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HDD Design Report
Nishisakawick Creek HDD
Crossing

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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 Nishisakawick Creek, part of the larger PennEast Pipeline Project. The proposed Project consists of 115 miles of 36-inch diameter (NPS 36) high pressure, natural gas pipeline from Luzerne County, Pennsylvania to Mercer County, New Jersey.

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

The drawings and design elements have been prepared and evaluated with the aid of a geotechnical subsurface investigation performed by Mott MacDonald, and laboratory assessment and testing analysis completed by Craig Testing Laboratories, Inc (CTL) and Terra Sense, LLC. Brief discussions on the geotechnical conditions summarized 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 3,301 feet (with a true length of approximately 3,362 feet). The HDD entry point is located approximately 1,123 feet southeast of Ridge Road and the HDD exit point is located approximately 179 feet northwest of Ridge Road. An elevation difference of approximately 6 feet exists between the HDD entry and exit locations, with the HDD entry location at the higher elevation. The southeast side of the crossing was selected as the HDD entry location to minimize noise disturbance to the residential property located on the northwest side of the crossing. Drill rig remobilization will be required prior to pullback operations, as the pipe staging area for the drag section is located on the southeast side of the crossing (the same side as the HDD entry location). It is envisioned that the pipe string will be fabricated into three (3) sections prior to pullback operations with two intermediate welds completed during pullback operations. The contractor will need to coordinate with PennEast and its Land/ROW group regarding the closure of Ridge Road for the fabrication, testing, and pullback operations of the product pipe.

An elevation difference of approximately 181 feet exists between the HDD entry location and Nishisakawick Creek. The elevation difference between the HDD exit location and Nishisakawick Creek is approximately 175 feet. This elevation difference has resulted in the need for steep entry and exit angles to achieve a sufficient depth of cover with the HDD installation beneath Nishisakawick Creek. The steep exit angle of 14 degrees will require additional equipment for the break over section of the product pipe.

2 Anticipated Geotechnical Conditions

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

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

2.1 Geotechnical Observations

The soils near of the crossing are part of two major formations within the area. The first formation is of the Weathered Shale, Mudstone and Sandstone formation of the Pleistocene Age, which consists primarily of silty sand to silty clay with shale, mudstone, or sandstone fragments. The second formation is the Alluvium formation of the Holocene and late Pleistocene eras and crosses a small strip of the HDD alignment. This formation consists of sand, gravel, silt, minor clay, and peat with variable amounts of organic matter that have been deposited in modern floodplains and channels. Surficial mapping from the Natural Resources Conservation Service's (NRCS) indicate the major soil components in the crossing area consist of Klinesville channery loam, Penn channery silt loam, shale, and Rowland silt loam. All three soil groups are mapped with a moderate rating for the corrosion of steel and a high rating for the corrosion of concrete.

2.2 Subsurface Geotechnical Investigation

The subsurface investigation consisted of five (5) boreholes (B-63, B-64, B-65, B-65A, and B-66). Borings B-63 and B-64 are located Southeast of Everittstown Road and Northwest of Nishisakawick Creek, Borings B-65, B65A, B-66 are located Southeast of Nishisakawick Creek. A summary of the boring elevations and depths are provided in Table 1. A brief description of the subsurface materials encountered at the site is provided below.

Table 1: Boring Elevations and Depths

Boring Number	Approximate Ground Surface Elevation[1] (feet)	Boring Depth (feet)	Boring Termination Elevation[1] (feet)
B-63	330	275	55
B-64	301	390	-89
B-65	293	120	173
B-65A[2]	285	330	-45
B-66	352	210	142

1 Based on North American Vertical Datum of 1988
2 Alternate boring completed and located 10 feet adjacent to Boring B-65 due to difficulties at 120 feet below ground surface

2.2.1 Geotechnical Observations Northwest of Nishisakawick Creek

The HDD installation on the northwest side of Nishisakawick Creek is anticipated to encounter decomposed rock overlying bedrock materials.

In the vicinity of Boring B-63, the geotechnical materials are anticipated to include the following:

- Topsoil and decomposed rock from the ground surface to a depth of 4.0 feet below ground surface (bgs) (from Elev. 330 to 326 feet).

- Fresh and weak siltstone to Elev. 180 feet. Rock Quality Designation (RQD) values range between 13 and 100 percent (average 77 percent). RQD value of 0 percent present within the first 5 feet of the Siltstone layer after the transition from the decomposed rock.
- Slightly weathered and weak shale to Elev. 160 feet. RQD values range between 67 and 91 percent (average 83 percent).
- Fresh and weak siltstone to Elev. 155 feet. RQD value of 100 percent.
- Fresh and weak shale to Elev. 150 feet. RQD value of 100 percent.
- Fresh and strong to very strong argillite to Elev. 71.8 feet. RQD values range between 63 and 100 percent (average 95 percent).
- Slightly weathered and medium strong shale to Elev. 65 feet. RQD value of 52 percent.
- Fresh and medium strong limestone to Elev. 60 feet. RQD value of 83 percent.
- Fresh and very strong argillite to a termination elevation of 55 feet. RQD value of 97 percent.

In the vicinity of Boring B-64, the geotechnical materials are anticipated to include the following:

- Very dense decomposed rock from the ground surface to a depth of 3.5 feet (from Elev. 301 to 297.5 feet).
- Slightly weathered and very weak to weak siltstone to Elev. 207 feet. RQD values range between 23 and 98 percent (average 66 percent). RQD value of 0 percent present within the first 5 feet of the siltstone layer after the transition from decomposed rock.
- Slightly weathered and weak shale to Elev. 197 feet. RQD values range between 45 to 58 percent (average 52 percent).
- Slightly weathered and weak siltstone to Elev. 117 feet. RQD values range between 73 and 100 percent (average 92 percent).
- Slightly weathered and weak shale to Elev. 112 feet. RQD value of 90 percent.
- Slightly weathered and weak siltstone to Elev. 99 feet. RQD values range between 81 to 97 percent (average 93 percent).
- Slightly weathered and weak shale to Elev. 87 feet. RQD values range between 63 to 95 percent (average 79 percent).
- Slightly weathered and weak siltstone to Elev. 77 feet. RQD value of 100 percent.
- Slightly weathered and weak shale to Elev. 72 feet. RQD value of 75 percent.
- Slightly weathered and weak siltstone to the termination elevation of -89 feet. RQD values range between 67 to 100 percent (average 92 percent).

Along the proposed HDD alignment, the bedrock on the northwest side of the Nishisakawick Creek appears to be of very poor to excellent quality with an overall good quality for the rock mass. The very poor quality appears to be located at the soil to bedrock interface and the quality and strength of the bedrock increased with depth. The core recovery values on the northwest side for all stratum ranged from 83 to 100 percent with an average value of 99.5 percent. .

Laboratory testing of the siltstone from boring B-64 indicate uniaxial compressive strengths (UCS) ranging from 12,942 psi to 17,392 psi, with an average of 15,167 psi. The axial point load UCS ranged from 14,377 psi to 31,346 psi, with an average of 22,682 psi. The diametral point load UCS ranged from 1,399 psi to 2,099 psi, with an average of 1,749 psi. The splitting tensile strength was 1862 psi.

Laboratory testing of the argillite from boring B-63 indicate a UCS range from 12,378 psi to 24,825 psi, with an average of 18,602 psi. The axial point load UCS ranged from 6,116 psi to 19,157 psi, with an average of 12,637 psi. The diametral point load UCS ranged from 4,162 psi to 15,712 psi, with an average of 9,937 psi. The splitting tensile strength ranged from 3,102 psi to 3,331 psi, with an average of 3,217 psi.

2.2.2 Geotechnical Observations Southeast of Nishisakawick Creek

The HDD installation on the southeast side of the Nishisakawick Creek is anticipated to encounter stiff to hard silt and decomposed rock overlying bedrock materials.

In the vicinity of Boring B-65, the geotechnical materials are anticipated to include the following:

- Stiff silt with trace medium to fine gravel and little fine sand from ground surface to a depth of 3.5 feet bgs (from Elev. 293 feet to 290 feet).
- Medium dense to very dense decomposed rock to Elev. 282.5 feet. Decomposed rock is primarily siltstone.
- Slightly weathered to moderate weathered and strong argillite to Elev. 258 feet. RQD values range between 8 and 60 percent (average 42 percent).
- Thin layer of slightly weathered and medium strong black coal to Elev. 257.3 feet.
- Slightly weathered and medium strong to very strong argillite to Elev. 248 feet. RQD values range between 52 and 88 percent (average 70 percent).
- Slightly weathered and medium strong marl to Elev. 243 feet. RQD value of 85 percent.
- Slightly weathered and medium strong to very strong argillite to a termination depth of 173 feet. RQD values range between 87 and 100 percent (average 95 percent).

In the vicinity of Boring B-65A, the geotechnical materials are anticipated to include the following:

- Stiff silt from ground surface to a depth of 3.5 feet bgs (from Elev. 285 feet to 281.5 feet).
- Very dense decomposed rock to Elev. 273.7 feet. Decomposed rock is primarily siltstone.
- Slightly weathered and weak to very strong argillite to Elev. 257.6 feet. RQD values range between 0 and 80 percent (average 35 percent).
- Fresh and weak to medium strong shale to Elev. 240 feet. RQD values range between 0 and 93 percent (average 51 percent).
- Fresh and medium strong argillite to Elev. 231.5 feet. RQD values range between 92 and 94 percent (average 93 percent).
- Slightly weathered and medium strong shale to Elev. 222 feet. RQD values range between 33 and 88 percent (average 61 percent)
- Thin layer of slightly weathered and medium strong marl to Elev. 220 feet.
- Fresh to moderately weathered and weak to medium strong argillite to Elev. 167.8 feet. RQD values range between 42 and 100 percent (average 78 percent).
- Thin layer of slightly weathered and weak to medium strong shale to Elev. 166.3 feet.
- Thin layer of slightly weathered and weak to medium strong argillite to Elev. 164.6 feet.
- Slightly weathered and weak to strong shale to Elev. 158 feet. RQD values range between 93 and 97 percent (average 95 percent).
- Small layer of fresh and weak to strong marl to Elev. 155 feet.
- Moderately weathered and weak to strong argillite to Elev. 150 feet. RQD value of 52 percent.
- Moderately weathered and weak to medium strong shale to Elev. 137.8 feet. RQD values range between 73 and 77 percent (average 75 percent).
- Slightly weathered and medium strong argillite to Elev. 126.6 feet. RQD values range between 75 and 100 percent (average 96 percent).
- Fresh and weak to medium strong shale to Elev. 120 feet. RQD value of 85 percent.
- Fresh and weak to strong argillite to a termination depth of Elev. -45 feet. RQD values range between 92 and 100 percent (average 98 percent).

In the vicinity of Boring B-66, the geotechnical materials are anticipated to include the following:

- Hard clayey silt from ground surface to a depth of 3.5 feet bgs (from Elev. 351.6 feet to 348.1 feet).
- Very dense decomposed bedrock to Elev. 346.2 feet.
- Moderately weathered to fresh and weak to strong argillite to Elev. 306.6 feet. Occasionally interbedded with shale. RQD values range between 0 and 100 percent (average 44 percent).
- Fresh and medium strong to strong shale to Elev. 301.6 feet. RQD value of 83 percent.
- Fresh and strong argillite interbedded with shale to Elev. 296.6 feet. RQD value of 99 percent.
- Fresh and medium strong to strong siltstone to Elev. 286.6 feet. Occasional interbedded with shale. RQD values range between 22 and 95 percent (average 59 percent).
- Fresh and medium strong to strong shale to Elev. 281.6 feet. RQD value of 50 percent.
- Fresh and medium strong siltstone to Elev. 276.6 feet. RQD value of 85 percent.
- Fresh and strong argillite to Elev. 266.6 feet. RQD values range between 93 and 98 percent (average 96 percent).
- Fresh and weak to medium strong shale to Elev. 256.6 feet. RQD values range between 93 and 97 percent (average 63 percent).
- Fresh and medium strong to strong argillite to Elev. 246.9 feet. RQD values range between 93 and 99 (average 96 percent).
- Fresh and weak to medium string shale to Elev. 245.2 feet. RQD value of 94 percent.
- Fresh to slightly weathered and medium strong to strong argillite to Elev. 199.0 feet. RQD values range between 80 to 97 percent (average 90 percent).
- Fresh and weak to medium strong shale to Elev. 193.6. RQD values range between 92 and 91 percent (average 92 percent).
- Fresh and medium strong to strong siltstone to Elev. 191.6 feet. RQD value of 91 percent.
- Fresh and strong argillite to Elev. 186.6 feet. RQD value of 98 percent.
- Fresh and medium strong shale to Elev. 176.6 feet. RQD values range between 71 and 98 percent (average 85 percent).
- Fresh and medium strong to strong argillite to Elev. 161.6 feet. RQD values range between 94 and 100 percent (average 98 percent).
- Fresh and weak to strong shale to Elev. 155.1 feet, RQD values range between 94 and 100 percent (average 97 percent).
- Fresh and medium strong to strong argillite to termination elevation of 141.6 feet. RQD values range between 85 and 100 percent (average 94 percent).

Along the proposed HDD alignment, the bedrock on the southeast side of the Nishisakawick Creek appears to be of very poor to excellent quality with an overall good quality of the rock mass. The very poor quality appears to be located at the soil to bedrock interface and the quality and strength of the bedrock increased with depth. The core recovery values on the southeast side for all stratum ranged from 79 to 100 percent, with an average value of 98.8 percent.

Laboratory testing of the argillite from boring B-65A indicate a UCS range from 17,267 psi to 24,373 psi, with an average of 20,820 psi. The splitting tensile strength ranged from 1,861 psi to 3,067 psi, with an average of 2,624 psi.

Laboratory testing of the argillite from boring B-66 indicate a UCS range from 11,468 psi to 33,049 psi, with an average of 20,045 psi. The splitting tensile strength ranged from 2,158 psi to 2,893 psi, with an average of 2,556 psi. The diametral point load UCS ranged from 4,212 psi to 30,362 psi, with an average of 10,967 psi.

Laboratory testing of the shale from boring B-65A indicate an axial point load UCS range from 36,738 psi to 37,679 psi, with an average of 37,209 psi. The diametral point load UCS ranged from 4,855 psi to 20,115 psi, with an average of 12,485 psi.

2.3 Groundwater Conditions

Groundwater was only observed near the ground surface in Boring B-66 for the Nishisakawick Creek crossing. The ground water was observed at a depth of 3.0 feet below ground surface (Elevation 349 feet). For the design of the Nishisakawick Creek HDD the groundwater elevation is assumed to be approximately 3.0 feet below ground surface in the vicinity of the HDD entry location on the southeast side, level with the water elevation of the creek in the vicinity of the creek location, and approximately 50.0 feet below ground surface in the vicinity of the of the HDD exit location on the northwest side.

2.4 Karst Features and Abandoned Mines

While a small limestone layer was encountered during the geotechnical investigation, no karst features were observed within the boreholes. According to the New Jersey Geological and Water Survey and the United States Geological Survey, no known karst features have been mapped on either side of Nishisakawick Creek, and no abandoned mines have been mapped in the area of the proposed HDD alignment.

3 Nishisakawick Creek 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 Nishisakawick Creek crossing the pipe staging area and break-over location has been selected to be on the southeastern side of the creek due to workspace constraints. The drill rig will be moved to the southeastern side once the reaming and swabbing operations are complete. The entry and exit angles have been both set at 14° relative to the horizontal. The entry and exit angles were selected to attain sufficient depth of cover beneath the creek bed while maintaining the installation within the current right of way due to topography constraints.

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 northwest of Nishisakawick Creek as shown in Appendix A is consistent with the HDD industry standard of 1,200 times the 36-inch outer diameter of the pipe. The proposed vertical curve radius of 3,400 feet southeast of Nishisakawick Creek as shown in Appendix A is slightly lower than the HDD industry standard of 1,200 times the 36-inch outer diameter of the pipe, or 3,600 feet. This radius on the southeast side of the creek has been selected due to constraints with the location of the HDD entry and exit points and site topography. Although the vertical radius southeast of Nishisakawick Creek is lower than the HDD industry standard, it remains feasible as a vertical design radius.

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
- Installation length

Of these, the two 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 the Nishisakawick Creek.

The proposed HDD installation crosses beneath surface features including Everittstown Road, Nishisakawick Creek, and Stream NJ-NHD-155. From a southeast to northwest orientation, the following minimum depths of cover are noted:

- Waterbody 012319_LD_1002_E_MI: Approximately 59 feet.
- Waterbody 012319_LD_1003_P_IN: Approximately 90 feet.
- Creek Road: Approximately 129 feet.
- Nishisakawick Creek Perennial (FW2-NTC1) 022317_SQ_1003_P_IN: Approximately 103 feet.
- Everittstown Road: Approximately 36 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 creek, 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 creek, 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 Nishisakawick Creek and adjacent wetlands. 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 is irregularly shaped and has been established as approximately 1.4 acres, and the staging area for the southeast side of the crossing has been established at 144 feet by 334 feet or 1.1 acres. 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 75 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 southeast side of the crossing. The available length of the staging area is approximately 1,540 feet, requiring the fabrication of the product pipe into three (3) pipe strings, with the shortest string recommended to be installed first. The proposed pipe staging width is 125 feet to accommodate the three (3) pipe strings. Additional lifting equipment will be needed to transition the pipe through the break over section due to the steep bore angle and the presence of a horizontal curve on this side of the crossing.

The temporary work space established for the Nishisakawick Creek crossing is sufficient for HDD operations.

3.4 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 20,000 to 40,000 gallons, 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 1,800,000 gallons. 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 150,000 gallons).

3.5 Disposal of Excess Drilling Fluid and Processed Spoils

Excess drilling fluids and processed spoils will need to be disposed of during the installation. The direct area around the HDD is not expected to be suitable for permanent disposal of drilling fluid or processed solids (based on local, state, and federal regulations).

Local, temporary storage will be required, either in above ground tanks or a lined burrow pit. A suitable offsite disposal site should be located for disposal of drilling fluid and processed spoil per the local, state, and federal guidelines.

Disposal volumes of excess drilling fluid and spoil are estimated at approximately 1,340,000 gallons (5,074 yd^3) and 2,348 yd^3, respectively. During pullback operations, the estimated displaced fluid volume is approximately 150,000 gallons.

3.6 Schedule

The duration of the HDD installation is conservatively estimated to take a total of 119 shifts, regardless of whether 24-hour operations are conducted to complete the crossing, as shown in Table 2 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 2: Estimated Schedule Duration for the HDD Crossing

Activity	Duration (Shifts)
Mobilization	3
Rig Up / Equipment Setup	5
Pilot Bore Drilling	25
Reaming	75
Swab Pass	3
Product Pipe Pullback	3
Rig Down and Demobilization	5
Total Number of Shifts	**119**

4 HDD Engineering Evaluation

4.1 Pipeline Properties

The pipeline properties used for the evaluation of the Nishisakawick Creek crossing have been provided by PennEast, and are summarized in Table 3 below:

Table 3: 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 3, 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 3 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 ensure that the pipe is not overstressed during the HDD installation process, and sufficiently below the design radius provided on the Contract 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 Nishisakawick Creek crossing profile has been established at 3,400 feet southeast of the creek and 3,600 feet northwest of the creek. The vertical bending radius of 3,400 feet is slightly lower than 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). Although the vertical radius southeast of Nishisakawick Creek is lower than the HDD industry standard, it remains feasible as a vertical design radius.

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 3. The results of the evaluation are provided in Table 4 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 4, 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 4: Summary of Operating Stress Evaluation

Stress Condition	Estimated Stress (psi)	Percent of SMYS[1] (%)	Maximum Allowable Percent of SMYS[1] (%)
Longitudinal Bending Stress	16,846	24.1	--
Hoop Stress	34,961	49.9	50[2]
Longitudinal Tensile Stress from Hoop Stress	10,488	15.0	--
Longitudinal Stress from Thermal Expansion	-14,235	20.3	90[3]
Net Longitudinal Stress (Compression Side of the Curve)	-20,593	29.4	90[4]
Net Longitudinal Stress (Tension Side of the Curve)	13,099	18.7	90[4]
Maximum Shear Stress	27,777	39.7	45
Combined Biaxial Stress	55,554	79.4	90[4]

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

4.4 HDD Installation Load and Stress Evaluation

A total of six (6) pull load evaluations were completed for the HDD bore profile. These calculations are based on the installation load calculation method provided in 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 5 below. Detailed calculations are provided in Appendix C. The anticipated installation loads shown in Table 5 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 3. 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 for intermediate welds. This is referred to as the start-up force after intermediate weld in Table 5.

Table 5: Summary of Anticipated Pullback Loads

Drilling Fluid Weight (ppg)	Product Pipe Buoyancy Condition	Estimated Pullback Force (lbs)	Start-up Force After Intermediate Weld 1 (lbs)	Start-up Force After Intermediate Weld 2 (lbs)
10 (Case 1)	Empty	775,715	417,108	798,039
10 (Case 2)	Full	446,646	237,585	399,539
11 (Case 3)	Empty	880,533	455,136	893,427
11 (Case 4)	Full	363,642	239,432	362,157
12 (Case 5)	Empty	984,880	493,163	988,496
12 (Case 6)	Full	280,201	241,278	324,579

Results of the corresponding installation stresses (based on the design bending radius of 3,400 feet) are summarized below in Table 6.

Table 6: 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)	9,196 psi (13.1%)	5,295 psi (7.6%)	10,438 psi (14.9%)	4,311 (6.2%)	11,675 (16.7%)	3,322 (4.8%)
Maximum Bending Stress (Percent of Allowable)	12,882 psi (18.4%)	12,882 (18.4%)	12,882 psi (18.4%)	12,882 (18.4%)	12,882 (18.4%)	12,882 (18.4%)
Maximum Hoop Stress (Percent of Allowable)	3,521 psi (5.0%)	584 (0.8%)	3,873 psi (5.5%)	936 (1.3%)	4,196 (6.0%)	1,279 (1.8%)
Maximum Unity Check – Tensile and Bending	0.42	0.34	0.44	0.33	0.46	0.32
Maximum Unity Check – Tensile, Bending, and Hoop	0.39	0.09	0.45	0.10	0.51	0.12

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 siltstone, shale, and argillite bedrock materials as a moderately strong soil. 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 7 below. These parameters have been selected based on Mott MacDonald's experience in drilling within similar anticipated geotechnical materials.

Table 7: 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)	10.5 ppg (1.26)
Yield Point	22.5 lb/100 ft^2
Plastic Viscosity	15 cP

In addition to the assumptions provided in Table 7, 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 Table 8 for the bedrock material that is 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, decomposed rock overlying siltstone/argillite/shale bedrock. For this evaluation, it has also been assumed that the drilling rig will be set up on the southeast side of the crossing to complete the pilot bore.

Table 8: Material Property Assumptions for the Site Geotechnical Materials

Evaluation Parameter	Value
Soil Unit Weight Above / Below Water Table	150 lb/ft^3 / 155 lb/ft^3
Effective Cohesion	6000 psf
Internal Friction Angle	6°
Young's Modulus	1,044 ksf
Poisson's Ratio	0.30

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. 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.

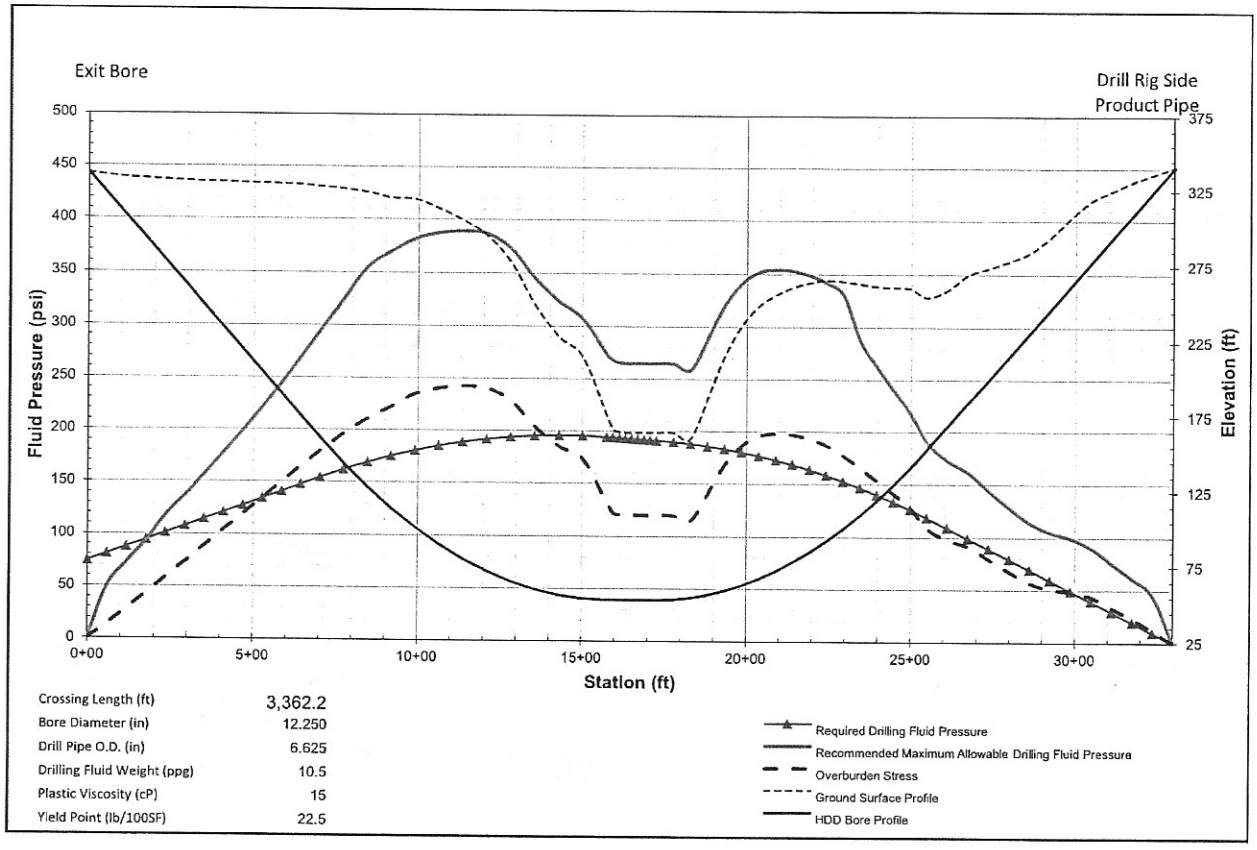


Figure 1: Calculated, Recommended, and Allowable Drilling Fluid Pressures

5 HDD Risk Discussions

5.1 HDD Risk Characterization

Risk identification and mitigation is paramount to successfully completing the Nishisakawick Creek 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, or beyond, the limits of the current state-of-practice for the HDD industry.

Table 9: State of the HDD Industry

Product Pipe Diameter	Installation Length												
	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 ensure comparison to the completed project listings is 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 above, several HDD installations have been successfully completed at a diameter of NPS 36 for lengths considerably longer than the horizontal installation length of approximately 3,301 feet, with a true pipe length of approximately 3,362 feet, required for this crossing. Therefore, from a

constructability standpoint, the Nishisakawick Creek Crossing falls within the zone of typical experience of what has been accomplished to date within the HDD industry.

5.3 Geotechnical Risk Discussions

5.3.1 Soil Materials

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.

Based on the geotechnical information, the site soils are shallow (less than 4 feet thick) and are not anticipated to present any significant risk to the HDD installation. The decomposed rock layers in the vicinity of the HDD entry and exit beneath the site soils are also shallow (less than 3.5 feet thick) and are not anticipated to present any significant challenges to the HDD installation.

5.3.2 Bedrock Materials

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 Nishisakawick Crossing, the rock quality appears to be between 70 and 90 percent through most of the bedrock, with lower RQD percentages in high fractured areas based on the information that is currently available. The strength of the bedrock appears to be weakest at the soil to bedrock interface and increases with depth. Isolated areas of poor-quality bedrock exist at depth but are bounded be rock layers with good to excellent quality. Areas of lower rock quality may be encountered but are not anticipated to significantly increase the risks associated with this installation.

The strength of the bedrock can impact construction duration, with higher strength leading to more frequent trips out of the bore to replace worn tooling. The laboratory tests completed to date on the rock samples indicate UCS values ranging between 11,468 psi and 33,049 psi, point load UCS ranging between 1,399 and 30,362 psi in the diametral direction and between 6,116 psi and 37,679 psi in the axial direction. Splitting tensile strength tests yielded strengths of 1,664 psi and 3,331 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, horizontal to the face of the slope, or upwards towards the ground surface. Fortunately, the presence of the drilling fluid slurry within the bore is often capable of sealing fractures and/or joints as drilling fluids 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.

5.3.3 Crossing-Specific Risk Discussions

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 geotechnical materials is not anticipated for this crossing.

The necessity of the steep exit angle for the Nishisakawick Creek crossing results in risk to the product pipe during pullback operations. Over break stresses induced by the steep angle of the product pipe can be mitigated by the pipe support methods implemented by the HDD contractor. Mott MacDonald recommends discussing this issue with the respective HDD contractor and requesting that the Contractor's work plan include an over break stress analysis consistent with their proposed equipment required to transition the product pipe into the bore.

The length of the pipe staging area is insufficient to fabricate the product pipe into a single string prior to pullback operations and intermediate welds will be required. Intermediate welds will require stoppage of pullback operations each time a new pipe segment is welded on. These stoppages represent a risk to the installation since the bore is required to remain open much longer than what would be required for the installation of a single pipe string. In good quality bedrock that is anticipated for the Nishisakawick Creek HDD Crossing, maintaining stability is possible yet represents a moderate risk. Stoppages for the intermediate welds also provide downtime, while welding occurs, that allows the drilling fluids to "gel" and making it harder to resume pullback operations due to the increased friction between the gelled fluids and the product pipe. Start-up loads will increase each time pullback operations are resumed. In some cases, the gel strength of the fluids is too great and the resulting loads lead to damage of the product pipe or the pipe may become stuck at its current position in the bore. With each additional weld this risk increases significantly. Prior to pullback operations, a swab pass should be completed to gauge whether the bore has been conditioned to accept the product pipe. Areas of high torque and/or pull force should be re-reamed to lower the drill rig effort to pass tools through this portion of the bore. The product pipe should be installed such that the minimal length of pipe is in the HDD bore at the time intermediate welds are required to decrease the startup loads on the pipe required to resume drilling operations.

6 Summary

An HDD construction approach for the Nishisakawick Creek Crossing is deemed feasible, based on known site conditions. Of the risks evaluated based on the available information, 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.

While not anticipated, if an attempted HDD installation is unsuccessful, the proposed HDD alignment could be modified using the same general location to accommodate an additional HDD attempt, depending on the condition and cause contributing to 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 Nishisakawick Creek 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

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 M M

BOREHOLE LOG GRAPHIC LEGEND

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Nishisakawick Creek, Hunterdon Co., NJ	**Project Manager:**	Vatsal Shah
Client:	PennEast Pipeline	**Project Director:**	Michael Wilcox

Soil Log Graphic Legend


DECOMPOSED ROCK: Decomposed Rock


ML: USCS Silt


TOPSOIL: Topsoil

Rock Log Graphic Legend


COAL - Coal


LIMESTONE - Limestone


MUDSTONE - Mudstone


SHALE - Shale


SILTSTONE - Siltstone

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

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

MOTT MACDONALD M M

SOIL BORING LOG

BORING NO.: **B-63**
Page 1 of 1

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Nishisakawick Creek, Hunterdon Co., NJ	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Jon Nelson/ Bernard Cortes
Drilling Co.:	Uni-Tech Drilling Co., Inc.	**Date/Time Started:**	August 3, 2016 at 2:30 pm
Driller/Helper:	Mike Shepherd /Gene Blemings	**Date/Time Finished:**	August 9, 2016 at 12:20 pm

Elevation: 330 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Near Hwy 513 **Coord.:** N: 40.538697 E: -75.052549 **Horizontal Datum:** NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HSA	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**	**Drilling Fluid**
☑ ATV	☐ Geoprobe	☑ Winch	☐ Safety	☐ Bentonite
☐ Track	☐ Air Track	☑ Roller Bit	☐ Doughnut	☐ Polymer
☐ Skid	☐	☐ Cutting Head	☑ Automatic	☑ Water
			☐	☐ None

Drill Rod Size: **Casing Advance:** Hollow Stem Auger

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
330	S-1A 0.0'- 0.1'	12	2, 2			Top (12") - TOPSOIL	N	-	NP	-	
						1.0					
	S-1B 1.0'- 1.2'	8	6, 15			Bottom (8") - Reddish brown, DECOMPOSED ROCK fragments	N	-	NP	-	
						4.0					
						Top of Rock at 4 feet BGS. See Rock Coring Log.					
5											
10 320											
15											

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
8/4/16	7:00	-		95.0	55.2
8/9/16	7:56	-		235.0	59.9

Sample Type

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

Notes:

PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-63**

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

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

MOTT MACDONALD M M

CORE BORING LOG

BORING NO.: **B-63**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Nishisakawick Creek, Hunterdon Co., NJ	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Jon Nelson/ Bernard Cortes
Drilling Co.:	Uni-Tech Drilling Co., Inc.	**Date/Time Started:**	August 3, 2016 at 2:30 pm
Driller/Helper:	Mike Shepherd /Gene Blemings	**Date/Time Finished:**	August 9, 2016 at 12:20 pm

Elevation: 330 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Near Hwy 513 **Coord.: N:** 40.538697 **E:** -75.052549

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

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

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec (in. / %)	RQD (in / %)	Rock Core Hard.	Rock Core Weath.	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
									SEE TEST BORING LOG FOR OVERBURDEN DETAILS		(See Legend for Rock Description System)						
	5.00	4.0 5.0	R-1	11 92%	0 0%	R2	SL		SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, very close to close spaced discontinuities								
5	2.00	5.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, very close to close spaced discontinuities 5' - 10' Highly Fractured zone								
	2.00																
	2.50		R-2	60 100%	0 0%	R2	SL										
	3.75																
	4.00	10.0															
10 320	3.80	10.0							SILTSTONE, Reddish brown, fine grained, slightly weathered, weak, extremely close to close spaced discontinuities 10' - 15' Highly Fractured zone								
	2.50																
	3.50		R-3	60 100%	10 17%	R2	SL										
	2.50																
	4.50	15.0								13.90	J	0	P,R	DS	O	ML	
										14.10	J	0	U,Sm	DS	O	ML	
15										14.60	J	10	U,R	DS	O	ML	
	4.00	15.0							SILTSTONE, Reddish brown, fine grained, fresh, weak, close to very close spaced discontinuities	15.00	J	0	U,R	DS	O	ML	
	3.75									16.50	J	10	U,Sm	DS	O	ML	
										16.75	J	0	P,Sm	DS	O	ML	
	3.50		R-4	60 100%	25 41%	R2	FR			16.90	J	5	P,Sm	DS	O	ML	
										17.20	J	0	P,Sm	DS	O	ML	
										17.60	J	0	P,Sm	DS	O	ML	
	3.50									18.40	J	15	U,R	DS	MW	ML	
	4.25	20.0								18.95	J	10	U,Sm	DS	O	N	
20 310	3.00	20.0							SILTSTONE, Reddish brown, fine grained, fresh, weak, close spaced discontinuities								
										20.75	J	10	U,Sm	FR	T	N	
	3.00									21.00	J	28	U,Sm	FR	T	N	
										21.40	J	8	U,Sm	FR	T	N	
	3.00		R-5	60 100%	11 18%	R2	FR			21.90	J	20	P,Sm	FR	T	N	
										22.25	J	10	U,Sm	FR	T	N	
	3.50									23.05	J	18	U,R	FR	O	N	
										23.55	J	0	U,Sm	FR	T	N	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
8/9/16	7:56	-		235.0	59.9
8/4/16	7:00	-		95.0	55.2

Notes:

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.50	25.0															
25	2.75	25.0							SILTSTONE, Reddish brown, fine grained, fresh to slightly weathered, weak, close spaced discontinuities								Pulldown approximately 350 psi.
										25.80	J	5	U,Sm	FR	T	N	
	3.00									26.55	J	12	U,Sm	FR	T	N	
	2.50		R-6	60 100%	41 68%	R2	FR			27.50	J	8	U,Sm	FR	T	N	
										27.90	J	0	U,Sm	DS	O	N	
	2.50									28.30	J	60	U,R	DS	O	ML	
	2.25	30.0															
30 300		30.0							SILTSTONE, Reddish brown, fine grained, slightly weathered, weak, very close to close spaced discontinuities	29.80	J	5	U,Sm	DS	O	N	
	2.25																
	1.75																
										31.80	J		X,R	DS	O	N	
	2.00		R-7	60 100%	8 13%	R2	SL			32.40	V		X,R	DS	O	ML	
	2.25																
	2.75	35.0															
35		35.0							SILTSTONE, Reddish brown, fine grained, slightly weathered, weak, very close to close spaced discontinuities								
	3.00									35.50	J		X,R	DS	O	N	
										35.80	J		X,R	DS	O	N	
	2.50									36.60	J	45	U,R	FR	O	N	
	2.75		R-8	60 100%	31 52%	R2	SL			37.30	J	8	P,R	FR	O	N	
	2.00									38.20	J	86	X,R	DG	O	CL	
	3.25	40.0							38.8' - 40' Highly Weathered zone								
40 290		40.0							SILTSTONE, Reddish brown, fine grained, slightly weathered, weak, close spaced discontinuities								
	3.00									40.85	J	16	U,Sm	FR	O	N	
	2.75									41.30	J	18	P,Sm	FR	O	N	
										41.85	J	0	P,Sm	FR	O	N	
	2.50		R-9	60 100%	51 85%	R2	SL			42.70	J	5	P,Sm	DS	O	N	
										42.95	J	5	P,Sm	DS	O	N	
	3.25																
	4.50	45.0							43.85' - 44.15' Highly Fractured zone	44.35	J	0	P,R	DS	O	ML	
45		45.0							SILTSTONE, Reddish brown, fine grained, fresh, weak, moderately spaced discontinuities								
	7.50									45.30	J	5	P,Sm	DS	T	ML	
	2.75									46.25	J	0	P,Sm	FR	T	N	
	3.50		R-10	60 100%	51 85%	R2	FR										
	2.50									48.00	J	0	P,Sm	FR	O	N	
	3.50																

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.50	50.0								49.55	J	0	P,Sm	FR	O	N	
50 280	3.25	50.0							SILTSTONE, Reddish brown, fine grained, fresh, weak, moderately spaced discontinuities	50.65	J	17	P,Sm	FR	O	N	
	3.00																
	3.00		R-11	60 100%	47 78%	R2	FR		52.45' - 53.5' Vertical joint encountered	52.45	J	32	P,Sm	FR	T	N	
	3.00																
	3.50	55.0								54.10	J	0	P,Sm	FR	T	N	
										54.40	J	0	P,Sm	FR	T	N	
55	3.00	55.0							SILTSTONE, Reddish brown, fine grained, slightly weathered, weak, close spaced discontinuities Shale interbedding 55' - 58.55' Vertical Calcite vein encountered								
	4.00																
	2.50		R-12	60 100%	13 22%	R2	SL										
	3.75																
	4.50	60.0								59.25	J	0	U,R	DS	O	ML	
										59.35	J	15	P,Sm	DS	O	ML	
60 270		60.0								59.70	J	0	P,R	DG	MW	ML	
	3.25								SILTSTONE, Reddish brown, fine grained, fresh, weak, moderately spaced discontinuities Shale interbedding	60.75	J	2	U,Sm	DS	T	N	
	3.00																
	3.00		R-13	60 100%	59 98%	R2	FR			62.00	J	17	U,Sm	FR	T	N	
	3.25									63.00	J	0	U,Sm	DS	T	N	
	3.25	65.0								64.55	J	14	P,Sm	FR	T	N	
65										64.70	J	0	U,Sm	DS	O	N	
	3.00	65.0							SILTSTONE, Reddish brown, fine grained, slightly weathered, weak, close to moderately spaced discontinuities Shale interbedding	65.65	J	0	U,Sm	DS	O	ML	
	2.75									66.30	J	0	U,R	DS	O	N	
	3.50		R-14	60 100%	55 91%	R2	SL			66.75	J	0	U,R	DS	O	N	
										66.85	J	0	U,Sm	DS	O	N	
	3.75									67.30	J	0	U,R	DS	O	N	
	3.00	70.0								67.50	J	0	U,Sm	DS	O	N	
70 260	3.00	70.0							SILTSTONE, Reddish brown, fine grained, fresh, weak, wide spaced discontinuities	69.20	J	0	U,Sm	DS	O	ML	Used up to 420 Gallons from R-2 to R-15.
	3.25																
	2.50		R-15	60 100%	60 100%	R2	FR										
	4.00																
	3.00	75.0								73.95	J	0	U,Sm	DS	T	N	

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.00	75.0							SILTSTONE, Reddish brown, fine grained, fresh, weak, wide spaced discontinuities	74.85	J	3	U,Sm	DS	O	N	
										75.25	MB						
	3.25									76.20	J	0	U,Sm	DS	O	N	
	2.50		R-16	60 100%	60 100%	R2	FR										
	4.25																
	3.00	80.0															
-80 250	3.50	80.0							SILTSTONE, Reddish brown, fine grained, fresh, weak, wide spaced discontinuities								Loss of water.
	4.00																
	3.50		R-17	60 100%	60 100%	R2	FR										
	4.00									83.15	J	4	U,Sm	FR	T	N	
	4.50	85.0															
-85	4.00	85.0							SILTSTONE, Reddish brown, fine grained, fresh, weak, moderately spaced discontinuities								
	4.00									86.10	J	19	P,Sm	FR	T	N	
	4.00		R-18	60 100%	55 91%	R2	FR			86.90	J	23	U,Sm	FR	O	N	
										87.10	J	18	U,Sm	FR	T	N	
	4.00									88.50	J	0	U,Sm	FR	T	N	
	4.00	90.0								89.60	J	0	U,Sm	DS	O	CL	
-90 240	5.00	90.0							SILTSTONE, Reddish brown, fine grained, fresh, weak, close spaced discontinuities	90.80	J	0	U,Sm	FR	T	N	
	4.00									91.30	J	0	U,Sm	FR	T	N	
	3.50		R-19	60 100%	46 76%	R2	FR			92.00	J	0	U,Sm	FR	T	N	
										92.65	J	8	U,Sm	FR	T	N	
	4.00									93.00	J	8	U,Sm	FR	T	N	
										93.30	J	0	U,Sm	FR	T	N	
	4.00	95.0								93.70	J	10	U,Sm	FR	T	N	
-95	3.50	95.0							SILTSTONE, Reddish brown, fine grained, fresh, weak, close to moderately spaced discontinuities								
	3.00																
	3.50		R-20	60 100%	58 97%	R2	FR			97.30	J	72	U,Sm	FR	T	N	
	4.00																
	3.70	100.0								99.15	J	0	U,R	FR	T	ML	
-100 230		100.0							SILTSTONE, Reddish brown, very fine to fine grained, fresh, weak, close to moderately spaced discontinuities	99.65	J	13	U,Sm	DS	PO	ML	

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
	2.70									100.35	J	13	P,Sm	FR	T	N	
	3.00																
	3.10		R-21	60 100%	60 100%	R2	FR										
	3.00								103' - 105' Shale interbedding								
	4.15	105.0								104.35	J	12	U,Sm	FR	T	N	
105																	
	3.75	105.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities 105' - 106.5' Vertical Calcite vein encountered								
	3.20																
	2.95		R-22	60 100%	35 58%	R2	SL			107.60	J	35	U,Sm	DS	O	ML	
										108.00	J	0	U,Sm	DS	T	ML	
	3.50																
	3.50	110.0								108.95	J	0	U,Sm	DS	T	ML	
										109.35	J	0	U,Sm	DS	T	ML	
110 220																	
	4.00	110.0							SILTSTONE, Reddish brown, very fine to fine grained, fresh, weak, wide spaced discontinuities								
	3.90																
	3.90		R-23	60 100%	60 100%	R2	FR										
	3.00																
	3.75	115.0															
115																	
	4.00	115.0							SILTSTONE, Reddish brown, very fine to fine grained, fresh, weak, very close to moderately spaced discontinuities								
	3.50																
	3.85		R-24	60 100%	45 75%	R2	FR										
										117.90	J	9	P,Sm	FR	T	N	
	3.85									118.10	J	11	U,Sm	FR	T	N	
										118.40	J	0	U,Sm	FR	T	N	
	3.80	120.0															
120 210																	
	4.00	120.0							SILTSTONE, Reddish brown, very fine to fine grained, fresh, weak, close to wide spaced discontinuities 120.4' - 121' Shale interbedding	120.70	J	12	U,Sm	FR	T	N	
	4.10																
	3.10		R-25	60 100%	58 97%	R2	FR										
	3.75																
	2.05	125.0															
125																	
	4.00	125.0							SILTSTONE, Reddish brown, very fine to fine grained, fresh, weak, moderate to wide spaced discontinuities								

