MOTT MACDONALD

PennEast PIPELINE

HDD Design Report
Interstate 81 / State Route 315 HDD Crossing

PennEast Pipeline Project

December 17, 2018

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Issue and revision record

Revision	Date	Originator	Checker	Approver	Description
A	02/14/18	S. Hammerschmidt	K. Nevins	G. Duyvestyn	Draft for Client Review
B	05/09/18	R. Chambers	G. Duyvestyn	M. Wilcox	Draft for Client Review
C	12/17/2018	A. Young / M. Lockwood	G. Duyvestyn	M. Wilcox	Issued for PADEP

Document reference: 353754-MM-EN-CO-084 RevC

Information class: Standard

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1 Introduction

Mott MacDonald has prepared this Horizontal Directional Drill (HDD) design report at the request of PennEast Pipeline Company, LLC (PennEast), for their proposed HDD crossing of Interstate 81 and State Route 315 (SR 315), 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 Interstate 81/SR 315 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. Additionally, a geophysical investigation was completed by Hager-Richter Geoscience, Inc. (Hager-Richter), to supplement the geotechnical borings. Discussions on the geotechnical aspects in this design report have been extracted from the information presented in the site specific Geotechnical 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 1,755 feet (with a true length of approximately 1,771 feet). The HDD entry point is located approximately 620 feet northwest of SR 315 and the HDD exit point is located approximately 775 feet southeast of the northbound lane of Interstate 81. An elevation difference of approximately 135 feet exists between the HDD entry and exit locations, with the HDD entry location at the lower elevation. The northwest side of the crossing was selected as the HDD entry location to lower the drilling fluid pressures beneath Interstate 81/SR 315. A small excavation may be used at the HDD entry location to provide some depth of cover at the HDD entry given the low entry angle, at the discretion of the HDD contractor.

The pipe staging area for the drag section is located on the northwest side of the crossing (the same side as the HDD entry location). Prior to pullback operations, the drill rig will be remobilized around to the HDD exit site on the southeast side of the crossing for pullback operations. It is envisioned that the pipe string will be fabricated into two (2) sections prior to pullback operations with an intermediate weld completed during pullback operations.

2 Anticipated Geotechnical Conditions

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

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

The subsurface investigation consisted of a geophysical survey and seven (7) exploratory borings. A down hole borehole camera was used to inspect the borings after termination depth was reached to identify voids in the bedrock stratigraphy. The surface investigation consisted of seven (7) borings (B-7, B-7A, B-8, B-9, B-I81-1, B-I81-2, and B-I81-3). Borings B-I81-1, B-7, and B-7A are located northwest of State Road 315, borings B-I81-2, B-8 and B-9 are located Southeast of Interstate 81, and B-I81-3 was completed within the median of Interstate 81.

A seismic survey was performed in January 2017 by geophysical subconsultant Hager-Richter Geosciences under the instruction of Mott MacDonald. A 1,075-foot long survey line was performed on the northwest side of the crossing approximately 25 to 30 feet north of the proposed HDD alignment. The objective of the investigation was to ascertain the thickness of fill material on the northern side of the crossing. More detailed discussions can be found in the Hager-Richter site-specific ERI Survey Report.

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

2.2 Geotechnical Observations

The crossing is located in the Wyoming Valley, within the former major coal mining region known as the Northern Anthracite Field. The features of the historic coal mining will have a major impact on this crossing.

Workings of the coal seams, known as the Top Ross and Ross coal seams, are found at relatively shallow depths below the interstate (approximately 100 to 110 feet below the northbound travel lane). These seams were worked via room and pillar mining methods in the early 1900's, and today are present as laterally extensive layers of open voids, collapsed rubble and fractured ground. The largest void encountered during the borehole investigation was 7.6 feet in height. Inspection using a down hole camera showed this void to extend off laterally in all directions. In some locations, the mine workings have collapsed, resulting in thick zones of rubble above the historic mine floor.

Strip mining was used on the northern side of the crossing to extract coal from the Cooper and Bennet coal seams. The backfill of this stripped area has resulted in thick fill of variable composition.

2.2.1 Geotechnical Observations North of State Route 315

The HDD installation on the northwest side of State Route 315 is anticipated to encounter historic mine backfill consisting of gravelly clay overlying bedrock materials.

In the vicinity of Boring B-I81-1, the geotechnical materials are anticipated to include the following. Note that B-I81-1 was drilled at a location elevated approximately 45 feet higher than the proposed entry location, thus significantly less fill material is anticipated at the entry location than was encountered in B-I81-1.

- Fill described as stiff gravelly silt, very dense sand with gravel, hard clay with gravel, and very stiff gravelly clay, from the ground surface to a depth of 53.5 feet (from Elev. 807 to 747.5 feet). Grain size distribution tests indicate gravel percentages up to 25 percent of the soil particles.
- Very stiff gravelly clay (possible fill layer) to a depth of 58.5 feet (to Elev. 748.5 feet).
- Abrupt change to bedrock with poor recovery of anthracite coal fragments to a depth of 65 feet (to Elev. 742 feet.)
- Fresh, strong shale to a depth of 70 feet (to Elev. 737 feet). Rock Quality Designation (RQD) value of 100 percent and recovery value of 100 percent.
- Fresh, strong slate to a depth of 90 feet (to Elev. 733.5 feet). RQD value of 82 percent and recovery value of 100 percent.
- Fresh, strong to very strong quartzite to a depth of 90 feet (to Elev. 717 feet). RQD values ranged between 80 and 97 percent (avg. 90 percent) and recovery values of 100 percent. Encountered a small layer of highly fractured anthracite coal approximately 1-foot thick at Elev. 719 feet.
- Fresh, medium strong to very strong slate to a depth of 98 feet (to Elev. 709 feet). RQD values ranged between 80 and 100 percent (avg. 90 percent) and recovery values of 100 percent.
- Fresh, very strong to extremely strong quartzite to a depth of 137.7 feet (to Elev. 669.3 feet). RQD values of 100 percent and recovery values of 100 percent.
- Small layer of fresh and extremely strong conglomerate, predominately quartz, to a depth of 139 feet (to Elev. 668 feet).
- Fresh, very strong to extremely strong quartzite to a depth of 148 feet (to Elev. 659 feet). RQD values ranged between 82 and 100 percent (avg. 91 percent) and recovery values of 100 percent.
- Fresh, strong shale with layers of anthracite coal and pyrite to a depth of 171.5 feet (to Elev. 635.5 feet). Anthracite coal layers ranging from 1 to 4-foot thick were encountered between the depths of 151 and 167 feet BGS. RQD values ranged between 55 and 83 percent (avg. 77 percent). Recovery values ranged between 80 and 100 percent (avg. 96 percent).
- Fresh, very strong to extremely strong quartzite to a termination depth of 180 feet (to Elev. 627 feet). RQD values ranged from 83 to 100 percent (avg. 92 percent) and recovery values of 100 percent.

In the vicinity of Boring B-7A, the geotechnical materials are anticipated to include the following:

- Fill described as very stiff clay with gravel and cobbles, very stiff sandy clay with gravel and silt, very stiff to hard gravelly clay with sand and silt, from the ground surface to a depth of 38.5 feet (from Elev. 812 to 773.5 feet).
- Sandstone fragments to Elev. 767 feet.
- Moderately weathered to slightly weathered, medium strong quartzite to a depth of 55 feet (to Elev. 757 feet). Some highly fractured zones including vertical fractures. RQD values ranged between 63 and 67 percent (avg. 65 percent). Recovery values ranged between 95 and 100 percent (avg. 98 percent).
- Fresh, strong to very strong quartzite to a depth of 73 feet (to Elev. 739 feet). RQD values ranged between 77 and 100 percent (avg. 89 percent). Recovery values ranged between 97 and 100 percent (avg. 99 percent).
- Small layer of fresh and strong sandy shale to a depth of 75 feet (to Elev. 737 feet). RQD value of 77 percent and recovery value of 97 percent.
- Fresh and very strong quartzite to a depth of 95 feet (to Elev. 717 feet). RQD values ranged between 87 and 95 percent (avg. 91 percent). Recovery values ranged between 95 and 98 percent (avg. 97 percent).
- Small layer of fresh and very strong conglomerate to a depth of 96.3 feet (to Elev. 715.7 feet).

- Fresh and very strong sandy shale with occasional anthracite coal seams to a depth of 105 feet (to Elev. 707 feet). RQD values ranged between 67 and 70 percent (avg. 69 percent). Recovery values ranged between 90 and 100 percent (avg. 95 percent).
- Slightly weathered to fresh and strong to very strong quartzite with multiple voids encountered to a depth of 117.2 feet (to Elev. 694.8 feet). RQD values ranged between 0 and 37 percent (avg. 16 percent). Recovery values ranged between 18 and 92 percent (avg. 61 percent). Three (3) voids of approximately 0.5 to 0.92 feet in height identified within layer.
- Slightly weathered and medium strong shale with multiple voids encountered to a depth of 125 feet (to Elev. 687 feet). RQD values ranged between 27 and 37 percent (avg. 32 percent). Recovery values ranged between 57 and 73 percent (avg. 65 percent). Two (2) voids of approximately 1 to 2 feet in height identified within layer.
- Small layer of anthracite coal fragments to a depth of 128.5 feet (to Elev. 683.5 feet).
- Slightly weathered to fresh and strong shale to a depth of 145 feet (to Elev. 667 feet). RQD values ranged between 62 and 100 percent (avg. 78 percent). Recovery values ranged between 97 and 100 percent (avg. 99 percent).
- Very strong shale and quartzite interbedded to a depth of 150 feet (to Elev. 662 feet). RQD value of 88 percent and recovery value of 100 percent.
- Fresh and very strong quartzite to a depth of 155 feet (to Elev. 657 feet). RQD value of 100 percent and recovery value of 100 percent.
- Fresh and very strong conglomerate, predominantly quartz, to a depth of 160 feet (to Elev. 652 feet). RQD value of 100 percent and recovery value of 100 percent.
- Fresh and very strong to extremely strong quartzite to a termination depth of 200 feet (to Elev. 612 feet). Small 1-foot thick layer of shale with anthracite coal encountered, along with occasional shale and coal bedding at fractures. RQD values ranged between 33 and 100 percent (avg. 75 percent). Recovery values ranged between 97 and 100 percent.

In the vicinity of Boring B-7, the geotechnical materials are anticipated to include the following:

- Medium stiff silt with decomposed rock fragments from ground surface to a depth of 3.5 feet (from Elev. 812 feet to 808.5 feet).
- Medium dense sand with gravel and silt to a depth of 18.5 feet (to Elev. 793.5 feet). Grain size distribution tests indicate gravel percentages up to 26 percent of the soil particles.
- Medium dense to very dense gravel with silty sand to a depth of 48.5 feet (to Elev. 763.5 feet). Grain size distribution tests indicate gravel percentages up to 74 percent of the soil particles.
- Very dense silty sand with gravel to a depth of 53.5 feet (to Elev. 758.5 feet). Grain size distribution tests indicate gravel percentages up to 41 percent of the soil particles.
- Very dense clayey sand with decomposed rock fragments to a depth of 58.5 feet (to Elev. 753.5 feet). Grain size distribution tests indicate gravel percentages up to 35 percent of the soil particles.
- No recovery with a possible boulder to a depth of 70 feet (to Elev. 742 feet).
- Slightly weathered to fresh, medium strong to extremely strong quartzite to a termination depth of 100 feet (to Elev. 742 feet). RQD values ranged from 43 to 100 percent (avg. 81 percent). Recovery values of 100 percent.

Along the proposed HDD alignment, the bedrock on the northwest side of the Interstate 81/SR 315 appears to be of very poor to very good quality with an overall good quality of the rock mass. RQD values range from 0 to 100 percent with an average value of 79.1 percent. The core recovery values on the northwest side ranged from 18 to 100 percent with an average value of 95.7 percent.

Laboratory testing of the quartzite from borings B-7 and B-7A indicate a Uniaxial Compressive Strength (UCS) range from 11,676 to 16,547 psi with an average of 14,112 psi. The axial point load UCS ranged from 19,496 to 19,589 psi with an average of 19,543 psi. The diametral point load UCS ranged from 10,366 to 19,859 psi with an average of 15,113 psi.

2.2.2 Geotechnical Observations beneath Interstate 81

The HDD installation between the Interstate 81 median is anticipated to encounter fill to glacial till and weathered bedrock overlying bedrock materials.

In the vicinity of Boring B-I81-3, the geotechnical materials are anticipated to include the following:

- Fill described as medium dense clayey sand with gravel and cobbles, dense clayey gravel, and dense gravelly silt with clay and cobbles, from the ground surface to a depth of 12.5 feet (from Elev. 827 to 814.5 feet).
- Very stiff gravelly clay to a depth of 17.2 feet (to Elev. 809.8 feet).
- Boulder of sandstone over gravelly clay to a depth of 18.5 feet (to Elev. 808.5 feet).
- Very dense weathered rock fragments to a depth of 25 feet (to Elev. 802 feet).
- Fresh, strong to very strong sandstone to a depth of 35 feet (to Elev. 792 feet). RQD values ranged between 78 and 100 percent (avg. 89 percent). UCS ranged between values of 9,819 psi and 11,413 psi (avg. 10,481 psi).
- Small layer of fresh, medium strong siltstone to a depth of 35.8 feet (to Elev. 791.2 feet).
- Fresh, very strong sandstone to a depth of 40.9 feet (to Elev. 786.1 feet) with occasional siltstone inclusions. RQD value of 75 percent and recovery value of 100 percent.
- Small layer of fresh, medium strong anthracite coal to a depth of 42.4 feet (to Elev. 784.6 feet).
- Small layer of strong siltstone to a depth of 45 feet (to Elev. 782 feet). RQD value of 90 percent and recovery value of 93 percent. UCS was tested as 5,979 psi.
- Fresh, strong sandstone to depth of 60 feet (to Elev. 767 feet). RQD values ranged between 78 and 97 percent (avg. 87 percent). Recovery values ranged between 98 and 100 percent (avg. 99 percent).
- Fresh, extremely strong quartzite to a depth of 89.5 feet (to Elev. 737.5 feet). RQD values ranged between 82 and 100 percent (avg. 93 percent). Recovery values ranged between 97 and 100 percent (avg. 100 percent).
- Fresh, strong to extremely strong sandstone with multiple voids to a depth of 117.4 feet (to Elev. 709.6 feet). RQD values ranged between 57 and 95 percent (avg. 84 percent). Recovery values ranged between 85 and 100 percent (avg. 98 percent). Two (2) voids ranging between 0.2 and 0.7 feet thick. UCS was tested as 12,001 psi.
- Anthracite coal with void and highly fractured zone to a depth of 120 feet (to Elev. 707 feet). RQD value of 57 percent and recovery value of 85 percent. One (1) void of 0.1 inches.
- Fresh, strong mudstone to a depth of 122 feet (to Elev. 705 feet). RQD value of 60 percent and recovery value of 93 percent.
- Small layer of anthracite coal to a depth of 122.8 feet (to Elev. 704.2 feet).
- Fresh, strong slate with multiple voids to a depth of 126.1 feet (to Elev. 700.9 feet). RQD value of 60 percent and recovery value of 93 percent. Two (2) voids ranging between 0.8 and 1 feet.
- Fresh, medium strong mudstone with multiple voids to a depth of 134 feet (to Elev. 693 feet). RQD values ranged between 15 and 22 percent (avg. 18.5 percent). Recovery values ranged between 58 and 63 percent (avg. 61 percent). Three (3) voids ranging between 0.2 and 0.9 feet.

- Small layer of fresh, strong sandstone to a depth of 135 feet (to Elev. 692 feet).
- Fresh, medium strong mudstone to a depth of 139 feet (to Elev. 688 feet). RQD value of 92 percent and recovery value of 100 percent.
- Fresh, strong to very strong sandstone to a depth of 147.5 feet (to Elev. 679.5 feet). RQD values ranged between 42 and 100 percent (avg. 78 percent) and recovery values of 100 percent.
- Fresh, strong to very strong conglomerate with a layer of weak anthracite coal with pyrite seams to a depth of 150 feet (to Elev. 672). RQD value or 83 percent and recovery value of 100 percent.
- Fresh, very strong sandstone to a depth of 160 feet (to Elev. 667 feet). RQD value of 100 percent and recovery value of 100 percent.
- Fresh, extremely strong quartzite to a depth of 172 feet (to Elev. 655 feet). RQD values ranged from 80 to 100 percent (avg. 93.3 percent) and recovery values of 100 percent.
- Anthracite coal with highly fractured zone to a depth of 173 feet (to Elev. 654 feet).
- Fresh, extremely strong sandstone to a termination depth of 175 feet to Elev. 652 feet. RQD value of 80 percent and recovery value of 100 percent.

Along the proposed HDD alignment, the bedrock in the median of the Interstate 81/SR 315 appears to be of very poor to very good quality with an overall good quality of the rock mass. RQD values range from 15 to 100 percent with an average value of 82.3 percent. The core recovery values in the median ranged from 56 to 100 percent with an average value of 92.9 percent.

2.2.3 Geotechnical Observations South of Interstate 81

The HDD installation southeast of Interstate 81 is anticipated to encounter glacial till over bedrock. Glacial till was seen to be between 15-20 feet thick and is characterized as a stiff gravely clay. The bedrock is composed of the same lithologies as the other side of the crossing.

In the vicinity of Boring B-I81-2, the geotechnical materials are anticipated to include the following:

- Glacial till consisting of medium stiff sandy clay with gravel and very stiff gravelly clay, from the ground surface to a depth of 23 feet (from Elev. 862 to 839 feet).
- Weathered rock to top of bedrock to a depth of 25 feet (to Elev. 837 feet).
- Fresh, very strong quartzite with void and highly fractured zones to a depth of 76.6 feet (to Elev. 785.4 feet). Layer of quartzite interbedded with shale. RQD values ranged between 25 and 100 percent (avg. 80 percent). Recovery values ranged between 90 and 100 percent (avg. 97 percent). Void of 0.6 feet at an elevation of 799.6 feet. UCS ranging between values of 2,340 psi and 20,116 psi (avg. 12,445 psi).
- Slightly weathered to fresh, weak mudstone and mudstone/shale with highly fractured zones to a depth of 89 feet (to Elev. 773 feet). RQD values ranged between 38 and 92 percent (avg. 56 percent). Recovery values ranged between 87 and 97 percent (avg. 94 percent). UCS value of 1,590 psi.
- Fresh, very strong to extremely strong quartzite with voids and highly fractured zones to a depth of 140 feet (to Elev. 722 feet). RQD values ranged between 65 and 100 percent (avg. 92 percent). Recovery values ranged between 90 and 100 percent (avg. 99 percent). Three (3) voids of 0.3 feet at bottom of layer. UCS ranging between values of 11,759 psi and 21,177 psi (avg. 17,447 psi).
- Lightly weathered to Fresh, medium strong shale with layers of fresh and weak anthracite coal to a depth of 150 feet (to Elev. 712 feet). RQD values of 68 percent.
- Slightly weathered to fresh, medium strong to strong slate with a void to a depth of 157 feet (to Elev. 705 feet). RQD values ranged between 28 and 35 percent (avg. 32 percent). Recovery values ranged between 42 and 93 percent (avg. 68 percent). Void of 0.4 feet within layer.
- A void of 3 feet with gravel lining bottom to a depth of 160 feet (to Elev. 702).

- Fresh, strong shale to a depth of 165 feet (to Elev. 697). RQD value of 72 percent and recovery value of 87 percent.
- Fresh and very strong Quartzite to a depth of 176 feet (to Elev. 686 feet). RQD values ranged from 93 to 100 percent (avg. 97 percent) and recovery values of 100 percent.
- Small layer of highly fractured shale/coal with clay infilling to a depth of 177.5 feet (to Elev. 684.5 feet).
- Fresh, very strong conglomerate to a depth of 183 feet (to Elev. 679 feet). RQD values ranged from 65 to 68 percent (avg. 67 percent). Recovery values ranged between 83 and 100 percent (avg. 92 percent).
- Fresh, very strong to extremely strong quartzite to a termination depth of 225 feet (to Elev. 637 feet). RQD values ranged between 75 and 100 percent (avg. 94 percent). Recovery values ranged between 95 and 100 percent (avg. 99 percent).

In the vicinity of Boring B-8, the geotechnical materials are anticipated to include the following:

- Medium stiff gravelly clay, from the ground surface to a depth of 3.5 feet (from Elev. 883 to 879.5 feet).
- Dense clayey gravel to a depth of 8.5 feet (to Elev. 874.5 feet).
- Hard gravelly clay with cobbles to a depth of 20 feet (to Elev. 863 feet).
- Slightly weathered to fresh, strong quartzite with a small layer of conglomerate to a depth of 40.5 feet (to Elev. 838 feet). RQD values ranging between 75 and 100 percent (avg. 84 percent). Recovery values ranged between 97 and 100 percent (avg. 99 percent).
- Fresh, very strong conglomerate to a depth of 46.3 feet (to Elev. 836.7 feet). RQD value of 100 percent and recovery value of 100 percent.
- Slightly weathered to fresh, very strong quartzite with small layer of slightly weathered and strong shale and coal to a depth of 73.1 feet (to Elev. 809.9 feet). RQD values ranged between 53 and 97 percent (avg. 75 percent). Recovery values ranged between 95 and 100 percent (avg. 99 percent).
- Multiple voids with small layers of fresh and very strong quartzite, coal, and slightly weathered and weak shale separating to a depth of 91.9 feet (to Elev. 791.1 feet). RQD values ranged between 0 and 25 percent (avg. 14 percent). Recovery values ranged between 32 and 42 percent (avg. 36 percent). Seven (7) voids ranging between 0.3 and 3.9 feet.
- Slightly weathered to fresh, medium strong to strong shale to a depth of 102.5 feet (to Elev. 780.5 feet). RQD values ranged between 22 and 92 percent (avg. 47 percent). Recovery values ranged between 38 and 97 percent (avg. 77 percent).
- Fresh, strong quartzite to a depth of 110 feet (to Elev. 773 feet). RQD value of 47 percent and recovery value of 100 percent.
- Slightly weathered, medium strong shale with highly fractured zones to a depth of 115 feet (to Elev. 768 feet). RQD value of 55 percent and recovery value of 95 percent.
- Void of 1.4 feet between layers of fresh and strong quartzite and extremely weathered and extremely weak shale to a depth of 120 feet (to Elev. 763 feet). RQD value of 55 percent and recovery value of 95 percent.
- Fresh, medium strong to very strong quartzite to a depth of 153 feet (to Elev. 730 feet). RQD values ranged from 57 to 100 percent (76 percent). Recovery values of 100 percent.
- Conglomerate to a depth of 155 feet (to Elev. 728 feet).
- Quartzite and conglomerate, highly disturbed with poor recovery to a depth of 160 feet (to Elev. 723 feet). Recovery value of 62 percent.

- Fresh, very strong quartzite to a depth of 165 feet (to Elev. 718 feet). RQD value of 85 percent and recovery value of 100 percent.
- Fresh, very strong to extremely strong conglomerate to a depth of 186 feet (to Elev. 697 feet). RQD values between 90 and 100 percent (avg. 96 percent) and recovery values of 100 percent.
- Small layer of fresh, very strong quartzite to a depth of 187.5 feet (to Elev. 695.5 feet).
- Fresh, very strong shale to a depth of 190 feet (to Elev. 693 feet). RQD value of 75 percent and recovery value of 100 percent.
- Fresh and very strong quartzite to a termination depth of 200 feet (to Elev. 683 feet). RQD values ranged between 93 and 100 percent (avg. 97 percent) and recovery values of 100 percent.

In the vicinity of Boring B-9, the geotechnical materials are anticipated to include the following:

- Stiff silt with gravel to a depth of 3.5 feet from the ground surface (from Elev. 900 to 897 feet).
- Very stiff gravelly clay to a depth of 17 feet (to Elev. 883 feet).
- Decomposed rock fragments (sandstone) to a depth of 20 feet (to Elev. 880)
- Slightly weathered to fresh, strong to very strong quartzite to a depth of 60.3 feet (to Elev. 839.7 feet). RQD values ranged between 57 and 100 percent (avg. 77 percent). Recovery values ranged between 95 and 100 percent (avg. 99 percent).
- Void of 7.6 feet between layers of fresh and moderately strong shale and clay/shale to a depth of 70 feet (to Elev. 830 feet).
- Slightly weathered, strong quartzite to a depth of 73 feet (to Elev. 827 feet). RQD value of 40 percent and recovery value of 83 percent.
- Brittle anthracite coal to a depth of 75 percent (to Elev. 825 feet).
- Slightly weathered to fresh, medium strong to strong slate with highly fractured zones to a depth of 91 feet (to Elev. 809 feet). RQD values ranging between 58 and 73 percent (avg. 64 percent). Recovery values ranged between 85 and 100 percent (avg. 95 percent).
- Fresh, strong to extremely strong quartzite to a depth of 133.7 feet (to Elev. 766.3 feet). RQD values ranged from 55 to 100 percent (avg. 92 percent). Recovery values ranged between 93 and 100 percent (avg. 99 percent).
- Fresh, medium strong shale with highly fractured zone to a depth of 135.4 feet (to Elev. 764.6).
- Fresh, very strong to extremely strong quartzite to a depth of 159.6 feet (to Elev. 740.4 feet). RQD values ranging from 87 to 100 percent (avg. 96 percent) and recovery values of 100 percent.
- Fresh, medium strong to strong shale with layers of medium strong and brittle anthracite coal to a depth of 180 feet (to Elev. 720 feet). RQD values between 42 and 100 percent (avg. 72 percent). Recovery values ranged between 93 and 100 percent (avg. 98 percent).
- Fresh, very strong to extremely strong quartzite to a termination depth of 200 feet to Elev. 700.3 feet. RQD values ranging between 78 and 100 percent (avg. 90.8 percent).

Along the proposed HDD alignment, the bedrock on the southeast side of the Interstate 81/SR 315 appears to be of very poor to very good quality with an overall fair quality of the rock mass. RQD values range from 0 to 100 percent with an average value of 76.2 percent. The core recovery values on the southeast side ranged from 12 to 100 percent with an average value of 94.1 percent.

2.3 Geophysical Investigation

A Multi-Channel Analysis of Surface Waves (MASW) seismic survey was performed in January 2017 by geophysical subconsultant Hager-Richter Geosciences under the instruction of Mott MacDonald. A 1,075-foot long survey line was performed. This survey line was completed approximately 25 to 30 feet north of the current pipeline alignment. The objective of the investigation was to determine the thickness of fill

materials and depth of the soil/bedrock interface on the northwest side of the crossing. On the basis of the MASW survey, the following was concluded:

- The depth of bedrock along the seismic line varies between approximately 15 feet and 46 feet below ground surface. The elevation of competent bedrock along the seismic lines varies between approximately 718 feet and 770 feet for a total relief of approximately 52 feet.
- Two areas where bedrock is deeper are interpreted as possible bedrock channels, collapsed areas, or former extensively mined areas.

2.4 Known Fault / Fold Feature

A fault is indicated on the USGS mapping of the crossing location (see GDR for greater detail). The elevations and notes observed on the historical mine mapping confirm the presence of a kink or drastic change in the stratigraphy, which is consistent with this structure. The feature lays beneath the southern travel lane of Interstate 81 between Elev. 725 and 750 feet between borings B-I81-2 and B-8. Historic mine maps show this area as not being mineable and there is an abrupt change in seam inclination. The Top Ross mine map records a rapid change in coal seam elevation and bedrock stability issues. The Ross mine maps also record rapid coal seam elevation changes but mining was uninterrupted through the zone implying that there is no brittle displacement of the fault and that it may actually be a fold.

2.5 Groundwater Conditions

The majority of the boreholes drilled were dry due to drainage into the coal mine workings. The coal mines and fractures are acting as conduits for ground water within the bedrock. A minor amount of perched ground water exists at shallow depths, but the bedrock appears to be well drained via mining-induced fracturing and voids.

2.6 Karst Features and Abandoned Mines

No Karst formations were observed during the geotechnical program. However, historic mining operations, consisting of both surface strip mining and underground room and pillar mining, are known to have occurred in the immediate vicinity of the crossing location. The Pennsylvania Department of Environmental Protection (PADEP) has mapped numerous abandoned coal mines near the proposed crossing. Strip mining was used on the northern side of SR315 to mine the Cooper and Bennet coal seams in the 1930s. Strip mining operations excavated the overlaying materials to expose and remove the mineral deposits, and it can be assumed that the Cooper and Bennet seams were totally removed. Some of the strip mine was backfilled in the mid-to-late 20th century. The fill material used was predominantly mine overburden spoil. The backfilling of pits was generally conducted with little regard to compaction or fill uniformity.

The significant seams below the crossing include the Top Ross, Ross, and Red Ash seams. At the center point of Interstate 81, the Top Ross, Ross, and Red Ash seams are located at approximate elevations of 720 feet, 690 feet and 540 feet, respectively. The proposed HDD is located approximately 30 feet higher in elevation than the Top Ross coal seam. Greater detail of historic mining operations can be found in the GDR completed for this crossing.

Most of the boreholes completed for this crossing encountered evidence of underground voids associated with historic coal mining operations. Room and pillar mining extracted areas of coal (rooms) and untouched areas of the coal seam left in place act as roof support (pillars). These supporting pillars of coal were often trimmed back to extract additional coal in episodes of secondary mining or “robbing”. Once robbing took place, collapse is more likely to occur. Due to variations in the seam thickness, bounding rock strength and amount of robbing the remnant voiding is seen to be inconsistent. Some

boreholes (such as B-9) contained a single large void and others contained a significant thickness of rubble with small voids present in between the collapsed blocks.

A 7.6-foot high void was encountered in Boring B-9 from a depth of 60.9 to 68.5 feet below ground surface (corresponding to Elev. 839 and 831 feet). This void is interpreted as possibly the combined remnants of both the Top Ross and Bottom Ross coal seam.

Voids ranging from 6 inches to 3 feet thick were encountered in boring B-I81-2. The majority of the voids were encountered between 137 feet BGS and 160 feet BGS (el. 725 and el. 702 feet, respectively). This 23-foot thick zone contained seven separate voids, likely upward fracture propagation and collapse from workings of the Ross seam.

On a geological scale, boreholes are one-dimensional. In contrast, the cross-section drawings are two dimensional, and the voids are three dimensional. These dimensional differences should be kept in mind when reviewing the voids in the boring logs. The voids may appear to be discreet layers interspersed by solid bedrock, but it is highly likely that these are zones consist of rubble and boulders with interconnected voids between them.

3 Interstate 81 & State Route 315 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 Interstate 81/SR 315 Crossing, the entry and exit angles have been set at 7° and 11.25°, respectively, relative to the horizontal. The entry and exit angles were selected to attain sufficient depth of cover beneath Interstate 81/SR 315 while attempting to avoid historic mining operations below the HDD installation.

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 crossing 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 36-inch outer diameter of the pipe (1200 X 36 inches = 43,200 inches or 3,600 feet). 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:

- Anticipated geotechnical materials,
- Presence of preferential flow pathways,
- Historical land use,
- Design bending radius,
- Presence of existing utilities and/or structures, and
- 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. For this installation, the HDD is anticipated to be within the bedrock prior to crossing under SR 315 and Interstate 81.

The proposed HDD installation crosses beneath surface features including an existing culvert, state route and interstate. From a northwest to southeast orientation, the following minimum depths of cover are noted:

- 36-inch Existing Culvert: approximately 23 feet.
- SR 315: approximately 92 feet.
- Interstate 81 southbound lanes: approximately 88 feet.
- Interstate 81 northbound lanes: approximately 67 feet.

3.1.4 Bore Diameter

The diameter of the HDD bore must 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 HDD industry standard for the final bore diameter is generally 12 inches larger than the outer diameter of the product pipe. 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 from which the downhole probe can 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.

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 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 to avoid the risks associated with laying a surface coil across SR 315 and Interstate 81. 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 northwest side of the crossing has been established at 325 feet by 250 feet, and the staging area for the southeast side of the crossing has been established at 300 feet by 200 feet. 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.

In addition to the entry and exit staging areas, a staging area of at least 50 feet wide by the length of the pipe string is also required for welding sections of the pipe string. The proposed staging area for the drag section is located on the northwest side of the crossing. The available length of the staging area is approximately 1,150 feet, requiring the fabrication of the product pipe into two (2) pipe strings, with the shortest string recommended to be installed first. The proposed pipe staging width is 100 feet to accommodate the two (2) pipe strings.

The temporary work space established for the Interstate 81/SR 315 is sufficient for HDD operations.

3.4 Requirement for Temporary Surface Casing

During the geotechnical investigation, layers of mining backfill were on the northwest side of SR 315 crossing consisting of mostly gravelly clay (percent gravel up to 25 percent of the soil) from the ground surface and extending down to Elev. 747 feet. The remaining 75 percent of this soil is comprised of 47 percent sand and 28 percent fines (clays and silts). Although the site soils are noted as being gravelly, the 25 percent gravel component is not anticipated to significantly increase the risk of this installation, especially given the 28 percent fines content associated with this soil layer. Hence, the requirement for temporary surface casing at this location is recommended to be left to the HDD contractor as a means of convenience to suit their means and methods. The HDD contractor must be prepared to deal with any bore instability and raveling, should it occur during drilling operations.

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

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, the contractor will be required to haul and store water on site for construction activities. Estimates of fresh water requirements is a function of maintaining drilling fluid flow within the bore during the HDD installation, and water requirements to adjust for hole volume, minor losses to processed spoils 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 five (5), the estimated total water usage (assuming no loss in circulation) is approximately 855,910 gallons (114,426 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 75,000 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 551,400 gallons (2,730 yd^3) and 1,211 yd^3, respectively. During pullback operations, the estimated displaced fluid volume is approximately 97,289 gallons (477 yd^3).

3.7 Schedule

The duration of the HDD installation is conservatively estimated to take a total of 75 shifts, regardless of whether 24-hour operations are conducted to complete the crossing, as shown in Table 1 below. This estimate is based on 12-hour shifts. 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 more difficult drilling conditions/extensive grouting operations.

Table 1: Estimated schedule duration for the HDD crossing

Activity	Duration (Shifts)
Mobilization	3
Rig Up / Equipment Setup	5
Pilot Bore Drilling	18
Reaming	42
Swab Pass	1
Product Pipe Pullback	1
Rig Down and Demobilization	5
Total Number of Shifts	**75**

4 HDD Engineering Evaluation

4.1 Pipeline Properties

The pipeline properties used for the evaluation of the I81/SR 315 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 Installation 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 presented 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 Interstate 81/SR 315 crossing 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 (1200 X 36 inches = 43,200 inches or 3,600 feet).

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 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 ASME 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 (based on 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	16,731	23.9	--
Hoop Stress	34,961	49.9	50[2]
Longitudinal Tensile Stress from Hoop Stress	10,488	15.0	--
Longitudinal Stress from Thermal Expansion	-13,898	19.9	90[3]
Net Longitudinal Stress (Compression Side of the Curve)	-20,141	28.8	90[4]
Net Longitudinal Stress (Tension Side of the Curve)	13,321	19.0	90[4]
Maximum Shear Stress	27,551	39.4	45
Combined Biaxial Stress	55,102	78.7	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 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, 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 were completed to investigate the effects of varying mud weights and buoyancy control measures during the installation of the pipe. The six (6) scenarios were:

- 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.

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 (lbs)
10 (Case 1)	Empty	291,989	437,984
10 (Case 2)	Full	242,098	363,147
11 (Case 3)	Empty	303,370	455,055
11 (Case 4)	Full	234,601	351,902
12 (Case 5)	Empty	312,680	469,020
12 (Case 6)	Full	228,858	343,287

Results of the corresponding installation stresses (based on the design bending radius of 3,600 feet) are summarized below 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)	3,461 psi (4.9%)	2,870 psi (4.1%)	3,596 psi (5.1%)	2,781 psi (4.0%)	3,707 psi (5.3%)	2,713 psi (3.9%)
Maximum Bending Stress (Percent of Allowable)	12,167 psi (17.4%)	12,167 psi (17.4%)	12,167 psi (17.4%)	12,167 psi (17.4%)	12,167 psi (17.4%)	12,167 psi (17.4%)
Maximum Hoop Stress (Percent of Allowable)	436 psi (0.6%)	72 psi (0.1%)	479 psi (0.7%)	116 psi (0.2%)	523 psi (0.8%)	159 psi (0.2%)
Maximum Unity Check – Tensile and Bending	0.32	0.31	0.32	0.31	0.33	0.31
Maximum Unity Check – Tensile, Bending, and Hoop	0.08	0.07	0.08	0.07	0.08	0.07

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 quartzite and shale bedrock materials as moderately strong soils. This conservative approach has been used by Mott MacDonald to successfully complete several HDD installations in similar bedrock materials. However, it is important to note that the presence of open preferential flow pathways within the bedrock mass may lead to drilling fluid losses at fluid pressures below predicted allowable values.

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.

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	600 gal/min
Drilling Fluid Weight (Specific Gravity)	10.25 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 and 8 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 2.0, namely, gravelly clay fill overlying quartzite bedrock. For this evaluation, it has also been assumed that the drilling rig will be set up on the northwest side of the crossing to complete the pilot bore.

Table 7: Material property assumptions for the site soils

Evaluation Parameter	Value
Soil Unit Weight Above / Below Water Table	120 lb./ft^3 / 125 lb./ft^3
Effective Cohesion	0 psf
Internal Friction Angle	20°
Young's Modulus	751,875 psf
Poisson's Ratio	0.33

Table 8: Material property assumptions for the bedrock materials

Evaluation Parameter	Value
Soil Unit Weight Above / Below Water Table	140 lb./ft^3 / 145 lb./ft^3
Effective Cohesion	3,000 psf
Internal Friction Angle	12°
Young's Modulus	1,002,501 psf
Poisson's Ratio	0.35

The results of the preliminary hydraulic fracture evaluation for the proposed crossing are provided in Figure 1 below 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. Hence, the risk of a hydraulic fracture or inadvertent return is relatively low for this crossing. The zero-pressure noted at approximate stationing 553+24 in the Figure 1 reflects the area where the drill bit is advanced above the elevation of the drill rig, where the fluids will tend to flow back towards the rig under the presence of gravity with no induced drilling fluid pressure.

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. Use of 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.

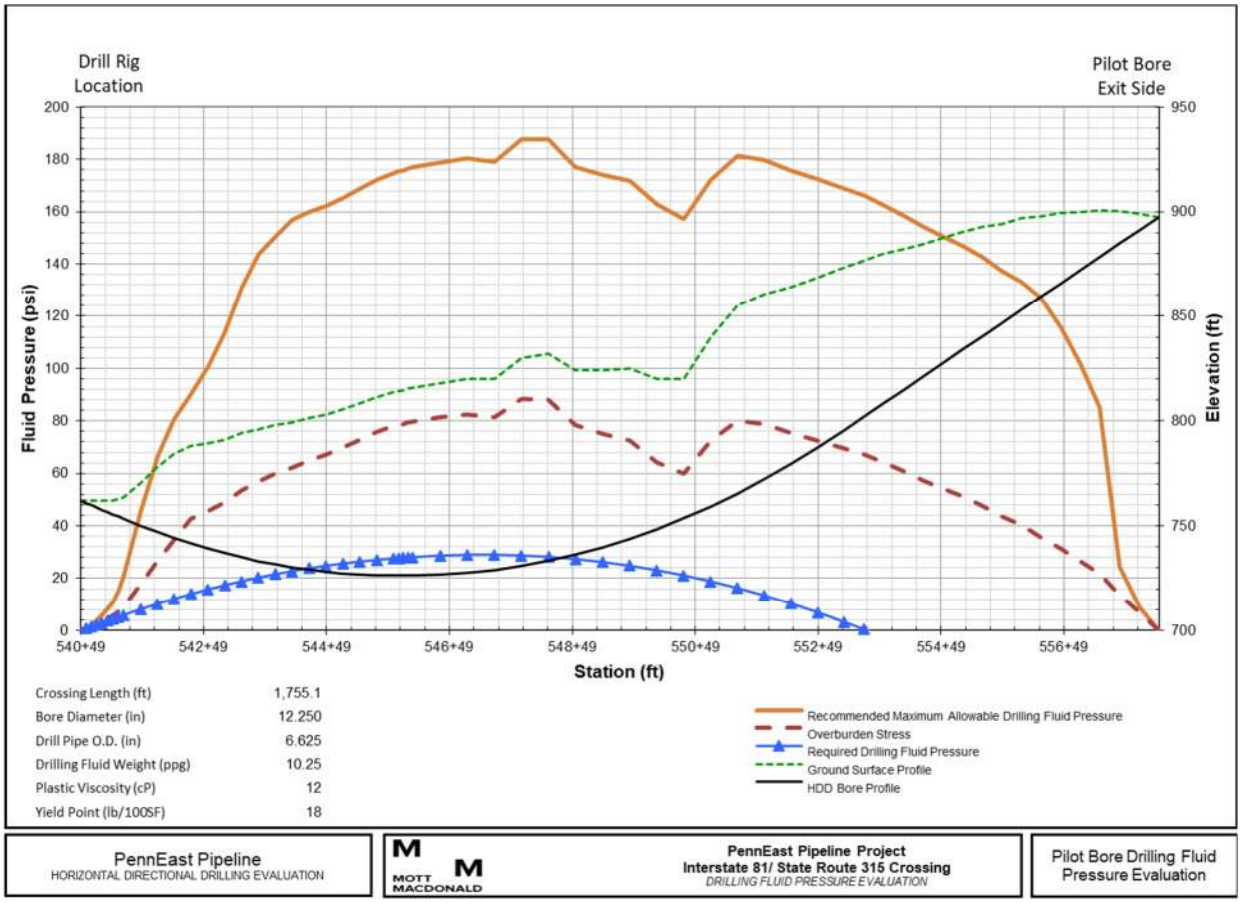


Figure 1: Calculated, recommended, and allowable drilling fluid pressures

5 HDD Risk Discussions

5.1 HDD Risk Characterization

Risk identification and mitigation is paramount to successfully completing the Interstate 81/SR 315 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 9 below. This database is used to 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 required pipe 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-practice for the HDD industry.

