Yes	0.43	Yes
10,804	74.49	15.43%	12,083	83.31	17.26%	2,997	20.67	4.28%	0.46	Yes	0.42	Yes
11,001	75.85	15.72%	12,083	83.31	17.26%	2,843	19.60	4.06%	0.47	Yes	0.40	Yes
11,195	77.19	15.99%	12,083	83.31	17.26%	2,664	18.37	3.81%	0.47	Yes	0.38	Yes
11,385	78.50	16.26%	12,083	83.31	17.26%	2,463	16.98	3.52%	0.47	Yes	0.36	Yes
11,572	79.78	16.53%	12,083	83.31	17.26%	2,239	15.44	3.20%	0.48	Yes	0.34	Yes
11,754	81.04	16.79%	12,083	83.31	17.26%	1,992	13.73	2.85%	0.48	Yes	0.32	Yes
11,931	82.26	17.04%	12,083	83.31	17.26%	1,721	11.87	2.46%	0.48	Yes	0.29	Yes
12,001	82.74	17.14%	0	0.00	0.00%	1,291	8.90	1.84%	0.21	Yes	0.10	Yes
12,071	83.22	17.24%	0	0.00	0.00%	861	5.93	1.23%	0.22	Yes	0.08	Yes
12,140	83.71	17.34%	0	0.00	0.00%	430	2.97	0.61%	0.22	Yes	0.06	Yes
12,210	84.19	17.44%	0	0.00	0.00%	0	0.00	0.00%	0.22	Yes	0.05	Yes

NOTE: Hoop stress taken as an empty pipe for no buoyancy control and with water with buoyancy control

Ground Elevation at Pipe Entry	780.00	feet
	237.75	metres
Ground Elevation at Pipe Exit	764.26	feet
	232.95	metres

	TOTAL PULL LOADS		
Maximum Values	1,030,000	lb	519.4 tons

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	Combined Tensile, Bending and Hoop Factor
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS		
12,315	84.9	17.59%	12,083	83.3	17.26%	3,626	25.0	5.18%	0.48	0.46

Input Pipe Properties

Pipe Outer Diameter	36	in
	914.4	mm
Pipe Wall Thickness	0.762	in
	19.3548	mm
DR	47.2	
Pipe Weight (in air)	287.04	lbs/ft
	428.06	kg/m
Weight of Water in pipe	0.0	lbs/ft
	0.00	kg/m
Net Buoyant Weight of pipe	-241.7	lbs/ft
	-360.42	kg/m
Young's Modulus of Elasticity	2.90E+07	psi
	199948	MPa
Yield Strength	70,000	psi
	482.6	MPa
Poisson Ratio	0.3	
Drill Pipe Diameter	6.625	in
	168.275	mm
Minimum Radius of Curvature	2,600	ft
	792	m
Ultimate Safe Pull Load	3,542,953	lb
	15,760	kN
Maximum Calculated Pull Load	1,030,000	lb
	4,582	kN
Factor of Safety	3.4	
Start-up Load Factor	1.5	
Required Pipe Pull Load	1,038,827	lb
	4,621	kN
Factor of Safety	3.4	

Soil and Mud Properties

Mud Weight	10	ppg of drill fluid and solids (typically 9.5 to 11 lb/gal)
	1.199	Specific Gravity
Friction Coeff. (GS or rollers)	0.15	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	24	lb/100ft^2 (Based on HDD experience from previous installations)
	114.912	dyne/cm^2
Plastic Viscosity	16	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	300	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	1.136	m^3/min
Drilling mud pumping rate	1093	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.138	m^3/min
Pipe Pullback Rate	15	feet/min (Based on HDD experience)
	4.57	m/min

MOTT MACDONALD

Horizontal Directional Drilling
Calculation of Pull Loads and Stresses during Pipe Installation

Calculated by: S. Crouse
Checked by: G. Duyvestyn
Date: 2/13/2017
Project No: 353754

PROJECT: PennEast Pipeline

HDD CROSSING LOCATION: Pohopoco Creek (Beltzville Lake) / Wild Creek

Reference:

1. **Installation of Pipelines by Horizontal Directional Drilling, an Engineering Guide, PRCI Publication 2015**
2. **Pipeline Design for Installation by Horizontal Directional Drilling, Manual of Practice, ASCE MREP 108, 2005**

HDD Installation Load Analysis

Segment Type	Type of Curve	Bore Stationing		Installed Length		Bore Elevation		Bore Diameter		Geotechnical Friction Factor	TOTAL PULL LOADS		
		feet	metres	feet	metres	feet	metres	inch	mm				
Pipe Entry Location		7+88	0+240	0.0	0.0	780.0	237.7	--	--		62,949	lb	**31.5** tons
straight		9+15	0+279	130.3	39.7	752.9	229.5	48.0	1219.2	0.3	63,575	lb	**31.8** tons
straight		10+43	0+318	260.7	79.5	725.8	221.2	48.0	1219.2	0.3	64,200	lb	**32.1** tons
straight		11+70	0+357	391.0	119.2	698.7	213.0	48.0	1219.2	0.3	64,826	lb	**32.4** tons
straight		12+98	0+396	521.4	158.9	671.6	204.7	48.0	1219.2	0.3	65,452	lb	**32.7** tons
straight		14+25	0+434	651.7	198.7	644.5	196.4	48.0	1219.2	0.3	66,078	lb	**33.0** tons
straight		15+53	0+473	782.1	238.4	617.4	188.2	48.0	1219.2	0.3	66,703	lb	**33.4** tons
straight		16+80	0+512	912.4	278.1	590.3	179.9	48.0	1219.2	0.3	67,329	lb	**33.7** tons
straight		18+08	0+551	1,042.8	317.8	563.2	171.7	48.0	1219.2	0.3	67,955	lb	**34.0** tons
curve	vertical	19+00	0+579	1,137.0	346.6	544.8	166.1	48.0	1219.2	0.3	86,999	lb	**43.5** tons
curve	vertical	19+93	0+607	1,231.3	375.3	528.8	161.2	48.0	1219.2	0.3	64,235	lb	**32.1** tons
curve	vertical	20+86	0+636	1,325.5	404.0	515.3	157.1	48.0	1219.2	0.3	63,867	lb	**31.9** tons
curve	vertical	21+80	0+664	1,419.8	432.8	504.2	153.7	48.0	1219.2	0.3	68,653	lb	**34.3** tons
curve	vertical	22+74	0+693	1,514.0	461.5	495.6	151.1	48.0	1219.2	0.3	260,515	lb	**130.3** tons
curve	vertical	23+68	0+722	1,608.3	490.2	489.5	149.2	48.0	1219.2	0.3	177,203	lb	**88.6** tons
curve	vertical	24+62	0+750	1,702.5	518.9	485.8	148.1	48.0	1219.2	0.3	180,770	lb	**90.4** tons
curve	vertical	25+56	0+779	1,796.8	547.7	484.5	147.7	48.0	1219.2	0.3	184,469	lb	**92.2** tons
straight		26+58	0+810	1,898.5	578.7	484.5	147.7	48.0	1219.2	0.3	188,512	lb	**94.3** tons
straight		27+60	0+841	2,000.3	609.7	484.5	147.7	48.0	1219.2	0.3	192,555	lb	**96.3** tons
straight		28+61	0+872	2,102.1	640.7	484.5	147.7	48.0	1219.2	0.3	196,598	lb	**98.3** tons
straight		29+63	0+903	2,203.9	671.7	484.5	147.7	48.0	1219.2	0.3	200,641	lb	**100.3** tons
straight		30+65	0+934	2,305.6	702.8	484.5	147.7	48.0	1219.2	0.3	204,684	lb	**102.3** tons
straight		31+67	0+965	2,407.4	733.8	484.5	147.7	48.0	1219.2	0.3	208,727	lb	**104.4** tons
straight		32+69	0+996	2,509.2	764.8	484.5	147.7	48.0	1219.2	0.3	212,770	lb	**106.4** tons
straight		33+70	1+027	2,611.0	795.8	484.5	147.7	48.0	1219.2	0.3	216,813	lb	**108.4** tons
straight		34+72	1+058	2,712.7	826.9	484.5	147.7	48.0	1219.2	0.3	224,585	lb	**112.3** tons
straight		35+74	1+089	2,814.5	857.9	484.5	147.7	48.0	1219.2	0.3	232,357	lb	**116.2** tons
straight		36+76	1+120	2,916.3	888.9	484.5	147.7	48.0	1219.2	0.3	240,128	lb	**120.1** tons
straight		37+77	1+151	3,018.1	919.9	484.5	147.7	48.0	1219.2	0.3	247,900	lb	**124.0** tons
straight		38+79	1+182	3,119.8	950.9	484.5	147.7	48.0	1219.2	0.3	255,672	lb	**127.8** tons
straight		39+81	1+213	3,221.6	982.0	484.5	147.7	48.0	1219.2	0.3	263,444	lb	**131.7** tons
straight		40+83	1+244	3,323.4	1,013.0	484.5	147.7	48.0	1219.2	0.3	271,216	lb	**135.6** tons
straight		41+85	1+275	3,425.2	1,044.0	484.5	147.7	48.0	1219.2	0.3	278,988	lb	**139.5** tons
straight		42+86	1+306	3,526.9	1,075.0	484.5	147.7	48.0	1219.2	0.3	286,760	lb	**143.4** tons
straight		43+88	1+338	3,628.7	1,106.0	484.5	147.7	48.0	1219.2	0.3	294,532	lb	**147.3** tons
straight		44+90	1+369	3,730.5	1,137.1	484.5	147.7	48.0	1219.2	0.3	302,304	lb	**151.2** tons
straight		45+92	1+400	3,832.3	1,168.1	484.5	147.7	48.0	1219.2	0.3	310,076	lb	**155.0** tons
straight		46+93	1+431	3,934.0	1,199.1	484.5	147.7	48.0	1219.2	0.3	631,775	lb	**315.9** tons
straight		47+95	1+462	4,035.8	1,230.1	484.5	147.7	48.0	1219.2	0.3	428,956	lb	**214.5** tons
straight		48+97	1+493	4,137.6	1,261.2	484.5	147.7	48.0	1219.2	0.3	436,727	lb	**218.4** tons
straight		49+99	1+524	4,239.4	1,292.2	484.5	147.7	48.0	1219.2	0.3	444,499	lb	**222.2** tons
straight		51+01	1+555	4,341.3	1,323.2	484.5	147.7	48.0	1219.2	0.3	452,284	lb	**226.1** tons
straight		52+03	1+586	4,443.2	1,354.3	484.5	147.7	48.0	1219.2	0.3	460,068	lb	**230.0** tons
straight		53+05	1+617	4,545.2	1,385.4	484.5	147.7	48.0	1219.2	0.3	467,852	lb	**233.9** tons
straight		54+07	1+648	4,647.1	1,416.5	484.5	147.7	48.0	1219.2	0.3	475,636	lb	**237.8** tons
curve	vertical	54+91	1+674	4,731.9	1,442.3	485.5	148.0	48.0	1219.2	0.3	526,639	lb	**263.3** tons
curve	vertical	55+76	1+700	4,816.8	1,468.2	488.5	148.9	48.0	1219.2	0.3	495,962	lb	**248.0** tons
curve	vertical	56+61	1+725	4,901.6	1,494.0	493.5	150.4	48.0	1219.2	0.3	483,795	lb	**241.9** tons
curve	vertical	57+45	1+751	4,986.4	1,519.9	500.5	152.6	48.0	1219.2	0.3	476,570	lb	**238.3** tons
curve	vertical	58+28	1+776	5,069.7	1,545.3	509.3	155.2	48.0	1219.2	0.3	479,675	lb	**239.8** tons
curve	vertical	59+11	1+802	5,152.9	1,570.6	520.0	158.5	48.0	1219.2	0.3	484,819	lb	**242.4** tons
curve	vertical	59+93	1+827	5,236.2	1,596.0	532.6	162.3	48.0	1219.2	0.3	489,613	lb	**244.8** tons
curve	vertical	60+75	1+852	5,319.4	1,621.4	547.1	166.8	48.0	1219.2	0.3	494,256	lb	**247.1** tons
curve	vertical	61+57	1+877	5,402.7	1,646.8	563.5	171.8	48.0	1219.2	0.3	498,861	lb	**249.4** tons
curve	vertical	62+38	1+901	5,485.9	1,672.1	581.8	177.3	48.0	1219.2	0.3	503,500	lb	**251.7** tons
curve	vertical	63+19	1+926	5,569.2	1,697.5	602.0	183.5	48.0	1219.2	0.3	508,216	lb	**254.1** tons
curve	vertical	63+99	1+950	5,652.4	1,722.9	624.0	190.2	48.0	1219.2	0.3	513,038	lb	**256.5** tons
straight		65+21	1+988	5,779.7	1,761.7	659.0	200.9	48.0	1219.2	0.3	528,044	lb	**264.0** tons
straight		66+43	2+025	5,906.9	1,800.4	694.1	211.6	48.0	1219.2	0.3	543,050	lb	**271.5** tons
straight		67+66	2+062	6,034.1	1,839.2	729.2	222.3	48.0	1219.2	0.3	558,056	lb	**279.0** tons
HDD Rig Location		68+88	2+099	6,161.4	1,878.0	764.3	233.0	48.0	1219.2	0.3	573,061	lb	**286.5** tons