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.20									125.90	J	59	U,Sm	FR	T	N	
	3.15		R-26	60 100%	60 100%	R2	FR										
	3.00																
	3.20	130.0							129.4' - 130' Shale interbedding								
130 200	4.00	130.0							SILTSTONE, Reddish brown, very fine to fine grained, fresh, weak, very close to moderately spaced discontinuities	130.70	J	0	U,Sm	FR	T	N	
	4.90									131.65	J	0	S,Sm	DS	O	N	Loss of water at 131.5 feet BGS.
	3.85		R-27	60 100%	54 90%	R2	FR			132.20	J	0	U,Sm	FR	T	N	
	3.00																
	4.00	135.0															
135	3.50	135.0							SILTSTONE, Reddish brown, very fine to fine grained, fresh, weak, close to wide spaced discontinuities	134.70	J	15	U,Sm	FR	T	N	
	3.30																
	3.50		R-28	60 100%	59 98%	R2	FR										
	4.50																
	3.20	140.0								139.20	J	31	U,Sm	FR	T	N	
										139.30	J	26	U,Sm	FR	T	N	
140 190										139.80	J	0	U,Sm				
	3.40	140.0							SILTSTONE, Reddish brown, very fine to fine grained, fresh, weak, moderate to wide spaced discontinuities								
	4.75																
	2.40		R-29	60 100%	60 100%	R2	FR										
	3.90									143.35	J	10	U,R	FR	T	N	
	4.45	145.0															
145	4.20	145.0							SILTSTONE, Reddish brown to gray, very fine to fine grained, fresh, weak, close to wide spaced discontinuities	145.50	J	0	U,R	FR	T	N	
	3.00																
	3.50		R-30	60 100%	59 98%	R2	FR			147.20	J	0	U,Sm	FR	T	N	
										147.30	J	0	U,Sm	FR	T	N	
	3.50																
	4.00	150.0							150.0								
150 180	3.70	150.0							SHALE, Gray to dark gray, very fine to fine grained, fresh, weak, very close to wide spaced discontinuities								
	3.70																

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-63**

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
	3.70																
	2.80		R-31	60 100%	55 91%	R2	FR										
	5.00									153.50	J	0	P,Sm	DS	O	N	
										153.80	J	0	U,Sm	FR	T	N	
	3.70									154.30	J	0	U,Sm	DS	T	N	
155		155.0								154.60	J	5	U,Sm	DS	T	N	
	3.15	155.0							SHALE, Gray to dark gray, very fine to fine grained, slightly weathered, weak, very close to close spaced discontinuities								
										155.70	J	0	U,Sm	FR	T	N	
	3.50									156.10	J	0	U,Sm	FR	T	N	
										156.40	J	13	U,Sm	FR	T	N	
										156.85	J	0	U,Sm	FR	T	N	
	3.15		R-32	60 100%	40 67%	R2	SL			157.25	J	11	U,R	FR	T		Coal infilling.
	3.15									158.30	J	0	U,Sm	DS	T		Coal infilling. Small water return at 158.5 feet BGS.
	3.80	160.0															
160 170		160.0							SHALE, Dark gray to gray, very fine to fine grained, slightly weathered, weak, very close to moderately spaced discontinuities								
	3.00									160.60	J	13	U,K	DS	T		Coal infilling.
	3.00									161.15	J	9	U,Sm	FR	T	N	
										161.85	J	0	U,Sm	FR	T	N	
	3.70		R-33	60 100%	54 89%	R2	SL			161.95	J	13	U,Sm	FR	T	N	
										162.70	J	0	U,Sm	FR	T	N	
	3.00																
	3.00	165.0								164.25	J	0	U,R	FR	T	N	
165		165.0							SHALE, Gray, very fine to fine grained, slightly weathered, weak, very close to moderately spaced discontinuities								
	3.75																
	3.00																
										167.05	J	0	U,Sm	FR	T	N	
	3.40		R-34	60 100%	50 83%	R2	SL										
										167.80	J	0	U,Sm	FR	T	N	
	3.30									168.40	J	0	U,Sm	FR	O	N	
										168.75	J	0	U,R	DS	T	N	
	3.40																
170 160		170.0							170.0	169.55	J	13	U,R	DS	T	N	
	3.40	170.0							SILTSTONE, Reddish brown, very fine to fine grained, fresh, weak, moderate to wide spaced discontinuities								
										170.85	J	0	U,Sm	FR	T	N	
	2.75																
	3.00		R-35	60 100%	60 100%	R2	FR										
	3.25																
	3.25	175.0							175.0								
175		175.0							SHALE, Reddish brown to dark gray, very fine to fine grained, fresh, weak, wide spaced discontinuities								
	3.00																
	2.70																

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.50																
	2.50		R-36	60 100%	60 100%	R2	FR										
	3.00																
	2.50	180.0							180.0								
180 150	2.75	180.0							ARGILLITE, Gray, very fine grained, fresh, strong, wide spaced discontinuities, calcareous Interbedded Limestone encountered								
	3.00																
	3.00		R-37	60 100%	60 100%	R4	FR			182.30	J	5	U,Sm	FR	T	N	
	2.50									183.20	J	10	P,Sm	FR	PO	N	
	2.50	185.0								184.50	J	5	P,R	FR	T	N	
185	3.00	185.0							ARGILLITE, Gray, very fine grained, slightly weathered, strong, extremely close to wide spaced discontinuities, calcareous	184.90 185.10 185.30	MB MB MB						
	3.00								186' - 186.7' Highly Fractured zone with Calcite infilling								
	3.00		R-38	60 100%	38 63%	R4	SL		187.1' - 188.3' Vertical fracture with Calcite infilling								
	3.00									188.70	MB						
	3.00	190.0								189.30 189.50 189.80	MB MB MB						
190 140	3.00	190.0							ARGILLITE, Reddish brown, very fine grained, fresh, very strong, wide spaced discontinuities, calcareous	189.90	MB						
	3.00																
	3.00		R-39	60 100%	60 100%	R5	FR										
	3.00																
	3.00	195.0								193.90 194.20 194.70	MB MB MB						
195	3.00	195.0							ARGILLITE, Reddish brown, very fine grained, fresh, strong, moderate to wide spaced discontintuities, calcareous								
	3.00																
	3.00		R-40	60 100%	60 100%	R4	FR			197.90	J	0	P,R	FR	PO	N	
	3.00									198.50	FJ	5	U,R	FR	T	N	
	3.00	200.0								199.30 199.50	MB MB						
200 130	3.00	200.0							ARGILLITE, Reddish brown, very fine grained, fresh, very strong, wide spaced discontinuities, calcareous								
	3.00																
	3.00		R-41	60	60	R5	FR										

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00			100%	100%												
	3.25									203.40	MB						
	3.50	205.0								204.30	MB						
205		205.0							ARGILLITE, Reddish brown, very fine grained, fresh, very strong, wide spaced discontinuities	204.90	MB						
	3.00																
	3.00																
	3.00		R-42	60 100%	60 100%	R5	FR										
	3.00									208.00	J	30	P,Sm	FR	O	N	
										208.60	MB						
	3.00	210.0								209.20	J	5	P,R	FR	PO	N	
210 120		210.0							ARGILLITE, Reddish brown, very fine grained, fresh, very strong, extremely close to wide spaced discontinuities								
	3.25																
	3.25									211.10	J	40	P,Sm	FR	VT	N	
	3.25		R-43	60 100%	56 93%	R5	FR										
	3.25																
	3.25	215.0															
215		215.0							214.5' Silt seam 214.5' - 214.7' Highly Fractured zone ARGILLITE, Reddish brown, very fine grained, fresh, very strong, close to wide spaced discontinuities								
	5.00									215.70	J	30	P,Sm	FR	VT	N	
	3.00																
	3.00		R-44	60 100%	60 100%	R5	FR			216.70	J	40	P,Sm	FR	T	N	
	2.75																
	2.75	220.0								218.80	J	5	U,Sm	FR	T	N	
										219.30	J	5	P,Sm	FR	T	N	
220 110		220.0							ARGILLITE, Reddish brown, very fine grained, fresh, very strong, wide spaced discontinuities								
	3.25																
	3.25																
	3.25		R-45	60 100%	60 100%	R5	FR										
	3.25																
	3.25	225.0															
225		225.0							ARGILLITE, Reddish brown, very fine grained, fresh, very strong, close to wide spaced discontinuities	224.60	MB						
										224.90	MB						
	3.25									225.20	MB						
	3.25																
	3.25		R-46	60 100%	60 100%	R5	FR										
										227.80	J	3	P,Sm	FR	T	N	

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.25									228.30	J		X,R	FR	T	N	
	3.25									228.90	J	3	P,Sm	FR	T	N	
	3.25	230.0															
230 100	3.25	230.0							ARGILLITE, Reddish brown, very fine grained, fresh, very strong, wide spaced discontinuities								
	3.25									231.30	J	70	P,Sm	FR	T	N	
	3.50		R-47	60 100%	60 100%	R5	FR										
	3.25																
	3.25	235.0								234.50	J	3	P,Sm	FR	T	N	
235	3.00	235.0							ARGILLITE, Reddish brown, very fine grained, fresh, very strong, extremely close to wide spaced discontinuities 235' - 236.2' Highly Fractured zone								
	3.00																
	3.25		R-48	60 100%	56 93%	R5	FR										
	3.25																
	3.25	240.0								238.90	J	0	P,Sm	FR	VT	N	
										239.60	J	5	P,Sm	FR	T	N	
240 90	3.50	240.0							ARGILLITE, Reddish brown, very fine grained, fresh, very strong, close to wide spaced discontinuities Calcite interbedding	240.40	J		X,R	FR	T	N	
	3.50																
	3.50		R-49	60 100%	56 93%	R5	FR										
	3.50									243.40	J	5	U,Sm	FR	VT	N	
	3.50	245.0							244.3' Transition from Reddish brown to gray	243.90	J	5	P,R	FR	VT	N	
										244.50	J	5	P,R	FR	VT	N	
245	3.50	245.0							ARGILLITE interbedded with Shale, Gray, very fine grained, fresh, very strong, close to moderate spaced discontinuities								
	3.50																
	3.50		R-50	60 100%	59 98%	R5	FR			246.80	J	5	P,R	FR	T	N	
										247.20	J	5	P,Sm	FR	VT	N	
	3.50									247.80	J	5	P,Sm	FR	VT	N	
	3.50																
	3.50	250.0								249.00	J	5	P,R	FR	T	N	
										249.50	J	5	U,R	FR	T	N	
250 80	4.00	250.0							ARGILLITE, Gray to reddish brown, very fine grained, fresh, strong, wide spaced discontinuities								
	4.00									250.80	J	5	P,Sm	FR	T	N	
	4.00									251.50	MB						
	4.00		R-51	60 100%	60 100%	R4	FR		252' Transition from Gray to reddish brown								
	4.00									253.30	MB						

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-63**
Page **11** of **11**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.00									253.90	MB						
	4.00	255.0															
255		255.0								254.70	MB						
	4.00								ARGILLITE, Gray to reddish brown, very fine grained, fresh, strong, close to wide spaced discontinuities Limestone interbedding	255.30	J	10	P,R	FR	PO	N	
	4.00																
	4.00		R-52	60 100%	52 87%	R4	FR										
	4.00								258.2' Transition to SHALE								
	4.00	260.0								259.20	J	5	P,R	DS	T	Ca	
										259.30	J	5	P,R	FR	T	N	
260 70		260.0							260.0								
	4.00								SHALE, Gray, very fine grained, slightly weathered, medium strong, extremely close to close spaced discontinuities Calcite interbedding with Dolomite	259.90	J	5	P,R	DS	T	Ca	
										260.20	MB						
										260.60	FJ	0	P,R	FR	VT	N	
	4.00								261.3' - 262.5' Highly Fractured zone								
	4.00		R-53	60 100%	31 52%	R3	SL										Loss of water at 262.5 feet BGS.
									262.9' - 263' Highly Fractured zone								
	4.00								263.3' - 264.5' Highly Fractured zone								
	4.00	265.0															
265		265.0							265.0								
	4.00								LIMESTONE, Gray, fresh, medium strong, extremely close to moderately spaced discontinuities Shale interbedding								Used up to 400 Gallons from R-48 to R-53.
									265.8' - 266.6' Highly Fractured zone								
	4.00																
	5.00		R-54	60 100%	50 83%	R3	FR			267.10	J	3	P,Sm	FR	T	N	
	5.00									267.90	FJ	3	P,R	FR	T	N	
										268.70	J	5	P,R	FR	T	N	
	6.00									269.40	MB						
		270.0							270.0	269.80	MB						
270 60		270.0							ARGILLITE, Reddish brown, very fine grained, fresh, very strong, close to wide spaced discontinuities 270' - 270.5' Transition from LIMESTONE								
	3.00																
	3.00																
										271.70	FJ	5	P,R	FR	VT	N	
	3.00		R-55	60 100%	58 97%	R5	FR			271.80	FJ	5	P,R	FR	VT	N	
	3.00																
	3.00	275.0															
275									275.0								
									End of Boring at 275 feet BGS. Borehole grouted with cement and bentonite hole plug.								

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-63**

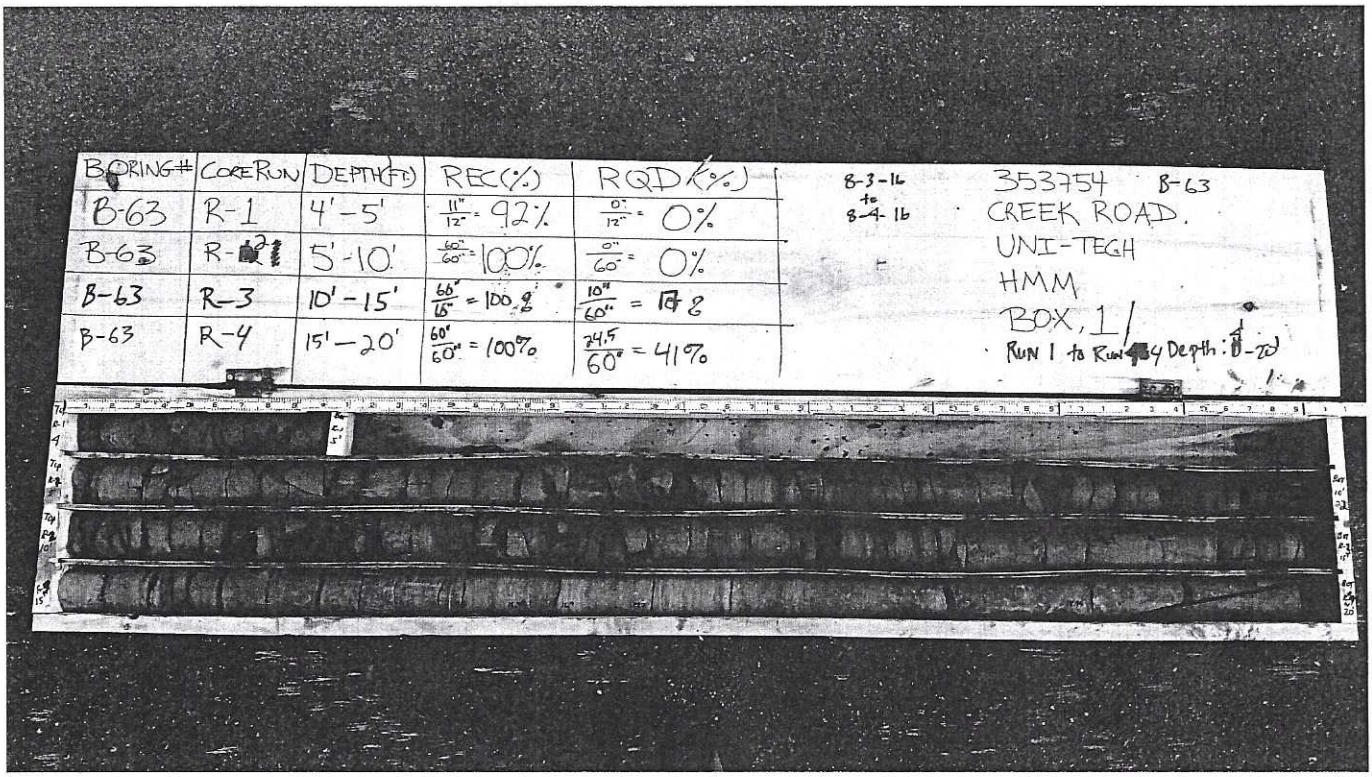


Figure B-63.1
B-63 Box 1 Runs 1-4 Dry

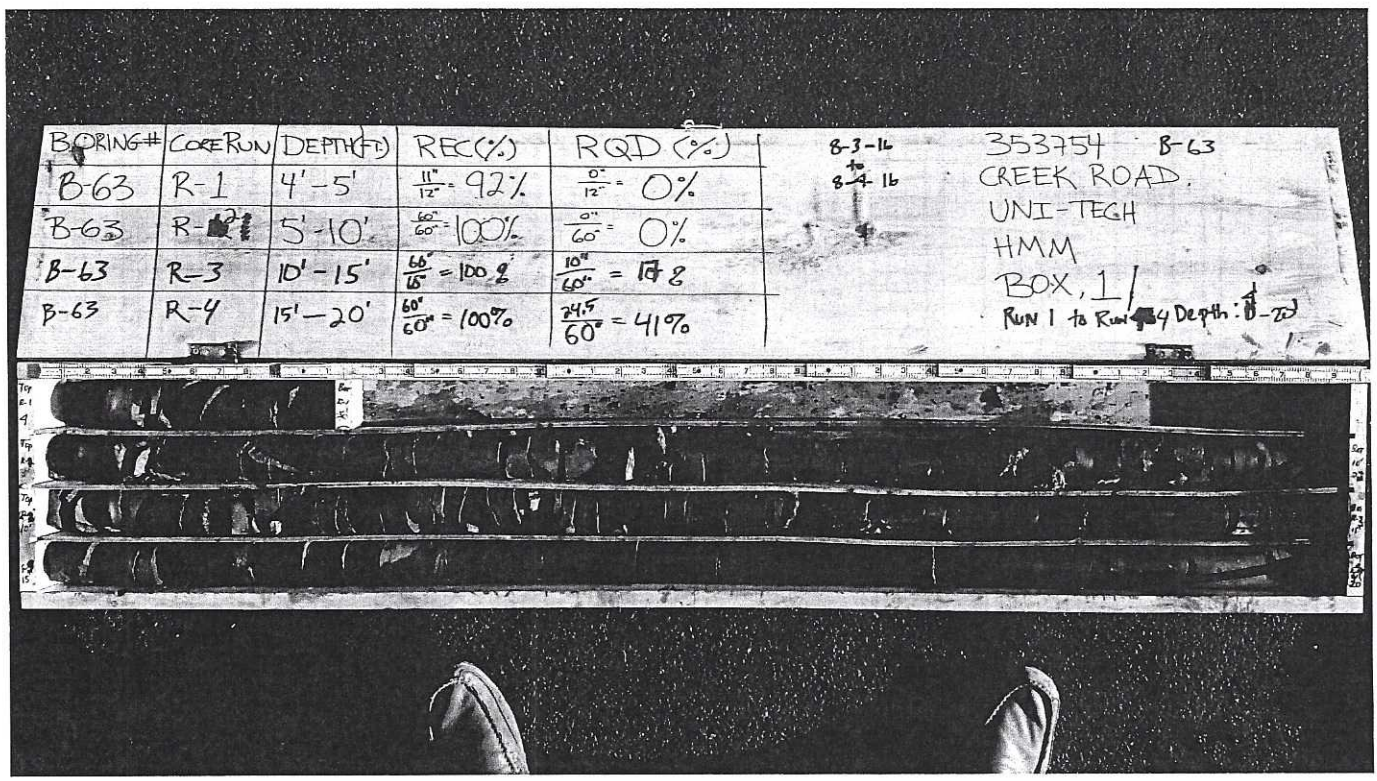


Figure B-63.2
B-63 Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-63

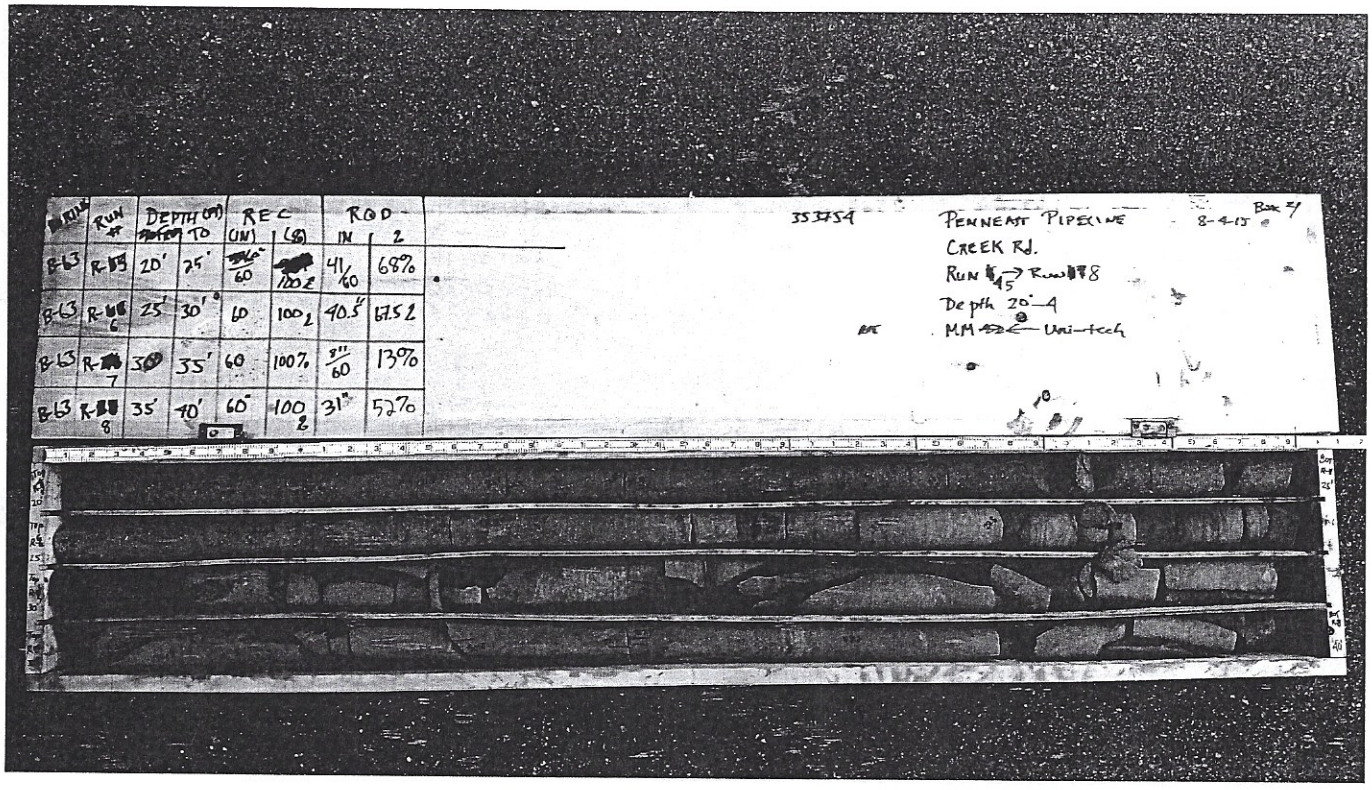


Figure B-63.3
B-63 Box 2 Runs 5-8 Dry

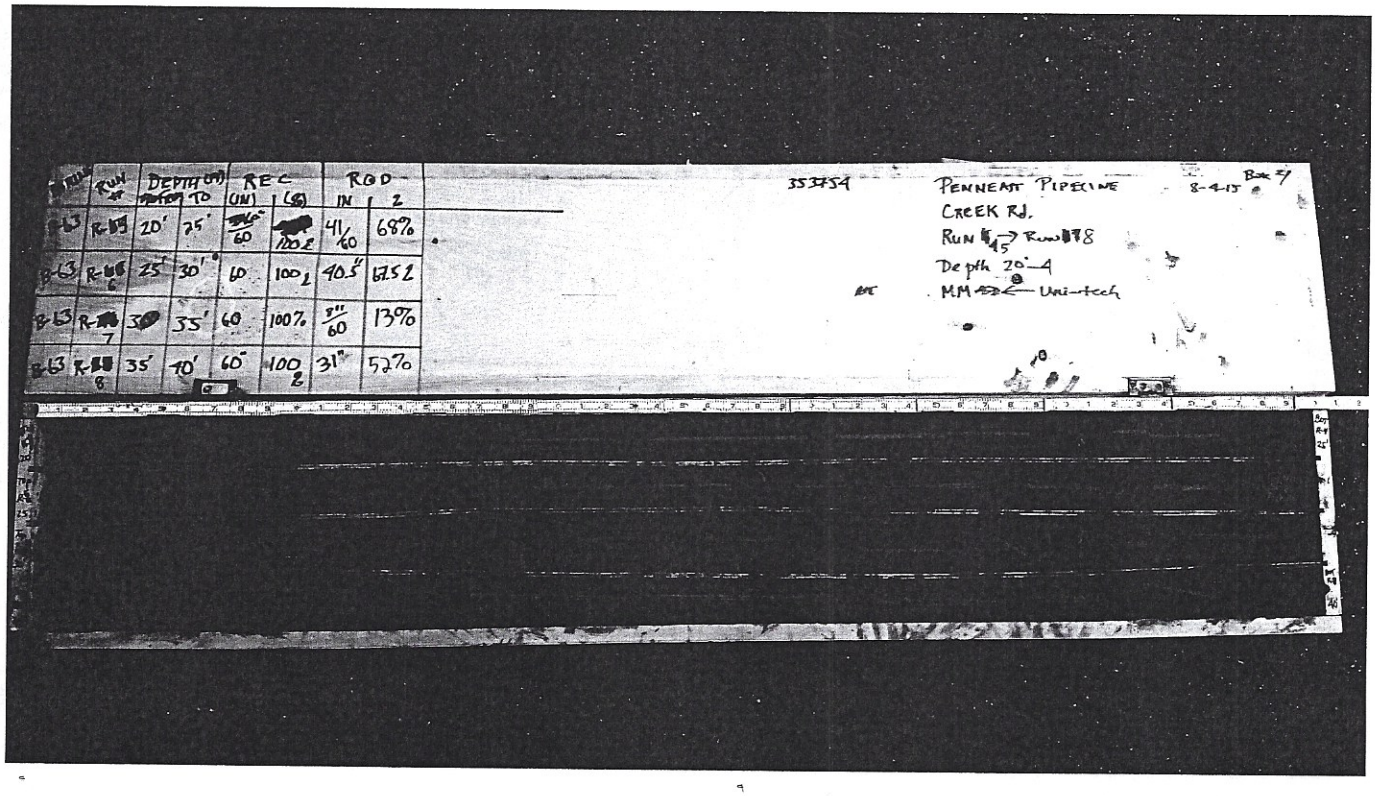
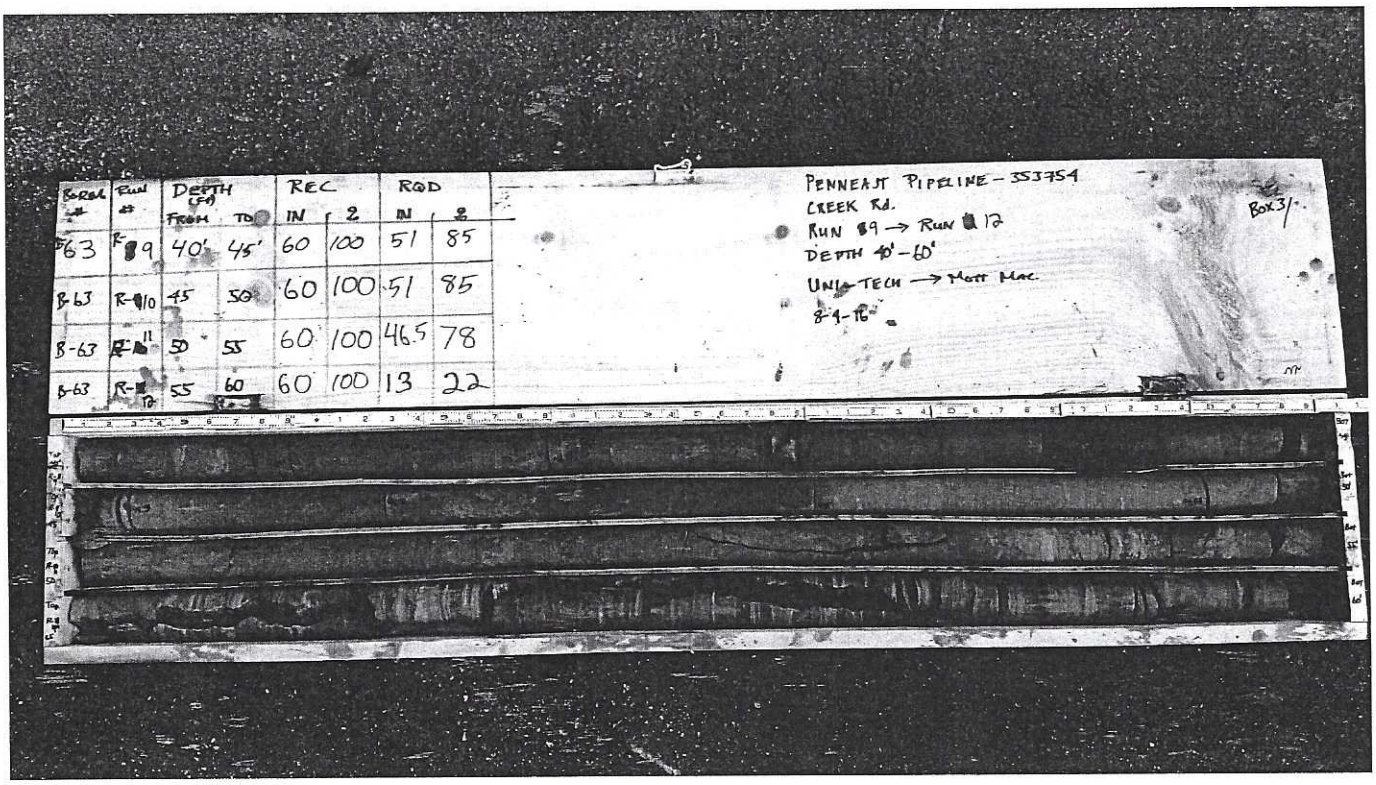


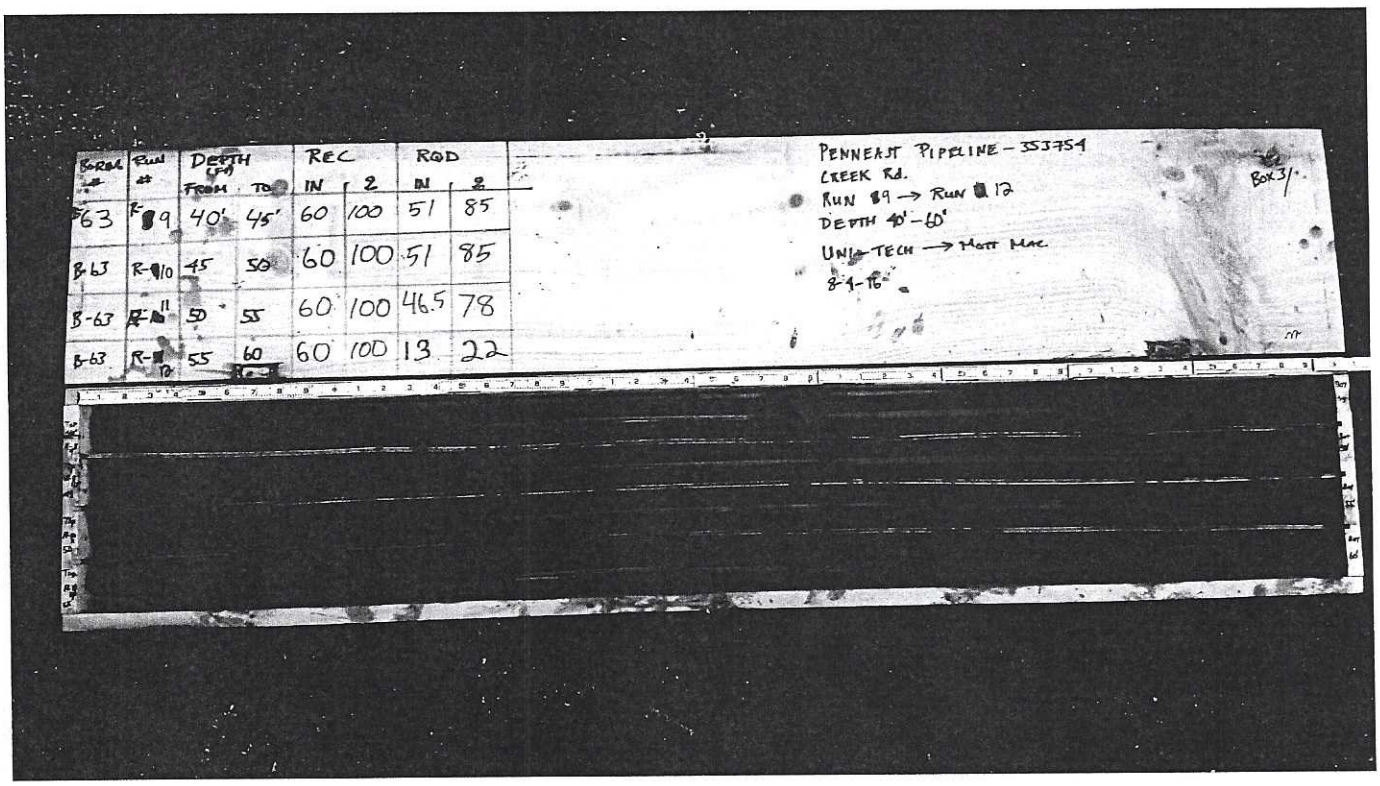
Figure B-63.4
B-63 Box 2 Runs 5-8 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-63



BORE #	RUN #	DEPTH (FT) FROM	TO	REC IN	2	RQD IN	2
B-63	R-9	40'	45'	60	100	51	85
B-63	R-10	45	50	60	100	51	85
B-63	R-11	50	55	60	100	46.5	78
B-63	R-12	55	60	60	100	13	22

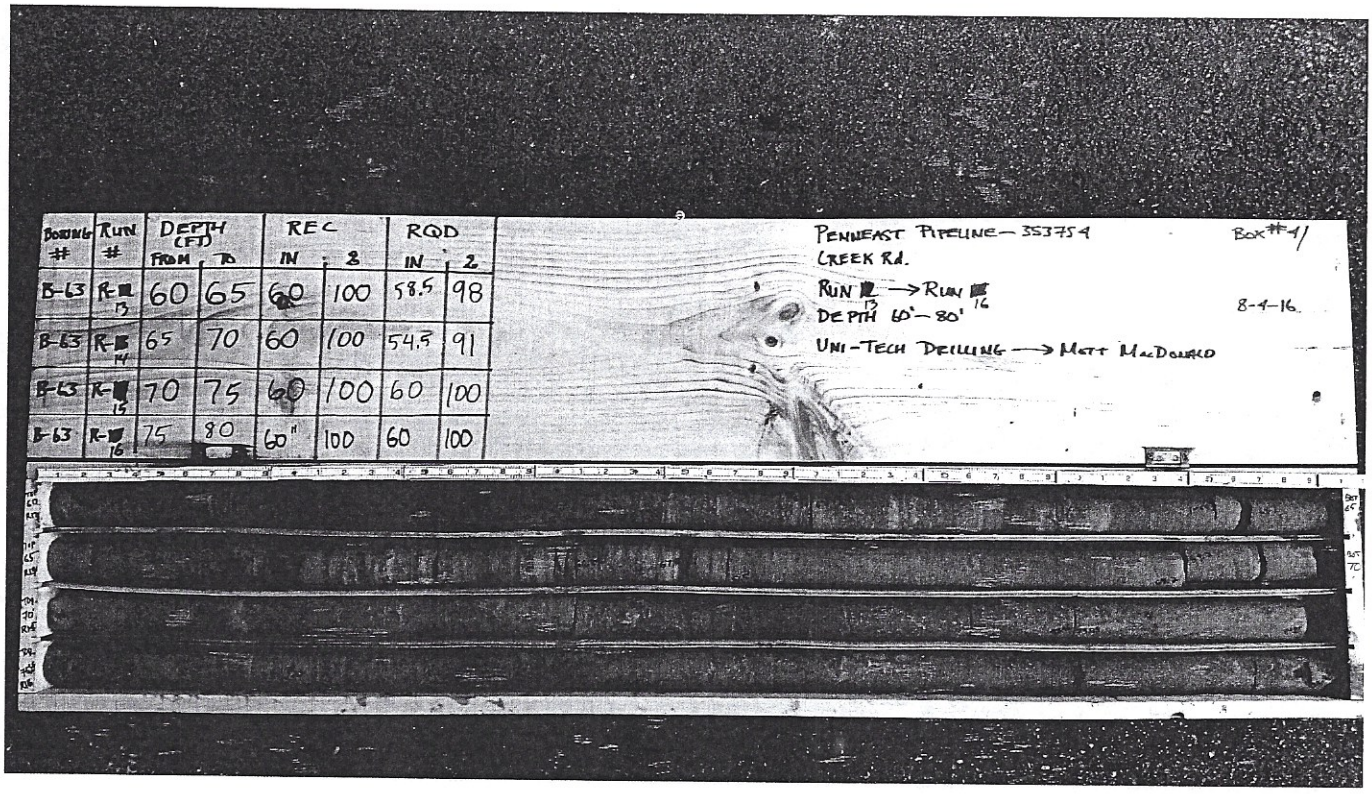
Figure B-63.5
B-63 Box 3 Runs 9-12 Dry



BORE #	RUN #	DEPTH (FT) FROM	TO	REC IN	2	RQD IN	2
B-63	R-9	40'	45'	60	100	51	85
B-63	R-10	45	50	60	100	51	85
B-63	R-11	50	55	60	100	46.5	78
B-63	R-12	55	60	60	100	13	22

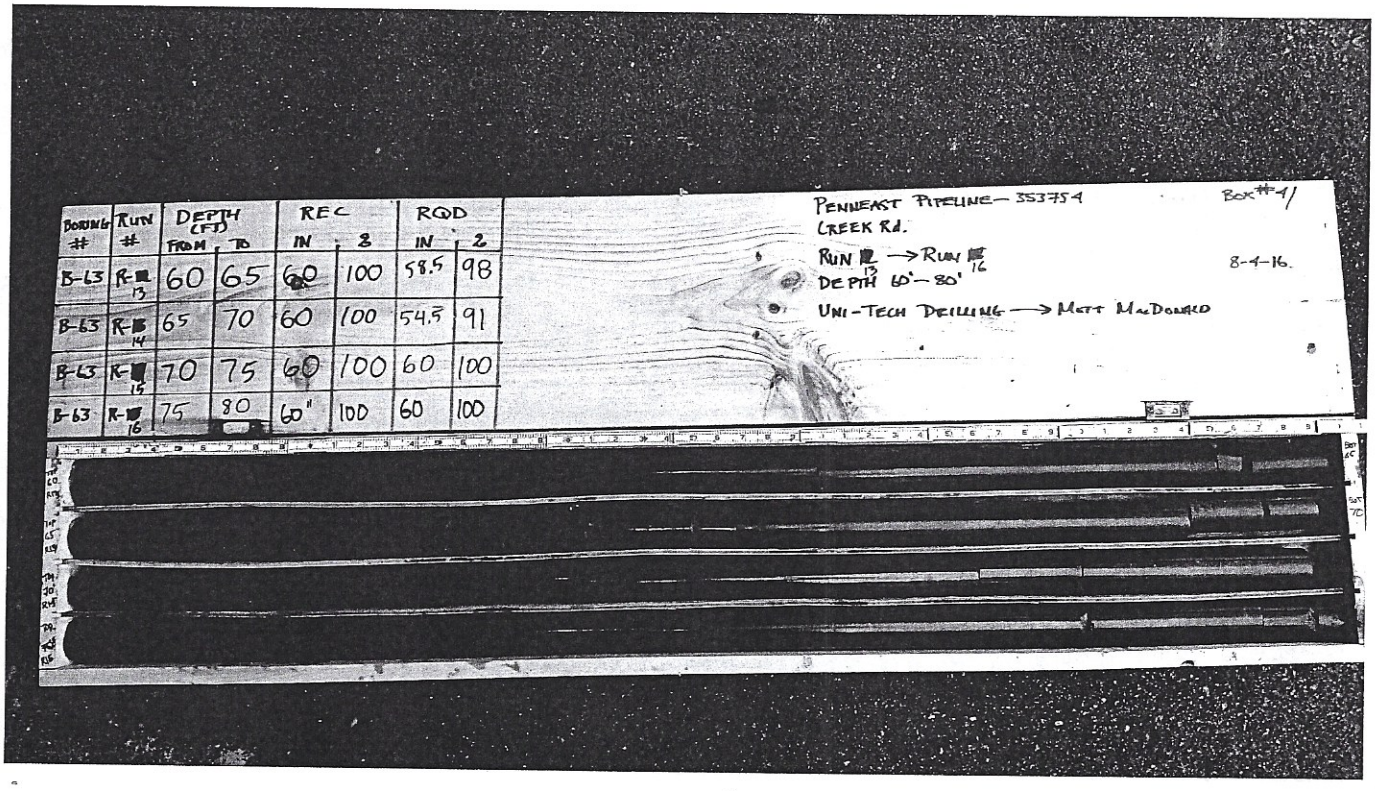
Figure B-63.6
B-63 Box 3 Runs 9-12 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-63



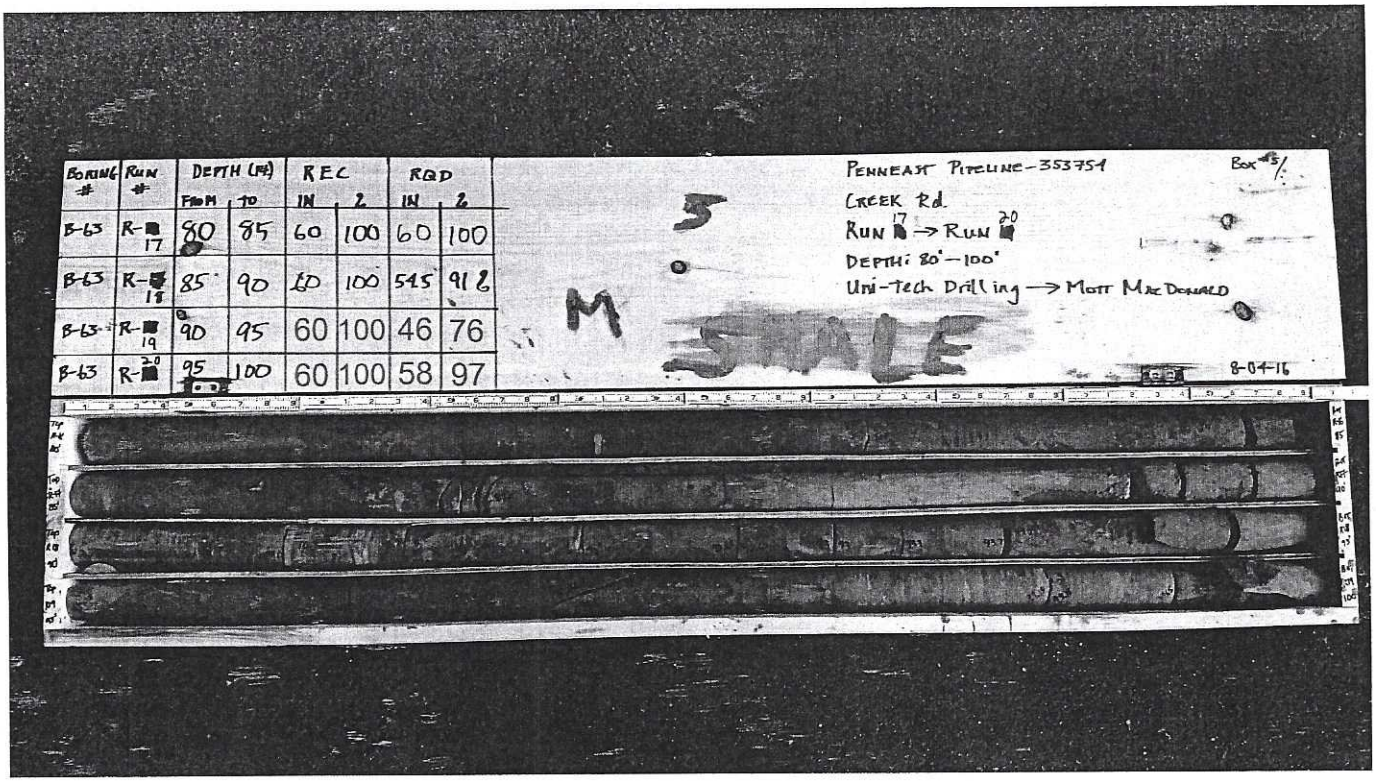
BORING #	RUN #	DEPTH (FT) FROM	TO	REC IN	%	RQD IN	%
B-63	R-13	60	65	60	100	58.5	98
B-63	R-14	65	70	60	100	54.5	91
B-63	R-15	70	75	60	100	60	100
B-63	R-16	75	80	60"	100	60	100