Table 9: 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 9 below, several HDD installations have been successfully completed at a diameter of NPS 36 for lengths considerably longer than the horizontal installation length of approximately 1,758 feet, with a true pipe length of approximately 1,774 feet, required for this crossing. Therefore, from a constructability standpoint, the Interstate 81/SR 315 Crossing falls within the zone of typical 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 by using 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, gravel-sized particles less than 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.

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, given the close proximity to historic mining operations, and potential over-stressing of bedrock formations from mining collapse, drilling fluid losses may occur when not anticipated. The HDD contractor will need to be prepared to grout open preferential pathways during drilling operations in event drilling fluid flow cannot be maintained or re-established through the HDD bore path.

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 Interstate 81/SR 315 Crossing, the rock quality is between 80 and 100 percent through most of the bedrock (in the vicinity of the borehole locations), with lower RQD percentages in high fractured areas near noted voids based on the information that is currently available. Areas of lower rock quality may increase risks associated with this installation in terms of potential drilling fluid loss and bore instability.

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 rock samples indicate a UCS ranging between 1,590 psi and 21,177 psi, point load UCS between 15,801 and 19,589 psi in the diametral direction and between 1,590 psi and 21,177 psi in the axial direction. Brazilian splitting tensile strength tests yielded strengths of 1,401 psi and 1,627 psi.

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 or down into the historic mine network. Fortunately, the presence of the drilling fluid slurry within the bore is often capable of sealing fractures and/or joints as drilling fluids migrates 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

Possible voids due to abandoned mining may be encountered during HDD construction based on noted voids in the geotechnical report. These features pose a risk for significant drilling fluid losses and an inability to maintain design line and grade/loss of downhole tooling. In efforts to mitigate this risk, Mott MacDonald designed the vertical alignment for the current proposed HDD crossing to be shallower in comparison to the initial vertical alignment submitted to FERC in September of 2016. The depths of cover beneath SR-315 and I-81 were decreased between 50 to 55 feet in attempts to avoid the Ross Coal Seam. The decrease in depth of cover is not deemed to present a significant risk to the installation, as indicated in the hydraulic fracture chart provided in Figure 1. While the current proposed HDD crossing is designed to avoid possible voided areas, Mott MacDonald recommends that this issue be discussed with the respective HDD contractor since there are still medium degree inherent risks with this HDD crossing. A contingency plan must be provided by the contractor to deal with this potential condition if it is encountered. In addition, as stated earlier, the HDD contractor should be prepared to grout during drilling operations to seal preferential drilling fluid flow pathways and/or voids in the event drilling fluid returns cannot be maintained through the HDD bore.

The HDD exit location is approximately 135 feet higher than the elevation of the entry location. Once the bore is advanced above the elevation of the drilling rig it will be difficult to maintain a column of drilling fluid within the portion of the bore above the elevation of the HDD entry location. Lack of a full column of drilling fluid to support the portion of the bore above the elevation of the drilling rig can lead to instability and raveling of the bore. However, this raveling and bore instability should be able to be managed by the HDD contractor given the clayey soils anticipated in the vicinity of the exit location and presence of bedrock beneath these soils at a depth of approximately 17 feet below ground surface.

A fold/fault exists beneath Interstate 81. Possible fracturing associated with this feature may present drilling fluid flow challenges but is considered less significant than the voids associated with historic mining operations. Grouting may be required to seal these features to allow for drilling fluid flow through the HDD bore. Bore instability may also be influenced by this feature and may require grouting to provide sufficient support to the surrounding bedrock mass.

6 Summary

For the Interstate 81/SR 315 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 several HDD installations of similar and greater installation lengths.

For the Interstate 81/SR 315 Crossing, geotechnical risks have been identified within the alignment. It is anticipated that this crossing carries a medium degree of risk for complications arising from the potential for an inability to manage or control drilling fluid flow through stress induced preferential flow pathways, joints, and possible voids along the drilled path. To overcome these risks, the HDD contractor will need to anticipated grouting events within the bore where drilling fluid losses are experienced to provide a sealed bore for drilling fluid flow through the HDD bore. Grouting may also be required to mitigate bore instability issues associated with heavily fractured/over-stressed bedrock materials.

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.

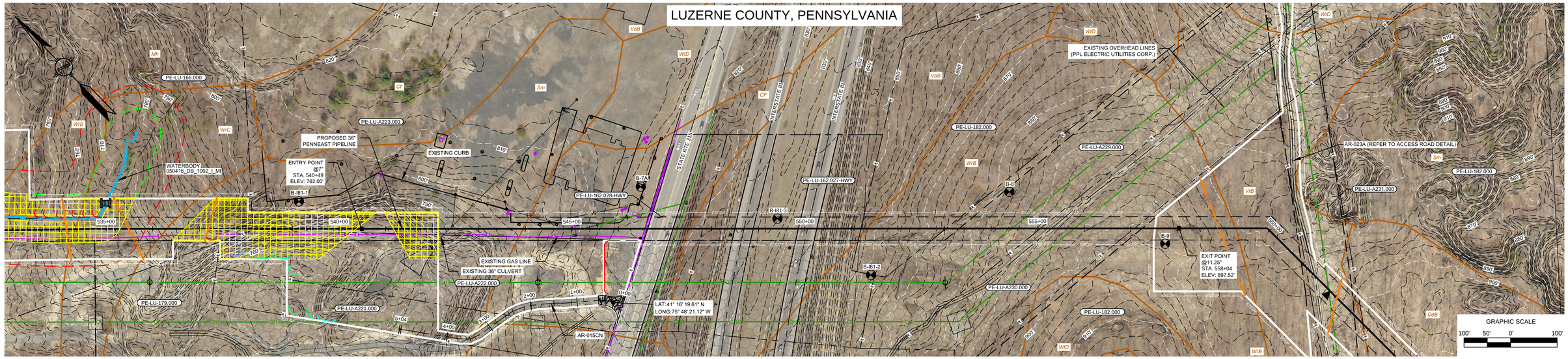
7 Limitations

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 Interstate 81/SR 315 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



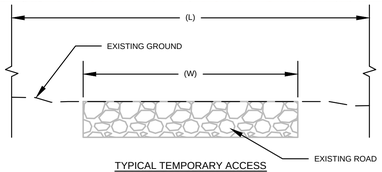
CROSSING SPECIFIC HDD NOTES:

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 1° (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 increase 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 grade utility or structure.

14. CROSS SECTIONS PRESENTS SUMMARY BOREHOLE LOG GRAPHICS, SEE FULL BOREHOLE LOG FOR DETAILS.
15. ROSS COAL SEAMS WERE WORKED VIA ROOM AND PILLAR MINING METHODS IN THE 1930'S AND 1940'S. DASHED RED LINE INDICATES APPROXIMATE LOCATION OF TOP OF WORKINGS. FRACTURING DUE TO MINING DISTURBANCE WILL EXIST ABOVE THIS ELEVATION. ADDITIONAL WORKED COAL SEAMS EXIST BELLOW THE ROSS COAL SEAMS.
16. SUMMARY GEOPHYSICAL PROFILE DISPLAYED, SEE FULL REPORT FOR DETAILS.

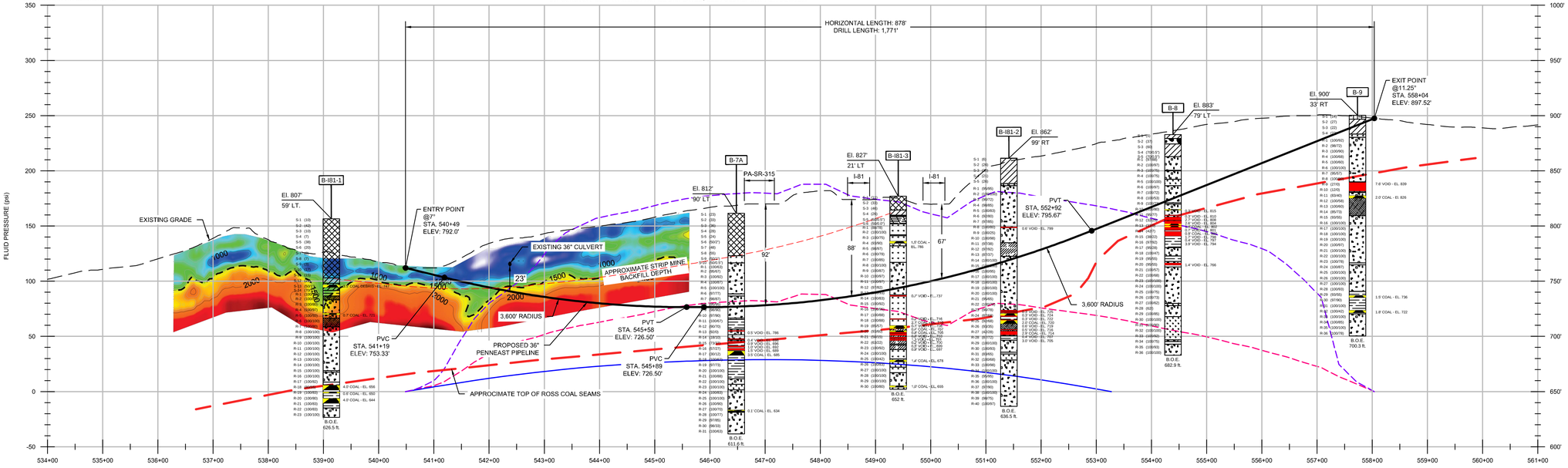
PA ST. ROUTE 315 / INTERSTATE 81 HDD PLAN VIEW
SCALE: 1" = 100'



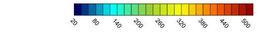
TYPICAL TEMPORARY ACCESS ROAD CROSS-SECTION DETAIL
N.T.S.

NOTES:
1. A TYPICAL LOD WIDTH OF 30' WAS UTILIZED FOR ACCESS ROADS WHERE POSSIBLE. LOD WIDTHS SHOWN DO NOT INCLUDE NECK DOWNS FOR CULVERTS.

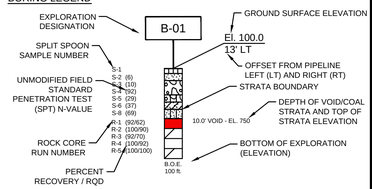
ACCESS ROAD #	STATION RANGE	EXISTING ROAD WIDTH (W) (FT)	ROAD SURFACE	LIMITS OF DISTURBANCE WIDTH (L) (FT)
AR-015CN	0+00 - 0+50	APRON	GRAVEL	APRON
AR-015CN	0+50 - 1+50	16	GRAVEL	20
AR-015CN	1+50 - 3+30	13	GRAVEL	20
AR-015CN	3+30 - 4+00	N/A	GRASS	20
AR-015CN	4+00 - 5+04	N/A	GRASS	VARIES



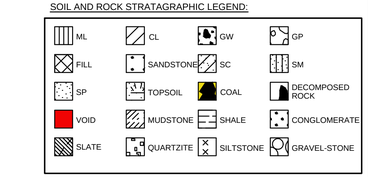
GEOTECHNICAL NOTE: MASW GEOPHYSICS CONDUCTED OFF CENTERLINE.



BORING LEGEND



SOIL AND ROCK STRATAGRAPHIC LEGEND:



GRAPHIC SCALE
HORIZ SCALE: 100' 50' 0' 100'
VERT SCALE: 50' 25' 0' 50'

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

PA ST. ROUTE 315 / INTERSTATE 81 HDD PROFILE
SCALE: 1" = 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
000-03-01-021	ALIGNMENT SHEET
000-03-01-022	ALIGNMENT SHEET
000-03-01-023	ALIGNMENT SHEET
000-03-03-012.1	ACCESS ROAD DETAIL

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
PA ST. ROUTE 315 / INTERSTATE 81 HDD
LUZERNE COUNTY, PENNSYLVANIA

SCALE	DRAWING NO.	REVISION
AS SHOWN	000-03-07-001	A

G:\PENNEAST\353754_PENNEAST_PIPELINE_EPCM\DATAPROD_STATE_PERMIT\WORK\PA\DRAFTING\EROSION_SEDIMENT_CONTROL_PLAN\HDD_DETAILS\000-03-07-001.DWG DUM64749

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)		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		
	SM	Silty sands, sand-silt mixtures			
	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	

*__Note__: The Uniaxial Compressive Strength ranges are approximate; therefore, a geotechnical engineer should be consulted for verification of rock strength.

MOTT MACDONALD

BOREHOLE LOG GRAPHIC LEGEND

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate - 81 Crossing, Wilkes - Barre, PA	**Project Manager:**	Vatsal Shah
Client:	PennEast Pipeline	**Project Director:**	Michael Wilcox

Soil Log Graphic Legend


CL: USCS Low Plasticity Clay


COAL: Coal


FILL: Miscellaneous and Manmade Fill


GP: USCS Poorly-graded Gravel


GW: USCS Well-graded Gravel


ML: USCS Silt


SANDSTONE: Sandstone


SC: USCS Sandy Clay to Clayey Sand


SM: USCS Silty Sand


SP: USCS Poorly-graded Sand


TOPSOIL: Topsoil


WEATHERED SANDSTONE: Highly or Severely Weathered Sandstone


WEATHERED SHALE: Highly or Severely Weathered Shale

Rock Log Graphic Legend


CL - USCS Low Plasticity Clay


COAL - Coal


CONGLOMERATE - Conglomerate


GRAVEL-STONE - Gravel or Crushed Stone


MUDSTONE - Mudstone


QUARTZITE - Quartz and Quartzite


SANDSTONE - Sandstone


SHALE - Shale


SILTSTONE - Siltstone


SLATE - Slate


VOID - Underground Void

▽ 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 M M

SOIL BORING LOG

BORING NO.: **B-I81-1**
Page **1** of **3**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate - 81 Crossing, Wilkes - Barre, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	August 4, 2016 at 2:15 pm
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	August 8, 2016 at 3:02 pm

Elevation: 807 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Northwest corner of construction site. **Coord.:** **N:** 14991695.36 **E:** 1418643.024 **Horizontal Datum:** UTM Zone 18 T

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	30	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	8 4 6 4		FILL	Stiff, Black and brown Gravelly SILT with Sand and Clay, dry (FILL)	N	-	NP	-	
5	S-2 5.0'- 7.0'	11	7 9 33 67		FILL	Very dense, Brown to gray SAND with Gravel, trace Clay and Silt, wet (FILL)	N	-	NP	-	
800											
10	S-3 10.0'- 12.0'	16	4 4 6 5		FILL	Stiff, Brown to black Lean CLAY with Gravel and Sand, wet (FILL)	N	-	M	-	Gravel is Sandstone and Coal.
15	S-4 15.0'- 17.0'	16	3 3 4 3		FILL	Medium stiff, Black Lean CLAY with Gravel, moist (FILL)	S	M	M	M	
790											

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
8/8/16	6:10	-	30.0	110.0	50
8/9/16	6:10	-	30.0	180.0	30

Sample Type

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

Notes:

PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-I81-1**

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.

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'	8	10 20 18 9		FILL	Hard, Black Lean CLAY with Gravel, moist (FILL)	N	M	M	L	Gravel is Coal, Shale, and Sandstone.
25	S-6 25.0'-27.0'	8	5 7 13 5		FILL	Very stiff, Black Gravelly Lean CLAY, moist (FILL)	N	M	M	L	Gravel is Quartzite, Coal, and Shale.
780											
30 ▽	S-7 30.0'-32.0'	10	3 4 4 6		FILL	Stiff, Dark gray Gravelly Lean CLAY, moist (FILL)	N	M	L	L	
35	S-8 35.0'-37.0'	13	3 3 4 6		FILL	Medium stiff, Dark gray Gravelly Lean CLAY with Silt, moist (FILL)	N	M	M	M	
770											
40	S-9 40.0'-42.0'	10	2 2 1 2		FILL	Soft, Dark gray Gravelly Lean CLAY, moist (FILL)	N	M	M	-	
45	S-10 45.0'-47.0'	17	6 6 11 10		FILL	Very stiff, Dark gray Gravelly Lean CLAY, moist (FILL)	N	M	M	M	

NOTES: PP = Pocket Penetrometer
TV = Torvane

PROJECT NO.: 353754

BORING NO.: B-I81-1

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 M M

SOIL BORING LOG
(continued)

BORING NO.: **B-I81-1**
Page **3** of **3**

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
760											
50 ▽	S-11 50.0'-52.0'	11	6 7 8 12		FILL	Stiff, Dark gray Gravelly Lean CLAY, moist (FILL)	-	-	-	-	
						53.5					
55	S-12 55.0'-57.0'	20	5 9 12 12		CL	Very stiff, Dark gray Gravelly Lean CLAY, moist (CL)	N	M	M	M	Possible Fill.
750						58.5					
60	S-13 60.0'-62.0'	1	50/1"			Poor Recovery of Anthracite COAL fragments. [Base of strip mine debris?]	-	-	-	-	Possible base of Strip mine.
						62.0					
65	S-14 65.0'-65.1'	1	70/1"			Top of Rock at 65 feet BGS. See Rock Coring Log.	-	-	-	-	Small fragments of Shale recovered.
740											
70											

NOTES: PP = Pocket Penetrometer
TV = Torvane

PROJECT NO.: **353754**

BORING NO.: **B-I81-1**

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 M M

CORE BORING LOG

BORING NO.: **B-I81-1**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate - 81 Crossing, Wilkes - Barre, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	August 4, 2016 at 2:15 pm
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	August 8, 2016 at 3:02 pm

Elevation: 807 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Northwest corner of construction site. **Coord.: N:** 14991695.36 **E:** 1418643.024

Item	Casing	Core Barrel	Core Bit
Type	HW	NQ2	Imp. Diamond
Length (ft)	30	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Horizontal Datum: UTM Zone 18 T
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)						
	3.50	65.0							SHALE, Dark gray, fine to very fine grained, fresh, strong, wide spaced discontinuities								Good water return.
	4.00																
740	4.00		R-1	60 100%	60 100%	R4	FR										
	4.00																
	6.00	70.0								69.30	B	5	P,Sm	DS	T	N	
70									70.0								
	4.00	70.0							SLATE, Dark gray, very fine to fine grained, fresh, strong, very close to wide spaced discontinuities 70' - 70.5' Highly Fractured zone								Good water return.
	3.00									71.30	B	5	U,R	FR	VT	N	
										71.80	B	10	U,R	FR	VT	N	
	4.00		R-2	60 100%	49 82%	R4	FR		72.4' - 72.7' Highly Fractured zone								
	4.00								73.5								
									QUARTZITE, Gray, medium grained, fresh, strong, wide spaced discontinuities	73.50	J	10	U,R	FR	VT	N	Quartzite is MetaSandstone.
	4.00	75.0															
75		75.0							QUARTZITE, Gray, fine to medium grained, fresh, strong, close to moderately spaced discontinuities Fine to medium grained laminations 75.5' - 76.4' Highly Fractured zone								Good water return.
	9.00																
	9.00									76.80	B	15	U,R	FR	VT	N	
730	9.00		R-3	60 100%	48 80%	R4	FR			77.50	J	10	P,R	FR	VT	N	
	10.00																
	12.00	80.0															Breif loss of water at 79 feet BGS.
80		80.0							QUARTZITE, Gray, fine to medium grained, fresh, strong, close to moderately spaced discontinuities Fine to medium grained laminations								Good water return all the way to 150ft depth.
	5.00									80.80	J	15	U,R	FR	PO	N	
	4.00																
	4.00		R-4	60 100%	58 97%	R4	FR		QUARTZITE, Gray, fine to coarse grained, fresh, very strong, moderate to wide spaced discontinuities 82' - 82.1' Anthracite COAL, highly fractured zone Occasional fine Slate layer	82.00	B	15	P,Sm	FR	T	N	
	5.00									83.50	J	10	P,R	FR	T	N	
	5.00	85.0								84.40	J	20	U,Sm	FR	T	Coal	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
8/8/16	6:10	-	30.0	110.0	50.0
8/9/16	6:10	-	30.0	180.0	30.0

Notes:

Coal seam encountered. Strip mined.

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
	3.00	85.0							85.8								
	3.00								Anthracite COAL, Black, very fine grained, fresh, medium strong, close spaced discontinuities	85.80	B	0	U,Sm	FR	T	N	
720									86.3								
	3.00		R-5	60 100%	55 92%	R4	FR		86.5 QUARTZITE, Dark gray, fine to medium grained, fresh, strong to very strong, wide spaced discontinuities								
									86.7								
									86.5' - 86.7' Highly Fractured Coal								
	3.00									88.10	J	10	P,R	FR	VT	N	
	3.00									88.50	J	35	P,R	FR	VT	N	
	4.00	90.0							90.0								
90		90.0							SLATE, Gray, very fine to fine grained, fresh, very strong, wide spaced discontinuities								
	3.00									90.40	J	40	P,R	FR	T	N	
	3.00																
	3.00		R-6	60 100%	60 100%	R5	FR										
	4.00									93.10	B	10	P,R	FR	T	N	
	4.00	95.0															
95		95.0							SLATE, Gray, very fine to fine grained, fresh, medium strong, close spaced discontinuities Laminated horizontal fracturing								
	4.00																
	4.00																
710										97.00	J	5	U,R	FR	VT	N	
	4.00		R-7	60 100%	48 80%	R3	FR		98.0								
	4.00								QUARTZITE, Gray, fine grained, fresh, very strong, wide spaced discontinuities	98.00	B	10	U,R	FR	T	N	
	4.50	100.0															
100		100.0							QUARTZITE, Gray, very fine to fine grained, fresh, very strong, wide spaced discontinuities Occasional Shale interbedding								
	3.00																
	3.00									101.30	J	70	S,R	FR	T	N	
	3.50		R-8	60 100%	60 100%	R5	FR										
	3.50																
	3.50	105.0															
105		105.0							QUARTZITE, Gray, fine to medium grained, fresh, very strong, wide spaced discontinuities								
	2.50																
	2.50																
700																	
	2.50		R-9	60 100%	60 100%	R5	FR										
	3.00																
	3.50	110.0								109.10	J	10	U,R	FR	VT	N	

NOTES: Coal seam encountered. Strip mined.

PROJECT NO.: **353754**

Boring No.: **B-I81-1**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-I81-1**
Page **3** 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	110.0															
	3.00								QUARTZITE, Gray, medium grained, fresh, very strong, wide spaced discontinuities								
	3.00		R-10	60 100%	60 100%	R5	FR										
	3.00																
	3.00	115.0															
115	3.00	115.0							QUARTZITE, Gray, fine to coarse grained, fresh, extremely strong, wide spaced discontinuities								
	3.50																
690	4.00		R-11	60 100%	60 100%	R6	FR										
	4.00																
	4.00	120.0								118.90	J	5	U,R	FR	VT	N	
120	3.50	120.0							QUARTZITE, Gray, fine to coarse grained, fresh, extremely strong, wide spaced discontinuities								
	4.00																
	4.00		R-12	60 100%	60 100%	R6	FR			122.50	J	15	U,R	FR	T	N	
	4.00																
	5.00	125.0															
125	4.00	125.0							QUARTZITE, Gray, medium to coarse grained, fresh, very strong, moderately spaced discontinuities								
	4.00									126.10	J	0	U,R	FR	T	N	
680	4.00		R-13	60 100%	60 100%	R5	FR			127.40	J	15	U,R	FR	T	N	
	4.00									128.70	J	30	P,R	FR	T	N	
	5.00	130.0															
130	3.00	130.0							QUARTZITE, Gray, fine to coarse grained, fresh, very strong, wide spaced discontinuities								
	4.00									130.70	J	24	U,R	FR	T	N	
	4.50		R-14	60 100%	60 100%	R5	FR										
	4.50																
	4.50	135.0															

NOTES: Coal seam encountered. Strip mined.

PROJECT NO.: **353754**

Boring No.: **B-I81-1**

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
	6.00	135.0							QUARTZITE, Gray, fine to coarse grained, fresh, extremely strong, wide spaced discontinuities								
	6.00									135.90	J	40	U,R	FR	T	N	
670	6.00		R-15	60 100%	60 100%	R6	FR										
									137.7								
	6.50								CONGLOMERATE, Gray and white, coarse grained, fresh, extremely strong, wide spaced discontinuities Conglomerate is of coarse angular grains predominantly quartz.								
									139.0	138.60	J	30	U,R	FR	T	N	
	7.00	140.0							QUARTZITE, Gray, fine to coarse grained, fresh, extremely strong, wide spaced discontinuities								
140		140.0															
	6.00									140.40	J	60	U,R	FR	PO	N	
	6.00																
	6.00		R-16	60 100%	60 100%	R6	FR										
	6.00																
	6.00	145.0															
145		145.0							QUARTZITE, Gray, medium to coarse grained, fresh, very strong, wide spaced discontinuities								
	6.00																
	6.00																
660	6.00		R-17	60 100%	49 82%	R5	FR										
									148.0								
	5.50								SHALE, Black, very fine grained, fresh, strong, close to very close spaced discontinuities Coal beds with Pyrite layers encountered 148.5' - 150' Highly Fractured zone with Pyrite	148.10	J	5	U,R	FR	T	N	
	6.00	150.0															
150		150.0							150' - 152' Highly Fractured zone								Loss of water.
	4.00																
									151.0								
	4.00								Anthracite COAL, Black, very fine grained, fresh, weak, close spaced discontinuities. Brittle.								
	1.00		R-18	48 80%	33 55%	R2	FR			152.20 152.40	J J	10 20	P,R S,R	FR FR	T T	N N	
	1.00																
										153.80	J	10	U,R	FR	T	N	
	1.50									154.20 154.50	J J	10 40	S,R S,R	FR FR	T T	N N	
		155.0															
155		155.0							155.0								Loss of water.
	4.00								SHALE, Dark gray, fine grained, fresh, strong, moderately spaced discontinuities								
	4.00																
650									157.2								
	2.00		R-19	60 100%	50 83%	R4	FR		157.2' - 157.8' Anthracite COAL, very fine grained, fresh								
									157.8 Highly Fractured zone								
	4.00								158.2' - 158.4' Highly Fractured zone								
	4.00	160.0															

NOTES: Coal seam encountered. Strip mined.

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-I81-1**
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 Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.00	160.0							SHALE, Dark gray, fine grained, fresh, strong, close spaced discontinuities	160.50	J	0	P,Sm	FR	VT	N	
										160.90	J	0	P,Sm	FR	T	N	
	4.00									161.50	J	0	P,Sm	FR	T	N	
										161.90	J	0	P,Sm	FR	VT	N	
	3.00		R-20	60 100%	48 80%	R4	FR			162.30	J	0	P,Sm	FR	T	N	
									163.0								
	3.00								Anthracite COAL, Black, very fine grained, fresh, weak, close to moderately spaced discontinuities 163.4' - 165' Highly Fractured zone								
	3.00	165.0															
165	3.00	165.0							165' - 165.7' Highly Fractured zone								
	3.00																
									167.0								
640	3.00		R-21	60 100%	50 83%	R4	FR		SHALE, Dark gray, fine grained, fresh, strong, moderately spaced discontinuities	167.30	B	20	P,R	FR	VT	N	
										167.70	B	5	P,R	FR	VT	N	
	3.00									168.00	J	0	P,R	FR	T	N	
	3.00	170.0															
170		170.0							SHALE, Dark gray, fine grained, fresh, strong, moderately spaced discontinuities								
	4.00									170.70	J	10	P,R	FR	T	N	
										171.00	B	20	P,Sm	FR	T	N	
	4.00								171.5								
	3.00		R-22	60 100%	50 83%	R5	FR		QUARTZITE, Dark gray, fine to medium grained, fresh, very strong, wide spaced discontinuities	171.60	J	10	P,R	FR	T	N	
	3.00																
	4.00	175.0															
175	3.00	175.0							QUARTZITE, Dark gray, fine to medium grained, fresh, extremely strong, wide spaced discontinuities								
	2.00									176.40	J	15	P,R	FR	T	N	
630	2.00		R-23	60 100%	60 100%	R6	FR										
	2.00																
	2.00	180.0															
180									180.0								
									End of Boring at 180 feet BGS. Borehole grouted with cement and bentonite hole plug.								

NOTES: Coal seam encountered. Strip mined.

PROJECT NO.: **353754**

Boring No.: **B-I81-1**

Figure B-I81-1.1
B-I81-1 Box 1 Runs 1-4 Dry

Figure B-I81-1.2
B-I81-1 Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I81-1

Figure B-I81-1.3
B-I81-1 Box 2 Runs 5-8 Dry

Figure B-I81-1.4
B-I81-1 Box 2 Runs 5-8 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I81-1

Figure B-I81-1.5
B-I81-1 Box 3 Runs 9-12 Dry

Figure B-I81-1.6
B-I81-1 Box 3 Runs 9-12 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-I81-1

Figure B-I81-1.7
B-I81-1 Box 4 Runs 13-16 Dry

Figure B-I81-1.8
B-I81-1 Box 4 Runs 13-16 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-I81-1

Figure B-I81-1.9
B-I81-1 Box 5 Runs 17-20 Dry

Figure B-I81-1.10
B-I81-1 Box 5 Runs 17-20 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-I81-1

Figure B-I81-1.11
B-I81-1 Box 6 Runs 21-23 Dry

Figure B-I81-1.12
B-I81-1 Box 6 Runs 21-23 Dry

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-I81-1

MOTT MACDONALD M M

SOIL BORING LOG

BORING NO.: **B-I81-2**
Page **1** of **2**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate - 81 Crossing, Wilkes - Barre, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	August 17, 2016 at 11:10 am
Driller/Helper:	Nick Beehler /Miles Neipert	**Date/Time Finished:**	August 19, 2016 at 12:05 pm

Elevation: 862 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** South of I81, top of I81 cutting **Coord.:** **N:** 14990729.45 **E:** 1419417.27 **Horizontal Datum:** UTM Zone 18 T

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	**Hammer Type** ☐ Safety	**Drilling Fluid** ☐ Bentonite
☑ ATV	☐ Geoprobe	☑ Winch	☐ Doughnut	☐ Polymer
☐ Track	☐ Air Track	☑ Roller Bit	☑ Automatic	☑ Water
☐ Skid	☐ _____	☐ Cutting Head	☐ _____	☐ 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'	22	1 2 4 12		CL	0.2 Top (2") TOPSOIL Bottom (20") Medium stiff, Light brown, Sandy Lean CLAY with Gravel, moist. (CL)	N	L	M	-	Installed 4-inch casing to 5 feet BGS.
860											
5	S-2 5.0'- 7.0'	22	9 13 13 12		CL	Very stiff, Black, Gravelly Lean CLAY, moist. (CL)	N	H	-	-	Gravel consists of angular Coal, Sandstone, and Quartz.
10	S-3 10.0'- 12.0'	22	9 15 15 14		CL	Very stiff, Black, Gravelly Lean CLAY, moist. (CL)	N	M	L	M	Gravel consists of angular Coal, Sandstone, and Quartz.
850											
15	S-4 15.0'- 17.0'	20	10 9 12 39		CL	Very stiff, Black, Gravelly Lean CLAY, moist. (CL) 17' - 17.5' Cobble encountered	N	H	L	M	Gravel consists of angular Coal, Sandstone, and Quartz.

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** Grab Sample

Notes:

PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-I81-2**

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-I81-2**
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	Field Tests: Toughness	Field Tests: Plasticity	Field Tests: Dry Strength	Remarks
	S-5 20.0'-22.0'	18	6 11 15 12		CL	Very stiff, Black, Gravelly Lean CLAY, moist. (CL)	N	H	-	-	Installed 4-inch casing to 20 feet BGS. Gravel consists of coarse to fine Coal, Sandstone, and Quartz. Rock chips present in water return.
840						23.0					
	23.0'-25.0'					23' - 25' Weathered Rock Top of Rock at 23 feet BGS. See Rock Coring Log.	-	-	-	-	Advanced to 25 feet BGS to begin 5 foot runs.
25						25.0					
30											
830											
35											
40											
820											
45											

NOTES: PP = Pocket Penetrometer
TV = Torvane

PROJECT NO.: **353754**

BORING NO.: **B-I81-2**

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-I81-2**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate - 81 Crossing, Wilkes - Barre, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	August 17, 2016 at 11:10 am
Driller/Helper:	Nick Beehler /Miles Neipert	**Date/Time Finished:**	August 19, 2016 at 12:05 pm

Elevation: 862 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** South of I81, top of I81 cutting **Coord.: N:** 14990729.45 **E:** 1419417.27

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: UTM Zone 18 T **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								
	2.00	25.0							QUARTZITE, Light gray, fine to medium grained, fresh, very strong, wide spaced discontinuities (Quartzite is MetaSandstone)								Good water return 25 to 40ft depth
	2.00									26.00	J	0	S,R	FR	T	N	
	1.50		R-1	57 95%	57 95%	R5	FR										
	1.50									27.90	J	5	U,R	FR	T	N	
	1.50	30.0															
30										29.60	J	0	S,R	FR	T	N	
	1.00	30.0							QUARTZITE, Light gray, fine to medium grained, fresh, very strong, wide spaced discontinuities. Occasional thin shale bed.								Fractures occure at fine grained laminations of shale not within quartzite
	1.00																
830																	
	1.50		R-2	60 100%	60 100%	R5	FR			32.70	J	5	P,Sm	FR	VT	N	
	1.50									33.20	J	15	P,R	FR	T	N	
	1.50	35.0															
35																	
	1.50	35.0							QUARTZITE, Light gray, fine to coarse grained, fresh, very strong, close to wide spaced discontinuities 38.6' - 40' Highly Fractured zone								
	1.50																
	1.50		R-3	54 90%	43 72%	R5	FR			37.60	J	5	P,R	FR	T	N	
	1.50																
	1.50	40.0															
40																	
	1.00	40.0							QUARTZITE, Light gray, fine to coarse grained, fresh, very strong, moderate to close spaced discontinuities Occasional fine, dark gray layer 44' - 45' Highly Fractured zone								Some water return
	1.00																
820										41.60	J	10	U,R	DS	T	N	
	1.00		R-4	59 98%	51 85%	R5	FR			42.40	J	10	U,R	FR	T	N	
										42.90	J	5	S,R	FR	VT	N	
	1.00																
										43.50	B	10	P,Sm	FR	T	N	
	1.00	45.0															

Water Level Data

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

Notes:

Coal seam encountered

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	45.0							Interbedded QUARTZITE and SHALE, fine to coarse grained, slightly weathered, strong, close spaced discontinuities	45.50	B	35	P,Sm	DG	O	CL	
	1.50									46.30	J	25	P,R	FR	T	Fe	
	1.50		R-5	60 100%	50 83%	R4	SL			47.10	B	10	P,R	DG	O	CL	
	1.50									47.80	B	25	P,R	FR	T	QZ	
	1.50	50.0															
50	1.00	50.0							QUARTZITE, Gray, fine to medium grained, fresh, very strong, wide spaced discontinuities								
	1.00																
810	1.00		R-6	55 92%	48 80%	R5	FR										
	1.00																
	2.00	55.0								54.20	J	0	S,R	FR	T	N	
										54.60	J	5	S,R	FR	PO	N	
55	1.00	55.0							QUARTZITE, Gray, fine to medium grained, fresh, very strong, moderately spaced discontinuities								
	1.50									56.50	J	20	P,R	FR	T	N	
	1.50		R-7	58 97%	51 85%	R5	FR			57.40	J	0	P,R	FR	O	QZ	
										57.80	J	20	S,R	FR	T	QZ	
	1.50									58.20	J	15	S,R	FR	W	QZ	
										58.90	J	0	P,Sm	FR	T	N	
	1.50	60.0								59.50	J	20	P,Sm	FR	T	N	
60	1.50	60.0							QUARTZITE, Gray, fine to medium grained, fresh, very strong, moderately spaced discontinuities 63.7' - 63.9' Major joint encountered 64.5' - 65' Highly Fractured zone								Loss of water at 61 feet BGS. Rod dropped 3 inches at 64 feet BGS.
	1.50																
800	1.50		R-8	60 100%	48 80%	R5	FR		62.4 62.4' - 63' Video confirmed VOID - field logged as: 63.0 (63.7' - 63.9' Major joint encountered) (64.5' - 65' Highly Fractured zone)								
	1.00									63.70	J	0	P,R	DG	VW	QZ	
	1.00	65.0															
65	1.00	65.0							QUARTZITE, Gray and orange, medium to coarse grained, slightly weathered, medium strong, moderately spaced discontinuities 65' - 70' Highly Fractured zone with Quartz veins and Iron infilling								Intense Fracturing with Quartzite veins and Iron staining. Potential fault zone.
	1.00																
	1.50		R-9	60 100%	15 25%	R3	SL										
	1.50																
	2.00	70.0															

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
	1.20	70.0							QUARTZITE, Gray, medium to coarse grained, fresh, very strong, close to moderately spaced discontinuities	70.40	J	40	S,R	FR	T	N	Displacement of Quartz veins indicates multiple deformation phases.
	1.20									70.90	J	40	P,R	FR	T	N	
790	1.20		R-10	60 100%	59 98%	R5	FR										
	1.20									72.70	J	50	S,R	FR	T	QZ	
	1.20									74.00	J	45	S,R	FR	T	N	
	1.20	75.0								74.60	J	0	S,R	FR	PO	N	
75	2.00	75.0							QUARTZITE, Gray, medium to coarse grained, fresh, very strong, close to moderately spaced discontinuities								
	2.00								76.6								
	3.00		R-11	58 97%	23 38%	R2	SL		MUDSTONE, Dark gray, very fine grained, slightly weathered, weak, very close spaced discontinuities 76.6' - 80' Highly Fractured zone								
	3.00																
	3.00	80.0															
80	2.00	80.0							MUDSTONE, Dark gray, very fine grained, fresh, weak, wide spaced discontinuities Occasional high angle fracture with Clay.								
	2.00																
780	2.00		R-12	58 97%	55 92%	R2	FR			82.00	B	60	P,Sm	FR	T	N	
	2.00																
	2.00	85.0								84.10	B	40	P,Sm	FR	O	CL	
85	1.50	85.0							MUDSTONE/SHALE, Dark gray, very fine grained, fresh, weak, extremely close to close spaced discontinuities Thin Clay laminations present 85' - 86' Highly Fractured zone								
	1.50																
	1.50		R-13	52 87%	22 37%	R2	FR		87' - 89' Highly Fractured zone								
	1.50																
	1.50								89.0								
	1.50	90.0															
90	1.50	90.0							QUARTZITE, Gray, fine to coarse grained, fresh, very strong, wide spaced discontinuities								
	1.50																
770	1.50		R-14	60 100%	60 100%	R5	FR										
	1.50																
	1.50	95.0															

NOTES: Coal seam encountered

PROJECT NO.: **353754**

Boring No.: **B-I81-2**

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
	2.00	95.0							QUARTZITE, Gray, medium grained, fresh, very strong, close to wide spaced discontinuities 95' - 96.2' Highly Fractured zone								
	2.00																
	2.00		R-15	60 100%	60 100%	R5	FR										
	2.00																
	2.00	100.0															
100	1.50	100.0							QUARTZITE, Gray, medium grained, fresh, very strong, close to wide spaced discontinuities								
	1.50																
760	1.50		R-16	60 100%	57 95%	R5	FR										
	1.50									104.10	J	0	U,R	FR	PO	N	
	1.50	105.0								104.30	J	60	P,R	FR	PO	N	
105	1.50	105.0							QUARTZITE, Gray, medium grained, fresh, extremely strong, moderate to wide spaced discontinuities								
	1.50									105.80	B	5	S,R	FR	VT	N	
	1.50									106.40	B	45	P,R	FR	T	N	
	1.50		R-17	60 100%	60 100%	R6	FR										
	1.50																
	1.50	110.0															
110	1.50	110.0							QUARTZITE, Gray, medium grained, fresh, extremely strong, wide spaced discontinuities								
	1.50																
750	1.00		R-18	60 100%	60 100%	R6	FR										
	1.00									113.10	B	20	S,R	FR	VT	N	
	1.00	115.0															
115	2.00	115.0							QUARTZITE, Gray, medium to coarse grained, fresh, extremely strong, wide spaced discontinuities	115.30	J	20	S,R	FR	T	Fe	
	2.00																
	2.00		R-19	60 100%	60 100%	R6	FR										
	2.00																
	2.00	120.0															

NOTES: Coal seam encountered

PROJECT NO.: **353754**

Boring No.: **B-I81-2**

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
	1.20	120.0							QUARTZITE, Gray, fine to medium grained, fresh, extremely strong, wide spaced discontinuities								
										120.70	J	5	U,R	DG	PO	N	
	1.20																
										121.60	J	30	P,R	FR	T	N	
740	1.20		R-20	60 100%	60 100%	R6	FR										
	1.20																
	1.00	125.0															
125		125.0							QUARTZITE, Gray, medium grained, fresh, very strong, very close to moderately spaced discontinuities								
	2.00								127.2' - 127.7' Highly Fractured zone	125.50	J	0	S,R	FR	T	N	
										126.00	J	75	U,R	FR	PO	CL	
	2.00																
	2.00		R-21	57 95%	39 65%	R5	FR										
	2.00																
	2.00	130.0								129.30	J	0	P,R	FR	PO	N	
130		130.0							QUARTZITE, Gray, medium grained, fresh, very strong, very close to moderately spaced discontinuities								
	2.00								134.3' - 135' Highly Fractured zone								
	2.00									131.30	J	10	S,R	FR	VT	N	
730										131.60	B	15	U,R	FR	PO	N	
	2.00		R-22	60 100%	47 78%	R5	FR										
	2.00									133.40	J	10	S,R	FR	T	N	
	2.00	135.0															
135		135.0							QUARTZITE, Gray, medium grained, fresh, very strong, very close to moderately spaced discontinuities								
	2.00									135.90	J	20	P,Sm	DS	VT	Fe	
	2.00																
	2.00		R-23	54 90%	47 78%	R5	FR		137.9								
									138.2137.9' - 138.2' Video confirmed VOID [V-23.1]								
	0.50								138.6								
									138.9138.6' -138.9' Video confirmed VOID [V-23.2]	138.50	J	20	S,R	FR	T	N	
	0.50								139.7								
		140.0							140.0139.7' -140' Video confirmed VOID [V-23.3]								Rod dropped 4 inches at 139 feet BGS.
140	1.50	140.0							SHALE/COAL, Black, very fine grained, fresh, medium strong, close spaced discontinuities								
									139' - 141.4' Highly Fractured zone								
									141.0								
	1.50								COAL, Black, fine grained, fresh, weak								
720										142.10	J	0	S,R	FR	VT	N	
	1.50		R-24	52 87%	41 68%	R2	FR		143.0	142.60	J	0	S,R	FR	VT	N	
									143.4143' - 143.4' Video confirmed VOID [V-24]								Rod dropped 5 inches at 143 feet BGS.
	1.50								SHALE, Black, very fine grained, fresh, medium strong, close spaced discontinuities								
									144' - 145' Highly Fractured zone								
	1.00	145.0															