HDD Installation Stress Analysis

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	CombinedTensile and Bending <1.0	Combined Tensile, Bending and Hoop Factor	Combined Tensile, Bending and Hoop <1.0
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS				
746	5.15	1.07%	0	0.00	0.00%	0	0.00	0.00%	0.01	Yes	0.00	Yes
754	5.20	1.08%	0	0.00	0.00%	55	0.38	0.08%	0.01	Yes	0.00	Yes
761	5.25	1.09%	0	0.00	0.00%	110	0.76	0.16%	0.01	Yes	0.00	Yes
768	5.30	1.10%	0	0.00	0.00%	165	1.14	0.24%	0.01	Yes	0.00	Yes
776	5.35	1.11%	0	0.00	0.00%	221	1.52	0.32%	0.01	Yes	0.00	Yes
783	5.40	1.12%	0	0.00	0.00%	276	1.90	0.39%	0.01	Yes	0.00	Yes
791	5.45	1.13%	0	0.00	0.00%	331	2.28	0.47%	0.01	Yes	0.00	Yes
798	5.50	1.14%	0	0.00	0.00%	386	2.66	0.55%	0.01	Yes	0.00	Yes
806	5.55	1.15%	0	0.00	0.00%	441	3.04	0.63%	0.01	Yes	0.00	Yes
1,031	7.11	1.47%	12,083	83.31	17.26%	478	3.30	0.68%	0.29	Yes	0.07	Yes
761	5.25	1.09%	12,083	83.31	17.26%	511	3.52	0.73%	0.28	Yes	0.06	Yes
757	5.22	1.08%	12,083	83.31	17.26%	538	3.71	0.77%	0.28	Yes	0.06	Yes
814	5.61	1.16%	12,083	83.31	17.26%	561	3.87	0.80%	0.29	Yes	0.07	Yes
3,088	21.29	4.41%	12,083	83.31	17.26%	578	3.99	0.83%	0.33	Yes	0.09	Yes
2,101	14.48	3.00%	12,083	83.31	17.26%	591	4.07	0.84%	0.31	Yes	0.08	Yes
2,143	14.78	3.06%	12,083	83.31	17.26%	599	4.13	0.86%	0.31	Yes	0.08	Yes
2,187	15.08	3.12%	12,083	83.31	17.26%	601	4.14	0.86%	0.31	Yes	0.08	Yes
2,235	15.41	3.19%	0	0.00	0.00%	601	4.14	0.86%	0.04	Yes	0.01	Yes
2,283	15.74	3.26%	0	0.00	0.00%	601	4.14	0.86%	0.04	Yes	0.01	Yes
2,331	16.07	3.33%	0	0.00	0.00%	601	4.14	0.86%	0.04	Yes	0.01	Yes
2,379	16.40	3.40%	0	0.00	0.00%	601	4.14	0.86%	0.04	Yes	0.01	Yes
2,426	16.73	3.47%	0	0.00	0.00%	601	4.14	0.86%	0.04	Yes	0.01	Yes
2,474	17.06	3.53%	0	0.00	0.00%	601	4.14	0.86%	0.04	Yes	0.01	Yes
2,522	17.39	3.60%	0	0.00	0.00%	601	4.14	0.86%	0.05	Yes	0.01	Yes
2,570	17.72	3.67%	0	0.00	0.00%	601	4.14	0.86%	0.05	Yes	0.01	Yes
2,662	18.36	3.80%	0	0.00	0.00%	569	3.92	0.81%	0.05	Yes	0.01	Yes
2,754	18.99	3.93%	0	0.00	0.00%	569	3.92	0.81%	0.05	Yes	0.01	Yes
2,847	19.63	4.07%	0	0.00	0.00%	569	3.92	0.81%	0.05	Yes	0.01	Yes
2,939	20.26	4.20%	0	0.00	0.00%	569	3.92	0.81%	0.05	Yes	0.01	Yes
3,031	20.90	4.33%	0	0.00	0.00%	569	3.92	0.81%	0.05	Yes	0.01	Yes
3,123	21.53	4.46%	0	0.00	0.00%	569	3.92	0.81%	0.06	Yes	0.01	Yes
3,215	22.17	4.59%	0	0.00	0.00%	569	3.92	0.81%	0.06	Yes	0.01	Yes
3,307	22.80	4.72%	0	0.00	0.00%	569	3.92	0.81%	0.06	Yes	0.01	Yes
3,399	23.44	4.86%	0	0.00	0.00%	569	3.92	0.81%	0.06	Yes	0.01	Yes
3,492	24.07	4.99%	0	0.00	0.00%	569	3.92	0.81%	0.06	Yes	0.01	Yes
3,584	24.71	5.12%	0	0.00	0.00%	569	3.92	0.81%	0.06	Yes	0.01	Yes
3,676	25.34	5.25%	0	0.00	0.00%	569	3.92	0.81%	0.07	Yes	0.01	Yes
7,489	51.64	10.70%	0	0.00	0.00%	569	3.92	0.81%	0.13	Yes	0.03	Yes
5,085	35.06	7.26%	0	0.00	0.00%	569	3.92	0.81%	0.09	Yes	0.02	Yes
5,177	35.70	7.40%	0	0.00	0.00%	569	3.92	0.81%	0.09	Yes	0.02	Yes
5,269	36.33	7.53%	0	0.00	0.00%	569	3.92	0.81%	0.09	Yes	0.02	Yes
5,362	36.97	7.66%	0	0.00	0.00%	569	3.92	0.81%	0.10	Yes	0.02	Yes
5,454	37.60	7.79%	0	0.00	0.00%	569	3.92	0.81%	0.10	Yes	0.02	Yes
5,546	38.24	7.92%	0	0.00	0.00%	569	3.92	0.81%	0.10	Yes	0.02	Yes
5,638	38.88	8.05%	0	0.00	0.00%	569	3.92	0.81%	0.10	Yes	0.02	Yes
6,243	43.04	8.92%	12,083	83.31	17.26%	567	3.91	0.81%	0.38	Yes	0.12	Yes
5,879	40.54	8.40%	12,083	83.31	17.26%	561	3.87	0.80%	0.38	Yes	0.12	Yes
5,735	39.54	8.19%	12,083	83.31	17.26%	551	3.80	0.79%	0.37	Yes	0.12	Yes
5,650	38.95	8.07%	12,083	83.31	17.26%	537	3.70	0.77%	0.37	Yes	0.12	Yes
5,686	39.21	8.12%	12,083	83.31	17.26%	519	3.58	0.74%	0.37	Yes	0.12	Yes
5,747	39.63	8.21%	12,083	83.31	17.26%	497	3.43	0.71%	0.37	Yes	0.12	Yes
5,804	40.02	8.29%	12,083	83.31	17.26%	471	3.25	0.67%	0.37	Yes	0.12	Yes
5,859	40.40	8.37%	12,083	83.31	17.26%	442	3.05	0.63%	0.38	Yes	0.12	Yes
5,914	40.77	8.45%	12,083	83.31	17.26%	408	2.82	0.58%	0.38	Yes	0.12	Yes
5,969	41.15	8.53%	12,083	83.31	17.26%	371	2.56	0.53%	0.38	Yes	0.11	Yes
6,025	41.54	8.61%	12,083	83.31	17.26%	330	2.28	0.47%	0.38	Yes	0.11	Yes
6,082	41.93	8.69%	12,083	83.31	17.26%	285	1.97	0.41%	0.38	Yes	0.11	Yes
6,260	43.16	8.94%	0	0.00	0.00%	214	1.48	0.31%	0.11	Yes	0.02	Yes
6,438	44.39	9.20%	0	0.00	0.00%	143	0.98	0.20%	0.11	Yes	0.01	Yes
6,615	45.61	9.45%	0	0.00	0.00%	71	0.49	0.10%	0.12	Yes	0.01	Yes
6,793	46.84	9.70%	0	0.00	0.00%	0	0.00	0.00%	0.12	Yes	0.01	Yes

NOTE: Hoop stress taken as an empty pipe for no buoyancy control and with water with buoyancy control

Ground Elevation at Pipe Entry	780.00	feet
	237.75	metres
Ground Elevation at Pipe Exit	764.26	feet
	232.95	metres

	TOTAL PULL LOADS		
Maximum Values	573,061	lb	315.9 tons

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	Combined Tensile, Bending and Hoop Factor
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS		
7,489	51.6	10.70%	12,083	83.3	17.26%	601	4.1	0.86%	0.38	0.12

Input Pipe Properties

Pipe Outer Diameter	36	in
	914.4	mm
Pipe Wall Thickness	0.762	in
	19.3548	mm
DR	47.2	
Pipe Weight (in air)	287.04	lbs/ft
	428.06	kg/m
Weight of Water in pipe	404.5	lbs/ft
	603.26	kg/m
Net Buoyant Weight of pipe	162.8	lbs/ft
	242.84	kg/m
Young's Modulus of Elasticity	2.90E+07	psi
	199948	MPa
Yield Strength	70,000	psi
	482.6	MPa
Poisson Ratio	0.3	
Drill Pipe Diameter	6.625	in
	168.275	mm
Minimum Radius of Curvature	2,600	ft
	792	m
Ultimate Safe Pull Load	3,542,953	lb
	15,760	kN
Maximum Calculated Pull Load	573,061	lb
	2,549	kN
Factor of Safety	6.2	
Start-up Load Factor	1.5	
Required Pipe Pull Load	631,775	lb
	2,810	kN
Factor of Safety	5.6	

Soil and Mud Properties

Mud Weight	10	ppg of drill fluid and solids (typically 9.5 to 11 lb/gal)
	1.199	Specific Gravity
Friction Coeff. (GS or rollers)	0.15	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	24	lb/100ft^2 (Based on HDD experience from previous installations)
	114.912	dyne/cm^2
Plastic Viscosity	16	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	300	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	1.136	m^3/min
Drilling mud pumping rate	1093	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.138	m^3/min
Pipe Pullback Rate	15	feet/min (Based on HDD experience)
	4.57	m/min

MOTT MACDONALD

Horizontal Directional Drilling
Calculation of Pull Loads and Stresses during Pipe Installation

Calculated by: S. Crouse
Checked by: G. Duyvestyn
Date: 2/13/2017
Project No: 353754

PROJECT: PennEast Pipeline

HDD CROSSING LOCATION: Pohopoco Creek (Beltzville Lake) / Wild Creek

Reference:

1. Installation of Pipelines by Horizontal Directional Drilling, an Engineering Guide, PRCI Publication 2015
2. Pipeline Design for Installation by Horizontal Directional Drilling, Manual of Practice, ASCE MREP 108, 2005

HDD Installation Load Analysis

Segment Type	Type of Curve	Bore Stationing		Installed Length		Bore Elevation		Bore Diameter		Geotechnical Friction Factor	TOTAL PULL LOADS		
		feet	metres	feet	metres	feet	metres	inch	mm				
Pipe Entry Location		7+88	0+240	0.0	0.0	780.0	237.7	--	--		62,949	lb	**31.5** tons
straight		9+15	0+279	130.3	39.7	752.9	229.5	48.0	1219.2	0.3	81,009	lb	**40.5** tons
straight		10+43	0+318	260.7	79.5	725.8	221.2	48.0	1219.2	0.3	99,069	lb	**49.5** tons
straight		11+70	0+357	391.0	119.2	698.7	213.0	48.0	1219.2	0.3	117,129	lb	**58.6** tons
straight		12+98	0+396	521.4	158.9	671.6	204.7	48.0	1219.2	0.3	135,189	lb	**67.6** tons
straight		14+25	0+434	651.7	198.7	644.5	196.4	48.0	1219.2	0.3	153,248	lb	**76.6** tons
straight		15+53	0+473	782.1	238.4	617.4	188.2	48.0	1219.2	0.3	171,308	lb	**85.7** tons
straight		16+80	0+512	912.4	278.1	590.3	179.9	48.0	1219.2	0.3	189,368	lb	**94.7** tons
straight		18+08	0+551	1,042.8	317.8	563.2	171.7	48.0	1219.2	0.3	207,428	lb	**103.7** tons
curve	vertical	19+00	0+579	1,137.0	346.6	544.8	166.1	48.0	1219.2	0.3	252,157	lb	**126.1** tons
curve	vertical	19+93	0+607	1,231.3	375.3	528.8	161.2	48.0	1219.2	0.3	254,195	lb	**127.1** tons
curve	vertical	20+86	0+636	1,325.5	404.0	515.3	157.1	48.0	1219.2	0.3	264,872	lb	**132.4** tons
curve	vertical	21+80	0+664	1,419.8	432.8	504.2	153.7	48.0	1219.2	0.3	277,110	lb	**138.6** tons
curve	vertical	22+74	0+693	1,514.0	461.5	495.6	151.1	48.0	1219.2	0.3	592,398	lb	**296.2** tons
curve	vertical	23+68	0+722	1,608.3	490.2	489.5	149.2	48.0	1219.2	0.3	407,219	lb	**203.6** tons
curve	vertical	24+62	0+750	1,702.5	518.9	485.8	148.1	48.0	1219.2	0.3	418,894	lb	**209.4** tons
curve	vertical	25+56	0+779	1,796.8	547.7	484.5	147.7	48.0	1219.2	0.3	429,876	lb	**214.9** tons
straight		26+58	0+810	1,898.5	578.7	484.5	147.7	48.0	1219.2	0.3	437,941	lb	**219.0** tons
straight		27+60	0+841	2,000.3	609.7	484.5	147.7	48.0	1219.2	0.3	446,005	lb	**223.0** tons
straight		28+61	0+872	2,102.1	640.7	484.5	147.7	48.0	1219.2	0.3	454,070	lb	**227.0** tons
straight		29+63	0+903	2,203.9	671.7	484.5	147.7	48.0	1219.2	0.3	462,135	lb	**231.1** tons
straight		30+65	0+934	2,305.6	702.8	484.5	147.7	48.0	1219.2	0.3	470,199	lb	**235.1** tons
straight		31+67	0+965	2,407.4	733.8	484.5	147.7	48.0	1219.2	0.3	478,264	lb	**239.1** tons
straight		32+69	0+996	2,509.2	764.8	484.5	147.7	48.0	1219.2	0.3	486,329	lb	**243.2** tons
straight		33+70	1+027	2,611.0	795.8	484.5	147.7	48.0	1219.2	0.3	494,393	lb	**247.2** tons
straight		34+72	1+058	2,712.7	826.9	484.5	147.7	48.0	1219.2	0.3	509,203	lb	**254.6** tons
straight		35+74	1+089	2,814.5	857.9	484.5	147.7	48.0	1219.2	0.3	524,013	lb	**262.0** tons
straight		36+76	1+120	2,916.3	888.9	484.5	147.7	48.0	1219.2	0.3	538,823	lb	**269.4** tons
straight		37+77	1+151	3,018.1	919.9	484.5	147.7	48.0	1219.2	0.3	553,633	lb	**276.8** tons
straight		38+79	1+182	3,119.8	950.9	484.5	147.7	48.0	1219.2	0.3	568,443	lb	**284.2** tons
straight		39+81	1+213	3,221.6	982.0	484.5	147.7	48.0	1219.2	0.3	583,252	lb	**291.6** tons
straight		40+83	1+244	3,323.4	1,013.0	484.5	147.7	48.0	1219.2	0.3	598,062	lb	**299.0** tons
straight		41+85	1+275	3,425.2	1,044.0	484.5	147.7	48.0	1219.2	0.3	612,872	lb	**306.4** tons
straight		42+86	1+306	3,526.9	1,075.0	484.5	147.7	48.0	1219.2	0.3	627,682	lb	**313.8** tons
straight		43+88	1+338	3,628.7	1,106.0	484.5	147.7	48.0	1219.2	0.3	642,492	lb	**321.2** tons
straight		44+90	1+369	3,730.5	1,137.1	484.5	147.7	48.0	1219.2	0.3	657,302	lb	**328.7** tons
straight		45+92	1+400	3,832.3	1,168.1	484.5	147.7	48.0	1219.2	0.3	672,111	lb	**336.1** tons
straight		46+93	1+431	3,934.0	1,199.1	484.5	147.7	48.0	1219.2	0.3	1,185,386	lb	**592.7** tons
straight		47+95	1+462	4,035.8	1,230.1	484.5	147.7	48.0	1219.2	0.3	805,067	lb	**402.5** tons
straight		48+97	1+493	4,137.6	1,261.2	484.5	147.7	48.0	1219.2	0.3	819,877	lb	**409.9** tons
straight		49+99	1+524	4,239.4	1,292.2	484.5	147.7	48.0	1219.2	0.3	834,687	lb	**417.3** tons
straight		51+01	1+555	4,341.3	1,323.2	484.5	147.7	48.0	1219.2	0.3	849,520	lb	**424.8** tons
straight		52+03	1+586	4,443.2	1,354.3	484.5	147.7	48.0	1219.2	0.3	864,354	lb	**432.2** tons
straight		53+05	1+617	4,545.2	1,385.4	484.5	147.7	48.0	1219.2	0.3	879,187	lb	**439.6** tons
straight		54+07	1+648	4,647.1	1,416.5	484.5	147.7	48.0	1219.2	0.3	894,021	lb	**447.0** tons
curve	vertical	54+91	1+674	4,731.9	1,442.3	485.5	148.0	48.0	1219.2	0.3	976,363	lb	**488.2** tons
curve	vertical	55+76	1+700	4,816.8	1,468.2	488.5	148.9	48.0	1219.2	0.3	975,978	lb	**488.0** tons
curve	vertical	56+61	1+725	4,901.6	1,494.0	493.5	150.4	48.0	1219.2	0.3	992,646	lb	**496.3** tons
curve	vertical	57+45	1+751	4,986.4	1,519.9	500.5	152.6	48.0	1219.2	0.3	1,012,665	lb	**506.3** tons
curve	vertical	58+28	1+776	5,069.7	1,545.3	509.3	155.2	48.0	1219.2	0.3	1,033,011	lb	**516.5** tons
curve	vertical	59+11	1+802	5,152.9	1,570.6	520.0	158.5	48.0	1219.2	0.3	1,053,316	lb	**526.7** tons
curve	vertical	59+93	1+827	5,236.2	1,596.0	532.6	162.3	48.0	1219.2	0.3	1,073,339	lb	**536.7** tons
curve	vertical	60+75	1+852	5,319.4	1,621.4	547.1	166.8	48.0	1219.2	0.3	1,092,993	lb	**546.5** tons
curve	vertical	61+57	1+877	5,402.7	1,646.8	563.5	171.8	48.0	1219.2	0.3	1,112,245	lb	**556.1** tons
curve	vertical	62+38	1+901	5,485.9	1,672.1	581.8	177.3	48.0	1219.2	0.3	1,131,076	lb	**565.5** tons
curve	vertical	63+19	1+926	5,569.2	1,697.5	602.0	183.5	48.0	1219.2	0.3	1,149,475	lb	**574.7** tons
curve	vertical	63+99	1+950	5,652.4	1,722.9	624.0	190.2	48.0	1219.2	0.3	1,167,429	lb	**583.7** tons
straight		65+21	1+988	5,779.7	1,761.7	659.0	200.9	48.0	1219.2	0.3	1,174,852	lb	**587.4** tons
straight		66+43	2+025	5,906.9	1,800.4	694.1	211.6	48.0	1219.2	0.3	1,182,274	lb	**591.1** tons
straight		67+66	2+062	6,034.1	1,839.2	729.2	222.3	48.0	1219.2	0.3	1,189,696	lb	**594.8** tons
HDD Rig Location		68+88	2+099	6,161.4	1,878.0	764.3	233.0	48.0	1219.2	0.3	1,197,118	lb	**598.6** tons