Figure B-63.7
B-63 Box 4 Runs 13-16 Dry



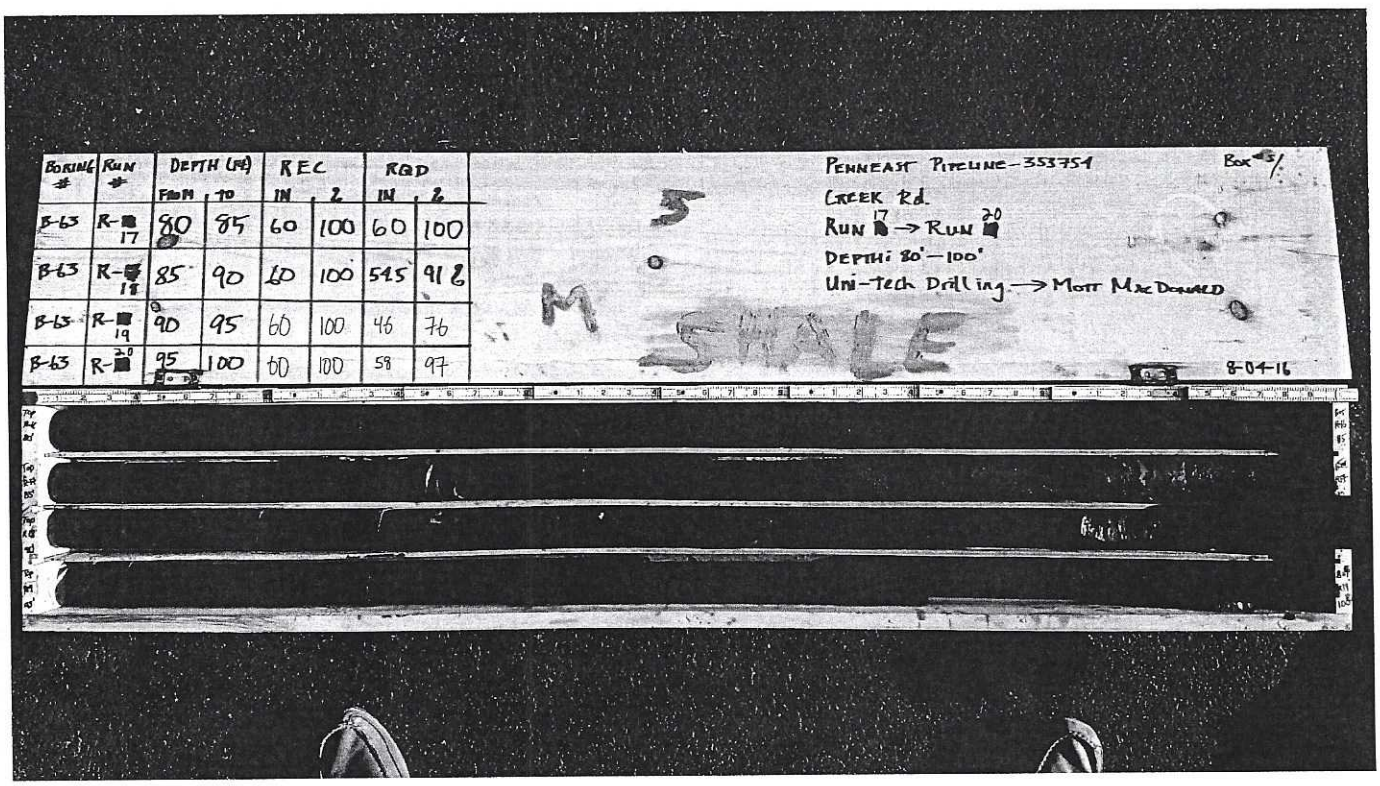
BORING #	RUN #	DEPTH (FT) FROM	TO	REC IN	%	RQD IN	%
B-63	R-13	60	65	60	100	58.5	98
B-63	R-14	65	70	60	100	54.5	91
B-63	R-15	70	75	60	100	60	100
B-63	R-16	75	80	60"	100	60	100

Figure B-63.8
B-63 Box 4 Runs 13-16 Wet



BORING #	RUN #	DEPTH (FT) FROM	TO	REC IN	%	RQD IN	%
B-63	R-17	80	85	60	100	60	100
B-63	R-18	85	90	60	100	545	91
B-63	R-19	90	95	60	100	46	76
B-63	R-20	95	100	60	100	58	97

Figure B-63.9
B-63 Box 5 Runs 17-20 Dry



BORING #	RUN #	DEPTH (FT) FROM	TO	REC IN	%	RQD IN	%
B-63	R-17	80	85	60	100	60	100
B-63	R-18	85	90	60	100	545	91
B-63	R-19	90	95	60	100	46	76
B-63	R-20	95	100	60	100	58	97

Figure B-63.10
B-63 Box 5 Runs 17-20 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-63

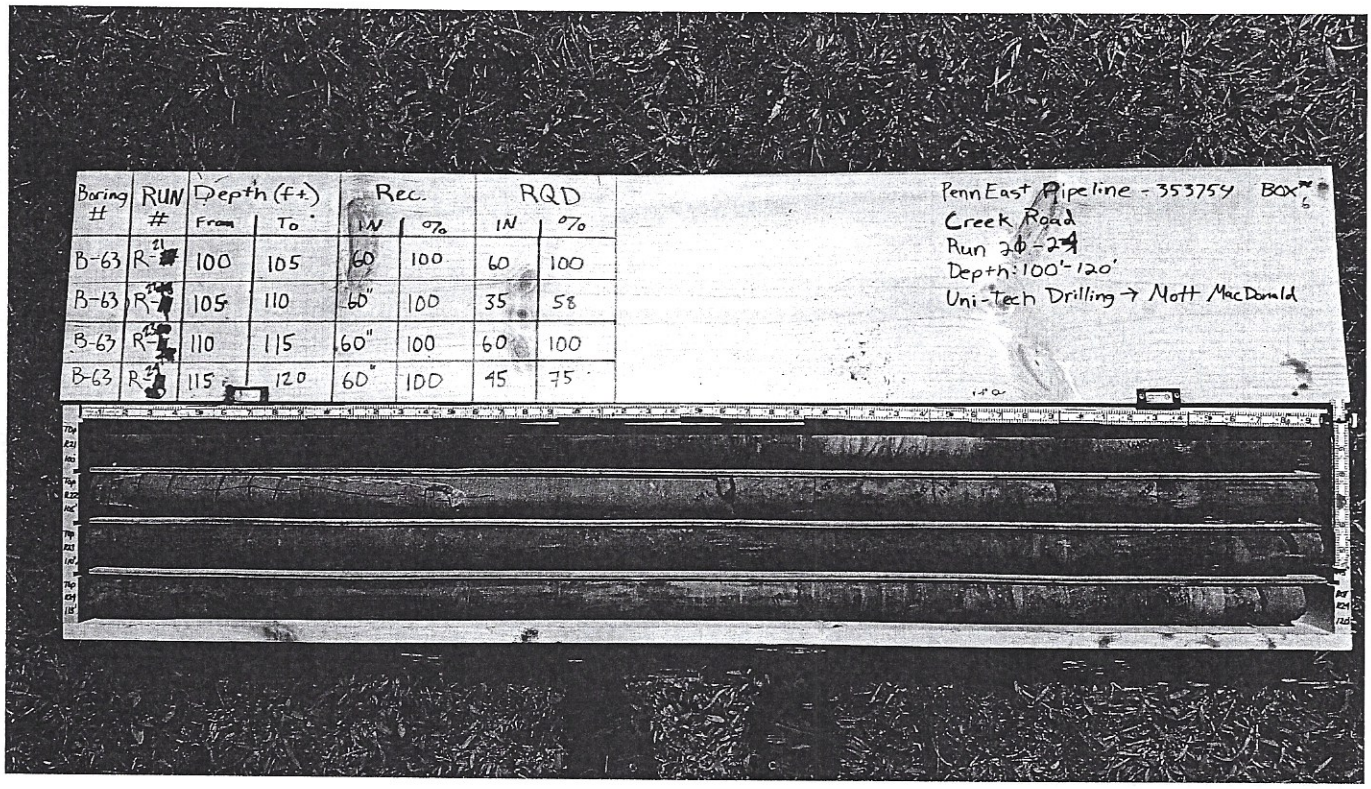


Figure B-63.11
B-63 Box 6 Runs 21-24 Dry

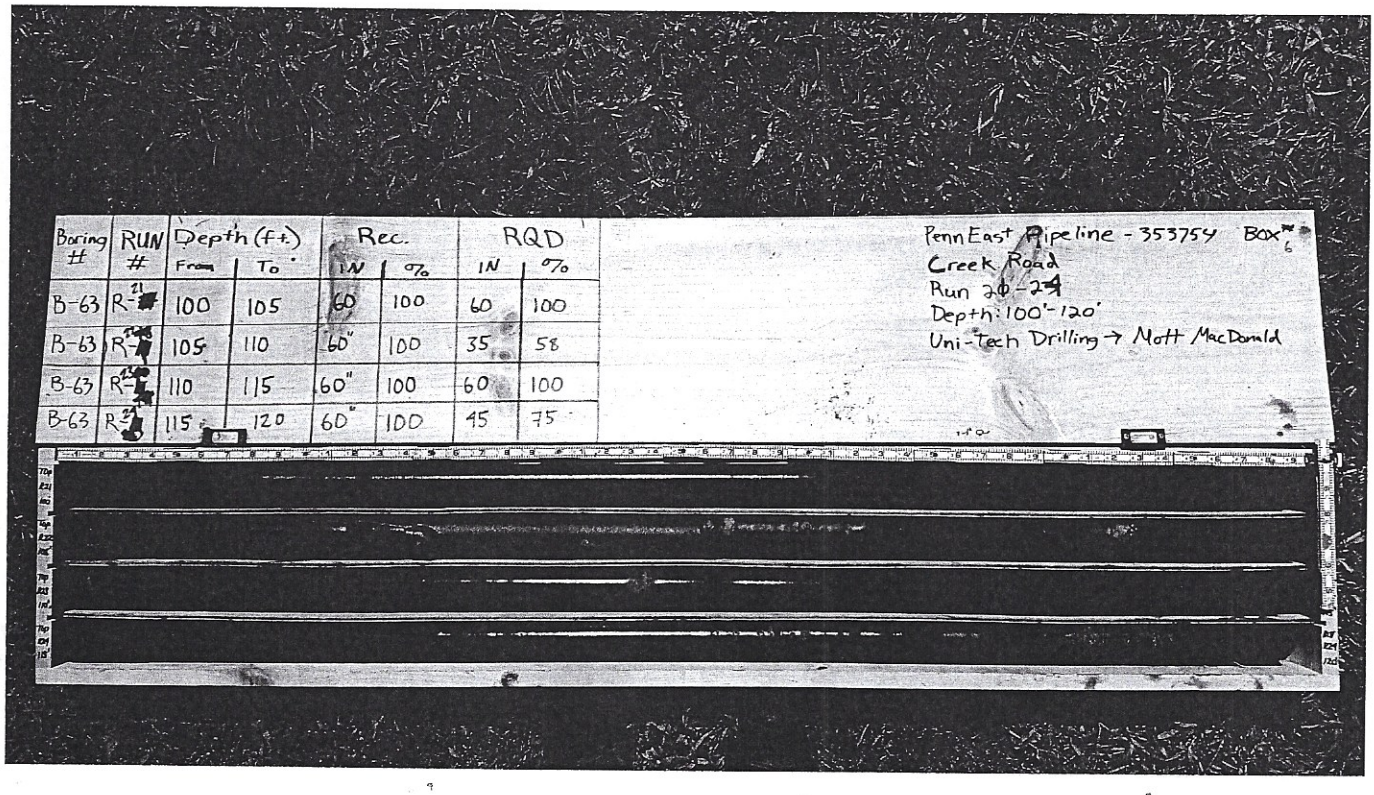
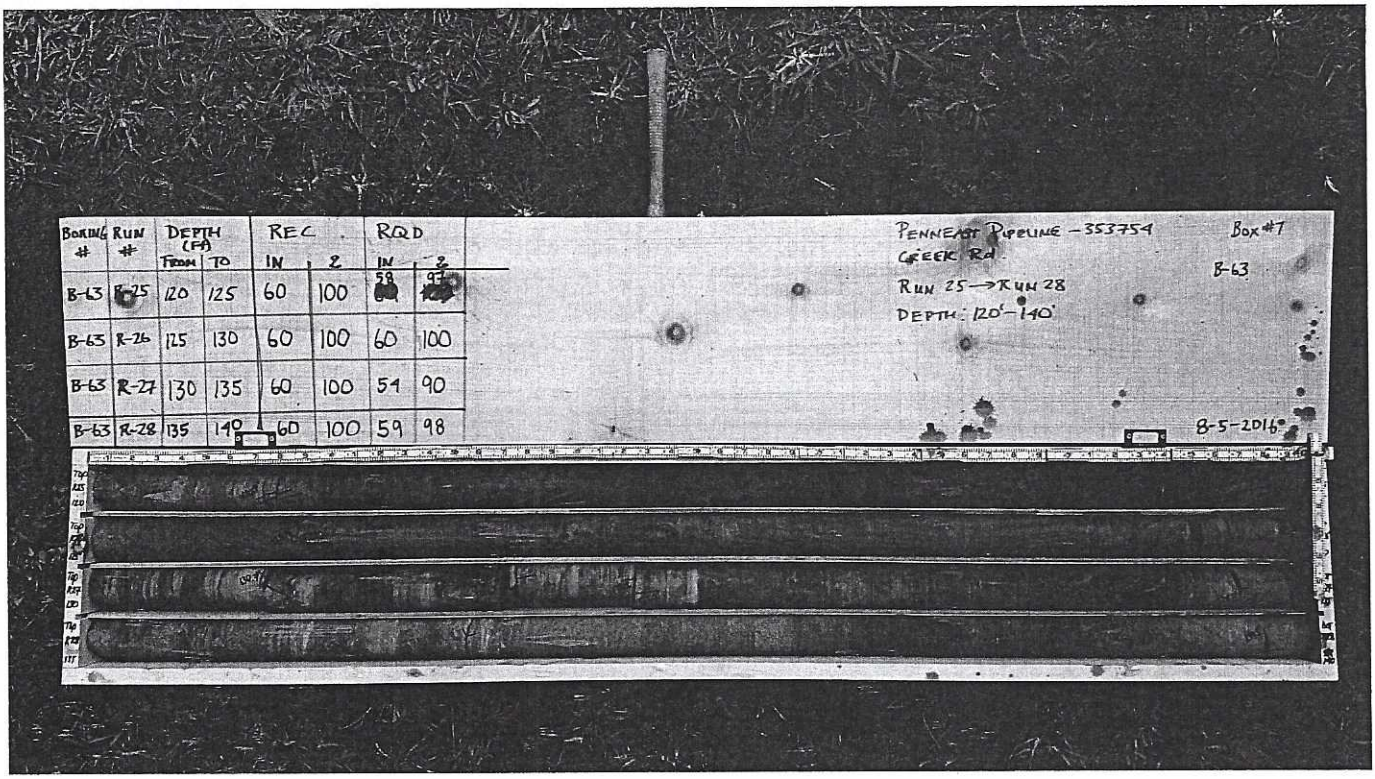


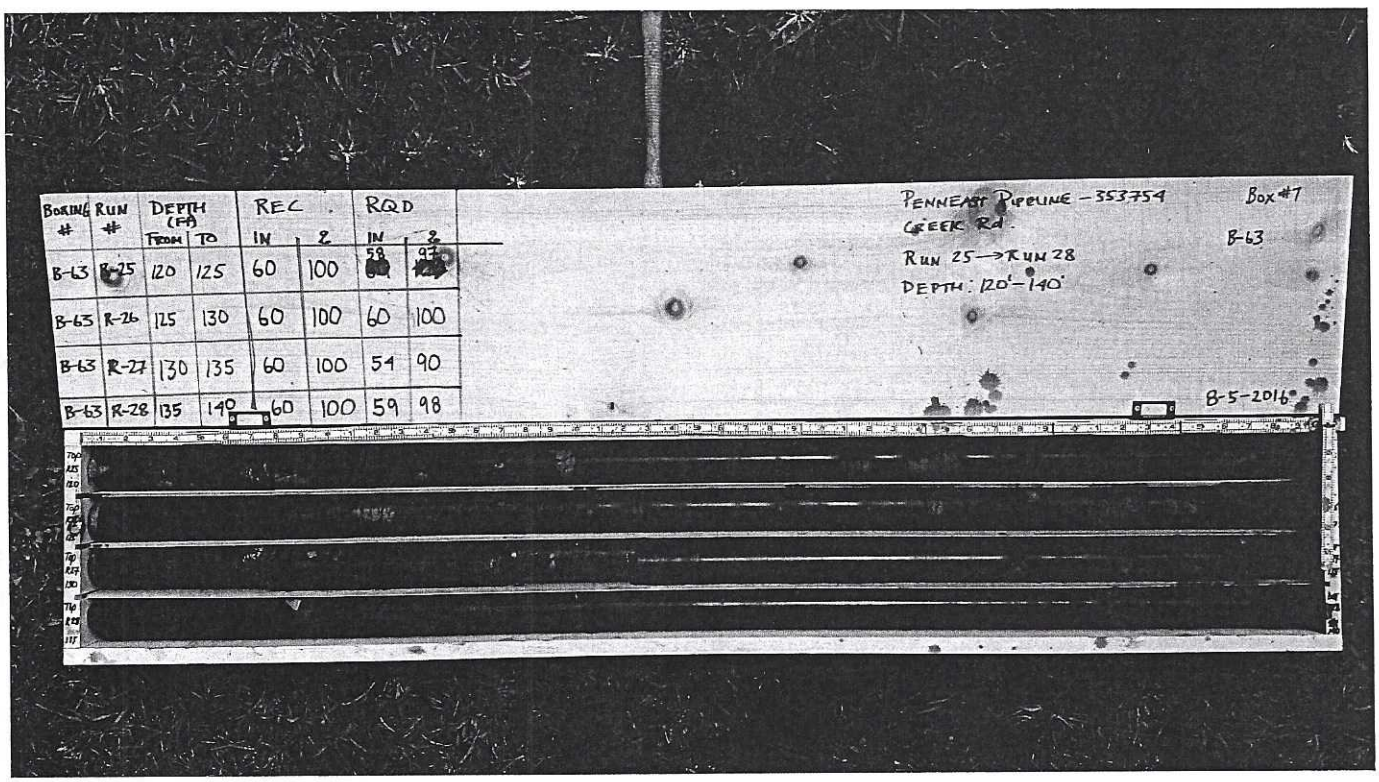
Figure B-63.12
B-63 Box 6 Runs 21-24 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-63



BORING #	RUN #	DEPTH (FT) FROM	TO	REC IN	%	RQD IN	%
B-63	R-25	120	125	60	100	58	97
B-63	R-26	125	130	60	100	60	100
B-63	R-27	130	135	60	100	54	90
B-63	R-28	135	140	60	100	59	98

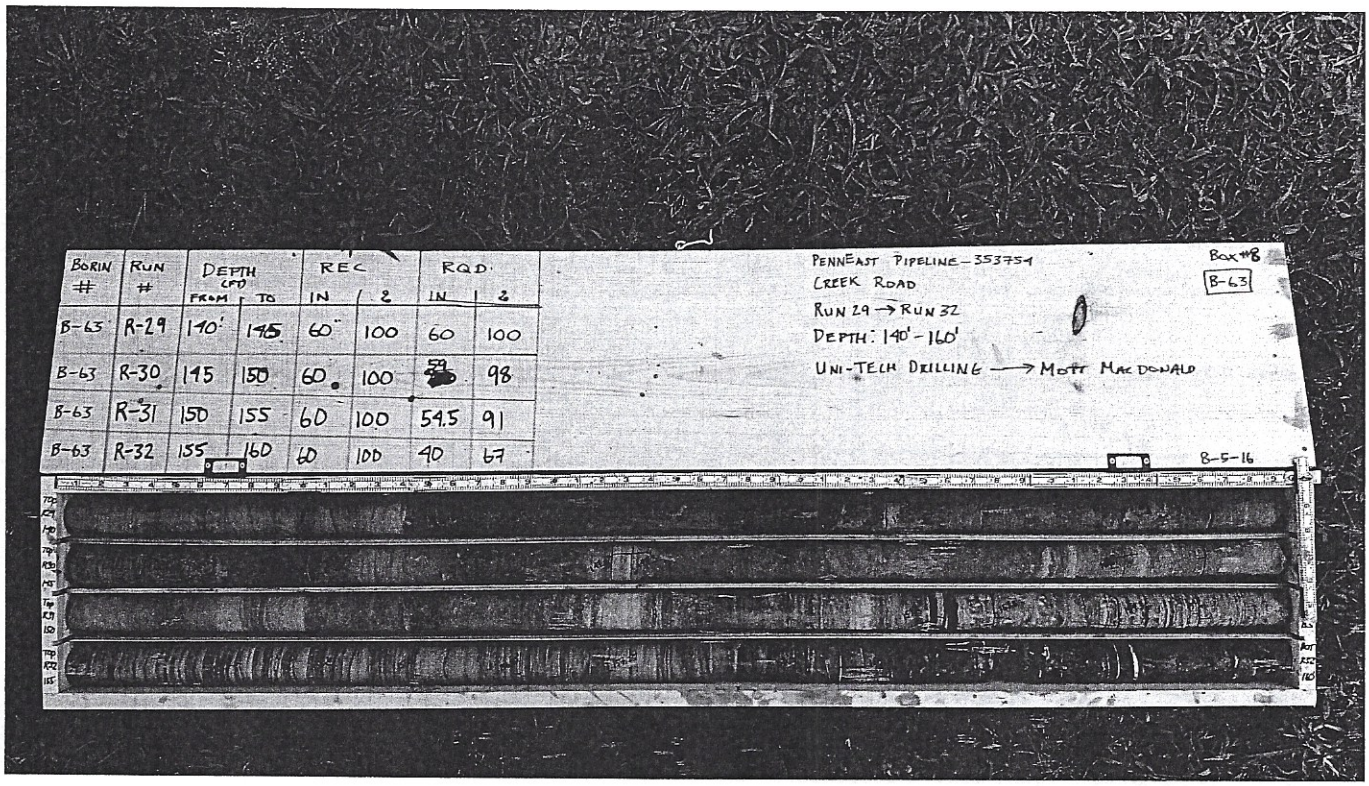
Figure B-63.13
B-63 Box 7 Runs 25-28 Dry



BORING #	RUN #	DEPTH (FT) FROM	TO	REC IN	%	RQD IN	%
B-63	R-25	120	125	60	100	58	97
B-63	R-26	125	130	60	100	60	100
B-63	R-27	130	135	60	100	54	90
B-63	R-28	135	140	60	100	59	98

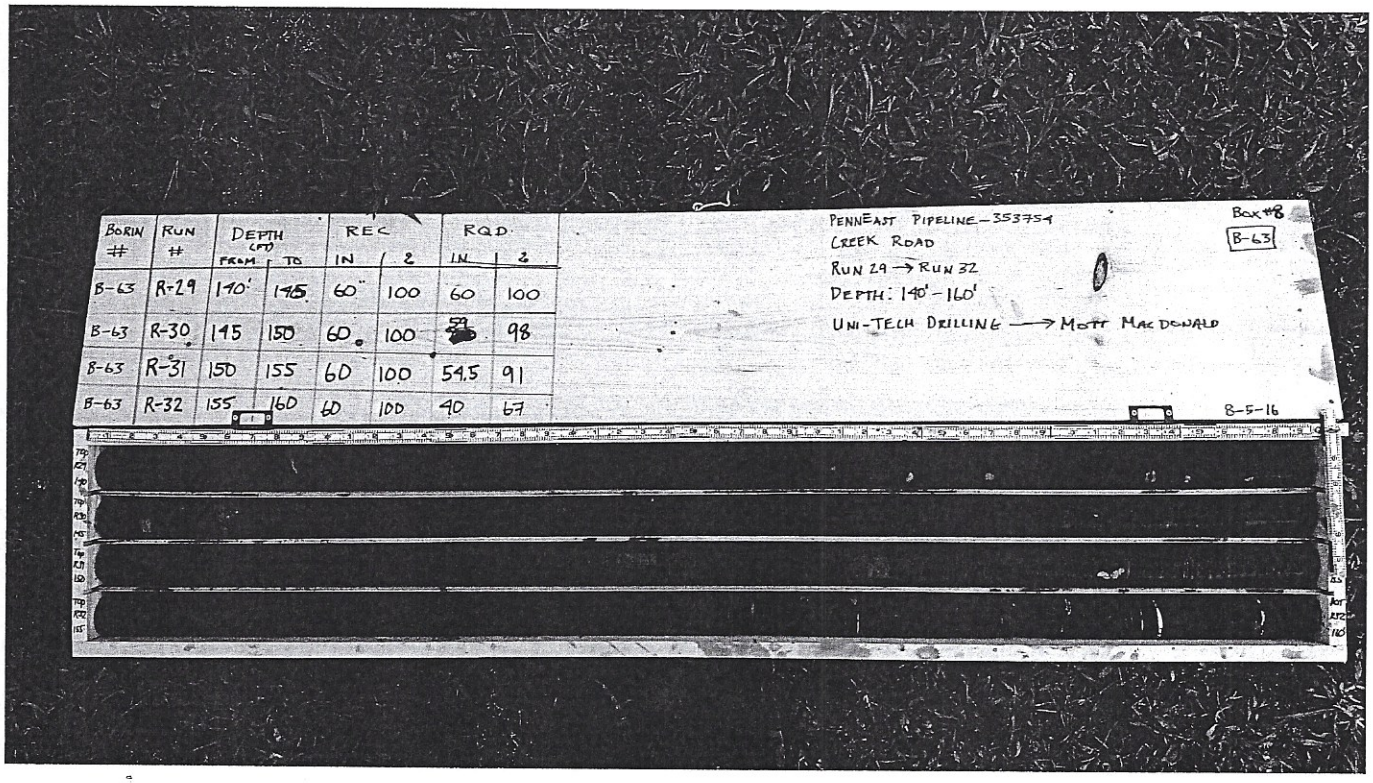
Figure B-63.14
B-63 Box 7 Runs 25-28 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-63



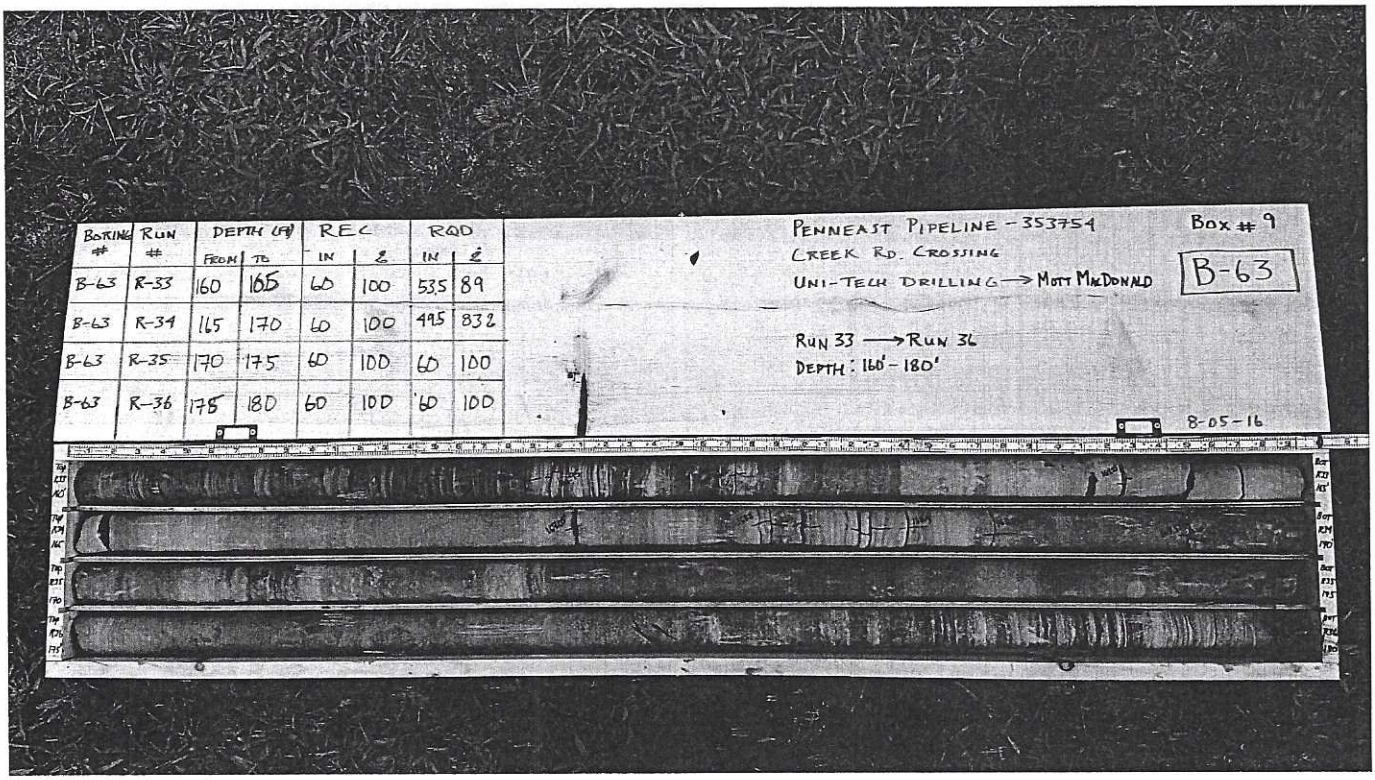
BORIN #	RUN #	DEPTH CFD FROM	TO	REC IN	%	RQD IN	%
B-63	R-29	140'	145	60"	100	60	100
B-63	R-30	145	150	60"	100	59	98
B-63	R-31	150	155	60"	100	54.5	91
B-63	R-32	155	160	60	100	40	67

Figure B-63.15
B-63 Box 8 Runs 29-32 Dry



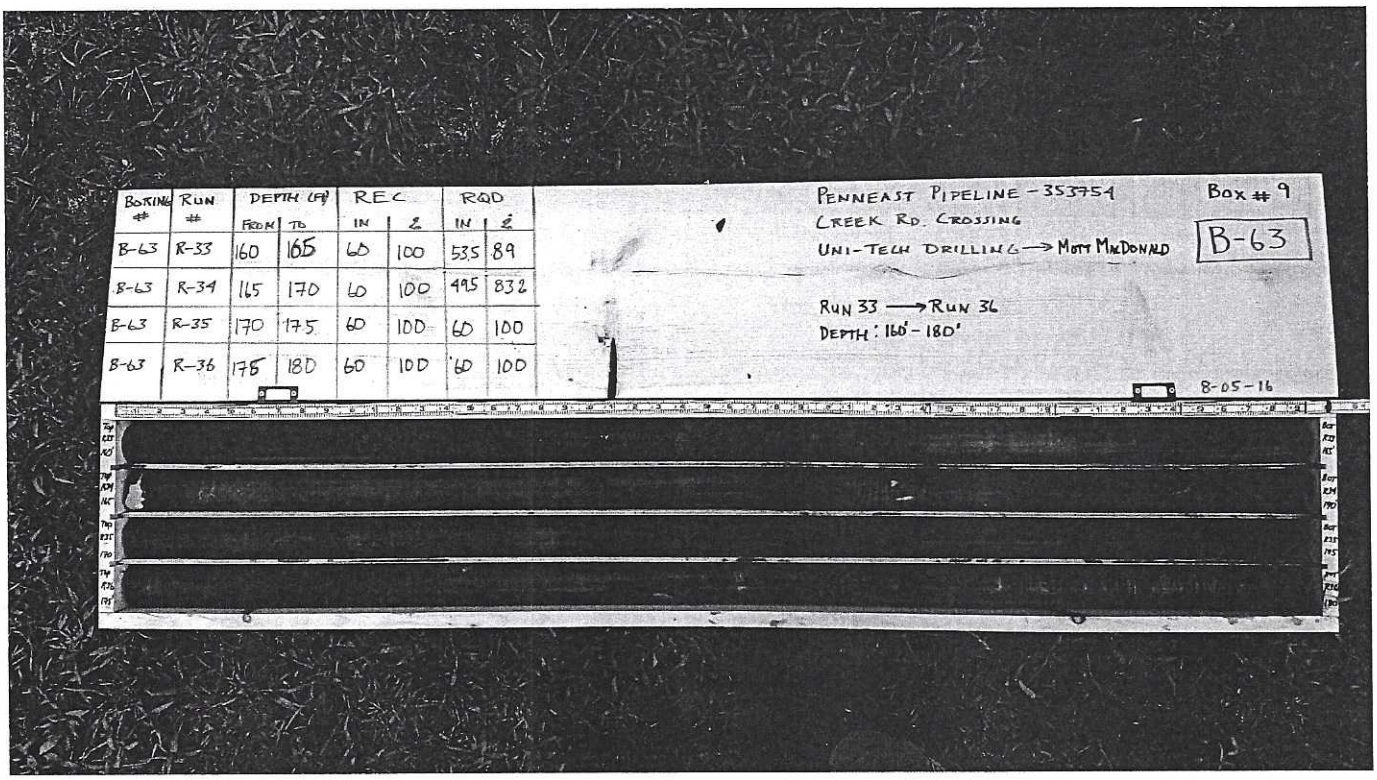
BORIN #	RUN #	DEPTH CFD FROM	TO	REC IN	%	RQD IN	%
B-63	R-29	140'	145	60"	100	60	100
B-63	R-30	145	150	60"	100	59	98
B-63	R-31	150	155	60"	100	54.5	91
B-63	R-32	155	160	60	100	40	67

Figure B-63.16
B-63 Box 8 Runs 29-32 Wet



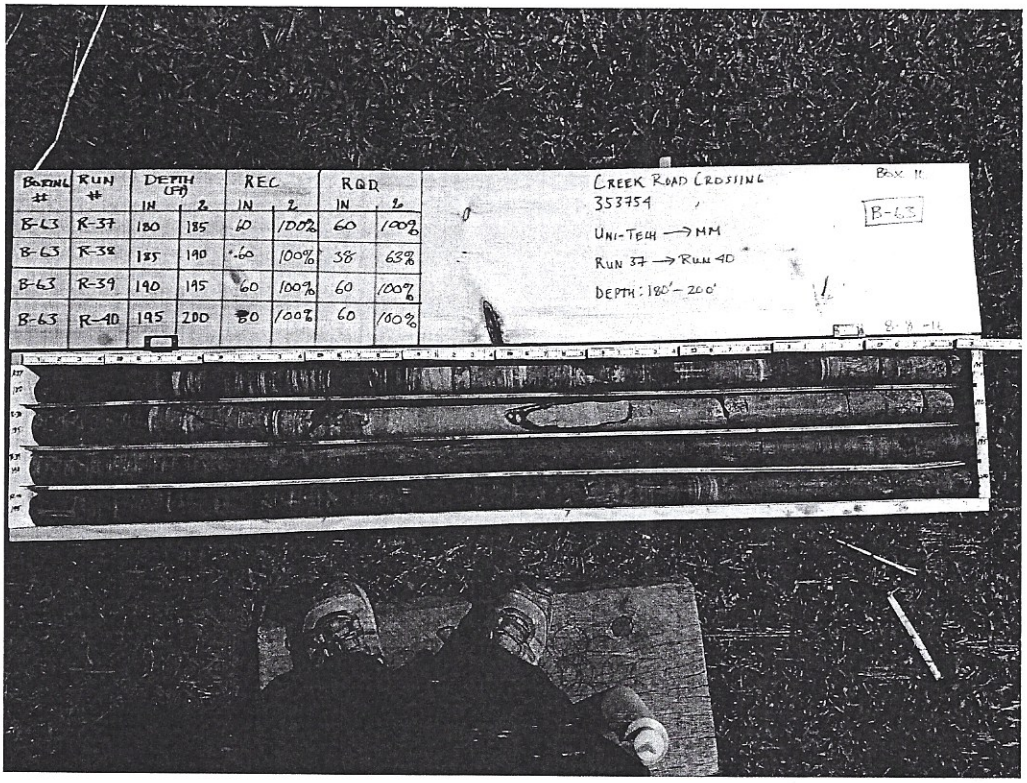
BORING #	RUN #	DEPTH (FT) FROM	TO	REC IN	%	RQD IN	%
B-63	R-33	160	165	60	100	535	89
B-63	R-34	165	170	60	100	495	832
B-63	R-35	170	175	60	100	60	100
B-63	R-36	175	180	60	100	60	100

Figure B-63.17
B-63 Box 9 Runs 33-36 Dry



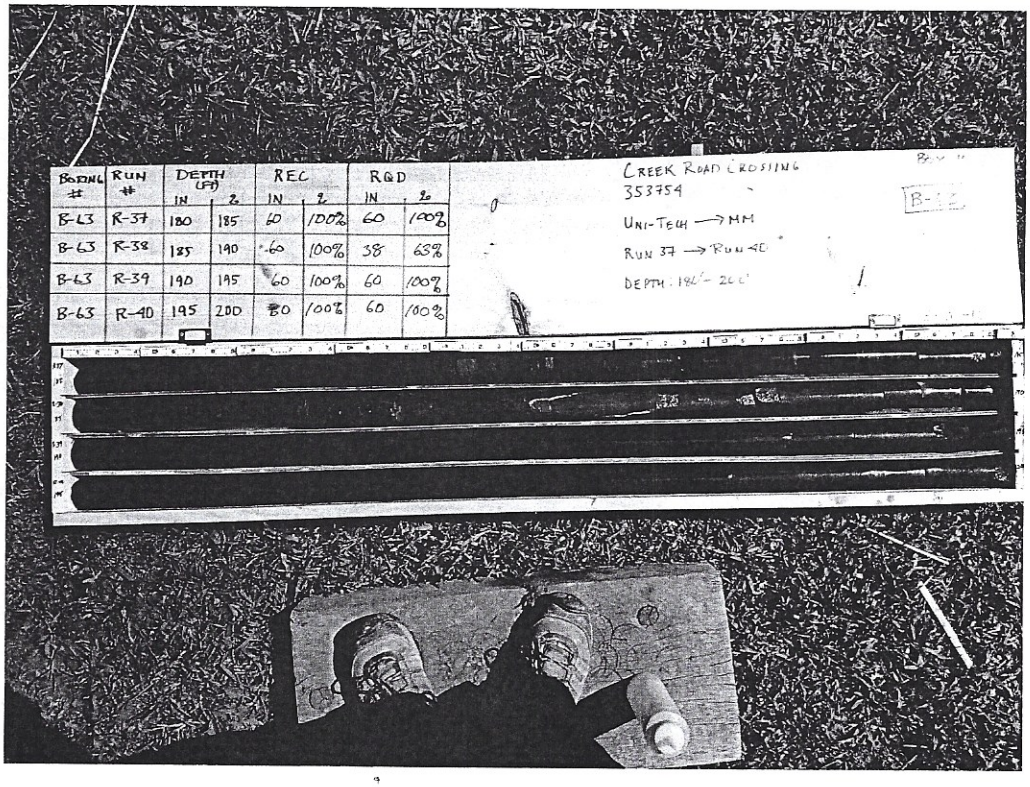
BORING #	RUN #	DEPTH (FT) FROM	TO	REC IN	%	RQD IN	%
B-63	R-33	160	165	60	100	535	89
B-63	R-34	165	170	60	100	495	832
B-63	R-35	170	175	60	100	60	100
B-63	R-36	175	180	60	100	60	100

Figure B-63.18
B-63 Box 9 Runs 33-36 Wet



BORING #	RUN #	DEPTH (FT) IN	DEPTH (FT) Z	REC IN	REC %	RQD IN	RQD %
B-63	R-37	180	185	60	100%	60	100%
B-63	R-38	185	190	60	100%	38	63%
B-63	R-39	190	195	60	100%	60	100%
B-63	R-40	195	200	60	100%	60	100%

Figure B-63.19
B-63 Box 10 Runs 37-40 Dry



BORING #	RUN #	DEPTH (FT) IN	DEPTH (FT) Z	REC IN	REC %	RQD IN	RQD %
B-63	R-37	180	185	60	100%	60	100%
B-63	R-38	185	190	60	100%	38	63%
B-63	R-39	190	195	60	100%	60	100%
B-63	R-40	195	200	60	100%	60	100%

Figure B-63.20
B-63 Box 10 Runs 37-40 Wet

MOTT MACDONALD	PennEast Pipeline Project	BORING NO.:
	Rock Core Photographs	B-63

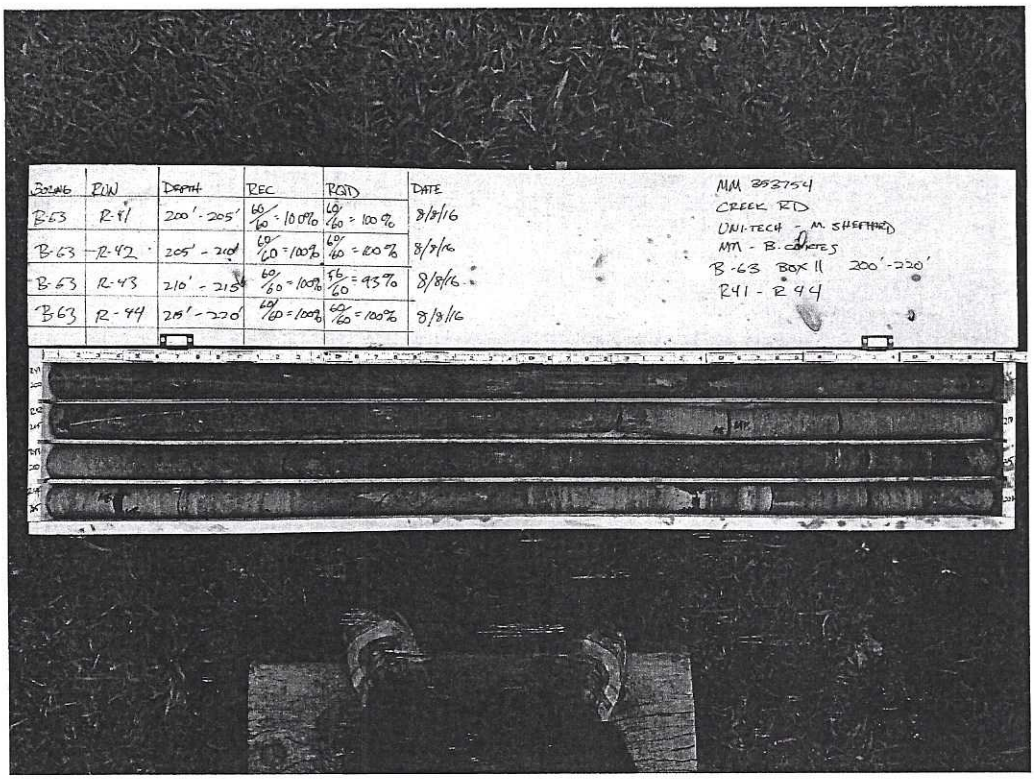


Figure B-63.21
B-63 Box 11 Runs 41-44 Dry

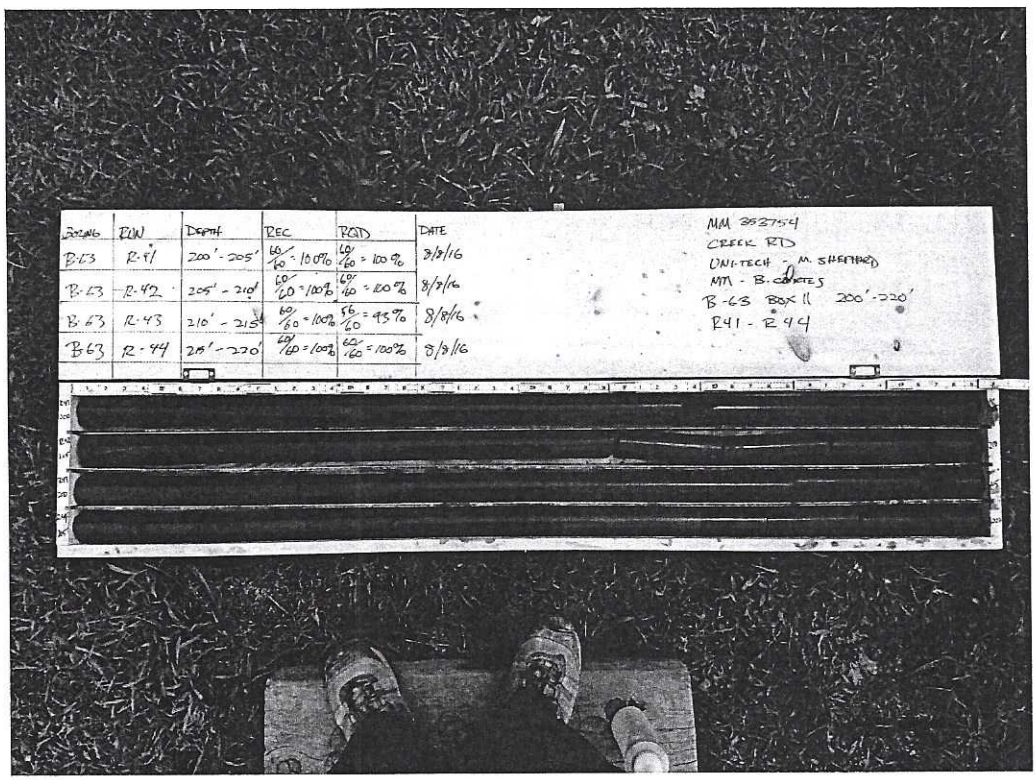


Figure B-63.22
B-63 Box 11 Runs 41-44 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-63