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
	1.50	145.0							SHALE, Dark gray, fine grained, medium strong, fresh, moderately spaced discontinuities	145.50	J	0	S,R	FR	VT	N	
	1.50								146.6								
									146.6' - 147.1' Video confirmed VOID [V-25]								
	1.50		R-25	55 92%	41 68%	R3	FR		147.1 COAL 148' - 150' Highly Fractured zone with Iron staining	147.20	J	10	S,R	FR	VT	N	
	1.00																
	1.00	150.0							150.0								
150	0.50	150.0							SLATE, Gray, fine grained, slightly weathered, medium strong, close to moderately spaced discontinuities 150' - 155' Highly Fractured zone with some decomposed joints and Iron staining								
	0.50																
710	0.50		R-26	56 93%	21 35%	R3	SL										
	1.00																
	0.50	155.0															
155	1.00	155.0							155.3 SLATE, Gray, fine grained, fresh, strong, close spaced discontinuities								
									155.7 155' - 157' Highly Fractured zone								
	1.00								155.3' - 155.7' Video confirmed VOID [27.1]								
	1.00								157.0								
	0.00		R-27	25 42%	17 28%				157' - 160' Video confirmed VOID [V-27.2]								Rod dropped 3 feet at 157 feet BGS.
	0.00																
	0.00	160.0							160.0								
160	3.00	160.0							GRAVEL Debris with Iron staining 160' - 161.2' Highly Fractured zone								
									161.0								
	2.00								SHALE Sands, Gray, fine grained, fresh, strong, wide spaced discontinuities fine grained laminations								
700	2.00		R-28	52 87%	43 72%	R4	FR										
	2.00																
	2.00	165.0							165.0								
165	1.50	165.0							QUARTZITE, Gray, fine to medium grained, fresh, very strong, wide spaced discontinuities	164.80	B	0	P,Sm	DE	PO	N	
	1.50																
	1.50		R-29	60 100%	60 100%	R5	FR										
	2.00									168.60	J	0	S,R	FR	T	N	
	2.00	170.0															

NOTES: Coal seam encountered

PROJECT NO.: **353754**

Boring No.: **B-I81-2**

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	170.0							QUARTZITE, Gray, fine to medium grained, fresh, very strong, wide spaced discontinuities								
	1.50																
690	1.50		R-30	60 100%	56 93%	R5	FR			172.80	J	20	P,R	FR	PO	N	
	1.50																
	1.50	175.0															
175	1.50	175.0							QUARTZITE, Gray, fine to medium grained, fresh, very strong, wide spaced discontinuities								
									176.0								
	1.00								SHALE/COAL 176' - 177.5' Highly Fractured zone with Clay infilling								
	1.00		R-31	50 83%	39 65%	R5	FR		177.5								
	1.00								CONGLOMERATE, White and gray, coarse grained, fresh, very strong, close spaced discontinuities								
	1.00									178.40	J	0	S,R	FR	VT	N	
	1.00	180.0								179.60	J	0	S,R	FR	T	N	
180		180.0							CONGLOMERATE, White and gray, coarse grained, fresh, very strong, close to moderately spaced discontinuities 180' - 180.6' Highly Fractured zone								Conglomerate contains clasts of angular Quartz.
	1.50																
	1.50									181.30	B	20	S,R	DG	PO	N	
680										182.00	J	10	S,R	FR	T	N	
	1.50		R-32	60 100%	41 68%	R5	FR			182.70	B	5	U,R	FR	T	N	
									183.0								
	1.50								QUARTZITE, Gray, fine to medium grained, fresh, very strong, wide spaced discontinuities								
	1.50	185.0															
185		185.0							QUARTZITE, Dark gray, fine to medium grained, fresh, very strong, wide spaced discontinuities Mica laminations present								
	1.50									185.80	J	50	P,Sm	FR	T	N	
	1.50																
	1.00		R-33	60 100%	59 98%	R5	FR										
	1.00																
	1.00	190.0															
190		190.0							QUARTZITE, Gray, medium to coarse grained, fresh, extremely strong, wide spaced discontinuities								
	1.50																
	1.50																
670																	
	1.50		R-34	60 100%	60 100%	R6	FR										
	1.50																
	1.50	195.0															

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	195.0							QUARTZITE, Gray, fine to coarse grained, fresh, extremely strong, wide spaced discontinuities 198' - 198.5' COAL								
	1.50																
	1.00		R-35	57 95%	57 95%	R6	FR			197.00	J	0	U,R	DG	VW	-	
	1.50																
	1.50	200.0															
200	1.00	200.0							QUARTZITE, Gray, fine to medium grained, fresh, extremely strong, wide spaced discontinuities Mica laminations present	200.30	J	50	S,R	DS	PO	Fe	
	1.50																
660	1.50		R-36	60 100%	60 100%	R6	FR										
	1.50																
	1.00	205.0															
205	1.00	205.0							QUARTZITE, Gray, fine to medium grained, fresh, extremely strong, wide spaced discontinuities 209.5' - 210' Highly Fractured zone								
	1.00																
	1.00		R-37	58 97%	54 90%	R6	FR			207.90	J	10	P,R	FR	VT	N	
	1.00									208.10	J	30	P,R	FR	VT	N	
	1.00									208.70	J	10	P,R	FR	T	N	
	1.00	210.0															
210	2.00	210.0							QUARTZITE, Light gray, medium grained, fresh, extremely strong, moderate to wide spaced discontinuities								
	2.00																
650	2.00		R-38	60 100%	60 100%	R6	FR										
	2.00									213.30	J	15	P,R	FR	VT	N	
	1.50	215.0															
215	2.00	215.0							QUARTZITE, Light gray, fine to coarse grained, fresh, very strong, close to moderate spaced discontinuities Occasional fine COAL laminations with Quartz veins 219' - 220' Highly Fractured zone	215.80	J	10	P,R	FR	VT	QZ	
	2.00									216.20	J	20	S,R	FR	VT	N	
	2.00		R-39	59 98%	45 75%	R5	FR			217.30	J	0	U,R	FR	O	N	
	2.00									218.30	J	20	U,R	FR	VT	N	
	2.00	220.0															

NOTES: Coal seam encountered

PROJECT NO.: **353754**

Boring No.: **B-I81-2**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-I81-2**
Page **9** of **9**

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	220.0							QUARTZITE, Gray, medium grained, fresh, extremely strong, close spaced discontinuities								
	1.50									220.80	J	20	P,R	FR	VT	N	
										220.90	J	20	P,R	DG	PO	N	
640	1.50		R-40	60 100%	58 97%	R6	FR										
	2.00									223.00	J	30	U,R	FR	VT	N	
	2.00	225.0							225.0								
225									End of Boring at 225 feet BGS. Borehole grouted with cement and bentonite hole plug.								
230																	
630																	
235																	
240																	
620																	

NOTES: Coal seam encountered

PROJECT NO.: **353754**

Boring No.: **B-I81-2**

Figure B-I81-2.1
B-I81-2 Box 1 Runs 1-4 Dry

Figure B-I81-2.2
B-I81-2 Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I81-2

Figure B-I81-2.3
B-I81-2 Box 2 Runs 5-8 Dry

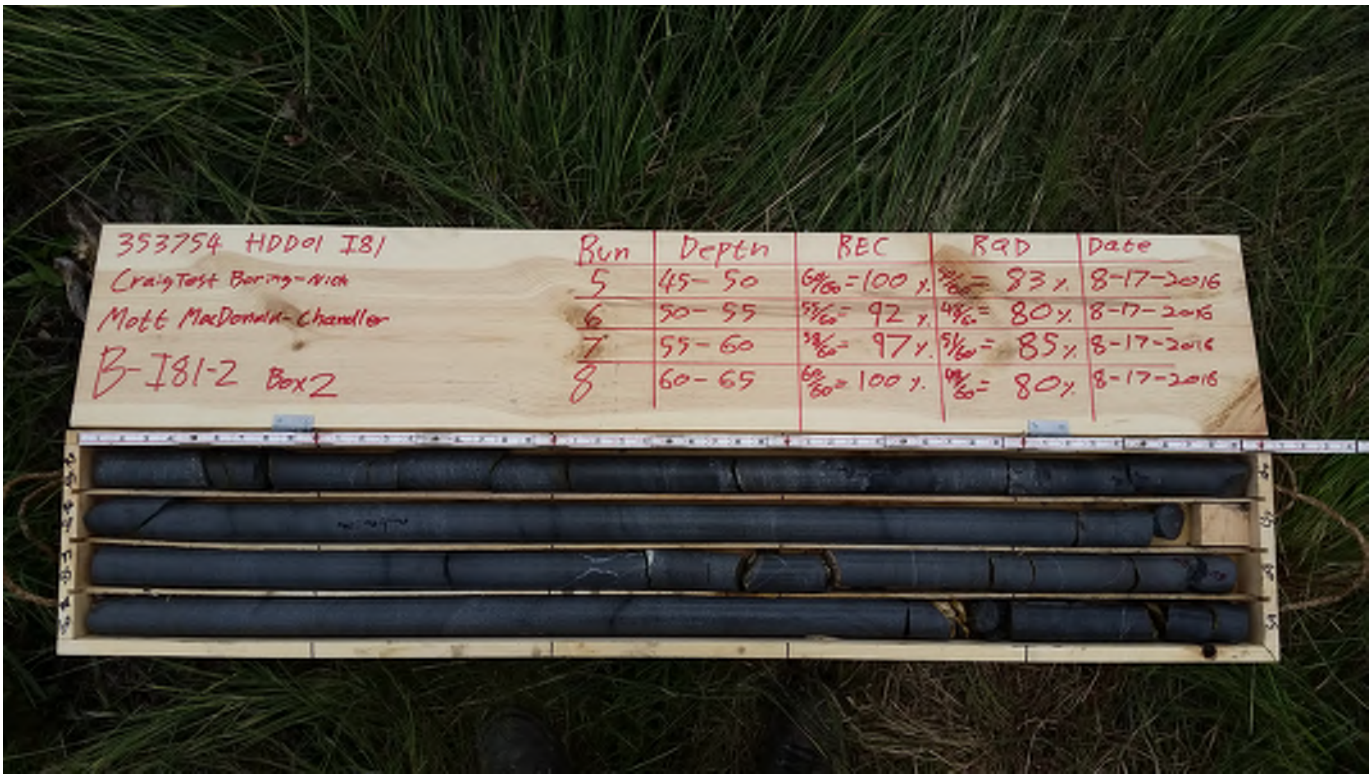


Figure B-I81-2.4
B-I81-2 Box 2 Runs 5-8 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I81-2

Figure B-I81-2.5
B-I81-2 Box 3 Runs 9-12 Dry

Figure B-I81-2.6
B-I81-2 Box 3 Runs 9-12 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-I81-2

Figure B-I81-2.7
B-I81-2 Box 4 Runs 13-16 Dry

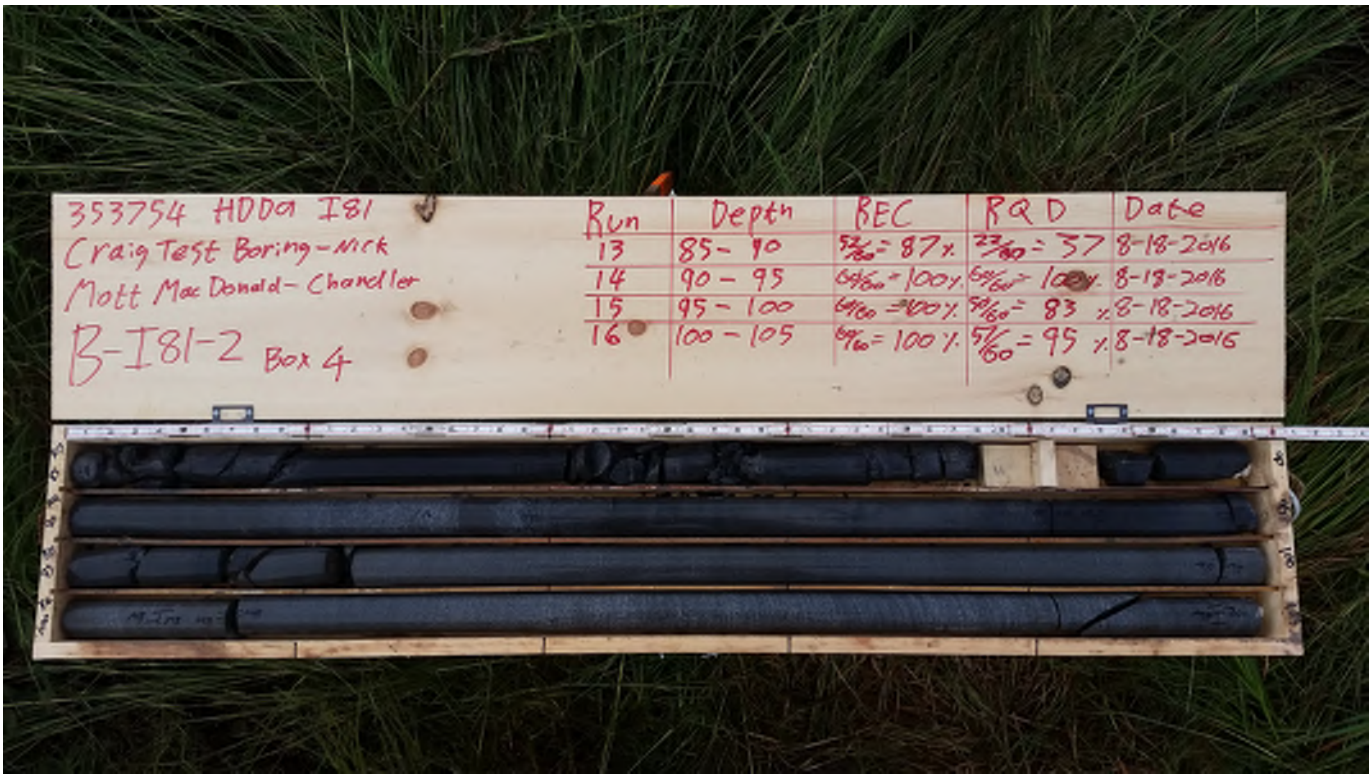


Figure B-I81-2.8
B-I81-2 Box 4 Runs 13-16 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I81-2

Figure B-I81-2.9
B-I81-2 Box 5 Runs 17-20 Dry

Figure B-I81-2.10
B-I81-2 Box 5 Runs 17-20 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I81-2

Figure B-I81-2.11
B-I81-2 Box 6 Runs 21-24 Dry

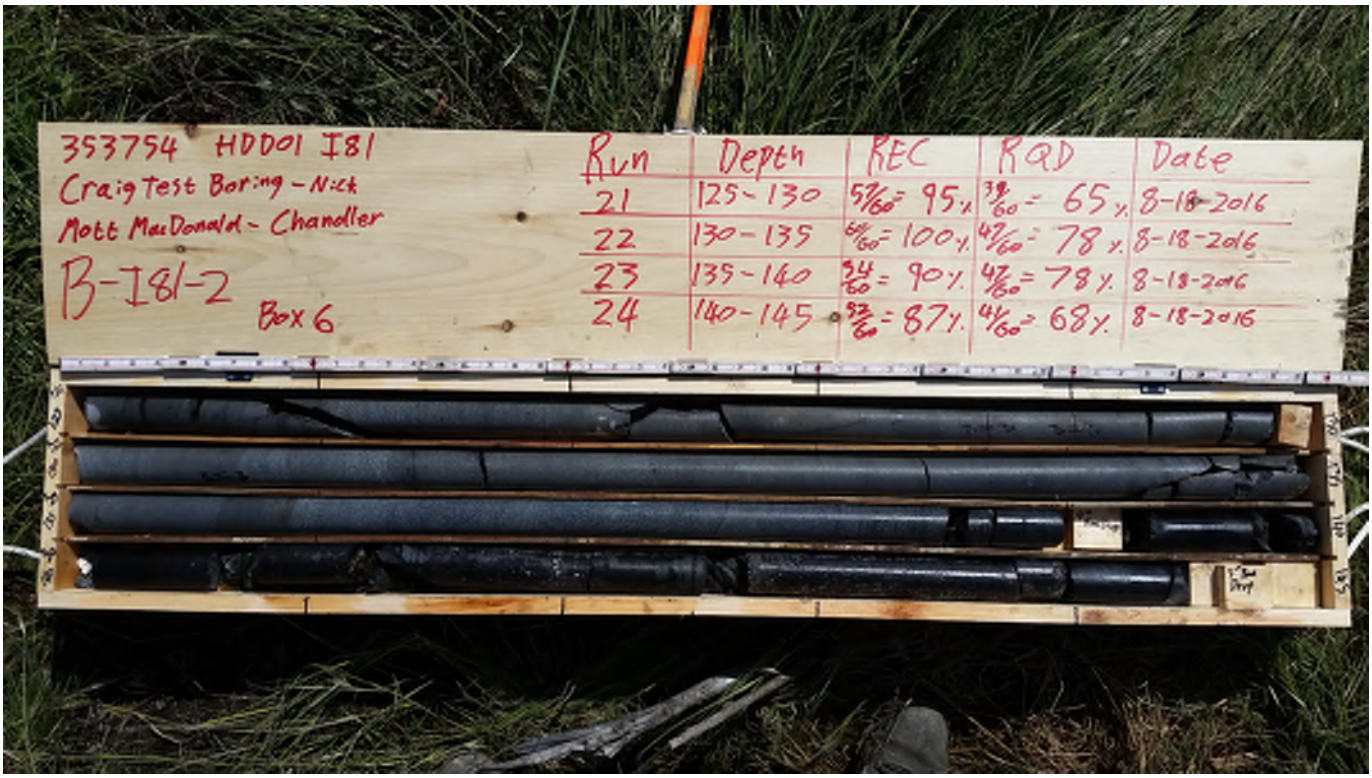


Figure B-I81-2.12
B-I81-2 Box 6 Runs 21-24 Wet

Figure B-I81-2.13
B-I81-2 Box 7 Runs 25-28 Dry

Figure B-I81-2.14
B-I81-2 Box 7 Runs 25-28 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I81-2

Figure B-I81-2.15
B-I81-2 Box 8 Runs 29-32 Dry

Figure B-I81-2.16
B-I81-2 Box 8 Runs 29-32 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I81-2

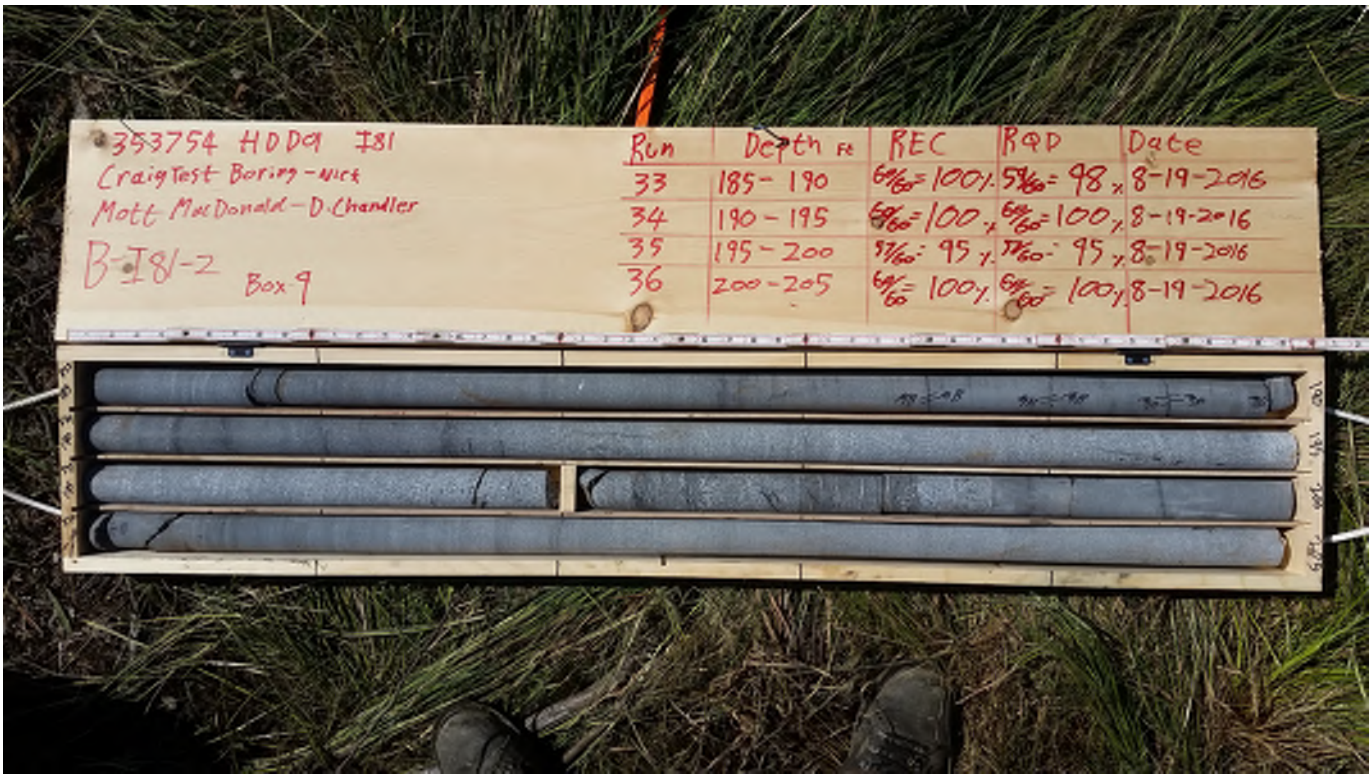


Figure B-I81-2.17
B-I81-2 Box 9 Runs 33-36 Dry

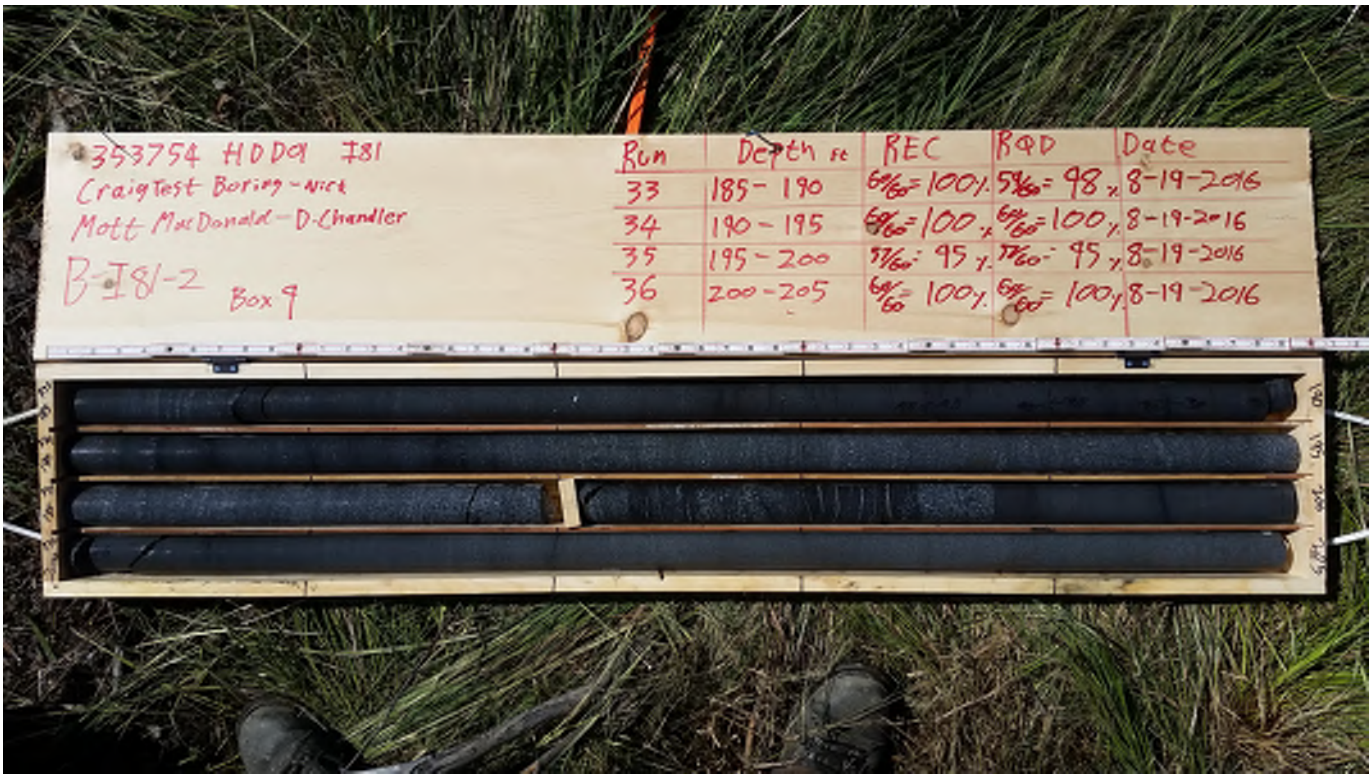


Figure B-I81-2.18
B-I81-2 Box 9 Runs 33-36 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I81-2

Figure B-I81-2.19
B-I81-2 Box 10 Runs 37-40 Dry

Figure B-I81-2.20
B-I81-2 Box 10 Runs 37-40 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I81-2

MOTT MACDONALD M M

SOIL BORING LOG

BORING NO.: **B-I81-3**
Page **1** of **2**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate - 81 Crossing, Wilkes - Barre, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	April 17, 2017 at 8:55 pm
Driller/Helper:	Paul Mullins /Dalton Lentes	**Date/Time Finished:**	April 19, 2017 at 11:00 pm

Elevation: 827 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Median of Interstate 81 in Wilkes-Barre, PA **Coord.:** **N:** 14990960.58 **E:** 1419357.591 **Horizontal Datum:** UTM Zone 18 T

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	10	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	5 6 5 5		FILL	Medium dense, Black and gray Clayey SAND with Gravel and Cobbles, dry (FILL)	N	H	NP	-	
5	S-2 5.0'- 7.0'	7	16 16 17 15		FILL	Dense, Gray Clayey medium to coarse GRAVEL, dry (FILL)	N	-	NP	-	Gravel is Sandstone, Siltstone and Coal fragments.
820											
10	S-3 10.0'- 12.0'	19	12 20 26 25		FILL	Dense, Gray Gravelly SILT with Clay and occasional Cobble, dry (FILL)	-	-	NP	-	Gravel is Coal and Sandstone fragments.
						12.5					
15	S-4 15.0'- 17.0'	18	14 12 14 12		CL	Very Stiff, Dark gray Gravelly CLAY, moist (CL)	-	-	NP	-	Glacial Till.
810						17.2					
						Boulder of Sandstone					
						17.9					
	17.9'-'				CL	Gravelly CLAY (CL)	-	-	-	-	Glacial Till.
	18.5'-'					18.5					
						Top of weathered rock at 18.5 feet BGS	-	-	-	-	Weathered rock is Shale.

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
4/18/17	20:00	0:00	10.0	75.0	Dry
4/19/17	19:45	0:00	10.0	175.0	Dry

Sample Type

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

Notes:

PP = Pocket Penetrometer
TV = Torvane
Night work

Boring No.: **B-I81-3**

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-I81-3**
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	Field Tests: Toughness	Field Tests: Plasticity	Field Tests: Dry Strength	Remarks
	S-5 20.0'- 22.0'	0.5	50/0.5"		GP	Very dense, dark gray WEATHERED ROCK fragments, dry	-	-	-	-	Weathered rock is Shale. Smooth slow roller bit drilling cuttings recovered as dark gray Gravel.
25						25.0					
	S-6 25.0'- 27.0'	0	50/0.0"			Top of Rock at 25 feet BGS. See Rock Coring Log.	-	-	-	-	
800											
30											
35											
790											
40											
45											

NOTES: PP = Pocket Penetrometer
TV = Torvane
Night work

PROJECT NO.: **353754**

BORING NO.: **B-I81-3**

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-I81-3**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate - 81 Crossing, Wilkes - Barre, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	April 17, 2017 at 8:55 pm
Driller/Helper:	Paul Mullins /Dalton Lentes	**Date/Time Finished:**	April 19, 2017 at 11:00 pm

Elevation: 827 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Median of Interstate 81 in Wilkes-Barre, PA **Coord.: N:** 14990960.58 **E:** 1419357.591

Item	Casing	Core Barrel	Core Bit
Type	HW	NQ2	Imp. Diamond
Length (ft)	10	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Horizontal Datum: UTM Zone 18 T **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								
	2.40	25.0							SANDSTONE, Gray, fine to medium grained, fresh, strong, wide spaced discontinuities	25.80	B	10	P,R	FR	VT	N	Good water return from 25 to 59 feet BGS.
	2.60																
800	2.70		R-1	53 88%	47 78%	R4	FR			27.50	MB	15	S,R	FR	T	N	
	3.60																
	3.60	30.0								29.80	B	5	P,R	FR	T	N	
30	3.00	30.0							SANDSTONE, Gray, fine grained, fresh, very strong, wide spaced discontinuities								
	3.10																
	3.00		R-2	60 100%	60 100%	R5	FR			32.80	B	10	P,R	FR	T	N	
	3.10									33.50	B	15	S,R	FR	VT	N	
	3.20	35.0															
35	3.00	35.0							35.0 SILTSTONE, Dark gray, very fine grained, fresh, medium strong, very close spaced discontinuities								
	3.00								35.8 35' - 36' Highly Fractured zone SANDSTONE, Gray, fine to medium grained, fresh, very strong, close to moderately spaced discontinuities Occasional Siltstone inclusion	36.50	B	20	P,R	FR	PO	N	
790	2.90		R-3	60 100%	45 75%	R5	FR			37.00	B	15	P,R	FR	VT	N	
										37.30	B	5	P,R	FR	VT	N	
										37.60	B	0	P,R	FR	VT	N	
	3.00									38.00	B	5	P,R	FR	VT	N	
	2.90	40.0								39.60	J	15	U,R	FR	T	Fe	
40	3.00	40.0							40.9	40.40	MB	15	P,R	FR	PO	Fe	
	2.00								COAL, Black anthracite Coal, medium strong, fresh	41.20	B	15	P,Sm	FR	T	N	
									42.4	41.90	B	5	P,Sm	FR	O	N	
	2.00		R-4	56 93%	54 90%	R4	FR		SILTSTONE, Gray, very fine grained, strong, wide spaced discontinuities	42.40	B	10	P,R	FR	O	Fe	
	3.00									43.00	J	10	S,R	DE	T	Fe	
	3.00	45.0							45.0	44.30	J	15	S,R	DE	PO	N	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
4/18/17	20:00	0:00	10.0	75.0	
4/19/17	19:45	0:00	10.0	175.0	

Notes:

Coal seam encountered

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
	2.80	45.0							SANDSTONE, Gray, fine grained, fresh, strong, wide spaced discontinuities	45.70	MB	5	S,R	FR	VT	N	
	2.80									46.70	B	0	S,R	FR	VT	N	
780	2.80		R-5	59 98%	58 97%	R4	FR			47.50	J	15	P,R	FR	VT	N	
	2.80																
	2.80	50.0															
50	2.50	50.0							SANDSTONE, Gray, fine grained, fresh, strong, moderately spaced discontinuities	50.20	B	0	P,R	DE	T	N	
										50.70	J	15	P,R	DE	PO	N	
	2.70																
	2.80		R-6	60 100%	47 78%	R4	FR			52.10	B	0	P,R	FR	T	N	
										53.00	B	15	P,R	FR	T	N	
	2.70									53.50	B	0	P,R	FR	T	N	
	2.80	55.0															
55	2.60	55.0							SANDSTONE, Gray, fine grained, fresh, strong, moderately spaced discontinuities								Loss of water from 59 to 175 feet BGS.
	2.60									56.50	B	15	P,R	FR	VT	N	
770	2.60		R-7	60 100%	51 85%	R4	FR										
	2.60																
	2.60	60.0								59.00	B	10	P,R	FR	PO	N	
60	2.20	60.0							60.0 QUARTZITE, Light gray, medium grained, fresh, extremely strong, wide spaced discontinuities								5 foot solid run.
	2.30																
	2.30		R-8	60 100%	60 100%	R6	FR										
	2.40																
	2.40	65.0															
65	1.90	65.0							QUARTZITE, Light gray, medium grained, fresh, extremely strong, wide spaced discontinuities								
	2.00																
760	2.00		R-9	60 100%	52 87%	R6	FR										
	2.00									68.50	J	40	S,R	FR	PO	N	
	1.90	70.0								68.80	B	10	P,R	FR	PO	N	

NOTES: Coal seam encountered

PROJECT NO.: **353754**

Boring No.: **B-I81-3**

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
	2.10	70.0															
	2.10								QUARTZITE, Light gray, medium grained, fresh, extremely strong, wide spaced discontinuities								
	2.10		R-10	60 100%	58 97%	R6	FR										
	2.20																
	2.10	75.0								74.20	J	50	P,R	FR	PO	N	
75	1.80	75.0							QUARTZITE, Light gray, medium grained, fresh, extremely strong, wide spaced discontinuities								
	1.90									76.30	J	20	P,R	FR	T	N	
750										76.80	J	25	P,R	FR	T	N	
	1.90		R-11	60 100%	58 97%	R6	FR										
	2.00									78.40	J	25	P,R	FR	T	N	
	2.00	80.0								79.50	J	0	P,R	FR	T	N	
80	1.80	80.0							QUARTZITE, Light gray, medium grained, fresh, extremely strong, wide spaced discontinuities								
	1.90																
	1.90		R-12	58 97%	49 82%	R6	FR										
	1.80									83.40	J	15	P,R	FR	PO	N	
	1.90	85.0															
85	1.90	85.0							QUARTZITE, Light gray, medium grained, light gray, fresh, extremely strong, wide spaced discontinuities								
	1.90									86.30	J	5	P,R	FR	VT	N	
740																	
	1.90		R-13	60 100%	56 93%	R6	FR										
	2.00									88.20	B	60	P,R	FR	PO	N	
	2.20								89.5								
		90.0							90.0 SANDSTONE, Dark gray, fine grained, fresh, very strong, close spaced discontinuities 89.6' - 90' Highly Fractured zone								
90	1.50	90.0							90.7 90' - 90.7' VOID	90.40	J	0	P,R	FR	T	N	
	1.50								SANDSTONE, Dark gray, fine grained, fresh, strong, moderately spaced discontinuities Minor Shale interbedding	91.30	B	30	S,R	FR	T	N	
										91.70	J	20	S,R	FR	PO	N	
	1.40		R-14	60 100%	50 83%	R4	FR			92.10	J	25	S,R	FR	PO	N	
	1.60									92.80	B	30	S,R	FR	T	N	
	1.50	95.0															

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
	1.50	95.0							SANDSTONE, Dark gray, fine grained, fresh, strong, moderately spaced discontinuities Minor shale interbedding								
	1.50									96.60	B	20	P,R	FR	T	N	
730										96.90	B	10	P,R	DE	PO	SL	
	1.50		R-15	60 100%	55 92%	R4	FR										
	1.50									98.00	J	10	P,R	DE	T	Fe	
	1.50	100.0								99.30	J	15	S,R	FR	T	Py	
100	1.40	100.0							SANDSTONE, Dark gray, fine grained, fresh, very strong, moderately spaced discontinuities Iron staining on some joints								
	1.40									101.30	B	1	P,R	DE	W	Fe	
	1.50		R-16	60 100%	57 95%	R5	FR			102.20	J	15	P,R	FR	W	N	
	1.40									102.80	J	40	P,R	DS	PO	Fe	
	1.40	105.0								104.00	J	25	P,R	DS	O	Fe	
105	1.40	105.0							SANDSTONE, Light gray, medium grained, fresh, very strong, moderately spaced discontinuities Occasional fine Shale and Coal interbedding								
	1.50									105.60	J	50	S,R	FR	T	N	
720										105.90	B	45	S,R	FR	T	N	
	1.60		R-17	60 100%	53 88%	R5	FR										
	1.70									108.00	J	5	P,R	FR	T	Fe	
	1.70	110.0								108.60	J	10	S,R	DS	T	Ca	
										109.50	J	15	P,R	FR	T	N	
110	1.50	110.0							SANDSTONE, Light gray, medium grained, fresh, extremely strong, moderately spaced discontinuities Occasional fine Shale and Coal interbedding								
	1.50								111.2 111.4 111.2' - 111.4' VOID	111.00	J	20	P,R	FR	T	N	
	1.60		R-18	60 100%	53 88%	R6	FR			112.50	J	10	P,R	FR	T	N	
	1.60									112.80	J	10	P,R	FR	T	N	
	1.50	115.0								113.70	B	10	P,R	DS	PO	Fe	
115	1.50	115.0							SANDSTONE, Gray, fine grained, fresh, very strong, moderately spaced discontinuities	115.00	J	20	P,R	DS	O	N	
	1.60									116.30	J	15	P,R	DS	PO	Fe	
710										117.00	J	10	P,R	FR	T	N	
	1.20		R-19	51 85%	34 57%	R5	FR		117.4 Black Anthracite COAL								
	1.20								118' - 120' Highly Fractured zone								
	1.30	120.0							119.5 119.6 119.5' - 119.6' VOID 120.0								

NOTES: Coal seam encountered

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 Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	1.30	120.0							MUDSTONE, Dark gray, very fine grained, fresh, strong, close spaced discontinuities								
	1.40								122.0								
	1.20		R-20	56 93%	36 60%	R4	FR		Black Anthracite COAL								Yellow staining on Coal.
	1.10								122.8 SLATE, Black, very fine grained, fresh, strong								
	1.20	125.0							123.4 123.4' - 124.2' VOID 124.2 SLATE, Black, very fine grained, fresh, strong 124.8								
125	1.30	125.0							124.8' - 126.1' 1-Foot VOID 125' - 130' Highly Fractured zone								
	1.10								126.1 MUDSTONE, Dark gray, very fine grained, fresh, medium strong Poor recovery, unrecovered material possibly CLAY								
700	1.10		R-21	35 58%	9 15%	R3	FR		127.8 128.0 127.8' - 128' VOID								
	1.20								128.5 128.5' - 129' VOID								
	1.20	130.0							129.0 129.8								
130	1.20	130.0							129.8' - 130.7' VOID 130.7								
	1.10								MUDSTONE, Dark gray, very fine grained, fresh, medium strong 130.7' - 135' Highly Fractured zone								
	1.10		R-22	38 63%	13 22%	R3	FR		Poor recovery, unrecovered material possibly CLAY Some Iron staining								
	1.10								134.0 SANDSTONE, Gray, fine grained, fresh, strong.								
	1.20	135.0							135.0								
135	1.60	135.0							MUDSTONE, Gray, very fine grained, fresh, medium strong, moderately spaced discontinuities Iron staining on fractures.	135.50 135.70	J J	0 0	P,R S,R	FR FR	VT VT	N N	
	1.60																
690	1.60		R-23	60 100%	55 92%	R3	FR			137.20 137.90	J J	40 15	P,R P,R	FR DE	T PO	N Fe	
	1.60								139.0								
	1.70	140.0							SANDSTONE, Gray, fine grained, fresh, strong								5 foot solid run.
140	1.80	140.0							SANDSTONE, Dark gray, fine grained, fresh, very strong, wide spaced discontinuities Some Shale interbedding								
	1.80																
	1.80		R-24	60 100%	60 100%	R5	FR										
	1.80																
	1.80	145.0															

NOTES: Coal seam encountered

PROJECT NO.: **353754**

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
	1.90	145.0							SANDSTONE, Dark gray, fine grained, fresh, strong, moderately spaced discontinuities	145.70	B	0	U,R	FR	T	N	
										146.00	J	80	P,R	FR	PO	N	
	1.90																
680										146.80	J	45	U,R	FR	T	N	
	2.00		R-25	60 100%	25 42%	R4	FR		147.5								
									CONGLOMARATE, White and gray, coarse grained, fresh, extremely strong	147.60	J	40	S,R	FR	T	N	
										147.90	J	40	S,R	FR	T	N	
	1.90								148.6								
									Black Anthracite COAL, weak, with pyrite seams 148.6' - 150' Highly Fractured zone								
	1.80	150.0							150.0								
150		150.0							CONGLOMERATE, Gray and white, coarse grained, fresh, very strong, moderately spaced discontinuities	150.20	J	0	P,R	FR	VT	N	
	2.00																
										150.80	J	20	U,R	FR	T	N	
	2.10																
										151.70	B	15	P,R	DE	T	N	
	2.20		R-26	60 100%	50 83%	R5	FR										
										153.00	J	15	S,R	FR	VT	N	
	2.20																
										154.00	B	15	S,R	FR	VT	N	
	2.20	155.0								154.30	B	10	P,R	FR	VT	N	
155									155.0	154.70	J	15	U,R	FR	VT	QZ	
	2.10	155.0							SANDSTONE, Gray, coarse grained, fresh, very strong, wide spaced discontinuities Occasional Quartz veins								
										155.90	J	15	S,R	FR	VT	N	
	2.10																
670																	
	2.00		R-27	60 100%	60 100%	R5	FR										
	1.70																
	1.90	160.0							160.0								
160		160.0							QUARTZITE, Gray, medium grained, fresh, extremely strong, wide spaced discontinuities								5 foot solid run.
	2.00																
	2.00																
			R-28	60 100%	60 100%	R6	FR										
	2.00																
	2.00	165.0															
165		165.0							QUARTZITE, Gray, medium grained, fresh, extremely strong, wide spaced discontinuities								
	1.80																
	1.90																
660																	
	1.90		R-29	60 100%	60 100%	R6	FR										
										168.10	J	55	U,R	FR	PO	N	
	1.90										J	25	P,R	FR	PO	N	
										169.00	J	50	U,R	FR	PO	N	
	1.90	170.0									J	35	P,R	FR	T	N	