HDD Installation Stress Analysis

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	CombinedTensile and Bending <1.0	Combined Tensile, Bending and Hoop Factor	Combined Tensile, Bending and Hoop <1.0
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS				
746	5.15	1.07%	0	0.00	0.00%	0	0.00	0.00%	0.01	Yes	0.00	Yes
960	6.62	1.37%	0	0.00	0.00%	366	2.52	0.52%	0.02	Yes	0.00	Yes
1,174	8.10	1.68%	0	0.00	0.00%	732	5.04	1.05%	0.02	Yes	0.01	Yes
1,389	9.57	1.98%	0	0.00	0.00%	1,097	7.57	1.57%	0.02	Yes	0.02	Yes
1,603	11.05	2.29%	0	0.00	0.00%	1,463	10.09	2.09%	0.03	Yes	0.04	Yes
1,817	12.53	2.60%	0	0.00	0.00%	1,829	12.61	2.61%	0.03	Yes	0.06	Yes
2,031	14.00	2.90%	0	0.00	0.00%	2,195	15.13	3.14%	0.04	Yes	0.09	Yes
2,245	15.48	3.21%	0	0.00	0.00%	2,561	17.65	3.66%	0.04	Yes	0.12	Yes
2,459	16.95	3.51%	0	0.00	0.00%	2,926	20.18	4.18%	0.04	Yes	0.15	Yes
2,989	20.61	4.27%	12,083	83.31	17.26%	3,175	21.89	4.54%	0.32	Yes	0.29	Yes
3,013	20.78	4.30%	12,083	83.31	17.26%	3,390	23.37	4.84%	0.32	Yes	0.32	Yes
3,140	21.65	4.49%	12,083	83.31	17.26%	3,572	24.63	5.10%	0.33	Yes	0.34	Yes
3,285	22.65	4.69%	12,083	83.31	17.26%	3,722	25.66	5.32%	0.33	Yes	0.37	Yes
7,023	48.42	10.03%	12,083	83.31	17.26%	3,838	26.46	5.48%	0.40	Yes	0.44	Yes
4,827	33.28	6.90%	12,083	83.31	17.26%	3,922	27.04	5.60%	0.36	Yes	0.42	Yes
4,966	34.24	7.09%	12,083	83.31	17.26%	3,972	27.38	5.67%	0.36	Yes	0.43	Yes
5,096	35.14	7.28%	12,083	83.31	17.26%	3,988	27.50	5.70%	0.36	Yes	0.43	Yes
5,192	35.79	7.42%	0	0.00	0.00%	3,988	27.50	5.70%	0.09	Yes	0.29	Yes
5,287	36.45	7.55%	0	0.00	0.00%	3,988	27.50	5.70%	0.09	Yes	0.30	Yes
5,383	37.11	7.69%	0	0.00	0.00%	3,988	27.50	5.70%	0.10	Yes	0.30	Yes
5,478	37.77	7.83%	0	0.00	0.00%	3,988	27.50	5.70%	0.10	Yes	0.30	Yes
5,574	38.43	7.96%	0	0.00	0.00%	3,988	27.50	5.70%	0.10	Yes	0.30	Yes
5,670	39.09	8.10%	0	0.00	0.00%	3,988	27.50	5.70%	0.10	Yes	0.30	Yes
5,765	39.75	8.24%	0	0.00	0.00%	3,988	27.50	5.70%	0.10	Yes	0.30	Yes
5,861	40.41	8.37%	0	0.00	0.00%	3,988	27.50	5.70%	0.10	Yes	0.30	Yes
6,036	41.62	8.62%	0	0.00	0.00%	3,776	26.03	5.39%	0.11	Yes	0.30	Yes
6,212	42.83	8.87%	0	0.00	0.00%	3,776	26.03	5.39%	0.11	Yes	0.30	Yes
6,387	44.04	9.12%	0	0.00	0.00%	3,776	26.03	5.39%	0.11	Yes	0.30	Yes
6,563	45.25	9.38%	0	0.00	0.00%	3,776	26.03	5.39%	0.12	Yes	0.31	Yes
6,739	46.46	9.63%	0	0.00	0.00%	3,776	26.03	5.39%	0.12	Yes	0.31	Yes
6,914	47.67	9.88%	0	0.00	0.00%	3,776	26.03	5.39%	0.12	Yes	0.31	Yes
7,090	48.88	10.13%	0	0.00	0.00%	3,776	26.03	5.39%	0.13	Yes	0.31	Yes
7,265	50.09	10.38%	0	0.00	0.00%	3,776	26.03	5.39%	0.13	Yes	0.31	Yes
7,441	51.30	10.63%	0	0.00	0.00%	3,776	26.03	5.39%	0.13	Yes	0.31	Yes
7,616	52.51	10.88%	0	0.00	0.00%	3,776	26.03	5.39%	0.14	Yes	0.32	Yes
7,792	53.72	11.13%	0	0.00	0.00%	3,776	26.03	5.39%	0.14	Yes	0.32	Yes
7,968	54.93	11.38%	0	0.00	0.00%	3,776	26.03	5.39%	0.14	Yes	0.32	Yes
14,052	96.89	20.07%	0	0.00	0.00%	3,776	26.03	5.39%	0.25	Yes	0.39	Yes
9,544	65.80	13.63%	0	0.00	0.00%	3,776	26.03	5.39%	0.17	Yes	0.33	Yes
9,719	67.01	13.88%	0	0.00	0.00%	3,776	26.03	5.39%	0.17	Yes	0.34	Yes
9,895	68.22	14.14%	0	0.00	0.00%	3,776	26.03	5.39%	0.18	Yes	0.34	Yes
10,071	69.43	14.39%	0	0.00	0.00%	3,776	26.03	5.39%	0.18	Yes	0.34	Yes
10,246	70.65	14.64%	0	0.00	0.00%	3,776	26.03	5.39%	0.18	Yes	0.34	Yes
10,422	71.86	14.89%	0	0.00	0.00%	3,776	26.03	5.39%	0.19	Yes	0.34	Yes
10,598	73.07	15.14%	0	0.00	0.00%	3,776	26.03	5.39%	0.19	Yes	0.35	Yes
11,574	79.80	16.53%	12,083	83.31	17.26%	3,762	25.94	5.37%	0.48	Yes	0.54	Yes
11,570	79.77	16.53%	12,083	83.31	17.26%	3,722	25.66	5.32%	0.48	Yes	0.54	Yes
11,767	81.13	16.81%	12,083	83.31	17.26%	3,654	25.20	5.22%	0.48	Yes	0.53	Yes
12,005	82.77	17.15%	12,083	83.31	17.26%	3,560	24.55	5.09%	0.48	Yes	0.52	Yes
12,246	84.43	17.49%	12,083	83.31	17.26%	3,441	23.73	4.92%	0.49	Yes	0.51	Yes
12,487	86.09	17.84%	12,083	83.31	17.26%	3,297	22.73	4.71%	0.49	Yes	0.49	Yes
12,724	87.73	18.18%	12,083	83.31	17.26%	3,127	21.56	4.47%	0.50	Yes	0.47	Yes
12,957	89.33	18.51%	12,083	83.31	17.26%	2,931	20.21	4.19%	0.50	Yes	0.45	Yes
13,185	90.91	18.84%	12,083	83.31	17.26%	2,710	18.68	3.87%	0.51	Yes	0.43	Yes
13,408	92.45	19.15%	12,083	83.31	17.26%	2,463	16.98	3.52%	0.51	Yes	0.40	Yes
13,626	93.95	19.47%	12,083	83.31	17.26%	2,191	15.10	3.13%	0.51	Yes	0.37	Yes
13,839	95.42	19.77%	12,083	83.31	17.26%	1,893	13.06	2.70%	0.52	Yes	0.35	Yes
13,927	96.03	19.90%	0	0.00	0.00%	1,420	9.79	2.03%	0.25	Yes	0.13	Yes
14,015	96.63	20.02%	0	0.00	0.00%	947	6.53	1.35%	0.25	Yes	0.10	Yes
14,103	97.24	20.15%	0	0.00	0.00%	473	3.26	0.68%	0.25	Yes	0.08	Yes
14,191	97.85	20.27%	0	0.00	0.00%	0	0.00	0.00%	0.25	Yes	0.07	Yes

NOTE: Hoop stress taken as an empty pipe for no buoyancy control and with water with buoyancy control

Ground Elevation at Pipe Entry	780.00	feet
	237.75	metres
Ground Elevation at Pipe Exit	764.26	feet
	232.95	metres

	TOTAL PULL LOADS		
Maximum Values	1,197,118	lb	598.6 tons

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	Combined Tensile, Bending and Hoop Factor
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS		
14,191	97.8	20.27%	12,083	83.3	17.26%	3,988	27.5	5.70%	0.52	0.54

Input Pipe Properties

Pipe Outer Diameter	36	in
	914.4	mm
Pipe Wall Thickness	0.762	in
	19.3548	mm
DR	47.2	
Pipe Weight (in air)	287.04	lbs/ft
	428.06	kg/m
Weight of Water in pipe	0.0	lbs/ft
	0.00	kg/m
Net Buoyant Weight of pipe	-294.6	lbs/ft
	-439.27	kg/m
Young's Modulus of Elasticity	2.90E+07	psi
	199948	MPa
Yield Strength	70,000	psi
	482.6	MPa
Poisson Ratio	0.3	
Drill Pipe Diameter	6.625	in
	168.275	mm
Minimum Radius of Curvature	2,600	ft
	792	m

Ultimate Safe Pull Load	3,542,953	lb
	15,760	kN
Maximum Calculated Pull Load	1,197,118	lb
	5,325	kN
Factor of Safety	3.0	

Start-up Load Factor	1.5	
Required Pipe Pull Load	1,185,386	lb
	5,273	kN
Factor of Safety	3.0	

Soil and Mud Properties

Mud Weight	11	ppg of drill fluid and solids (typically 9.5 to 11 lb/gal)
	1.319	Specific Gravity
Friction Coeff. (GS or rollers)	0.15	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	24	lb/100ft^2 (Based on HDD experience from previous installations)
	114.912	dyne/cm^2
Plastic Viscosity	16	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	300	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	1.136	m^3/min
Drilling mud pumping rate	1093	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.138	m^3/min
Pipe Pullback Rate	15	feet/min (Based on HDD experience)
	4.57	m/min

MOTT MACDONALD

Horizontal Directional Drilling
Calculation of Pull Loads and Stresses during Pipe Installation

Calculated by: S. Crouse
Checked by: G. Duyvestyn
Date: 2/13/2017
Project No: 353754

PROJECT: PennEast Pipeline

HDD CROSSING LOCATION: Pohopoco Creek (Beltzville Lake) / Wild Creek

Reference:

1. **Installation of Pipelines by Horizontal Directional Drilling, an Engineering Guide, PRCI Publication 2015**
2. **Pipeline Design for Installation by Horizontal Directional Drilling, Manual of Practice, ASCE MREP 108, 2005**