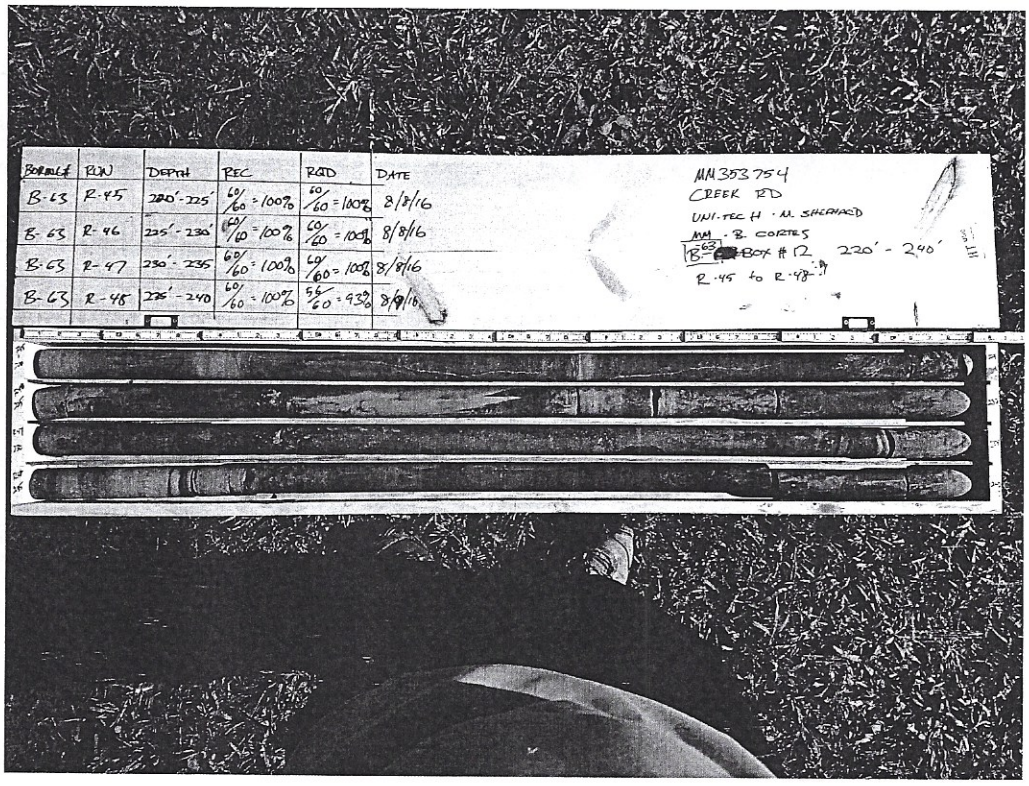


Figure B-63.23
B-63 Box 12 Runs 45-48 Dry

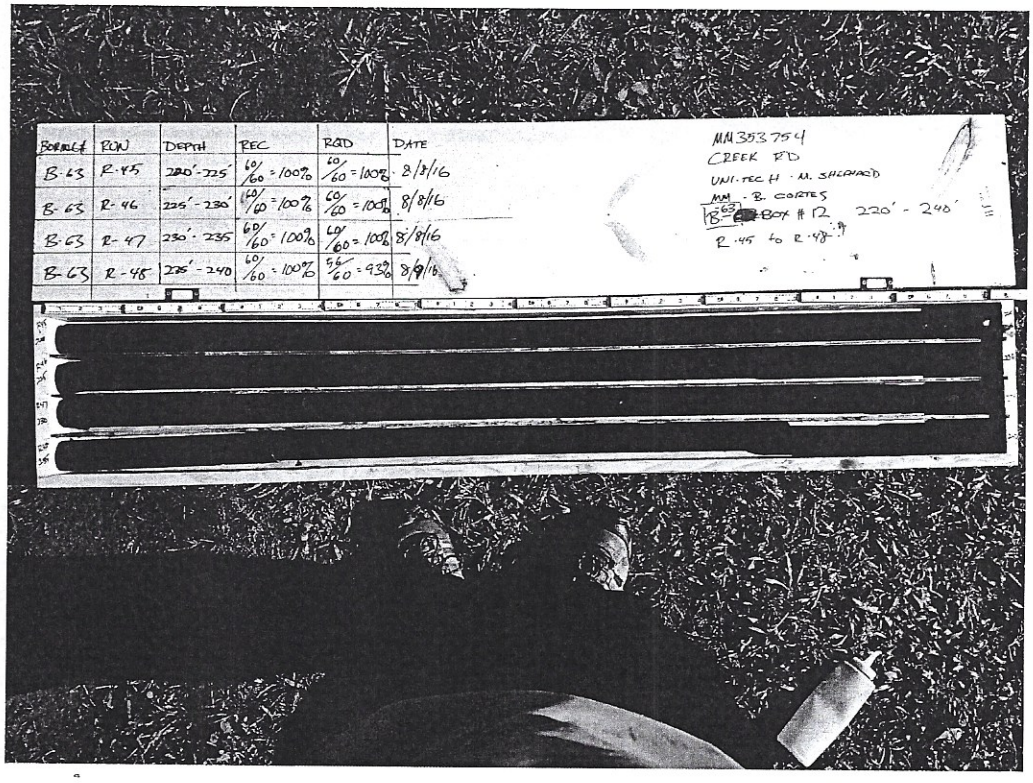


Figure B-63.24
B-63 Box 12 Runs 45-48 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-63

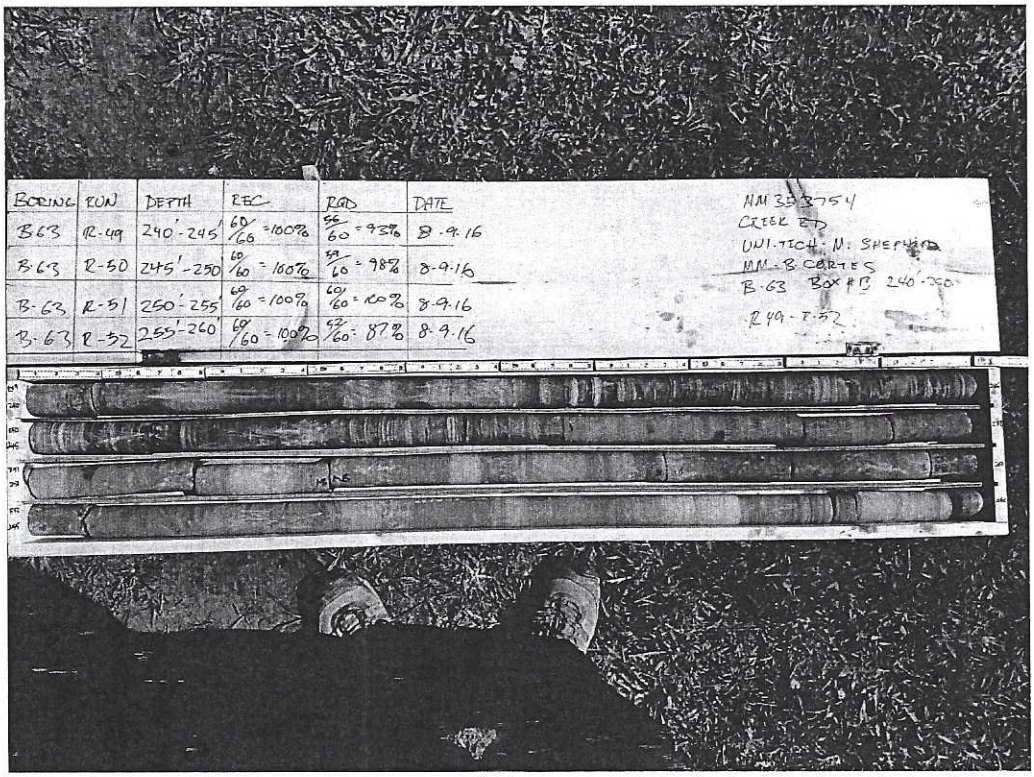


Figure B-63.25
Box 63 Box 13 Runs 49-52 Dry

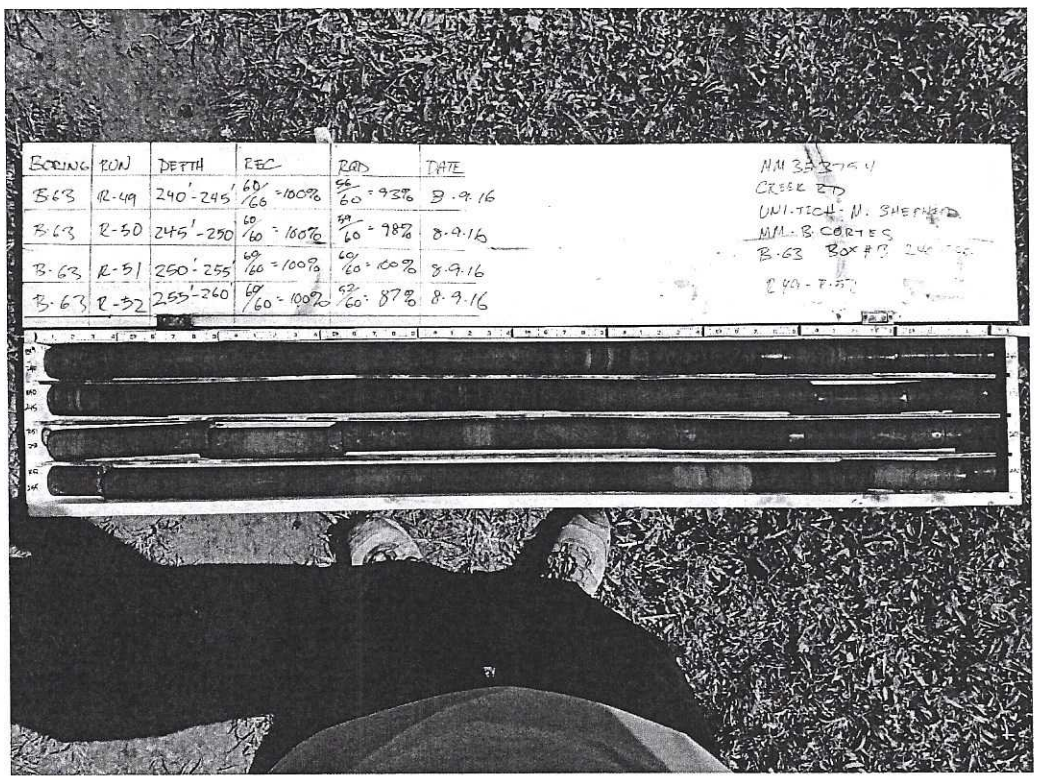


Figure B-63.26
B-63 Box 13 Runs 49-52 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-63

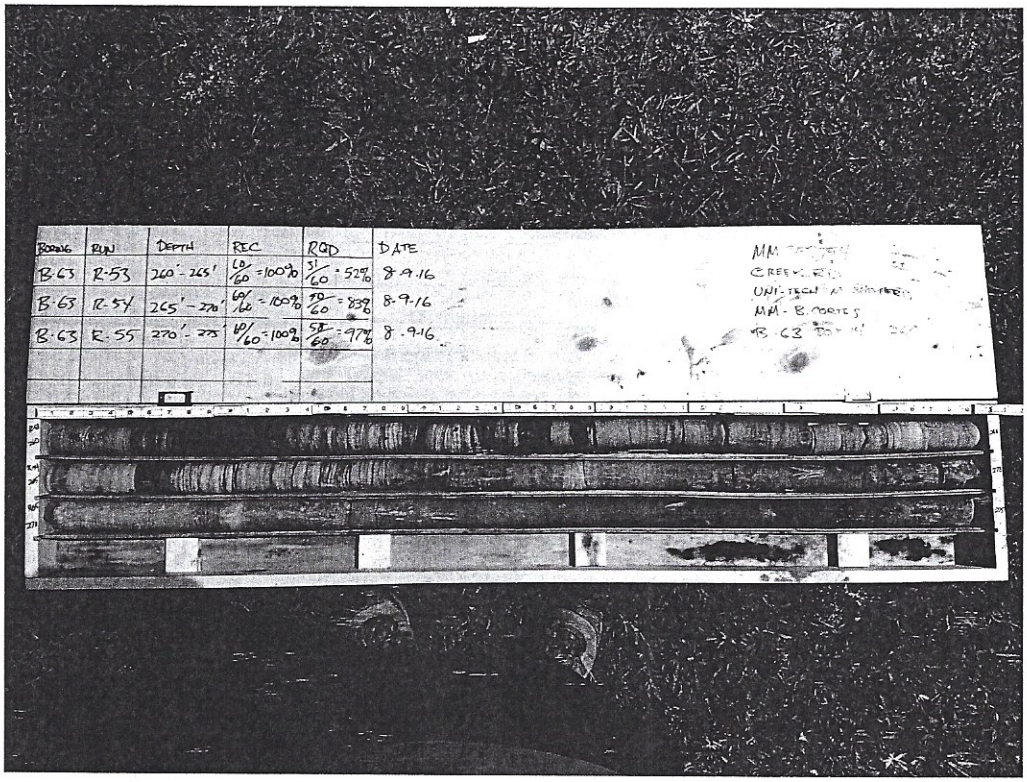


Figure B-63.27
B-63 Box 14 Runs 53-55 Dry

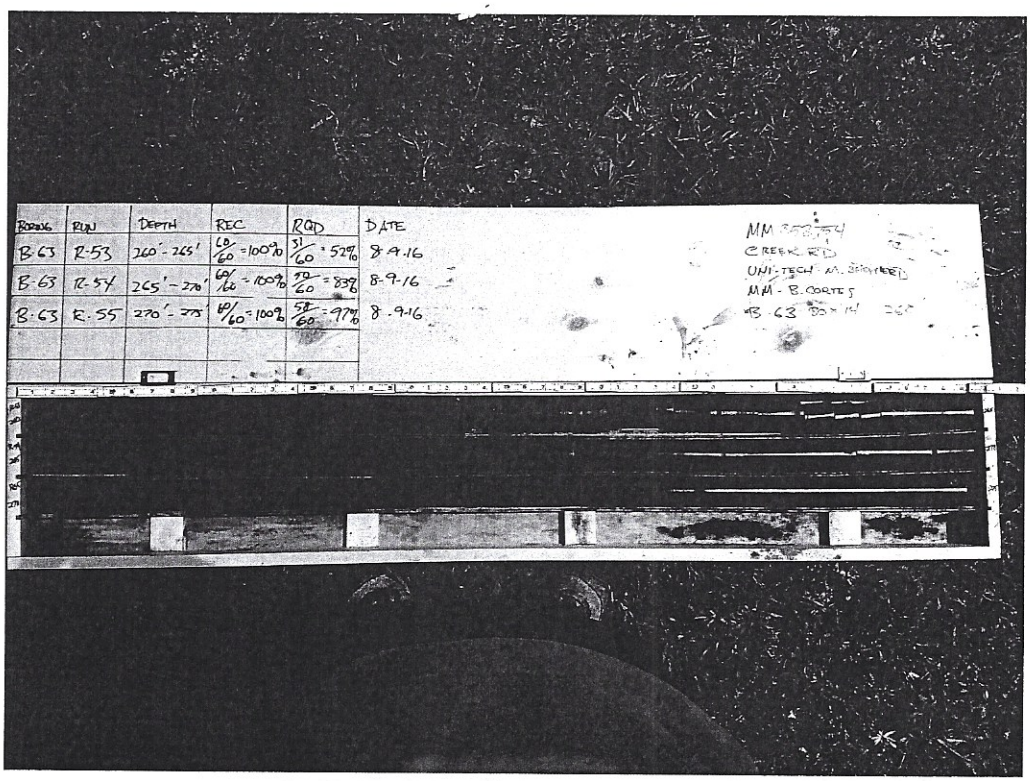


Figure B-63.28
B-63 Box 14 Runs 53-55 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-63

MOTT MACDONALD M M

SOIL BORING LOG

BORING NO.: **B-64**
Page 1 of 1

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Nishisakawick Creek, Hunterdon Co., NJ	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Bobby Kalpouzos
Drilling Co.:	Uni-Tech Drilling Co., Inc.	**Date/Time Started:**	July 26, 2016 at 7:00 am
Driller/Helper:	Mike Shepherd /Gene Blemings	**Date/Time Finished:**	August 2, 2016 at 3:00 pm

Elevation: 301 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Staked location near wooded area. **Coord.:** N: 40.537602 E: -75.050749 **Horizontal Datum:** NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HSA	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:** Hollow Stem Auger

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
300	S-1 0.0'- 0.2'	12	5 10 50/2"			Very dense, Reddish brown DECOMPOSED ROCK fragments	N	-	NP	-	
						3.5 Top of Rock at 3.5 feet BGS. See Rock Coring Log.					
5											
10											
290											
15											

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
7/27/16	7:00	-		64.0	60
8/1/16	7:00	-		284.0	Dry

Sample Type

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

Notes:

PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-64**

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

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

MOTT MACDONALD M M

CORE BORING LOG

BORING NO.: **B-64**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Nishisakawick Creek, Hunterdon Co., NJ	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Bobby Kalpouzos
Drilling Co.:	Uni-Tech Drilling Co., Inc.	**Date/Time Started:**	July 26, 2016 at 7:00 am
Driller/Helper:	Mike Shepherd /Gene Blemings	**Date/Time Finished:**	August 2, 2016 at 3:00 pm

Elevation: 301 ft. **Vertical Datum:** NAVD 1988

Boring Location: Staked location near wooded area.

Coord.: N: 40.537602 E: -75.050749

Horizontal Datum: NAD 1983

Rig Make & Model: CME-750X

Drilling Method: Wireline

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

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
									SEE TEST BORING LOG FOR OVERBURDEN DETAILS		(See Legend for Rock Description System)						
	2.50	4.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, very weak, very close to close spaced discontinuities								Cored 6 inches to begin R-1 from 3.5 feet to 4 feet BGS.
5	2.00								4' - 9' Highly Fractured zone								
	2.00		R-1	59 98%	0 0%	R1	SL										
	1.50																
	2.00	9.0															Loss of water at 8.5 feet BGS.
	1.50	9.0							SILTSTONE, Reddish brown, very fine grained, slightly weathered, weak to medium strong, very close to close spaced discontinuities								
10	2.00								9' - 10.4' Highly Fractured zone								
290										10.40	J	0	P,R	DS	PO	N	
	1.50		R-2	60 100%	14 23%	R2	SL		10.9' Vertical Fracture 10.9' - 11.4' Highly Fractured zone	10.90 11.40	J J	0 0	P,R S,R	DS DS	PO T	ML ML	
	5.00								11.8' - 14' Highly Fractured zone								Loss of water from 12 to 13 feet BGS.
	5.00	14.0															
	3.00	14.0							SILTSTONE, Reddish brown, very fine grained, slightly weathered, very weak to weak, very close to close spaced discontinuities								
15									14' - 14.8' Highly Fractured zone	14.80	J	30	S,R	DS	T	N	
	2.25									15.10	J	0	S,R	DS	T	N	
										15.50	J	60	U,R	DS	T	N	
	2.00		R-3	60 100%	26 43%	R1	SL		16' - 17.3' Highly Fractured zone	16.00	J	0	U,R	DS	PO	N	
	2.50									17.30	J	70	S,R	DS	T	ML	
										17.80	J	20	S,R	DS	O	N	
	2.50	19.0								18.20	J	0	S,R	DS	PO	N	
		19.0							18.7' - 19' Highly Fractured zone	18.70	J	0	S,R	DS	T	N	
	1.50								SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, very close to close spaced discontinuities	19.40	J	0	U,R	DS	PO	N	Used up to 450 Gallons from R-1 to R-3.
20	1.50								19' - 19.4' Highly Fractured zone 19.9' - 21' Highly Fractured zone	19.90	J	0	U,R	DS	O	N	Loss of water from 19 to 23 feet BGS.
280										21.00	J	60	S,R	DS	O	N	
	1.75		R-4	60 100%	23 38%	R2	SL			21.40	J	0	U,R	DS	PO	N	
										21.70	J	0	U,R	DS	T	N	
	2.00								22.2' - 23' Highly Fractured zone	22.20	J	0	U,R	DS	PO	N	
	2.50									23.00	J	30	U,R	DS	T	N	
		24.0							23.6' - 24' Fractured zone	23.60	J	0	U,R	DS	O	N	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
7/27/16	7:00	-		64.0	60.0
8/1/16	7:00	-		284.0	

Notes:

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.00	24.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, very close to close spaced discontinuities	24.30	J	0	S,R	DS	T	N	
25	2.00									25.20	J	0	S,R	DS	T	CL	
										25.70	J	40	U,R	DS	VT	CL	
	3.00		R-5	60 100%	31 52%	R2	SL		26' - 26.8' Fractured zone	26.00	J	30	U,R	DS	VT	CL	
									2-inch thick Clay seam at 26.4'								
	2.80									26.80	J	0	U,R	DS	PO	CL	
										27.20	J	0	P,R	DS	T	CL	
	3.50	29.0							27.6' - 29' Fractured zone	27.60	J	0	U,R	DS	VT	CL	
	3.00	29.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, very close to close spaced discontinuities	29.30	J	0	U,R	DS	VT	N	
30									29.6' - 31.4' Highly Fractured zone	29.60	J	0	S,Sm	DS	PO	N	
	2.80																
270																	
	2.50		R-6	60 100%	29 48%	R2	SL			31.40	J	0	U,R	DS	T	N	
										31.80	J	0	S,R	DS	T	N	
										31.90	J	0	P,R	DS	T	N	
	2.30								32.2' - 32.9' Fractured zone	32.20	J	0	P,R	DS	PO	N	
										32.90	J	0	S,R	DS	VT	N	
	3.25	34.0								33.60	J	0	U,R	DS	PO	N	
	2.00	34.0							SILTSTONE, Reddish brown, very fine grained, slightly weathered, weak, close to moderately spaced discontinuities	34.10	J	0	U,R	DS	PO	N	Used up to 450 Gallons from R-4 to R-6.
35	2.00																
										36.30	J	0	U,R	DS	O	N	
	2.00		R-7	60 100%	37 62%	R2	SL			36.80	J	20	U,R	DS	O	N	
										37.10	J	0	U,R	DS	T	N	
	2.00								37.5' - 39' Fractured zone	37.50	J	0	U,R	DS	T	N	
	2.50	39.0															
	3.00	39.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities	39.00	J	0	U,R	DS	O	N	Loss of water.
									39.6' - 40.3' Fractured zone	39.50	J	0	S,R	DS	T	N	
40	2.50									40.30	J	0	U,R	DS	T	N	
260									40.8' - 41.4' Fractured zone	40.80	J	70	U,R	DS	PO	N	
	2.50		R-8	60 100%	33 54%	R2	SL			41.40	J	0	U,R	DS	PO	N	
										41.80	J	0	P,R	DS	PO	N	
										42.10	J	30	U,R	DS	T	N	
	2.50									42.50	J	20	P,R	DS	T	N	
										42.70	J	0	U,R	DS	O	N	
	2.00	44.0								43.20	J	0	P,R	DS	PO	N	
										43.40	J	0	U,R	DS	PO	N	
	2.50	44.0							SILTSTONE, Reddish brown, fine to medium grained, slightly weathered, weak, very close to close spaced discontinuities	43.90	J	0	P,R	DS	PO	N	Loss of water.
45	2.75								45.5' - 47.2' Gray banding	45.50	J	5	P,R	DS	PO	N	
	2.50		R-9	60 100%	40 67%	R2	SL			46.70	J	0	Ũ,R	DS	PO	N	
										46.80	J	5		DS	PO	N	
	4.00																
	4.00	49.0							47.8' - 48.2' Fractured zone	47.80	J	10	U,R	DS	PO	N	
										48.20	J	0	P,R	DS	VT	N	
		49.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close spaced discontinuities	48.70	J	5	P,R	DS	T	N	Used up to 450 Gallons from R-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
	2.75																to R-9.
50	3.00									49.80	J	5	U,R	DS	PO	N	Loss of water.
250	2.50		R-10	60 100%	59 98%	R2	SL			51.40	J	0	U,R	DS	VT	N	
	3.00								52.5' - 52.7' Fractured zone	52.40	J	20	P,R	DS	PO	N	
	3.50	54.0								52.70	J	5	P,R	DS	T	N	
	3.00	54.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close spaced discontinuities	54.30	J	5	P,R	DS	T	N	
55	2.50																
	2.50		R-11	60 100%	52 87%	R2	SL			56.30	J	10	U,R	DS	PO	N	
	2.75									57.50	J	25	U,R	DS	O	N	
	3.00	59.0								57.80	J	0	P,R	DS	VT	N	
									1.5-inch thick Clay seam at 58.5'	58.50	J	10	U,R	DS	PO	CL	
	2.50	59.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, very close to close spaced discontinuities	59.20	J	5	P,R	DS	T	N	
60									59.8' - 60.2' Fractured zone	59.80	J	0	P,R	DS	VT	N	
	2.75									60.20	J	0	P,R	DS	O	N	
240	2.00		R-12	60 100%	53 88%	R2	SL										
	2.00									62.10	J	10	U,R	DS	PO	N	
	2.00	64.0								63.60	J	5	U,R	DS	PO	N	
	2.50	64.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Used up to 450 Gallons from R-10 to R-12. Loss of water.
65	3.00									65.50	J	5	P,R	DS	PO	N	
	2.25		R-13	60 100%	51 85%	R2	SL			66.10	J	10	U,R	DS	O	N	
	2.25																
	3.50	69.0								67.90	J	5	P,R	DS	PO	N	
										68.30	J	30	P,R	DS	PO	N	
										68.70	J	20	P,R	DS	T	N	
	2.75	69.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, very close to close spaced discontinuities								Loss of water.
70	2.50									70.30	J	0	U,R	FR	PO	N	
230	2.50		R-14	60 100%	41 68%	R2	SL			71.30	J	5	P,R	DS	T	N	
										71.80	J	10	P,R	DS	PO	N	
	2.75								72.3' - 72.9' Fractured zone	72.30	J	10	S,R	DS	PO	ML	
										72.90	J	5	P,R	DS	T	ML	
	3.00	74.0								73.30	J	5	P,R	DS	PO	ML	
	2.75	74.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities	73.80	J	10	U,R	DS	PO	N	Used up to 450 Gallons for R-13/R-14. Loss of water.

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-64**
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Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.50																
	2.75		R-15	60 100%	55 92%	R2	SL			76.20	J	3	U,R	DS	PO	ML	
	2.50																
	2.75									77.70	J	10	U,R	DS	VT	N	
		79.0								78.50	J	5	U,Sm	FR	PO	N	
	2.50	79.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, very close to moderately spaced discontinuities								Loss of water.
80	2.50																
220										80.50	J	10	P,R	DS	PO	N	
	3.00		R-16	60 100%	53 88%	R2	SL			81.00	J	10	U,R	DS	O	N	
										81.60	J	15	U,R	FR	PO	N	
	3.00								82' - 82.6' Fractured zone								
										82.70	J	10	P,R	FR	PO	N	
	2.50	84.0															
	2.50	84.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Loss of water.
85	2.50																
	2.50		R-17	60 100%	58 97%	R2	SL			86.05	J	5	U,R	DS	O	N	
										86.20	J	10	S,R	DS	PO	N	
	2.00																
	3.00	89.0															
	2.50	89.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Used up to 450 Gallons from R-15 to R-17. Loss of water.
90	2.75																
210	3.00		R-18	60 100%	57 94%	R2	SL			92.20	J	5	P,R	FR	PO	N	
										92.35	J	10	U,R	FR	PO	N	
	2.50																
	2.50	94.0								93.50	J	10	U,R	FR	O	N	
	2.50	94.0							94.0 SHALE, Gray to dark gray, very fine grained, slightly weathered, weak, very close to close spaced discontinuities	93.90	J	5	P,R	FR	O	N	Loss of water.
95									1-inch thick Clay seam at 94.5'	94.50	J	0	U,Sm	DS	PO	CL	
										94.75	J	5	P,Sm	DS	O	N	
	2.50									95.20	J	0	P,R	DS	O	N	
										95.60	J	5	P,Sm	DS	PO	N	
	2.50		R-19	60 100%	35 58%	R2	SL			96.40	J	5	U,R	DS	VT	N	
	2.00									97.10	J	10	P,R	DS	T	N	
										97.80	J	10	P,Sm	DS	VT	N	
	2.50	99.0								98.20	J	5	P,Sm	DS	PO	N	
	2.50	99.0								98.80	J	10	U,R	DS	T	N	Loss of water.
100									SHALE, Gray to dark gray very fine grained, slightly weathered, weak, very close to close spaced discontinuities 99' - 101.1' Highly Fractured zone								
	2.50																

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-64**

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
200	2.50																
	2.00		R-20	60 100%	27 45%	R2	SL		3-inch thick Coal seam at 101'	101.10	J	0	U,Sm	FR	O	N	
										101.60	J	5	U,Sm	FR	O	N	
	2.50									102.50	J	0	P,Sm	FR	T	N	
										102.70	J	5	U,Sm	FR	O	N	
	3.25	104.0								103.20	J	0	P,Sm	FR	PO	N	
									104.0								
	2.75	104.0							SILTSTONE, Light gray, very fine to fine grained, slightly weathered, weak, moderate to wide spaced discontinuities	104.30	J	10	U,R	DS	PO	N	Used up to 450 Gallons from R18 to R-21. Loss of water.
105																	
	2.50																
	2.50		R-21	60 100%	54 89%	R2	SL										
	1.50									107.60	J	0	U,R	DS	PO	N	
		109.0															
	2.50	109.0							SILTSTONE, Gray, very fine to fine grained, slightly weathered, weak, moderate to wide spaced discontinuities	108.80	J	5	U,R	DS	PO	N	Loss of water.
110																	
	2.00																
190																	
	2.50		R-22	60 100%	60 100%	R2	SL		111.5' Color transition to Reddish brown	111.10	J	10	U,Sm	DS	T	N	
	2.00																
	3.00	114.0								113.60	J	0	U,Sm	DS	PO	N	
	2.50	114.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, moderate to wide spaced discontinuities								Loss of water.
115																	
	2.50																
	2.00		R-23	60 100%	60 100%	R2	SL		116.5' Color transition to Light gray								
	2.00																
	3.00	119.0								118.60	J	15	U,R	DS	T	N	
	3.00	119.0							SILTSTONE, Dark to light gray, very fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Used up to 450 Gallons from R-22 to R-24. Loss of water.
120																	
	3.00									120.10	J	10	U,R	DS	O	N	
180									1-foot thick SHALE zone at 120.5'								
	2.00		R-24	60 100%	51 85%	R2	SL			121.80	J	5	P,Sm	DS	O	N	
										122.10	J	3	U,Sm	DS	O	N	
	2.50																
										122.70	J	5	P,Sm	DS	PO	N	
										123.00	J	3	U,R	DS	T	N	
	3.50	124.0															
	3.00	124.0							SILTSTONE, Gray to light gray, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities 124.6' Vertical fracture	123.70	J	0	P,Sm	DS	T	N	Loss of water.
125																	
	2.00									125.80	J	40	U,K	DS	O	N	

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.50		R-25	60 100%	59 98%	R2	SL			126.60	J	10	U,R	DS	PO	N	
	2.50																
	3.50	129.0								128.20	J	10	U,R	DS	T	N	
	2.50	129.0							SILTSTONE, Light gray to reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Loss of water.
130	2.50																
170	3.00		R-26	60 100%	56 93%	R2	SL										
	2.50									132.20	J	60	U,R	DS	T	N	
										132.80	J	0	P,R	DS	PO	N	
	3.00	134.0								133.30	J	0	U,R	DS	O	N	
										133.60	J	0	U,R	DS	PO	N	
	2.00	134.0							SILTSTONE, Reddish brown, very fine grained, slightly weathered, weak, moderate to wide spaced discontinuities								Used up to 450 Gallons from R-25 to R-27. Loss of water.
135	2.00																
	3.00		R-27	59 98%	54 90%	R2	SL										
	2.50																
	4.50	139.0							137.7' Vertical fracture								
	3.00	139.0							SILTSTONE, Reddish brown, very fine grained, slightly weathered, weak, close to moderately spaced discontinuities	138.60	J	0	S,Sm	DS	O	N	Loss of water.
140	3.00																
160	3.00		R-28	58 97%	58 97%	R2	SL		141.3' Vertical fracture								
	3.00																
	3.75	144.0								143.20	J	5	P,R	DS	T	N	
	3.00	144.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, moderate to wide spaced discontinuities								Loss of water.
145	3.00																
	2.50		R-29	59 98%	57 95%	R2	SL										
	2.00																
	3.25	149.0								148.75	J	40	U,R	DS	T	N	Loss of water.
	2.50	149.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to wide spaced discontinuities	149.30	J	20	U,R	DS	O	N	
150	2.00																
150	3.00		R-30	60	52	R2	SL										

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00			100%	87%												
	2.00									152.60	J	35	S,R	DS	O	N	
	3.00									153.20	J	0	U,R	DS	O	N	
		154.0								153.60	J	0	U,R	DS	O	N	
	3.00	154.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Used up to 450 Gallons from R-28 to R-30. Loss of water.
155	2.50									155.50	J	0	P,Sm	DS	O	N	
										155.80	J	0	U,Sm	DS	O	N	
	2.50		R-31	60 100%	49 82%	R2	SL			156.40	J	0	U,R	DS	T	N	
	2.00								157.4' - 158.2' Vertical fracture with Calcite infill								
	3.00	159.0								158.50	J	70	U,R	DS	PO	SD	
	2.00	159.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Loss of water.
160	2.75																
140										160.70	J	0	U,Sm	DS	PO	N	
	2.50		R-32	60 100%	44 73%	R2	SL			160.90	J	5	U,Sm	DS	PO	N	
	2.50								162.3' Calcite vein								
	3.00	164.0								163.20	J	10	U,Sm	DS	PO	N	
	2.75	164.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, wide spaced discontinuities								Loss of water.
165	2.50																
	3.00		R-33	60 100%	60 100%	R2	SL										
	2.50																
	3.00	169.0															
	2.50	169.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Used up to 450 Gallons from R-31 to R-34. Loss of water.
170	3.00									169.80	J	40	U,R	FR	PO	N	
130																	
	2.50		R-34	56 93%	56 93%	R2	SL										
	2.785																
	3.00	174.0															
	2.75	174.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Loss of water.
175	3.00									175.10	J	5	U,R	DS	O	N	
									175.6' Calcite vein								
	2.25		R-35	60 100%	57 94%	R2	SL										

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-64**

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.75																
	2.75																
										178.00	J	5	U,R	DS	PO	N	
	3.00									178.40	J	0	U,R	DS	PO	N	
		179.0															
	3.00	179.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, moderate to wide spaced discontinuities								Loss of water.
180																	
	2.75																
120																	
	3.00		R-36	60 100%	60 100%	R2	SL		181.5' Calcite present								
	2.75																
	3.00								183.2' - 184' Calcite present								
		184.0							184.0								
	2.75	184.0							SHALE, Reddish brown to gray, very fine grained, slightly weathered, weak, close to moderately spaced discontinuities Calcite layers throughout								Used up to 450 Gallons from R-35 to R-37. Loss of water.
185										184.90	J	5	P,Sm	DS	PO	N	
	3.00									185.60	J	10	P,Sm	DS	T	N	
	2.50		R-37	60 100%	54 90%	R2	SL										
	2.50									187.80	J	10	U,Sm	DS	PO	N	
	2.50	189.0							189.0								
	2.00	189.0							SILTSTONE, Gray to light gray, very fine to fine grained, slightly weathered, weak, moderate to wide spaced discontinuities								Loss of water.
190																	
	2.25									190.30	J	30	S,Sm	DS	O	N	
110																	
	2.50		R-38	60 100%	58 97%	R2	SL										
	2.25																
	3.00	194.0															
	2.50	194.0							SILTSTONE, Light gray, very fine to fine grained, slightly weathered, weak, moderately spaced discontinuities								Loss of water.
195																	
	2.50																
	2.25		R-39	60 100%	60 100%	R2	SL			196.00	J	5	P,R	DS	O	N	
	2.50																
	3.00	199.0								198.30	J	0	U,R	DS	O	N	
	2.50	199.0							SILTSTONE, Gray to light gray, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Loss of water.
200										199.90	J	10	P,R	DS	T	N	
	2.50									200.10	J	0	U,R	DS	PO	N	
										200.20	J	0	U,Sm	DS	PO	N	
100										200.80	J	0	U,Sm	DS	PO	N	
	2.25		R-40	60 100%	49 81%	R2	SL			201.20	J	0	U,Sm	DS	T	N	
									202.0								
	2.25								202' Transition to SHALE	201.90	J	0	P,Sm	DS	PO	N	

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.25									202.70	J	0	P,Sm	DS	T	N	
	2.50	204.0								203.50	J	10	U,Sm	DS	VT	N	
	2.50	204.0							SHALE, Dark gray to light gray, very fine to fine grained, slightly weathered, weak, very close to close spaced discontinuities Coal infill present	204.30	J	0	U,R	DS	VT	N	Used up to 450 Gallons from R-38 to R-41. Loss of water.
205	2.50									204.90	J	10	U,R	DS	VT	N	
	2.25		R-41	60 100%	38 63%	R2	SL			205.50 205.70	J J	0 5	U,R U,Sm	DS DS	T T	N N	
	2.00									206.90 207.00	J J	0 5	U,Sm U,Sm	DS DS	VT T	N N	
	3.00	209.0								207.80	J	0	U,Sm	DS	VT	N	
	2.50	209.0							SHALE, Dark gray to gray, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities Transitions to gray to reddish brown SILTSTONE	208.30 208.40	J J	10 5	U,Sm U,Sm	DS DS	VT T	N N	
210	2.00																Loss of water.
90	2.00		R-42	60 100%	57 95%	R2	SL										
	2.50																
	2.00	214.0								212.80 213.20	J J	10 0	S,Sm P,Sm	DS DS	T T	N N	
	3.00	214.0							214.0 SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Loss of water
215	1.50																
	2.00		R-43	60 100%	60 100%	R2	SL										
	3.00																
	3.00	219.0								218.40	J	0	P,R	DS	PO	N	
	2.00	219.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak rock, close to moderately spaced discontinuities	218.90	J	0	P,R	DS	T	N	Loss of water.
220	2.00																
80	3.00		R-44	60 100%	60 100%	R2	SL										
	1.75									221.70	J	0	P,R	DS	T	N	
	2.50	224.0								223.20	J	5	P,R	DS	O	N	
	2.50	224.0							224.0 SHALE, Light to dark gray, very fine to fine grained, slightly weathered, weak, very close to close spaced discontinuities Calcite veins present	223.80	J	0	U,Sm	DS	T	N	Loss of water.
225	2.00																
	2.00		R-45	58 96%	45 75%	R2	SL										
	2.25									226.60 227.00 227.50	J J J	5 0 5	U,R U,R U,R	DS DS DS	PO PO PO	N N Ca	

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.50																
	3.50	229.0							229.0	228.40	J	0	U,R	DS	O	N	
		229.0							SILTSTONE, Dark gray to reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Used up to 450 Gallons from R-42 to R-45. Loss of water.
	3.00																
230										229.90	J	10	P,Sm	DS	PO	N	
	2.00																
70																	
	2.25		R-46	56 93%	56 93%	R2	SL										
	2.00																
										232.80	J	15	U,R	DS	VT	N	
	2.50	234.0															
	2.25	234.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, wide spaced discontinuities								Loss of water.
235																	
	3.00																
	2.50		R-47	60 100%	60 100%	R2	SL										
	2.00																
	2.50	239.0															
	2.00	239.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to wide spaced discontinuities								Loss of water.
240																	
	3.25																
60																	
	3.00		R-48	60 100%	58 96%	R2	SL		241.7' Calcite present								
	2.50																
	2.50	244.0															
	2.50	244.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Loss of water.
245										244.50	J	0	U,R	DS	PO	N	
	2.75																
	3.00		R-49	60 100%	58 96%	R2	SL		246' Calcite veins present								
									246.8' Vertical fracture with Calcite infill								
	3.00																
	3.00	249.0															
	3.00	249.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, moderate to wide spaced discontinuities	248.80	J	0	U,R	DS	O	N	Loss of water.
250									249.8' Calcite present								
	2.50																
50																	
	2.75		R-50	59 98%	59 98%	R2	SL										
	3.00									252.30	J	15	U,R	DS	O	N	
	3.00																

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00	254.0															
	3.00	254.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Used up to 450 Gallons from R-47 to R-51. Loss of water.
255	3.00									255.30	J	5	U,R	DS	T	N	
	2.50		R-51	60 100%	59 98%	R2	SL			256.80	J	15	U,R	DS	T	N	
	2.75									257.20	J	5	U,R	DS	T	N	
										257.60	J	30	U,R	DS	T	N	
	3.50									258.20	J	5	P,R	DS	T	N	
		259.0								258.80	J	10	U,R	DS	T	N	Loss of water.
		259.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities 2-inch thick Clay pocket at 259.2'								
260	7.00																
40	4.00		R-52	60 100%	53 88%	R2	SL			261.30	J	5	P,R	DS	PO	N	
										261.70	J	20	P,R	DS	PO	N	
	3.50																
	3.50	264.0															
	3.00	264.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, very close to close spaced discontinuities 264' Calcite present								Loss of water.
265	3.00									265.10	J	0	U,Sm	DS	PO	N	
	4.00		R-53	60 100%	50 83%	R2	SL			266.30	J	10	U,R	DS	O	N	
										266.80	J	20	U,Sm	DS	O	N	
	4.00									267.30	J	5	P,Sm	DS	O	N	
										267.60	J	0	U,Sm	DS	PO	N	
	4.25	269.0								268.40	J	5	P,R	DS	O	N	
	4.00	269.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, wide spaced discontinuities								Used up to 450 Gallons from R-52 to R-53. Loss of water.
270	4.00																
30	3.75		R-54	60 100%	60 100%	R2	SL		271' Calcite veins present								
	3.00																
	3.75	274.0															
	3.00	274.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, very close to moderately spaced discontinuities								Loss of water.
275	3.00																
	3.00		R-55	56 93%	48 80%	R2	SL			276.60	J	10	U,Sm	DS	O	N	
										276.80	J	10	P,Sm	DS	O	N	
	3.00									277.30	J	30	U,Sm	DS	T	N	
	3.75	279.0															
																	Loss of water.

NOTES:

PROJECT NO.: 353754

Boring No.: B-64

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.50	279.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								
280	3.25																
20	4.00		R-56	60 100%	54 90%	R2	SL										
	3.00																
	2.50	284.0															
	3.50	284.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Loss of water.
285	3.25																
	3.50		R-57	60 100%	56 93%	R2	SL			286.00	J	5	P,R	DS	PO	N	
	3.00									287.60	J	0	S,R	DS	PO	N	
	3.25									288.10	J	30	P,R	DS	PO	N	
		289.0								288.60	J	10	U,R	DS	PO	N	
	3.50	289.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities Calcite veins present								Loss of water.
290	3.00																
10	3.50		R-58	60 100%	58 96%	R2	SL			290.80	J	0	P,R	DS	PO	N	
	3.25																
	4.00	294.0								293.10	J	10	P,R	DS	O	N	
	3.25	294.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities	294.50	J	0	U,R	DS	O	N	Used up to 450 Gallons from R-57 to R-59. Loss of water.
295	3.50																
	3.50		R-59	60 100%	53 88%	R2	SL										
	3.25																
	4.00	299.0								298.00	J	5	U,Sm	DS	PO	N	
										298.40	J	10	U,Sm	DS	PO	ML	
	3.25	299.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Loss of water.
300	3.25									300.40	J	10	U,R	DS	T	N	
0	3.50		R-60	59 98%	57 95%	R2	SL										
	4.00																
	4.00	304.0															
	3.25	304.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced								Loss of water.