NOTES: Coal seam encountered

PROJECT NO.: **353754**

Boring No.: **B-I81-3**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-I81-3**
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
	2.00	170.0							QUARTZITE, Gray, medium grained, fresh, extremely strong, wide spaced discontinuities								
	2.00								172.0								
	1.10		R-30	60 100%	48 80%	R6	FR		Black Anthracite COAL 172' - 173' Highly Fractured zone								
	2.00								173.0 SANDSTONE, Gray, medium to coarse grained, fresh, extremely strong	173.40	J	20	P,R	FR	T	N	
	2.00	175.0							175.0								
175									End of Boring at 175 feet BGS. Borehole grouted with cement and bentonite hole plug.								
650																	
180																	
185																	
640																	
190																	

NOTES: Coal seam encountered

PROJECT NO.: **353754**

Boring No.: **B-I81-3**

Figure B-I81-3.1
B-I81-3 Box 1 Runs 1-4 Dry

Figure B-I81-3.2
B-I81-3 Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-I81-3

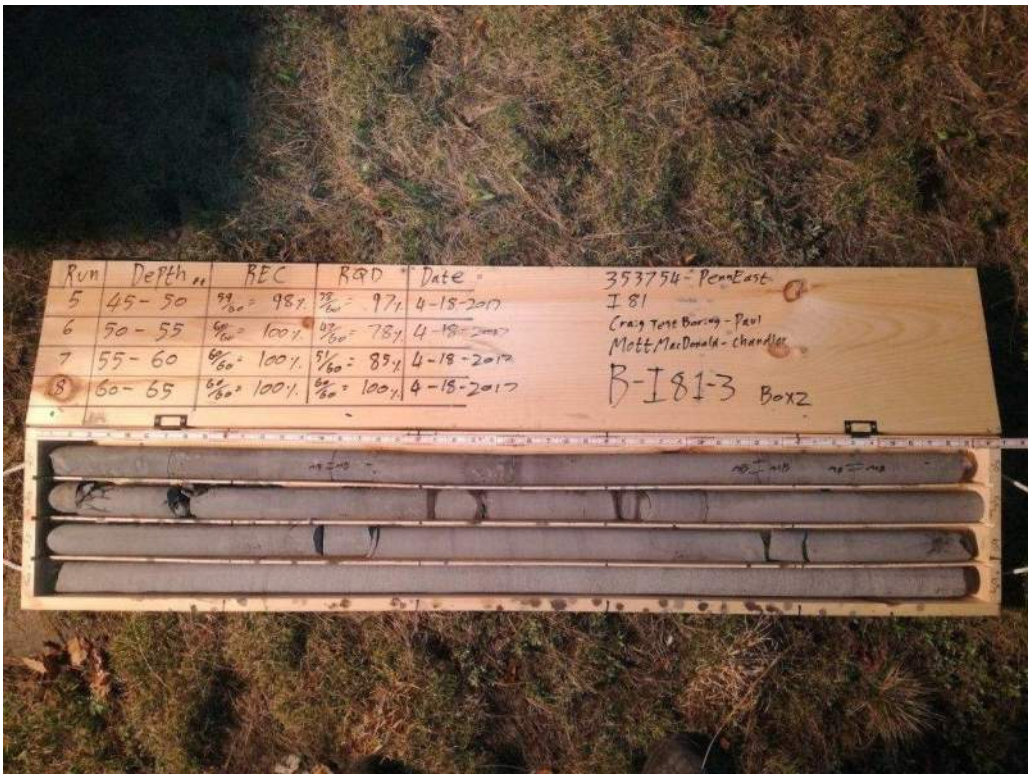


Figure B-I81-3.3
B-I81-3 Box 2 Runs 5-8 Dry

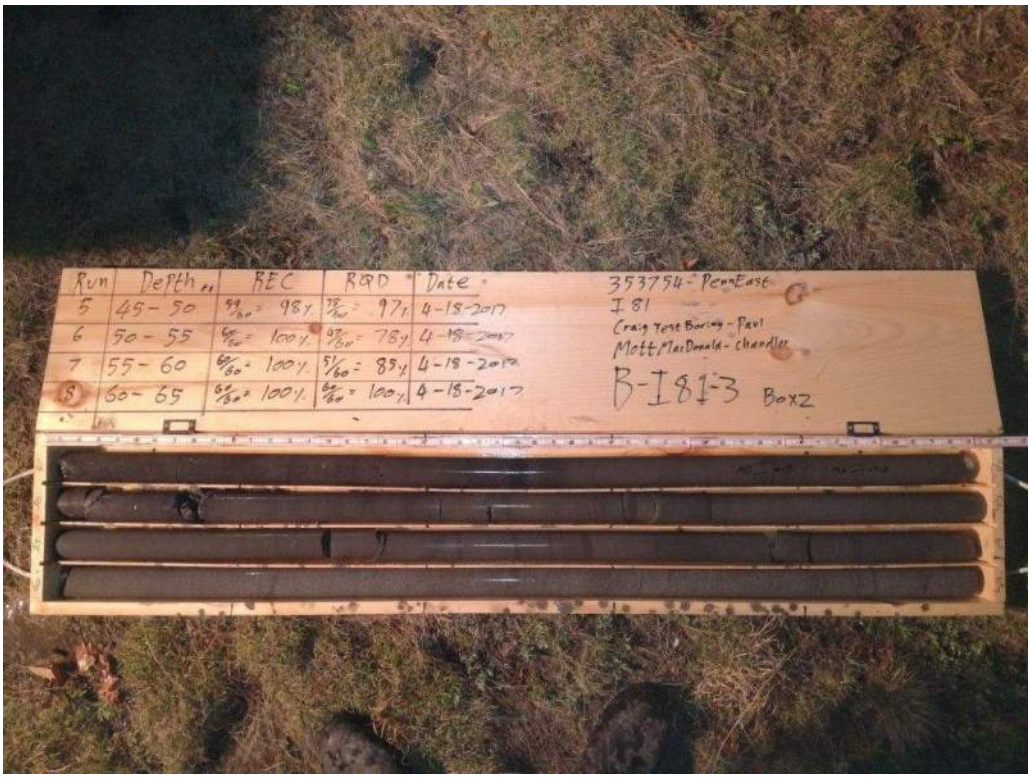


Figure B-I81-3.4
B-I81-3 Box 2 Runs 5-8 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I81-3

Figure B-I81-3.5
B-I81-3 Box 3 Runs 9-12 Dry

Figure B-I81-3.6
B-I81-3 Box 3 Runs 9-12 Wet

Figure B-I81-3.7
B-I81-3 Box 4 Runs 13-16 Dry

Figure B-I81-3.8
B-I81-3 Box 4 Runs 13-16 Wet

Figure B-I81-3.9
B-I81-3 Box 5 Runs 17-20 Dry

Figure B-I81-3.10
B-I81-3 Box 5 Runs 17-20 Wet

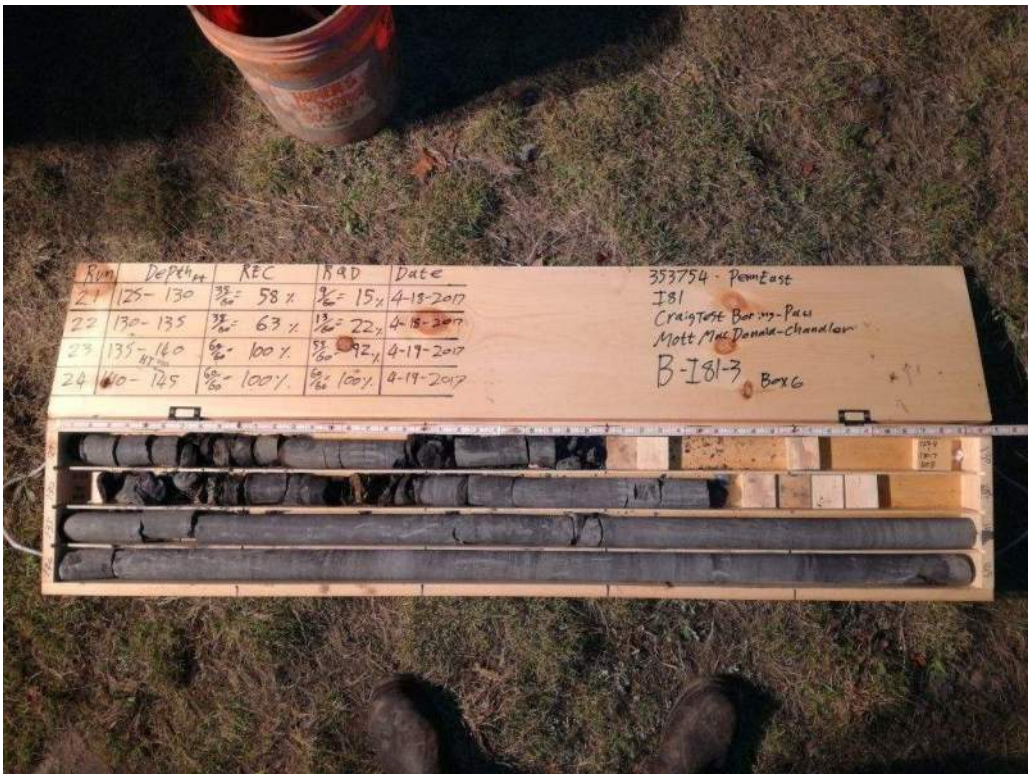


Figure B-I81-3.11
B-I81-3 Box 6 Runs 21-24 Dry

Figure B-I81-3.12
B-I81-3 Box 6 Runs 21-24 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I81-3

Figure B-I81-3.13
B-I81-3 Box 7 Runs 25-28 Dry

Figure B-I81-3.14
B-I81-3 Box 7 Runs 25-28 Wet

Figure B-I81-3.15
B-I81-3 Box 8 Runs 29-30 Dry

Figure B-I81-3.16
B-I81-3 Box 8 Runs 29-30 Wet

MOTT MACDONALD M M

SOIL BORING LOG

BORING NO.: **B-7A**
Page **1** of **2**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate - 81 Crossing, Wilkes - Barre, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	August 2, 2016 at 8:47 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	August 4, 2016 at 1:45 pm

Elevation: 812 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Southwest corner of construction site. **Coord.:** **N:** 14991208.71 **E:** 1419193.09 **Horizontal Datum:** UTM Zone 18 T

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: A Rod

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'	23	10 11 12 10		FILL	Very stiff, Dark gray Lean CLAY with Gravel and cobbles, moist (FILL)	N	-	L	L	Gravel is coarse to fine Coal and Sandstone.
810											
5	S-2 5.0'- 7.0'	20	21 15 18 22		FILL	Very stiff, Dark gray Sandy Lean CLAY with Gravel and Silt, moist (FILL)	N	-	L	L	Gravel is coarse to fine Coal and Sandstone.
10	S-3 10.0'- 12.0'	4	19 20 16 18		FILL	Very stiff, Dark gray Gravelly Lean CLAY with Sand, moist (FILL)	N	-	L	L	Poor recovery due to Gravel in tip of spoon. Gravel is Sandstone.
800											
15	S-4 15.0'- 17.0'	12	13 13 15 30		FILL	Very stiff, Dark gray Gravelly Lean CLAY with Sand, moist (FILL)	N	-	L	L	Gravel is Sandstone, Coal, and Quartzite.

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
8/4/16	6:15	-	5.0	160.0	129.6

Sample Type

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

Notes:

Strip mining backfill
PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-7A**

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-7A**
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'	12	9 10 14 18		FILL	Very stiff, Dark gray Gravelly Lean CLAY with Sand and Silt, moist (FILL)	N	-	L	L	Gravel is coarse to fine Sandstone, Coal, and Quartzite.
790											
25	S-6 25.0'-27.0'	10	10 12 50/2"		FILL	Hard, Dark gray Gravelly Lean CLAY with Sand and Silt, moist (FILL)	N	-	L	L	Gravel is coarse to fine Sandstone, Coal, and Quartzite.
30	S-7 30.0'-32.0'	11	9 27 21 19		FILL	Hard, Dark gray Gravelly Lean CLAY with Sand and Silt, moist (FILL)	N	-	L	L	Gravel is coarse to fine Sandstone, Coal, and Quartzite.
780											
35	S-8 35.0'-37.0'	9	12 30 25 40		FILL	Hard, Dark gray Gravelly Lean CLAY with Sand and Silt, moist (FILL)	N	-	L	L	Gravel is Sandstone, Quartzite, and Gneiss.
						38.5					
40	S-9 40.0'-42.0'	0.5	50/1"			SANDSTONE fragments	-	-	-	-	Slow drilling from 40 to 45 feet BGS.
770											
						45.0					
45	S-10 45.0'-47.1'	0.5	50/0.5"			Top of Rock at 45 feet BGS. See Rock Coring Log.	-	-	-	-	Top of weathered rock 40ft

NOTES: Strip mining backfill
PP = Pocket Penetrometer
TV = Torvane

PROJECT NO.: **353754**

BORING NO.: **B-7A**

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-7A**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate - 81 Crossing, Wilkes - Barre, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	August 2, 2016 at 8:47 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	August 4, 2016 at 1:45 pm

Elevation: 812 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Southwest corner of construction site. **Coord.: N:** 14991208.71 **E:** 1419193.09

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: UTM Zone 18 T **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								
	3.00	45.0							QUARTZITE, Gray, medium to coarse grained, moderately weathered, medium strong, close to moderately spaced discontinuities Mica present. (Quartzite is MetaSandstone) 46' - 47.4' Highly Fractured zone	45.70	J	10	P,R	FR	T	N	
	2.00																
	1.50		R-1	60 100%	38 63%	R3	M										
	1.50									48.00	J	0	P,R	DG	O	CL	
	1.50									49.00	J	5	P,R	FR	T	N	
50		50.0															
	2.00	50.0							QUARTZITE, Gray, medium to coarse grained, slightly weathered, medium strong, close spaced discontinuities Mica present	50.70	J	20	P,R	FR	T	N	
	1.50									51.10	J	0	P,R	FR	W	N	Sudden loss of water at 51 feet BGS.
760										51.50	J	0	P,R	FR	T	N	
	1.50		R-2	57 95%	40 67%	R3	SL			52.10	J	10	P,R	FR	T	N	
	1.50								53' - 55' Highly Fractured zone including vertical fractures								
	1.50	55.0															
55																	
	1.00	55.0							QUARTZITE, Gray, fine to coarse grained, fresh, strong, moderately spaced discontinuities Mica present								
	1.50									56.70	J	20	P,R	DS	T	N	
	1.50		R-3	60 100%	55 92%	R4	FR			57.40	J	30	P,Sm	DG	PO	SD	
	1.00								58.7' - 59.4' Highly Fractured zone								
	1.00	60.0															
60																	
	1.00	60.0							QUARTZITE, Gray, fine to coarse grained, fresh, strong, moderate to wide spaced discontinuities								Used up to 270 Gallons for R-3.
	1.00									60.70	J	70	P,R	FR	PO	N	
750										61.50	J	10	P,R	FR	T	N	
	1.50		R-4	60 100%	52 87%	R4	FR			62.10	J	15	P,R	FR	T	N	
	1.50																
	1.50									64.20	J	0	U,R	FR	PO	N	
		65.0								64.50	J	0	U,R	FR	PO	N	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
8/4/16	6:15	-	5.0	160.0	129.6

Notes:

Coal seam encountered.

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-7A**
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
	2.00	65.0							QUARTZITE, Light gray, fine to coarse grained, fresh, very strong, wide spaced discontinuities								Hole is very dry, all drilling water loosed rapidly when drilling stops.
	2.00									66.10	J	20	P,R	FR	PO	N	
	1.50		R-5	60 100%	60 100%	R5	FR			66.90	J	45	P,R	FR	T	N	
	3.00									68.60	J	10	U,R	FR	T	N	
	3.00	70.0								69.60	J	20	U,R	FR	T	N	
70	2.00	70.0							QUARTZITE, Light gray, fine to coarse grained, fresh, very strong, wide spaced discontinuities								
	2.00									70.70	J	15	P,R	FR	T	N	
	2.00									71.20	J	10	U,R	FR	O	N	
740	2.00		R-6	58 97%	46 77%	R5	FR			72.20	J	5	P,R	FR	T	N	
										72.50	J	15	P,R	FR	T	N	
									73.0								
	2.00								73' - 75' Sandy SHALE, Dark gray, very fine to fine grained, fresh, strong, wide spaced discontinuities	73.00	J	25	P,R	DS	T	Fe	
	2.00	75.0								74.40	J	20	P,R	DS	T	Fe	
75		75.0							75.0 QUARTZITE, Light gray, fine to coarse grained, fresh, very strong, close to wide spaced discontinuities								
	2.00																
	3.00									76.40	J	45	P,R	FR	T	N	
	3.00		R-7	59 98%	52 87%	R5	FR										
	4.00								78' - 80' Highly Fractured zone								
	4.00	80.0															
80		80.0							QUARTZITE, Light gray, fine to coarse grained, fresh, very strong, close to wide spaced discontinuities								
	2.00																
	2.50																
730	2.50		R-8	57 95%	57 95%	R5	FR										
	3.00																
	3.00	85.0								84.60	J	15	P,R	FR	T	N	
85		85.0							QUARTZITE, Light gray, fine to coarse grained, fresh, very strong, wide spaced discontinuities								
	2.00									85.50	J	40	P,R	FR	T	N	
	2.00								86.3' - 86.7' Highly Fractured zone								
	2.00		R-9	59 98%	54 90%	R5	FR			87.50	J	35	P,R	FR	T	N	
	2.00																
	2.00	90.0								89.00	J	10	U,R	DS	PO	N	

NOTES: Coal seam encountered.

PROJECT NO.: **353754**

Boring No.: **B-7A**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-7A**
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 Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.00	90.0							QUARTZITE, Gray, fine to coarse grained, fresh, very strong, close to wide spaced discontinuities	90.50	J	30	U,R	DS	PO	N	
	2.00									91.20	J	45	P,R	FR	T	N	
										91.60	J	30	U,R	DS	W	Fe	
720	2.00		R-10	58 97%	54 90%	R5	FR			92.30	J	30	P,R	FR	T	N	
	2.00									93.30	J	15	P,R	FR	T	N	
										93.80	J	5	U,R	DS	PO	N	
	2.00	95.0							95.0	94.20	J	40	U,R	DS	T	N	
95	1.50	95.0							CONGLOMERATE, Gray and white, coarse grained, fresh, very strong, wide spaced discontinuities Conglomerate is of coarse angular grains predominantly quartz.								
	1.50								96.3 95' - 96.3' Highly Fractured zone								
									Sandy SHALE, Gray, very fine to medium grained, fresh, very strong, close to moderately spaced discontinuities 0.2-inch thick Anthracite COAL seam at 96.5'								
	1.50		R-11	60 100%	40 67%	R5	FR			97.30	J	20	U,R	FR	T	N	
										97.80	J	20	U,R	FR	T	N	
	1.50																
										98.80	J	15	U,R	DS	PO	N	
	1.50	100.0															
100	1.50	100.0							Sandy SHALE, Gray, very fine to medium grained, fresh, very strong, very close to moderately spaced discontinuities Occasional very think Coal seam 100' - 101.9' Highly Fractured zone								3 inch rod drop at 103 feet BGS.
	2.00																
710																	
	2.00		R-12	54 90%	42 70%	R5	FR										
	2.00									103.30	J	10	U,R	FR	T	N	
										103.90	J	10	S,R	FR	T	N	
	2.00	105.0							104.3' - 105' Highly fractured zone 105.0								
105	2.00	105.0							QUARTZITE, Gray, fine to medium grained, slightly weathered, very strong, very close to close spaced discontinuities 105' - 110' Highly Fractured zone								
	2.00								106.4 106.4' - 106.9' Video confirmed Open Features [V-13] 106.9								
	2.00		R-13	55 92%	0 0%	R5	SL										
	3.00																
	3.00	110.0															
110	3.00	110.0							QUARTZITE, Gray, fine to medium grained, slightly weathered, strong, very close to close spaced discontinuities 110' - 115' Highly Fractured zone								Rod dropped 4 inches from 114 to 114.3 feet BGS.
	3.00																
700																	
	2.00		R-14	11 18%	6 10%	R4	SL										
	2.00								113.9								
									114.3 113.9' - 114.3' Video confirmed VOID [V-14]								
	2.00	115.0															

NOTES: Coal seam encountered.

PROJECT NO.: **353754**

Boring No.: **B-7A**

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	115.0							QUARTZITE, Gray, fine to coarse grained, fresh, very strong, extremely close to close spaced discontinuities 115' - 120' Highly Fractured zone								Rod dropped 18 inches from 116 to 117.5 feet BGS.
	1.50								116.3								
									116.3'-117.2' Video confirmed VOID [V-15]								
	0.00		R-15	44 73%	22 37%	R5	FR		117.2								
	0.50																
	1.50	120.0															
120									120.2								
	0.50	120.0							SHALE, Dark gray, very fine grained, slightly weathered, medium strong, extremely close to moderately spaced discontinuities 120' - 125' Highly Fractured zone								Rod dropped 12 inches from 122 to 123 feet and 124 to 125 feet BGS.
									121.2								
	1.00								120.2' - 121.2' Video confirmed VOID [V-16]								
690																	
	0.00		R-16	34 57%	16 27%				122.5								
									122.5' - 124' Video confirmed VOID [V-17] - (Field logged as 124' - 128.5' VOID)								
	2.00								124.0								
	0.00	125.0															
125									125.0								
	0.00	125.0							125' - 128.5' Small Athracite Coal fragments								Drill rods dropped at 125 feet BGS.
	0.00																
	0.00		R-17	18 30%	7 12%	R3	SL										
	0.20								128.5								
▽	0.50	130.0							128.5' - 130' SHALE, Dark gray, very fine to fine grained, slightly weathered, medium strong, extremely close to close spaced discontinuities								
130																	
	1.00	130.0							SHALE, Gray, very fine grained, fresh, strong, close to moderately spaced discontinuities 130' - 130.5' Highly Fractured zone								
	1.50									131.60	J	70	U,R	FR	T	N	
680										131.90	B	10	P,R	FR	T	N	
	2.00		R-18	60 100%	37 62%	R4	FR			132.10	B	5	P,R	FR	T	N	
										132.40	B	5	P,Sm	FR	T	N	
	2.00									133.50	J	10	P,R	FR	T	N	
	3.00	135.0															
135									SHALE, Dark gray, very fine grained, fresh, strong, very close to wide spaced discontinuities 136' - 137.2' Highly Fractured zone								
	1.50	135.0															
	2.00																
	2.00		R-19	58 97%	44 73%	R4	FR										
	2.50																
	2.50	140.0															

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
	2.50	140.0							SHALE, Dark gray, very fine grained, fresh, strong, wide to very wide spaced discontinuities	140.40	B	5	U,R	DS	PO	N	No water return.
	2.00																
670	2.00		R-20	60 100%	60 100%	R4	FR										
	2.50									143.40	B	0	P,K	FR	PO	N	
	2.50																
145	2.50	145.0															
	2.00	145.0							SHALE with interbedded QUARTZITE, Light to dark gray, very fine to coarse grained, fresh, very strong, close to moderately spaced discontinuities Laminated interbedding								
	2.00									146.60	J	20	P,R	FR	T	N	
	2.50		R-21	60 100%	53 88%	R5	FR			147.60	J	15	U,R	FR	PO	N	
	2.50																
	2.50	150.0							150.0								
150	2.00	150.0							QUARTZITE, Light gray, coarse grained, fresh, very strong, wide spaced discontinuities	150.40	B	5	U,Sm	DS	PO	Py	
	1.50																
660	1.50		R-22	60 100%	60 100%	R5	FR										
	2.00																
	3.00	155.0							155.0								
155	2.50	155.0							CONGLOMERATE, Gray and white, coarse grained, fresh, very strong, wide spaced discontinuities Conglomerate is of coarse angular grains predominantly quartz								
	3.00																
	3.00		R-23	60 100%	60 100%	R5	FR										
	3.50																
	5.00	160.0							160.0								
160	3.00	160.0							QUARTZITE, Light gray, medium to coarse grained, fresh, very strong, close to wide spaced discontinuities								Used up to 8,000 Gallons from 105 to 160 feet BGS.
	3.00																
650	3.00		R-24	60 100%	50 83%	R5	FR										
	3.00																
	3.00	165.0															

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	165.0							QUARTZITE, Dark gray, fine to medium grained, fresh, extremely strong, wide spaced discontinuities Mica crystals present								
	2.00									166.50	J	15	U,R	FR	VT	N	
	2.50		R-25	60 100%	60 100%	R6	FR										
	2.50																
	2.50	170.0															
170	2.50	170.0							QUARTZITE, Dark gray, fine to medium grained, fresh, extremely strong, wide spaced discontinuities								
	3.00																
640	3.00		R-26	60 100%	54 90%	R6	FR			171.80	J	30	P,R	FR	VT	N	
	3.00									173.70	J	10	U,R	FR	VT	N	
	3.00	175.0								174.60	J	40	P,R	DS	T	Fe	
175	1.50	175.0							QUARTZITE, Dark gray, fine to medium grained, fresh, extremely strong, wide spaced discontinuities								
	1.50								176.3' - 177.3' Highly Fractured zone	176.30	J	20	P,R	DS	T	Fe	
	2.00		R-27	60 100%	42 70%	R5	FR										
	2.50								178.6 178.7 178.6' Anthracite Coal encountered								
	2.50	180.0							179.6 179.5' - 181' Highly Fractured zone								
180		180.0							179.6' - 180.4' SHALE with Anthracite Coal 180.4 encountered								
	2.00								QUARTZITE, Light gray, coarse grained, fresh, very strong, moderately spaced discontinuities								
	2.00									181.60 181.70	J J	15 15	P,R P,R	FR FR	T T	N N	
630	2.00		R-28	60 100%	46 77%	R5	FR										
	2.00									183.20	J	20	U,R	FR	T	N	
	3.00	185.0								184.00	J	15	P,R	DS	T	N	
185	2.50	185.0							QUARTZITE, Light gray, medium grained, fresh, very strong, moderately spaced discontinuities								
	2.50									185.80	J	10	P,R	FR	T	N	
	2.50		R-29	58 97%	51 85%	R5	FR			186.70	J	20	U,R	FR	T	N	
	3.00								188.2' - 188.6' Highly Fractured zone	187.50	J	25	U,R	FR	T	N	
	2.50	190.0								189.20 189.60	J J	10 5	U,R U,R	FR FR	T T	N N	

NOTES: Coal seam encountered.

PROJECT NO.: **353754**

Boring No.: **B-7A**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-7A**
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
	2.50	190.0							QUARTZITE, Gray, fine to coarse grained, slightly weathered, strong, very close spaced discontinuities Occassional fine Shale bedding at fractures Occasional Coal encountered 190' - 195' Highly Fractured zone								
	2.50																
620	3.00		R-30	59 98%	20 33%	R4	SL										
	2.50																
	2.50	195.0															
195	2.00	195.0							QUARTZITE, Gray, medium grained, fresh, strong, very close to moderately spaced discontinuities Occasional fine Shale bedding	195.70	J	30	P,R	FR	T	N	
										195.90	J	30	U,R	FR	T	N	
	2.00									196.10	J	30	U,R	FR	T	N	
										196.70	J	30	U,R	FR	T	N	
	2.00		R-31	60 100%	38 63%	R4	FR			196.90	J	5	U,R	FR	T	N	
										197.00	J	5	U,R	FR	T	N	
										197.40	J	5	P,R	FR	T	N	
	3.00									198.40	J	10	P,R	FR	T	N	
	4.00								199.2' - 200' Highly Fractured zone								
200		200.0							200.0 End of Boring at 200 feet BGS. Borehole grouted with cement and bentonite hole plug.								
610																	
205																	
210																	
600																	

NOTES: Coal seam encountered.

PROJECT NO.: **353754**

Boring No.: **B-7A**

Figure B-7A.1
B-7A Box 1 Runs 1-4 Dry

Figure B-7A.2
B-7A Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-7A

Figure B-7A.3
B-7A Box 2 Runs 5-8 Dry

Figure B-7A.4
B-7A Box 2 Runs 5-8 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-7A

Figure B-7A.5
B-7A Box 3 Runs 9-12 Dry

Figure B-7A.6
B-7A Box 3 Runs 9-12 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-7A

Figure B-7A.7
B-7A Box 4 Runs 13-16 Dry

Figure B-7A.8
B-7A Box 4 Runs 13-16 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-7A

Figure B-7A.9
B-7A Box 5 Runs 17-20 Dry

Figure B-7A.10
B-7A Box 5 Runs 17-20 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-7A

Figure B-7A.11
B-7A Box 6 Runs 21-24 Dry

Figure B-7A.12
B-7A Box 6 Runs 21-24 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-7A

Figure B-7A.13
B-7A Box 7 Runs 25-28 Dry

Figure B-7A.14
B-7A Box 7 Runs 25-28 Wet

Figure B-7A.15
B-7A Box 8 Runs 29-31 Dry

Figure B-7A.16
B-7A Box 8 Runs 29-31 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-7A

MOTT MACDONALD M M

SOIL BORING LOG

BORING NO.: **B-7**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate - 81 Crossing, Wilkes - Barre, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Bernard Cortes
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	February 11, 2016 at 7:00 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	February 12, 2016 at 1:30 pm

Elevation: 815 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off Hwy 315. **Coord.:** **N:** 14991241.03 **E:** 1419204.376

Horizontal Datum: UTM Zone 18 T

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'	17	7 3 6 5		ML	Medium stiff, Yellowish red SILT with Decomposed Rock fragments, moist (FILL)	N	-	NP	N	
						3.5					
5 810	S-2 5.0'- 7.0'	16	5 7 7 5		CL	Very stiff, Dark gray Sandy Lean CLAY with Gravel and Silt, moist (FILL)	N	L	M	N	
10	S-3 10.0'- 12.0'	16	6 7 7 6		CL	Very stiff, Dark gray Sandy Lean CLAY with Gravel and Silt, moist (FILL)	N	H	H	N	
15 800	S-4 15.0'- 17.0'	12	12 14 50/3"		CL	Very stiff, Dark gray Sandy Lean CLAY with Gravel and Silt, moist (FILL)	N	H	M	N	
						18.5					

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
2/12/16	8:00	-	45.0	67.0	28

Sample Type

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

Notes:

PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-7**

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.

SOIL BORING LOG
(continued)

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'	7	12 17 38 14		GP	Very dense, gray GRAVEL with Silty Clay, wet (FILL)	N	H	M	L	
25 790	S-6 25.0'-27.0'	8	9 11 12 13		GP	Medium dense, gray GRAVEL with Sandy Clay, wet (FILL)	N	H	M	N	
30	S-7 30.0'-32.0'	12	10 16 14 11		GP	Medium dense, gray GRAVEL with Clayey Sand, wet (FILL)	N	L	M	N	
35 780	S-8 35.0'-37.0'	10	16 17 35 12		GP	Very dense, gray GRAVEL with Silty Sand, wet (FILL)	N	L	M	N	
40	S-9 40.0'-42.0'	8	13 12 14 12		GP	Medium dense, gray GRAVEL with Clayey Sand, wet (FILL)	N	M	M	N	
45 770	S-10 45.0'-47.0'	16	19 24 33 31		GP	Very dense, gray GRAVEL with Silty Sand, moist (FILL)	N	M	L	N	Installed Casing to 45 feet.

NOTES: PP = Pocket Penetrometer
TV = Torvane

PROJECT NO.: 353754

BORING NO.: B-7

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-7**
Page **3** of **3**

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
						48.5					
50	S-11 50.0'-52.0'	15	22 33 26 34		SM	Very dense, Brown Silty SAND with Gravel, moist (SM)	N	L	L	N	
						53.5					
55 760	S-12 55.0'-57.0'	1	50/1"		SC	Very dense, Brown Clayey SAND with Decomposed Rock fragments (SC)	N	L	M	N	
60	S-13 60.0'-62.0'		50/0"			No Recovery in SPT. Borehole advanced using roller bit. Possible boulder or top of rock	-	-	-	-	
65 750	S-14 65.0'-67.0'		50/0"			No Recovery in SPT. Borehole advanced using roller bit. Possible boulder or top of rock	-	-	-	-	
70						70.0 Rock coring from 70 feet BGS. See Rock Coring Log.					

NOTES: PP = Pocket Penetrometer
TV = Torvane

PROJECT NO.: **353754**

BORING NO.: **B-7**

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-7**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate - 81 Crossing, Wilkes - Barre, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Bernard Cortes
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	February 11, 2016 at 7:00 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	February 12, 2016 at 1:30 pm

Elevation: 815 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off Hwy 315. **Coord.: N:** 14991241.03 **E:** 1419204.376

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: UTM Zone 18 T **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)						
	2.50	70.0							QUARTZITE, Light gray, medium grained, fresh, extremely strong, extremely close to close spaced discontinuities. (Quartzite is MetaSandstone)	70.10	J	10	X,R	DE	O	N	Losing Water.
										70.30	J	10	P,R	DE	O	N	
										70.80	J	10	P,R	DE	PO	N	
	2.50									71.00	J	0	P,Sm	FR	PO	N	
										71.20	J	5	P,R	FR	PO	N	
	2.50		R-1	60 100%	26 43%	R6	FR		72' - 72.9' Highly Fractured Zone								Core barrel moving side to side.
	2.50																
	2.50	75.0							74' - 75' Highly Fractured Zone								
75 740	4.00	75.0							QUARTZITE with Silica cement, Light gray, medium to coarse grained, slightly weathered, medium strong, close spaced discontinuities.	75.20	J		X,R	FR	O	N	
	4.00									76.40	J	10	P,R	DG	O	CL	
										76.90	V	30	P,R	FR	O	X	
	3.50		R-2	60 100%	47 78%	R3	M			77.60	J	5	P,Sm	FR	T	N	
	3.50									78.20	MB						
										78.70	J	10	P,R	FR	PO	N	
	4.00									79.00	V	30	P,R	FR	PO	X	
		80.0								79.30	V	30	P,R	FR	T	X	
80	5.00	80.0							QUARTZITE, Light gray, fine to medium grained, fresh, strong, close to moderately spaced discontinuities	80.30	J	5	P,R	FR	PO	N	Used up to 275 Gallons for R1/R2/R3.
										80.90	J	10	P,R	DS	O	ML	
	3.00									81.20	J	10	S,K	DG	O	Sa	
										81.90	J	0	P,Sm	FR	T	N	
	2.30		R-3	60 100%	55 92%	R4	FR			82.60	J	0	P,R	FR	PO	N	
	2.50																
	3.00	85.0								84.50	J	5	P,R	FR	PO	N	
85 730	6.00	85.0							QUARTZITE with Silica cement, Light gray, medium to coarse grained, fresh, very strong, extremely close to moderately spaced discontinuities								
	5.00									86.20	J	5	P,R	FR	PO	N	
										86.30	J	60	P,R	DG	T	N	
										86.60	J	0	P,R	DG	O	N	
	3.00		R-4	60 100%	53 88%	R5	FR			86.80	J		X,R	DG	W	N	
	3.00									88.30	J	40	P,R	DG	T	X	
										88.70	J	30	P,R	FR	PO	N	
	3.00	90.0								89.60	J	0	P,Sm	FR	PO	N	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
2/12/16	8:00	-	45.0	67.0	28.0

Notes:

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-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
	2.00	90.0							QUARTZITE, Light gray, fine to medium grained, fresh, extremely strong, coarse to wide spaced discontinuities								
										90.70	J	20	P,R	FR	T	N	
	2.00									91.50	J	20	P,R	FR	T	N	
										91.60	J	30	P,R	DG	T	X	
	3.50		R-5	60 100%	60 100%	R6	FR			92.20	J	5	P,R	FR	T	N	
	3.50																
	3.00	95.0															
95 720		95.0							QUARTZITE, Light gray, medium grained, fresh, extremely strong, extremely close to moderately spaced discontinuities								
	4.00									95.20	J	20	P,R	FR	MW	N	
										95.80	J	30	P,R	FR	PO	N	
										96.10	J	10	X,R	DG	W	N	
	6.00									96.20	J		P,R	DG	PO	X	
										96.60	J	40	P,R	FR	PO	N	
	6.00		R-6	60 100%	50 83%	R6	FR			97.30	J	10	P,R	DS	PO	X	
										97.70	J		X,R	DS	MW	X	
										98.10	J	10	P,R	DS	PO	X	
	6.50									98.30	J	10	P,R	DS	PO	X	
										98.80	J	10	P,Sm	DG	PO	X	
	7.00	100.0							100.0								
100									End of Boring at 100 feet BGS. Borehole grouted with cement and bentonite hole plug.	99.80	MB						
105 710																	
110																	

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-7**

Figure B-7.1
B-7 Box 1 Runs 1-4 Dry

Figure B-7.2
B-7 Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-7

Figure B-7.3
B-7 Box 2 Runs 5-6 Dry

Figure B-7.4
B-7 Box 2 Runs 5-6 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-7

MOTT MACDONALD

SOIL BORING LOG

BORING NO.: **B-8**
Page **1** of **2**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate - 81 Crossing, Wilkes - Barre, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	August 12, 2016 at 11:39 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	August 16, 2016 at 3:15 pm

Elevation: 883 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off PP&L ROW **Coord.:** **N:** 14990651.3 **E:** 1419754.868 **Horizontal Datum:** UTM Zone 18 T

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	17	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	2 2 3 6		CL	Medium stiff, Light brown Gravelly Lean CLAY, moist. (CL)	N	L	M	M	Installed 4-inch casing to 5 feet BGS.
880						3.5					
5	S-2 5.0'- 7.0'	4	17 17 20 19		GW	Dense, Brownish gray Clayey GRAVEL, moist. (GW)	-	-	-	-	Gravel consists of fine to coarse sandstone.
						8.5					
10	S-3 10.0'- 12.0'	16	10 10 50 60		CL	Hard, Blackish Brown Gravelly Lean CLAY with Cobbles, moist. (CL)	N	L	L	L	Installed 4-inch casing to 10 feet BGS.
870											
15	S-4 15.0'- 17.0'	6.5	9 70/0.5"		CL	Hard, Blackish Brown Gravelly Lean CLAY with Cobbles, moist. (CL)	-	-	-	-	Installed 4-inch casing to 15 feet BGS.
						20.0					

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
8/15/16	6:45	-	17.0	20.0	1.5
8/16/16	6:00	-	17.0	120.0	110

Sample Type

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

Notes:
PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-8**

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-8**
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	Field Tests: Toughness	Field Tests: Plasticity	Field Tests: Dry Strength	Remarks
	S-5 20.0'- 20.0'	0	70/0.5"			Top of Rock at 20 feet BGS. See Rock Coring Log.	-	-	-	-	Installed 4-inch casing to 17 feet BGS. No Rec. Start coring from 20ft
860											
25											
30											
850											
35											
40											
840											
45											

NOTES: PP = Pocket Penetrometer
TV = Torvane

PROJECT NO.: **353754**

BORING NO.: **B-8**

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-8**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate - 81 Crossing, Wilkes - Barre, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	August 12, 2016 at 11:39 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	August 16, 2016 at 3:15 pm

Elevation: 883 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off PP&L ROW **Coord.: N:** 14990651.3 **E:** 1419754.868

Item	Casing	Core Barrel	Core Bit
Type	HW	NQ2	Imp. Diamond
Length (ft)	17	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Horizontal Datum: UTM Zone 18 T
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								
	2.00	20.0							QUARTZITE, Gray, medium grained, slightly weathered, strong, close spaced discontinuities. (Quartzite is MetaSandstone)								Good drilling water return from 20 to 25 feet BGS.
	2.00									21.70	B	0	U,R	DS	PO	N	
	1.50		R-1	58 97%	53 88%	R4	SL										
860										22.90	B	15	U,R	DS	PO	N	
	1.50																
										23.90	B	10	U,R	DS	PO	N	
	1.50	25.0															
25										24.70	B	10	U,R	DS	PO	N	
	1.50	25.0							QUARTZITE, Gray, medium grained, slightly weathered, strong, close spaced discontinuities								
	1.00									26.20	B	0	S,R	FR	T	N	
	1.00		R-2	60 100%	58 97%	R4	SL			27.20	J	25	S,R	FR	VT	N	
										27.90	J	10	S,R	FR	T	N	
	1.00									28.50	B	10	P,R	DS	PO	N	
	1.00	30.0															
30		30.0							QUARTZITE, Gray, medium grained, fresh, strong, very close to moderately spaced discontinuities								
	1.50									31.00	B	0	P,R	DG	W	N	
	1.50									31.60	B	15	U,R	FR	PO	N	
	1.50		R-3	60 100%	45 75%	R4	FR		32.4								
850									32.8 32.4' - 32.8' CONGLOMERATE								No drilling water return below 31 feet BGS.
	1.50									33.10	B	10	S,R	DS	PO	N	
	1.50									33.40	J	50	P,R	FR	T	N	
	1.50	35.0															
35		35.0							QUARTZITE, Gray, medium grained, fresh, strong, very close to moderately spaced discontinuities								
	1.50									35.40	J	60	P,R	FR	VT	N	
	1.50																
	1.50		R-4	60 100%	45 75%	R4	FR		36.8' - 37.2' Highly Fractured zone								
	1.50																
	1.50	40.0								39.50	B	0	S,R	DS	PO	N	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
8/15/16	6:45	-	17.0	20.0	1.5
8/16/16	6:00	-	17.0	120.0	110.0