HDD Installation Load Analysis

Segment Type	Type of Curve	Bore Stationing		Installed Length		Bore Elevation		Bore Diameter		Geotechnical Friction Factor	TOTAL PULL LOADS		
		feet	metres	feet	metres	feet	metres	inch	mm				
Pipe Entry Location		7+88	0+240	0.0	0.0	780.0	237.7	--	--		62,949	lb	**31.5** tons
straight		9+15	0+279	130.3	39.7	752.9	229.5	48.0	1219.2	0.3	62,985	lb	**31.5** tons
straight		10+43	0+318	260.7	79.5	725.8	221.2	48.0	1219.2	0.3	63,021	lb	**31.5** tons
straight		11+70	0+357	391.0	119.2	698.7	213.0	48.0	1219.2	0.3	63,058	lb	**31.5** tons
straight		12+98	0+396	521.4	158.9	671.6	204.7	48.0	1219.2	0.3	63,094	lb	**31.5** tons
straight		14+25	0+434	651.7	198.7	644.5	196.4	48.0	1219.2	0.3	63,130	lb	**31.6** tons
straight		15+53	0+473	782.1	238.4	617.4	188.2	48.0	1219.2	0.3	63,167	lb	**31.6** tons
straight		16+80	0+512	912.4	278.1	590.3	179.9	48.0	1219.2	0.3	63,203	lb	**31.6** tons
straight		18+08	0+551	1,042.8	317.8	563.2	171.7	48.0	1219.2	0.3	63,239	lb	**31.6** tons
curve	vertical	19+00	0+579	1,137.0	346.6	544.8	166.1	48.0	1219.2	0.3	85,056	lb	**42.5** tons
curve	vertical	19+93	0+607	1,231.3	375.3	528.8	161.2	48.0	1219.2	0.3	64,968	lb	**32.5** tons
curve	vertical	20+86	0+636	1,325.5	404.0	515.3	157.1	48.0	1219.2	0.3	56,347	lb	**28.2** tons
curve	vertical	21+80	0+664	1,419.8	432.8	504.2	153.7	48.0	1219.2	0.3	59,965	lb	**30.0** tons
curve	vertical	22+74	0+693	1,514.0	461.5	495.6	151.1	48.0	1219.2	0.3	245,649	lb	**122.8** tons
curve	vertical	23+68	0+722	1,608.3	490.2	489.5	149.2	48.0	1219.2	0.3	165,948	lb	**83.0** tons
curve	vertical	24+62	0+750	1,702.5	518.9	485.8	148.1	48.0	1219.2	0.3	168,082	lb	**84.0** tons
curve	vertical	25+56	0+779	1,796.8	547.7	484.5	147.7	48.0	1219.2	0.3	170,262	lb	**85.1** tons
straight		26+58	0+810	1,898.5	578.7	484.5	147.7	48.0	1219.2	0.3	172,690	lb	**86.3** tons
straight		27+60	0+841	2,000.3	609.7	484.5	147.7	48.0	1219.2	0.3	175,119	lb	**87.6** tons
straight		28+61	0+872	2,102.1	640.7	484.5	147.7	48.0	1219.2	0.3	177,548	lb	**88.8** tons
straight		29+63	0+903	2,203.9	671.7	484.5	147.7	48.0	1219.2	0.3	179,976	lb	**90.0** tons
straight		30+65	0+934	2,305.6	702.8	484.5	147.7	48.0	1219.2	0.3	182,405	lb	**91.2** tons
straight		31+67	0+965	2,407.4	733.8	484.5	147.7	48.0	1219.2	0.3	184,834	lb	**92.4** tons
straight		32+69	0+996	2,509.2	764.8	484.5	147.7	48.0	1219.2	0.3	187,262	lb	**93.6** tons
straight		33+70	1+027	2,611.0	795.8	484.5	147.7	48.0	1219.2	0.3	189,691	lb	**94.8** tons
straight		34+72	1+058	2,712.7	826.9	484.5	147.7	48.0	1219.2	0.3	194,638	lb	**97.3** tons
straight		35+74	1+089	2,814.5	857.9	484.5	147.7	48.0	1219.2	0.3	199,584	lb	**99.8** tons
straight		36+76	1+120	2,916.3	888.9	484.5	147.7	48.0	1219.2	0.3	204,531	lb	**102.3** tons
straight		37+77	1+151	3,018.1	919.9	484.5	147.7	48.0	1219.2	0.3	209,478	lb	**104.7** tons
straight		38+79	1+182	3,119.8	950.9	484.5	147.7	48.0	1219.2	0.3	214,425	lb	**107.2** tons
straight		39+81	1+213	3,221.6	982.0	484.5	147.7	48.0	1219.2	0.3	219,372	lb	**109.7** tons
straight		40+83	1+244	3,323.4	1,013.0	484.5	147.7	48.0	1219.2	0.3	224,318	lb	**112.2** tons
straight		41+85	1+275	3,425.2	1,044.0	484.5	147.7	48.0	1219.2	0.3	229,265	lb	**114.6** tons
straight		42+86	1+306	3,526.9	1,075.0	484.5	147.7	48.0	1219.2	0.3	234,212	lb	**117.1** tons
straight		43+88	1+338	3,628.7	1,106.0	484.5	147.7	48.0	1219.2	0.3	239,159	lb	**119.6** tons
straight		44+90	1+369	3,730.5	1,137.1	484.5	147.7	48.0	1219.2	0.3	244,106	lb	**122.1** tons
straight		45+92	1+400	3,832.3	1,168.1	484.5	147.7	48.0	1219.2	0.3	249,052	lb	**124.5** tons
straight		46+93	1+431	3,934.0	1,199.1	484.5	147.7	48.0	1219.2	0.3	536,003	lb	**268.0** tons
straight		47+95	1+462	4,035.8	1,230.1	484.5	147.7	48.0	1219.2	0.3	362,282	lb	**181.1** tons
straight		48+97	1+493	4,137.6	1,261.2	484.5	147.7	48.0	1219.2	0.3	367,229	lb	**183.6** tons
straight		49+99	1+524	4,239.4	1,292.2	484.5	147.7	48.0	1219.2	0.3	372,176	lb	**186.1** tons
straight		51+01	1+555	4,341.3	1,323.2	484.5	147.7	48.0	1219.2	0.3	377,130	lb	**188.6** tons
straight		52+03	1+586	4,443.2	1,354.3	484.5	147.7	48.0	1219.2	0.3	382,085	lb	**191.0** tons
straight		53+05	1+617	4,545.2	1,385.4	484.5	147.7	48.0	1219.2	0.3	387,040	lb	**193.5** tons
straight		54+07	1+648	4,647.1	1,416.5	484.5	147.7	48.0	1219.2	0.3	391,994	lb	**196.0** tons
curve	vertical	54+91	1+674	4,731.9	1,442.3	485.5	148.0	48.0	1219.2	0.3	444,653	lb	**222.3** tons
curve	vertical	55+76	1+700	4,816.8	1,468.2	488.5	148.9	48.0	1219.2	0.3	415,522	lb	**207.8** tons
curve	vertical	56+61	1+725	4,901.6	1,494.0	493.5	150.4	48.0	1219.2	0.3	404,766	lb	**202.4** tons
curve	vertical	57+45	1+751	4,986.4	1,519.9	500.5	152.6	48.0	1219.2	0.3	398,805	lb	**199.4** tons
curve	vertical	58+28	1+776	5,069.7	1,545.3	509.3	155.2	48.0	1219.2	0.3	394,990	lb	**197.5** tons
curve	vertical	59+11	1+802	5,152.9	1,570.6	520.0	158.5	48.0	1219.2	0.3	392,327	lb	**196.2** tons
curve	vertical	59+93	1+827	5,236.2	1,596.0	532.6	162.3	48.0	1219.2	0.3	393,237	lb	**196.6** tons
curve	vertical	60+75	1+852	5,319.4	1,621.4	547.1	166.8	48.0	1219.2	0.3	395,958	lb	**198.0** tons
curve	vertical	61+57	1+877	5,402.7	1,646.8	563.5	171.8	48.0	1219.2	0.3	398,596	lb	**199.3** tons
curve	vertical	62+38	1+901	5,485.9	1,672.1	581.8	177.3	48.0	1219.2	0.3	401,217	lb	**200.6** tons
curve	vertical	63+19	1+926	5,569.2	1,697.5	602.0	183.5	48.0	1219.2	0.3	403,863	lb	**201.9** tons
curve	vertical	63+99	1+950	5,652.4	1,722.9	624.0	190.2	48.0	1219.2	0.3	406,562	lb	**203.3** tons
straight		65+21	1+988	5,779.7	1,761.7	659.0	200.9	48.0	1219.2	0.3	416,318	lb	**208.2** tons
straight		66+43	2+025	5,906.9	1,800.4	694.1	211.6	48.0	1219.2	0.3	426,075	lb	**213.0** tons
straight		67+66	2+062	6,034.1	1,839.2	729.2	222.3	48.0	1219.2	0.3	435,831	lb	**217.9** tons
HDD Rig Location		68+88	2+099	6,161.4	1,878.0	764.3	233.0	48.0	1219.2	0.3	445,588	lb	**222.8** tons

HDD Installation Stress Analysis

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	CombinedTensile and Bending <1.0	Combined Tensile, Bending and Hoop Factor	Combined Tensile, Bending and Hoop <1.0
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS				
746	5.15	1.07%	0	0.00	0.00%	0	0.00	0.00%	0.01	Yes	0.00	Yes
747	5.15	1.07%	0	0.00	0.00%	88	0.61	0.13%	0.01	Yes	0.00	Yes
747	5.15	1.07%	0	0.00	0.00%	177	1.22	0.25%	0.01	Yes	0.00	Yes
748	5.15	1.07%	0	0.00	0.00%	265	1.83	0.38%	0.01	Yes	0.00	Yes
748	5.16	1.07%	0	0.00	0.00%	354	2.44	0.51%	0.01	Yes	0.00	Yes
748	5.16	1.07%	0	0.00	0.00%	442	3.05	0.63%	0.01	Yes	0.00	Yes
749	5.16	1.07%	0	0.00	0.00%	530	3.66	0.76%	0.01	Yes	0.01	Yes
749	5.17	1.07%	0	0.00	0.00%	619	4.27	0.88%	0.01	Yes	0.01	Yes
750	5.17	1.07%	0	0.00	0.00%	707	4.87	1.01%	0.01	Yes	0.01	Yes
1,008	6.95	1.44%	12,083	83.31	17.26%	767	5.29	1.10%	0.29	Yes	0.08	Yes
770	5.31	1.10%	12,083	83.31	17.26%	819	5.65	1.17%	0.28	Yes	0.08	Yes
668	4.61	0.95%	12,083	83.31	17.26%	863	5.95	1.23%	0.28	Yes	0.08	Yes
711	4.90	1.02%	12,083	83.31	17.26%	899	6.20	1.28%	0.28	Yes	0.08	Yes
2,912	20.08	4.16%	12,083	83.31	17.26%	927	6.39	1.32%	0.32	Yes	0.10	Yes
1,967	13.56	2.81%	12,083	83.31	17.26%	948	6.53	1.35%	0.31	Yes	0.09	Yes
1,993	13.74	2.85%	12,083	83.31	17.26%	960	6.62	1.37%	0.31	Yes	0.09	Yes
2,018	13.92	2.88%	12,083	83.31	17.26%	964	6.64	1.38%	0.31	Yes	0.09	Yes
2,047	14.11	2.92%	0	0.00	0.00%	964	6.64	1.38%	0.04	Yes	0.02	Yes
2,076	14.31	2.97%	0	0.00	0.00%	964	6.64	1.38%	0.04	Yes	0.02	Yes
2,105	14.51	3.01%	0	0.00	0.00%	964	6.64	1.38%	0.04	Yes	0.02	Yes
2,134	14.71	3.05%	0	0.00	0.00%	964	6.64	1.38%	0.04	Yes	0.02	Yes
2,162	14.91	3.09%	0	0.00	0.00%	964	6.64	1.38%	0.04	Yes	0.02	Yes
2,191	15.11	3.13%	0	0.00	0.00%	964	6.64	1.38%	0.04	Yes	0.02	Yes
2,220	15.31	3.17%	0	0.00	0.00%	964	6.64	1.38%	0.04	Yes	0.02	Yes
2,249	15.50	3.21%	0	0.00	0.00%	964	6.64	1.38%	0.04	Yes	0.02	Yes
2,307	15.91	3.30%	0	0.00	0.00%	912	6.29	1.30%	0.04	Yes	0.02	Yes
2,366	16.31	3.38%	0	0.00	0.00%	912	6.29	1.30%	0.04	Yes	0.02	Yes
2,425	16.72	3.46%	0	0.00	0.00%	912	6.29	1.30%	0.04	Yes	0.02	Yes
2,483	17.12	3.55%	0	0.00	0.00%	912	6.29	1.30%	0.04	Yes	0.02	Yes
2,542	17.53	3.63%	0	0.00	0.00%	912	6.29	1.30%	0.05	Yes	0.02	Yes
2,601	17.93	3.72%	0	0.00	0.00%	912	6.29	1.30%	0.05	Yes	0.02	Yes
2,659	18.33	3.80%	0	0.00	0.00%	912	6.29	1.30%	0.05	Yes	0.02	Yes
2,718	18.74	3.88%	0	0.00	0.00%	912	6.29	1.30%	0.05	Yes	0.02	Yes
2,776	19.14	3.97%	0	0.00	0.00%	912	6.29	1.30%	0.05	Yes	0.02	Yes
2,835	19.55	4.05%	0	0.00	0.00%	912	6.29	1.30%	0.05	Yes	0.02	Yes
2,894	19.95	4.13%	0	0.00	0.00%	912	6.29	1.30%	0.05	Yes	0.02	Yes
2,952	20.36	4.22%	0	0.00	0.00%	912	6.29	1.30%	0.05	Yes	0.02	Yes
6,354	43.81	9.08%	0	0.00	0.00%	912	6.29	1.30%	0.11	Yes	0.03	Yes
4,295	29.61	6.14%	0	0.00	0.00%	912	6.29	1.30%	0.08	Yes	0.03	Yes
4,353	30.02	6.22%	0	0.00	0.00%	912	6.29	1.30%	0.08	Yes	0.03	Yes
4,412	30.42	6.30%	0	0.00	0.00%	912	6.29	1.30%	0.08	Yes	0.03	Yes
4,471	30.82	6.39%	0	0.00	0.00%	912	6.29	1.30%	0.08	Yes	0.03	Yes
4,529	31.23	6.47%	0	0.00	0.00%	912	6.29	1.30%	0.08	Yes	0.03	Yes
4,588	31.63	6.55%	0	0.00	0.00%	912	6.29	1.30%	0.08	Yes	0.03	Yes
4,647	32.04	6.64%	0	0.00	0.00%	912	6.29	1.30%	0.08	Yes	0.03	Yes
5,271	36.34	7.53%	12,083	83.31	17.26%	909	6.27	1.30%	0.36	Yes	0.13	Yes
4,926	33.96	7.04%	12,083	83.31	17.26%	899	6.20	1.28%	0.36	Yes	0.12	Yes
4,798	33.08	6.85%	12,083	83.31	17.26%	883	6.09	1.26%	0.36	Yes	0.12	Yes
4,728	32.60	6.75%	12,083	83.31	17.26%	860	5.93	1.23%	0.36	Yes	0.12	Yes
4,682	32.28	6.69%	12,083	83.31	17.26%	832	5.73	1.19%	0.35	Yes	0.12	Yes
4,651	32.07	6.64%	12,083	83.31	17.26%	797	5.49	1.14%	0.35	Yes	0.12	Yes
4,662	32.14	6.66%	12,083	83.31	17.26%	755	5.21	1.08%	0.35	Yes	0.11	Yes
4,694	32.36	6.71%	12,083	83.31	17.26%	708	4.88	1.01%	0.35	Yes	0.11	Yes
4,725	32.58	6.75%	12,083	83.31	17.26%	655	4.51	0.94%	0.35	Yes	0.11	Yes
4,756	32.79	6.79%	12,083	83.31	17.26%	595	4.10	0.85%	0.36	Yes	0.11	Yes
4,788	33.01	6.84%	12,083	83.31	17.26%	529	3.65	0.76%	0.36	Yes	0.11	Yes
4,820	33.23	6.89%	12,083	83.31	17.26%	457	3.15	0.65%	0.36	Yes	0.10	Yes
4,935	34.03	7.05%	0	0.00	0.00%	343	2.37	0.49%	0.09	Yes	0.01	Yes
5,051	34.82	7.22%	0	0.00	0.00%	229	1.58	0.33%	0.09	Yes	0.01	Yes
5,167	35.62	7.38%	0	0.00	0.00%	114	0.79	0.16%	0.09	Yes	0.01	Yes
5,282	36.42	7.55%	0	0.00	0.00%	0	0.00	0.00%	0.09	Yes	0.01	Yes

NOTE: Hoop stress taken as an empty pipe for no buoyancy control and with water with buoyancy control

Ground Elevation at Pipe Entry	780.00	feet
	237.75	metres
Ground Elevation at Pipe Exit	764.26	feet
	232.95	metres

	TOTAL PULL LOADS		
Maximum Values	445,588	lb	268.0 tons

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	Combined Tensile, Bending and Hoop Factor
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS		
6,354	43.8	9.08%	12,083	83.3	17.26%	964	6.6	1.38%	0.36	0.13

Input Pipe Properties

Pipe Outer Diameter	36	in
	914.4	mm
Pipe Wall Thickness	0.762	in
	19.3548	mm
DR	47.2	
Pipe Weight (in air)	287.04	lbs/ft
	428.06	kg/m
Weight of Water in pipe	404.5	lbs/ft
	603.26	kg/m
Net Buoyant Weight of pipe	110.0	lbs/ft
	163.99	kg/m
Young's Modulus of Elasticity	2.90E+07	psi
	199948	MPa
Yield Strength	70,000	psi
	482.6	MPa
Poisson Ratio	0.3	
Drill Pipe Diameter	6.625	in
	168.275	mm
Minimum Radius of Curvature	2,600	ft
	792	m

Ultimate Safe Pull Load	3,542,953	lb
	15,760	kN
Maximum Calculated Pull Load	445,588	lb
	1,982	kN
Factor of Safety	8.0	

Start-up Load Factor	1.5	
Required Pipe Pull Load	536,003	lb
	2,384	kN
Factor of Safety	6.6	

Soil and Mud Properties

Mud Weight	11	ppg of drill fluid and solids (typically 9.5 to 11 lb/gal)
	1.319	Specific Gravity
Friction Coeff. (GS or rollers)	0.15	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	24	lb/100ft^2 (Based on HDD experience from previous installations)
	114.912	dyne/cm^2
Plastic Viscosity	16	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	300	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	1.136	m^3/min
Drilling mud pumping rate	1093	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.138	m^3/min
Pipe Pullback Rate	15	feet/min (Based on HDD experience)
	4.57	m/min

MOTT MACDONALD

Horizontal Directional Drilling
Calculation of Pull Loads and Stresses during Pipe Installation

Calculated by: S. Crouse
Checked by: G. Duyvestyn
Date: 2/13/2017
Project No: 353754

PROJECT: PennEast Pipeline

HDD CROSSING LOCATION: Pohopoco Creek (Beltzville Lake) / Wild Creek

Reference:

1. Installation of Pipelines by Horizontal Directional Drilling, an Engineering Guide, PRCI Publication 2015
2. Pipeline Design for Installation by Horizontal Directional Drilling, Manual of Practice, ASCE MREP 108, 2005