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
305									discontinuities								
	3.25									305.20	J	5	U,R	DS	PO	N	
	3.00		R-61	60 100%	59 98%	R2	SL		306.6' - 309' Vertical fractures with Calcite infill								
	3.25																
	3.50	309.0															
	3.00	309.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Loss of water.
310																	
	3.25								310.5' Vertical fracture								
-10																	
	3.00		R-62	59 98%	59 98%	R2	SL										
	3.25																
	3.00	314.0															
	3.00	314.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Used up to 450 Gallons from R-60 to R-62. Loss of water.
315																	
	3.00									315.20	J	0	U,R	DS	PO	N	
	3.50		R-63	60 100%	60 100%	R2	SL										
	3.50																
	4.00	319.0															
	3.25	319.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Loss of water.
320																	
	3.25																
-20																	
	3.50		R-64	59 98%	43 71%	R2	SL			321.30 321.50	J J	0 0	P,R P,R	DS DS	PO T	N N	
	3.50									322.10	J	30	P,R	DS	T	N	
	3.50	324.0								323.00	J	10	U,R	DS	VT	N	
	3.00	324.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Loss of water.
325																	
	2.50																
	3.00		R-65	60 100%	59 98%	R2	SL			326.10	J	20	P,R	DS	PO	N	
	3.00																
	4.50	329.0															
	3.25	329.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities Calcite vein present								Loss of water.
330	3.50																

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-64**

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
-30	3.50																
	3.50		R-66	60 100%	55 91%	R2	SL										
	3.50									332.20	J	5	P,R	DS	VT	N	
										332.80	J	10	P,R	DS	T	N	
	4.50	334.0								333.60	J	0	U,R	DS	VT	N	
	3.00	334.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Used up to 450 Gallons from R-63 to R-66. Loss of water.
-335	3.50																
	3.75		R-67	58 96%	57 95%	R2	SL										
	3.50																
	3.50	339.0								338.20	J	10	S,R	DS	O	N	
	5.00	339.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities	339.40	J	10	P,R	DS	O	N	Loss of water. Rig chatter.
-340	4.00																
-40	4.75		R-68	60 100%	53 88%	R2	SL										
	5.00																
	2.50	344.0															
	5.00	344.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, moderately spaced discontinuities								Loss of water. Rig chatter.
-345	5.50																
	5.00		R-69	60 100%	60 100%	R2	SL		346.6' Calcite vein present	346.60	J	50	P,R	DS	PO	N	
	5.00																
	5.50	349.0															
	5.00	349.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, very close to moderately spaced discontinuities								Used up to 450 Gallons for R-69. Loss of water. Rig chatter.
-350	5.00																
-50	4.00		R-70	59 98%	54 90%	R2	SL			350.80	J	5	U,R	DS	O	N	
	5.00									352.20	J	5	U,R	DS	PO	N	
										352.30	J	0	U,R	DS	PO	Ca	
	4.00	354.0								353.00	J	0	U,R	DS	O	N	
	4.00	354.0								353.70	J	0	U,R	DS	VT	N	
-355	4.00								SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, moderately spaced discontinuities								Loss of water. Rig chatter.

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-64**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-64**
Page **15** of **16**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.00																
	4.50		R-71	60 100%	60 100%	R2	SL										
	5.00																
	5.00	359.0															
	6.00	359.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Used up to 450 Gallons from R-70 to R-71. Loss of water. Rig chatter.
360	5.00																
-60	5.00		R-72	60 100%	53 88%	R2	SL										
	4.75																
	4.50	364.0								363.40	J	0	P,Sm	DS	O	Ca	
	7.00	364.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, very close to moderately spaced discontinuities Calcite veins present	364.40	J	0	P,Sm	DS	T	N	Loss of water. Rig chatter from 365 to 369 feet BGS.
365	4.00																
	5.00		R-73	60 100%	55 92%	R2	SL										
	4.75																
	6.00	369.0															
	5.00	369.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, very close to moderately spaced discontinuities Calcite veins present								Used up to 450 Gallons from R-72 to R-73. Loss of water. Rig chatter.
370	4.50																
-70	6.00		R-74	60 100%	56 93%	R2	SL			370.90 371.20	J J	0 20	U,R U,R	DS DS	O O	Ca Ca	
	4.50									372.40	J	0	U,Sm	DS	O	N	
	3.50	374.0															
	5.50	374.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, moderately spaced discontinuities Calcite vein present								Loss of water. Rig chatter.
375	4.00									375.40	J	0	U,R	DS	T	N	
	4.00		R-75	60 100%	60 100%	R2	SL			376.00	J	0	U,R	DS	PO	N	
	5.25																
	6.00	379.0								378.20	J	5	U,R	DS	T	N	
	4.50	379.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities 379.4' - 380.6' Vertical fracture with Calcite infill and Iron staining								Loss of water. Rig chatter.
380	4.25																
-80	4.25																

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-64**

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.25		R-76	60 100%	56 93%	R2	SL										
	4.00																
	5.25	384.0															
	4.50	384.0							SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close to moderately spaced discontinuities								Used up to 450 Gallons from R-74 to R-76. Loss of water. Rig chatter.
-385	4.25								385' Vertical fracture with Calcite infill								
	4.25		R-77	58 96%	56 93%	R2	SL										
	4.50									387.60	J	0	P,R	DS	PO	N	
	5.50	389.0															
	6.25	389.0	R-78	10 83%	8 67%	R2	SL		SILTSTONE, Reddish brown, very fine to fine grained, slightly weathered, weak, close spaced discontinuities								Used up to 450 Gallons for R-77. Loss of water. Rig chatter.
-390		390.0							390.0	389.70	J	0	U,R	DS	PO	N	
									End of Boring at 390 feet BGS. Borehole grouted with cement and bentonite hole plug.								
-90																	
-395																	
-400																	
-100																	
-405																	

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-64**

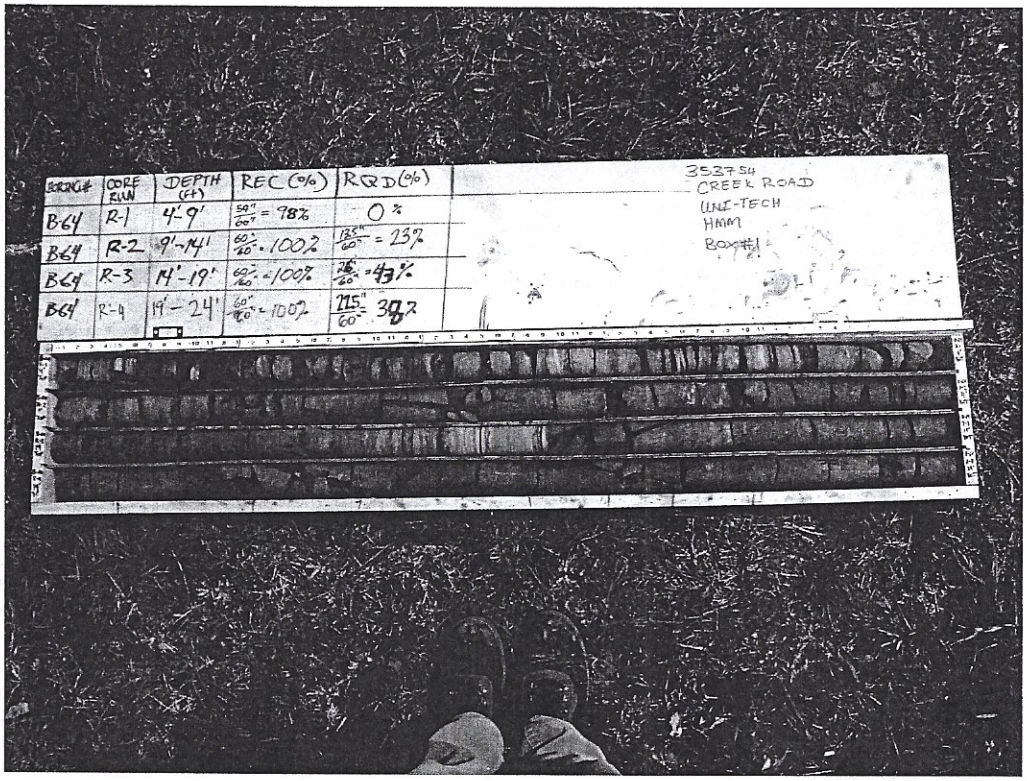

Figure B-64.1
B-64 Box 1 Runs 1-4 Dry

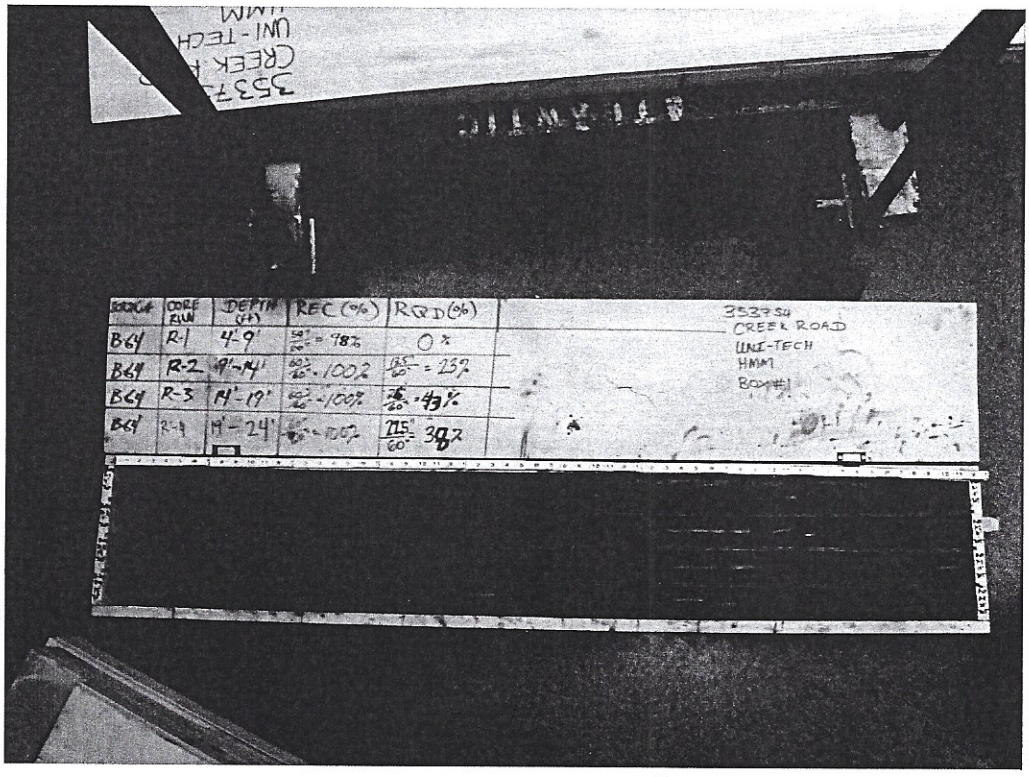

Figure B-64.2
B-64 Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

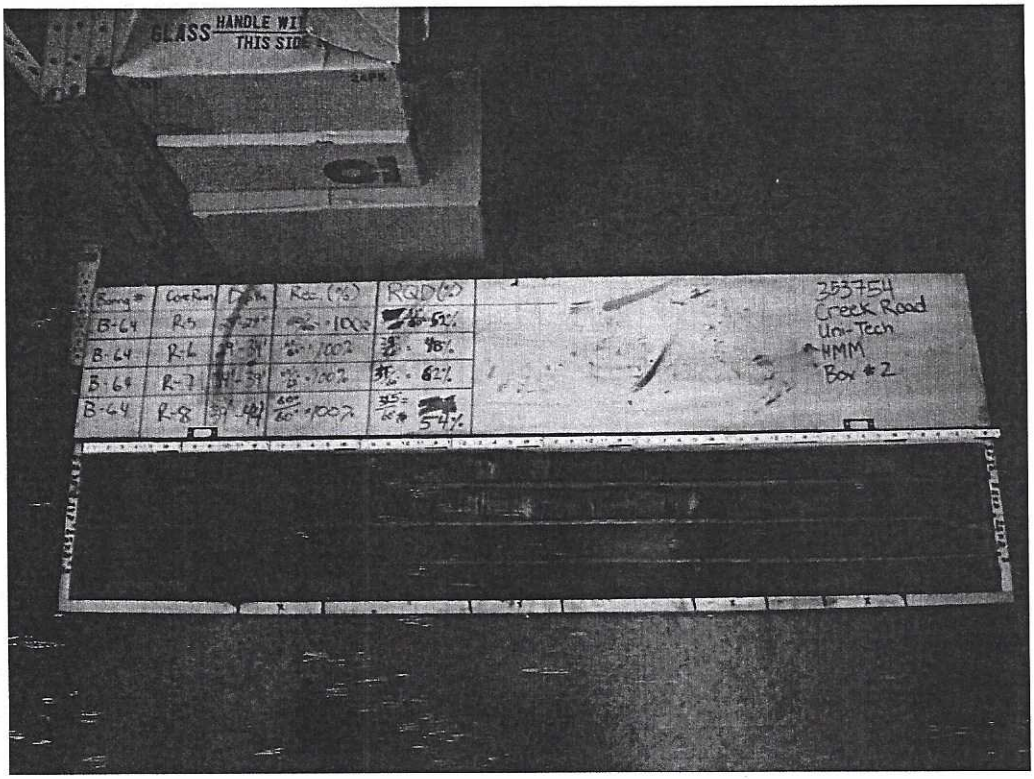

Figure B-64.3
B-64 Box 2 Runs 5-8 Dry

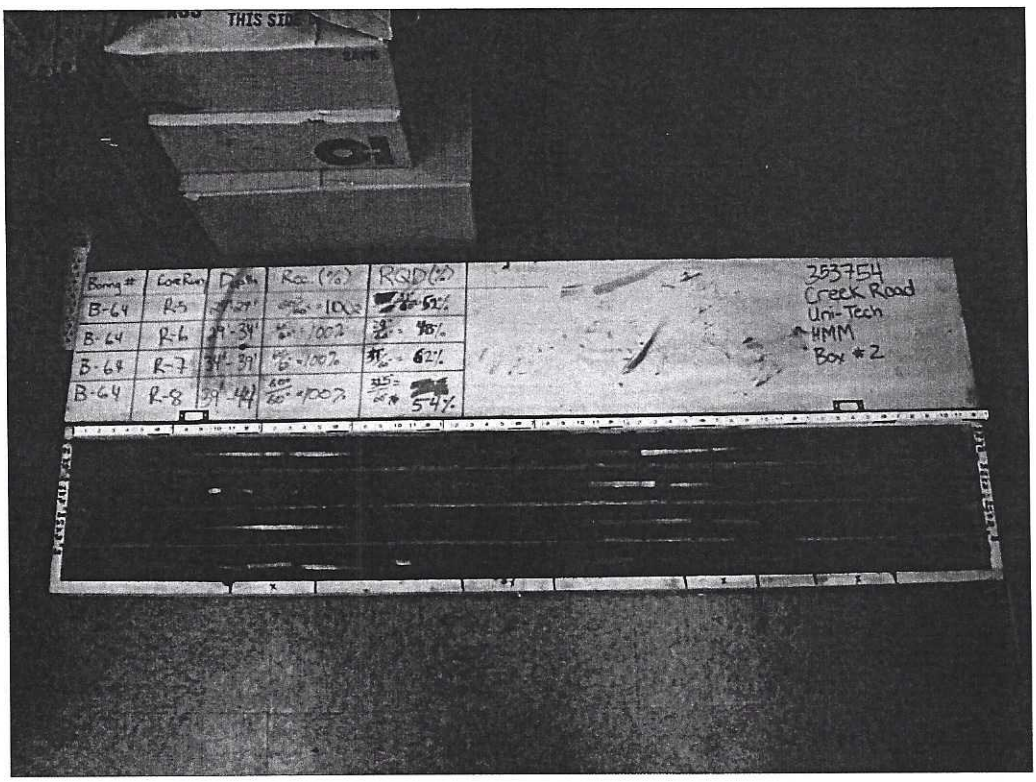

Figure B-64.4
B-64 Box 2 Runs 5-8 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-64

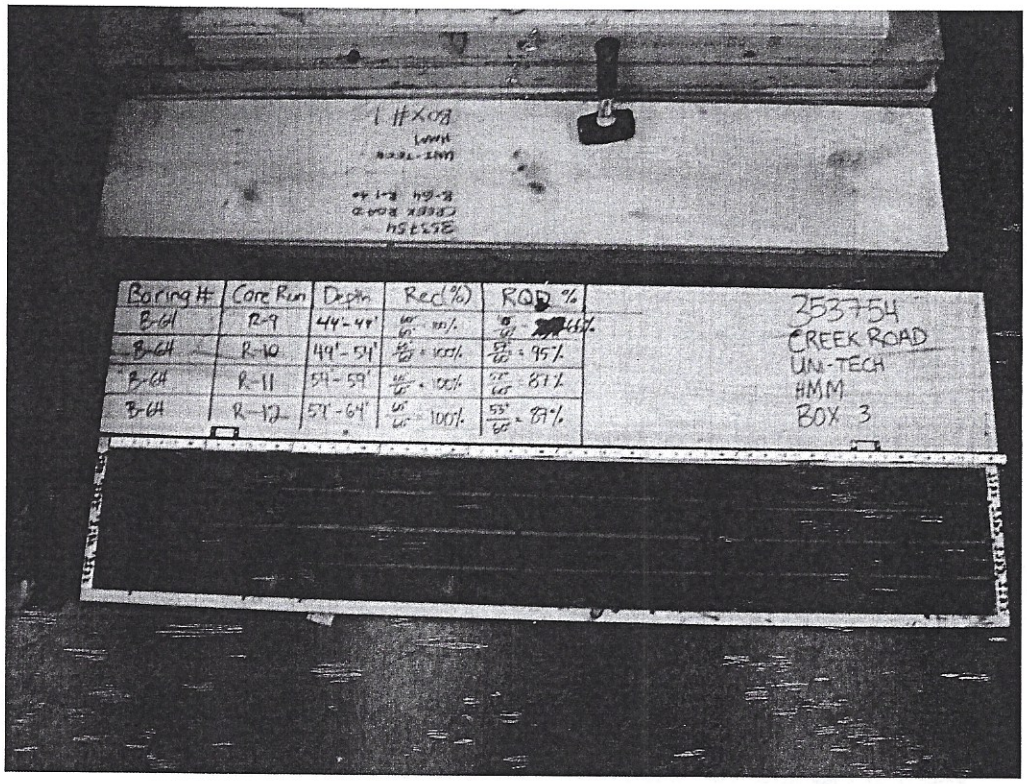

Figure B-64.5
B-64 Box 3 Runs 9-12 Dry

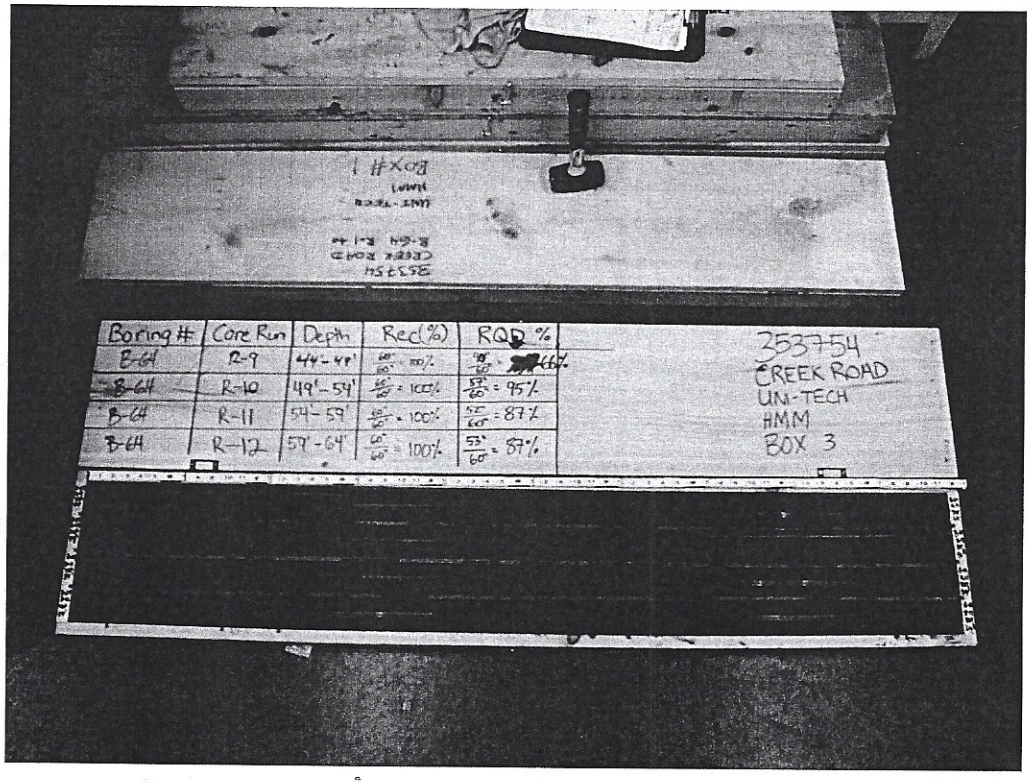

Figure B-64.6
B-64 Box 3 Runs 9-12 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

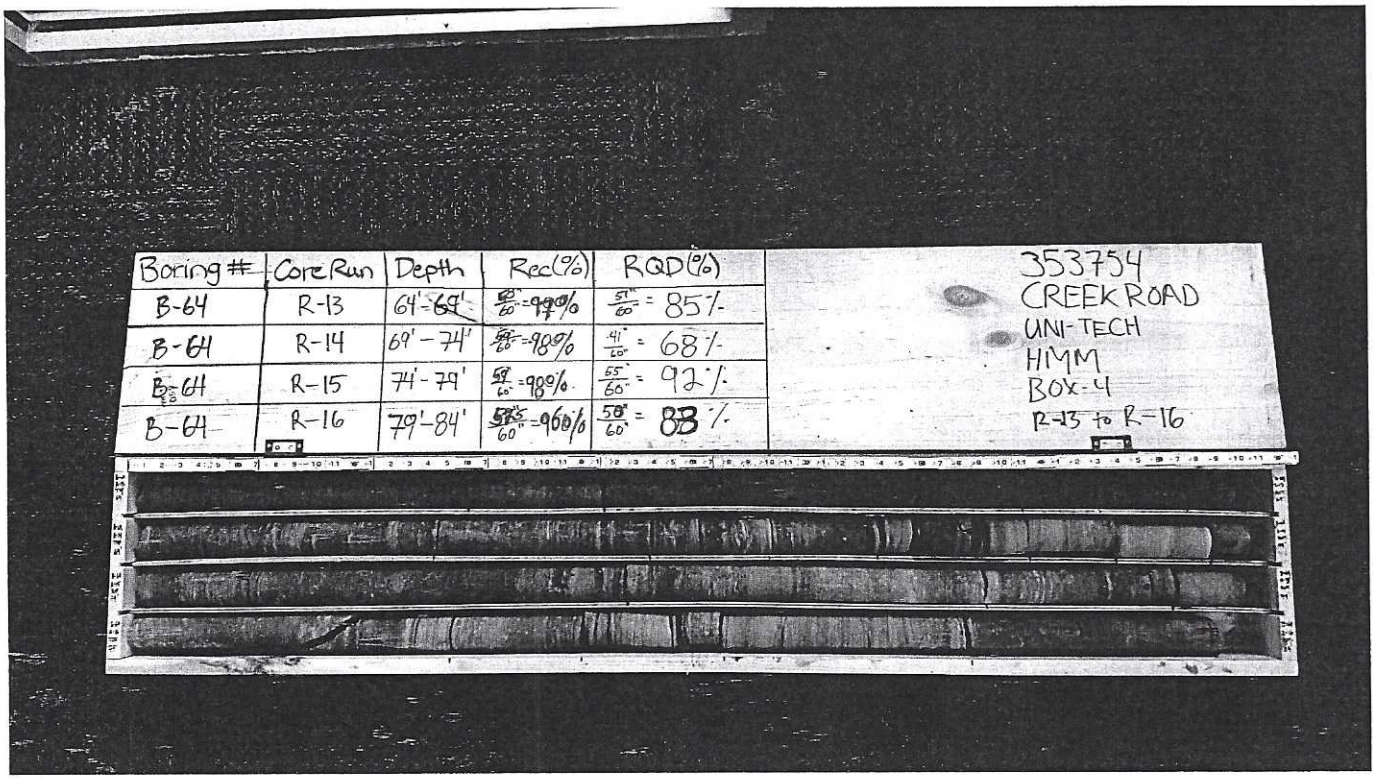

Figure B-64.7
B-64 Box 4 Runs 13-16 Dry

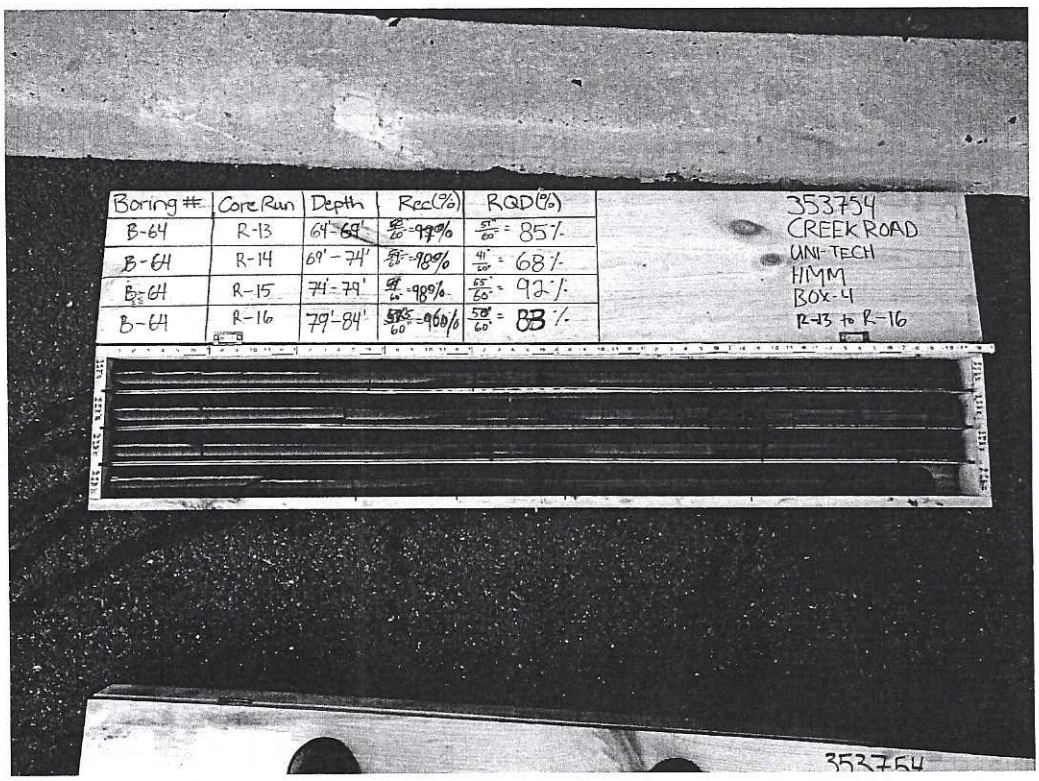

Figure B-64.8
B-64 Box 4 Runs 13-16 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

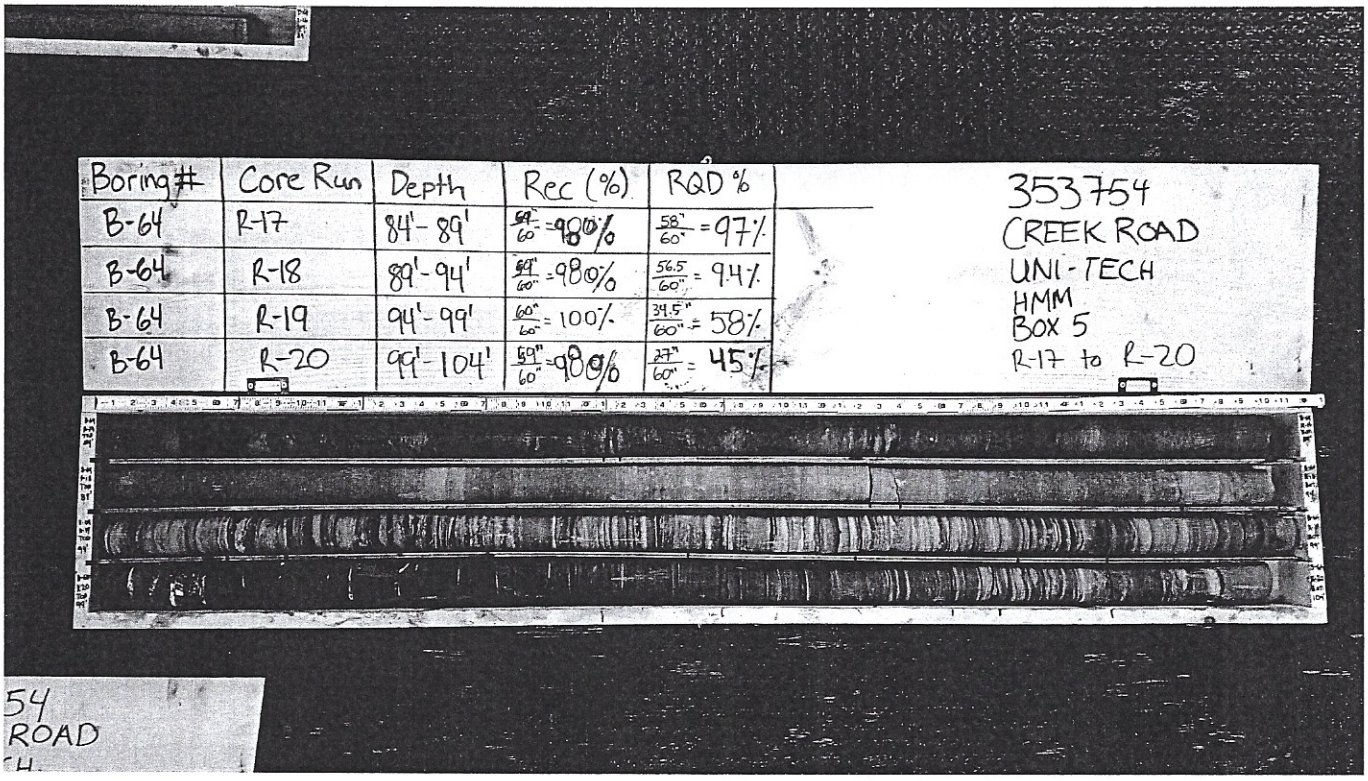

Figure B-64.9
B-64 Box 5 Runs 17-20 Dry

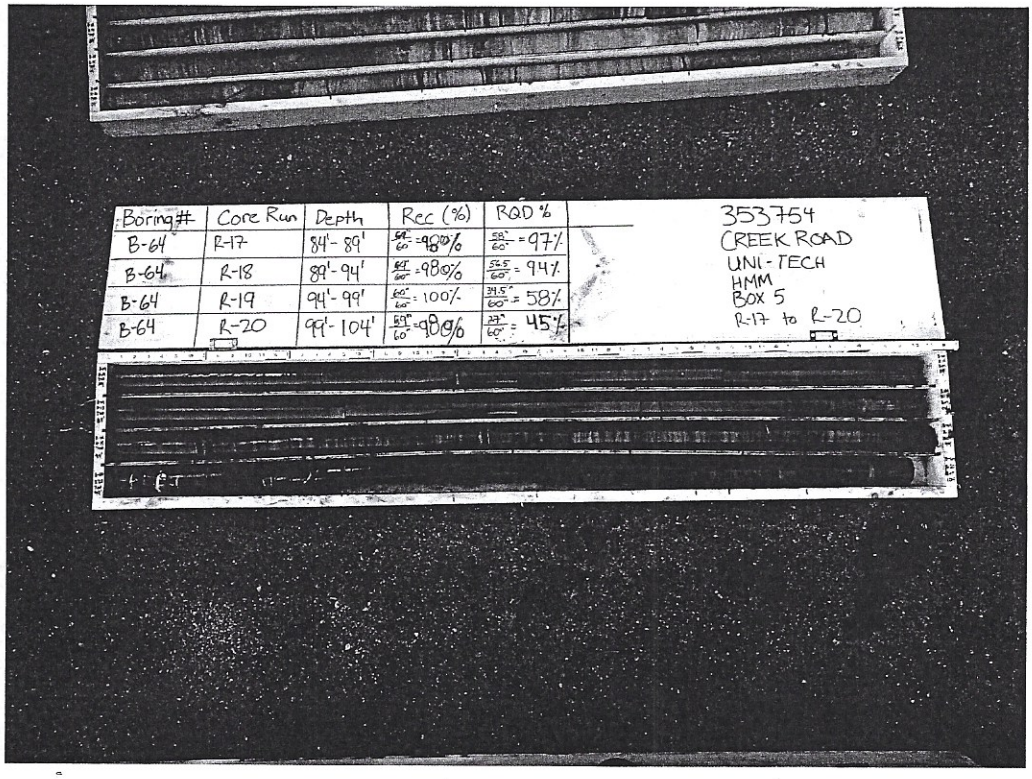

Figure B-64.10
B-64 Box 5 Runs 17-20 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

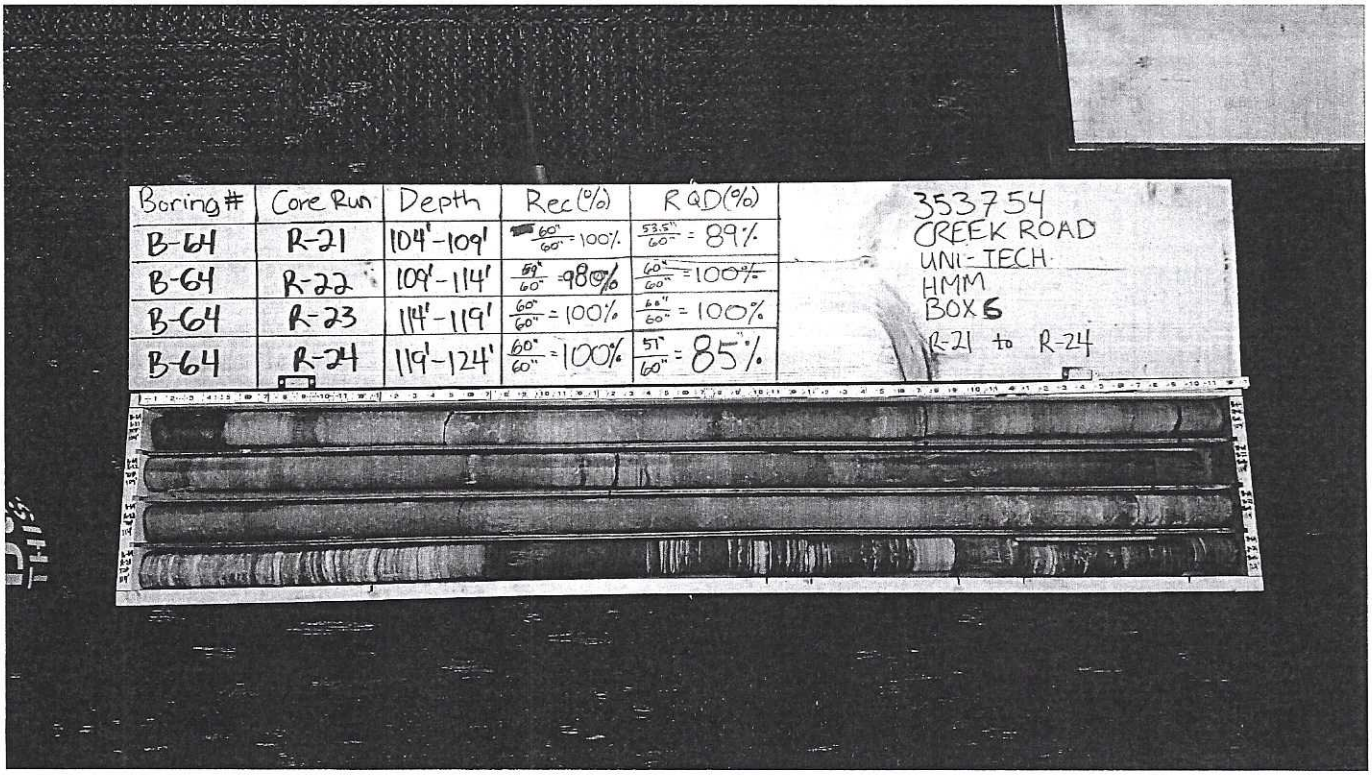

Figure B-64.11
B-64 Box 6 Runs 21-24 Dry

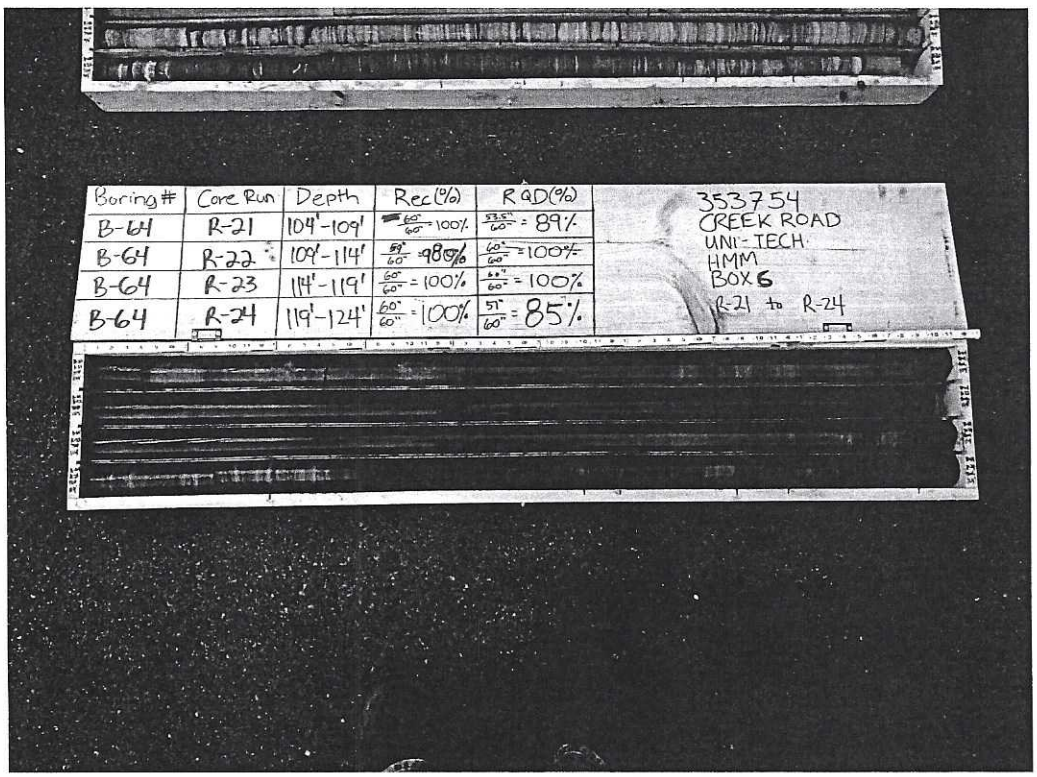

Figure B-64.12
B-64 Box 6 Runs 21-24 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

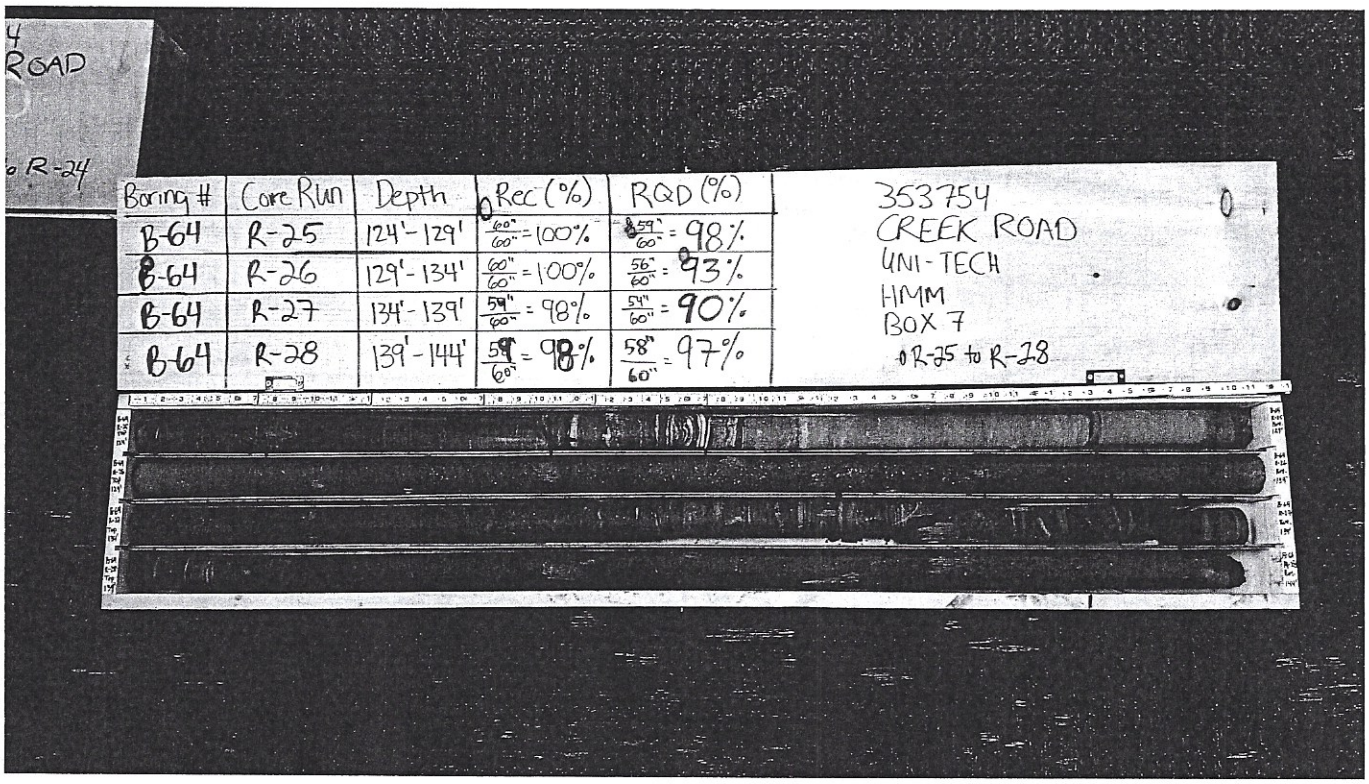

Figure B-64.13
B-64 Box 7 Runs 25-28 Dry

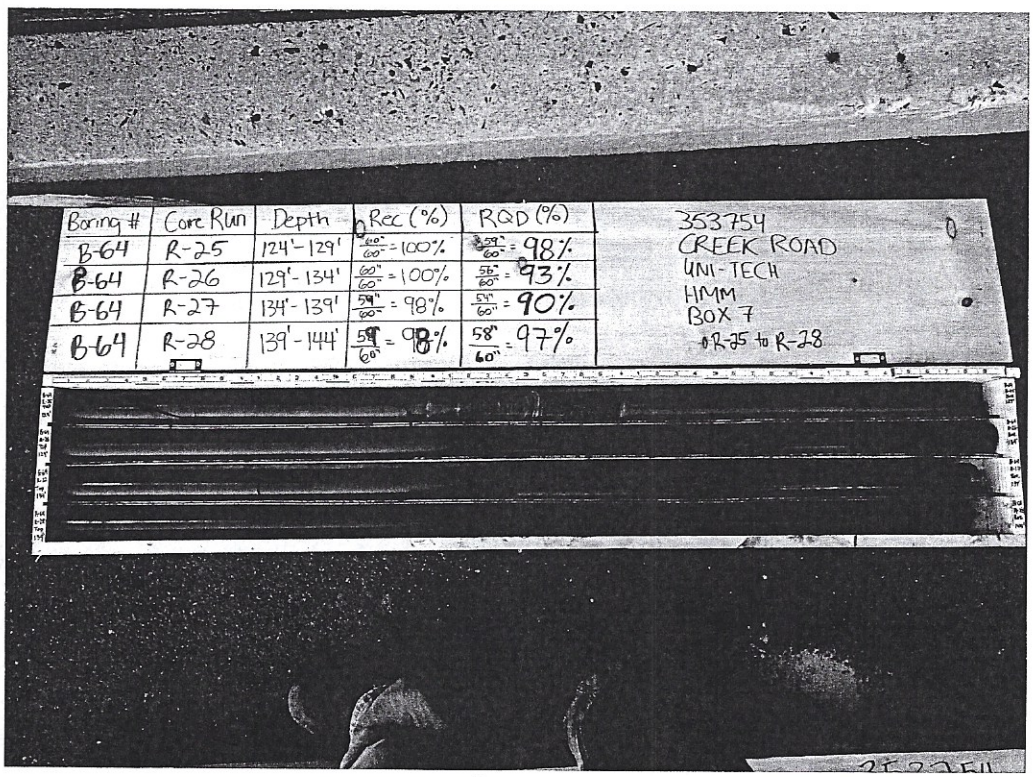

Figure B-64.14
B-64 Box 7 Runs 25-28 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-64