Notes:

Coal seam encountered

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	40.0							40.5 QUARTZITE, Gray, medium grained, slightly weathered, strong, close spaced discontinuities								
	2.00								CONGLOMERATE, Gray, coarse grained, fresh, very strong, modeate to wide spaced discontinuities								Rod dropped 4 inches at 44 feet BGS.
	2.00		R-5	60 100%	60 100%	R5	FR			41.90	J	15	P,R	DS	PO	N	
840	2.00									44.00	J	0	S,R	FR	VT	N	
	2.00	45.0								44.20	J	0	P,R	DG	W	SD	
45	1.50	45.0							46.3								
	1.50								QUARTZITE, Gray, coarse to medium grained, fresh, very strong, moderately spaced discontinuities	46.20	B	10	P,R	DS	T	N	
	1.50		R-6	60 100%	58 97%	R5	FR			47.30	B	10	U,R	FR	VT	N	
	1.50									48.10	B	0	P,R	FR	T	N	
	1.50	50.0								49.10	B	5	U,R	FR	T	N	
50	1.50	50.0							QUARTZITE, Gray, fine to medium grained, fresh, very strong, very close to close spaced discontinuities 50' - 51.4' Highly Fractured zone								
	1.50																
	1.50		R-7	60 100%	43 72%	R5	FR			52.50	J	0	U,R	DG	W	SD	
830	1.50									52.90	B	15	P,R	FR	VT	N	
	1.50	55.0															
55	1.50	55.0							QUARZITE, Gray, fine to medium grained, slightly weathered, strong, extremely close to moderately spaced discontinuities 55' - 56' Highly Fractured zone with high angle fractures.								
	1.50									56.50	J	40	P,R	FR	T	N	
	1.50		R-8	60 100%	32 53%	R4	SL			56.80	J	40	P,R	FR	T	N	
	1.50									57.80	J	25	S,R	FR	PO	N	
	1.50	60.0								59.30	B	30	S,R	DG	PO	N	
60	1.00	60.0							60' - 61' Highly Fractured zone								
	1.50								61.8 61.5' - 62.5' Highly Fractured zone								Coal infilling
	1.00		R-9	60 100%	44 73%	R4	SL		SHALE, Black, fine grained, slightly weathered, strong, very close spaced discontinuities 61.8' - 63' Highly Fractured zone	62.40	J	40	P,Sm	DS	T	Fe	
820									63.0								
	1.50								QUARTZITE, Gray, fresh, medium grained, very strong, moderately spaced discontinuities	63.20	J	20	U,R	FR	VT	N	
										63.70	J	20	U,R	FR	VT	N	
	1.50	65.0															

NOTES: Coal seam encountered

PROJECT NO.: **353754**

Boring No.: **B-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
	1.20	65.0							QUARTZITE, Gray, medium to coarse grained, fresh, strong, close spaced discontinuities	65.40	B	20	P,Sm	FR	VT		Coal infilling
	1.20									66.40	J	10	U,R	FR	T	N	
										66.50	J	10	U,R	FR	T	N	
	1.30		R-10	60 100%	48 80%	R4	FR			67.20	B	10	P,Sm	FR	VT		Coal infilling
									68.0								
	1.40								68.3 68' - 68.3' Coal								
										68.70	B	15	P,Sm	FR	VT	Fe	
	1.40	70.0								69.60	J	10	P,Sm	FR	T		
70		70.0							QUARTZITE, Gray, medium to coarse grained, fresh, very strong, extremely close to wide spaced discontinuities								3-inch Rod drop at 74.5' (See V-11.1)
	1.50																
	1.50																
										71.70	B	10	U,R	FR	T		
	1.50		R-11	57 95%	46 77%	R5	FR			72.30	J	80	U,R	DS	T	Fe	
										72.40	B	10	P,Sm	FR	VT	N	
810									73.1								
	1.50								73.4 73.1' - 73.4' Video confirmed VOID [V-11.1]								
	1.50																
		75.0							74.9								
75		75.0							74.9' - 77.6' Video confirmed VOID [V-11.2]								
			R-12	19 32%	15 25%	R4	FR		77.6								Rod drop 77' - 79' (See V-12)
									QUARTZITE, Gray, medium to coarse grained, fresh, very strong, extremely close to wide spaced discontinuities								
									78.4								
									78.4' - 81' Video confirmed VOID [V-12] - field logged as: (76.6' - 79' VOID) (79' - 79.5' COAL) (79.5' - 81' VOID) voids contain rubble of shale and anthracite coal								
		80.0							81.0								
80		80.0							81' - 82.4' COAL								
									82.4								
			R-13	20 33%	0 0%	R1	FR		82.4' - 83.1' Video confirmed VOID [V-13.1] - (field logged as 81.5' - 83.4' VOID)								
800									83.1								
									83.1' - 84' COAL								
									84.0								
									84' - 85.7' Video confirmed VOID [V-13.2] - (field logged as 85.5' - 87.5' VOID)								
		85.0															
85		85.0							85.7								
									85.7' - 86.2' SHALE, Dark gray, very fine grained, weak, slightly weathered, iron staining								
									86.2								
									86.2' - 86.6' Video confirmed VOID [V-14.1] 88' - 91.2' VOID								
									86.6								
			R-14	25 42%	4 7%	R2	SL		86.6' - 88' SHALE, Gray, very fine grainedm, slightly weathered, strong, iron staining (field logged as 91.2' - 92.5')								
									88.0								
									88' - 91.9' Video confirmed VOID [14.2]								
		90.0															

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-8**
Page **4** 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
		90.0															
			R-15	23 38%	13 22%	R4	SL		91.9								
790																	
		95.0															
95		95.0							SHALE, Black, very fine grained, fresh, strong, wide spaced discontinuities								
	1.00																
	1.50																
	1.50		R-16	58 97%	55 92%	R4	FR			97.00	J	15	U,R	DG	PO	N	
										97.70	J	0	P,R	DG	T	N	
	1.00																
	1.00	100.0								99.50	J	10	P,R	FR	T	N	
100		100.0							SHALE, Black, very fine grained, slightly weathered, medium strong, extremely close spaced discontinuities 100' - 102.5' Highly Fractured zone								
	1.50																
	1.50									101.10	J	45	P,R		PO	QZ	
	1.50		R-17	57 95%	17 28%	R4	FR		102.5								
780									QUARTZITE, Gray, medium grained, fresh, strong, very close to close spaced discontinuities								
	1.50									103.50	J	0	U,R	DS	O	N	
	1.50	105.0															
105		105.0							QUARTZITE, Dark gray, fine to medium grained, fresh, strong, moderately spaced discontinuities								
	1.00																
	1.00									106.20	J	0	S,R	DG	W	N	
	1.00		R-18	60 100%	28 47%	R4	FR			107.30	J	30	P,R	FR	VT	N	
	1.50																
	1.50	110.0							110.0								
▽ 110		110.0							SHALE, Dark gray, fine grained, slightly weathered, medium strong, extremely close to moderately spaced discontinuities 110' - 110.5' Highly Fractured zone								
	1.00																
	1.00									111.30	J	50	P,Sm	FR	PO	N	
	1.00		R-19	57 95%	33 55%	R3	SL			112.00	J	25	S,R	DS	PO	Fe	
770									113' - 115' Highly Fractured zone								
	1.00																
	1.00	115.0							115.0								

NOTES: Coal seam encountered

PROJECT NO.: **353754**

Boring No.: **B-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
	1.00	115.0							QUARTZITE, Gray, fine to medium grained, fresh, strong, close to moderately spaced discontinuities								
	1.00								116.6	116.20	J	40	S,R	FR	VT	N	
	1.00		R-20	57 95%	33 55%	R4	FR		116.6' -118.2' Video confirmed VOID [V-20] - (field logged as 117.9' -119.7' Highly Fractured zone)								
	1.00								118.2								
	1.00								SHALE, Gray, very fine grained, extremely weathered, extremely weak 118' - 120' Highly Weathered to CLAY								
	1.00	120.0							120.0								
120	1.00	120.0							QUARTZITE, Dark gray, fine to medium grained, medium strong, extremely close to close spaced discontinuities 120' - 122.2' Highly Fractured zone								
	1.50																
	1.00		R-21	60 100%	34 57%	R3	SL										
760										123.00	J	30	P,Sm	FR	T	N	
	1.50									123.60	J	45	U,R	FR	PO	CL	
	1.50	125.0															
125		125.0							QUARTZITE, Dark gray, fine to medium grained, fresh, strong, close to moderately spaced discontinuities	125.00	J	50	S,R	FR	T	QZ	
	1.00									125.50	J	40	U,R	FR	T	N	
	1.50																
	1.50		R-22	60 100%	41 68%	R4	FR			127.00	J	30	S,R	FR	T	N	
										127.30	J	0	S,R	FR	VT	N	
	1.50																
	1.50									129.00	J	60	S,R	FR	T	N	
	1.50	130.0															
130	1.50	130.0							QUARTZITE, Light gray, medium grained, fresh, very strong, wide spaced discontinuities								
	2.00																
	2.00		R-23	60 100%	60 100%	R5	FR										
750										133.20	B	20	S,R	FR	VT	N	
	2.00																
	2.00	135.0															
135	1.50	135.0							QUARTZITE, Light gray, medium grained, fresh, very strong, wide spaced discontinuities								
	1.50																
	1.50		R-24	60 100%	60 100%	R5	FR										
	1.50									138.50	J	10	P,Sm	FR	O	QZ	
	1.50	140.0								139.10	J	55	U,R	FR	O	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
	2.00	140.0							QUARTZITE, Light gray, fresh, strong, medium grained, moderately spaced discontinuities	140.30	J	80	S,R	DS	T	Fe	
	2.00																
	2.00									142.00	B	10	P,R	DS	T	N	
	2.00		R-25	60 100%	45 75%	R5	FR			142.40	J	80	S,R	DS	T	Fe	
740	2.00									143.00	B	10	P,Sm	FR	VT	QZ	
	2.00	145.0															
145	1.50	145.0							QUARTZITE, Light to dark gray, fine to coarse grained, fresh, strong, close to moderately spaced discontinuities	145.30	B	0	S,R	FR	T	N	
	1.50																
	1.50		R-26	60 100%	44 73%	R4	FR			147.00	J	0	S,R	DG	W	Fe	
	1.50								148' - 150' Highly Fractured zone								
	1.50	150.0															
150	1.00	150.0							QUARTZITE, Light to dark gray, medium to coarse grained, slightly weathered, medium strong, very close to close spaced discontinuities								
	1.00								151' Subvertical fracture encountered	151.20	J	0	S,R	FR	T	N	
	1.00										J	90	P,R	DS	O	Fe	
	1.00		R-27	60 100%	37 62%	R3	SL			152.00	J	30	U,R	DG	W	Fe	
730									153.0								
	1.00								153' - 155' CONGLOMERATE	153.30	J	0	S,R	FR	VT	N	
	1.00									154.00	B	0	S,R	FR	VT	N	
	1.00	155.0							155.0								
155	1.00	155.0							155' - 160' QUARTZITE and CONGLOMERATE encountered, poor recovery, highly disturbed								Inner barrel not engaged from 155 to 160 feet BGS. Run highly disturbed. RQD cannot be determined.
	1.50																
	2.00		R-28	37 62%	-- --	-	-										
	1.50																
	1.50	160.0															
160	2.00	160.0							QUARTZITE, Light gray, coarse to medium grained, fresh, very strong, very close to moderately spaced discontinuities Fine grained laminations								
	2.00																
	2.00		R-29	60 100%	51 85%	R5	FR			162.10	B	0	P,R	FR	T	N	
720	2.00									163.40	J	10	P,R	FR	T	N	
	2.00									163.90	J	20	S,R	FR	T	N	
		165.0							165.0								

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
	2.00	165.0							CONGLOMERATE, Light gray to gray, coarse grained, fresh, very strong, moderately spaced discontinuities	165.60	J	0	P,R	DS	PO	N	
	2.00									166.60	J	20	P,R	FR	T	N	
	2.00		R-30	60 100%	60 100%	R5	FR			167.30	J	5	P,Sm	FR	T		Mica infilling
	2.00																
	2.00	170.0								169.40	J	20	P,Sm	FR	VT		Mica infilling
170	2.00	170.0							CONGLOMERATE, Light gray, coarse grained, fresh, extremely strong, wide to extremely close spaced discontinuities	170.40	J	5	P,R	FR	T	N	
	3.00																
	3.00		R-31	60 100%	54 90%	R6	FR			172.30	J	45	S,R	DS	PO	SD	
710	3.00									173.70	J	30	P,R	FR	T		Mica infilling
	2.00	175.0								174.50	J	45	S,R	FR	T	N	
175	2.00	175.0							CONGLOMERATE, Light gray, coarse grained, fresh, extremely strong, wide spaced discontinuities Clasts of angular Quartz encountered								
	2.00																
	2.00		R-32	60 100%	60 100%	R6	FR			177.80	J	50	P,Sm	FR	T		Mica infilling
	2.00																
	2.00	180.0								179.00	J	40	U,R	DS	PO	Fe	
180	1.50	180.0							CONGLOMERATE, Light gray, coarse grained, fresh, extremely strong, wide to close spaced discontinuities								
	1.50																
	1.50		R-33	60 100%	55 92%	R6	FR										
700	1.50																
	1.50	185.0								184.30	B	40	P,R	FR	VT	Sh	
185	1.50	185.0							0.08-inch thick layer of Graphite at 184.8' CONGLOMERATE, Light gray, coarse grained, fresh, extremely strong, wide to close spaced discontinuities	184.80	B	40	S,R	FR	VT	N	
									186.0								
	1.50								QUARTZITE, Dark gray, fine to medium grained, fresh, very strong, very close to close spaced discontinuities	186.10	B	30	U,R	FR	T	N	
	1.50									186.40	B	15	U,R	FR	T	N	
	1.50		R-34	60 100%	45 75%	R5	FR		187.1' - 187.6' Highly Fractured zone								
									187.5								
	1.50								SHALE, Black, fine grained, fresh, very strong, moderately spaced discontinuities Occassional Iron staining Occassional 0.12-inch thick Coal layer								
	1.50																
	1.50	190.0								188.90	B	20	P,R	DS	PO	Fe	
									190.0								

NOTES: Coal seam encountered

PROJECT NO.: **353754**

Boring No.: **B-8**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-8**
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 (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	1.50	190.0							QUARTZITE, Dark gray, fine to medium grained, fresh, very strong, wide spaced discontinuities Fine Sandstone encountered	190.40	J	0	S,R	FR	T	N	
										190.70	J	20	S,R	FR	T	N	
	1.50																
	1.00		R-35	60 100%	56 93%	R5	FR										
690	1.00																
	1.00	195.0															
195		195.0							QUARTZITE, Dark gray, fine to medium grained, fresh, very strong, wide spaced discontinuities Fine Sandstone encountered								
	1.50																
	1.50																
	1.50		R-36	60 100%	60 100%	R5	FR										
	1.50									198.70	J	5	U,R	FR	T	N	
	1.50	200.0							200.0								
200									End of Boring at 200 feet BGS. Borehole grouted with cement and bentonite hole plug.								
680																	
205																	
210																	
670																	

NOTES: Coal seam encountered

PROJECT NO.: **353754**

Boring No.: **B-8**

Figure B-8.1
B-8 Box 1 Runs 1-4 Dry

Figure B-8.2
B-8 Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-8

Figure B-8.3
B-8 Box 2 Runs 5-8 Dry

Figure B-8.4
B-8 Box 2 Runs 5-8 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-8

Figure B-8.5
B-8 Box 3 Runs 9-12 Dry

Figure B-8.6
B-8 Box 3 Runs 9-12 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-8

Figure B-8.7
B-8 Box 4 Runs 13-16 Dry

Figure B-8.8
B-8 Box 4 Runs 13-16 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-8

Figure B-8.9
B-8 Box 5 Runs 17-20 Dry

Figure B-8.10
B-8 Box 5 Runs 17-20 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-8

Figure B-8.11
B-8 Box 6 Runs 21-24 Dry

Figure B-8.12
B-8 Box 6 Runs 21-24 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-8

Figure B-8.13
B-8 Box 7 Runs 25-28 Dry

Figure B-8.14
B-8 Box 7 Runs 25-28 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-8

Figure B-8.15
B-8 Box 8 Runs 29-32 Dry

Figure B-8.16
B-8 Box 8 Runs 29-32 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-8

Figure B-8.17
B-8 Box 9 Runs 33-36 Dry

Figure B-8.18
B-8 Box 9 Runs 33-36 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-8

MOTT MACDONALD M M

SOIL BORING LOG

BORING NO.: **B-9**

Page **1** of **2**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate - 81 Crossing, Wilkes - Barre, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	August 9, 2016 at 11:48 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	August 12, 2016 at 9:00 am

Elevation: 900 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off PP&L ROW **Coord.:** **N:** 14990338.7 **E:** 1419918.221 **Horizontal Datum:** UTM Zone 18 T

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	17	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
900	S-1 0.0'- 2.0'	13	3 4 10 11		ML	Stiff, Brownish yellow SILT with Gravel, dry (ML)	-	M	L	M	Installed 4-inch casing to 10 feet BGS.
						3.5					
5	S-2 5.0'- 7.0'	11	9 10 17 15		CL	Very stiff, Gray Gravelly Lean CLAY, moist (CL)	-	M	L	M	Gravel is Coal and Sandstone.
10 890	S-3 10.0'- 12.0'	18	9 9 13 11		CL	Very stiff, Dark gray Gravelly Lean CLAY, moist (CL)	-	M	L	M	Gravel is Coal and Sandstone.
15	S-4 15.0'- 17.0'	16	14 14 8 27		CL	Very stiff, Dark gray Gravelly Lean CLAY, moist (CL)	-	M	L	M	Gravel is Coal and Sandstone. Installed 4-inch casing to 17 feet BGS. Hit casing refusal at 17 feet BGS.
						17.0					
						DECOMPOSED ROCK FRAGMENTS. Sandstone					
						20.0					

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
8/11/16	6:20	-		125.0	84

Sample Type

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

Notes:

PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-9**

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-9**
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
880						Top of Rock at 20 feet BGS. See Rock Coring Log.					
25											
30 870											
35											
40 860											
45											

NOTES: PP = Pocket Penetrometer
TV = Torvane

PROJECT NO.: **353754**

BORING NO.: **B-9**

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-9**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate - 81 Crossing, Wilkes - Barre, PA	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Dafydd Chandler
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	August 9, 2016 at 11:48 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	August 12, 2016 at 9:00 am

Elevation: 900 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Off PP&L ROW **Coord.: N:** 14990338.7 **E:** 1419918.221

Item	Casing	Core Barrel	Core Bit
Type	HW	NQ2	Imp. Diamond
Length (ft)	17	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Horizontal Datum: UTM Zone 18 T
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
880		20.0							SEE TEST BORING LOG FOR OVERBURDEN DETAILS								
	1.00								QUARTZITE, Light gray, medium grained, slightly weathered, strong, close spaced discontinuities. (Quartzite is MetaSandstone)	20.30	J	30	U,R	DG	PO	CL	
	1.50									21.10	J	0	P,R	DS	PO	N	
	1.50		R-1	60 100%	55 92%	R4	FR			22.70	J	10	U,R	DS	T	N	
	1.50									22.90	J	10	U,R	DS	PO	CL	
	1.50									23.70	J	5	U,R	FR	T	N	
	1.50	25.0								24.60	J	10	S,R	DS	PO	N	
25		25.0							QUARTZITE, Light gray, medium grained, fresh, strong, close to moderately spaced discontinuities 25' - 26.5' Highly Fractured zone								
	1.50																
	1.50																No water return from 26 feet to base of hole.
	1.50		R-2	59 98%	43 72%	R5	FR			27.50	J	15	U,R	FR	PO	N	
	1.50									28.40	J	20	U,R	FR	PO	N	
	1.50	30.0								28.90	J	5	U,R	FR	T	N	
30 870		30.0							QUARTZITE, Light gray, medium grained, fresh, strong, close to moderately spaced discontinuities								
	2.00																
	2.00									31.00	J	30	P,R	DG	O	N	
	2.00		R-3	60 100%	54 90%	R5	FR			32.70	J	30	U,R	DS	PO	N	
	1.50																
	1.50	35.0															
35		35.0							QUARTZITE, Light gray, medium grained, fresh, strong, close to moderately spaced discontinuities 35' - 36.5' Highly Fractured zone								
	1.50																
	1.50																
	1.50		R-4	60 100%	41 68%	R4	FR			37.50	J	60	P,R	FR	PO	N	
	1.50																
	1.50	40.0															

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
8/11/16	6:20	-		125.0	84.0

Notes:

Coal seam encountered

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
860	1.50	40.0							QUARTZITE, Gray, fine to coarse grained, fresh, strong, moderate to wide spaced discontinuities 43.2' - 44' Highly fractured zone	40.70	J	10	U,R	FR	T	N	
	2.00									41.70	J	25	P,R	FR	T	N	
	2.00		R-5	60 100%	36 60%	R4	FR			42.50	J	30	U,R	FR	T	N	
	2.00																
	2.00	45.0															
45	1.50	45.0							QUARTZITE, Gray, medium grained, fresh, very strong, wide spaced discontinuities								
	1.50									46.70	J	15	S,R	FR	T	N	
	2.00		R-6	60 100%	60 100%	R5	FR										
	2.00									48.20	J	15	U,R	FR	VT	N	
	3.00	50.0															
50 850	2.50	50.0							QUARTZITE, Gray, medium to coarse grained, fresh, very strong, extremely close to wide spaced discontinuities 51' - 52' Highly Fractured zone 53.9' - 55' Highly Fractured zone								
	2.50																
	2.50		R-7	57 95%	34 57%	R5	FR										
	2.50																
	2.50	55.0															
55	2.50	55.0							QUARTZITE, Gray, coarse grained, fresh, very strong, extremely close to wide spaced discontinuities 55' - 55.4' Highly Fractured zone								
	2.50																
	2.50		R-8	60 100%	48 80%	R5	FR			57.30	J	40	U,R	FR	T	N	
	2.50									58.30	J	0	P,R	DG	VT	N	
	2.50	60.0															
60 840	2.00	60.0							60.3 SHALE, Black, fine grained, fresh, moderately strong, very close discontinuities. 60.9 Highly Fractured zone 60.9' - 68.5' Video confirmed VOID [V-10] - (field logged as 62' - 69' VOID)								
	2.00																
	0.00		R-9	16 27%	0 0%												
	0.00																
	0.00	65.0															

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
	0.00	65.0							VOID								
	0.00																
	0.00		R-10	7 12%	0 0%												
	0.00								68.5								
	1.00	70.0							CLAY								No clay recovery but drilling indicated soft base.
70 830		70.0							69.5 SHALE, Black, fine grained 70.0								
	2.00								QUARTZITE, Dark gray, fine grained, slightly weathered, strong Iron stains on fractures Highly Fractured zone								Used 4200 gallons of water from 45 to 85 feet BGS.
	2.00																
	2.00		R-11	50 83%	24 40%	R3	SL										
	2.00								73.0 Anthracite COAL. Brittle.								
	1.00	75.0							75.0								
75		75.0							SLATE, Dark gray, very fine grained, fresh, strong, close spaced discontinuities Some Iron stains on fractures 79' - 80' Highly Fractured zone	75.70	J	35	P,R	FR	T	N	
	1.50									76.40	J	0	P,R	FR	PO	N	
	1.50									76.70	J	0	P,Sm	FR	PO	N	
	1.50		R-12	60 100%	35 58%	R4	FR			77.30	J	0	U,R	DS	W	Fe	
	1.50									77.70	J	0	P,R	DS	T	N	
	1.50									78.50	J	10	S,R	DS	PO	N	
	1.50	80.0															
80 820	1.50	80.0							SLATE, Black, very fine grained, slightly weathered, medium strong, extremely close to moderately spaced discontinuities 80' - 82' Occasional thin COAL bed 80' - 82' Highly Fractured zone								
	1.50																
	1.50		R-13	60 100%	36 60%	R3	SL			82.30	J	0	S,R	FR	VT	N	
	1.50																
▽	1.50	85.0															
85	1.50	85.0							SLATE, Black, very fine grained, fresh, strong, moderately spaced discontinuities								
	1.50									85.90	J	25	P,Sm	FR	VT	N	
	1.50									86.50	J	5	P,Sm	FR	VT	N	
	1.50		R-14	51 85%	44 73%	R4	FR										
	0.50																
	1.50	90.0							89' - 89.7' CLAY Soft. (R1)								

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
810	1.50	90.0							SLATE, Black, very fine grained, fresh, strong, moderately spaced discontinuities								
	1.50								91.0 QUARTZITE, Dark gray, fine grained, fresh, strong, extremely close to wide spaced discontinuities 92.7' - 93.6' Highly Fractured zone with vertical joints	91.70	J	0	P,R	FR	VT	N	
	1.50		R-15	56 93%	33 55%	R4	FR			92.00	J	0	P,R	FR	VT	N	
	1.50									92.30	J	15	P,R	FR	PO	N	
	1.50	95.0															
95	2.00	95.0							QUARTZITE, Gray, fine to coarse grained, fresh, very strong, wide spaced discontinuities								
	2.00																
	2.00		R-16	60 100%	60 100%	R5	FR			97.10	J	0	P,R	DS	VT	N	
	2.00																
	2.00	100.0															
100 800	3.00	100.0							QUARTZITE, Gray, fine to coarse grained, fresh, extremely strong, wide spaced discontinuities								
	3.00																
	2.00		R-17	60 100%	60 100%	R6	FR										
	2.00									103.50	J	10	U,R	FR	VT	N	
	2.00	105.0															
105	2.50	105.0							QUARTZITE, Gray, fine to coarse grained, fresh, extremely strong, wide spaced discontinuities								
	2.50																
	2.50		R-18	60 100%	60 100%	R6	FR										
	2.50																
	2.50	110.0															
110 790	3.00	110.0							QUARTZITE, Gray, fine to coarse grained, fresh, extremely strong, wide spaced discontinuities Graphite on some broken surfaces								
	3.00									111.80	J	0	S,R	FR	T	N	
	3.00		R-19	60 100%	60 100%	R6	FR			112.50	J	5	S,R	DG	PO	N	
	4.00																
	5.00	115.0								114.60	J	10	U,R	FR	VT		Graphite Infilling

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
	4.00	115.0							QUARTZITE, Gray, fine to coarse grained, fresh, extremely strong, wide spaced discontinuities Laminated by grain size	115.60	J	0	S,R	FR	W	N	
	4.00									116.20	J	10	U,R	FR	T	N	
	4.00		R-20	60 100%	58 97%	R6	FR										
	4.00									118.60	J	10	U,R	FR	PO	N	
	4.00	120.0															
120 780	4.00	120.0							QUARTZITE, Dark gray, fine to medium grained, fresh, extremely strong, wide spaced discontinuities								
	4.00									121.50	J	15	P,R	FR	T	N	
	4.00		R-21	60 100%	60 100%	R6	FR										
	4.00									123.20	J	20	P,R	FR	VT	Coal	
	4.00	125.0															
125	3.00	125.0							QUARTZITE, Dark gray, fine to medium grained, fresh, extremely strong, wide spaced discontinuities Occasional fine Shale interbedding								
	3.00																
	3.00		R-22	60 100%	60 100%	R6	FR										
	3.00																
	3.00	130.0															
130 770	2.50	130.0							QUARTZITE, Dark gray, fine to medium grained, fresh, extremely strong, wide spaced discontinuities Occasional fine Shale interbedding								
	2.50																
	2.50		R-23	60 100%	47 78%	R6	FR										
	3.00								133.7								
	3.00	135.0							SHALE, Black, very fine to fine grained, fresh, medium strong, extremely close spaced discontinuities 133.9' - 135' Highly Fractured zone								
135	3.00	135.0							135.4 QUARTZITE, Dark gray, fine grained, fresh, very strong, wide spaced discontinuities	135.20	J	5	P,R	DS	PO	N	
	3.00																
	3.00		R-24	60 100%	52 87%	R5	FR			137.40	J	70	U,R	DG	O	N	
	3.00									138.00	J	10	P,R	FR	T	N	
	3.00	140.0															

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-9**
Page **6** 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
760	1.50	140.0							QUARTZITE, Dark gray, fine to coarse grained, fresh, extremely strong, moderate spaced discontinuities Occasional Shale interbedding								
	1.50									141.50	B	15	P,Sm	FR	VT	N	
	1.50		R-25	60 100%	60 100%	R6	FR			142.40	J	30	P,R	FR	T	N	
	1.50									143.10	J	10	U,R	FR	VT	N	
	1.50	145.0															
145	1.50	145.0							QUARTZITE, Dark gray, fine to coarse grained, fresh, extremely strong, moderate to wide spaced discontinuities Occasional Shale interbedding								
	1.50									145.60	J	5	P,R	FR	T	N	
	1.50									145.90	J	5	P,R	FR	T	N	
	1.50		R-26	60 100%	60 100%	R6	FR			147.10	J	5	P,R	FR	T	N	
	2.00																
	2.00	150.0															
150 750	2.00	150.0							QUARTZITE, Dark gray, medium grained, fresh, extremely strong, wide spaced discontinuities								
	2.00																
	2.00		R-27	60 100%	60 100%	R6	FR										
	2.00																
	2.00	155.0															
155	3.00	155.0							QUARTZITE, Dark gray, medium grained, fresh, extremely strong, moderate to wide spaced discontinuities								
	3.50									156.50	J	10	P,R	FR	T	N	
	3.50		R-28	60 100%	56 93%	R5	FR			157.30	J	50	U,R	FR	VT	N	
										157.50	J	0	P,R	FR	T	N	
	3.50								2" thick Shale bed with very rich in Pyrite at 158'	158.00	J	0	P,R	FR	T	Py	
										159.00	J	30	U,R	FR	T	N	
	4.00	160.0							159.6	159.40	J	5	U,R	FR	T	N	
160 740	3.00	160.0							SHALE, Black, very fine to fine grained, fresh, medium strong 162.6' - 165' Highly Fractured zone								
	3.00									160.70	J	10	S,R	FR	VT	N	
	3.00									161.50	J	15	S,R	FR	VT	N	
	3.00		R-29	56 93%	33 55%	R3	FR			162.00	J	0	P,R	FR	VT	N	
	3.00								163.5								
	2.00	165.0							Anthracite COAL, Black, very fine grained, medium strong, brittle 165.0								

NOTES: Coal seam encountered

PROJECT NO.: **353754**

Boring No.: **B-9**

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
	2.50	165.0							SHALE, Dark gray, very fine grained, fresh, strong, close to wide spaced discontinuities								
	2.50									166.40	J	40	S,R	FR	VT	N	
	2.50		R-30	58 97%	54 90%	R4	FR			167.10	J	10	S,R	FR	PO	N	
	2.50																
	3.00	170.0															
170 730	2.50	170.0							SHALE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities								
	2.50																
	2.50		R-31	60 100%	60 100%	R4	FR			171.90	J	40	U,R	DS	O	N	
	2.50																
	2.50	175.0															
175	3.00	175.0							SHALE, Dark gray, very fine grained, fresh, strong, wide spaced discontinuities	174.80	J	0	S,R	DS	T	N	
	3.00																
	3.00		R-32	60 100%	25 42%	R4	FR		177.0 Anthracite COAL								
	3.00								178.8								
	3.00	180.0							SHALE, Dark gray, fine grained, fresh, strong 180.0								
180 720	2.50	180.0							QUARTZITE, Dark gray, fine to medium grained, fresh, extremely strong, wide to very wide spaced discontinuities								
	2.50																
	2.50		R-33	60 100%	60 100%	R6	FR										
	2.50																
	2.50	185.0															
185	3.00	185.0							QUARTZITE, Dark gray, fine to medium grained, fresh, very strong, wide to close spaced discontinuities 187.3' - 188' Highly Fractured zone with subvertical joins and Iron staining								
	3.00									186.60	J	10	S,R	DS	T	Fe	
	3.00		R-34	60 100%	51 85%	R5	FR										
	3.00																
	3.00	190.0															

NOTES: Coal seam encountered

PROJECT NO.: **353754**

Boring No.: **B-9**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-9**

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
710	3.00	190.0							QUARTZITE, Gray, medium grained, fresh, extremely strong, wide spaced discontinuities								
	3.00																
	3.00		R-35	60 100%	60 100%	R6	FR										
	3.00																
	3.00	195.0															
195	3.00	195.0							QUARTZITE, Gray, medium to fine grained, fresh, extremely strong, wide to close spaced discontinuities								
	3.00																
	3.00		R-36	60 100%	47 78%	R6	FR			197.70	J	0	U,R	FR	T	N	
	3.00									198.40	B	5	U,R	FR	PO	N	
	3.00	200.0								199.10	J	80	U,R	FR	VT	N	
200 700									200.0 End of Boring at 200 feet BGS. Borehole grouted with cement and bentonite hole plug.								
205																	
210 690																	

NOTES: Coal seam encountered

PROJECT NO.: **353754**

Boring No.: **B-9**

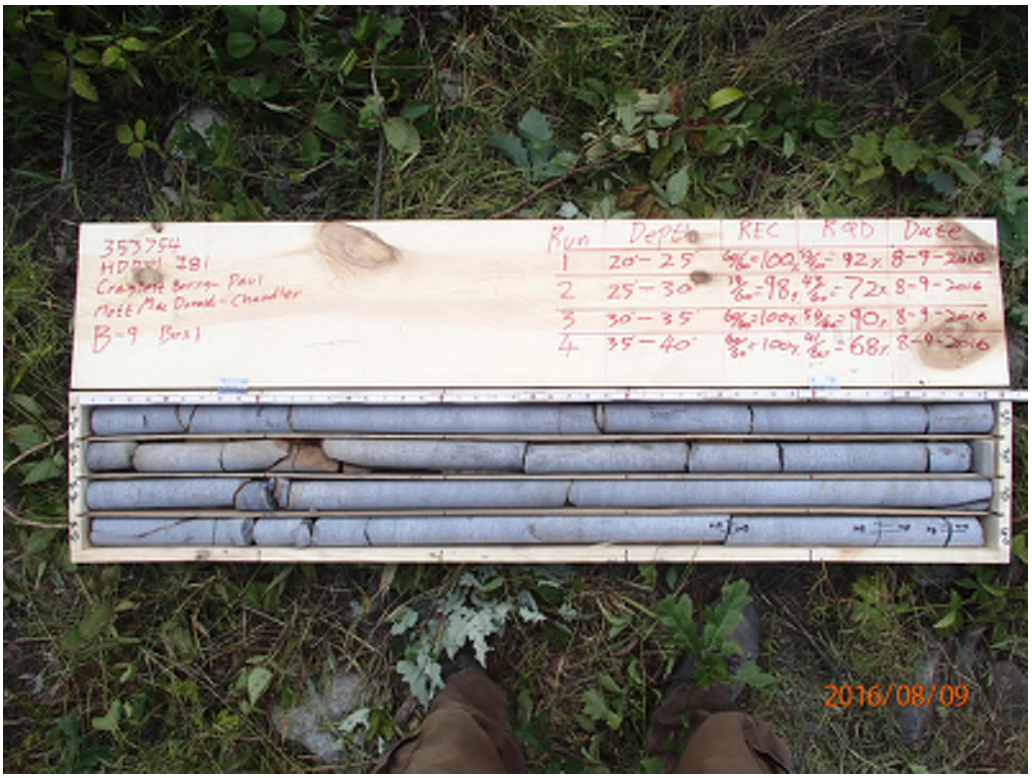


Figure B-9.1
B-9 Box 1 Runs 1-4 Dry

Figure B-9.2
B-9 Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-9

Figure B-9.3
B-9 Box 2 Runs 5-8 Dry

Figure B-9.4
B-9 Box 2 Runs 5-8 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-9

Figure B-9.5
B-9 Box 3 Runs 9-12 Dry

Figure B-9.6
B-9 Box 3 Runs 9-12 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-9

Figure B-9.7
B-9 Box 4 Runs 13-16 Dry

Figure B-9.8
B-9 Box 4 Runs 13-16 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-9

Figure B-9.9
B-9 Box 5 Runs 17-20 Dry

Figure B-9.10
B-9 Box 5 Runs 17-20 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-9

Figure B-9.11
B-9 Box 6 Runs 21-24 Dry

Figure B-9.12
B-9 Box 6 Runs 21-24 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-9

Figure B-9.13
B-9 Box 7 Runs 25-28 Dry

Figure B-9.14
B-9 Box 7 Runs 25-28 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-9

Figure B-9.15
B-9 Box 8 Runs 29-32 Dry

Figure B-9.16
B-9 Box 8 Runs 29-32 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-9

Figure B-9.17
B-9 Box 9 Runs 33-36 Dry

Figure B-9.18
B-9 Box 9 Runs 33-36 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-9

Appendix C

Installation Load and Stress Evaluation

MOTT MACDONALD

Project Name:	PennEast Pipeline	**By:**	S. Crouse
Project No:	353754	**Checked:**	G. Duyvestyn
HDD Name:	Interstate 81	**Owner:**	PennEast Pipeline
Location:	Northampton County, PA	**Date:**	2/14/2018

Horizontal Directional Drilling
Minimum Radius Calculations - MAOP Based

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	47.2	
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

Project Name: PennEast Pipeline
Project No: 353754
HDD Name: Interstate 81
Location: Northampton County, PA

By: S. Crouse
Checked: G. Duyvestyn
Owner: PennEast Pipeline
Date: 2/14/2018

Horizontal Directional Drilling
Operating Stress Analysis - MAOP Based

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	36.0	inches
Wall Thickness	0.762	inches
D/t Ratio	47.2	
MAOP	1480	psi
SMYS	70,000	psi
Modulus of Elasticity	2.90E+07	
Design Factor	0.5	
Poisson's Ratio	0.30	
Minimum Radius of Curvature	2600	feet
Coefficient of Thermal Expansion	6.39E-06	in/in/°F
Assumed Installation Temperature	45	°F
Assumed Operating Temperature	120	°F
Temperature Derating Factor	1	

Longitudinal Stress from Bending

Longitudinal Stress from Bending 16730.77 psi
Percent SMYS 23.90%

Hoop Stress

Calculated Hoop Stress 34960.63 psi Should be less than Design Factor x SMYS = 35000
Percent SMYS 49.94% Limited by Design Factor according to 49 CFR 192.11

Longitudinal Tensile Stress from Hoop Stress

Longitudinal Tensile Stress from Hoop Stress 10488.19 psi
Percent SMYS 14.98%

Longitudinal Stress from Thermal Expansion

Longitudinal Stress from Thermal Expansion -13898.3 psi
Percent SMYS 19.85% 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) -20140.8 psi
Percent SMYS 28.77% 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) 13320.71 psi
Percent SMYS 19.03% Limited by 90% SMYS by ASME/ANSI B31.8 section 833.3

Maximum Shear Stress

Maximum Shear Stress 27550.73 psi
Percent SMYS 39.36% Limited by 45% SMYS by ASME/ANSI B31.4 section 402.3.1

Combined Biaxial Stress Check

Combined Biaxial Stress Check 55101.46 psi
Percent SMYS 78.72% 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: M. Lockwood
Checked by: G. Duyvestyn
Date: 10/22/2018
Project No: 353754