HDD Installation Load Analysis

Segment Type	Type of Curve	Bore Stationing		Installed Length		Bore Elevation		Bore Diameter		Geotechnical Friction Factor	TOTAL PULL LOADS		
		feet	metres	feet	metres	feet	metres	inch	mm				
Pipe Entry Location		7+88	0+240	0.0	0.0	780.0	237.7	--	--		62,949	lb	**31.5** tons
straight		9+15	0+279	130.3	39.7	752.9	229.5	48.0	1219.2	0.3	84,464	lb	**42.2** tons
straight		10+43	0+318	260.7	79.5	725.8	221.2	48.0	1219.2	0.3	105,979	lb	**53.0** tons
straight		11+70	0+357	391.0	119.2	698.7	213.0	48.0	1219.2	0.3	127,495	lb	**63.7** tons
straight		12+98	0+396	521.4	158.9	671.6	204.7	48.0	1219.2	0.3	149,010	lb	**74.5** tons
straight		14+25	0+434	651.7	198.7	644.5	196.4	48.0	1219.2	0.3	170,525	lb	**85.3** tons
straight		15+53	0+473	782.1	238.4	617.4	188.2	48.0	1219.2	0.3	192,040	lb	**96.0** tons
straight		16+80	0+512	912.4	278.1	590.3	179.9	48.0	1219.2	0.3	213,555	lb	**106.8** tons
straight		18+08	0+551	1,042.8	317.8	563.2	171.7	48.0	1219.2	0.3	235,071	lb	**117.5** tons
curve	vertical	19+00	0+579	1,137.0	346.6	544.8	166.1	48.0	1219.2	0.3	282,875	lb	**141.4** tons
curve	vertical	19+93	0+607	1,231.3	375.3	528.8	161.2	48.0	1219.2	0.3	287,870	lb	**143.9** tons
curve	vertical	20+86	0+636	1,325.5	404.0	515.3	157.1	48.0	1219.2	0.3	301,357	lb	**150.7** tons
curve	vertical	21+80	0+664	1,419.8	432.8	504.2	153.7	48.0	1219.2	0.3	316,238	lb	**158.1** tons
curve	vertical	22+74	0+693	1,514.0	461.5	495.6	151.1	48.0	1219.2	0.3	654,736	lb	**327.4** tons
curve	vertical	23+68	0+722	1,608.3	490.2	489.5	149.2	48.0	1219.2	0.3	451,064	lb	**225.5** tons
curve	vertical	24+62	0+750	1,702.5	518.9	485.8	148.1	48.0	1219.2	0.3	464,865	lb	**232.4** tons
curve	vertical	25+56	0+779	1,796.8	547.7	484.5	147.7	48.0	1219.2	0.3	477,825	lb	**238.9** tons
straight		26+58	0+810	1,898.5	578.7	484.5	147.7	48.0	1219.2	0.3	487,504	lb	**243.8** tons
straight		27+60	0+841	2,000.3	609.7	484.5	147.7	48.0	1219.2	0.3	497,183	lb	**248.6** tons
straight		28+61	0+872	2,102.1	640.7	484.5	147.7	48.0	1219.2	0.3	506,862	lb	**253.4** tons
straight		29+63	0+903	2,203.9	671.7	484.5	147.7	48.0	1219.2	0.3	516,541	lb	**258.3** tons
straight		30+65	0+934	2,305.6	702.8	484.5	147.7	48.0	1219.2	0.3	526,220	lb	**263.1** tons
straight		31+67	0+965	2,407.4	733.8	484.5	147.7	48.0	1219.2	0.3	535,899	lb	**267.9** tons
straight		32+69	0+996	2,509.2	764.8	484.5	147.7	48.0	1219.2	0.3	545,578	lb	**272.8** tons
straight		33+70	1+027	2,611.0	795.8	484.5	147.7	48.0	1219.2	0.3	563,213	lb	**281.6** tons
straight		34+72	1+058	2,712.7	826.9	484.5	147.7	48.0	1219.2	0.3	580,848	lb	**290.4** tons
straight		35+74	1+089	2,814.5	857.9	484.5	147.7	48.0	1219.2	0.3	598,483	lb	**299.2** tons
straight		36+76	1+120	2,916.3	888.9	484.5	147.7	48.0	1219.2	0.3	616,118	lb	**308.1** tons
straight		37+77	1+151	3,018.1	919.9	484.5	147.7	48.0	1219.2	0.3	633,753	lb	**316.9** tons
straight		38+79	1+182	3,119.8	950.9	484.5	147.7	48.0	1219.2	0.3	651,388	lb	**325.7** tons
straight		39+81	1+213	3,221.6	982.0	484.5	147.7	48.0	1219.2	0.3	669,023	lb	**334.5** tons
straight		40+83	1+244	3,323.4	1,013.0	484.5	147.7	48.0	1219.2	0.3	686,658	lb	**343.3** tons
straight		41+85	1+275	3,425.2	1,044.0	484.5	147.7	48.0	1219.2	0.3	704,293	lb	**352.1** tons
straight		42+86	1+306	3,526.9	1,075.0	484.5	147.7	48.0	1219.2	0.3	721,928	lb	**361.0** tons
straight		43+88	1+338	3,628.7	1,106.0	484.5	147.7	48.0	1219.2	0.3	739,563	lb	**369.8** tons
straight		44+90	1+369	3,730.5	1,137.1	484.5	147.7	48.0	1219.2	0.3	757,198	lb	**378.6** tons
straight		45+92	1+400	3,832.3	1,168.1	484.5	147.7	48.0	1219.2	0.3	774,833	lb	**387.4** tons
straight		46+93	1+431	3,934.0	1,199.1	484.5	147.7	48.0	1219.2	0.3	1,343,706	lb	**671.9** tons
straight		47+95	1+462	4,035.8	1,230.1	484.5	147.7	48.0	1219.2	0.3	913,439	lb	**456.7** tons
straight		48+97	1+493	4,137.6	1,261.2	484.5	147.7	48.0	1219.2	0.3	931,075	lb	**465.5** tons
straight		49+99	1+524	4,239.4	1,292.2	484.5	147.7	48.0	1219.2	0.3	948,709	lb	**474.4** tons
straight		51+01	1+555	4,341.3	1,323.2	484.5	147.7	48.0	1219.2	0.3	966,372	lb	**483.2** tons
straight		52+03	1+586	4,443.2	1,354.3	484.5	147.7	48.0	1219.2	0.3	984,035	lb	**492.0** tons
straight		53+05	1+617	4,545.2	1,385.4	484.5	147.7	48.0	1219.2	0.3	1,001,698	lb	**500.8** tons
straight		54+07	1+648	4,647.1	1,416.5	484.5	147.7	48.0	1219.2	0.3	1,019,361	lb	**509.7** tons
curve	vertical	54+91	1+674	4,731.9	1,442.3	485.5	148.0	48.0	1219.2	0.3	1,106,456	lb	**553.2** tons
curve	vertical	55+76	1+700	4,816.8	1,468.2	488.5	148.9	48.0	1219.2	0.3	1,110,615	lb	**555.3** tons
curve	vertical	56+61	1+725	4,901.6	1,494.0	493.5	150.4	48.0	1219.2	0.3	1,131,537	lb	**565.8** tons
curve	vertical	57+45	1+751	4,986.4	1,519.9	500.5	152.6	48.0	1219.2	0.3	1,155,547	lb	**577.8** tons
curve	vertical	58+28	1+776	5,069.7	1,545.3	509.3	155.2	48.0	1219.2	0.3	1,179,614	lb	**589.8** tons
curve	vertical	59+11	1+802	5,152.9	1,570.6	520.0	158.5	48.0	1219.2	0.3	1,203,502	lb	**601.8** tons
curve	vertical	59+93	1+827	5,236.2	1,596.0	532.6	162.3	48.0	1219.2	0.3	1,227,002	lb	**613.5** tons
curve	vertical	60+75	1+852	5,319.4	1,621.4	547.1	166.8	48.0	1219.2	0.3	1,250,044	lb	**625.0** tons
curve	vertical	61+57	1+877	5,402.7	1,646.8	563.5	171.8	48.0	1219.2	0.3	1,272,603	lb	**636.3** tons
curve	vertical	62+38	1+901	5,485.9	1,672.1	581.8	177.3	48.0	1219.2	0.3	1,294,661	lb	**647.3** tons
curve	vertical	63+19	1+926	5,569.2	1,697.5	602.0	183.5	48.0	1219.2	0.3	1,316,207	lb	**658.1** tons
curve	vertical	63+99	1+950	5,652.4	1,722.9	624.0	190.2	48.0	1219.2	0.3	1,337,228	lb	**668.6** tons
straight		65+21	1+988	5,779.7	1,761.7	659.0	200.9	48.0	1219.2	0.3	1,346,191	lb	**673.1** tons
straight		66+43	2+025	5,906.9	1,800.4	694.1	211.6	48.0	1219.2	0.3	1,355,154	lb	**677.6** tons
straight		67+66	2+062	6,034.1	1,839.2	729.2	222.3	48.0	1219.2	0.3	1,364,117	lb	**682.1** tons
HDD Rig Location		68+88	2+099	6,161.4	1,878.0	764.3	233.0	48.0	1219.2	0.3	1,373,080	lb	**686.5** tons

Ground Elevation at Pipe Entry	780.00	feet
	237.75	metres
Ground Elevation at Pipe Exit	764.26	feet
	232.95	metres

	TOTAL PULL LOADS		
Maximum Values	1,373,080	lb	686.5 tons

HDD Installation Stress Analysis

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	CombinedTensile and Bending <1.0	Combined Tensile, Bending and Hoop Factor	Combined Tensile, Bending and Hoop <1.0
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS				
746	5.15	1.07%	0	0.00	0.00%	0	0.00	0.00%	0.01	Yes	0.00	Yes
1,001	6.90	1.43%	0	0.00	0.00%	399	2.75	0.57%	0.02	Yes	0.00	Yes
1,256	8.66	1.79%	0	0.00	0.00%	798	5.50	1.14%	0.02	Yes	0.01	Yes
1,511	10.42	2.16%	0	0.00	0.00%	1,197	8.25	1.71%	0.03	Yes	0.03	Yes
1,766	12.18	2.52%	0	0.00	0.00%	1,596	11.01	2.28%	0.03	Yes	0.05	Yes
2,021	13.94	2.89%	0	0.00	0.00%	1,995	13.76	2.85%	0.04	Yes	0.07	Yes
2,277	15.70	3.25%	0	0.00	0.00%	2,394	16.51	3.42%	0.04	Yes	0.10	Yes
2,532	17.45	3.62%	0	0.00	0.00%	2,793	19.26	3.99%	0.05	Yes	0.14	Yes
2,787	19.21	3.98%	0	0.00	0.00%	3,192	22.01	4.56%	0.05	Yes	0.18	Yes
3,353	23.12	4.79%	12,083	83.31	17.26%	3,463	23.88	4.95%	0.33	Yes	0.33	Yes
3,413	23.53	4.88%	12,083	83.31	17.26%	3,698	25.50	5.28%	0.33	Yes	0.37	Yes
3,572	24.63	5.10%	12,083	83.31	17.26%	3,897	26.87	5.57%	0.33	Yes	0.40	Yes
3,749	25.85	5.36%	12,083	83.31	17.26%	4,060	28.00	5.80%	0.34	Yes	0.42	Yes
7,762	53.51	11.09%	12,083	83.31	17.26%	4,187	28.87	5.98%	0.41	Yes	0.51	Yes
5,347	36.87	7.64%	12,083	83.31	17.26%	4,278	29.50	6.11%	0.37	Yes	0.48	Yes
5,511	38.00	7.87%	12,083	83.31	17.26%	4,333	29.87	6.19%	0.37	Yes	0.49	Yes
5,664	39.05	8.09%	12,083	83.31	17.26%	4,351	30.00	6.22%	0.37	Yes	0.50	Yes
5,779	39.85	8.26%	0	0.00	0.00%	4,351	30.00	6.22%	0.10	Yes	0.35	Yes
5,894	40.64	8.42%	0	0.00	0.00%	4,351	30.00	6.22%	0.11	Yes	0.35	Yes
6,009	41.43	8.58%	0	0.00	0.00%	4,351	30.00	6.22%	0.11	Yes	0.35	Yes
6,123	42.22	8.75%	0	0.00	0.00%	4,351	30.00	6.22%	0.11	Yes	0.35	Yes
6,238	43.01	8.91%	0	0.00	0.00%	4,351	30.00	6.22%	0.11	Yes	0.36	Yes
6,353	43.80	9.08%	0	0.00	0.00%	4,351	30.00	6.22%	0.11	Yes	0.36	Yes
6,468	44.59	9.24%	0	0.00	0.00%	4,351	30.00	6.22%	0.12	Yes	0.36	Yes
6,677	46.03	9.54%	0	0.00	0.00%	4,119	28.40	5.88%	0.12	Yes	0.36	Yes
6,886	47.48	9.84%	0	0.00	0.00%	4,119	28.40	5.88%	0.12	Yes	0.36	Yes
7,095	48.92	10.14%	0	0.00	0.00%	4,119	28.40	5.88%	0.13	Yes	0.36	Yes
7,304	50.36	10.43%	0	0.00	0.00%	4,119	28.40	5.88%	0.13	Yes	0.37	Yes
7,513	51.80	10.73%	0	0.00	0.00%	4,119	28.40	5.88%	0.13	Yes	0.37	Yes
7,722	53.24	11.03%	0	0.00	0.00%	4,119	28.40	5.88%	0.14	Yes	0.37	Yes
7,931	54.68	11.33%	0	0.00	0.00%	4,119	28.40	5.88%	0.14	Yes	0.37	Yes
8,140	56.12	11.63%	0	0.00	0.00%	4,119	28.40	5.88%	0.15	Yes	0.37	Yes
8,349	57.56	11.93%	0	0.00	0.00%	4,119	28.40	5.88%	0.15	Yes	0.38	Yes
8,558	59.01	12.23%	0	0.00	0.00%	4,119	28.40	5.88%	0.15	Yes	0.38	Yes
8,767	60.45	12.52%	0	0.00	0.00%	4,119	28.40	5.88%	0.16	Yes	0.38	Yes
8,976	61.89	12.82%	0	0.00	0.00%	4,119	28.40	5.88%	0.16	Yes	0.38	Yes
9,185	63.33	13.12%	0	0.00	0.00%	4,119	28.40	5.88%	0.16	Yes	0.38	Yes
15,929	109.83	22.76%	0	0.00	0.00%	4,119	28.40	5.88%	0.28	Yes	0.47	Yes
10,828	74.66	15.47%	0	0.00	0.00%	4,119	28.40	5.88%	0.19	Yes	0.40	Yes
11,037	76.10	15.77%	0	0.00	0.00%	4,119	28.40	5.88%	0.20	Yes	0.41	Yes
11,246	77.54	16.07%	0	0.00	0.00%	4,119	28.40	5.88%	0.20	Yes	0.41	Yes
11,456	78.99	16.37%	0	0.00	0.00%	4,119	28.40	5.88%	0.20	Yes	0.41	Yes
11,665	80.43	16.66%	0	0.00	0.00%	4,119	28.40	5.88%	0.21	Yes	0.41	Yes
11,875	81.87	16.96%	0	0.00	0.00%	4,119	28.40	5.88%	0.21	Yes	0.42	Yes
12,084	83.32	17.26%	0	0.00	0.00%	4,119	28.40	5.88%	0.22	Yes	0.42	Yes
13,117	90.44	18.74%	12,083	83.31	17.26%	4,104	28.30	5.86%	0.50	Yes	0.63	Yes
13,166	90.78	18.81%	12,083	83.31	17.26%	4,060	27.99	5.80%	0.51	Yes	0.63	Yes
13,414	92.49	19.16%	12,083	83.31	17.26%	3,987	27.49	5.70%	0.51	Yes	0.62	Yes
13,698	94.45	19.57%	12,083	83.31	17.26%	3,884	26.78	5.55%	0.52	Yes	0.61	Yes
13,984	96.41	19.98%	12,083	83.31	17.26%	3,754	25.89	5.36%	0.52	Yes	0.59	Yes
14,267	98.37	20.38%	12,083	83.31	17.26%	3,597	24.80	5.14%	0.53	Yes	0.57	Yes
14,546	100.29	20.78%	12,083	83.31	17.26%	3,411	23.52	4.87%	0.53	Yes	0.55	Yes
14,819	102.17	21.17%	12,083	83.31	17.26%	3,197	22.05	4.57%	0.54	Yes	0.53	Yes
15,086	104.01	21.55%	12,083	83.31	17.26%	2,956	20.38	4.22%	0.54	Yes	0.50	Yes
15,348	105.82	21.93%	12,083	83.31	17.26%	2,687	18.52	3.84%	0.54	Yes	0.47	Yes
15,603	107.58	22.29%	12,083	83.31	17.26%	2,390	16.48	3.41%	0.55	Yes	0.44	Yes
15,852	109.30	22.65%	12,083	83.31	17.26%	2,066	14.24	2.95%	0.55	Yes	0.41	Yes
15,958	110.03	22.80%	0	0.00	0.00%	1,549	10.68	2.21%	0.28	Yes	0.16	Yes
16,065	110.76	22.95%	0	0.00	0.00%	1,033	7.12	1.48%	0.29	Yes	0.13	Yes
16,171	111.49	23.10%	0	0.00	0.00%	516	3.56	0.74%	0.29	Yes	0.11	Yes
16,277	112.23	23.25%	0	0.00	0.00%	0	0.00	0.00%	0.29	Yes	0.09	Yes