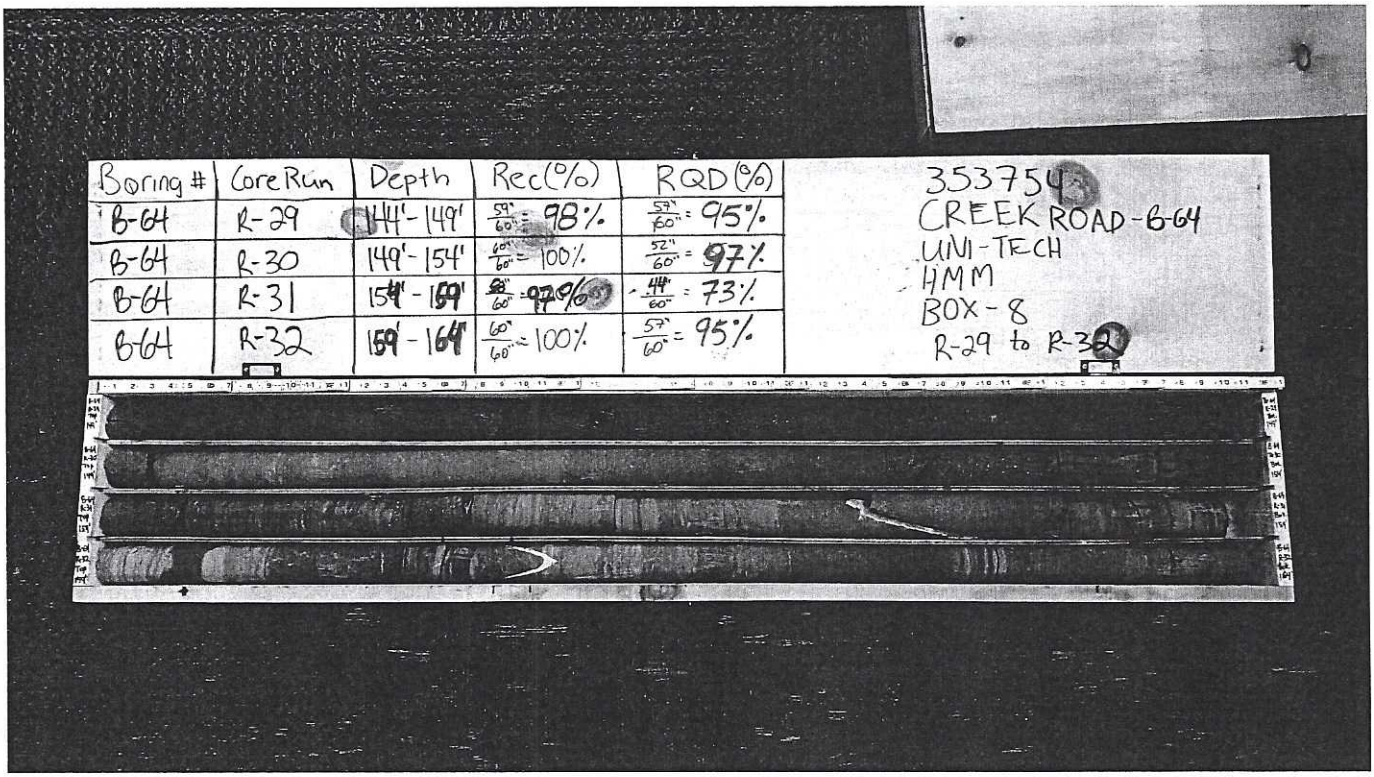

Figure B-64.15
B-64 Box 8 Runs 29-32 Dry

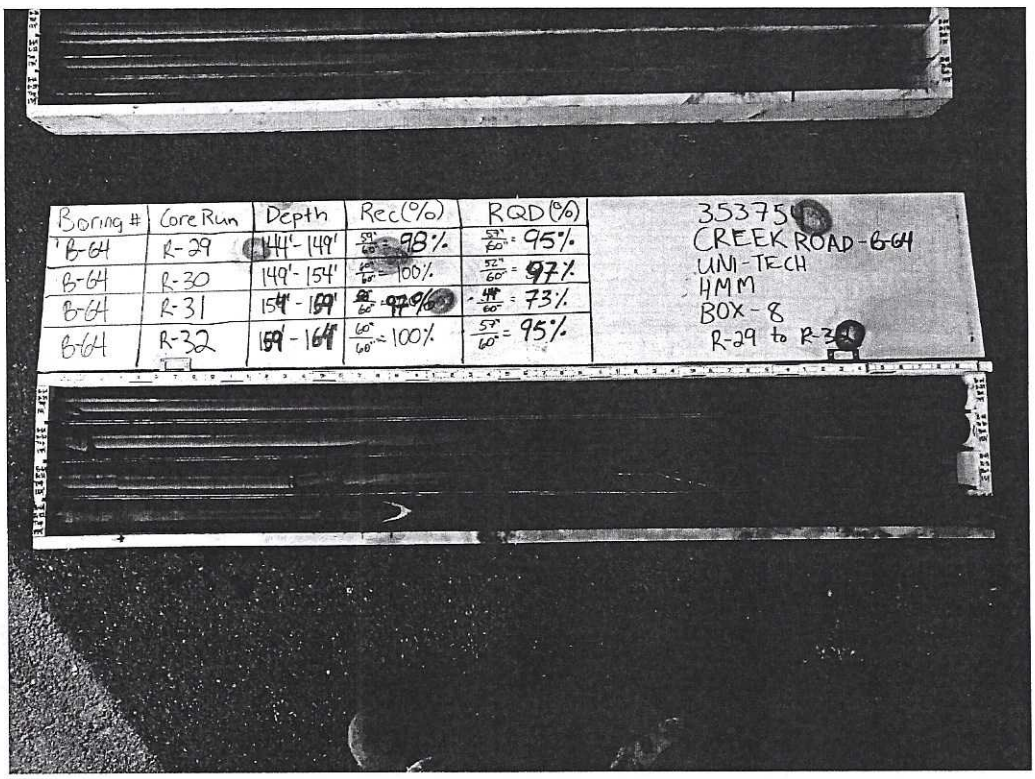

Figure B-64.16
B-64 Box 8 Runs 29-32 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

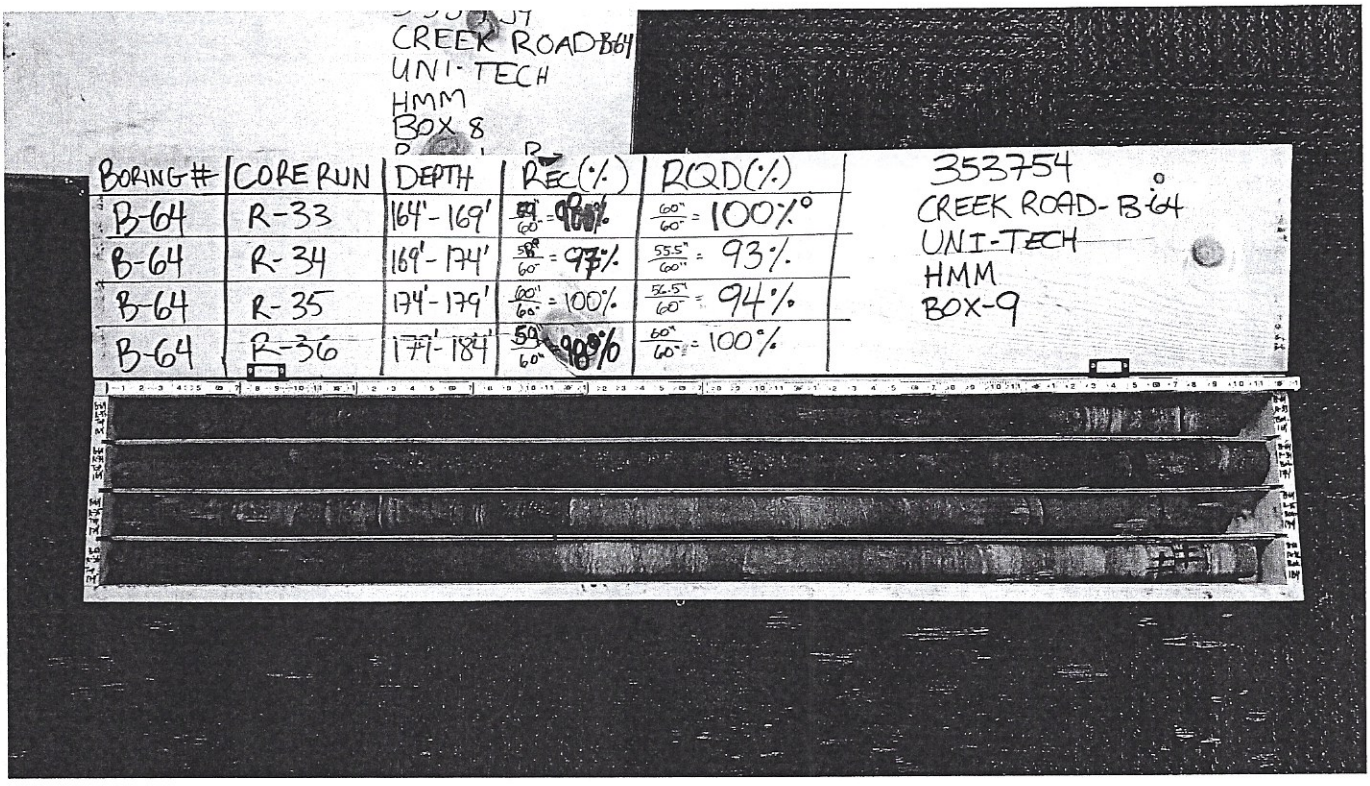

Figure B-64.17
B-64 Box 9 Runs 33-36 Dry

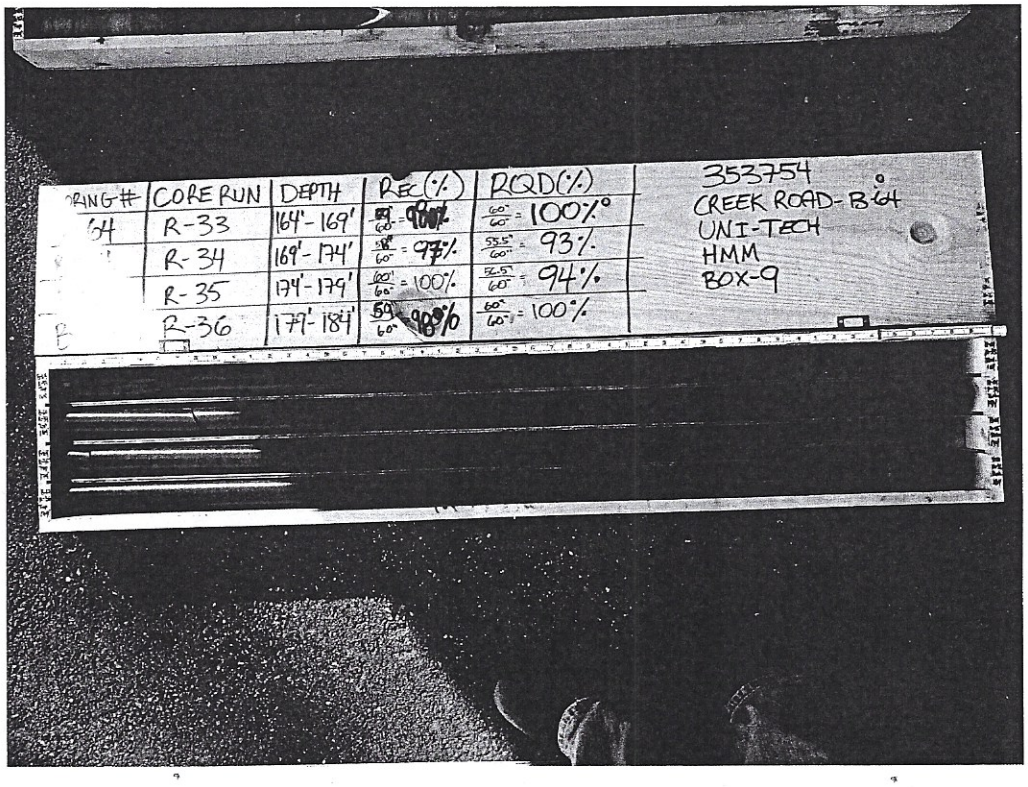

Figure B-64.18
B-64 Box 9 Runs 33-36 Wet

MOTT MACDONALD	PennEast Pipeline Project	BORING NO.:
	Rock Core Photographs	B-64

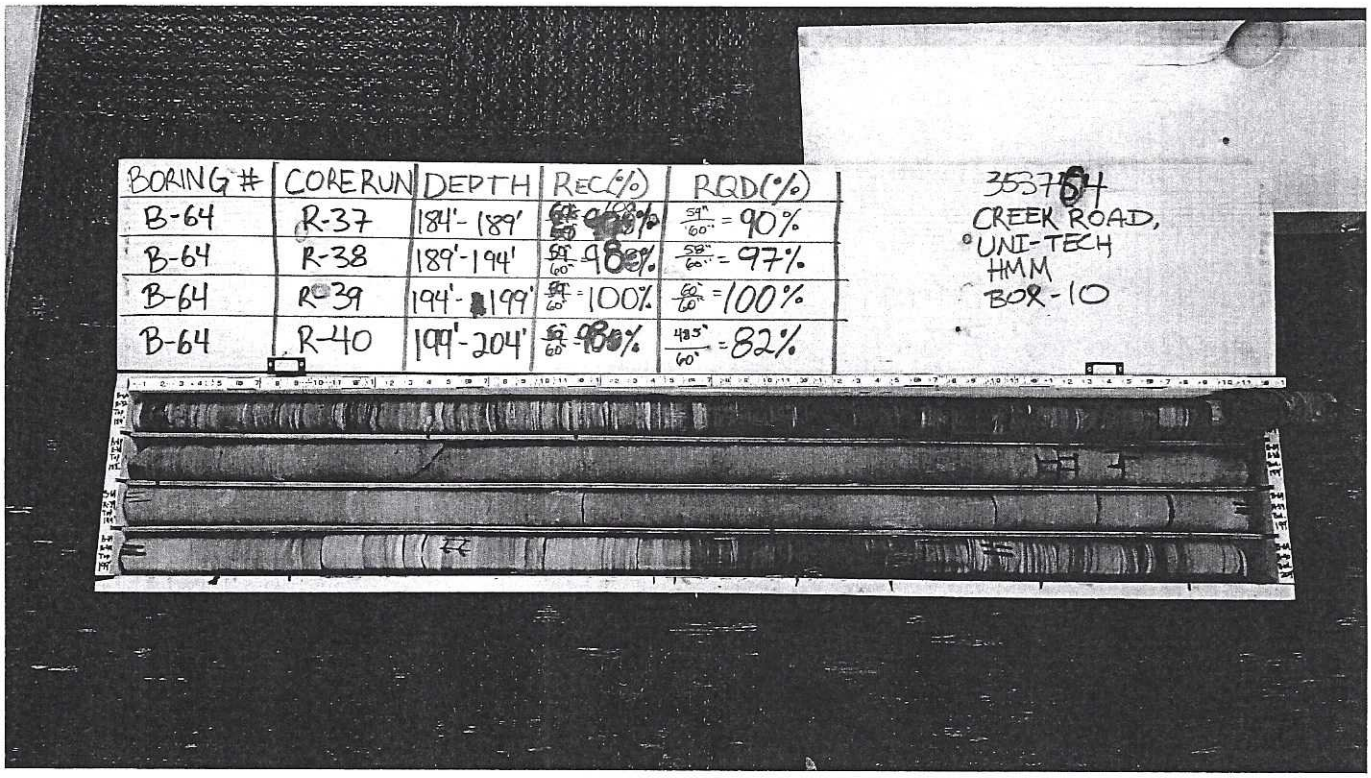

Figure B-64.19
B-64 Box 10 Runs 37-40 Dry

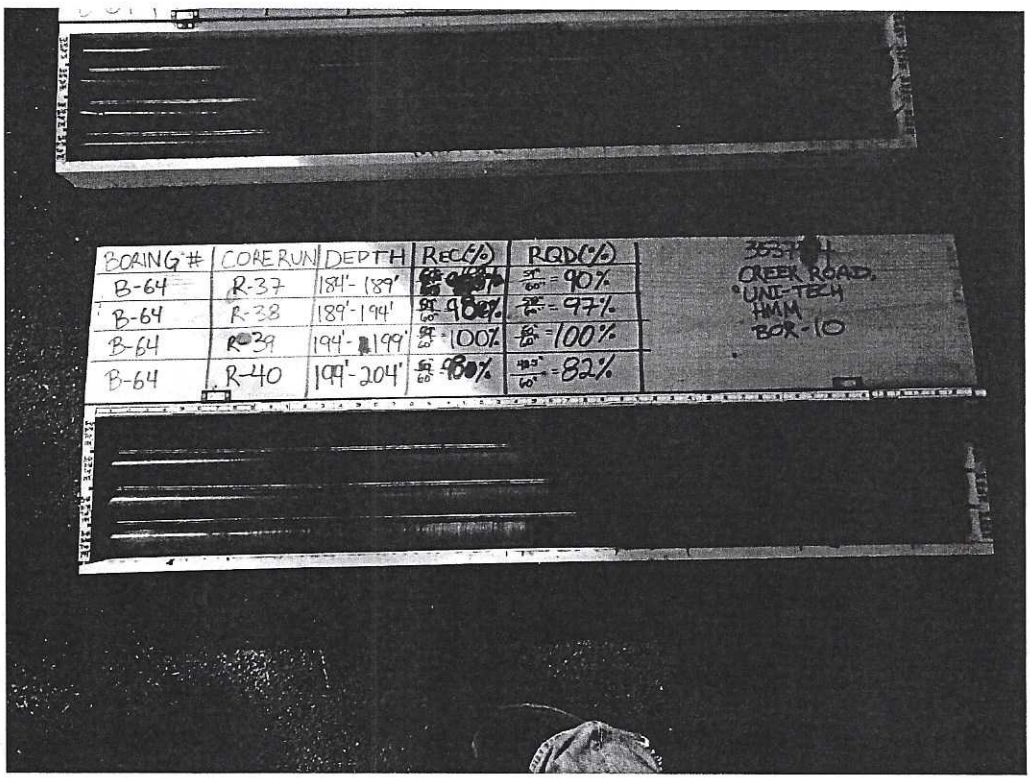

Figure B-64.20
B-64 Box 10 Runs 37-40 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

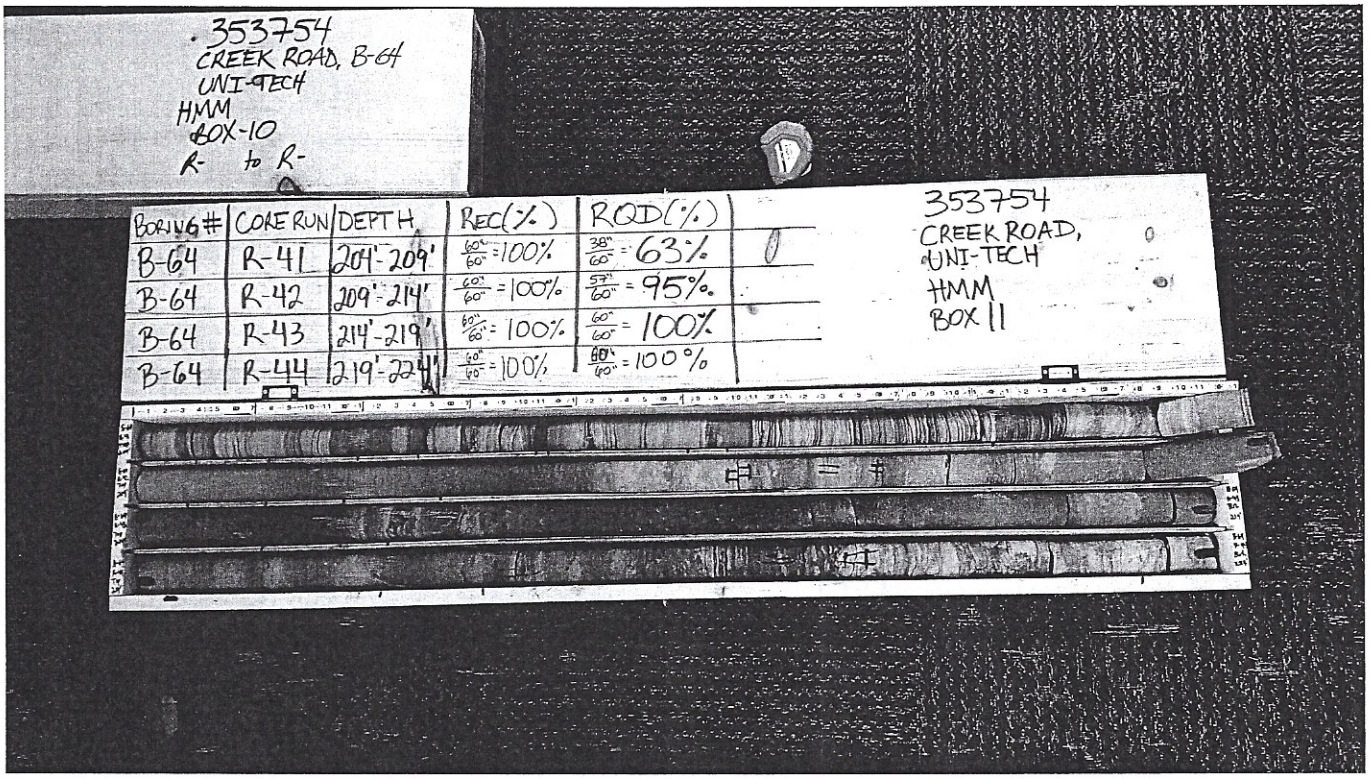

Figure B-64.21
B-64 Box 11 Runs 41-44 Dry

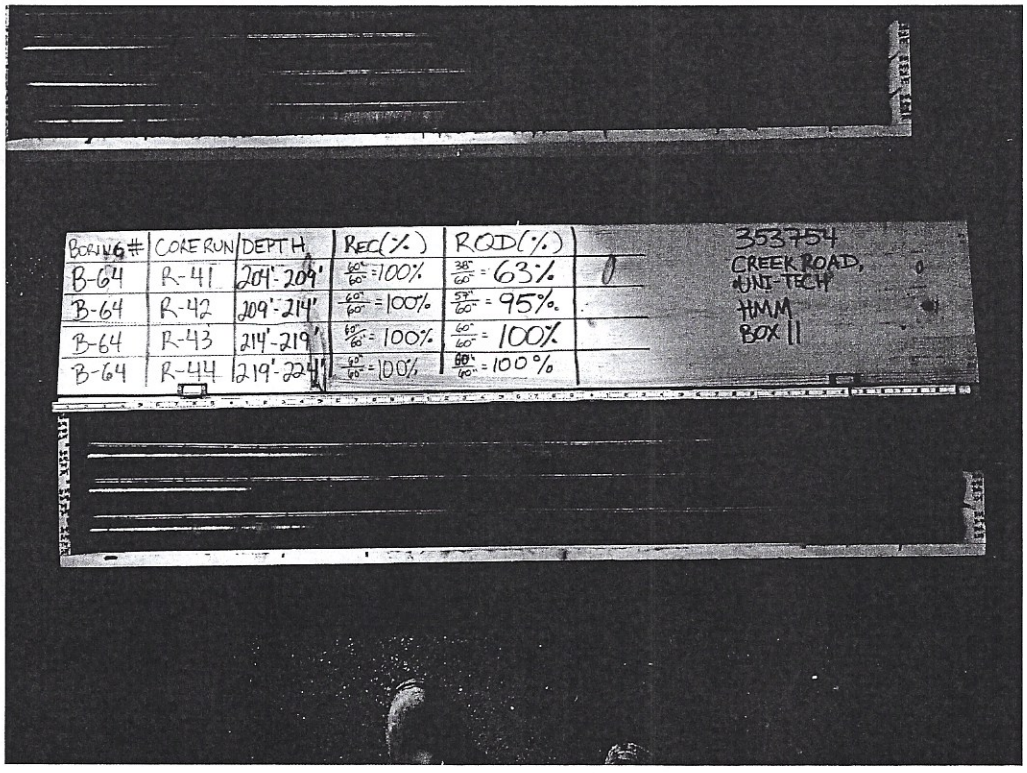

Figure B-64.22
B-64 Box 11 Runs 41-44 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

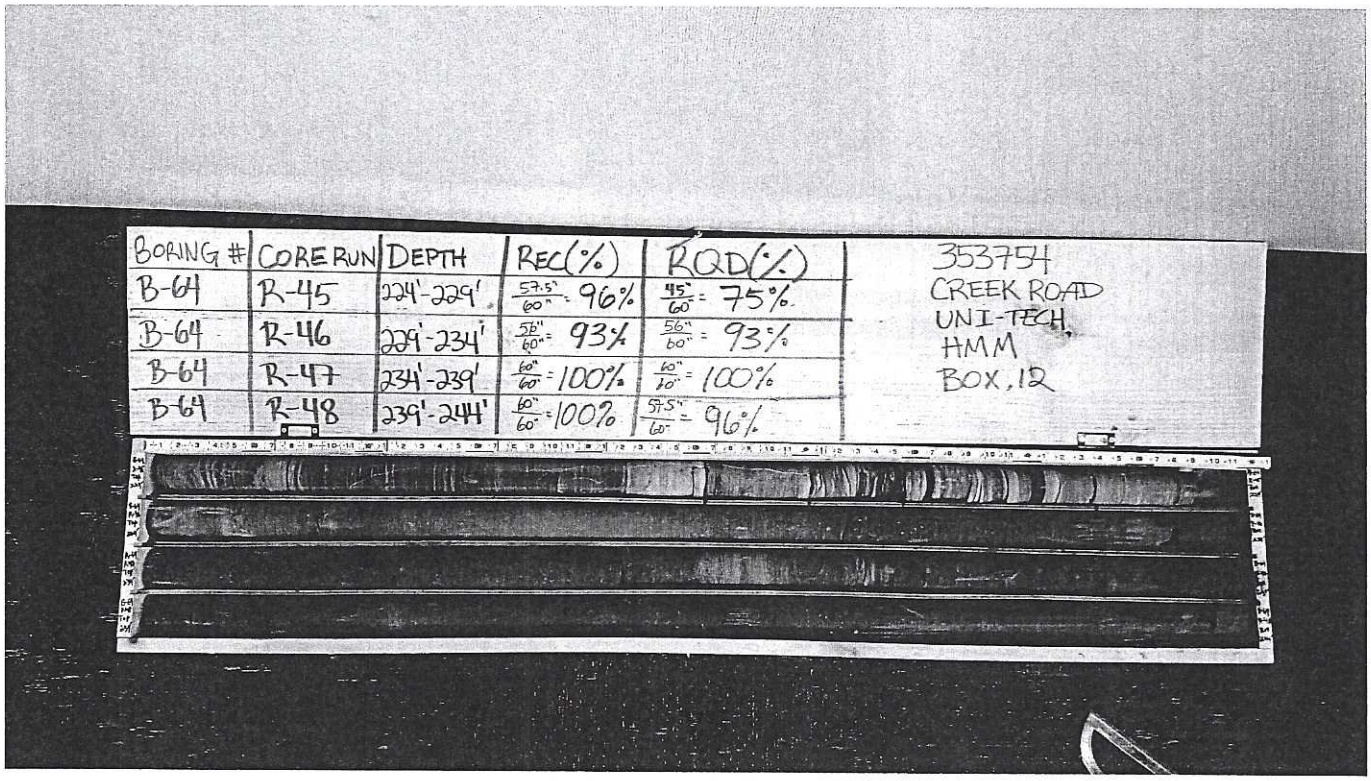

Figure B-64.23
B-64 Box 12 Runs 45-48 Dry

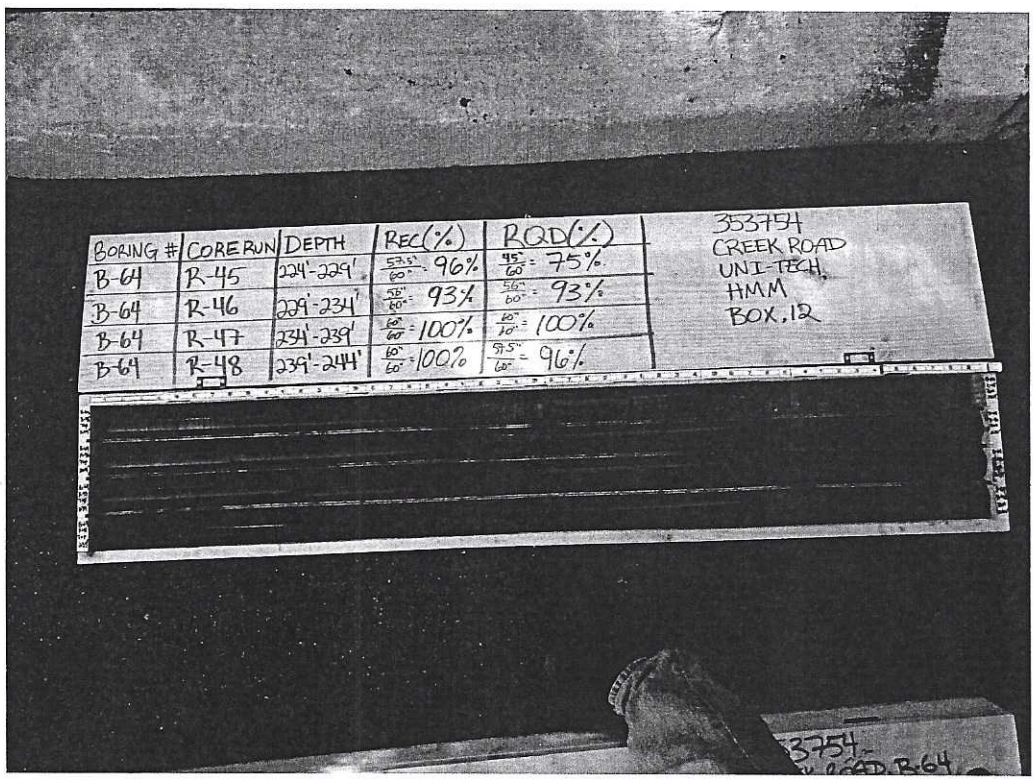

Figure B-64.24
B-64 Box 12 Runs 45-48 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

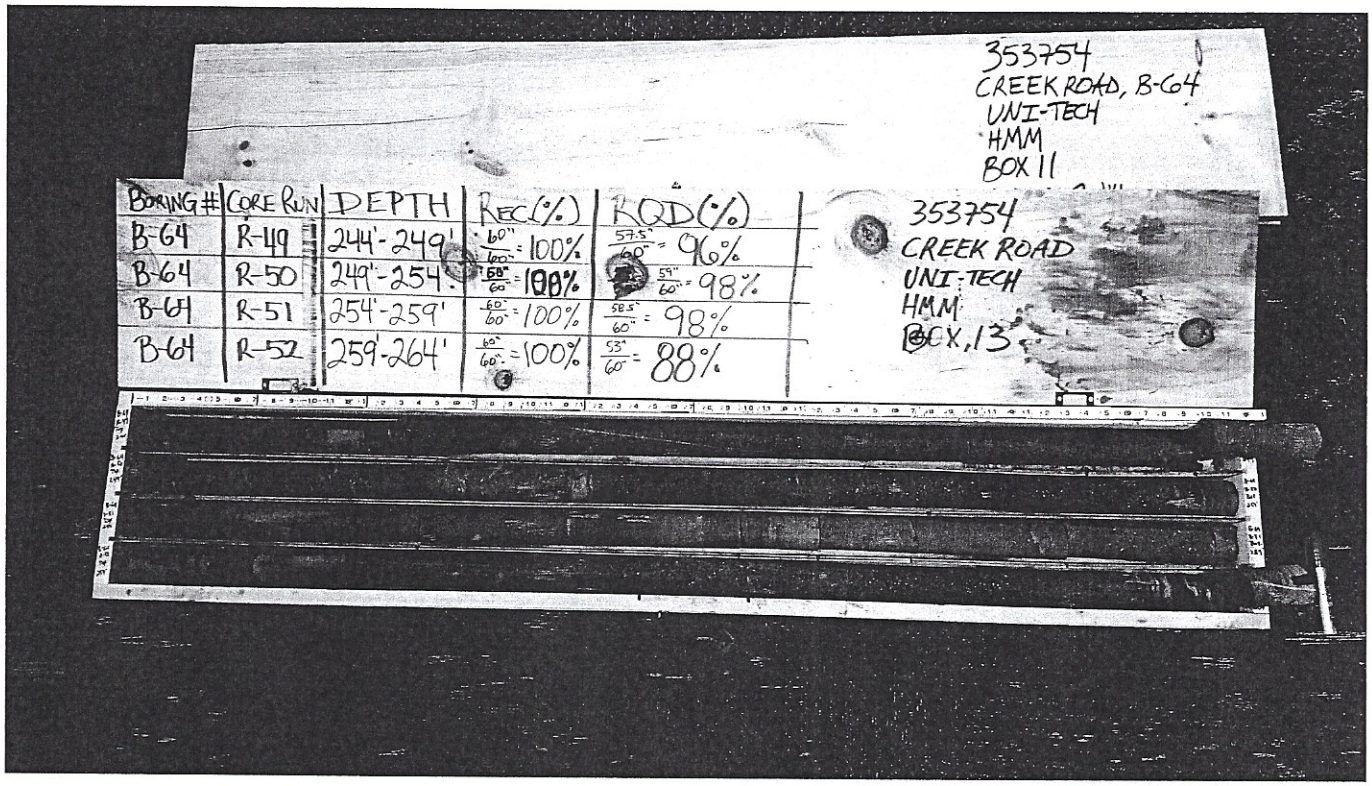

Figure B-64.25
B-64 Box 13 Runs 49-52 Dry

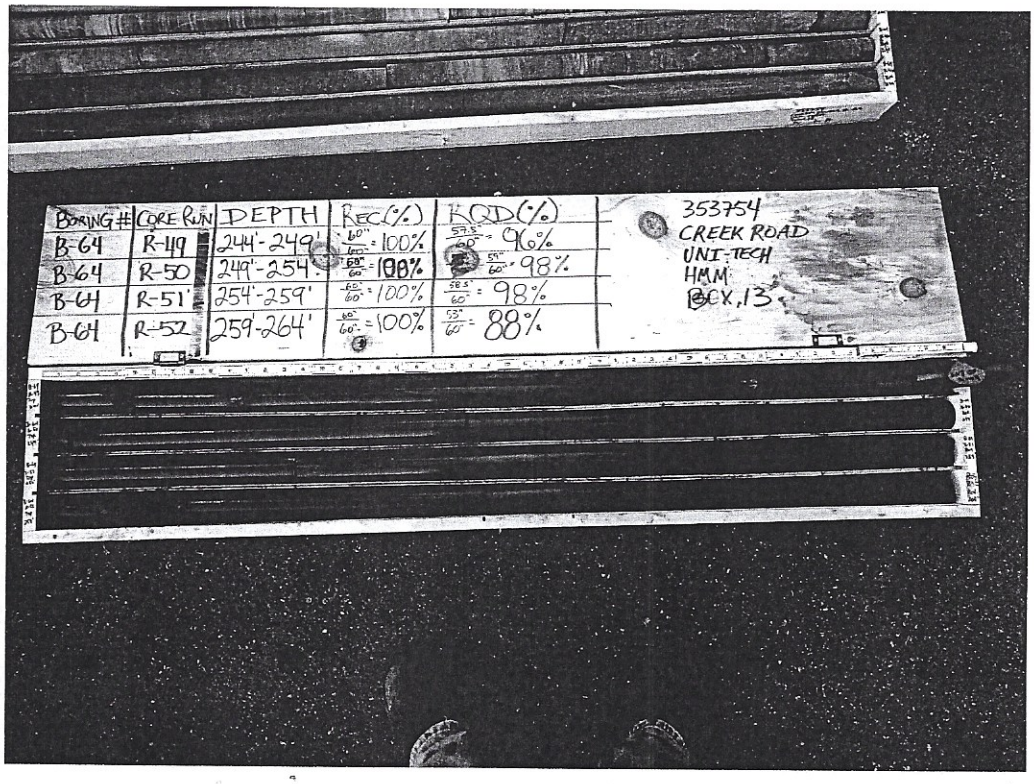

Figure B-64.26
B-64 Box 13 Runs 49-52 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

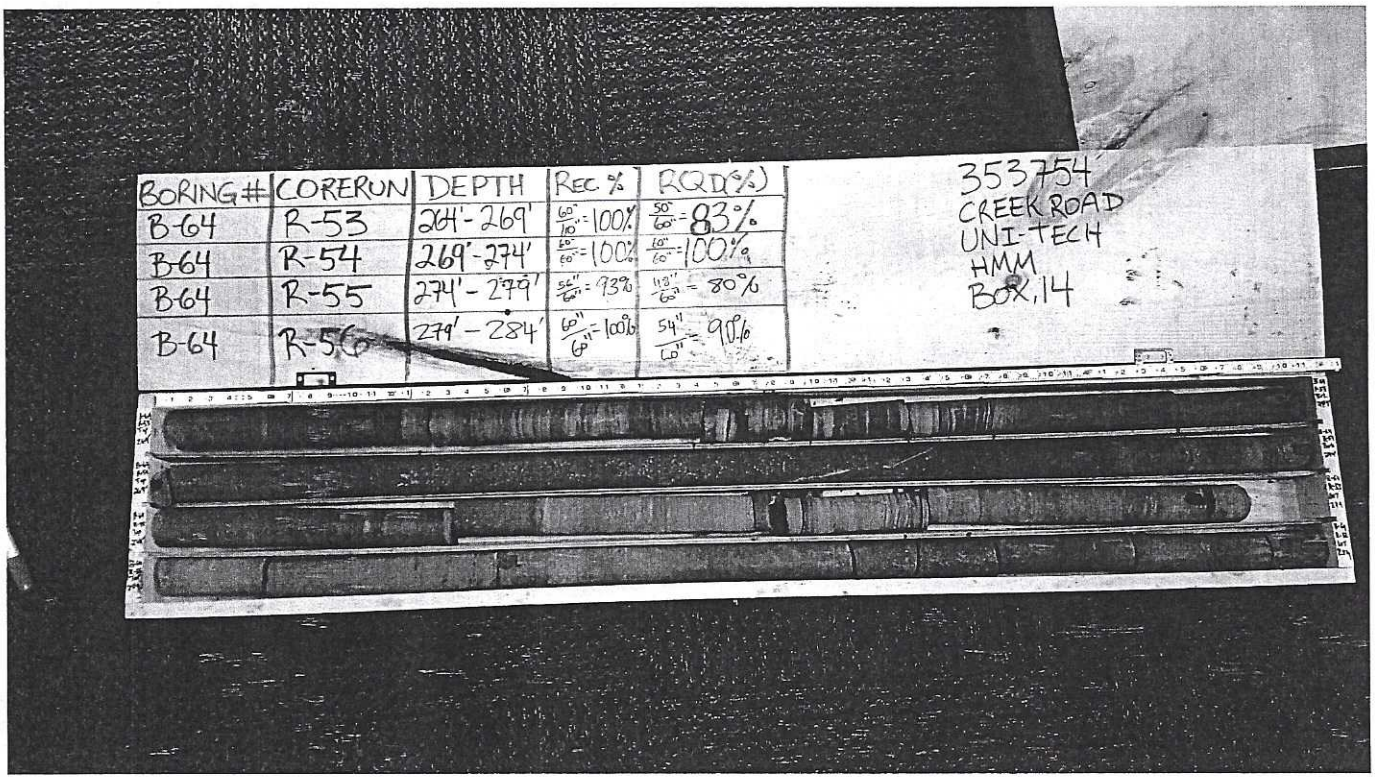

Figure B-64.27
B-64 Box 14 Runs 53-56 Dry

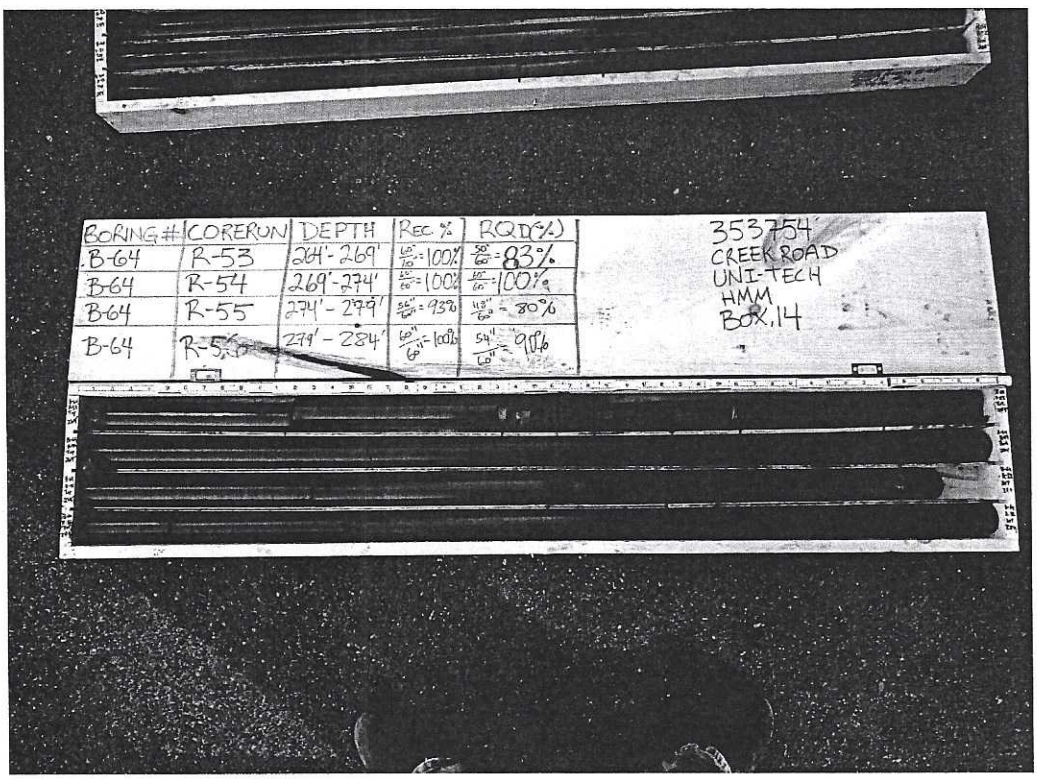

Figure B-64.28
B-64 Box 14 Runs 53-56 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

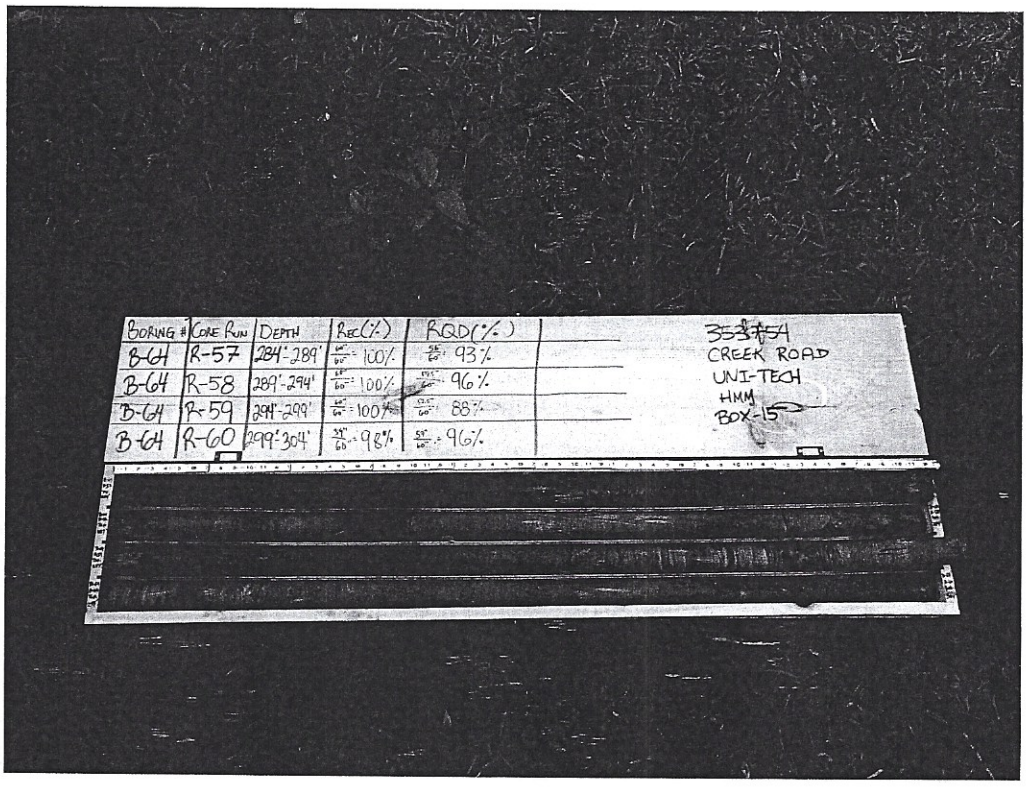

Figure B-64.29
B-64 Box 15 Runs 57-60 Dry

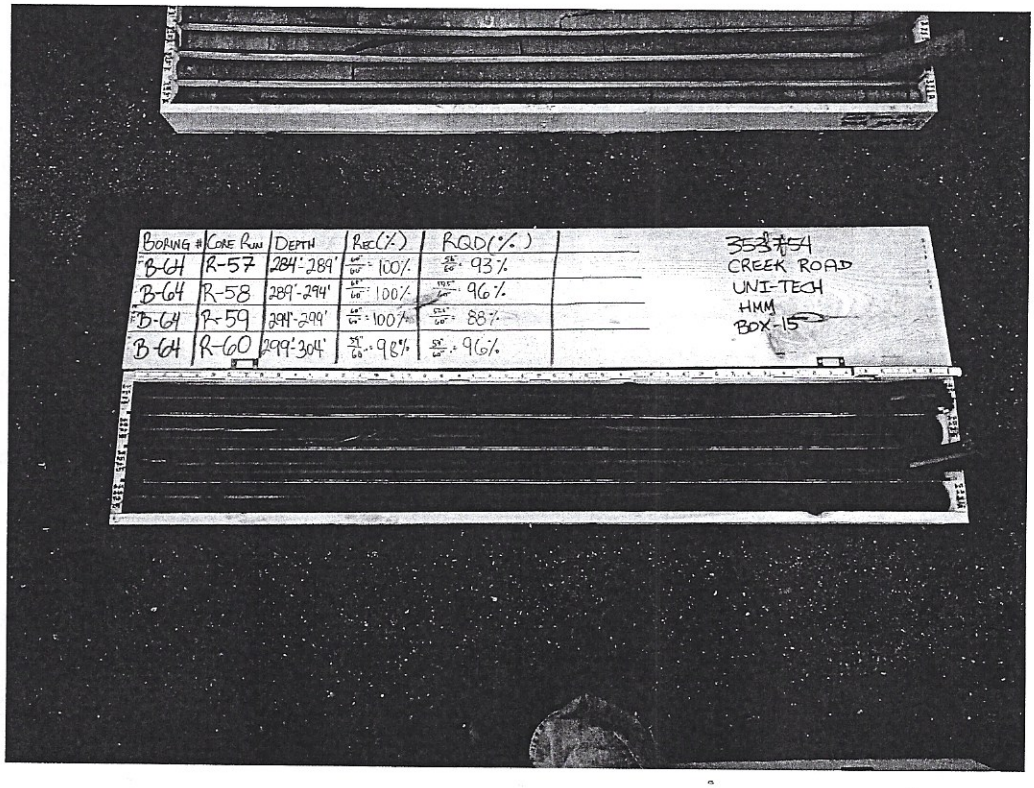

Figure B-64.30
B-64 Box 15 Runs 57-60 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