PROJECT: PennEast Pipeline Project

HDD CROSSING LOCATION: Interstate 81 / State Route 315

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		540+49	16+474	0.0	0.0	762.0	232.3	--	--		134,285 lb	**67.1** tons
straight		540+57	16+477	8.9	2.7	760.9	231.9	48.0	1219.2	0.3	134,850 lb	**67.4** tons
straight		540+66	16+480	17.8	5.4	759.8	231.6	48.0	1219.2	0.3	135,415 lb	**67.7** tons
straight		540+75	16+482	26.7	8.1	758.7	231.3	48.0	1219.2	0.3	135,980 lb	**68.0** tons
straight		540+84	16+485	35.5	10.8	757.7	230.9	48.0	1219.2	0.3	136,545 lb	**68.3** tons
straight		540+93	16+488	44.4	13.5	756.6	230.6	48.0	1219.2	0.3	137,110 lb	**68.6** tons
straight		541+02	16+490	53.3	16.3	755.5	230.3	48.0	1219.2	0.3	137,675 lb	**68.8** tons
straight		541+10	16+493	62.2	19.0	754.4	229.9	48.0	1219.2	0.3	138,240 lb	**69.1** tons
straight		541+19	16+496	71.1	21.7	753.3	229.6	48.0	1219.2	0.3	138,805 lb	**69.4** tons
curve	vertical	541+47	16+504	98.6	30.0	750.1	228.6	48.0	1219.2	0.3	188,182 lb	**94.1** tons
curve	vertical	541+74	16+512	126.1	38.4	747.1	227.7	48.0	1219.2	0.3	192,389 lb	**96.2** tons
curve	vertical	542+01	16+521	153.6	46.8	744.2	226.8	48.0	1219.2	0.3	178,805 lb	**89.4** tons
curve	vertical	542+29	16+529	181.0	55.2	741.6	226.0	48.0	1219.2	0.3	173,225 lb	**86.6** tons
curve	vertical	542+56	16+537	208.5	63.6	739.2	225.3	48.0	1219.2	0.3	170,817 lb	**85.4** tons
curve	vertical	542+83	16+546	236.0	71.9	737.0	224.6	48.0	1219.2	0.3	169,971 lb	**85.0** tons
curve	vertical	543+11	16+554	263.5	80.3	735.0	224.0	48.0	1219.2	0.3	169,995 lb	**85.0** tons
curve	vertical	543+38	16+562	291.0	88.7	733.2	223.5	48.0	1219.2	0.3	170,543 lb	**85.3** tons
curve	vertical	543+66	16+571	318.5	97.1	731.6	223.0	48.0	1219.2	0.3	171,421 lb	**85.7** tons
curve	vertical	543+93	16+579	346.0	105.5	730.3	222.6	48.0	1219.2	0.3	172,514 lb	**86.3** tons
curve	vertical	544+21	16+588	373.5	113.8	729.1	222.2	48.0	1219.2	0.3	173,746 lb	**86.9** tons
curve	vertical	544+48	16+596	401.0	122.2	728.2	222.0	48.0	1219.2	0.3	175,069 lb	**87.5** tons
curve	vertical	544+75	16+604	428.4	130.6	727.4	221.7	48.0	1219.2	0.3	176,446 lb	**88.2** tons
curve	vertical	545+03	16+613	455.9	139.0	726.9	221.6	48.0	1219.2	0.3	177,853 lb	**88.9** tons
curve	vertical	545+30	16+621	483.4	147.3	726.6	221.5	48.0	1219.2	0.3	179,272 lb	**89.6** tons
curve	vertical	545+58	16+629	510.9	155.7	726.5	221.4	48.0	1219.2	0.3	180,688 lb	**90.3** tons
straight		545+66	16+632	518.8	158.1	726.5	221.4	48.0	1219.2	0.3	180,960 lb	**90.5** tons
straight		545+74	16+634	526.6	160.5	726.5	221.4	48.0	1219.2	0.3	181,233 lb	**90.6** tons
straight		545+82	16+637	534.5	162.9	726.5	221.4	48.0	1219.2	0.3	181,506 lb	**90.8** tons
straight		545+89	16+639	542.4	165.3	726.5	221.4	48.0	1219.2	0.3	181,778 lb	**90.9** tons
curve	vertical	546+34	16+653	586.5	178.8	726.8	221.5	48.0	1219.2	0.3	213,275 lb	**106.6** tons
curve	vertical	546+78	16+666	630.7	192.2	727.6	221.8	48.0	1219.2	0.3	217,905 lb	**109.0** tons
curve	vertical	547+22	16+679	674.9	205.7	728.9	222.2	48.0	1219.2	0.3	210,667 lb	**105.3** tons
curve	vertical	547+66	16+693	719.1	219.2	730.8	222.8	48.0	1219.2	0.3	208,298 lb	**104.1** tons
curve	vertical	548+10	16+706	763.3	232.6	733.3	223.5	48.0	1219.2	0.3	207,786 lb	**103.9** tons
curve	vertical	548+54	16+720	807.4	246.1	736.3	224.4	48.0	1219.2	0.3	208,124 lb	**104.1** tons
curve	vertical	548+98	16+733	851.6	259.6	739.8	225.5	48.0	1219.2	0.3	208,877 lb	**104.4** tons
curve	vertical	549+42	16+747	895.8	273.0	743.8	226.7	48.0	1219.2	0.3	209,826 lb	**104.9** tons
curve	vertical	549+86	16+760	940.0	286.5	748.4	228.1	48.0	1219.2	0.3	210,847 lb	**105.4** tons
curve	vertical	550+30	16+773	984.1	300.0	753.6	229.7	48.0	1219.2	0.3	211,865 lb	**105.9** tons
curve	vertical	550+74	16+787	1,028.3	313.4	759.3	231.4	48.0	1219.2	0.3	212,833 lb	**106.4** tons
curve	vertical	551+18	16+800	1,072.5	326.9	765.5	233.3	48.0	1219.2	0.3	213,492 lb	**106.7** tons
curve	vertical	551+61	16+813	1,116.7	340.4	772.2	235.4	48.0	1219.2	0.3	217,589 lb	**108.8** tons
curve	vertical	552+05	16+827	1,160.9	353.8	779.5	237.6	48.0	1219.2	0.3	221,724 lb	**110.9** tons
curve	vertical	552+48	16+840	1,205.0	367.3	787.3	240.0	48.0	1219.2	0.3	225,907 lb	**113.0** tons
curve	vertical	552+92	16+853	1,249.2	380.8	795.7	242.5	48.0	1219.2	0.3	230,146 lb	**115.1** tons
straight		553+24	16+863	1,281.9	390.7	802.0	244.5	48.0	1219.2	0.3	233,494 lb	**116.7** tons
straight		553+56	16+873	1,314.5	400.7	808.4	246.4	48.0	1219.2	0.3	236,843 lb	**118.4** tons
straight		553+88	16+882	1,347.1	410.6	814.8	248.3	48.0	1219.2	0.3	240,191 lb	**120.1** tons
straight		554+20	16+892	1,379.7	420.5	821.1	250.3	48.0	1219.2	0.3	243,540 lb	**121.8** tons
straight		554+52	16+902	1,412.4	430.5	827.5	252.2	48.0	1219.2	0.3	246,888 lb	**123.4** tons
straight		554+84	16+912	1,445.0	440.4	833.9	254.2	48.0	1219.2	0.3	250,237 lb	**125.1** tons
straight		555+16	16+921	1,477.6	450.4	840.2	256.1	48.0	1219.2	0.3	253,585 lb	**126.8** tons
straight		555+48	16+931	1,510.2	460.3	846.6	258.0	48.0	1219.2	0.3	256,934 lb	**128.5** tons
straight		555+80	16+941	1,542.9	470.3	853.0	260.0	48.0	1219.2	0.3	260,282 lb	**130.1** tons
straight		556+12	16+951	1,575.5	480.2	859.3	261.9	48.0	1219.2	0.3	263,631 lb	**131.8** tons
straight		556+44	16+960	1,608.1	490.2	865.7	263.9	48.0	1219.2	0.3	266,980 lb	**133.5** tons
straight		556+76	16+970	1,640.8	500.1	872.1	265.8	48.0	1219.2	0.3	270,328 lb	**135.2** tons
straight		557+08	16+980	1,673.4	510.1	878.4	267.7	48.0	1219.2	0.3	275,743 lb	**137.9** tons
straight		557+40	16+990	1,706.0	520.0	884.8	269.7	48.0	1219.2	0.3	281,159 lb	**140.6** tons
straight		557+72	16+999	1,738.6	529.9	891.2	271.6	48.0	1219.2	0.3	286,574 lb	**143.3** tons
HDD Rig Location		558+04	17+009	1,771.3	539.9	897.5	273.6	48.0	1219.2	0.3	291,989 lb	**146.0** 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				
1,592	10.98	2.27%	0	0.00	0.00%	0.0	0.00	0.00%	0.03	Yes	0.00	Yes
1,599	11.02	2.28%	0	0.00	0.00%	13.3	0.09	0.02%	0.03	Yes	0.00	Yes
1,605	11.07	2.29%	0	0.00	0.00%	26.6	0.18	0.04%	0.03	Yes	0.00	Yes
1,612	11.11	2.30%	0	0.00	0.00%	39.9	0.27	0.06%	0.03	Yes	0.00	Yes
1,619	11.16	2.31%	0	0.00	0.00%	53.2	0.37	0.08%	0.03	Yes	0.00	Yes
1,625	11.21	2.32%	0	0.00	0.00%	66.4	0.46	0.09%	0.03	Yes	0.00	Yes
1,632	11.25	2.33%	0	0.00	0.00%	79.7	0.55	0.11%	0.03	Yes	0.00	Yes
1,639	11.30	2.34%	0	0.00	0.00%	93.0	0.64	0.13%	0.03	Yes	0.00	Yes
1,645	11.35	2.35%	0	0.00	0.00%	106.3	0.73	0.15%	0.03	Yes	0.00	Yes
2,231	15.38	3.19%	12,167	83.89	17.38%	146.1	1.01	0.21%	0.31	Yes	0.07	Yes
2,281	15.72	3.26%	12,167	83.89	17.38%	183.4	1.26	0.26%	0.31	Yes	0.07	Yes
2,120	14.61	3.03%	12,167	83.89	17.38%	218.1	1.50	0.31%	0.31	Yes	0.07	Yes
2,053	14.16	2.93%	12,167	83.89	17.38%	250.3	1.73	0.36%	0.31	Yes	0.07	Yes
2,025	13.96	2.89%	12,167	83.89	17.38%	279.8	1.93	0.40%	0.31	Yes	0.07	Yes
2,015	13.89	2.88%	12,167	83.89	17.38%	306.9	2.12	0.44%	0.31	Yes	0.07	Yes
2,015	13.89	2.88%	12,167	83.89	17.38%	331.3	2.28	0.47%	0.31	Yes	0.07	Yes
2,022	13.94	2.89%	12,167	83.89	17.38%	353.2	2.44	0.50%	0.31	Yes	0.07	Yes
2,032	14.01	2.90%	12,167	83.89	17.38%	372.5	2.57	0.53%	0.31	Yes	0.07	Yes
2,045	14.10	2.92%	12,167	83.89	17.38%	389.2	2.68	0.56%	0.31	Yes	0.07	Yes
2,060	14.20	2.94%	12,167	83.89	17.38%	403.4	2.78	0.58%	0.31	Yes	0.07	Yes
2,075	14.31	2.96%	12,167	83.89	17.38%	415.0	2.86	0.59%	0.31	Yes	0.07	Yes
2,092	14.42	2.99%	12,167	83.89	17.38%	424.0	2.92	0.61%	0.31	Yes	0.07	Yes
2,108	14.54	3.01%	12,167	83.89	17.38%	430.4	2.97	0.61%	0.31	Yes	0.07	Yes
2,125	14.65	3.04%	12,167	83.89	17.38%	434.3	2.99	0.62%	0.31	Yes	0.07	Yes
2,142	14.77	3.06%	12,167	83.89	17.38%	435.6	3.00	0.62%	0.31	Yes	0.08	Yes
2,145	14.79	3.06%	0	0.00	0.00%	435.6	3.00	0.62%	0.04	Yes	0.01	Yes
2,148	14.81	3.07%	0	0.00	0.00%	435.6	3.00	0.62%	0.04	Yes	0.01	Yes
2,152	14.84	3.07%	0	0.00	0.00%	435.6	3.00	0.62%	0.04	Yes	0.01	Yes
2,155	14.86	3.08%	0	0.00	0.00%	435.6	3.00	0.62%	0.04	Yes	0.01	Yes
2,528	17.43	3.61%	12,167	83.89	17.38%	432.2	2.98	0.62%	0.32	Yes	0.08	Yes
2,583	17.81	3.69%	12,167	83.89	17.38%	422.3	2.91	0.60%	0.32	Yes	0.08	Yes
2,497	17.22	3.57%	12,167	83.89	17.38%	405.6	2.80	0.58%	0.32	Yes	0.08	Yes
2,469	17.03	3.53%	12,167	83.89	17.38%	382.4	2.64	0.55%	0.32	Yes	0.08	Yes
2,463	16.98	3.52%	12,167	83.89	17.38%	352.4	2.43	0.50%	0.32	Yes	0.08	Yes
2,467	17.01	3.52%	12,167	83.89	17.38%	315.9	2.18	0.45%	0.32	Yes	0.07	Yes
2,476	17.07	3.54%	12,167	83.89	17.38%	272.7	1.88	0.39%	0.32	Yes	0.07	Yes
2,487	17.15	3.55%	12,167	83.89	17.38%	222.9	1.54	0.32%	0.32	Yes	0.07	Yes
2,499	17.23	3.57%	12,167	83.89	17.38%	166.4	1.15	0.24%	0.32	Yes	0.07	Yes
2,512	17.32	3.59%	12,167	83.89	17.38%	103.4	0.71	0.15%	0.32	Yes	0.07	Yes
2,523	17.40	3.60%	12,167	83.89	17.38%	33.7	0.23	0.05%	0.32	Yes	0.07	Yes
2,531	17.45	3.62%	12,167	83.89	17.38%	-42.5	-0.29	-0.06%	0.32	Yes	0.07	Yes
2,579	17.78	3.68%	12,167	83.89	17.38%	-125.4	-0.86	-0.18%	0.32	Yes	0.07	Yes
2,628	18.12	3.75%	12,167	83.89	17.38%	-214.8	-1.48	-0.31%	0.32	Yes	0.07	Yes
2,678	18.46	3.83%	12,167	83.89	17.38%	-310.7	-2.14	-0.44%	0.32	Yes	0.07	Yes
2,728	18.81	3.90%	12,167	83.89	17.38%	-413.2	-2.85	-0.59%	0.32	Yes	0.07	Yes
2,768	19.08	3.95%	0	0.00	0.00%	-491.3	-3.39	-0.70%	0.05	Yes	0.00	Yes
2,808	19.36	4.01%	0	0.00	0.00%	-569.4	-3.93	-0.81%	0.05	Yes	0.01	Yes
2,847	19.63	4.07%	0	0.00	0.00%	-647.5	-4.46	-0.93%	0.05	Yes	0.01	Yes
2,887	19.91	4.12%	0	0.00	0.00%	-725.6	-5.00	-1.04%	0.05	Yes	0.01	Yes
2,927	20.18	4.18%	0	0.00	0.00%	-803.7	-5.54	-1.15%	0.05	Yes	0.01	Yes
2,966	20.45	4.24%	0	0.00	0.00%	-881.8	-6.08	-1.26%	0.05	Yes	0.01	Yes
3,006	20.73	4.29%	0	0.00	0.00%	-960.0	-6.62	-1.37%	0.05	Yes	0.01	Yes
3,046	21.00	4.35%	0	0.00	0.00%	-1,038.1	-7.16	-1.48%	0.05	Yes	0.02	Yes
3,086	21.27	4.41%	0	0.00	0.00%	-1,116.2	-7.70	-1.59%	0.06	Yes	0.02	Yes
3,125	21.55	4.46%	0	0.00	0.00%	-1,194.3	-8.23	-1.71%	0.06	Yes	0.02	Yes
3,165	21.82	4.52%	0	0.00	0.00%	-1,272.4	-8.77	-1.82%	0.06	Yes	0.03	Yes
3,205	22.09	4.58%	0	0.00	0.00%	-1,350.5	-9.31	-1.93%	0.06	Yes	0.03	Yes
3,269	22.54	4.67%	0	0.00	0.00%	234.3	1.62	0.33%	0.06	Yes	0.03	Yes
3,333	22.98	4.76%	0	0.00	0.00%	156.2	1.08	0.22%	0.06	Yes	0.04	Yes
3,397	23.42	4.85%	0	0.00	0.00%	78.1	0.54	0.11%	0.06	Yes	0.04	Yes
3,461	23.87	4.94%	0	0.00	0.00%	0.0	0.00	0.00%	0.06	Yes	0.04	Yes

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

Ground Elevation at Pipe Entry	762.00	feet
	232.26	metres
Ground Elevation at Pipe Exit	897.52	feet
	273.57	metres

	TOTAL PULL LOADS		
Maximum Values	291,989	lb	146.0 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		
3,461	23.9	4.94%	12,167	83.9	17.38%	436	3.0	0.62%	0.32	0.08

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	2.92E+07	psi
	201327	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	291,989	lb
	1,299	kN
Factor of Safety	12.1	
Start-Up Load Factor	1.5	
Maximum Calculated Start-Up Pipe Pull Load	437,984	lb
	1,948	kN
Factor of Safety	8.1	

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)	0.25	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	18	lb/100ft^2 (Based on HDD experience from previous installations)
	86.184	dyne/cm^2
Plastic Viscosity	12	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	600	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	2.271	m^3/min
Drilling mud pumping rate	1129	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.273	m^3/min
Pipe Pullback Rate	10	feet/min (Based on HDD experience)
	3.05	m/min

MOTT MACDONALD

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

Calculated by: M. Lockwood
Checked by: G. Duyvestyn
Date: 10/22/2018
Project No: 353754

PROJECT: PennEast Pipeline Project

HDD CROSSING LOCATION: Interstate 81 / State Route 315

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		540+49	16+474	0.0	0.0	762.0	232.3	--	--		134,285 lb	**67.1** tons
straight		540+57	16+477	8.9	2.7	760.9	231.9	48.0	1219.2	0.3	134,203 lb	**67.1** tons
straight		540+66	16+480	17.8	5.4	759.8	231.6	48.0	1219.2	0.3	134,122 lb	**67.1** tons
straight		540+75	16+482	26.7	8.1	758.7	231.3	48.0	1219.2	0.3	134,040 lb	**67.0** tons
straight		540+84	16+485	35.5	10.8	757.7	230.9	48.0	1219.2	0.3	133,958 lb	**67.0** tons
straight		540+93	16+488	44.4	13.5	756.6	230.6	48.0	1219.2	0.3	133,877 lb	**66.9** tons
straight		541+02	16+490	53.3	16.3	755.5	230.3	48.0	1219.2	0.3	133,795 lb	**66.9** tons
straight		541+10	16+493	62.2	19.0	754.4	229.9	48.0	1219.2	0.3	133,713 lb	**66.9** tons
straight		541+19	16+496	71.1	21.7	753.3	229.6	48.0	1219.2	0.3	133,632 lb	**66.8** tons
curve	vertical	541+47	16+504	98.6	30.0	750.1	228.6	48.0	1219.2	0.3	180,594 lb	**90.3** tons
curve	vertical	541+74	16+512	126.1	38.4	747.1	227.7	48.0	1219.2	0.3	176,332 lb	**88.2** tons
curve	vertical	542+01	16+521	153.6	46.8	744.2	226.8	48.0	1219.2	0.3	157,410 lb	**78.7** tons
curve	vertical	542+29	16+529	181.0	55.2	741.6	226.0	48.0	1219.2	0.3	146,564 lb	**73.3** tons
curve	vertical	542+56	16+537	208.5	63.6	739.2	225.3	48.0	1219.2	0.3	138,965 lb	**69.5** tons
curve	vertical	542+83	16+546	236.0	71.9	737.0	224.6	48.0	1219.2	0.3	133,003 lb	**66.5** tons
curve	vertical	543+11	16+554	263.5	80.3	735.0	224.0	48.0	1219.2	0.3	127,989 lb	**64.0** tons
curve	vertical	543+38	16+562	291.0	88.7	733.2	223.5	48.0	1219.2	0.3	123,579 lb	**61.8** tons
curve	vertical	543+66	16+571	318.5	97.1	731.6	223.0	48.0	1219.2	0.3	121,867 lb	**60.9** tons
curve	vertical	543+93	16+579	346.0	105.5	730.3	222.6	48.0	1219.2	0.3	122,971 lb	**61.5** tons
curve	vertical	544+21	16+588	373.5	113.8	729.1	222.2	48.0	1219.2	0.3	123,909 lb	**62.0** tons
curve	vertical	544+48	16+596	401.0	122.2	728.2	222.0	48.0	1219.2	0.3	124,730 lb	**62.4** tons
curve	vertical	544+75	16+604	428.4	130.6	727.4	221.7	48.0	1219.2	0.3	125,468 lb	**62.7** tons
curve	vertical	545+03	16+613	455.9	139.0	726.9	221.6	48.0	1219.2	0.3	126,146 lb	**63.1** tons
curve	vertical	545+30	16+621	483.4	147.3	726.6	221.5	48.0	1219.2	0.3	126,781 lb	**63.4** tons
curve	vertical	545+58	16+629	510.9	155.7	726.5	221.4	48.0	1219.2	0.3	127,386 lb	**63.7** tons
straight		545+66	16+632	518.8	158.1	726.5	221.4	48.0	1219.2	0.3	127,473 lb	**63.7** tons
straight		545+74	16+634	526.6	160.5	726.5	221.4	48.0	1219.2	0.3	127,559 lb	**63.8** tons
straight		545+82	16+637	534.5	162.9	726.5	221.4	48.0	1219.2	0.3	127,646 lb	**63.8** tons
straight		545+89	16+639	542.4	165.3	726.5	221.4	48.0	1219.2	0.3	127,732 lb	**63.9** tons
curve	vertical	546+34	16+653	586.5	178.8	726.8	221.5	48.0	1219.2	0.3	155,900 lb	**77.9** tons
curve	vertical	546+78	16+666	630.7	192.2	727.6	221.8	48.0	1219.2	0.3	150,370 lb	**75.2** tons
curve	vertical	547+22	16+679	674.9	205.7	728.9	222.2	48.0	1219.2	0.3	136,695 lb	**68.3** tons
curve	vertical	547+66	16+693	719.1	219.2	730.8	222.8	48.0	1219.2	0.3	128,108 lb	**64.1** tons
curve	vertical	548+10	16+706	763.3	232.6	733.3	223.5	48.0	1219.2	0.3	121,606 lb	**60.8** tons
curve	vertical	548+54	16+720	807.4	246.1	736.3	224.4	48.0	1219.2	0.3	122,315 lb	**61.2** tons
curve	vertical	548+98	16+733	851.6	259.6	739.8	225.5	48.0	1219.2	0.3	124,750 lb	**62.4** tons
curve	vertical	549+42	16+747	895.8	273.0	743.8	226.7	48.0	1219.2	0.3	126,896 lb	**63.4** tons
curve	vertical	549+86	16+760	940.0	286.5	748.4	228.1	48.0	1219.2	0.3	128,869 lb	**64.4** tons
curve	vertical	550+30	16+773	984.1	300.0	753.6	229.7	48.0	1219.2	0.3	130,739 lb	**65.4** tons
curve	vertical	550+74	16+787	1,028.3	313.4	759.3	231.4	48.0	1219.2	0.3	132,551 lb	**66.3** tons
curve	vertical	551+18	16+800	1,072.5	326.9	765.5	233.3	48.0	1219.2	0.3	162,509 lb	**81.3** tons
curve	vertical	551+61	16+813	1,116.7	340.4	772.2	235.4	48.0	1219.2	0.3	166,882 lb	**83.4** tons
curve	vertical	552+05	16+827	1,160.9	353.8	779.5	237.6	48.0	1219.2	0.3	171,291 lb	**85.6** tons
curve	vertical	552+48	16+840	1,205.0	367.3	787.3	240.0	48.0	1219.2	0.3	175,746 lb	**87.9** tons
curve	vertical	552+92	16+853	1,249.2	380.8	795.7	242.5	48.0	1219.2	0.3	180,254 lb	**90.1** tons
straight		553+24	16+863	1,281.9	390.7	802.0	244.5	48.0	1219.2	0.3	183,603 lb	**91.8** tons
straight		553+56	16+873	1,314.5	400.7	808.4	246.4	48.0	1219.2	0.3	186,951 lb	**93.5** tons
straight		553+88	16+882	1,347.1	410.6	814.8	248.3	48.0	1219.2	0.3	190,300 lb	**95.1** tons
straight		554+20	16+892	1,379.7	420.5	821.1	250.3	48.0	1219.2	0.3	193,648 lb	**96.8** tons
straight		554+52	16+902	1,412.4	430.5	827.5	252.2	48.0	1219.2	0.3	196,997 lb	**98.5** tons
straight		554+84	16+912	1,445.0	440.4	833.9	254.2	48.0	1219.2	0.3	200,345 lb	**100.2** tons
straight		555+16	16+921	1,477.6	450.4	840.2	256.1	48.0	1219.2	0.3	203,694 lb	**101.8** tons
straight		555+48	16+931	1,510.2	460.3	846.6	258.0	48.0	1219.2	0.3	207,042 lb	**103.5** tons
straight		555+80	16+941	1,542.9	470.3	853.0	260.0	48.0	1219.2	0.3	210,391 lb	**105.2** tons
straight		556+12	16+951	1,575.5	480.2	859.3	261.9	48.0	1219.2	0.3	213,739 lb	**106.9** tons
straight		556+44	16+960	1,608.1	490.2	865.7	263.9	48.0	1219.2	0.3	217,088 lb	**108.5** tons
straight		556+76	16+970	1,640.8	500.1	872.1	265.8	48.0	1219.2	0.3	220,436 lb	**110.2** tons
straight		557+08	16+980	1,673.4	510.1	878.4	267.7	48.0	1219.2	0.3	225,852 lb	**112.9** tons
straight		557+40	16+990	1,706.0	520.0	884.8	269.7	48.0	1219.2	0.3	231,267 lb	**115.6** tons
straight		557+72	16+999	1,738.6	529.9	891.2	271.6	48.0	1219.2	0.3	236,683 lb	**118.3** tons
HDD Rig Location		558+04	17+009	1,771.3	539.9	897.5	273.6	48.0	1219.2	0.3	242,098 lb	**121.0** 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				
1,592	10.98	2.27%	0	0.00	0.00%	0.0	0.00	0.00%	0.03	Yes	0.00	Yes
1,591	10.97	2.27%	0	0.00	0.00%	2.2	0.02	0.00%	0.03	Yes	0.00	Yes
1,590	10.96	2.27%	0	0.00	0.00%	4.4	0.03	0.01%	0.03	Yes	0.00	Yes
1,589	10.96	2.27%	0	0.00	0.00%	6.6	0.05	0.01%	0.03	Yes	0.00	Yes
1,588	10.95	2.27%	0	0.00	0.00%	8.8	0.06	0.01%	0.03	Yes	0.00	Yes
1,587	10.94	2.27%	0	0.00	0.00%	11.0	0.08	0.02%	0.03	Yes	0.00	Yes
1,586	10.94	2.27%	0	0.00	0.00%	13.2	0.09	0.02%	0.03	Yes	0.00	Yes
1,585	10.93	2.26%	0	0.00	0.00%	15.4	0.11	0.02%	0.03	Yes	0.00	Yes
1,584	10.92	2.26%	0	0.00	0.00%	17.6	0.12	0.03%	0.03	Yes	0.00	Yes
2,141	14.76	3.06%	12,167	83.89	17.38%	24.2	0.17	0.03%	0.31	Yes	0.07	Yes
2,090	14.41	2.99%	12,167	83.89	17.38%	30.4	0.21	0.04%	0.31	Yes	0.07	Yes
1,866	12.87	2.67%	12,167	83.89	17.38%	36.2	0.25	0.05%	0.31	Yes	0.06	Yes
1,737	11.98	2.48%	12,167	83.89	17.38%	41.5	0.29	0.06%	0.30	Yes	0.06	Yes
1,647	11.36	2.35%	12,167	83.89	17.38%	46.4	0.32	0.07%	0.30	Yes	0.06	Yes
1,577	10.87	2.25%	12,167	83.89	17.38%	50.9	0.35	0.07%	0.30	Yes	0.06	Yes
1,517	10.46	2.17%	12,167	83.89	17.38%	54.9	0.38	0.08%	0.30	Yes	0.06	Yes
1,465	10.10	2.09%	12,167	83.89	17.38%	58.5	0.40	0.08%	0.30	Yes	0.06	Yes
1,445	9.96	2.06%	12,167	83.89	17.38%	61.7	0.43	0.09%	0.30	Yes	0.06	Yes
1,458	10.05	2.08%	12,167	83.89	17.38%	64.5	0.44	0.09%	0.30	Yes	0.06	Yes
1,469	10.13	2.10%	12,167	83.89	17.38%	66.9	0.46	0.10%	0.30	Yes	0.06	Yes
1,479	10.19	2.11%	12,167	83.89	17.38%	68.8	0.47	0.10%	0.30	Yes	0.06	Yes
1,487	10.26	2.12%	12,167	83.89	17.38%	70.3	0.48	0.10%	0.30	Yes	0.06	Yes
1,495	10.31	2.14%	12,167	83.89	17.38%	71.4	0.49	0.10%	0.30	Yes	0.06	Yes
1,503	10.36	2.15%	12,167	83.89	17.38%	72.0	0.50	0.10%	0.30	Yes	0.06	Yes
1,510	10.41	2.16%	12,167	83.89	17.38%	72.2	0.50	0.10%	0.30	Yes	0.06	Yes
1,511	10.42	2.16%	0	0.00	0.00%	72.2	0.50	0.10%	0.03	Yes	0.00	Yes
1,512	10.43	2.16%	0	0.00	0.00%	72.2	0.50	0.10%	0.03	Yes	0.00	Yes
1,513	10.43	2.16%	0	0.00	0.00%	72.2	0.50	0.10%	0.03	Yes	0.00	Yes
1,514	10.44	2.16%	0	0.00	0.00%	72.2	0.50	0.10%	0.03	Yes	0.00	Yes
1,848	12.74	2.64%	12,167	83.89	17.38%	71.7	0.49	0.10%	0.31	Yes	0.06	Yes
1,783	12.29	2.55%	12,167	83.89	17.38%	70.0	0.48	0.10%	0.30	Yes	0.06	Yes
1,620	11.17	2.31%	12,167	83.89	17.38%	67.2	0.46	0.10%	0.30	Yes	0.06	Yes
1,519	10.47	2.17%	12,167	83.89	17.38%	63.4	0.44	0.09%	0.30	Yes	0.06	Yes
1,442	9.94	2.06%	12,167	83.89	17.38%	58.4	0.40	0.08%	0.30	Yes	0.06	Yes
1,450	10.00	2.07%	12,167	83.89	17.38%	52.4	0.36	0.07%	0.30	Yes	0.06	Yes
1,479	10.20	2.11%	12,167	83.89	17.38%	45.2	0.31	0.06%	0.30	Yes	0.06	Yes
1,504	10.37	2.15%	12,167	83.89	17.38%	36.9	0.25	0.05%	0.30	Yes	0.06	Yes
1,528	10.53	2.18%	12,167	83.89	17.38%	27.6	0.19	0.04%	0.30	Yes	0.06	Yes
1,550	10.69	2.21%	12,167	83.89	17.38%	17.1	0.12	0.02%	0.30	Yes	0.06	Yes
1,571	10.83	2.24%	12,167	83.89	17.38%	5.6	0.04	0.01%	0.30	Yes	0.06	Yes
1,926	13.28	2.75%	12,167	83.89	17.38%	-7.1	-0.05	-0.01%	0.31	Yes	0.06	Yes
1,978	13.64	2.83%	12,167	83.89	17.38%	-20.8	-0.14	-0.03%	0.31	Yes	0.06	Yes
2,031	14.00	2.90%	12,167	83.89	17.38%	-35.6	-0.25	-0.05%	0.31	Yes	0.06	Yes
2,083	14.36	2.98%	12,167	83.89	17.38%	-51.5	-0.36	-0.07%	0.31	Yes	0.06	Yes
2,137	14.73	3.05%	12,167	83.89	17.38%	-68.5	-0.47	-0.10%	0.31	Yes	0.06	Yes
2,177	15.01	3.11%	0	0.00	0.00%	-81.4	-0.56	-0.12%	0.04	Yes	0.00	Yes
2,216	15.28	3.17%	0	0.00	0.00%	-94.4	-0.65	-0.13%	0.04	Yes	0.00	Yes
2,256	15.55	3.22%	0	0.00	0.00%	-107.3	-0.74	-0.15%	0.04	Yes	0.00	Yes
2,296	15.83	3.28%	0	0.00	0.00%	-120.3	-0.83	-0.17%	0.04	Yes	0.00	Yes
2,335	16.10	3.34%	0	0.00	0.00%	-133.2	-0.92	-0.19%	0.04	Yes	0.00	Yes
2,375	16.38	3.39%	0	0.00	0.00%	-146.2	-1.01	-0.21%	0.04	Yes	0.00	Yes
2,415	16.65	3.45%	0	0.00	0.00%	-159.1	-1.10	-0.23%	0.04	Yes	0.00	Yes
2,454	16.92	3.51%	0	0.00	0.00%	-172.1	-1.19	-0.25%	0.04	Yes	0.00	Yes
2,494	17.20	3.56%	0	0.00	0.00%	-185.0	-1.28	-0.26%	0.04	Yes	0.00	Yes
2,534	17.47	3.62%	0	0.00	0.00%	-198.0	-1.37	-0.28%	0.05	Yes	0.00	Yes
2,573	17.74	3.68%	0	0.00	0.00%	-210.9	-1.45	-0.30%	0.05	Yes	0.00	Yes
2,613	18.02	3.73%	0	0.00	0.00%	-223.9	-1.54	-0.32%	0.05	Yes	0.00	Yes
2,677	18.46	3.82%	0	0.00	0.00%	38.8	0.27	0.06%	0.05	Yes	0.00	Yes
2,742	18.90	3.92%	0	0.00	0.00%	25.9	0.18	0.04%	0.05	Yes	0.00	Yes
2,806	19.35	4.01%	0	0.00	0.00%	12.9	0.09	0.02%	0.05	Yes	0.00	Yes
2,870	19.79	4.10%	0	0.00	0.00%	0.0	0.00	0.00%	0.05	Yes	0.00	Yes

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

Ground Elevation at Pipe Entry	762.00	feet
	232.26	metres
Ground Elevation at Pipe Exit	897.52	feet
	273.57	metres

	TOTAL PULL LOADS		
Maximum Values	242,098	lb	121.0 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		
2,870	19.8	4.10%	12,167	83.9	17.38%	72	0.5	0.10%	0.31	0.07

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	2.92E+07	psi
	201327	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	242,098	lb
	1,077	kN
Factor of Safety	14.6	

Start-Up Load Factor	1.5	
Maximum Calculated Start-Up Pipe Pull Load	363,147	lb
	1,615	kN
Factor of Safety	9.8	

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)	0.25	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	18	lb/100ft^2 (Based on HDD experience from previous installations)
	86.184	dyne/cm^2
Plastic Viscosity	12	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	600	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	2.271	m^3/min
Drilling mud pumping rate	1129	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.273	m^3/min
Pipe Pullback Rate	10	feet/min (Based on HDD experience)
	3.05	m/min

MOTT MACDONALD

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

Calculated by: M. Lockwood
Checked by: G. Duyvestyn
Date: 10/22/2018
Project No: 353754

PROJECT: PennEast Pipeline Project

HDD CROSSING LOCATION: Interstate 81 / State Route 315

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		540+49	16+474	0.0	0.0	762.0	232.3	--	--		134,285 lb	**67.1** tons
straight		540+57	16+477	8.9	2.7	760.9	231.9	48.0	1219.2	0.3	135,047 lb	**67.5** tons
straight		540+66	16+480	17.8	5.4	759.8	231.6	48.0	1219.2	0.3	135,809 lb	**67.9** tons
straight		540+75	16+482	26.7	8.1	758.7	231.3	48.0	1219.2	0.3	136,572 lb	**68.3** tons
straight		540+84	16+485	35.5	10.8	757.7	230.9	48.0	1219.2	0.3	137,334 lb	**68.7** tons
straight		540+93	16+488	44.4	13.5	756.6	230.6	48.0	1219.2	0.3	138,096 lb	**69.0** tons
straight		541+02	16+490	53.3	16.3	755.5	230.3	48.0	1219.2	0.3	138,858 lb	**69.4** tons
straight		541+10	16+493	62.2	19.0	754.4	229.9	48.0	1219.2	0.3	139,621 lb	**69.8** tons
straight		541+19	16+496	71.1	21.7	753.3	229.6	48.0	1219.2	0.3	140,383 lb	**70.2** tons
curve	vertical	541+47	16+504	98.6	30.0	750.1	228.6	48.0	1219.2	0.3	190,020 lb	**95.0** tons
curve	vertical	541+74	16+512	126.1	38.4	747.1	227.7	48.0	1219.2	0.3	195,393 lb	**97.7** tons
curve	vertical	542+01	16+521	153.6	46.8	744.2	226.8	48.0	1219.2	0.3	182,510 lb	**91.3** tons
curve	vertical	542+29	16+529	181.0	55.2	741.6	226.0	48.0	1219.2	0.3	177,620 lb	**88.8** tons
curve	vertical	542+56	16+537	208.5	63.6	739.2	225.3	48.0	1219.2	0.3	175,893 lb	**87.9** tons
curve	vertical	542+83	16+546	236.0	71.9	737.0	224.6	48.0	1219.2	0.3	175,718 lb	**87.9** tons
curve	vertical	543+11	16+554	263.5	80.3	735.0	224.0	48.0	1219.2	0.3	176,401 lb	**88.2** tons
curve	vertical	543+38	16+562	291.0	88.7	733.2	223.5	48.0	1219.2	0.3	177,598 lb	**88.8** tons
curve	vertical	543+66	16+571	318.5	97.1	731.6	223.0	48.0	1219.2	0.3	179,114 lb	**89.6** tons
curve	vertical	543+93	16+579	346.0	105.5	730.3	222.6	48.0	1219.2	0.3	180,832 lb	**90.4** tons
curve	vertical	544+21	16+588	373.5	113.8	729.1	222.2	48.0	1219.2	0.3	182,678 lb	**91.3** tons
curve	vertical	544+48	16+596	401.0	122.2	728.2	222.0	48.0	1219.2	0.3	184,602 lb	**92.3** tons
curve	vertical	544+75	16+604	428.4	130.6	727.4	221.7	48.0	1219.2	0.3	186,568 lb	**93.3** tons
curve	vertical	545+03	16+613	455.9	139.0	726.9	221.6	48.0	1219.2	0.3	188,551 lb	**94.3** tons
curve	vertical	545+30	16+621	483.4	147.3	726.6	221.5	48.0	1219.2	0.3	190,533 lb	**95.3** tons
curve	vertical	545+58	16+629	510.9	155.7	726.5	221.4	48.0	1219.2	0.3	192,498 lb	**96.2** tons
straight		545+66	16+632	518.8	158.1	726.5	221.4	48.0	1219.2	0.3	192,895 lb	**96.4** tons
straight		545+74	16+634	526.6	160.5	726.5	221.4	48.0	1219.2	0.3	193,293 lb	**96.6** tons
straight		545+82	16+637	534.5	162.9	726.5	221.4	48.0	1219.2	0.3	193,690 lb	**96.8** tons
straight		545+89	16+639	542.4	165.3	726.5	221.4	48.0	1219.2	0.3	194,087 lb	**97.0** tons
curve	vertical	546+34	16+653	586.5	178.8	726.8	221.5	48.0	1219.2	0.3	225,980 lb	**113.0** tons
curve	vertical	546+78	16+666	630.7	192.2	727.6	221.8	48.0	1219.2	0.3	232,023 lb	**116.0** tons
curve	vertical	547+22	16+679	674.9	205.7	728.9	222.2	48.0	1219.2	0.3	225,647 lb	**112.8** tons
curve	vertical	547+66	16+693	719.1	219.2	730.8	222.8	48.0	1219.2	0.3	224,110 lb	**112.1** tons
curve	vertical	548+10	16+706	763.3	232.6	733.3	223.5	48.0	1219.2	0.3	224,398 lb	**112.2** tons
curve	vertical	548+54	16+720	807.4	246.1	736.3	224.4	48.0	1219.2	0.3	225,501 lb	**112.8** tons
curve	vertical	548+98	16+733	851.6	259.6	739.8	225.5	48.0	1219.2	0.3	226,983 lb	**113.5** tons
curve	vertical	549+42	16+747	895.8	273.0	743.8	226.7	48.0	1219.2	0.3	228,624 lb	**114.3** tons
curve	vertical	549+86	16+760	940.0	286.5	748.4	228.1	48.0	1219.2	0.3	230,300 lb	**115.2** tons
curve	vertical	550+30	16+773	984.1	300.0	753.6	229.7	48.0	1219.2	0.3	231,935 lb	**116.0** tons
curve	vertical	550+74	16+787	1,028.3	313.4	759.3	231.4	48.0	1219.2	0.3	233,482 lb	**116.7** tons
curve	vertical	551+18	16+800	1,072.5	326.9	765.5	233.3	48.0	1219.2	0.3	225,111 lb	**112.6** tons
curve	vertical	551+61	16+813	1,116.7	340.4	772.2	235.4	48.0	1219.2	0.3	229,148 lb	**114.6** tons
curve	vertical	552+05	16+827	1,160.9	353.8	779.5	237.6	48.0	1219.2	0.3	233,223 lb	**116.6** tons
curve	vertical	552+48	16+840	1,205.0	367.3	787.3	240.0	48.0	1219.2	0.3	237,346 lb	**118.7** tons
curve	vertical	552+92	16+853	1,249.2	380.8	795.7	242.5	48.0	1219.2	0.3	241,526 lb	**120.8** tons
straight		553+24	16+863	1,281.9	390.7	802.0	244.5	48.0	1219.2	0.3	244,875 lb	**122.4** tons
straight		553+56	16+873	1,314.5	400.7	808.4	246.4	48.0	1219.2	0.3	248,224 lb	**124.1** tons
straight		553+88	16+882	1,347.1	410.6	814.8	248.3	48.0	1219.2	0.3	251,572 lb	**125.8** tons
straight		554+20	16+892	1,379.7	420.5	821.1	250.3	48.0	1219.2	0.3	254,921 lb	**127.5** tons
straight		554+52	16+902	1,412.4	430.5	827.5	252.2	48.0	1219.2	0.3	258,269 lb	**129.1** tons
straight		554+84	16+912	1,445.0	440.4	833.9	254.2	48.0	1219.2	0.3	261,618 lb	**130.8** tons
straight		555+16	16+921	1,477.6	450.4	840.2	256.1	48.0	1219.2	0.3	264,966 lb	**132.5** tons
straight		555+48	16+931	1,510.2	460.3	846.6	258.0	48.0	1219.2	0.3	268,315 lb	**134.2** tons
straight		555+80	16+941	1,542.9	470.3	853.0	260.0	48.0	1219.2	0.3	271,663 lb	**135.8** tons
straight		556+12	16+951	1,575.5	480.2	859.3	261.9	48.0	1219.2	0.3	275,012 lb	**137.5** tons
straight		556+44	16+960	1,608.1	490.2	865.7	263.9	48.0	1219.2	0.3	278,360 lb	**139.2** tons
straight		556+76	16+970	1,640.8	500.1	872.1	265.8	48.0	1219.2	0.3	281,709 lb	**140.9** tons
straight		557+08	16+980	1,673.4	510.1	878.4	267.7	48.0	1219.2	0.3	287,124 lb	**143.6** tons
straight		557+40	16+990	1,706.0	520.0	884.8	269.7	48.0	1219.2	0.3	292,540 lb	**146.3** tons
straight		557+72	16+999	1,738.6	529.9	891.2	271.6	48.0	1219.2	0.3	297,955 lb	**149.0** tons
HDD Rig Location		558+04	17+009	1,771.3	539.9	897.5	273.6	48.0	1219.2	0.3	303,370 lb	**151.7** 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				
1,592	10.98	2.27%	0	0.00	0.00%	0.0	0.00	0.00%	0.03	Yes	0.00	Yes
1,601	11.04	2.29%	0	0.00	0.00%	14.6	0.10	0.02%	0.03	Yes	0.00	Yes
1,610	11.10	2.30%	0	0.00	0.00%	29.2	0.20	0.04%	0.03	Yes	0.00	Yes
1,619	11.16	2.31%	0	0.00	0.00%	43.9	0.30	0.06%	0.03	Yes	0.00	Yes
1,628	11.22	2.33%	0	0.00	0.00%	58.5	0.40	0.08%	0.03	Yes	0.00	Yes
1,637	11.29	2.34%	0	0.00	0.00%	73.1	0.50	0.10%	0.03	Yes	0.00	Yes
1,646	11.35	2.35%	0	0.00	0.00%	87.7	0.60	0.13%	0.03	Yes	0.00	Yes
1,655	11.41	2.36%	0	0.00	0.00%	102.3	0.71	0.15%	0.03	Yes	0.00	Yes
1,664	11.47	2.38%	0	0.00	0.00%	116.9	0.81	0.17%	0.03	Yes	0.00	Yes
2,253	15.53	3.22%	12,167	83.89	17.38%	160.7	1.11	0.23%	0.31	Yes	0.07	Yes
2,316	15.97	3.31%	12,167	83.89	17.38%	201.7	1.39	0.29%	0.31	Yes	0.07	Yes
2,164	14.92	3.09%	12,167	83.89	17.38%	239.9	1.65	0.34%	0.31	Yes	0.07	Yes
2,106	14.52	3.01%	12,167	83.89	17.38%	275.3	1.90	0.39%	0.31	Yes	0.07	Yes
2,085	14.38	2.98%	12,167	83.89	17.38%	307.8	2.12	0.44%	0.31	Yes	0.07	Yes
2,083	14.36	2.98%	12,167	83.89	17.38%	337.5	2.33	0.48%	0.31	Yes	0.07	Yes
2,091	14.42	2.99%	12,167	83.89	17.38%	364.4	2.51	0.52%	0.31	Yes	0.07	Yes
2,105	14.52	3.01%	12,167	83.89	17.38%	388.5	2.68	0.55%	0.31	Yes	0.07	Yes
2,123	14.64	3.03%	12,167	83.89	17.38%	409.7	2.82	0.59%	0.31	Yes	0.07	Yes
2,144	14.78	3.06%	12,167	83.89	17.38%	428.1	2.95	0.61%	0.31	Yes	0.07	Yes
2,166	14.93	3.09%	12,167	83.89	17.38%	443.7	3.06	0.63%	0.31	Yes	0.08	Yes
2,188	15.09	3.13%	12,167	83.89	17.38%	456.5	3.15	0.65%	0.31	Yes	0.08	Yes
2,212	15.25	3.16%	12,167	83.89	17.38%	466.4	3.22	0.67%	0.31	Yes	0.08	Yes
2,235	15.41	3.19%	12,167	83.89	17.38%	473.5	3.26	0.68%	0.31	Yes	0.08	Yes
2,259	15.57	3.23%	12,167	83.89	17.38%	477.7	3.29	0.68%	0.31	Yes	0.08	Yes
2,282	15.73	3.26%	12,167	83.89	17.38%	479.1	3.30	0.68%	0.31	Yes	0.08	Yes
2,287	15.77	3.27%	0	0.00	0.00%	479.1	3.30	0.68%	0.04	Yes	0.01	Yes
2,291	15.80	3.27%	0	0.00	0.00%	479.1	3.30	0.68%	0.04	Yes	0.01	Yes
2,296	15.83	3.28%	0	0.00	0.00%	479.1	3.30	0.68%	0.04	Yes	0.01	Yes
2,301	15.86	3.29%	0	0.00	0.00%	479.1	3.30	0.68%	0.04	Yes	0.01	Yes
2,679	18.47	3.83%	12,167	83.89	17.38%	475.5	3.28	0.68%	0.32	Yes	0.08	Yes
2,751	18.96	3.93%	12,167	83.89	17.38%	464.5	3.20	0.66%	0.32	Yes	0.08	Yes
2,675	18.44	3.82%	12,167	83.89	17.38%	446.2	3.08	0.64%	0.32	Yes	0.08	Yes
2,657	18.32	3.80%	12,167	83.89	17.38%	420.6	2.90	0.60%	0.32	Yes	0.08	Yes
2,660	18.34	3.80%	12,167	83.89	17.38%	387.7	2.67	0.55%	0.32	Yes	0.08	Yes
2,673	18.43	3.82%	12,167	83.89	17.38%	347.5	2.40	0.50%	0.32	Yes	0.08	Yes
2,691	18.55	3.84%	12,167	83.89	17.38%	300.0	2.07	0.43%	0.32	Yes	0.08	Yes
2,710	18.69	3.87%	12,167	83.89	17.38%	245.1	1.69	0.35%	0.32	Yes	0.08	Yes
2,730	18.82	3.90%	12,167	83.89	17.38%	183.1	1.26	0.26%	0.32	Yes	0.07	Yes
2,749	18.96	3.93%	12,167	83.89	17.38%	113.7	0.78	0.16%	0.32	Yes	0.07	Yes
2,768	19.08	3.95%	12,167	83.89	17.38%	37.1	0.26	0.05%	0.32	Yes	0.07	Yes
2,669	18.40	3.81%	12,167	83.89	17.38%	-46.8	-0.32	-0.07%	0.32	Yes	0.07	Yes
2,716	18.73	3.88%	12,167	83.89	17.38%	-137.9	-0.95	-0.20%	0.32	Yes	0.07	Yes
2,765	19.06	3.95%	12,167	83.89	17.38%	-236.2	-1.63	-0.34%	0.32	Yes	0.07	Yes
2,814	19.40	4.02%	12,167	83.89	17.38%	-341.8	-2.36	-0.49%	0.32	Yes	0.07	Yes
2,863	19.74	4.09%	12,167	83.89	17.38%	-454.5	-3.13	-0.65%	0.32	Yes	0.07	Yes
2,903	20.01	4.15%	0	0.00	0.00%	-540.4	-3.73	-0.77%	0.05	Yes	0.01	Yes
2,943	20.29	4.20%	0	0.00	0.00%	-626.4	-4.32	-0.89%	0.05	Yes	0.01	Yes
2,982	20.56	4.26%	0	0.00	0.00%	-712.3	-4.91	-1.02%	0.05	Yes	0.01	Yes
3,022	20.84	4.32%	0	0.00	0.00%	-798.2	-5.50	-1.14%	0.05	Yes	0.01	Yes
3,062	21.11	4.37%	0	0.00	0.00%	-884.1	-6.10	-1.26%	0.05	Yes	0.01	Yes
3,101	21.38	4.43%	0	0.00	0.00%	-970.0	-6.69	-1.39%	0.06	Yes	0.02	Yes
3,141	21.66	4.49%	0	0.00	0.00%	-1,056.0	-7.28	-1.51%	0.06	Yes	0.02	Yes
3,181	21.93	4.54%	0	0.00	0.00%	-1,141.9	-7.87	-1.63%	0.06	Yes	0.02	Yes
3,220	22.20	4.60%	0	0.00	0.00%	-1,227.8	-8.47	-1.75%	0.06	Yes	0.02	Yes
3,260	22.48	4.66%	0	0.00	0.00%	-1,313.7	-9.06	-1.88%	0.06	Yes	0.03	Yes
3,300	22.75	4.71%	0	0.00	0.00%	-1,399.6	-9.65	-2.00%	0.06	Yes	0.03	Yes
3,340	23.03	4.77%	0	0.00	0.00%	-1,485.5	-10.24	-2.12%	0.06	Yes	0.03	Yes
3,404	23.47	4.86%	0	0.00	0.00%	257.8	1.78	0.37%	0.06	Yes	0.04	Yes
3,468	23.91	4.95%	0	0.00	0.00%	171.8	1.18	0.25%	0.06	Yes	0.04	Yes
3,532	24.35	5.05%	0	0.00	0.00%	85.9	0.59	0.12%	0.06	Yes	0.05	Yes
3,596	24.80	5.14%	0	0.00	0.00%	0.0	0.00	0.00%	0.06	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	762.00	feet
	232.26	metres
Ground Elevation at Pipe Exit	897.52	feet
	273.57	metres