NOTE: Hoop stress taken as an empty pipe for no buoyancy control and with water with buoyancy control

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	Combined Tensile, Bending and Hoop Factor
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS		
16,277	112.2	23.25%	12,083	83.3	17.26%	4,351	30.0	6.22%	0.55	0.63

Input Pipe Properties

Pipe Outer Diameter	36	in
	914.4	mm
Pipe Wall Thickness	0.762	in
	19.3548	mm
DR	47.2	
Pipe Weight (in air)	287.04	lbs/ft
	428.06	kg/m
Weight of Water in pipe	0.0	lbs/ft
	0.00	kg/m
Net Buoyant Weight of pipe	-347.4	lbs/ft
	-518.11	kg/m
Young's Modulus of Elasticity	2.90E+07	psi
	199948	MPa
Yield Strength	70,000	psi
	482.6	MPa
Poisson Ratio	0.3	
Drill Pipe Diameter	6.625	in
	168.275	mm
Minimum Radius of Curvature	2,600	ft
	792	m
Ultimate Safe Pull Load	3,542,953	lb
	15,760	kN
Maximum Calculated Pull Load	1,373,080	lb
	6,108	kN
Factor of Safety	2.6	
Start-up Load Factor	1.5	
Required Pipe Pull Load	1,343,706	lb
	5,977	kN
Factor of Safety	2.6	

Soil and Mud Properties

Mud Weight	12	ppg of drill fluid and solids (typically 9.5 to 11 lb/gal)
	1.439	Specific Gravity
Friction Coeff. (GS or rollers)	0.15	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	24	lb/100ft^2 (Based on HDD experience from previous installations)
	114.912	dyne/cm^2
Plastic Viscosity	16	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	300	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	1.136	m^3/min
Drilling mud pumping rate	1093	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.138	m^3/min
Pipe Pullback Rate	15	feet/min (Based on HDD experience)
	4.57	m/min

MOTT MACDONALD

Horizontal Directional Drilling
Calculation of Pull Loads and Stresses during Pipe Installation

Calculated by: S. Crouse
Checked by: G. Duyvestyn
Date: 2/13/2017
Project No: 353754

PROJECT: PennEast Pipeline

HDD CROSSING LOCATION: Pohopoco Creek (Beltzville Lake) / Wild Creek

Reference:

1. **Installation of Pipelines by Horizontal Directional Drilling, an Engineering Guide, PRCI Publication 2015**
2. **Pipeline Design for Installation by Horizontal Directional Drilling, Manual of Practice, ASCE MREP 108, 2005**

HDD Installation Load Analysis

Segment Type	Type of Curve	Bore Stationing		Installed Length		Bore Elevation		Bore Diameter		Geotechnical Friction Factor	TOTAL PULL LOADS		
		feet	metres	feet	metres	feet	metres	inch	mm				
Pipe Entry Location		7+88	0+240	0.0	0.0	780.0	237.7	--	--		62,949	lb	**31.5** tons
straight		9+15	0+279	130.3	39.7	752.9	229.5	48.0	1219.2	0.3	62,396	lb	**31.2** tons
straight		10+43	0+318	260.7	79.5	725.8	221.2	48.0	1219.2	0.3	61,842	lb	**30.9** tons
straight		11+70	0+357	391.0	119.2	698.7	213.0	48.0	1219.2	0.3	61,289	lb	**30.6** tons
straight		12+98	0+396	521.4	158.9	671.6	204.7	48.0	1219.2	0.3	60,736	lb	**30.4** tons
straight		14+25	0+434	651.7	198.7	644.5	196.4	48.0	1219.2	0.3	60,183	lb	**30.1** tons
straight		15+53	0+473	782.1	238.4	617.4	188.2	48.0	1219.2	0.3	59,630	lb	**29.8** tons
straight		16+80	0+512	912.4	278.1	590.3	179.9	48.0	1219.2	0.3	59,076	lb	**29.5** tons
straight		18+08	0+551	1,042.8	317.8	563.2	171.7	48.0	1219.2	0.3	58,523	lb	**29.3** tons
curve	vertical	19+00	0+579	1,137.0	346.6	544.8	166.1	48.0	1219.2	0.3	83,113	lb	**41.6** tons
curve	vertical	19+93	0+607	1,231.3	375.3	528.8	161.2	48.0	1219.2	0.3	65,702	lb	**32.9** tons
curve	vertical	20+86	0+636	1,325.5	404.0	515.3	157.1	48.0	1219.2	0.3	57,721	lb	**28.9** tons
curve	vertical	21+80	0+664	1,419.8	432.8	504.2	153.7	48.0	1219.2	0.3	52,178	lb	**26.1** tons
curve	vertical	22+74	0+693	1,514.0	461.5	495.6	151.1	48.0	1219.2	0.3	230,760	lb	**115.4** tons
curve	vertical	23+68	0+722	1,608.3	490.2	489.5	149.2	48.0	1219.2	0.3	154,668	lb	**77.3** tons
curve	vertical	24+62	0+750	1,702.5	518.9	485.8	148.1	48.0	1219.2	0.3	155,354	lb	**77.7** tons
curve	vertical	25+56	0+779	1,796.8	547.7	484.5	147.7	48.0	1219.2	0.3	155,996	lb	**78.0** tons
straight		26+58	0+810	1,898.5	578.7	484.5	147.7	48.0	1219.2	0.3	156,810	lb	**78.4** tons
straight		27+60	0+841	2,000.3	609.7	484.5	147.7	48.0	1219.2	0.3	157,624	lb	**78.8** tons
straight		28+61	0+872	2,102.1	640.7	484.5	147.7	48.0	1219.2	0.3	158,439	lb	**79.2** tons
straight		29+63	0+903	2,203.9	671.7	484.5	147.7	48.0	1219.2	0.3	159,253	lb	**79.6** tons
straight		30+65	0+934	2,305.6	702.8	484.5	147.7	48.0	1219.2	0.3	160,067	lb	**80.0** tons
straight		31+67	0+965	2,407.4	733.8	484.5	147.7	48.0	1219.2	0.3	160,881	lb	**80.4** tons
straight		32+69	0+996	2,509.2	764.8	484.5	147.7	48.0	1219.2	0.3	161,696	lb	**80.8** tons
straight		33+70	1+027	2,611.0	795.8	484.5	147.7	48.0	1219.2	0.3	163,817	lb	**81.9** tons
straight		34+72	1+058	2,712.7	826.9	484.5	147.7	48.0	1219.2	0.3	165,939	lb	**83.0** tons
straight		35+74	1+089	2,814.5	857.9	484.5	147.7	48.0	1219.2	0.3	168,061	lb	**84.0** tons
straight		36+76	1+120	2,916.3	888.9	484.5	147.7	48.0	1219.2	0.3	170,182	lb	**85.1** tons
straight		37+77	1+151	3,018.1	919.9	484.5	147.7	48.0	1219.2	0.3	172,304	lb	**86.2** tons
straight		38+79	1+182	3,119.8	950.9	484.5	147.7	48.0	1219.2	0.3	174,426	lb	**87.2** tons
straight		39+81	1+213	3,221.6	982.0	484.5	147.7	48.0	1219.2	0.3	176,548	lb	**88.3** tons
straight		40+83	1+244	3,323.4	1,013.0	484.5	147.7	48.0	1219.2	0.3	178,669	lb	**89.3** tons
straight		41+85	1+275	3,425.2	1,044.0	484.5	147.7	48.0	1219.2	0.3	180,791	lb	**90.4** tons
straight		42+86	1+306	3,526.9	1,075.0	484.5	147.7	48.0	1219.2	0.3	182,913	lb	**91.5** tons
straight		43+88	1+338	3,628.7	1,106.0	484.5	147.7	48.0	1219.2	0.3	185,034	lb	**92.5** tons
straight		44+90	1+369	3,730.5	1,137.1	484.5	147.7	48.0	1219.2	0.3	187,156	lb	**93.6** tons
straight		45+92	1+400	3,832.3	1,168.1	484.5	147.7	48.0	1219.2	0.3	189,278	lb	**94.6** tons
straight		46+93	1+431	3,934.0	1,199.1	484.5	147.7	48.0	1219.2	0.3	442,103	lb	**221.1** tons
straight		47+95	1+462	4,035.8	1,230.1	484.5	147.7	48.0	1219.2	0.3	296,857	lb	**148.4** tons
straight		48+97	1+493	4,137.6	1,261.2	484.5	147.7	48.0	1219.2	0.3	298,979	lb	**149.5** tons
straight		49+99	1+524	4,239.4	1,292.2	484.5	147.7	48.0	1219.2	0.3	301,101	lb	**150.6** tons
straight		51+01	1+555	4,341.3	1,323.2	484.5	147.7	48.0	1219.2	0.3	303,226	lb	**151.6** tons
straight		52+03	1+586	4,443.2	1,354.3	484.5	147.7	48.0	1219.2	0.3	305,351	lb	**152.7** tons
straight		53+05	1+617	4,545.2	1,385.4	484.5	147.7	48.0	1219.2	0.3	307,476	lb	**153.7** tons
straight		54+07	1+648	4,647.1	1,416.5	484.5	147.7	48.0	1219.2	0.3	309,601	lb	**154.8** tons
curve	vertical	54+91	1+674	4,731.9	1,442.3	485.5	148.0	48.0	1219.2	0.3	363,936	lb	**182.0** tons
curve	vertical	55+76	1+700	4,816.8	1,468.2	488.5	148.9	48.0	1219.2	0.3	336,379	lb	**168.2** tons
curve	vertical	56+61	1+725	4,901.6	1,494.0	493.5	150.4	48.0	1219.2	0.3	327,077	lb	**163.5** tons
curve	vertical	57+45	1+751	4,986.4	1,519.9	500.5	152.6	48.0	1219.2	0.3	322,436	lb	**161.2** tons
curve	vertical	58+28	1+776	5,069.7	1,545.3	509.3	155.2	48.0	1219.2	0.3	319,780	lb	**159.9** tons
curve	vertical	59+11	1+802	5,152.9	1,570.6	520.0	158.5	48.0	1219.2	0.3	318,138	lb	**159.1** tons
curve	vertical	59+93	1+827	5,236.2	1,596.0	532.6	162.3	48.0	1219.2	0.3	317,139	lb	**158.6** tons
curve	vertical	60+75	1+852	5,319.4	1,621.4	547.1	166.8	48.0	1219.2	0.3	316,595	lb	**158.3** tons
curve	vertical	61+57	1+877	5,402.7	1,646.8	563.5	171.8	48.0	1219.2	0.3	316,404	lb	**158.2** tons
curve	vertical	62+38	1+901	5,485.9	1,672.1	581.8	177.3	48.0	1219.2	0.3	316,503	lb	**158.3** tons
curve	vertical	63+19	1+926	5,569.2	1,697.5	602.0	183.5	48.0	1219.2	0.3	316,853	lb	**158.4** tons
curve	vertical	63+99	1+950	5,652.4	1,722.9	624.0	190.2	48.0	1219.2	0.3	317,430	lb	**158.7** tons
straight		65+21	1+988	5,779.7	1,761.7	659.0	200.9	48.0	1219.2	0.3	321,937	lb	**161.0** tons
straight		66+43	2+025	5,906.9	1,800.4	694.1	211.6	48.0	1219.2	0.3	326,444	lb	**163.2** tons
straight		67+66	2+062	6,034.1	1,839.2	729.2	222.3	48.0	1219.2	0.3	330,951	lb	**165.5** tons
HDD Rig Location		68+88	2+099	6,161.4	1,878.0	764.3	233.0	48.0	1219.2	0.3	335,458	lb	**167.7** tons