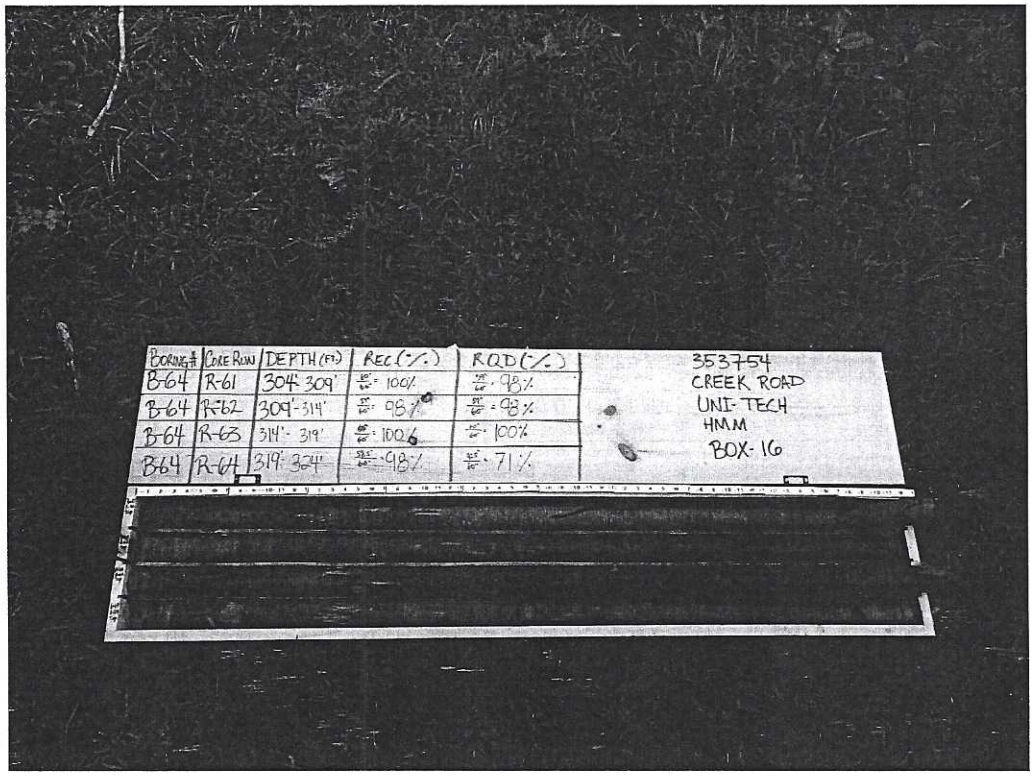

Figure B-64.31
B-64 Box 16 Runs 61-64 Dry

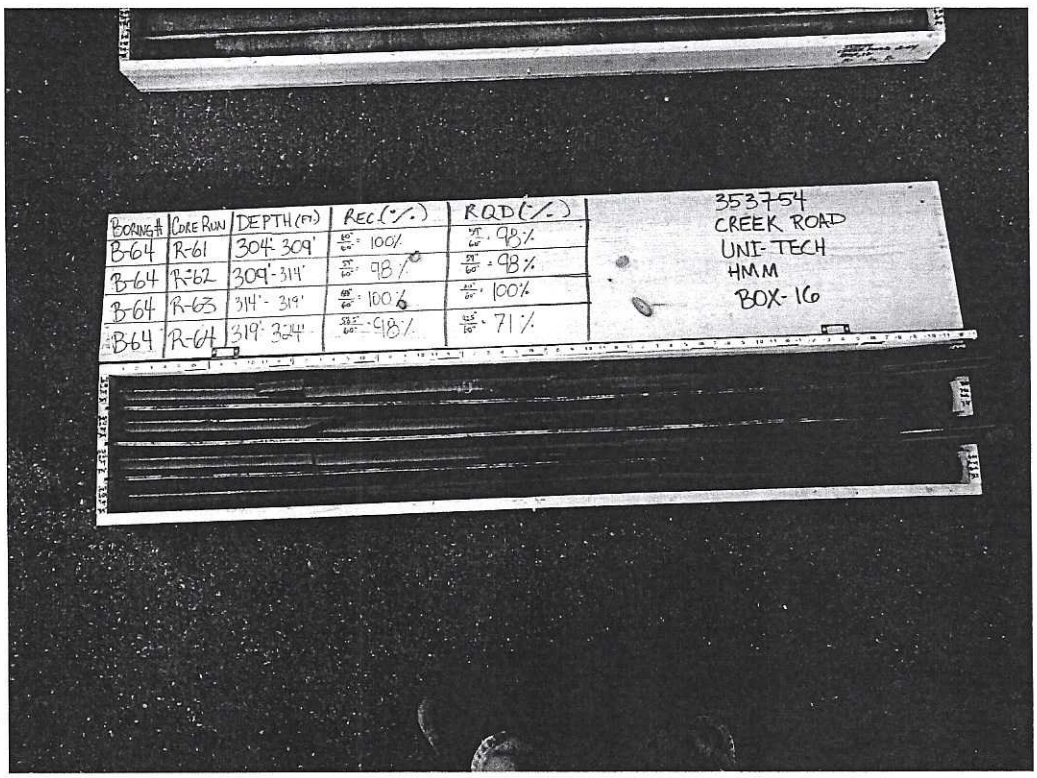

Figure B-64.32
B-64 Box 16 Runs 61-64 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

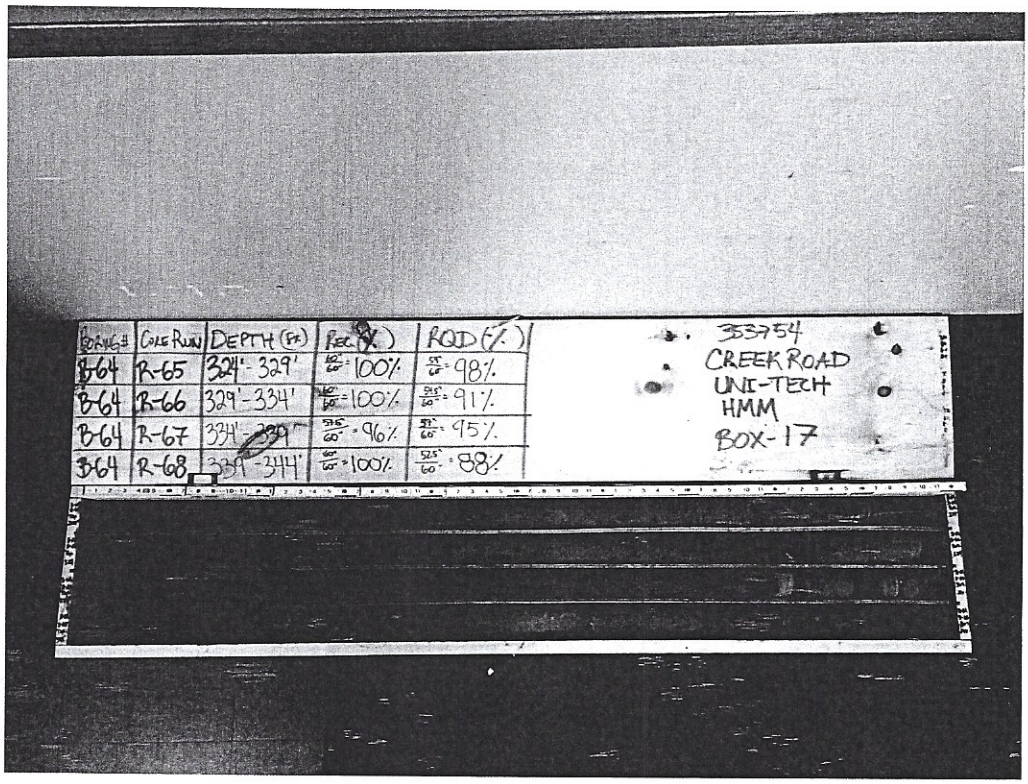

Figure B-64.33
B-64 Box 17 Runs 65-68 Dry

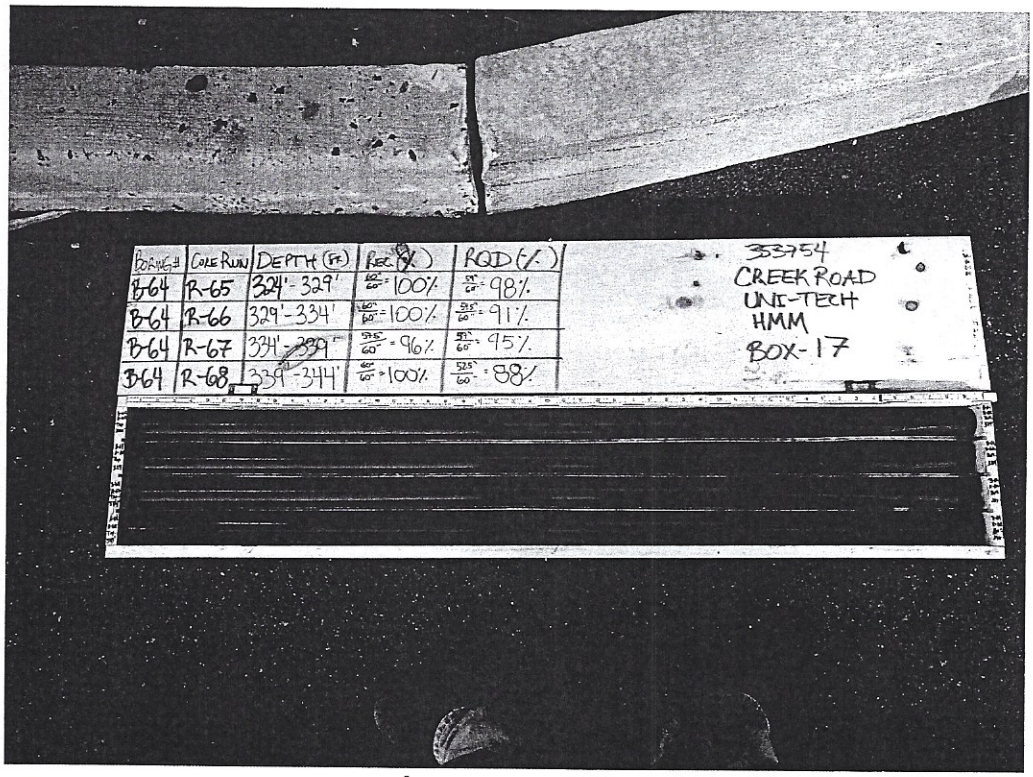

Figure B-64.34
B-64 Box 17 Runs 65-68 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

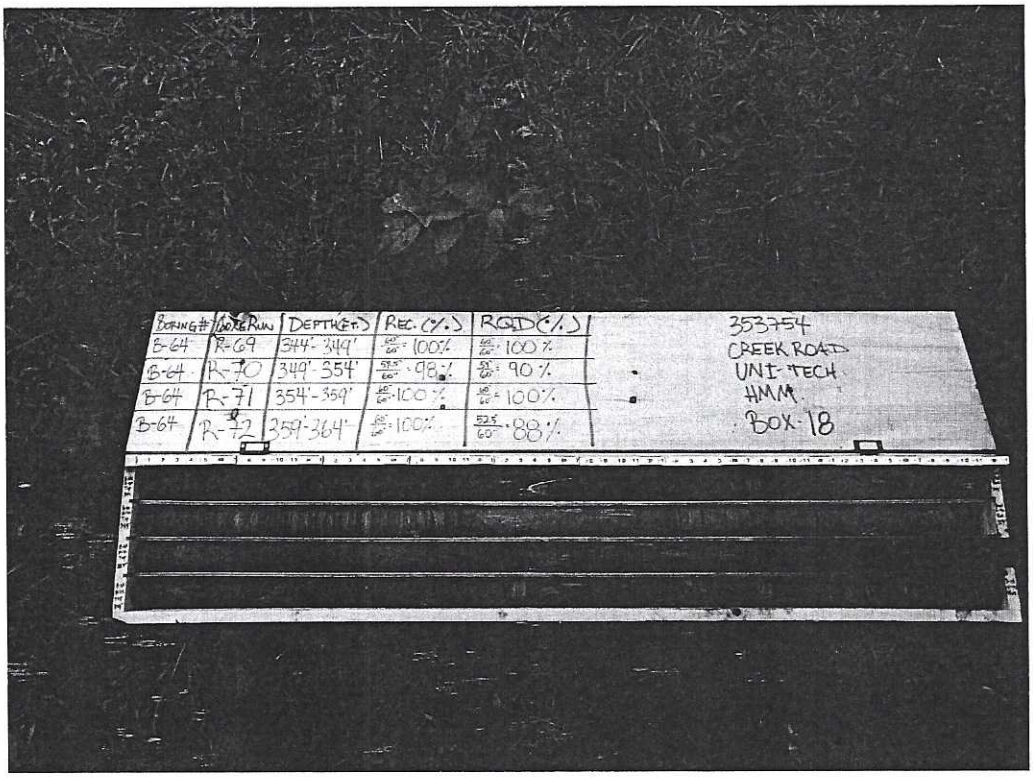

Figure B-64.35
B-64 Box 18 Runs 69-72 Dry

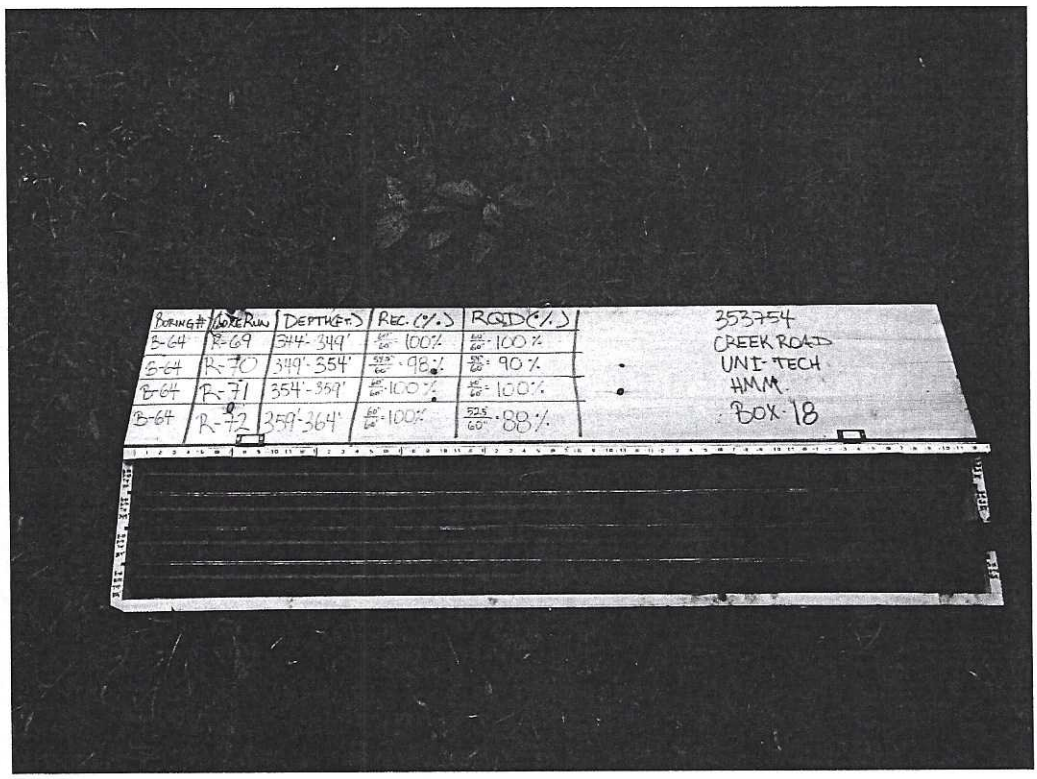

Figure B-64.36
B-64 Box 18 Runs 69-72 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

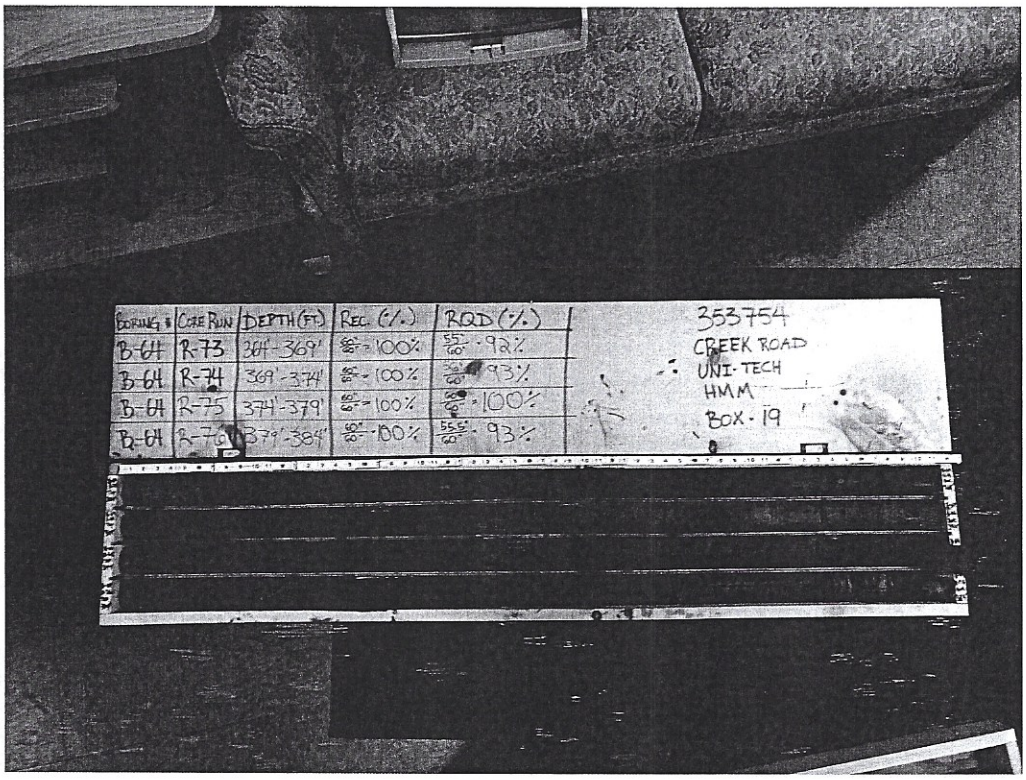

Figure B-64.37
B-64 Box 19 Runs 73-76 Dry

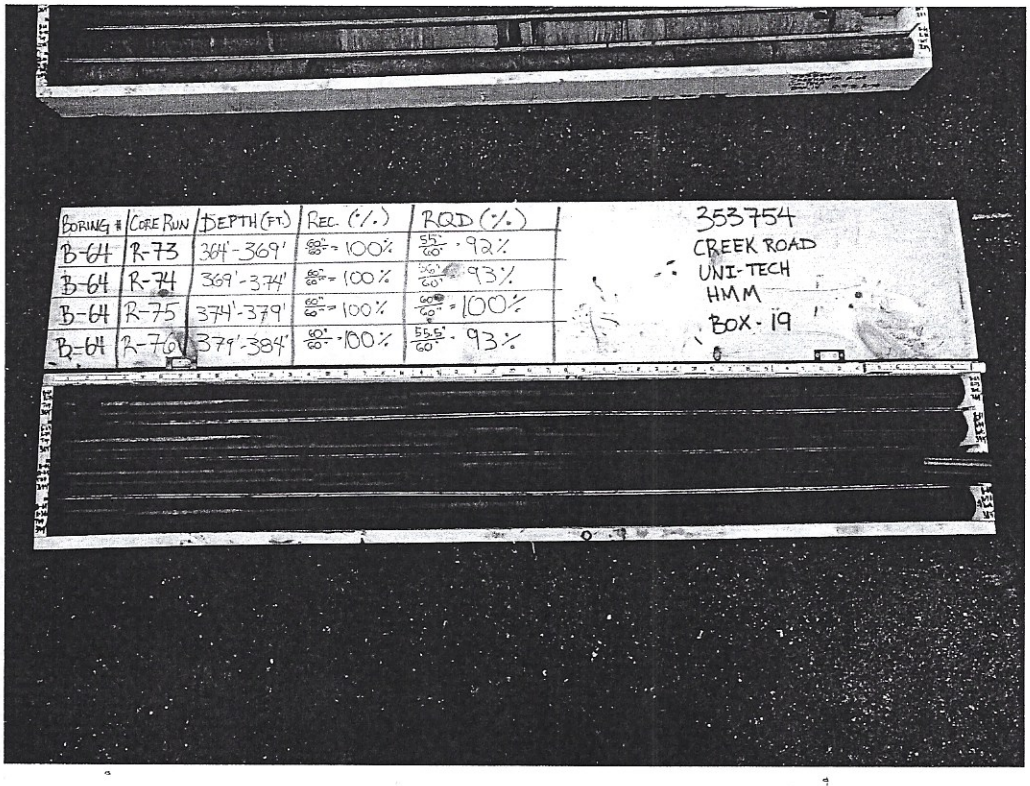

Figure B-64.38
B-64 Box 19 Runs 73-76 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

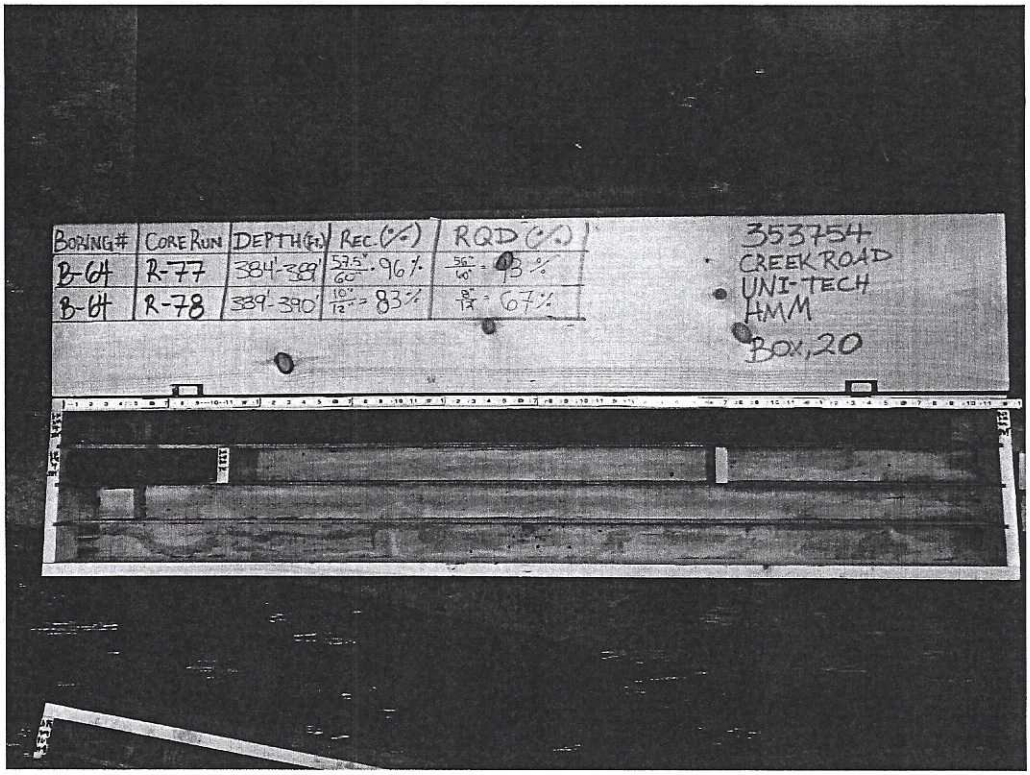

Figure B-64.39
B-64 Box 20 Runs 77-78 Dry

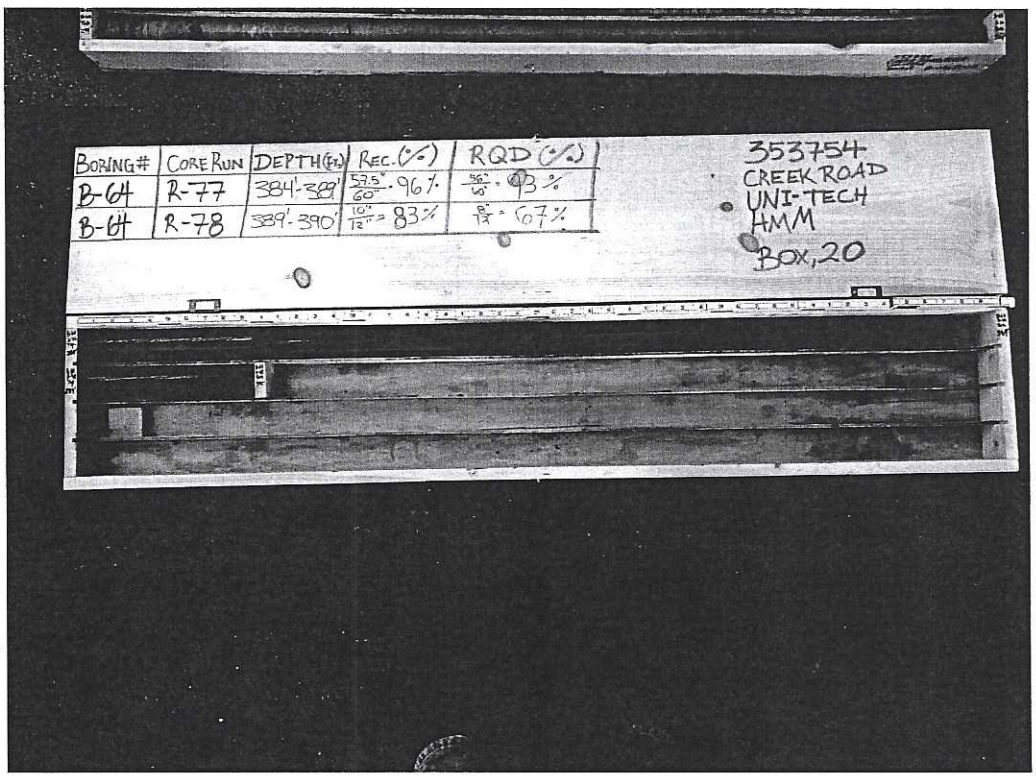

Figure B-64.40
B-64 Box 20 Runs 77-78 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-64

MOTT MACDONALD M M

SOIL BORING LOG

BORING NO.: **B-65**
Page 1 of 1

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Nishisakawick Creek, Hunterdon Co., NJ	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Erica Viglorolo
Drilling Co.:	Uni-Tech Drilling Co., Inc.	**Date/Time Started:**	September 21, 2016 at 10:15 am
Driller/Helper:	Cunard Lopez /Chris Meyers	**Date/Time Finished:**	September 27, 2016 at 11:00 am

Elevation: 293 ft. **Vertical Datum:** NAVD 1988

Boring Location: Wooded area west of field.

Coord.: N: 40.53524 E: -75.04752

Horizontal Datum: NAD 1983

Item	Casing	Sampler	Core Barre
Type	HSA	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
Hollow Stem Auger

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'	21	1 4 5 6		ML	0.3 3" - TOPSOIL Bottom (21") Stiff, Light brown SILT, trace medium to fine Gravel, little fine Sand, dry (ML)	-	-	-	-	PP = N/A TV = N/A
290						3.5 Medium dense, Reddish brown DECOMPOSED ROCK fragments, dry					
5	S-2 5.0'- 7.0'	24	17 12 15 18				-	-	-	-	Decomposed rock is Siltstone. Difficulty drilling from 7 to 8 feet BGS.
10	S-3 10.0'- 10.4'	5	50/5"			10.5 Very dense, Reddish brown DECOMPOSED ROCK fragments, dry Top of Rock at 10 feet BGS. See Rock Coring Log.	-	-	-	-	Decomposed rock is Siltstone.
280											
15											

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
9/22/16	8:00	-	10.0	15.0	8.65
9/26/16	8:20	-	10.0	85.0	18.3
9/27/16	9:00	-	10.0	120.0	18.3

Sample Type

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

Notes:

PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-65**

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

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

MOTT MACDONALD M M

CORE BORING LOG

BORING NO.: **B-65**
Page 1 of 5

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Nishisakawick Creek, Hunterdon Co., NJ	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Erica Vigliorolo
Drilling Co.:	Uni-Tech Drilling Co., Inc.	**Date/Time Started:**	September 21, 2016 at 10:15 am
Driller/Helper:	Cunard Lopez /Chris Meyers	**Date/Time Finished:**	September 27, 2016 at 11:00 am

Elevation: 293 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Wooded area west of field. **Coord.:** N: 40.53524 E: -75.04752

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

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

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec (in. / %)	RQD (in / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
									SEE TEST BORING LOG FOR OVERBURDEN DETAILS		(See Legend for Rock Description System)						
	10.50	10.0							ARGILLITE, Reddish brown, very fine grained, slightly weathered, medium strong, very close to moderately spaced discontinuities	10.60	J	18	P,R	DS	T	N	
	11.00								10' - 10.3' Highly Fractured zone	11.10	J	17	P,R	DS	PO	N	
	6.50		R-1	60 100%	35 58%	R3	SL		10.6' - 10.75' Highly Fractured zone 11.1' - 12.1' Highly Fractured zone	12.10	J	7	P,Sm	DS	VT	N	
280	6.50									12.90 13.00	J J	10 10	U,R U,R	DS DS	PO T	N N	
	7.00	15.0								13.90 14.20	J MB	5	P,Sm	DS	PO	N	
15	12.00	15.0							ARGILLITE, Reddish brown, very fine grained, slightly weathered, strong, very close to close spaced discontinuities	15.40	J	9	P,R	DS	T	N	
	9.90								15.3' - 15.7' Fractured zone	15.70	J	15	U,R	DS	PO	N	
	11.50		R-2	59 98%	36 60%	R4	SL		16.3' - 16.4' Fractured zone 17' - 19.1' Highly Fractured zone	16.30 16.40 17.00	J J J	20 10 3	P,R P,R P,R	FR FR FR	PO PO PO	N N N	Loss of water at 17 feet BGS.
	8.00																
	7.50	20.0								19.50	J	17	P,R	DS	T	N	
20	8.00	20.0							ARGILLITE, Reddish brown, very fine grained, slightly weathered, strong, extremely close to moderately spaced discontinuities	20.50	J	19	U,R	DS	PO	N	Low water return from 22.4 to 23.4 feet BGS.
	11.00								20.5' - 23.1' Highly Fractured zone								
	9.50		R-3	60 100%	34 57%	R4	SL		22.6' - 22.7' Highly Weathered to Silt								
270	12.40									23.10	J	20	P,R	FR	PO	N	
	13.00	25.0								24.00 24.70	J J	5 4	U,R P,R	DS FR	PO T	N N	
25	12.40	25.0							ARGILLITE, Reddish brown to gray, very fine grained, moderately weathered, strong, close to moderately spaced discontinuities								Used up to 400 gallons of water from 10 to 25 feet BGS.
	10.20									26.40	J	24	P,R	FR	T	N	
	11.50		R-4	57 95%	17 28%	R4	M		26.9' - 28.1' Vertical Fracture								
	9.50																
	9.50	30.0							28.9' - 29.8' Fractured zone								

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
9/27/16	9:00	-	10.0	120.0	18.3
9/22/16	8:00	-	10.0	15.0	8.7
9/26/16	8:20	-	10.0	85.0	18.3

Notes:
Drill core bit damaged and lost at 120ft. Hole off set and re drilled at B-65A.

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
	10.25	30.0							ARGILLITE, Gray to black, very fine grained, moderately weathered, strong, extremely close to close spaced discontinuities 30' - 35' Highly Fractured zone								
	9.90																
	8.50		R-5	60 100%	5 8%	R4	M										
260	9.10																
	7.90	35.0															
35		35.0							35.0								
	7.00								35' - 35.7' COAL, Black, very fine grained, slightly weathered, medium strong, very close to close spaced discontinuities 35.7 35' - 36.9' Highly Fractured zone	35.80	V					Ca	
	6.50								ARGILLITE, Dark gary to black, fine grained, slightly weathered, medium strong, very close to close spaced discontinuities	36.10 36.20	V V					Ca Ca	
	6.10		R-6	60 100%	31 52%	R3	SL			36.90 37.50 37.80	J J J	4 13 7	P,Sm P,Sm P,Sm	FR FR FR	T T VT	N N N	
	7.50								38.5' - 38.6' Highly Fractured zone	38.50 38.60 39.00	J J J	10 10 15	P,Sm P,Sm P,Sm	DS DS DS	T T T	N N N	
	7.40	40.0								39.30	J	12	P,Sm	FR	T	N	
40		40.0							ARGILLITE, Dark to light gray, fine grained, slightly weathered, very strong, close to wide spaced discontinuities								
	10.40									40.30	J	5	P,R	FR	PO	N	
	6.55									41.20	J	16	U,R	DS	PO	ML	
	5.45		R-7	60 100%	53 88%	R5	SL										
250	6.50									43.60	J	12	P,Sm	FR	PO	N	
	6.05									44.30 44.60	J J	11 13	P,R U,R	DS FR	PO T	N N	
		45.0							45.0								
45	6.80	45.0							MARL, Gray to light gray, fine grained, slightly weathered, medium strong, close to moderately spaced discontinuities 45' - 45.5' Fractured zone	45.50	J	16	P,Sm	FR	T	N	Used up to 400 gallons of water from 25 to 45 feet BGS.
	7.50																
	5.40		R-8	57 95%	51 85%	R3	SL			47.00 47.50 47.90	J J J	18 14 28	P,R U,R U,R	FR FR FR	T T T	N N N	
	5.50																
	5.90	50.0								49.00	J	18	P,R	FR	T	N	
50		50.0							50.0								
	5.00								ARGILLITE, Light brown to light gray, very fine grained, slightly weathered, very strong, wide spaced discontinuities								
	4.90																
	4.40		R-9	60 100%	60 100%	R5	SL										
240	5.50																
	5.50	55.0								54.60	J	16	U,R	FR	PO	N	
55		55.0							ARGILLITE, Light gray to black, fine to very fine grained, slightly weathered, medium strong to strong,								

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	5.50								close to wide spaced discontinuities	55.50	MB						
									56' - 60' Shale and Coal interbedding	55.90	J	28	U,R	DS	T	Ca	
	6.60								57.4' - 58.8' Calcite parting	56.00	MB	27	U,Sm	DS	T	Ca	
									ARGILLITE, Light gray to black, fine to very fine grained, slightly weathered, medium strong to strong, close to wide spaced discontinuities	56.10	J						
									56' - 60' Shale and Coal interbedding								
	5.50		R-10	59 98%	55 92%	R3	SL		57.4' - 58.8' Calcite parting								
										57.90	J	2	S,Sm	DS	VT	N	
	6.75																
										58.90	J	7	P,Sm	FR	T	N	
	6.90	60.0								59.60	MB						
60		60.0							ARGILLITE, Gray to light gray, fine grained, slightly weathered, very strong, very close to moderately spaced discontinuities								
	7.55																
	5.50									61.60	J	16	P,R	FR	T	N	
	6.50		R-11	60 100%	55 92%	R5	SL		62.2' - 62.3' Fractured zone	62.20	J	40	U,R	FR	O	N	
										62.30	J	49	U,R	FR	O	N	
230									62.7' - 63.1' Calcite parting	62.70	J	6	S,R	DS	PO	N	
	5.90								63.2' - 63.5' Fractured zone	63.30	J	12	U,R	FR	T	N	
										63.60	J	7	U,R	DS	PO	N	
	6.55	65.0															
65		65.0								64.80	MB						
	6.25								ARGILLITE, Light gray to reddish brown, fine grained, slightly weathered, very strong, close to moderately spaced discontinuities	65.20	MB						Used up to 400 gallons of water from 45 to 65 feet BGS.
									65' - 70' Calcite partings encountered								
	7.00									66.70	J	18	P,R	DS	PO	N	
	4.75		R-12	60 100%	56 93%	R5	SL			67.50	J	14	P,R	DS	T	N	
	4.50																
	4.40	70.0								69.70	J	50	P,R	DS	O	N	
70		70.0							ARGILLITE, Reddish brown, fine grained, slightly weathered, strong, close to wide spaced discontinuities	70.40	MB						
	5.75									70.70	J	14	U,R	DS	T	N	
	5.50																
	6.50		R-13	60 100%	60 100%	R4	SL										
220										73.00	J	16	P,R	DS	T	N	
	5.50																
	5.70								74.2' - 75' Calcite parting								
		75.0								74.60	J	13	P,Sm	DS	VT	N	
75		75.0							ARGILLITE, Reddish brown, fine grained, slightly weathered, medium strong, close to wide spaced discontinuities	75.10	MB			DS			
	6.00									75.40	MB			DS			
										75.70	J	18	U,Sm	DS	T	Ca	
	6.90																
	5.40		R-14	57 95%	55 92%	R3	SL										
										78.20	J	69	U,R	DS	T	N	
	5.60																
	5.50	80.0															
80		80.0							ARGILLITE, Reddish brown, fine grained, slightly weathered, very strong, close to moderately spaced discontinuities	80.20	J	5	P,R	DS	O	N	
	6.90								81.7' - 82' Calcite parting								

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-65**
Page **4** 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
	5.80																
	5.60		R-15	60 100%	58 97%	R5	SL			82.50	J	49	P,R	DS	T	Ca	
210	5.50																
	5.60	85.0								84.10	J	0	P,R	DS	T	N	
85	5.90	85.0							ARGILLITE, Reddish brown, fine grained, slightly weathered, medium strong, close to wide spaced discontinuities	85.10	J	4	P,R	FR	T	N	
	6.00									86.20	J	20	P,R	FR	T	N	
	5.75		R-16	59 98%	58 97%	R3	SL			86.90	J	78	P,R	DS	VT	N	
	5.00																
	4.70	90.0								89.50	B	44	P,R	FR		N	
90	6.25	90.0							ARGILLITE, Reddish brown, fine grained, slightly weathered, strong, very close to wide spaced discontinuities	90.30	J	11	P,R	FR	PO	N	
	6.25																
	5.70		R-17	57 95%	52 87%	R4	SL										
200	5.25									93.10 93.20	J J	0 11	P,R U,R	FR FR	O T	N N	
										93.80	J	25	P,R	FR	T	N	
	4.55	95.0								94.40	J	3	P,R	FR	PO	N	
95	4.75	95.0							ARGILLITE, Reddish brown, fine grained, slightly weathered, strong, close to wide spaced discontinuities								
	5.75									96.00	J	8	P,R	FR	O	N	
	5.70		R-18	58 97%	57 95%	R4	SL										
	4.90									98.20	J	15	U,R	FR	T	N	
	5.00	100.0								98.80	J	18	S,Sm	DS	T	N	
100	6.00	100.0							ARGILLITE, Reddish brown, fine grained, slightly weathered, medium strong, close to wide spaced discontinuities								Used up to 400 gallons of water from 65 to 100 feet BGS.
	5.00																
	5.00		R-19	60 100%	60 100%	R3	SL										
190	4.50									103.10	J	28	P,R	DS	T	N	
	5.50	105.0								104.20	J	40	P,R	DS	T	N	
105	6.70	105.0							ARGILLITE, Reddish brown, fine grained, slightly weathered, strong, moderate to wide spaced discontinuities 105.6' - 106.2' Calcite partings								
	5.25																

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-65**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-65**
Page **5** of **5**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath.	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	5.25									106.40	J	8	U,Sm	FR	PO	N	
	5.40		R-20	58 97%	58 97%	R4	SL										
	5.40																
	5.75	110.0															
110	5.40	110.0							ARGILLITE, Reddish brown, fine grained, slightly weathered, strong, close to wide spaced discontinuities								
	6.25																
	6.75		R-21	59 98%	56 93%	R4	SL			112.30	J	60	P,R	DS	T	N	
180	5.70									113.60	J	16	P,R	DS	T	N	
	6.00	115.0							114.1' - 114.4' Highly Fractured zone	114.10	J	28	U,R	DS	O	N	
115	5.90	115.0							ARGILLITE, Reddish brown, fine grained, slightly weathered, strong, close to moderately spaced discontinuities	115.30	J	7	P,R	DS	PO	N	Core barrel clogging. Drill bit stuck in hole at 120 feet BGS.
	5.40									116.00	J	80	P,R	DS	T	N	
									116.5' - 116.7' Calcite parting	116.70	J	63	P,R	DS	T	Ca	
	4.75		R-22	60 100%	55 92%	R4	SL			118.10	J	60	P,R	DS	T	N	
	4.75								118.4' - 119.1' Calcite parting	118.60	J	73	U,R	DS	T	Ca	
	6.00	120.0															
120									120.0 Drill bit lost. Borehole abandoned and offset as B-65A. Borehole grouted with cement and bentonite hole plug.								
170																	
125																	
130																	