	TOTAL PULL LOADS		
Maximum Values	303,370	lb	151.7 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		
3,596	24.8	5.14%	12,167	83.9	17.38%	479	3.3	0.68%	0.32	0.08

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	2.92E+07	psi
	201327	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	303,370	lb
	1,349	kN
Factor of Safety	11.7	
Start-Up Load Factor	1.5	
Maximum Calculated Start-Up Pipe Pull Load	455,056	lb
	2,024	kN
Factor of Safety	7.8	

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)	0.25	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	18	lb/100ft^2 (Based on HDD experience from previous installations)
	86.184	dyne/cm^2
Plastic Viscosity	12	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	600	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	2.271	m^3/min
Drilling mud pumping rate	1129	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.273	m^3/min
Pipe Pullback Rate	10	feet/min (Based on HDD experience)
	3.05	m/min

MOTT MACDONALD

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

Calculated by: M. Lockwood
Checked by: G. Duyvestyn
Date: 10/22/2018
Project No: 353754

PROJECT: PennEast Pipeline Project

HDD CROSSING LOCATION: Interstate 81 / State Route 315

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		540+49	16+474	0.0	0.0	762.0	232.3	--	--		134,285	lb	**67.1** tons
straight		540+57	16+477	8.9	2.7	760.9	231.9	48.0	1219.2	0.3	134,121	lb	**67.1** tons
straight		540+66	16+480	17.8	5.4	759.8	231.6	48.0	1219.2	0.3	133,956	lb	**67.0** tons
straight		540+75	16+482	26.7	8.1	758.7	231.3	48.0	1219.2	0.3	133,792	lb	**66.9** tons
straight		540+84	16+485	35.5	10.8	757.7	230.9	48.0	1219.2	0.3	133,628	lb	**66.8** tons
straight		540+93	16+488	44.4	13.5	756.6	230.6	48.0	1219.2	0.3	133,463	lb	**66.7** tons
straight		541+02	16+490	53.3	16.3	755.5	230.3	48.0	1219.2	0.3	133,299	lb	**66.6** tons
straight		541+10	16+493	62.2	19.0	754.4	229.9	48.0	1219.2	0.3	133,135	lb	**66.6** tons
straight		541+19	16+496	71.1	21.7	753.3	229.6	48.0	1219.2	0.3	132,971	lb	**66.5** tons
curve	vertical	541+47	16+504	98.6	30.0	750.1	228.6	48.0	1219.2	0.3	180,330	lb	**90.2** tons
curve	vertical	541+74	16+512	126.1	38.4	747.1	227.7	48.0	1219.2	0.3	177,086	lb	**88.5** tons
curve	vertical	542+01	16+521	153.6	46.8	744.2	226.8	48.0	1219.2	0.3	158,858	lb	**79.4** tons
curve	vertical	542+29	16+529	181.0	55.2	741.6	226.0	48.0	1219.2	0.3	148,697	lb	**74.3** tons
curve	vertical	542+56	16+537	208.5	63.6	739.2	225.3	48.0	1219.2	0.3	141,772	lb	**70.9** tons
curve	vertical	542+83	16+546	236.0	71.9	737.0	224.6	48.0	1219.2	0.3	136,476	lb	**68.2** tons
curve	vertical	543+11	16+554	263.5	80.3	735.0	224.0	48.0	1219.2	0.3	132,118	lb	**66.1** tons
curve	vertical	543+38	16+562	291.0	88.7	733.2	223.5	48.0	1219.2	0.3	128,353	lb	**64.2** tons
curve	vertical	543+66	16+571	318.5	97.1	731.6	223.0	48.0	1219.2	0.3	124,991	lb	**62.5** tons
curve	vertical	543+93	16+579	346.0	105.5	730.3	222.6	48.0	1219.2	0.3	121,917	lb	**61.0** tons
curve	vertical	544+21	16+588	373.5	113.8	729.1	222.2	48.0	1219.2	0.3	119,058	lb	**59.5** tons
curve	vertical	544+48	16+596	401.0	122.2	728.2	222.0	48.0	1219.2	0.3	119,038	lb	**59.5** tons
curve	vertical	544+75	16+604	428.4	130.6	727.4	221.7	48.0	1219.2	0.3	119,301	lb	**59.7** tons
curve	vertical	545+03	16+613	455.9	139.0	726.9	221.6	48.0	1219.2	0.3	119,497	lb	**59.7** tons
curve	vertical	545+30	16+621	483.4	147.3	726.6	221.5	48.0	1219.2	0.3	119,642	lb	**59.8** tons
curve	vertical	545+58	16+629	510.9	155.7	726.5	221.4	48.0	1219.2	0.3	119,750	lb	**59.9** tons
straight		545+66	16+632	518.8	158.1	726.5	221.4	48.0	1219.2	0.3	119,712	lb	**59.9** tons
straight		545+74	16+634	526.6	160.5	726.5	221.4	48.0	1219.2	0.3	119,674	lb	**59.8** tons
straight		545+82	16+637	534.5	162.9	726.5	221.4	48.0	1219.2	0.3	119,636	lb	**59.8** tons
straight		545+89	16+639	542.4	165.3	726.5	221.4	48.0	1219.2	0.3	119,597	lb	**59.8** tons
curve	vertical	546+34	16+653	586.5	178.8	726.8	221.5	48.0	1219.2	0.3	148,241	lb	**74.1** tons
curve	vertical	546+78	16+666	630.7	192.2	727.6	221.8	48.0	1219.2	0.3	143,863	lb	**71.9** tons
curve	vertical	547+22	16+679	674.9	205.7	728.9	222.2	48.0	1219.2	0.3	130,963	lb	**65.5** tons
curve	vertical	547+66	16+693	719.1	219.2	730.8	222.8	48.0	1219.2	0.3	123,122	lb	**61.6** tons
curve	vertical	548+10	16+706	763.3	232.6	733.3	223.5	48.0	1219.2	0.3	117,337	lb	**58.7** tons
curve	vertical	548+54	16+720	807.4	246.1	736.3	224.4	48.0	1219.2	0.3	112,608	lb	**56.3** tons
curve	vertical	548+98	16+733	851.6	259.6	739.8	225.5	48.0	1219.2	0.3	110,184	lb	**55.1** tons
curve	vertical	549+42	16+747	895.8	273.0	743.8	226.7	48.0	1219.2	0.3	111,332	lb	**55.7** tons
curve	vertical	549+86	16+760	940.0	286.5	748.4	228.1	48.0	1219.2	0.3	112,290	lb	**56.1** tons
curve	vertical	550+30	16+773	984.1	300.0	753.6	229.7	48.0	1219.2	0.3	113,128	lb	**56.6** tons
curve	vertical	550+74	16+787	1,028.3	313.4	759.3	231.4	48.0	1219.2	0.3	113,892	lb	**56.9** tons
curve	vertical	551+18	16+800	1,072.5	326.9	765.5	233.3	48.0	1219.2	0.3	133,984	lb	**67.0** tons
curve	vertical	551+61	16+813	1,116.7	340.4	772.2	235.4	48.0	1219.2	0.3	159,256	lb	**79.6** tons
curve	vertical	552+05	16+827	1,160.9	353.8	779.5	237.6	48.0	1219.2	0.3	163,708	lb	**81.9** tons
curve	vertical	552+48	16+840	1,205.0	367.3	787.3	240.0	48.0	1219.2	0.3	168,206	lb	**84.1** tons
curve	vertical	552+92	16+853	1,249.2	380.8	795.7	242.5	48.0	1219.2	0.3	172,757	lb	**86.4** tons
straight		553+24	16+863	1,281.9	390.7	802.0	244.5	48.0	1219.2	0.3	176,105	lb	**88.1** tons
straight		553+56	16+873	1,314.5	400.7	808.4	246.4	48.0	1219.2	0.3	179,454	lb	**89.7** tons
straight		553+88	16+882	1,347.1	410.6	814.8	248.3	48.0	1219.2	0.3	182,802	lb	**91.4** tons
straight		554+20	16+892	1,379.7	420.5	821.1	250.3	48.0	1219.2	0.3	186,151	lb	**93.1** tons
straight		554+52	16+902	1,412.4	430.5	827.5	252.2	48.0	1219.2	0.3	189,499	lb	**94.7** tons
straight		554+84	16+912	1,445.0	440.4	833.9	254.2	48.0	1219.2	0.3	192,848	lb	**96.4** tons
straight		555+16	16+921	1,477.6	450.4	840.2	256.1	48.0	1219.2	0.3	196,196	lb	**98.1** tons
straight		555+48	16+931	1,510.2	460.3	846.6	258.0	48.0	1219.2	0.3	199,545	lb	**99.8** tons
straight		555+80	16+941	1,542.9	470.3	853.0	260.0	48.0	1219.2	0.3	202,894	lb	**101.4** tons
straight		556+12	16+951	1,575.5	480.2	859.3	261.9	48.0	1219.2	0.3	206,242	lb	**103.1** tons
straight		556+44	16+960	1,608.1	490.2	865.7	263.9	48.0	1219.2	0.3	209,591	lb	**104.8** tons
straight		556+76	16+970	1,640.8	500.1	872.1	265.8	48.0	1219.2	0.3	212,939	lb	**106.5** tons
straight		557+08	16+980	1,673.4	510.1	878.4	267.7	48.0	1219.2	0.3	218,354	lb	**109.2** tons
straight		557+40	16+990	1,706.0	520.0	884.8	269.7	48.0	1219.2	0.3	223,770	lb	**111.9** tons
straight		557+72	16+999	1,738.6	529.9	891.2	271.6	48.0	1219.2	0.3	229,185	lb	**114.6** tons
HDD Rig Location		558+04	17+009	1,771.3	539.9	897.5	273.6	48.0	1219.2	0.3	234,601	lb	**117.3** 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				
1,592	10.98	2.27%	0	0.00	0.00%	0.0	0.00	0.00%	0.03	Yes	0.00	Yes
1,590	10.96	2.27%	0	0.00	0.00%	3.5	0.02	0.01%	0.03	Yes	0.00	Yes
1,588	10.95	2.27%	0	0.00	0.00%	7.1	0.05	0.01%	0.03	Yes	0.00	Yes
1,586	10.94	2.27%	0	0.00	0.00%	10.6	0.07	0.02%	0.03	Yes	0.00	Yes
1,584	10.92	2.26%	0	0.00	0.00%	14.1	0.10	0.02%	0.03	Yes	0.00	Yes
1,582	10.91	2.26%	0	0.00	0.00%	17.7	0.12	0.03%	0.03	Yes	0.00	Yes
1,580	10.90	2.26%	0	0.00	0.00%	21.2	0.15	0.03%	0.03	Yes	0.00	Yes
1,578	10.88	2.25%	0	0.00	0.00%	24.7	0.17	0.04%	0.03	Yes	0.00	Yes
1,576	10.87	2.25%	0	0.00	0.00%	28.3	0.19	0.04%	0.03	Yes	0.00	Yes
2,138	14.74	3.05%	12,167	83.89	17.38%	38.8	0.27	0.06%	0.31	Yes	0.07	Yes
2,099	14.47	3.00%	12,167	83.89	17.38%	48.7	0.34	0.07%	0.31	Yes	0.07	Yes
1,883	12.98	2.69%	12,167	83.89	17.38%	58.0	0.40	0.08%	0.31	Yes	0.06	Yes
1,763	12.15	2.52%	12,167	83.89	17.38%	66.5	0.46	0.10%	0.30	Yes	0.06	Yes
1,681	11.59	2.40%	12,167	83.89	17.38%	74.4	0.51	0.11%	0.30	Yes	0.06	Yes
1,618	11.15	2.31%	12,167	83.89	17.38%	81.6	0.56	0.12%	0.30	Yes	0.06	Yes
1,566	10.80	2.24%	12,167	83.89	17.38%	88.1	0.61	0.13%	0.30	Yes	0.06	Yes
1,522	10.49	2.17%	12,167	83.89	17.38%	93.9	0.65	0.13%	0.30	Yes	0.06	Yes
1,482	10.22	2.12%	12,167	83.89	17.38%	99.0	0.68	0.14%	0.30	Yes	0.06	Yes
1,445	9.96	2.06%	12,167	83.89	17.38%	103.4	0.71	0.15%	0.30	Yes	0.06	Yes
1,411	9.73	2.02%	12,167	83.89	17.38%	107.2	0.74	0.15%	0.30	Yes	0.06	Yes
1,411	9.73	2.02%	12,167	83.89	17.38%	110.3	0.76	0.16%	0.30	Yes	0.06	Yes
1,414	9.75	2.02%	12,167	83.89	17.38%	112.7	0.78	0.16%	0.30	Yes	0.06	Yes
1,417	9.77	2.02%	12,167	83.89	17.38%	114.4	0.79	0.16%	0.30	Yes	0.06	Yes
1,418	9.78	2.03%	12,167	83.89	17.38%	115.4	0.80	0.16%	0.30	Yes	0.06	Yes
1,420	9.79	2.03%	12,167	83.89	17.38%	115.8	0.80	0.17%	0.30	Yes	0.06	Yes
1,419	9.78	2.03%	0	0.00	0.00%	115.8	0.80	0.17%	0.03	Yes	0.00	Yes
1,419	9.78	2.03%	0	0.00	0.00%	115.8	0.80	0.17%	0.03	Yes	0.00	Yes
1,418	9.78	2.03%	0	0.00	0.00%	115.8	0.80	0.17%	0.03	Yes	0.00	Yes
1,418	9.78	2.03%	0	0.00	0.00%	115.8	0.80	0.17%	0.03	Yes	0.00	Yes
1,757	12.12	2.51%	12,167	83.89	17.38%	114.9	0.79	0.16%	0.30	Yes	0.06	Yes
1,705	11.76	2.44%	12,167	83.89	17.38%	112.2	0.77	0.16%	0.30	Yes	0.06	Yes
1,553	10.70	2.22%	12,167	83.89	17.38%	107.8	0.74	0.15%	0.30	Yes	0.06	Yes
1,460	10.06	2.09%	12,167	83.89	17.38%	101.6	0.70	0.15%	0.30	Yes	0.06	Yes
1,391	9.59	1.99%	12,167	83.89	17.38%	93.7	0.65	0.13%	0.30	Yes	0.06	Yes
1,335	9.20	1.91%	12,167	83.89	17.38%	84.0	0.58	0.12%	0.30	Yes	0.06	Yes
1,306	9.01	1.87%	12,167	83.89	17.38%	72.5	0.50	0.10%	0.30	Yes	0.06	Yes
1,320	9.10	1.89%	12,167	83.89	17.38%	59.2	0.41	0.08%	0.30	Yes	0.06	Yes
1,331	9.18	1.90%	12,167	83.89	17.38%	44.2	0.30	0.06%	0.30	Yes	0.06	Yes
1,341	9.25	1.92%	12,167	83.89	17.38%	27.5	0.19	0.04%	0.30	Yes	0.06	Yes
1,350	9.31	1.93%	12,167	83.89	17.38%	9.0	0.06	0.01%	0.30	Yes	0.06	Yes
1,588	10.95	2.27%	12,167	83.89	17.38%	-11.3	-0.08	-0.02%	0.30	Yes	0.06	Yes
1,888	13.02	2.70%	12,167	83.89	17.38%	-33.3	-0.23	-0.05%	0.31	Yes	0.06	Yes
1,941	13.38	2.77%	12,167	83.89	17.38%	-57.1	-0.39	-0.08%	0.31	Yes	0.06	Yes
1,994	13.75	2.85%	12,167	83.89	17.38%	-82.6	-0.57	-0.12%	0.31	Yes	0.06	Yes
2,048	14.12	2.93%	12,167	83.89	17.38%	-109.8	-0.76	-0.16%	0.31	Yes	0.06	Yes
2,088	14.39	2.98%	0	0.00	0.00%	-130.6	-0.90	-0.19%	0.04	Yes	0.00	Yes
2,127	14.67	3.04%	0	0.00	0.00%	-151.3	-1.04	-0.22%	0.04	Yes	0.00	Yes
2,167	14.94	3.10%	0	0.00	0.00%	-172.1	-1.19	-0.25%	0.04	Yes	0.00	Yes
2,207	15.21	3.15%	0	0.00	0.00%	-192.9	-1.33	-0.28%	0.04	Yes	0.00	Yes
2,246	15.49	3.21%	0	0.00	0.00%	-213.6	-1.47	-0.31%	0.04	Yes	0.00	Yes
2,286	15.76	3.27%	0	0.00	0.00%	-234.4	-1.62	-0.33%	0.04	Yes	0.00	Yes
2,326	16.04	3.32%	0	0.00	0.00%	-255.1	-1.76	-0.36%	0.04	Yes	0.00	Yes
2,366	16.31	3.38%	0	0.00	0.00%	-275.9	-1.90	-0.39%	0.04	Yes	0.00	Yes
2,405	16.58	3.44%	0	0.00	0.00%	-296.6	-2.05	-0.42%	0.04	Yes	0.00	Yes
2,445	16.86	3.49%	0	0.00	0.00%	-317.4	-2.19	-0.45%	0.04	Yes	0.00	Yes
2,485	17.13	3.55%	0	0.00	0.00%	-338.2	-2.33	-0.48%	0.04	Yes	0.00	Yes
2,524	17.40	3.61%	0	0.00	0.00%	-358.9	-2.47	-0.51%	0.05	Yes	0.00	Yes
2,588	17.85	3.70%	0	0.00	0.00%	62.3	0.43	0.09%	0.05	Yes	0.00	Yes
2,653	18.29	3.79%	0	0.00	0.00%	41.5	0.29	0.06%	0.05	Yes	0.00	Yes
2,717	18.73	3.88%	0	0.00	0.00%	20.8	0.14	0.03%	0.05	Yes	0.00	Yes
2,781	19.17	3.97%	0	0.00	0.00%	0.0	0.00	0.00%	0.05	Yes	0.00	Yes

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

Ground Elevation at Pipe Entry	762.00	feet
	232.26	metres
Ground Elevation at Pipe Exit	897.52	feet
	273.57	metres

	TOTAL PULL LOADS		
Maximum Values	234,601	lb	117.3 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		
2,781	19.2	3.97%	12,167	83.9	17.38%	116	0.8	0.17%	0.31	0.07

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	2.92E+07	psi
	201327	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	234,601	lb
	1,044	kN
Factor of Safety	15.1	

Start-Up Load Factor	1.5	
Maximum Calculated Start-Up Pipe Pull Load	351,901	lb
	1,565	kN
Factor of Safety	10.1	

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)	0.25	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	18	$lb/100ft^2$ (Based on HDD experience from previous installations)
	86.184	$dyne/cm^2$
Plastic Viscosity	12	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	600	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	2.271	m^3/min
Drilling mud pumping rate	1129	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.273	m^3/min
Pipe Pullback Rate	10	feet/min (Based on HDD experience)
	3.05	m/min

MOTT MACDONALD

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

Calculated by: M. Lockwood
Checked by: G. Duyvestyn
Date: 10/22/2018
Project No: 353754

PROJECT: PennEast Pipeline Project

HDD CROSSING LOCATION: Interstate 81 / State Route 315

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		540+49	16+474	0.0	0.0	762.0	232.3	--	--		134,285	lb	**67.1** tons
straight		540+57	16+477	8.9	2.7	760.9	231.9	48.0	1219.2	0.3	135,244	lb	**67.6** tons
straight		540+66	16+480	17.8	5.4	759.8	231.6	48.0	1219.2	0.3	136,204	lb	**68.1** tons
straight		540+75	16+482	26.7	8.1	758.7	231.3	48.0	1219.2	0.3	137,163	lb	**68.6** tons
straight		540+84	16+485	35.5	10.8	757.7	230.9	48.0	1219.2	0.3	138,123	lb	**69.1** tons
straight		540+93	16+488	44.4	13.5	756.6	230.6	48.0	1219.2	0.3	139,082	lb	**69.5** tons
straight		541+02	16+490	53.3	16.3	755.5	230.3	48.0	1219.2	0.3	140,041	lb	**70.0** tons
straight		541+10	16+493	62.2	19.0	754.4	229.9	48.0	1219.2	0.3	141,001	lb	**70.5** tons
straight		541+19	16+496	71.1	21.7	753.3	229.6	48.0	1219.2	0.3	141,960	lb	**71.0** tons
curve	vertical	541+47	16+504	98.6	30.0	750.1	228.6	48.0	1219.2	0.3	191,858	lb	**95.9** tons
curve	vertical	541+74	16+512	126.1	38.4	747.1	227.7	48.0	1219.2	0.3	198,398	lb	**99.2** tons
curve	vertical	542+01	16+521	153.6	46.8	744.2	226.8	48.0	1219.2	0.3	186,214	lb	**93.1** tons
curve	vertical	542+29	16+529	181.0	55.2	741.6	226.0	48.0	1219.2	0.3	182,015	lb	**91.0** tons
curve	vertical	542+56	16+537	208.5	63.6	739.2	225.3	48.0	1219.2	0.3	180,969	lb	**90.5** tons
curve	vertical	542+83	16+546	236.0	71.9	737.0	224.6	48.0	1219.2	0.3	181,463	lb	**90.7** tons
curve	vertical	543+11	16+554	263.5	80.3	735.0	224.0	48.0	1219.2	0.3	182,807	lb	**91.4** tons
curve	vertical	543+38	16+562	291.0	88.7	733.2	223.5	48.0	1219.2	0.3	184,652	lb	**92.3** tons
curve	vertical	543+66	16+571	318.5	97.1	731.6	223.0	48.0	1219.2	0.3	186,804	lb	**93.4** tons
curve	vertical	543+93	16+579	346.0	105.5	730.3	222.6	48.0	1219.2	0.3	189,148	lb	**94.6** tons
curve	vertical	544+21	16+588	373.5	113.8	729.1	222.2	48.0	1219.2	0.3	191,607	lb	**95.8** tons
curve	vertical	544+48	16+596	401.0	122.2	728.2	222.0	48.0	1219.2	0.3	194,131	lb	**97.1** tons
curve	vertical	544+75	16+604	428.4	130.6	727.4	221.7	48.0	1219.2	0.3	196,685	lb	**98.3** tons
curve	vertical	545+03	16+613	455.9	139.0	726.9	221.6	48.0	1219.2	0.3	199,242	lb	**99.6** tons
curve	vertical	545+30	16+621	483.4	147.3	726.6	221.5	48.0	1219.2	0.3	201,784	lb	**100.9** tons
curve	vertical	545+58	16+629	510.9	155.7	726.5	221.4	48.0	1219.2	0.3	204,297	lb	**102.1** tons
straight		545+66	16+632	518.8	158.1	726.5	221.4	48.0	1219.2	0.3	204,819	lb	**102.4** tons
straight		545+74	16+634	526.6	160.5	726.5	221.4	48.0	1219.2	0.3	205,341	lb	**102.7** tons
straight		545+82	16+637	534.5	162.9	726.5	221.4	48.0	1219.2	0.3	205,863	lb	**102.9** tons
straight		545+89	16+639	542.4	165.3	726.5	221.4	48.0	1219.2	0.3	206,385	lb	**103.2** tons
curve	vertical	546+34	16+653	586.5	178.8	726.8	221.5	48.0	1219.2	0.3	238,675	lb	**119.3** tons
curve	vertical	546+78	16+666	630.7	192.2	727.6	221.8	48.0	1219.2	0.3	246,129	lb	**123.1** tons
curve	vertical	547+22	16+679	674.9	205.7	728.9	222.2	48.0	1219.2	0.3	240,616	lb	**120.3** tons
curve	vertical	547+66	16+693	719.1	219.2	730.8	222.8	48.0	1219.2	0.3	239,909	lb	**120.0** tons
curve	vertical	548+10	16+706	763.3	232.6	733.3	223.5	48.0	1219.2	0.3	240,994	lb	**120.5** tons
curve	vertical	548+54	16+720	807.4	246.1	736.3	224.4	48.0	1219.2	0.3	242,860	lb	**121.4** tons
curve	vertical	548+98	16+733	851.6	259.6	739.8	225.5	48.0	1219.2	0.3	245,068	lb	**122.5** tons
curve	vertical	549+42	16+747	895.8	273.0	743.8	226.7	48.0	1219.2	0.3	247,397	lb	**123.7** tons
curve	vertical	549+86	16+760	940.0	286.5	748.4	228.1	48.0	1219.2	0.3	249,723	lb	**124.9** tons
curve	vertical	550+30	16+773	984.1	300.0	753.6	229.7	48.0	1219.2	0.3	251,969	lb	**126.0** tons
curve	vertical	550+74	16+787	1,028.3	313.4	759.3	231.4	48.0	1219.2	0.3	254,087	lb	**127.0** tons
curve	vertical	551+18	16+800	1,072.5	326.9	765.5	233.3	48.0	1219.2	0.3	236,723	lb	**118.4** tons
curve	vertical	551+61	16+813	1,116.7	340.4	772.2	235.4	48.0	1219.2	0.3	240,700	lb	**120.4** tons
curve	vertical	552+05	16+827	1,160.9	353.8	779.5	237.6	48.0	1219.2	0.3	244,716	lb	**122.4** tons
curve	vertical	552+48	16+840	1,205.0	367.3	787.3	240.0	48.0	1219.2	0.3	248,780	lb	**124.4** tons
curve	vertical	552+92	16+853	1,249.2	380.8	795.7	242.5	48.0	1219.2	0.3	252,903	lb	**126.5** tons
straight		553+24	16+863	1,281.9	390.7	802.0	244.5	48.0	1219.2	0.3	256,252	lb	**128.1** tons
straight		553+56	16+873	1,314.5	400.7	808.4	246.4	48.0	1219.2	0.3	259,600	lb	**129.8** tons
straight		553+88	16+882	1,347.1	410.6	814.8	248.3	48.0	1219.2	0.3	262,949	lb	**131.5** tons
straight		554+20	16+892	1,379.7	420.5	821.1	250.3	48.0	1219.2	0.3	266,297	lb	**133.1** tons
straight		554+52	16+902	1,412.4	430.5	827.5	252.2	48.0	1219.2	0.3	269,646	lb	**134.8** tons
straight		554+84	16+912	1,445.0	440.4	833.9	254.2	48.0	1219.2	0.3	272,994	lb	**136.5** tons
straight		555+16	16+921	1,477.6	450.4	840.2	256.1	48.0	1219.2	0.3	276,343	lb	**138.2** tons
straight		555+48	16+931	1,510.2	460.3	846.6	258.0	48.0	1219.2	0.3	279,691	lb	**139.8** tons
straight		555+80	16+941	1,542.9	470.3	853.0	260.0	48.0	1219.2	0.3	283,040	lb	**141.5** tons
straight		556+12	16+951	1,575.5	480.2	859.3	261.9	48.0	1219.2	0.3	286,388	lb	**143.2** tons
straight		556+44	16+960	1,608.1	490.2	865.7	263.9	48.0	1219.2	0.3	289,737	lb	**144.9** tons
straight		556+76	16+970	1,640.8	500.1	872.1	265.8	48.0	1219.2	0.3	293,085	lb	**146.5** tons
straight		557+08	16+980	1,673.4	510.1	878.4	267.7	48.0	1219.2	0.3	296,434	lb	**148.2** tons
straight		557+40	16+990	1,706.0	520.0	884.8	269.7	48.0	1219.2	0.3	301,849	lb	**150.9** tons
straight		557+72	16+999	1,738.6	529.9	891.2	271.6	48.0	1219.2	0.3	307,265	lb	**153.6** tons
HDD Rig Location		558+04	17+009	1,771.3	539.9	897.5	273.6	48.0	1219.2	0.3	312,680	lb	**156.3** 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				
1,592	10.98	2.27%	0	0.00	0.00%	0.0	0.00	0.00%	0.03	Yes	0.00	Yes
1,603	11.05	2.29%	0	0.00	0.00%	15.9	0.11	0.02%	0.03	Yes	0.00	Yes
1,615	11.13	2.31%	0	0.00	0.00%	31.9	0.22	0.05%	0.03	Yes	0.00	Yes
1,626	11.21	2.32%	0	0.00	0.00%	47.8	0.33	0.07%	0.03	Yes	0.00	Yes
1,637	11.29	2.34%	0	0.00	0.00%	63.8	0.44	0.09%	0.03	Yes	0.00	Yes
1,649	11.37	2.36%	0	0.00	0.00%	79.7	0.55	0.11%	0.03	Yes	0.00	Yes
1,660	11.45	2.37%	0	0.00	0.00%	95.7	0.66	0.14%	0.03	Yes	0.00	Yes
1,671	11.52	2.39%	0	0.00	0.00%	111.6	0.77	0.16%	0.03	Yes	0.00	Yes
1,683	11.60	2.40%	0	0.00	0.00%	127.6	0.88	0.18%	0.03	Yes	0.00	Yes
2,274	15.68	3.25%	12,167	83.89	17.38%	175.4	1.21	0.25%	0.31	Yes	0.07	Yes
2,352	16.22	3.36%	12,167	83.89	17.38%	220.1	1.52	0.31%	0.31	Yes	0.07	Yes
2,207	15.22	3.15%	12,167	83.89	17.38%	261.7	1.80	0.37%	0.31	Yes	0.07	Yes
2,158	14.88	3.08%	12,167	83.89	17.38%	300.3	2.07	0.43%	0.31	Yes	0.07	Yes
2,145	14.79	3.06%	12,167	83.89	17.38%	335.8	2.32	0.48%	0.31	Yes	0.07	Yes
2,151	14.83	3.07%	12,167	83.89	17.38%	368.2	2.54	0.53%	0.31	Yes	0.07	Yes
2,167	14.94	3.10%	12,167	83.89	17.38%	397.6	2.74	0.57%	0.31	Yes	0.07	Yes
2,189	15.09	3.13%	12,167	83.89	17.38%	423.8	2.92	0.61%	0.31	Yes	0.08	Yes
2,214	15.27	3.16%	12,167	83.89	17.38%	447.0	3.08	0.64%	0.31	Yes	0.08	Yes
2,242	15.46	3.20%	12,167	83.89	17.38%	467.1	3.22	0.67%	0.31	Yes	0.08	Yes
2,271	15.66	3.24%	12,167	83.89	17.38%	484.1	3.34	0.69%	0.31	Yes	0.08	Yes
2,301	15.87	3.29%	12,167	83.89	17.38%	498.0	3.43	0.71%	0.31	Yes	0.08	Yes
2,332	16.08	3.33%	12,167	83.89	17.38%	508.8	3.51	0.73%	0.31	Yes	0.08	Yes
2,362	16.28	3.37%	12,167	83.89	17.38%	516.5	3.56	0.74%	0.31	Yes	0.08	Yes
2,392	16.49	3.42%	12,167	83.89	17.38%	521.1	3.59	0.74%	0.31	Yes	0.08	Yes
2,422	16.70	3.46%	12,167	83.89	17.38%	522.7	3.60	0.75%	0.32	Yes	0.08	Yes
2,428	16.74	3.47%	0	0.00	0.00%	522.7	3.60	0.75%	0.04	Yes	0.01	Yes
2,434	16.78	3.48%	0	0.00	0.00%	522.7	3.60	0.75%	0.04	Yes	0.01	Yes
2,440	16.83	3.49%	0	0.00	0.00%	522.7	3.60	0.75%	0.04	Yes	0.01	Yes
2,447	16.87	3.50%	0	0.00	0.00%	522.7	3.60	0.75%	0.04	Yes	0.01	Yes
2,829	19.51	4.04%	12,167	83.89	17.38%	518.7	3.58	0.74%	0.32	Yes	0.08	Yes
2,918	20.12	4.17%	12,167	83.89	17.38%	506.7	3.49	0.72%	0.32	Yes	0.08	Yes
2,852	19.67	4.07%	12,167	83.89	17.38%	486.8	3.36	0.70%	0.32	Yes	0.08	Yes
2,844	19.61	4.06%	12,167	83.89	17.38%	458.8	3.16	0.66%	0.32	Yes	0.08	Yes
2,857	19.70	4.08%	12,167	83.89	17.38%	422.9	2.92	0.60%	0.32	Yes	0.08	Yes
2,879	19.85	4.11%	12,167	83.89	17.38%	379.1	2.61	0.54%	0.32	Yes	0.08	Yes
2,905	20.03	4.15%	12,167	83.89	17.38%	327.2	2.26	0.47%	0.32	Yes	0.08	Yes
2,933	20.22	4.19%	12,167	83.89	17.38%	267.4	1.84	0.38%	0.32	Yes	0.08	Yes
2,960	20.41	4.23%	12,167	83.89	17.38%	199.7	1.38	0.29%	0.33	Yes	0.08	Yes
2,987	20.59	4.27%	12,167	83.89	17.38%	124.0	0.86	0.18%	0.33	Yes	0.08	Yes
3,012	20.77	4.30%	12,167	83.89	17.38%	40.4	0.28	0.06%	0.33	Yes	0.07	Yes
2,806	19.35	4.01%	12,167	83.89	17.38%	-51.0	-0.35	-0.07%	0.32	Yes	0.07	Yes
2,853	19.67	4.08%	12,167	83.89	17.38%	-150.4	-1.04	-0.21%	0.32	Yes	0.07	Yes
2,901	20.00	4.14%	12,167	83.89	17.38%	-257.7	-1.78	-0.37%	0.32	Yes	0.07	Yes
2,949	20.33	4.21%	12,167	83.89	17.38%	-372.9	-2.57	-0.53%	0.32	Yes	0.07	Yes
2,998	20.67	4.28%	12,167	83.89	17.38%	-495.9	-3.42	-0.71%	0.33	Yes	0.07	Yes
3,038	20.94	4.34%	0	0.00	0.00%	-589.6	-4.06	-0.84%	0.05	Yes	0.01	Yes
3,077	21.22	4.40%	0	0.00	0.00%	-683.3	-4.71	-0.98%	0.05	Yes	0.01	Yes
3,117	21.49	4.45%	0	0.00	0.00%	-777.0	-5.36	-1.11%	0.06	Yes	0.01	Yes
3,157	21.77	4.51%	0	0.00	0.00%	-870.8	-6.00	-1.24%	0.06	Yes	0.01	Yes
3,197	22.04	4.57%	0	0.00	0.00%	-964.5	-6.65	-1.38%	0.06	Yes	0.02	Yes
3,236	22.31	4.62%	0	0.00	0.00%	-1,058.2	-7.30	-1.51%	0.06	Yes	0.02	Yes
3,276	22.59	4.68%	0	0.00	0.00%	-1,151.9	-7.94	-1.65%	0.06	Yes	0.02	Yes
3,316	22.86	4.74%	0	0.00	0.00%	-1,245.7	-8.59	-1.78%	0.06	Yes	0.02	Yes
3,355	23.13	4.79%	0	0.00	0.00%	-1,339.4	-9.23	-1.91%	0.06	Yes	0.03	Yes
3,395	23.41	4.85%	0	0.00	0.00%	-1,433.1	-9.88	-2.05%	0.06	Yes	0.03	Yes
3,435	23.68	4.91%	0	0.00	0.00%	-1,526.9	-10.53	-2.18%	0.06	Yes	0.04	Yes
3,474	23.96	4.96%	0	0.00	0.00%	-1,620.6	-11.17	-2.32%	0.06	Yes	0.04	Yes
3,514	24.23	5.02%	0	0.00	0.00%	-1,714.3	-11.82	-2.45%	0.06	Yes	0.05	Yes
3,578	24.67	5.11%	0	0.00	0.00%	187.5	1.29	0.27%	0.06	Yes	0.05	Yes
3,642	25.11	5.20%	0	0.00	0.00%	93.7	0.65	0.13%	0.07	Yes	0.06	Yes
3,707	25.56	5.30%	0	0.00	0.00%	0.0	0.00	0.00%	0.07	Yes	0.06	Yes