HDD Installation Stress Analysis

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	CombinedTensile and Bending <1.0	Combined Tensile, Bending and Hoop Factor	Combined Tensile, Bending and Hoop <1.0
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS				
746	5.15	1.07%	0	0.00	0.00%	0	0.00	0.00%	0.01	Yes	0.00	Yes
740	5.10	1.06%	0	0.00	0.00%	122	0.84	0.17%	0.01	Yes	0.00	Yes
733	5.05	1.05%	0	0.00	0.00%	243	1.68	0.35%	0.01	Yes	0.00	Yes
727	5.01	1.04%	0	0.00	0.00%	365	2.52	0.52%	0.01	Yes	0.00	Yes
720	4.96	1.03%	0	0.00	0.00%	487	3.35	0.70%	0.01	Yes	0.00	Yes
713	4.92	1.02%	0	0.00	0.00%	608	4.19	0.87%	0.01	Yes	0.01	Yes
707	4.87	1.01%	0	0.00	0.00%	730	5.03	1.04%	0.01	Yes	0.01	Yes
700	4.83	1.00%	0	0.00	0.00%	851	5.87	1.22%	0.01	Yes	0.01	Yes
694	4.78	0.99%	0	0.00	0.00%	973	6.71	1.39%	0.01	Yes	0.02	Yes
985	6.79	1.41%	12,083	83.31	17.26%	1,056	7.28	1.51%	0.29	Yes	0.09	Yes
779	5.37	1.11%	12,083	83.31	17.26%	1,127	7.77	1.61%	0.28	Yes	0.09	Yes
684	4.72	0.98%	12,083	83.31	17.26%	1,188	8.19	1.70%	0.28	Yes	0.09	Yes
619	4.26	0.88%	12,083	83.31	17.26%	1,238	8.53	1.77%	0.28	Yes	0.09	Yes
2,736	18.86	3.91%	12,083	83.31	17.26%	1,276	8.80	1.82%	0.32	Yes	0.12	Yes
1,834	12.64	2.62%	12,083	83.31	17.26%	1,304	8.99	1.86%	0.30	Yes	0.11	Yes
1,842	12.70	2.63%	12,083	83.31	17.26%	1,321	9.11	1.89%	0.30	Yes	0.11	Yes
1,849	12.75	2.64%	12,083	83.31	17.26%	1,326	9.14	1.89%	0.30	Yes	0.11	Yes
1,859	12.82	2.66%	0	0.00	0.00%	1,326	9.14	1.89%	0.03	Yes	0.03	Yes
1,869	12.88	2.67%	0	0.00	0.00%	1,326	9.14	1.89%	0.03	Yes	0.03	Yes
1,878	12.95	2.68%	0	0.00	0.00%	1,326	9.14	1.89%	0.03	Yes	0.03	Yes
1,888	13.02	2.70%	0	0.00	0.00%	1,326	9.14	1.89%	0.03	Yes	0.03	Yes
1,898	13.08	2.71%	0	0.00	0.00%	1,326	9.14	1.89%	0.03	Yes	0.03	Yes
1,907	13.15	2.72%	0	0.00	0.00%	1,326	9.14	1.89%	0.03	Yes	0.03	Yes
1,917	13.22	2.74%	0	0.00	0.00%	1,326	9.14	1.89%	0.03	Yes	0.03	Yes
1,942	13.39	2.77%	0	0.00	0.00%	1,256	8.66	1.79%	0.03	Yes	0.03	Yes
1,967	13.56	2.81%	0	0.00	0.00%	1,256	8.66	1.79%	0.04	Yes	0.03	Yes
1,992	13.74	2.85%	0	0.00	0.00%	1,256	8.66	1.79%	0.04	Yes	0.03	Yes
2,017	13.91	2.88%	0	0.00	0.00%	1,256	8.66	1.79%	0.04	Yes	0.03	Yes
2,043	14.08	2.92%	0	0.00	0.00%	1,256	8.66	1.79%	0.04	Yes	0.03	Yes
2,068	14.26	2.95%	0	0.00	0.00%	1,256	8.66	1.79%	0.04	Yes	0.03	Yes
2,093	14.43	2.99%	0	0.00	0.00%	1,256	8.66	1.79%	0.04	Yes	0.03	Yes
2,118	14.60	3.03%	0	0.00	0.00%	1,256	8.66	1.79%	0.04	Yes	0.03	Yes
2,143	14.78	3.06%	0	0.00	0.00%	1,256	8.66	1.79%	0.04	Yes	0.03	Yes
2,168	14.95	3.10%	0	0.00	0.00%	1,256	8.66	1.79%	0.04	Yes	0.03	Yes
2,193	15.12	3.13%	0	0.00	0.00%	1,256	8.66	1.79%	0.04	Yes	0.03	Yes
2,219	15.30	3.17%	0	0.00	0.00%	1,256	8.66	1.79%	0.04	Yes	0.03	Yes
2,244	15.47	3.21%	0	0.00	0.00%	1,256	8.66	1.79%	0.04	Yes	0.03	Yes
5,241	36.13	7.49%	0	0.00	0.00%	1,256	8.66	1.79%	0.09	Yes	0.05	Yes
3,519	24.26	5.03%	0	0.00	0.00%	1,256	8.66	1.79%	0.06	Yes	0.04	Yes
3,544	24.44	5.06%	0	0.00	0.00%	1,256	8.66	1.79%	0.06	Yes	0.04	Yes
3,569	24.61	5.10%	0	0.00	0.00%	1,256	8.66	1.79%	0.06	Yes	0.04	Yes
3,595	24.78	5.14%	0	0.00	0.00%	1,256	8.66	1.79%	0.06	Yes	0.04	Yes
3,620	24.96	5.17%	0	0.00	0.00%	1,256	8.66	1.79%	0.06	Yes	0.04	Yes
3,645	25.13	5.21%	0	0.00	0.00%	1,256	8.66	1.79%	0.07	Yes	0.04	Yes
3,670	25.30	5.24%	0	0.00	0.00%	1,256	8.66	1.79%	0.07	Yes	0.04	Yes
4,314	29.75	6.16%	12,083	83.31	17.26%	1,251	8.63	1.79%	0.35	Yes	0.14	Yes
3,988	27.49	5.70%	12,083	83.31	17.26%	1,238	8.53	1.77%	0.34	Yes	0.13	Yes
3,877	26.73	5.54%	12,083	83.31	17.26%	1,215	8.38	1.74%	0.34	Yes	0.13	Yes
3,822	26.35	5.46%	12,083	83.31	17.26%	1,184	8.16	1.69%	0.34	Yes	0.13	Yes
3,791	26.14	5.42%	12,083	83.31	17.26%	1,144	7.89	1.63%	0.34	Yes	0.13	Yes
3,771	26.00	5.39%	12,083	83.31	17.26%	1,096	7.56	1.57%	0.34	Yes	0.12	Yes
3,760	25.92	5.37%	12,083	83.31	17.26%	1,040	7.17	1.49%	0.34	Yes	0.12	Yes
3,753	25.88	5.36%	12,083	83.31	17.26%	975	6.72	1.39%	0.34	Yes	0.12	Yes
3,751	25.86	5.36%	12,083	83.31	17.26%	901	6.21	1.29%	0.34	Yes	0.11	Yes
3,752	25.87	5.36%	12,083	83.31	17.26%	819	5.65	1.17%	0.34	Yes	0.11	Yes
3,756	25.90	5.37%	12,083	83.31	17.26%	728	5.02	1.04%	0.34	Yes	0.10	Yes
3,763	25.94	5.38%	12,083	83.31	17.26%	630	4.34	0.90%	0.34	Yes	0.10	Yes
3,816	26.31	5.45%	0	0.00	0.00%	472	3.26	0.67%	0.07	Yes	0.01	Yes
3,870	26.68	5.53%	0	0.00	0.00%	315	2.17	0.45%	0.07	Yes	0.01	Yes
3,923	27.05	5.60%	0	0.00	0.00%	157	1.09	0.22%	0.07	Yes	0.01	Yes
3,977	27.42	5.68%	0	0.00	0.00%	0	0.00	0.00%	0.07	Yes	0.01	Yes

NOTE: Hoop stress taken as an empty pipe for no buoyancy control and with water with buoyancy control

Ground Elevation at Pipe Entry	780.00	feet
	237.75	metres
Ground Elevation at Pipe Exit	764.26	feet
	232.95	metres

	TOTAL PULL LOADS		
Maximum Values	363,936	lb	221.1 tons

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	Combined Tensile, Bending and Hoop Factor
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS		
5,241	36.1	7.49%	12,083	83.3	17.26%	1,326	9.1	1.89%	0.35	0.14

Input Pipe Properties

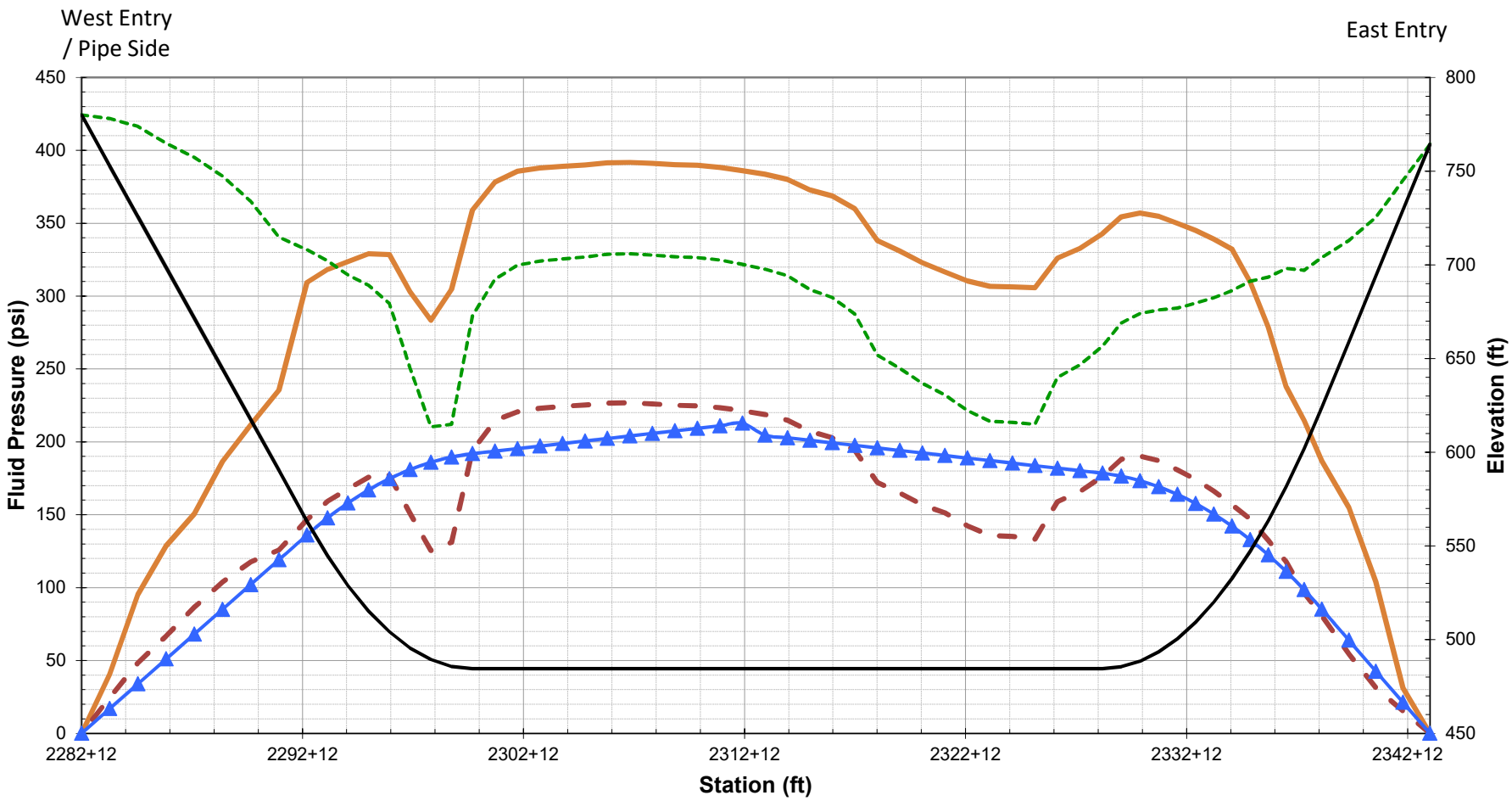
Pipe Outer Diameter	36	in
	914.4	mm
Pipe Wall Thickness	0.762	in
	19.3548	mm
DR	47.2	
Pipe Weight (in air)	287.04	lbs/ft
	428.06	kg/m
Weight of Water in pipe	404.5	lbs/ft
	603.26	kg/m
Net Buoyant Weight of pipe	57.1	lbs/ft
	85.14	kg/m
Young's Modulus of Elasticity	2.90E+07	psi
	199948	MPa
Yield Strength	70,000	psi
	482.6	MPa
Poisson Ratio	0.3	
Drill Pipe Diameter	6.625	in
	168.275	mm
Minimum Radius of Curvature	2,600	ft
	792	m
Ultimate Safe Pull Load	3,542,953	lb
	15,760	kN
Maximum Calculated Pull Load	363,936	lb
	1,619	kN
Factor of Safety	9.7	
Start-up Load Factor	1.5	
Required Pipe Pull Load	442,103	lb
	1,967	kN
Factor of Safety	8.0	

Soil and Mud Properties

Mud Weight	12	ppg of drill fluid and solids (typically 9.5 to 11 lb/gal)
	1.439	Specific Gravity
Friction Coeff. (GS or rollers)	0.15	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	24	lb/100ft^2 (Based on HDD experience from previous installations)
	114.912	dyne/cm^2
Plastic Viscosity	16	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	300	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	1.136	m^3/min
Drilling mud pumping rate	1093	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.138	m^3/min
Pipe Pullback Rate	15	feet/min (Based on HDD experience)
	4.57	m/min

Appendix D

Hydraulic Fracture Evaluation



Crossing Length (ft)	6,100
Bore Diameter (in)	12.250
Drill Pipe O.D. (in)	6.625
Drilling Fluid Weight (ppg)	10.5
Plastic Viscosity (cP)	12
Yield Point (lb/100SF)	18

PennEast Pipeline
HORIZONTAL DIRECTIONAL DRILLING EVALUATION

MOTT MACDONALD

PennEast Pipeline Project
Beltzville Lake HDD Installation
DRILLING FLUID PRESSURE EVALUATION

Pilot Bore Drilling Fluid Pressure Evaluation

MOTT MACDONALD

Horizontal Directional Drilling
Drilling Fluid Hydraulic Fracture Calculations

Calculated by: _____
Checked by: _____
Date: _____
Project No: _____

PROJECT: PennEast Pipeline Project **CROSSING LOCATION: Beltzville Lake**

Reference:
1. Latoore, C.A., Wakeley, L.D., and Conroy, P.J., Guidelines for Installation of Utilities Beneath Corps of Engineers Levees using Horizontal Directional Drilling, June 2002, ERDC/GSL TR-02-9
2. HDD Consortium, Horizontal Directional Drilling Good Practices Guidelines, Third Edition, North American Society of Trenchless Technology, 2008.

Geotechnical Inputs

Note that soil type assumes entire soil layer above the bore consists of the same soil type and properties. Need to input appropriate soil properties into evaluation sheet for soils above the bore.

Only Change cells shaded in green
Changing other cells will interfere with calculations

Soil Properties	Soil Type 1	Soil Type 2	Soil Type 3	Soil Type 4	Soil Type 5
c, soil effective cohesion (psf)	0	7500	7500	0	0
c, soil effective cohesion (N/m^2 or Pa)	0	359,102	359,102	0	0
ϕ, soil internal friction angle (deg)	30.0	11.0	11.0	0.0	0.0
ϕ, soil internal friction angle (rad)	0.52	0.19	0.19	0.0	0.0
Equivalent 'SPT Blow Count N60 (blows per 12 inch)	50			0	0
E , Young's Modulus based on blow count (lb/ft^2)	1,500,000	0	0	0	0
E , Young's Modulus (kPa)	25,000	65,000	80,000	0	0
E , Young's Modulus (lb/ft^2)	522,136	1,357,553	1,670,834	0	0
ν , Poisson's ratio	0.33	0.33	0.33	0.00	0.00
G, soil shear modulus (ksf)	196	510	628	0	0
G, soil shear modulus (kPa)	9,398	24,436	30,075	0	0
G, soil shear modulus (Pa)	9,398,496	24,436,090	30,075,188	0	0
γ, soil total unit weight (pcf) below water table	140	150	155	0	0
γ, soil total unit weight (kN/m^3) below water table	22.0	23.6	24.4	0.0	0.0
γ, soil total unit weight (pcf) above water table	130	145	150	0	0
γ, soil total unit weight (kN/m^3) above water table	20.4	22.8	23.6	0.0	0.0
Top Elevation Soil Type encountered (feet)					
Top Elevation Soil Type encountered (metre)					
Bottom Elevation Soil Type encountered (feet)					
Bottom Elevation Soil Type encountered (metre)					

HDD Installation Inputs

Drill and Intersect Used	yes	yes or no
Target Drill and Intersect Location		input stationing in feet (do not enter + sig
	0+000	Stationing in metres
Drill Rig setup on Pipe Side (Single Rig Option Only). **For Drill and Intersect, this must be "no"**	no	yes or no (must be no for direct and inter
Drill Rig #1 Elevation	764.3	feet
	233.0	metre
Drill Rig #2 Elevation (Pipe Entry Location)	780.0	feet
	237.7	metre
Recommended Allowable Pressure Factor	2.00	
Total Horizontal Installation Length	6,100	feet
	1,859.4	metre
True Installation Length	6,161	feet
	1,878.0	metre
Pilot Bore Diameter	12.250	inch
	311.15	mm
Drill Pipe Diameter	6.625	inch
	168.28	mm
Yield Point	18	lb/100ft^2
Plastic Viscosity	12	cP
Drilling Fluid Pumping Rate	750	gal/min
	2.84	m^3/min
Calculated Drilling Fluid Velocity	2.882	ft/sec
	0.878	m/sec
Pressure Required for Bore Slurry Flow	0.017	psi per ft of bore
	0.118	kPa per metre of bore
	0.513	psi per 30 ft drill pipe
Drilling Fluid Mud Weight	10.5	ppg
	78.5	lb/ft^3
	1.26	specific gravity

Note: Stationing should be at least every 200 feet and finer detail where required. Check Start and Stop STA for proper direction.