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

Ground Elevation at Pipe Entry	762.00	feet
	232.26	metres
Ground Elevation at Pipe Exit	897.52	feet
	273.57	metres

	TOTAL PULL LOADS		
Maximum Values	312,680	lb	156.3 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		
3,707	25.6	5.30%	12,167	83.9	17.38%	523	3.6	0.75%	0.33	0.08

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	2.92E+07	psi
	201327	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	312,680	lb
	1,391	kN
Factor of Safety	11.3	

Start-Up Load Factor	1.5	
Maximum Calculated Start-Up Pipe Pull Load	469,020	lb
	2,086	kN
Factor of Safety	7.6	

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)	0.25	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	18	lb/100ft^2 (Based on HDD experience from previous installations)
	86.184	dyne/cm^2
Plastic Viscosity	12	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	600	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	2.271	m^3/min
Drilling mud pumping rate	1129	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.273	m^3/min
Pipe Pullback Rate	10	feet/min (Based on HDD experience)
	3.05	m/min

MOTT MACDONALD

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

Calculated by: M. Lockwood
Checked by: G. Duyvestyn
Date: 10/22/2018
Project No: 353754

PROJECT: PennEast Pipeline Project

HDD CROSSING LOCATION: Interstate 81 / State Route 315

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		540+49	16+474	0.0	0.0	762.0	232.3	--	--		134,285 lb	**67.1** tons
straight		540+57	16+477	8.9	2.7	760.9	231.9	48.0	1219.2	0.3	134,038 lb	**67.0** tons
straight		540+66	16+480	17.8	5.4	759.8	231.6	48.0	1219.2	0.3	133,791 lb	**66.9** tons
straight		540+75	16+482	26.7	8.1	758.7	231.3	48.0	1219.2	0.3	133,544 lb	**66.8** tons
straight		540+84	16+485	35.5	10.8	757.7	230.9	48.0	1219.2	0.3	133,297 lb	**66.6** tons
straight		540+93	16+488	44.4	13.5	756.6	230.6	48.0	1219.2	0.3	133,050 lb	**66.5** tons
straight		541+02	16+490	53.3	16.3	755.5	230.3	48.0	1219.2	0.3	132,803 lb	**66.4** tons
straight		541+10	16+493	62.2	19.0	754.4	229.9	48.0	1219.2	0.3	132,556 lb	**66.3** tons
straight		541+19	16+496	71.1	21.7	753.3	229.6	48.0	1219.2	0.3	132,309 lb	**66.2** tons
curve	vertical	541+47	16+504	98.6	30.0	750.1	228.6	48.0	1219.2	0.3	180,066 lb	**90.0** tons
curve	vertical	541+74	16+512	126.1	38.4	747.1	227.7	48.0	1219.2	0.3	177,840 lb	**88.9** tons
curve	vertical	542+01	16+521	153.6	46.8	744.2	226.8	48.0	1219.2	0.3	160,306 lb	**80.2** tons
curve	vertical	542+29	16+529	181.0	55.2	741.6	226.0	48.0	1219.2	0.3	150,830 lb	**75.4** tons
curve	vertical	542+56	16+537	208.5	63.6	739.2	225.3	48.0	1219.2	0.3	144,580 lb	**72.3** tons
curve	vertical	542+83	16+546	236.0	71.9	737.0	224.6	48.0	1219.2	0.3	139,949 lb	**70.0** tons
curve	vertical	543+11	16+554	263.5	80.3	735.0	224.0	48.0	1219.2	0.3	136,246 lb	**68.1** tons
curve	vertical	543+38	16+562	291.0	88.7	733.2	223.5	48.0	1219.2	0.3	133,127 lb	**66.6** tons
curve	vertical	543+66	16+571	318.5	97.1	731.6	223.0	48.0	1219.2	0.3	130,399 lb	**65.2** tons
curve	vertical	543+93	16+579	346.0	105.5	730.3	222.6	48.0	1219.2	0.3	127,949 lb	**64.0** tons
curve	vertical	544+21	16+588	373.5	113.8	729.1	222.2	48.0	1219.2	0.3	125,703 lb	**62.9** tons
curve	vertical	544+48	16+596	401.0	122.2	728.2	222.0	48.0	1219.2	0.3	123,612 lb	**61.8** tons
curve	vertical	544+75	16+604	428.4	130.6	727.4	221.7	48.0	1219.2	0.3	121,643 lb	**60.8** tons
curve	vertical	545+03	16+613	455.9	139.0	726.9	221.6	48.0	1219.2	0.3	119,773 lb	**59.9** tons
curve	vertical	545+30	16+621	483.4	147.3	726.6	221.5	48.0	1219.2	0.3	117,982 lb	**59.0** tons
curve	vertical	545+58	16+629	510.9	155.7	726.5	221.4	48.0	1219.2	0.3	116,259 lb	**58.1** tons
straight		545+66	16+632	518.8	158.1	726.5	221.4	48.0	1219.2	0.3	116,096 lb	**58.0** tons
straight		545+74	16+634	526.6	160.5	726.5	221.4	48.0	1219.2	0.3	115,933 lb	**58.0** tons
straight		545+82	16+637	534.5	162.9	726.5	221.4	48.0	1219.2	0.3	115,771 lb	**57.9** tons
straight		545+89	16+639	542.4	165.3	726.5	221.4	48.0	1219.2	0.3	115,608 lb	**57.8** tons
curve	vertical	546+34	16+653	586.5	178.8	726.8	221.5	48.0	1219.2	0.3	144,736 lb	**72.4** tons
curve	vertical	546+78	16+666	630.7	192.2	727.6	221.8	48.0	1219.2	0.3	141,539 lb	**70.8** tons
curve	vertical	547+22	16+679	674.9	205.7	728.9	222.2	48.0	1219.2	0.3	129,432 lb	**64.7** tons
curve	vertical	547+66	16+693	719.1	219.2	730.8	222.8	48.0	1219.2	0.3	122,356 lb	**61.2** tons
curve	vertical	548+10	16+706	763.3	232.6	733.3	223.5	48.0	1219.2	0.3	117,308 lb	**58.7** tons
curve	vertical	548+54	16+720	807.4	246.1	736.3	224.4	48.0	1219.2	0.3	113,286 lb	**56.6** tons
curve	vertical	548+98	16+733	851.6	259.6	739.8	225.5	48.0	1219.2	0.3	109,862 lb	**54.9** tons
curve	vertical	549+42	16+747	895.8	273.0	743.8	226.7	48.0	1219.2	0.3	106,822 lb	**53.4** tons
curve	vertical	549+86	16+760	940.0	286.5	748.4	228.1	48.0	1219.2	0.3	104,047 lb	**52.0** tons
curve	vertical	550+30	16+773	984.1	300.0	753.6	229.7	48.0	1219.2	0.3	101,466 lb	**50.7** tons
curve	vertical	550+74	16+787	1,028.3	313.4	759.3	231.4	48.0	1219.2	0.3	99,152 lb	**49.6** tons
curve	vertical	551+18	16+800	1,072.5	326.9	765.5	233.3	48.0	1219.2	0.3	126,273 lb	**63.1** tons
curve	vertical	551+61	16+813	1,116.7	340.4	772.2	235.4	48.0	1219.2	0.3	155,517 lb	**77.8** tons
curve	vertical	552+05	16+827	1,160.9	353.8	779.5	237.6	48.0	1219.2	0.3	159,990 lb	**80.0** tons
curve	vertical	552+48	16+840	1,205.0	367.3	787.3	240.0	48.0	1219.2	0.3	164,509 lb	**82.3** tons
curve	vertical	552+92	16+853	1,249.2	380.8	795.7	242.5	48.0	1219.2	0.3	169,081 lb	**84.5** tons
straight		553+24	16+863	1,281.9	390.7	802.0	244.5	48.0	1219.2	0.3	172,430 lb	**86.2** tons
straight		553+56	16+873	1,314.5	400.7	808.4	246.4	48.0	1219.2	0.3	175,778 lb	**87.9** tons
straight		553+88	16+882	1,347.1	410.6	814.8	248.3	48.0	1219.2	0.3	179,127 lb	**89.6** tons
straight		554+20	16+892	1,379.7	420.5	821.1	250.3	48.0	1219.2	0.3	182,475 lb	**91.2** tons
straight		554+52	16+902	1,412.4	430.5	827.5	252.2	48.0	1219.2	0.3	185,824 lb	**92.9** tons
straight		554+84	16+912	1,445.0	440.4	833.9	254.2	48.0	1219.2	0.3	189,172 lb	**94.6** tons
straight		555+16	16+921	1,477.6	450.4	840.2	256.1	48.0	1219.2	0.3	192,521 lb	**96.3** tons
straight		555+48	16+931	1,510.2	460.3	846.6	258.0	48.0	1219.2	0.3	195,869 lb	**97.9** tons
straight		555+80	16+941	1,542.9	470.3	853.0	260.0	48.0	1219.2	0.3	199,218 lb	**99.6** tons
straight		556+12	16+951	1,575.5	480.2	859.3	261.9	48.0	1219.2	0.3	202,566 lb	**101.3** tons
straight		556+44	16+960	1,608.1	490.2	865.7	263.9	48.0	1219.2	0.3	205,915 lb	**103.0** tons
straight		556+76	16+970	1,640.8	500.1	872.1	265.8	48.0	1219.2	0.3	209,263 lb	**104.6** tons
straight		557+08	16+980	1,673.4	510.1	878.4	267.7	48.0	1219.2	0.3	212,612 lb	**106.3** tons
straight		557+40	16+990	1,706.0	520.0	884.8	269.7	48.0	1219.2	0.3	218,027 lb	**109.0** tons
straight		557+72	16+999	1,738.6	529.9	891.2	271.6	48.0	1219.2	0.3	223,443 lb	**111.7** tons
HDD Rig Location		558+04	17+009	1,771.3	539.9	897.5	273.6	48.0	1219.2	0.3	228,858 lb	**114.4** 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				
1,592	10.98	2.27%	0	0.00	0.00%	0.0	0.00	0.00%	0.03	Yes	0.00	Yes
1,589	10.96	2.27%	0	0.00	0.00%	4.9	0.03	0.01%	0.03	Yes	0.00	Yes
1,586	10.94	2.27%	0	0.00	0.00%	9.7	0.07	0.01%	0.03	Yes	0.00	Yes
1,583	10.92	2.26%	0	0.00	0.00%	14.6	0.10	0.02%	0.03	Yes	0.00	Yes
1,580	10.89	2.26%	0	0.00	0.00%	19.4	0.13	0.03%	0.03	Yes	0.00	Yes
1,577	10.87	2.25%	0	0.00	0.00%	24.3	0.17	0.03%	0.03	Yes	0.00	Yes
1,574	10.85	2.25%	0	0.00	0.00%	29.2	0.20	0.04%	0.03	Yes	0.00	Yes
1,571	10.83	2.24%	0	0.00	0.00%	34.0	0.23	0.05%	0.03	Yes	0.00	Yes
1,568	10.81	2.24%	0	0.00	0.00%	38.9	0.27	0.06%	0.03	Yes	0.00	Yes
2,135	14.72	3.05%	12,167	83.89	17.38%	53.5	0.37	0.08%	0.31	Yes	0.07	Yes
2,108	14.54	3.01%	12,167	83.89	17.38%	67.1	0.46	0.10%	0.31	Yes	0.07	Yes
1,900	13.10	2.71%	12,167	83.89	17.38%	79.8	0.55	0.11%	0.31	Yes	0.06	Yes
1,788	12.33	2.55%	12,167	83.89	17.38%	91.5	0.63	0.13%	0.30	Yes	0.06	Yes
1,714	11.82	2.45%	12,167	83.89	17.38%	102.4	0.71	0.15%	0.30	Yes	0.06	Yes
1,659	11.44	2.37%	12,167	83.89	17.38%	112.2	0.77	0.16%	0.30	Yes	0.06	Yes
1,615	11.14	2.31%	12,167	83.89	17.38%	121.2	0.84	0.17%	0.30	Yes	0.06	Yes
1,578	10.88	2.25%	12,167	83.89	17.38%	129.2	0.89	0.18%	0.30	Yes	0.06	Yes
1,546	10.66	2.21%	12,167	83.89	17.38%	136.2	0.94	0.19%	0.30	Yes	0.06	Yes
1,517	10.46	2.17%	12,167	83.89	17.38%	142.4	0.98	0.20%	0.30	Yes	0.06	Yes
1,490	10.27	2.13%	12,167	83.89	17.38%	147.5	1.02	0.21%	0.30	Yes	0.06	Yes
1,465	10.10	2.09%	12,167	83.89	17.38%	151.8	1.05	0.22%	0.30	Yes	0.06	Yes
1,442	9.94	2.06%	12,167	83.89	17.38%	155.1	1.07	0.22%	0.30	Yes	0.06	Yes
1,420	9.79	2.03%	12,167	83.89	17.38%	157.4	1.09	0.22%	0.30	Yes	0.06	Yes
1,399	9.64	2.00%	12,167	83.89	17.38%	158.8	1.10	0.23%	0.30	Yes	0.06	Yes
1,378	9.50	1.97%	12,167	83.89	17.38%	159.3	1.10	0.23%	0.30	Yes	0.06	Yes
1,376	9.49	1.97%	0	0.00	0.00%	159.3	1.10	0.23%	0.02	Yes	0.00	Yes
1,374	9.48	1.96%	0	0.00	0.00%	159.3	1.10	0.23%	0.02	Yes	0.00	Yes
1,372	9.46	1.96%	0	0.00	0.00%	159.3	1.10	0.23%	0.02	Yes	0.00	Yes
1,370	9.45	1.96%	0	0.00	0.00%	159.3	1.10	0.23%	0.02	Yes	0.00	Yes
1,716	11.83	2.45%	12,167	83.89	17.38%	158.1	1.09	0.23%	0.30	Yes	0.06	Yes
1,678	11.57	2.40%	12,167	83.89	17.38%	154.5	1.06	0.22%	0.30	Yes	0.06	Yes
1,534	10.58	2.19%	12,167	83.89	17.38%	148.4	1.02	0.21%	0.30	Yes	0.06	Yes
1,450	10.00	2.07%	12,167	83.89	17.38%	139.9	0.96	0.20%	0.30	Yes	0.06	Yes
1,391	9.59	1.99%	12,167	83.89	17.38%	128.9	0.89	0.18%	0.30	Yes	0.06	Yes
1,343	9.26	1.92%	12,167	83.89	17.38%	115.5	0.80	0.17%	0.30	Yes	0.06	Yes
1,302	8.98	1.86%	12,167	83.89	17.38%	99.7	0.69	0.14%	0.30	Yes	0.06	Yes
1,266	8.73	1.81%	12,167	83.89	17.38%	81.5	0.56	0.12%	0.29	Yes	0.06	Yes
1,233	8.50	1.76%	12,167	83.89	17.38%	60.9	0.42	0.09%	0.29	Yes	0.06	Yes
1,203	8.29	1.72%	12,167	83.89	17.38%	37.8	0.26	0.05%	0.29	Yes	0.06	Yes
1,175	8.10	1.68%	12,167	83.89	17.38%	12.3	0.09	0.02%	0.29	Yes	0.06	Yes
1,497	10.32	2.14%	12,167	83.89	17.38%	-15.6	-0.11	-0.02%	0.30	Yes	0.06	Yes
1,844	12.71	2.63%	12,167	83.89	17.38%	-45.9	-0.32	-0.07%	0.31	Yes	0.06	Yes
1,897	13.08	2.71%	12,167	83.89	17.38%	-78.6	-0.54	-0.11%	0.31	Yes	0.06	Yes
1,950	13.45	2.79%	12,167	83.89	17.38%	-113.7	-0.78	-0.16%	0.31	Yes	0.06	Yes
2,004	13.82	2.86%	12,167	83.89	17.38%	-151.1	-1.04	-0.22%	0.31	Yes	0.06	Yes
2,044	14.09	2.92%	0	0.00	0.00%	-179.7	-1.24	-0.26%	0.04	Yes	0.00	Yes
2,084	14.37	2.98%	0	0.00	0.00%	-208.3	-1.44	-0.30%	0.04	Yes	0.00	Yes
2,123	14.64	3.03%	0	0.00	0.00%	-236.8	-1.63	-0.34%	0.04	Yes	0.00	Yes
2,163	14.91	3.09%	0	0.00	0.00%	-265.4	-1.83	-0.38%	0.04	Yes	0.00	Yes
2,203	15.19	3.15%	0	0.00	0.00%	-294.0	-2.03	-0.42%	0.04	Yes	0.00	Yes
2,243	15.46	3.20%	0	0.00	0.00%	-322.6	-2.22	-0.46%	0.04	Yes	0.00	Yes
2,282	15.74	3.26%	0	0.00	0.00%	-351.1	-2.42	-0.50%	0.04	Yes	0.00	Yes
2,322	16.01	3.32%	0	0.00	0.00%	-379.7	-2.62	-0.54%	0.04	Yes	0.00	Yes
2,362	16.28	3.37%	0	0.00	0.00%	-408.3	-2.81	-0.58%	0.04	Yes	0.00	Yes
2,401	16.56	3.43%	0	0.00	0.00%	-436.8	-3.01	-0.62%	0.04	Yes	0.00	Yes
2,441	16.83	3.49%	0	0.00	0.00%	-465.4	-3.21	-0.66%	0.04	Yes	0.00	Yes
2,481	17.10	3.54%	0	0.00	0.00%	-494.0	-3.41	-0.71%	0.04	Yes	0.00	Yes
2,520	17.38	3.60%	0	0.00	0.00%	-522.5	-3.60	-0.75%	0.05	Yes	0.01	Yes
2,585	17.82	3.69%	0	0.00	0.00%	57.1	0.39	0.08%	0.05	Yes	0.01	Yes
2,649	18.26	3.78%	0	0.00	0.00%	28.6	0.20	0.04%	0.05	Yes	0.01	Yes
2,713	18.71	3.88%	0	0.00	0.00%	0.0	0.00	0.00%	0.05	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	762.00	feet
	232.26	metres
Ground Elevation at Pipe Exit	897.52	feet
	273.57	metres

	TOTAL PULL LOADS		
Maximum Values	228,858	lb	114.4 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		
2,713	18.7	3.88%	12,167	83.9	17.38%	159	1.1	0.23%	0.31	0.07

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	2.92E+07	psi
	201327	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	228,858	lb
	1,018	kN
Factor of Safety	15.5	

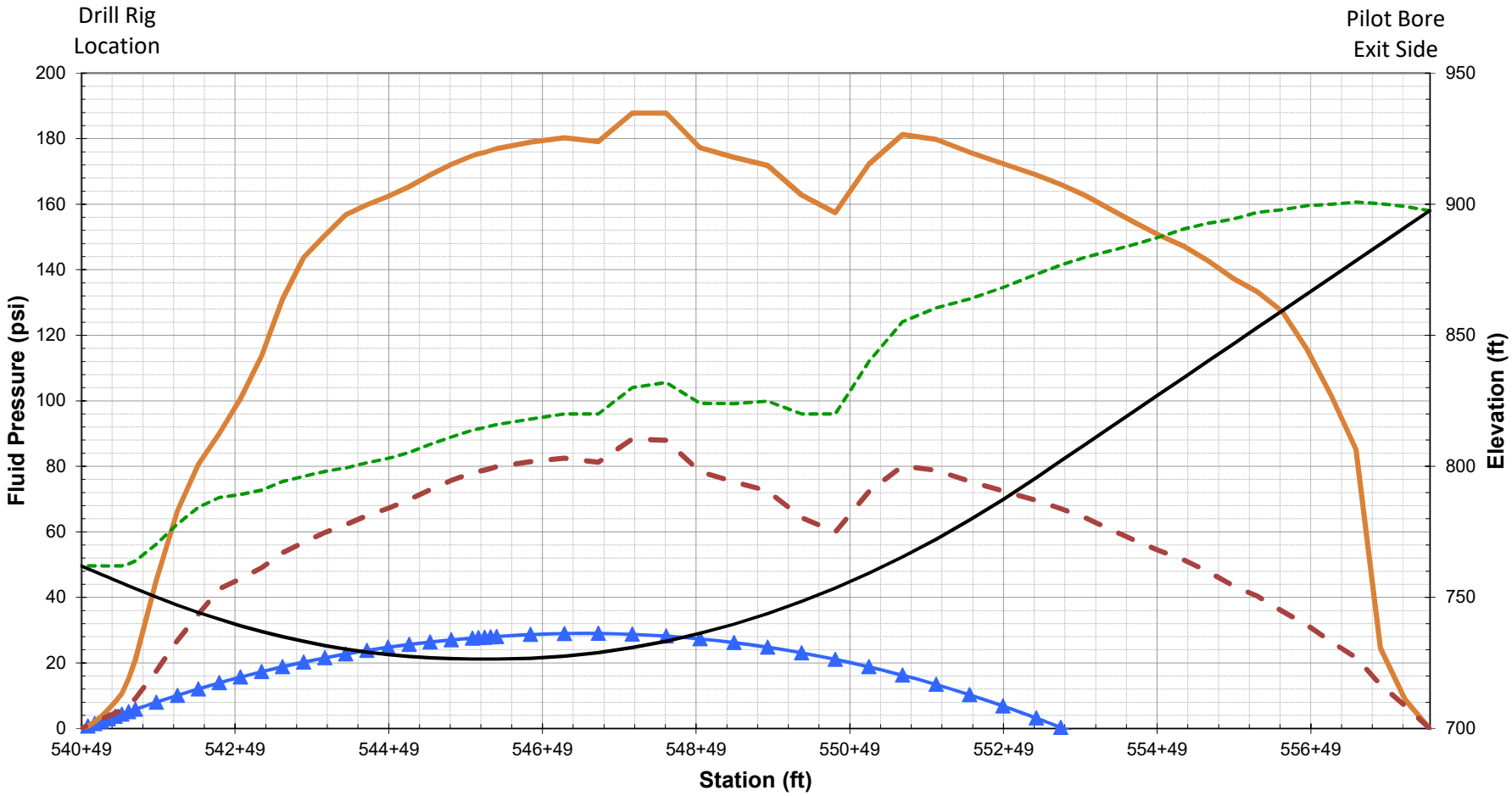
Start-Up Load Factor	1.5	
Maximum Calculated Start-Up Pipe Pull Load	343,287	lb
	1,527	kN
Factor of Safety	10.3	

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)	0.25	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	18	$lb/100ft^2$ (Based on HDD experience from previous installations)
	86.184	$dyne/cm^2$
Plastic Viscosity	12	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	600	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	2.271	m^3/min
Drilling mud pumping rate	1129	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.273	m^3/min
Pipe Pullback Rate	10	feet/min (Based on HDD experience)
	3.05	m/min

Appendix D

Hydraulic Fracture Evaluation



Crossing Length (ft)	1,755.1
Bore Diameter (in)	12.250
Drill Pipe O.D. (in)	6.625
Drilling Fluid Weight (ppg)	10.25
Plastic Viscosity (cP)	12
Yield Point (lb/100SF)	18

PennEast Pipeline
HORIZONTAL DIRECTIONAL DRILLING EVALUATION

MOTT MACDONALD

PennEast Pipeline Project
Interstate 81/ State Route 315 Crossing
DRILLING FLUID PRESSURE EVALUATION

Pilot Bore Drilling Fluid Pressure Evaluation

MOTT MACDONALD

Horizontal Directional Drilling
Drilling Fluid Hydraulic Fracture Calculations

Calculated by: M. Lockwood
Checked by: G. Duyvestyn
Date: 10/22/2018
Project No: 353754

PROJECT: PennEast Pipeline Project **CROSSING LOCATION: Interstate 81 / S. R. 315**

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	3000			
c, soil effective cohesion (N/m^2 or Pa)	0	143,641	0	0	0
ϕ, soil internal friction angle (deg)	20.0	12.0			
ϕ, soil internal friction angle (rad)	0.35	0.21	0.00	0.0	0.0
Equivalent 'SPT Blow Count N60 (blows per 12 inch)	25	34			
E , Young's Modulus based on blow count (lb/ft^2)	750,000	1,020,000	0	0	0
E , Young's Modulus (kPa)	36,000	48,000			
E , Young's Modulus (lb/ft^2)	751,875	1,002,501	0	0	0
ν , Poisson's ratio	0.33	0.35			
G, soil shear modulus (ksf)	283	371	0	0	0
G, soil shear modulus (kPa)	13,534	17,778	0	0	0
G, soil shear modulus (Pa)	13,533,835	17,777,778	0	0	0
γ, soil total unit weight (pcf) below water table	125	145			
γ, soil total unit weight (kN/m^3) below water table	19.6	22.8	0.0	0.0	0.0
γ, soil total unit weight (pcf) above water table	120	140			
γ, soil total unit weight (kN/m^3) above water table	18.9	22.0	0.0	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	No	yes or no
Target Drill and Intersect Location	418+00	input stationing in feet (do not enter + sig
	12+741	Stationing in metres
Drill Rig setup on Pipe Side (Single Rig Option Only). **For Drill and Intersect, this must be "no"**	yes	yes or no (must be no for direct and inter
Drill Rig #1 Elevation	762.0	feet
	232.3	metre
Drill Rig #2 Elevation (Pipe Entry Location)	N/A	feet
	N/A	metre
Recommended Allowable Pressure Factor	2.00	
Total Horizontal Installation Length	1,755.1	feet
	535.0	metre
True Installation Length	1,771.3	feet
	539.9	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	600	gal/min
	2.27	m^3/min
Calculated Drilling Fluid Velocity	2.306	ft/sec
	0.703	m/sec
Pressure Required for Bore Slurry Flow	0.017	psi per ft of bore
	0.116	kPa per metre of bore
	0.506	psi per 30 ft drill pipe
Drilling Fluid Mud Weight	10.25	ppg
	76.7	lb/ft^3
	1.23	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	558+04	17+009	1,771.3	539.9	897.5	273.6	897.5	273.6	747.0	227.7	0.0	0.0	Type 1	0.0	0.0	29.89	206.1	--	-72.16	-291.42	--	-42.27	-291.4	--
	557+72	16+999	1,738.6	529.9	891.2	271.6	899.1	274.1	747.0	227.7	8.0	2.4	Type 1	28.5	196.6	29.3	202.3	0.97	-68.8	-474.1	-0.41	-39.4	-271.9	-0.72
	557+40	16+990	1,706.0	520.0	884.8	269.7	900.2	274.4	747.0	227.7	15.4	4.7	Type 1	67.6	466.0	28.8	198.5	2.35	-65.4	-450.8	-1.03	-36.6	-252.3	-1.85
	557+08	16+980	1,673.4	510.1	878.4	267.7	900.8	274.6	747.0	227.7	22.4	6.8	Type 2	212.9	1468.2	28.2	194.7	7.54	-62.0	-427.4	-3.44	-33.8	-232.7	-6.31
	556+76	16+970	1,640.8	500.1	872.1	265.8	900.0	274.3	747.0	227.7	27.9	8.5	Type 2	228.4	1574.7	27.7	190.9	8.25	-58.6	-404.0	-3.90	-30.9	-213.1	-7.39
	556+44	16+960	1,608.1	490.2	865.7	263.9	899.5	274.2	747.0	227.7	33.8	10.3	Type 2	243.1	1676.1	27.1	187.1	8.96	-55.2	-380.7	-4.40	-28.1	-193.6	-8.66
	556+12	16+951	1,575.5	480.2	859.3	261.9	898.0	273.7	747.0	227.7	38.6	11.8	Type 2	254.5	1754.7	26.6	183.3	9.57	-51.8	-357.3	-4.91	-25.2	-174.0	-10.08
	555+80	16+941	1,542.9	470.3	853.0	260.0	896.8	273.4	747.0	227.7	43.9	13.4	Type 2	266.4	1836.9	26.0	179.5	10.23	-48.4	-333.9	-5.50	-22.4	-154.4	-11.90
	555+48	16+931	1,510.2	460.3	846.6	258.0	894.3	272.6	747.0	227.7	47.7	14.5	Type 2	274.8	1894.6	25.5	175.7	10.78	-45.0	-310.6	-6.10	-19.6	-134.9	-14.05
	555+16	16+921	1,477.6	450.4	840.2	256.1	892.7	272.1	747.0	227.7	52.5	16.0	Type 2	285.3	1967.2	24.9	171.9	11.44	-41.7	-287.2	-6.85	-16.7	-115.3	-17.06
	554+84	16+912	1,445.0	440.4	833.9	254.2	890.5	271.4	747.0	227.7	56.7	17.3	Type 2	294.3	2028.9	24.4	168.1	12.07	-38.3	-263.8	-7.69	-13.9	-95.7	-21.20
	554+52	16+902	1,412.4	430.5	827.5	252.2	887.4	270.5	747.0	227.7	59.9	18.3	Type 2	301.2	2076.4	23.8	164.3	12.64	-34.9	-240.5	-8.64	-11.0	-76.1	-27.27
	554+20	16+892	1,379.7	420.5	821.1	250.3	884.7	269.7	747.0	227.7	63.6	19.4	Type 2	308.9	2129.6	23.3	160.5	13.27	-31.5	-217.1	-9.81	-8.2	-56.6	-37.65
	553+88	16+882	1,347.1	410.6	814.8	248.3	882.2	268.9	747.0	227.7	67.5	20.6	Type 2	317.0	2185.8	22.7	156.7	13.95	-28.1	-193.7	-11.28	-5.4	-37.0	-59.08
	553+56	16+873	1,314.5	400.7	808.4	246.4	879.9	268.2	747.0	227.7	71.4	21.8	Type 2	325.3	2242.8	22.2	152.9	14.67	-24.7	-170.4	-13.17	-2.5	-17.4	-128.73
	553+24	16+863	1,281.9	390.7	802.0	244.5	876.8	267.3	747.0	227.7	74.8	22.8	Type 2	332.1	2290.1	21.6	149.1	15.36	-21.3	-147.0	-15.58	0.3	2.1	1066.11
	552+92	16+853	1,249.2	380.8	795.7	242.5	873.2	266.2	747.0	227.7	77.6	23.6	Type 2	337.9	2329.9	21.1	145.3	16.03	-17.9	-123.6	-18.85	3.2	21.7	107.27
	552+48	16+840	1,205.0	367.3	787.3	240.0	868.3	264.6	747.0	227.7	80.9	24.7	Type 2	344.8	2377.3	20.3	140.2	16.96	-13.5	-93.0	-25.57	6.9	47.2	50.32
	552+05	16+827	1,160.9	353.8	779.5	237.6	863.8	263.3	747.0	227.7	84.3	25.7	Type 2	351.7	2425.0	19.6	135.1	17.95	-9.3	-64.3	-37.74	10.3	70.8	34.25
	551+61	16+813	1,116.7	340.4	772.2	235.4	860.4	262.3	747.0	227.7	88.2	26.9	Type 2	359.6	2479.2	18.8	129.9	19.08	-5.4	-37.5	-66.10	13.4	92.4	26.83
	551+18	16+800	1,072.5	326.9	765.5	233.3	855.1	260.6	747.0	227.7	89.7	27.3	Type 2	362.6	2499.8	18.1	124.8	20.03	-1.8	-12.7	-196.41	16.3	112.1	22.31
	550+74	16+787	1,028.3	313.4	759.3	231.4	840.0	256.0	747.0	227.7	80.8	24.6	Type 2	344.4	2374.8	17.4	119.6	19.85	1.5	10.1	235.49	18.8	129.7	18.31
	550+30	16+773	984.1	300.0	753.6	229.7	820.0	249.9	747.0	227.7	66.4	20.2	Type 2	314.8	2170.3	16.6	114.5	18.95	4.5	30.9	70.18	21.1	145.4	14.92
	549+86	16+760	940.0	286.5	748.4	228.1	820.0	249.9	747.0	227.7	71.6	21.8	Type 2	325.5	2244.5	15.9	109.4	20.52	7.2	49.8	45.08	23.1	159.1	14.10
	549+42	16+747	895.8	273.0	743.8	226.7	824.8	251.4	747.0	227.7	81.0	24.7	Type 2	343.6	2369.1	15.1	104.2	22.73	9.7	66.7	35.53	24.8	170.9	13.86
	548+98	16+733	851.6	259.6	739.8	225.5	823.9	251.1	747.0	227.7	84.2	25.7	Type 2	348.6	2403.2	14.4	99.1	24.25	11.8	81.6	29.46	26.2	180.7	13.30
	548+54	16+720	807.4	246.1	736.3	224.4	824.0	251.2	747.0	227.7	87.7	26.7	Type 2	354.5	2443.9	13.6	93.9	26.01	13.7	94.5	25.86	27.3	188.4	12.97
	548+10	16+706	763.3	232.6	733.3	223.5	832.0	253.6	747.0	227.7	98.8	30.1	Type 2	375.5	2589.3	12.9	88.8	29.16	15.3	105.4	24.56	28.2	194.2	13.33
	547+66	16+693	719.1	219.2	730.8	222.8	830.1	253.0	747.0	227.7	99.2	30.2	Type 2	375.6	2589.3	12.1	83.7	30.95	16.6	114.4	22.64	28.7	198.1	13.07
	547+22	16+679	674.9	205.7	728.9	222.2	820.0	249.9	747.0	227.7	91.1	27.8	Type 2	358.3	2470.4	11.4	78.5	31.46	17.6	121.4	20.36	29.0	199.9	12.36
	546+78	16+666	630.7	192.2	727.6	221.8	820.0	249.9	747.0	227.7	92.4	28.2	Type 2	360.6	2486.0	10.6	73.4	33.88	18.3	126.3	19.68	29.0	199.7	12.45
	546+34	16+653	586.5	178.8	726.8	221.5	818.0	249.3	747.0	227.7	91.2	27.8	Type 2	357.8	2467.1	9.9	68.2	36.15	18.8	129.3	19.08	28.7	197.6	12.49
	545+89	16+639	542.4	165.3	726.5	221.4	815.9	248.7	747.0	227.7	89.4	27.3	Type 2	354.0	2440.7	9.2	63.1	38.68	18.9	130.3	18.73	28.1	193.4	12.62
	545+82	16+637	534.5	162.9	726.5	221.4	815.3	248.5	747.0	227.7	88.8	27.1	Type 2	352.8	2432.4	9.0	62.2	39.11	18.9	130.3	18.67	27.9	192.5	12.64
	545+74	16+634	526.6	160.5	726.5	221.4	814.8	248.3	747.0	227.7	88.3	26.9	Type 2	351.7	2424.7	8.9	61.3	39.57	18.9	130.3	18.61	27.8	191.6	12.66
	545+66	16+632	518.8	158.1	726.5	221.4	814.3	248.2	747.0	227.7	87.8	26.8	Type 2	350.8	2418.4	8.8	60.4	40.07	18.9	130.3	18.56	27.7	190.7	12.68
	545+58	16+629	510.9	155.7	726.5	221.4	813.8	248.0	747.0	227.7	87.3	26.6	Type 2	349.7	2410.9	8.6	59.4	40.56	18.9	130.3	18.50	27.5	189.8	12.71
	545+30	16+621	483.4	147.3	726.6	221.5	811.2	247.3	747.0	227.7	84.6	25.8	Type 2	344.2	2373.4	8.2	56.2	42.20	18.8	129.9	18.27	27.0	186.2	12.75
	545+03	16+613	455.9	139.0	726.9	221.6	808.3	246.4	747.0	227.7	81.4	24.8	Type 2	337.8	2329.1	7.7	53.0	43.91	18.7	128.8	18.09	26.4	181.8	12.81
	544+75	16+604	428.4	130.6	727.4	221.7	805.3	245.5	747.0	227.7	77.9	23.7	Type 2	330.7	2279.9	7.2	49.8	45.74	18.4	126.8	17.97	25.6	176.7	12.90
	544+48	16+596	401.0	122.2	728.2	222.0	803.0	244.8	747.0	227.7	74.9	22.8	Type 2	324.7	2239.1	6.8	46.6	48.00	18.0	124.1	18.04	24.8	170.8	13.11
	544+21	16+588	373.5	113.8	729.1	222.2	801.4	244.3	747.0	227.7	72.3	22.0	Type 2	319.7	2204.4	6.3	43.5	50.73	17.5	120.7	18.27	23.8	164.1	13.43
	543+93	16+579	346.0	105.5	730.3	222.6	799.4	243.6	747.0	227.7	69.1	21.1	Type 2	313.6	2162.0	5.8	40.3	53.71	16.9	116.4	18.57	22.7	156.7	13.80
	543+66	16+571	318.5	97.1	731.6	223.0	798.0	243.2	747.0	227.7	66.4	20.2	Type 2	308.4	2126.4	5.4	37.1	57.38	16.2	111.4	19.08	21.5	148.5	14.32
	543+38	16+562	291.0	88.7	733.2	223.5	796.2	242.7	747.0	227.7	63.0	19.2	Type 2	301.9	2081.3	4.9	33.9	61.47	15.3	105.7	19.70	20.2	139.5	14.92
	543+11	16+554	263.5	80.3	735.0	224.0	794.2	242.1	747.0	227.7	59.2	18.1	Type 2	294.7	2032.0	4.4	30.7	66.28	14.4	99.1	20.50	18.8	129.8	15.66
	542+83	16+546	236.0	71.9	737.0	224.6	790.9	241.1	747.0	227.7	53.9	16.4	Type 2	284.2	1959.6	4.0	27.5	71.36	13.3	91.8	21.35	17.3	119.3	16.43
	542+56	16+537	208.5	63.6	739.2	225.3	789.2	240.6	747.0	227.7	50.0	15.3	Type 2	276.7	1907.6	3.5	24.3	78.62	12.1	83.7	22.78	15.7	108.0	17.67
	542+29	16+529	181.0	55.2	741.6	226.0	788.1	240.2	747.0	227.7	46.5	14.2	Type 2	269.9	1861.1	3.1	21.1	88.36	10.9	74.9	24.86	13.9	95.9	19.40
	542+01	16+521	153.6	46.8	744.2	226.8	784.4	239.1	747.0	227.7	40.2	12.2	Type 1	161.2	1111.6	2.6	17.9	62.22	9.5	65.3	17.04	12.1	83.1	13.37
	541+74	16+512	126.1	38.4	747.1	227.7	778.0	237.1	747.0	227.7	30.9	9.4	Type 1	132.8	915.7	2.1	14.7	62.43	8.0	54.9	16.69	10.1	69.5	13.17
	541+47	16+504	98.6	30.0	750.1	228.6	770.3	234.8	747.0	227.7	20.2	6.2	Type 1	90.1	621.4	1.7	11.5	54.18	6.3	43.7	14.21	8.0	55.2	11.26
	541+19	16+496	71.1	21.7	753.3	229.6	763.9	232.8	747.0	227.7	10.5	3.2	Type 1	42.0	289.4	1.2	8.3	34.99	4.6	31.8	9.10	5.8	40.1	7.22
	541+10	16+493	62.2	19.0	754.4	229.9	762.7	232.5	747.0	227.7	8.3	2.5	Type 1	30.3	209.1	1.0	7.2	28.89	4.0	27.8	7.51	5.1	35.1	5.96
	541+02	16+490	53.3	16.3	755.5	230.3	762.0	232.3	747.0	227.7	6.5	2.0	Type 1	21.2	146.5	0.9	6.2	23.61	3.5	23.9	6.14	4.4	30.1	4.87
	540+93	16+488	44.4	13.5	756.6	230.6	762.0	232.3	747.0	227.7	5.4	1.6	Type 1	16.2	111.6	0.7	5.2	21.59	2.9	19.9	5.61	3.6	25.0	4.46
	540+84	16+485	35.5	10.8	757.7	230.9	762.0	232.3	747.0	227.7	4.3	1.3	Type 1	11.6	79.9	0.6	4.1	19.31	2.3	15.9	5.02	2.9	20.0	3.99
	540+75	16+482	26.7	8.1	758.7	231.3	762.0	232.3	747.0	227.7	3.2	1.0	Type 1	7.5	51.9	0.4	3.1	16.72	1.7	11.9	4.35	2.2	15.0	3.45
	540+66	16+480	17.8	5.4	759.8	231.6	762.0	232.3	747.0	227.7	2.2	0.7	Type 1	4.1	28.2	0.3	2.1	13.63	1.2	8.0	3.55	1.5	10.0	2.81
	540+57	16+477	8.9	2.7	760.9	231.9	762.0	232.3	747.0	227.7	1.1	0.3	Type 1	1.4	9.9	0.1	1.0	9.59	0.6	4.0	2.49	0.7	5.0	1.98
Pipe Entry Side	540+49	16+474	0.0	0.0	762.0	232.3	762.0	232.3	747.0	227.7	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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