Type 1 , Type 2, Type 3, Type 4, Type 5 or leave blank

Location	Bore Stationing		Drilled Length wrt Drill Rig(s) and Locations (True Bore Length)		Bore Elevation		Ground Surface Elevation		Water Table Elevation		Depth of Cover		Soil Type	Theoretical Unfactored Drilling Fluid Pressure		Estimated Bore Fluid Pressure for Drilling Fluid Flow		Factor of Safety	Estimated Hydrostatic Fluid Pressure Within Bore		Factor of Safety	Estimated Bore Fluid Pressure for Drilling Fluid Flow and Hydrostatic Column		Factor of Safety
	feet	metre	feet	metre	feet	metre	feet	metre	feet	metre	feet	metre		psi	kPa	psi	kPa		psi	kPa		psi	kPa	
Pipe Exit Side	234313	2+099	0.0	0.0	764.3	233.0	764.3	233.0	628.0	191.4	0.0	0.0	Type 1	0.0	0.0	0.00	0.0	--	0.00	0.00	--	0.00	0.0	--
	2341+91	2+062	127.2	38.8	729.2	222.3	745.0	227.1	628.0	191.4	15.8	4.8	Type 1	108.8	750.4	2.2	15.0	50.04	19.1	131.9	5.69	21.3	146.9	5.11
	2340+68	2+025	254.5	77.6	694.1	211.6	725.4	221.1	628.0	191.4	31.2	9.5	Type 2	415.8	2866.7	4.3	30.0	95.59	38.3	263.8	10.87	42.6	293.8	9.76
	2339+46	1+988	381.7	116.3	659.0	200.9	713.1	217.3	628.0	191.4	54.0	16.5	Type 2	464.6	3203.2	6.5	45.0	71.21	57.4	395.7	8.10	63.9	440.6	7.27
	2338+24	1+950	508.9	155.1	624.0	190.2	703.9	214.5	628.0	191.4	79.9	24.4	Type 2	514.2	3545.5	8.7	60.0	59.11	76.5	527.5	6.72	85.2	587.5	6.03
	2337+43	1+926	592.2	180.5	602.0	183.5	697.1	212.5	628.0	191.4	95.1	29.0	Type 2	536.5	3698.9	10.1	69.8	53.00	88.5	610.4	6.06	98.6	680.1	5.44
	2336+63	1+901	675.5	205.9	581.8	177.3	698.1	212.8	628.0	191.4	116.3	35.4	Type 2	570.5	3933.2	11.5	79.6	49.41	99.5	686.2	5.73	111.1	765.8	5.14
	2335+81	1+877	758.7	231.3	563.5	171.8	693.4	211.4	628.0	191.4	129.9	39.6	Type 3	627.2	4324.5	13.0	89.4	48.36	109.5	754.9	5.73	122.5	844.3	5.12
	2335+00	1+852	842.0	256.6	547.1	166.8	691.3	210.7	628.0	191.4	144.1	43.9	Type 3	650.4	4484.2	14.4	99.2	45.19	118.4	816.6	5.49	132.8	915.8	4.90
	2334+18	1+827	925.2	282.0	532.6	162.3	686.2	209.1	628.0	191.4	153.6	46.8	Type 3	664.5	4581.4	15.8	109.0	42.02	126.4	871.2	5.26	142.2	980.2	4.67
	2333+36	1+802	1,008.5	307.4	520.0	158.5	682.5	208.0	628.0	191.4	162.5	49.5	Type 3	678.1	4675.4	17.2	118.8	39.34	133.2	918.6	5.09	150.5	1037.4	4.51
	2332+53	1+776	1,091.7	332.8	509.3	155.2	679.5	207.1	628.0	191.4	170.2	51.9	Type 3	690.1	4758.4	18.7	128.7	36.98	139.1	958.8	4.96	157.7	1087.5	4.38
	2331+70	1+751	1,175.0	358.1	500.5	152.6	677.0	206.3	628.0	191.4	176.5	53.8	Type 3	699.7	4824.5	20.1	138.5	34.84	143.9	991.9	4.86	163.9	1130.4	4.27
	2330+86	1+725	1,259.8	384.0	493.5	150.4	676.0	206.0	628.0	191.4	182.5	55.6	Type 3	709.4	4890.9	21.5	148.5	32.94	147.7	1018.2	4.80	169.2	1166.6	4.19
	2330+01	1+700	1,344.6	409.8	488.5	148.9	674.1	205.5	628.0	191.4	185.6	56.6	Type 3	713.9	4922.2	23.0	158.5	31.06	150.4	1036.9	4.75	173.4	1195.4	4.12
	2329+16	1+674	1,429.4	435.7	485.5	148.0	669.0	203.9	628.0	191.4	183.5	55.9	Type 3	708.8	4886.7	24.4	168.5	29.01	152.0	1048.2	4.66	176.5	1216.7	4.02
	2328+31	1+648	1,514.3	461.6	484.5	147.7	656.6	200.1	628.0	191.4	172.1	52.5	Type 3	685.7	4727.5	25.9	178.5	26.49	152.6	1052.0	4.49	178.5	1230.4	3.84
	2327+30	1+617	1,616.2	492.6	484.5	147.7	646.6	197.1	628.0	191.4	162.1	49.4	Type 3	665.6	4589.2	27.6	190.5	24.09	152.6	1052.0	4.36	180.2	1242.4	3.69
	2326+28	1+586	1,718.1	523.7	484.5	147.7	640.0	195.1	628.0	191.4	155.5	47.4	Type 3	652.2	4496.9	29.4	202.5	22.21	152.6	1052.0	4.27	181.9	1254.5	3.58
	2325+26	1+555	1,820.1	554.8	484.5	147.7	615.0	187.5	628.0	191.4	130.5	39.8	Type 3	611.5	4216.5	31.1	214.5	19.66	152.6	1052.0	4.01	183.7	1266.5	3.33
	2324+24	1+524	1,922.0	585.8	484.5	147.7	616.0	187.8	628.0	191.4	131.5	40.1	Type 3	612.8	4225.0	32.9	226.5	18.65	152.6	1052.0	4.02	185.4	1278.5	3.30
	2323+22	1+493	2,023.8	616.9	484.5	147.7	616.5	187.9	628.0	191.4	132.0	40.2	Type 3	613.5	4229.7	34.6	238.5	17.73	152.6	1052.0	4.02	187.2	1290.5	3.28
	2322+20	1+462	2,125.6	647.9	484.5	147.7	622.4	189.7	628.0	191.4	137.8	42.0	Type 3	620.8	4280.4	36.3	250.5	17.09	152.6	1052.0	4.07	188.9	1302.5	3.29
	2321+18	1+431	2,227.3	678.9	484.5	147.7	630.6	192.2	628.0	191.4	146.1	44.5	Type 3	633.2	4365.9	38.1	262.5	16.63	152.6	1052.0	4.15	190.6	1314.5	3.32
	2320+17	1+400	2,329.1	709.9	484.5	147.7	636.8	194.1	628.0	191.4	152.3	46.4	Type 3	645.8	4452.5	39.8	274.5	16.22	152.6	1052.0	4.23	192.4	1326.5	3.36
	2319+15	1+369	2,430.9	740.9	484.5	147.7	644.8	196.5	628.0	191.4	160.3	48.9	Type 3	661.9	4563.9	41.6	286.5	15.93	152.6	1052.0	4.34	194.1	1338.5	3.41
	2318+13	1+338	2,532.7	772.0	484.5	147.7	651.9	198.7	628.0	191.4	167.4	51.0	Type 3	676.2	4662.1	43.3	298.5	15.62	152.6	1052.0	4.43	195.9	1350.5	3.45
	2317+11	1+306	2,634.4	803.0	484.5	147.7	673.8	205.4	628.0	191.4	189.3	57.7	Type 3	719.9	4963.5	45.0	310.5	15.99	152.6	1052.0	4.72	197.6	1362.5	3.64
	2316+10	1+275	2,736.2	834.0	484.5	147.7	682.6	208.1	628.0	191.4	198.1	60.4	Type 3	737.4	5084.4	46.8	322.5	15.77	152.6	1052.0	4.83	199.3	1374.4	3.70
	2315+08	1+244	2,838.0	865.0	484.5	147.7	686.8	209.3	628.0	191.4	202.3	61.6	Type 3	745.7	5141.3	48.5	334.5	15.37	152.6	1052.0	4.89	201.1	1386.4	3.71
	2314+06	1+213	2,939.8	896.0	484.5	147.7	694.2	211.6	628.0	191.4	209.7	63.9	Type 3	760.3	5242.0	50.2	346.5	15.13	152.6	1052.0	4.98	202.8	1398.4	3.75
	2313+04	1+182	3,041.5	927.1	484.5	147.7	697.7	212.7	628.0	191.4	213.2	65.0	Type 3	767.2	5289.5	52.0	358.5	14.76	152.6	1052.0	5.03	204.6	1410.4	3.75
	2312+02	1+151	3,018.1	919.9	484.5	147.7	700.2	213.4	628.0	191.4	215.7	65.7	Type 3	772.2	5324.0	51.6	355.7	14.97	161.2	1111.1	4.79	212.7	1466.8	3.63
	2311+01	1+120	2,916.3	888.9	484.5	147.7	702.5	214.1	628.0	191.4	218.0	66.5	Type 3	776.7	5355.4	49.8	343.7	15.58	161.2	1111.1	4.82	211.0	1454.8	3.68
	2309+99	1+089	2,814.5	857.9	484.5	147.7	703.9	214.6	628.0	191.4	219.4	66.9	Type 3	779.5	5374.5	48.1	331.7	16.20	161.2	1111.1	4.84	209.3	1442.8	3.72
	2308+97	1+058	2,712.7	826.9	484.5	147.7	704.3	214.7	628.0	191.4	219.8	67.0	Type 3	780.3	5379.8	46.4	319.7	16.83	161.2	1111.1	4.84	207.5	1430.8	3.76
	2307+95	1+027	2,611.0	795.8	484.5	147.7	705.3	215.0	628.0	191.4	220.8	67.3	Type 3	782.1	5392.5	44.6	307.7	17.52	161.2	1111.1	4.85	205.8	1418.9	3.80
	2306+94	0+996	2,509.2	764.8	484.5	147.7	706.0	215.2	628.0	191.4	221.5	67.5	Type 3	783.5	5402.0	42.9	295.7	18.27	161.2	1111.1	4.86	204.0	1406.9	3.84
	2305+92	0+965	2,407.4	733.8	484.5	147.7	705.7	215.1	628.0	191.4	221.1	67.4	Type 3	782.9	5397.6	41.2	283.7	19.02	161.2	1111.1	4.86	202.3	1394.9	3.87
	2304+90	0+934	2,305.6	702.8	484.5	147.7	704.3	214.7	628.0	191.4	219.7	67.0	Type 3	780.1	5378.7	39.4	271.7	19.79	161.2	1111.1	4.84	200.6	1382.9	3.89
	2303+88	0+903	2,203.9	671.7	484.5	147.7	703.2	214.3	628.0	191.4	218.7	66.7	Type 3	778.1	5364.7	37.7	259.7	20.65	161.2	1111.1	4.83	198.8	1370.9	3.91
	2302+86	0+872	2,102.1	640.7	484.5	147.7	702.1	214.0	628.0	191.4	217.5	66.3	Type 3	775.8	5348.9	35.9	247.7	21.59	161.2	1111.1	4.81	197.1	1358.9	3.94
	2301+85	0+841	2,000.3	609.7	484.5	147.7	699.8	213.3	628.0	191.4	215.3	65.6	Type 3	771.4	5318.6	34.2	235.7	22.56	161.2	1111.1	4.79	195.3	1346.9	3.95
	2300+83	0+810	1,898.5	578.7	484.5	147.7	692.3	211.0	628.0	191.4	207.8	63.3	Type 3	756.6	5216.6	32.5	223.7	23.31	161.2	1111.1	4.69	193.6	1334.9	3.91
	2299+81	0+779	1,796.8	547.7	484.5	147.7	672.8	205.1	628.0	191.4	188.3	57.4	Type 3	717.9	4949.9	30.7	211.8	23.38	161.2	1111.1	4.45	191.9	1322.9	3.74
	2298+87	0+750	1,702.5	518.9	485.8	148.1	615.0	187.5	628.0	191.4	129.2	39.4	Type 3	609.4	4201.9	29.1	200.6	20.94	160.5	1106.5	3.80	189.6	1307.2	3.21
	2297+93	0+722	1,608.3	490.2	489.5	149.2	613.6	187.0	628.0	191.4	124.1	37.8	Type 2	566.8	3908.0	27.5	189.5	20.62	158.5	1092.6	3.58	186.0	1282.1	3.05
	2296+99	0+693	1,514.0	461.5	495.6	151.1	644.9	196.6	628.0	191.4	149.3	45.5	Type 2	605.9	4177.7	25.9	178.4	23.41	155.1	1069.4	3.91	181.0	1247.8	3.35
	2296+05	0+664	1,419.8	432.8	504.2	153.7	679.4	207.1	628.0	191.4	175.1	53.4	Type 2	657.1	4530.7	24.3	167.3	27.08	150.4	1037.0	4.37	174.7	1204.3	3.76
	2295+11	0+636	1,325.5	404.0	515.3	157.1	689.1	210.0	628.0	191.4	173.7	53.0	Type 2	657.9	4536.3	22.7	156.2	29.04	144.4	995.3	4.56	167.0	1151.5	3.94
	2294+18	0+607	1,231.3	375.3	528.8	161.2	694.7	211.7	628.0	191.4	165.8	50.6	Type 2	647.3	4463.2	21.0	145.1	30.76	137.0	944.5	4.73	158.0	1089.6	4.10
	2293+25	0+579	1,137.0	346.6	544.8	166.1	702.2	214.0	628.0	191.4	157.4	48.0	Type 2	636.4	4387.9	19.4	134.0	32.75	128.3	884.5	4.96	147.7	1018.5	4.31
	2292+33	0+551	1,042.8	317.8	563.2	171.7	708.1	215.8	628.0	191.4	144.9	44.2	Type 2	618.6	4265.0	17.8	122.9	34.70	118.3	815.3	5.23	136.1	938.2	4.55
	2291+05	0+512	912.4	278.1	590.3	179.9	714.8	217.9	628.0	191.4	124.5	38.0	Type 2	588.7	4058.9	15.6	107.5	37.75	103.5	713.4	5.69	119.1	820.9	4.94
	2289+78	0+473	782.1	238.4	617.4	188.2	733.9	223.7	628.0	191.4	116.5	35.5	Type 2	581.9	4012.1	13.4	92.2	43.53	88.7	611.5	6.56	102.1	703.7	5.70
	2288+50	0+434	651.7	198.7	644.5	196.4	747.3	227.8	628.0	191.4	102.8	31.3	Type 2	559.4	3857.0	11.1	76.8	50.21	73.9	509.6	7.57	85.0	586.4	6.58
	2287+23	0+396	521.4	158.9	671.6	204.7	757.3	230.8	628.0	191.4	85.7	26.1	Type 2	526.8	3632.0	8.9	61.4	59.11	59.1	407.7	8.91	68.0	469.1	7.74
	2285+95	0+357	391.0	119.2	698.7	213.0	764.9	233.2	628.0	191.4	66.3	20.2	Type 2	489.0	3371.2	6.7	46.1	73.15	44.3	305.7	11.03	51.0	351.8	9.58
	2284+68	0+318	260.7	79.5	725.8	221.2	773.8	235.9	628.0	191.4	48.0	14.6	Type 2	452.4	3119.3	4.5	30.7	101.53	29.6	203.8	15.30	34.0	234.6	13.30
	2283+40	0+279	130.3	39.7	752.9	229.5	778.0	237.1	628.0	191.4	25.1	7.7	Type 1	162.2	1118.4	2.2	15.4	72.80	14.8	101.9	10.97	17.0	117.3	9.54
Pipe Entry Side	2282+13	0+240	0.0	0.0	780.0	237.7	780.0	237.7	628.0	191.4	0.0	0.0	Type 1	0.0	0.0	0.0	0.0	--	0.0	0.0	--	0.0	0.0	--

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