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-65**

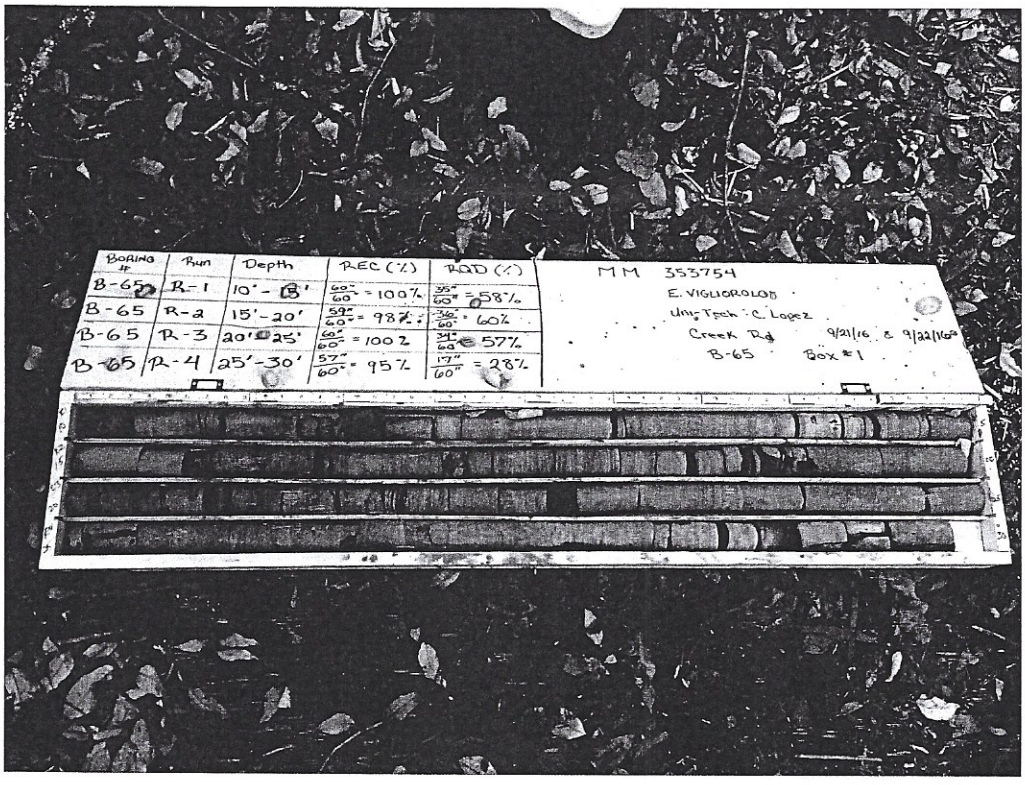

Figure B-65.1
B-65 Box 1 Runs 1-4 Dry

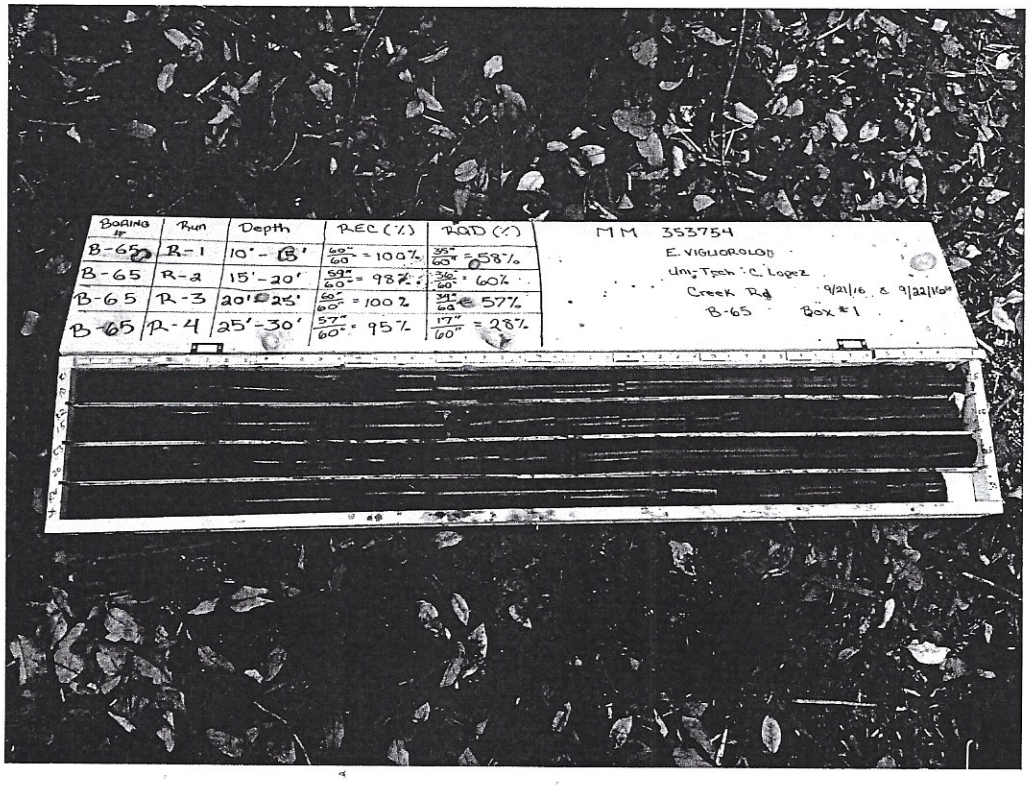

Figure B-65.2
B-65 Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65

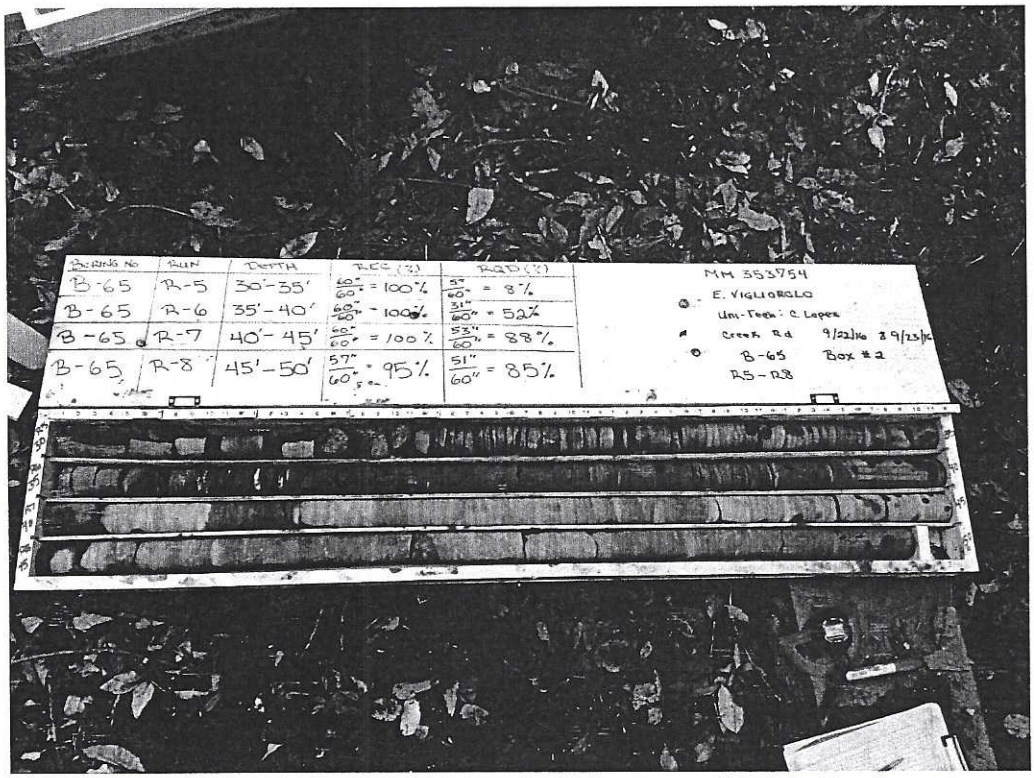

Figure B-65.3
B-65 Box 2 Runs 5-8 Dry

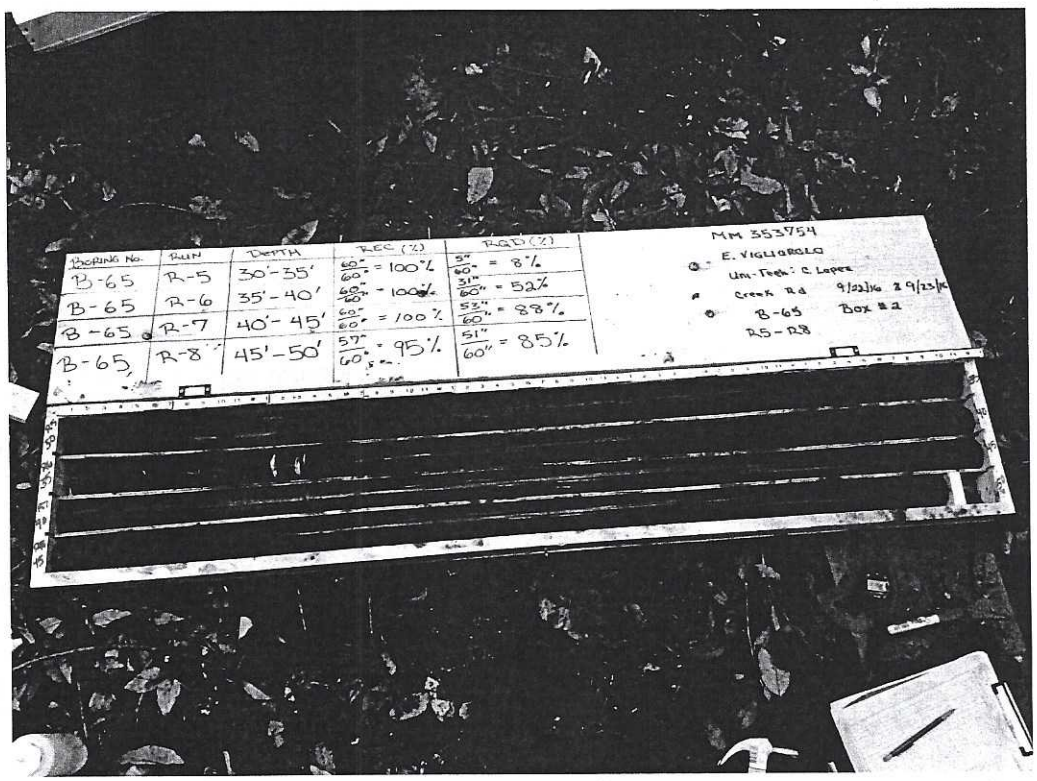

Figure B-65.4
B-65 Box 2 Runs 5-8 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65

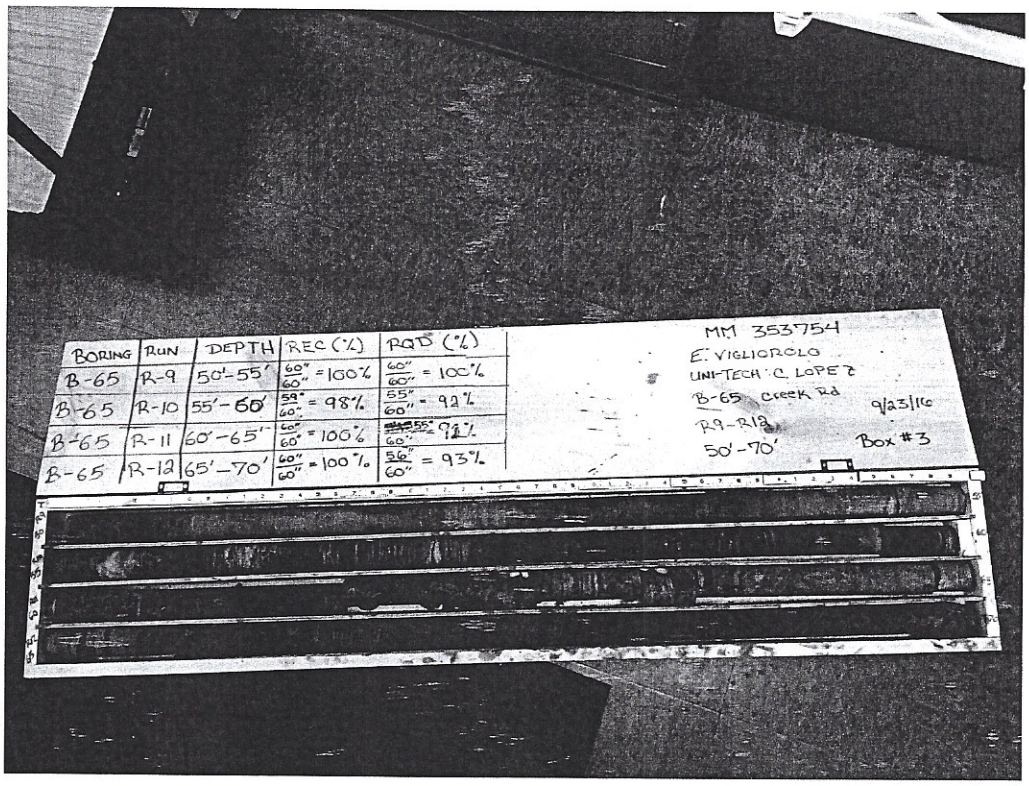

Figure B-65.5
B-65 Box 3 Runs 9-12 Dry

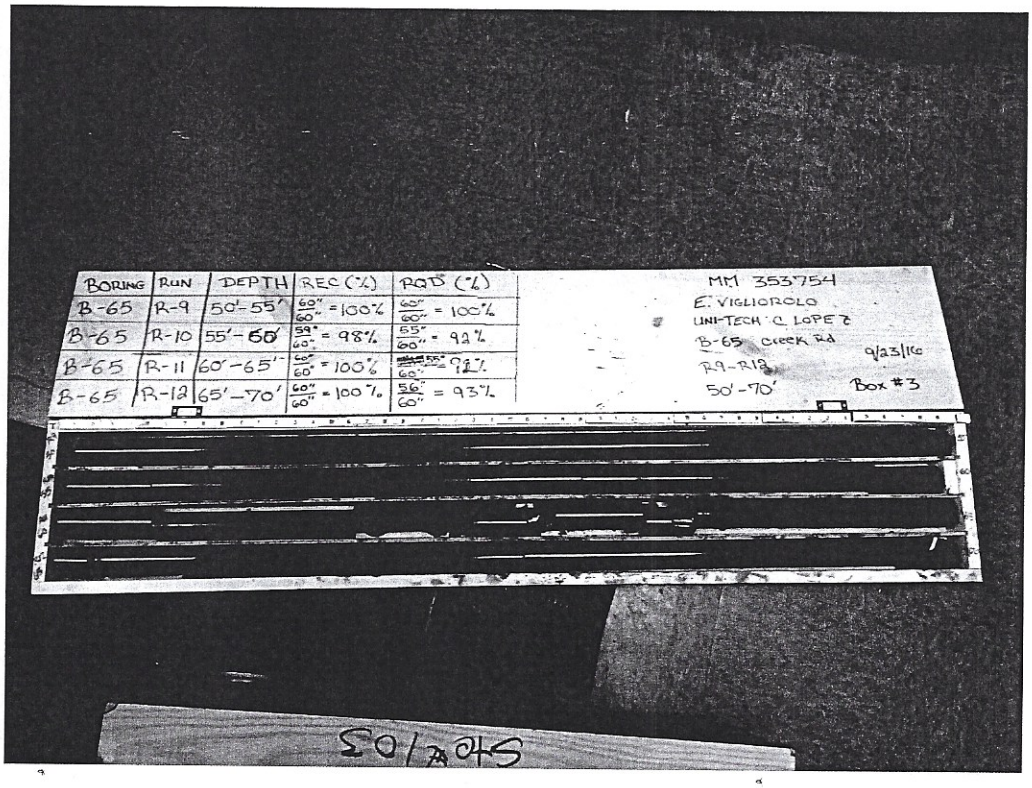

Figure B-65.6
B-65 Box 3 Runs 9-12 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65

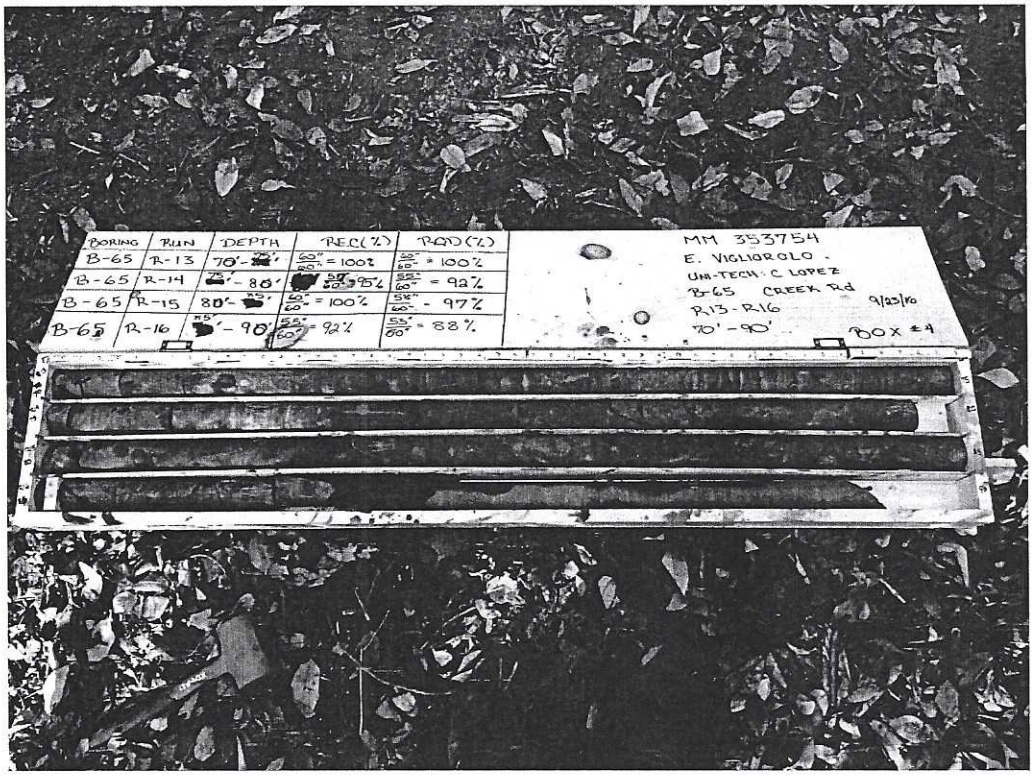

Figure B-65.7
B-65 Box 4 Runs 13-16 Dry

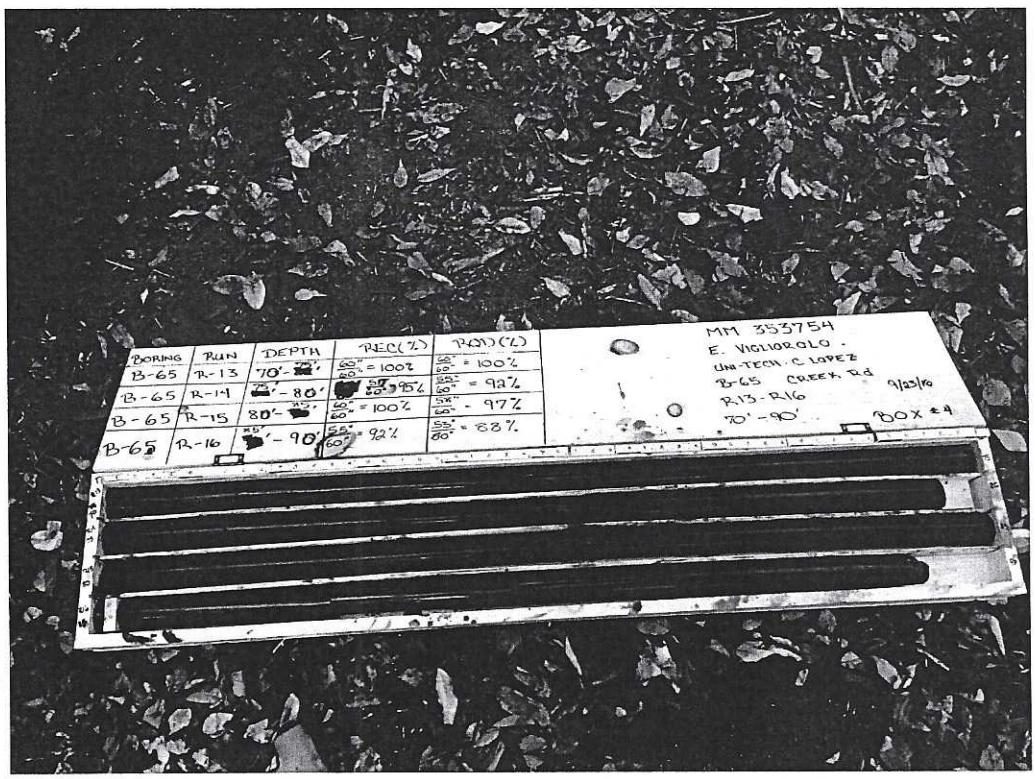

Figure B-65.8
B-65 Box 4 Runs 13-16 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65

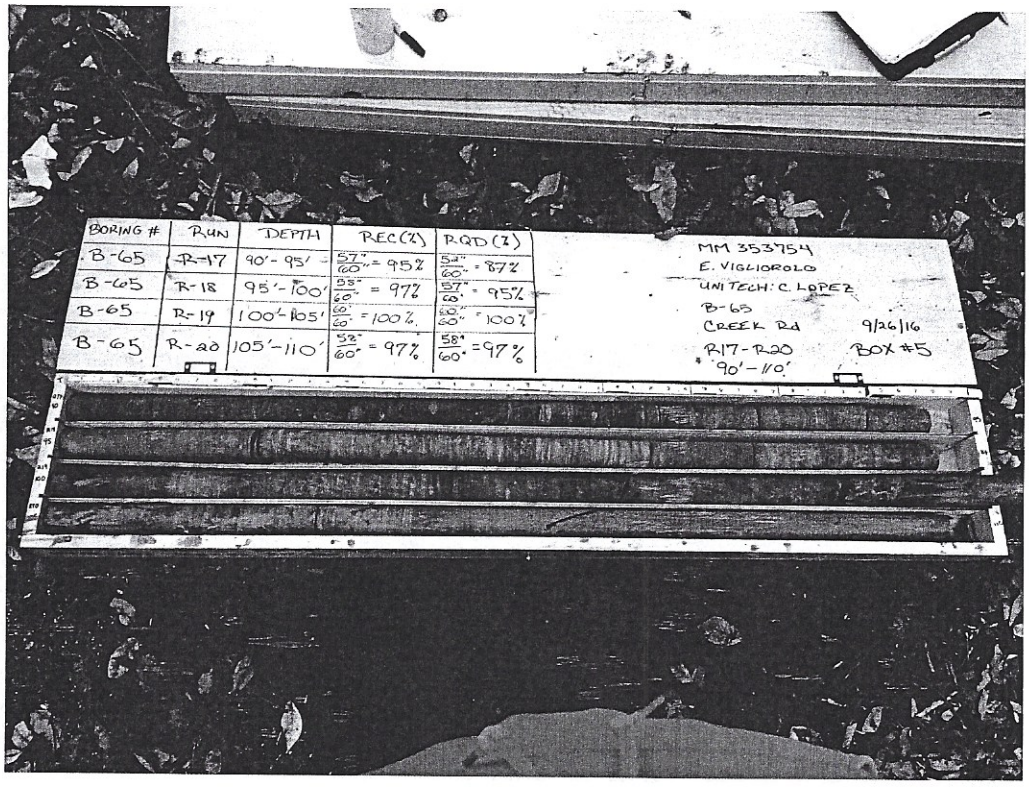

Figure B-65.9
B-65 Box 5 Runs 17-20 Dry

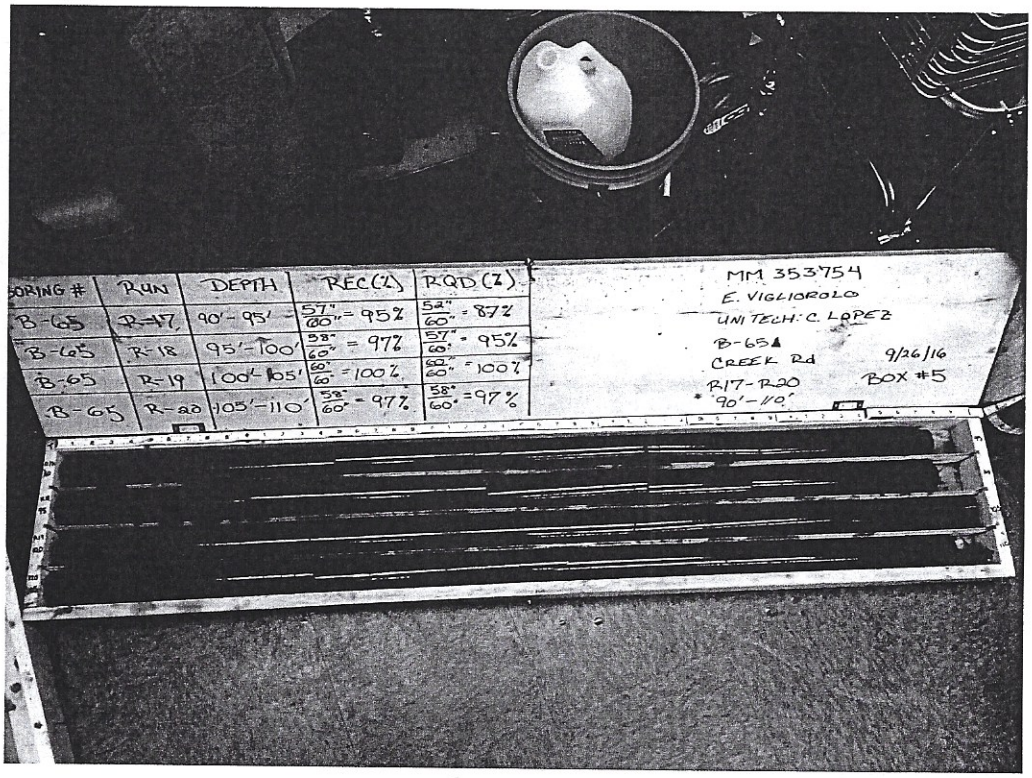

Figure B-65.10
B-65 Box 5 Runs 17-20 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65

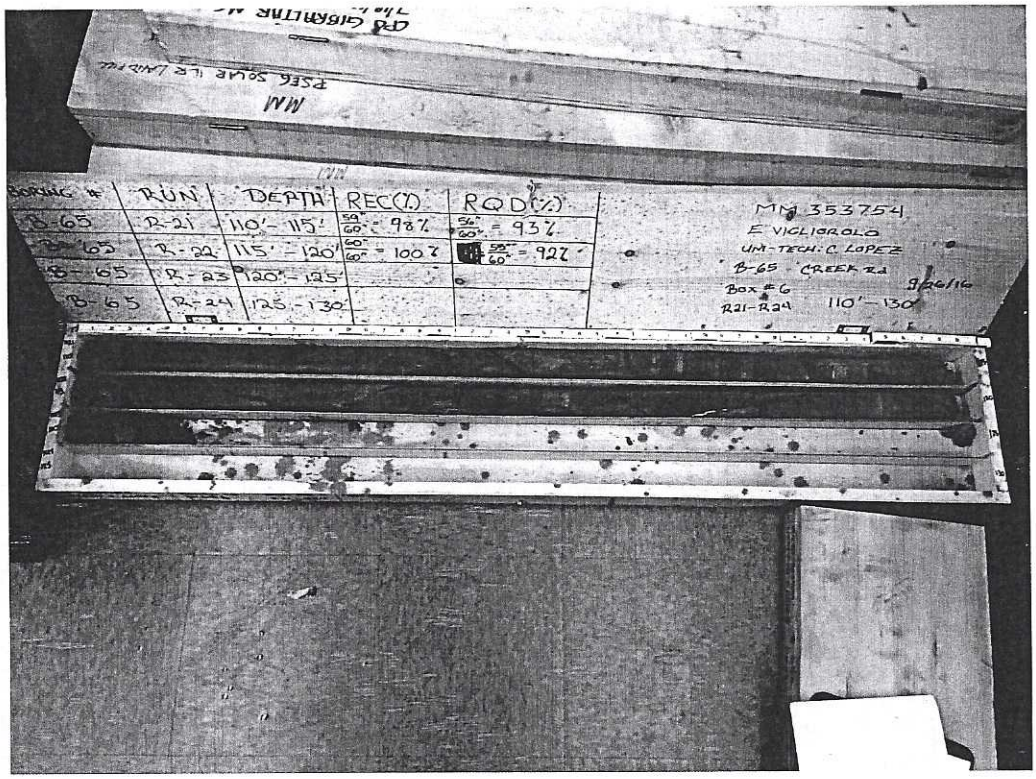

Figure B-65.11
B-65 Box 6 Runs 21-22 Dry

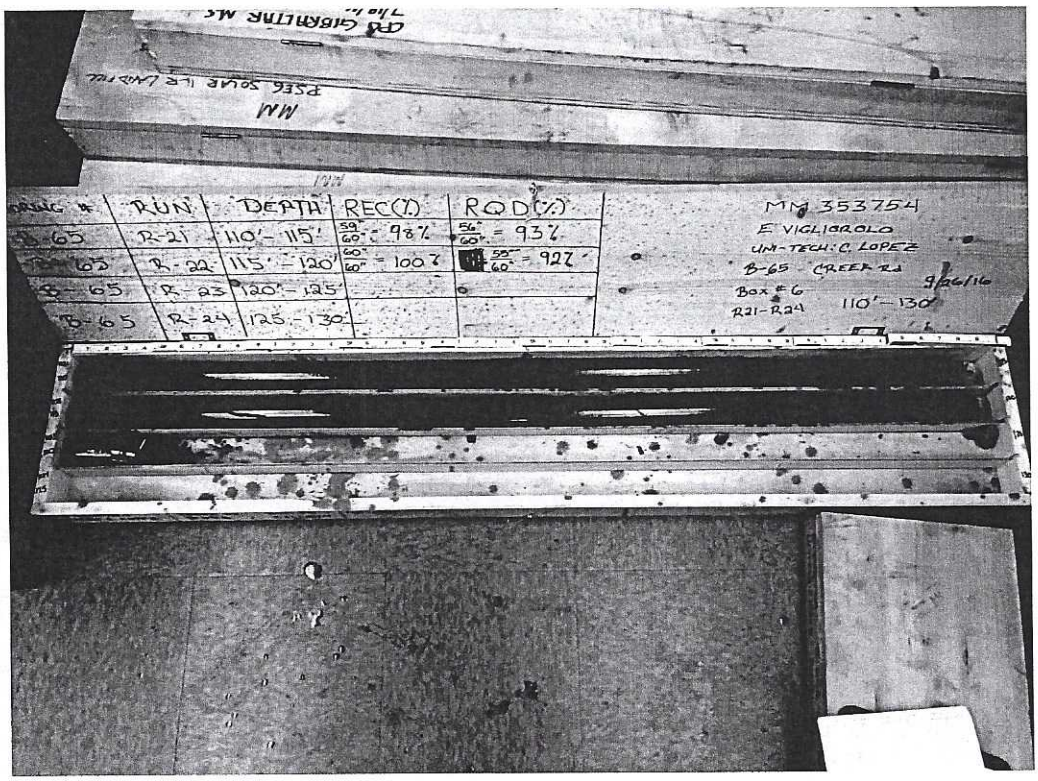

Figure B-65.12
B-65 Box 6 Runs 21-22 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-65

MOTT MACDONALD M M

SOIL BORING LOG

BORING NO.: **B-65A**
Page 1 of 1

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Nishisakawick Creek, Hunterdon Co., NJ	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Erica Vigliorolo/Bobby Kalpouzos
Drilling Co.:	Uni-Tech Drilling Co., Inc.	**Date/Time Started:**	September 27, 2016 at 11:30 am
Driller/Helper:	Cunard Lopez/Dave Conover /Chris Meyers	**Date/Time Finished:**	October 11, 2016 at 11:00 am

Elevation: 285 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** 10 feet South of B-65 **Coord.:** N: 40.535205 E: -75.047519 **Horizontal Datum:** NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HSA	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-55LC

☐ 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:** Hollow Stem Auger

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Group Symbol	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks
	S-1 0.0'- 2.0'	6.5	3 6 8 9		ML	0.2 2" - TOPSOIL Stiff, Brown to light brown SILT, dry	-	-	-	N	PP = N/A TV = N/A
						3.5					
5 280	S-2 5.0'- 7.0'	23	8 31 45 30			Very dense, Yellowish red DECOMPOSED ROCK fragments, dry	-	-	-	-	Decomposed rock is Siltstone.
10	S-3 10.0'- 11.0'	8	24 50/3			Very dense, Reddish brown DECOMPOSED ROCK fragments, dry	-	-	-	-	Decomposed rock is Siltstone.
						11.3 Top of Rock at 11.3 feet BGS. See Rock Coring Log.					
15 270											

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
9/29/16	8:50	-	10.0	65.0	47
9/30/16	8:15	-	10.0	100.0	39.8
10/6/16	8:00	-	10.0	220.0	93
10/7/06	7:50	-	10.0	270.0	84

Sample Type

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

Notes:
PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-65A**

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

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

MOTT MACDONALD M M

CORE BORING LOG

BORING NO.: **B-65A**
Page 1 of 13

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Nishisakawick Creek, Hunterdon Co., NJ	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Erica Vigliorolo/Bobby Kalpouzos
Drilling Co.:	Uni-Tech Drilling Co., Inc.	**Date/Time Started:**	September 27, 2016 at 11:30 am
Driller/Helper:	Cunard Lopez/Dave Conover /Chris Meyers	**Date/Time Finished:**	October 11, 2016 at 11:00 am

Elevation: 285 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** 10 feet South of B-65 **Coord.:** N: 40.535205 E: -75.047519

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

Horizontal Datum: NAD 1983
Rig Make & Model: CME-55LC
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								
	3.90	11.3							ARGILLITE, Reddish brown, fine grained, slightly weathered, very strong, very close to close spaced discontinuities 11.3' - 14.3' Highly Fractured zone								Loss of water at 14 feet BGS.
	4.50		R-1	35 79%	-- --	R5	SL										
	4.20																
15 270		15.0															
	2.60	15.0							ARGILLITE, Reddish brown, fine grained, slightly weathered, weak, very close to close spaced discontinuities 15' - 15.9' Highly Fractured zone								Loss of water.
	3.25									15.90 16.20	J J	30 18	U,R P,R	FR FR	T PO	N N	
	2.90		R-2	54 90%	4 7%	R2	SL										
	5.40																
	7.40	20.0															
20																	
	4.50	20.0							ARGILLITE, Reddish brown, fine grained, slightly weathered, weak, very close to close spaced discontinuities 20' - 22.3' Highly Fractured zone								Used up to 400 Gallons for R-3. Loss of water.
	5.50																
	4.00		R-3	60 100%	32 53%	R2	SL			22.30 22.65	J J	0 0	U,R U,R	FR FR	O PO	ML N	
	4.75									23.40 23.80	J J	0 0	U,R U,R	FR FR	PO T	N N	
	5.25	25.0								24.30	J	0	U,R	FR	PO	N	
25 260		25.0							ARGILLITE, Reddish brown, fine grained, fresh, weak, close spaced discontinuities								Used up to 400 Gallons for R-4. Loss of water.
	4.00									25.70	J	0	U,Sm	FR	O	N	
	5.25									26.20	J	55	U,R	FR	PO	N	
	4.75		R-4	60 100%	48 80%	R2	SL		27.4	27.00	J	60	U,R	FR	PO	N	
	6.25								SHALE, Gray, fine grained, slightly weathered, weak, very close to close spaced discontinuities 28.2' - 28.9' Highly Fractured zone	27.70	J	5	U,Sm	DS	O	ML	
	7.50	30.0								29.30 29.50	J J	0 0	U,R U,R	DS DS	MW O	CL CL	
30																	
	4.75	30.0							SHALE, Dark gray to light gray, very fine grained, slightly weathered, weak, extremely close to close spaced discontinuities 30' - 35' Highly Fractured zone								Used up to 400 Gallons for R-5. Loss of water.
	6.50																

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
10/7/06	7:50	-	10.0	270.0	84.0
10/6/16	8:00	-	10.0	220.0	93.0
9/30/16	8:15	-	10.0	100.0	39.8
9/29/16	8:50	-	10.0	65.0	47.0

Notes:

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	6.50																
	5.50		R-5	56 93%	0 0%	R2	SL										
	4.75																
	5.75	35.0															
35 250	4.00	35.0							SHALE, Dark gray to light gray, very fine grained, fresh, medium strong, very close to close spaced discontinuities 35' - 36' Highly Fractured Anthracite Coal seam								Used up to 400 Gallons for R-6. Loss of water.
	5.00									36.50	J	5	P,Sm	FR	VT	N	
	5.25		R-6	60 100%	36 59%	R3	FR			37.50	J	0	P,Sm	FR	T	N	
										37.60	J	0	P,Sm	FR	T	N	
	4.25									38.20	J	0	U,Sm	DS	T	N	
										38.30	J	0	U,Sm	DS	T	N	
	4.50	40.0								39.00	J	0	U,Sm	DS	PO	N	
40										39.30	J	0	U,R	FR	T	N	
	3.50	40.0							SHALE, Gray, very fine grained, fresh, medium strong, close to moderately spaced discontinuities 40' - 41' Vertical vein with Iron infilling								
	6.25									40.90	J	10	U,R	DS	PO	N	
	6.00		R-7	60 100%	56 93%	R3	FR										
	5.50									43.40	J	0	U,Sm	FR	PO	N	
										43.60	J	0	U,Sm	FR	T	N	
	5.50	45.0								44.30	J	0	U,Sm	FR	PO	N	
45 240									45.0								
	4.25	45.0							ARGILLITE, Reddish gray, fine grained, fresh, medium strong, close to moderately spaced discontinuities	45.30	J	15	U,R	FR	T	N	
	5.00									46.25	J	25	U,R	FR	T	N	
										46.80	J	10	U,R	DS	O	N	
	5.00		R-8	60 100%	57 94%	R3	FR										
	5.50																
										48.95	J	0	U,R	FR	PO	N	
	6.25	50.0															
50										49.65	J	0	P,R	FR	T	N	
	6.00	50.0							ARGILLITE, Reddish gray, fine grained, fresh, medium strong, moderate to wide spaced discontinuities	50.20	J	0	U,R	FR	T	N	
	5.50																
	5.00		R-9	58 97%	55 92%	R3	FR										
	5.00																
									53.5								
	6.00	55.0							SHALE, Light gray, very fine grained, fresh, medium strong, very close to moderately spaced discontinuities	53.85	J	20	P,R	FR	T	N	
55 230	4.50	55.0							SHALE, Dark gray to light gray, very fine grained, fresh, medium strong, close to moderately spaced discontinuities	54.75	J	0	U,Sm	FR	PO	N	
	5.00									56.20	J	0	P,Sm	DS	PO	N	
										56.50	J	0	U,Sm	FR	PO	N	

NOTES:

PROJECT NO.: **353754**

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
										56.80	J	5	U,Sm	FR	PO	N	
	5.75		R-10	60 100%	53 88%	R3	FR			57.30	J	0	P,Sm	FR	PO	N	
										57.80	J	0	P,Sm	FR	PO	N	
	5.50																
										58.60	J	5	U,Sm	FR	PO	N	
	6.50	60.0															
60										59.60	J	0	U,Sm	FR	PO	N	
		60.0							SHALE, Dark gray to light gray, very fine grained, slightly weathered, medium strong, very close to close spaced discontinuities 60' - 63.5' Highly Fractured zone with Calcite infilling 60' - 61' Vertical vein with Calcite infilling								
	7.00																
	6.00																
	7.00		R-11	60 100%	20 33%	R3	SL										
									63.0								
	6.50								MARL, Light gray, very fine grained, slightly weathered, medium strong, very close to close spaced discontinuities								
										64.10	J	5	U,R	DS	PO	CL	
	10.00	65.0								64.60	J	0	P,R	DS	PO	N	
65 220		65.0							65.0 ARGILLITE, Reddish brown, fine grained, slightly weathered, strong, close to wide spaced discontinuities 66' Calcite parting								Used up to 400 Gallons for R-12. Loss of water.
	5.75																
	6.50									65.90	J	53	P,R	FR	T	N	
	6.75		R-12	60 100%	55 92%	R4	SL			67.10	J	70	P,R	FR	T	N	
										67.80	J	16	U,R	DS	PO	N	
	6.90									68.00	J	42	U,R	FR	T	N	
										68.70	J	60	P,R	FR	O	N	
	6.75	70.0								69.40	J	20	U,R	FR	PO	N	
70		70.0							ARGILLITE, Reddish brown, very fine grained, slightly weathered, weak to strong, very close to moderately spaced discontinuities 70' - 70.1' Light brown Silt seam, dry 71.6' - 71.7' Dark brown Silty Clay seam, moist 72.7' - 75' Highly Fractured zone 73' - 75' Vertical Fracture with Calcite and Iron infilling								Used up to 400 Gallons for R-13. Loss of water.
	7.00									70.30	J	0	P,R	FR	O	N	
	5.50																
										71.60	J	0	P,R	FR	O	N	
	6.00		R-13	60 100%	25 42%	R4	SL			71.90	J	3	P,R	FR	O	N	
										72.70	J	10	P,R	DS	T	N	
	6.50																
	6.00	75.0															
75 210		75.0							ARGILLITE, Reddish brown, fine grained, moderately weathered, weak to medium strong, close to wide spaced discontinuities 75' - 75.7' Highly Fractured zone 75.1' Vertical Fracture with Calcite and Iron infillings 75.6' Vertical Fracture with Calcite and Iron infillings 75.7' - 76.1' Vertical Fracture with Calcite and Iron infilling								Loss of water.
	6.95																
	8.00									76.10	J	25	S,Sm	FR	O	N	
										76.50	J	27	P,R	DS		N	
	7.75		R-14	60 100%	47 78%	R3	M										
	4.60																
	3.75	80.0															
80		80.0								79.80	V					Ca	
	7.50								ARGILLITE, Reddish brown, fine grained, moderately weathered, weak to strong, very close to moderately spaced discontinuities Calcareous partings throughout 80' - 80.2' Brown highly plastic Clay seam 80.2' - 80.6' Highly Fractured zone 80.6' - 81.6' Vertical Fracture with Calcite and Iron infilling								Used up to 400 Gallons for R-14 to R-15. Loss of water.
	6.25																
	6.00																

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-65A**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-65A**

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		R-15	58 97%	33 55%	R4	M										
	6.50																
	6.50	85.0								83.60	J	82	P,R	FR	T	N	
85 200	6.60	85.0							ARGILLITE, Reddish brown, fine grained, slightly weathered, weak to medium strong, very close to moderately spaced discontinuities	85.00	MB						Loss of water.
	7.50									85.90	J	0	P,R	FR	O	N	
										86.40	J	24	U,R	FR	PO	N	
	6.25		R-16	60 100%	35 58%	R3	SL		87.5' - 88.2' Vertical Fracture with Calcite infilling								
	4.55								88.3' - 88.6' Fractured zone 88.7' - 89.5' Vertical Fracture	88.30	J	5	S,Sm	FR	T	N	
	3.10	90.0															
90	4.75	90.0							ARGILLITE with interbedded Shale, Reddish brown, fine to very fine grained, fresh, weak to strong, close to wide spaced discontinuities 90.6' Vertical Fracture	90.50	J	55	P,R	DS	O	N	Used up to 400 Gallons for R-16 to R-17. Loss of water.
	6.50																
	3.14		R-17	60 100%	51 85%	R3	FR										
	5.00									93.10	J	0	P,Sm	FR	O	N	
	6.40	95.0							94.1' - 94.2' Calcite parting 94.4' - 95' Calcite vein	94.40	J	3	P,Sm	DS	O	N	
95 190	4.40	95.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to medium strong, very close to wide spaced discontinuities 95' - 96.9' Highly Fractured zone								Loss of water.
	3.50																
	4.40		R-18	60 100%	41 68%	R3	FR			96.90	J	0	P,R	DS	T	N	
	4.50																
	4.75	100.0															
100	8.00	100.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to strong, very close to moderately spaced discontinuities	100.40 100.50	J MB	5	U,R	FR	T	N	Used up to 400 Gallons for R-19 to R-20. Loss of water.
	7.50																
	6.25		R-19	57 95%	55 92%	R4	FR			101.80	J	0	P,R	FR	PO	N	
										102.80	J	49	P,R	FR	T	N	
	5.50																
	7.25	105.0								104.00	J	3	S,R	FR	T	N	
105 180	4.75	105.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to medium strong, close to wide spaced discontinuities Calcareous partings throughout	105.10	J	5	U,R	FR	O	N	Loss of water.
	5.00									106.30	J	56	U,R	FR	O	N	
										106.80	MB						
	5.00		R-20	60 100%	60 100%	R3	FR			107.40	MB						

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PROJECT NO.: **353754**

Boring No.: **B-65A**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-65A**
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Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	5.60									108.60	J	2	P,R	FR	T	N	
	6.00	110.0															
110	4.50	110.0							ARGILLITE, Reddish brown, fine grained, slightly weathered, weak to medium strong, moderate to wide spaced discontinuities								Used up to 400 Gallons for R-21 to R-22. Loss of water.
	5.50																
	5.20		R-21	60 100%	60 100%	R3	SL			112.40	J	5	S,R	FR	O	N	
	5.25									113.30	J	26	U,R	DS	PO	N	
	5.50	115.0								114.70	MB						
115 170	4.00	115.0							ARGILLITE, Reddish brown, fine grained, slightly weathered, weak to medium strong, close to moderately spaced discontinuities	115.60	MB						Loss of water.
	4.70																
	5.20		R-22	60 100%	52 87%	R3	SL		117.2 SHALE, Reddish brown, very fine grained, slightly weathered, weak to medium strong, very close to moderately spaced discontinuities	117.30	J	48	U,R	FR	T	N	
	5.40								117.4' Calcite parting	118.00	J	0	P,Sm	FR	T	N	
									118' - 118.3' Fractured zone	118.40	J	0	P,Sm	FR	T	Sa	
	5.50	120.0							118.7 ARGILLITE, Reddish brown, fine grained, slightly weathered, weak to medium strong, close to moderately spaced discontinuities	119.30	MB						
120	6.00	120.0							120.4 SHALE, Light to dark gray, very fine grained, slightly weathered, weak to strong, very close to moderately spaced discontinuities	120.90	J	16	U,Sm	DS	VT	N	Used up to 400 Gallons for R-23. Loss of water.
	5.75									121.50	J	0	P,Sm	DS	T	N	
	5.90		R-23	60 100%	56 93%	R4	SL										
										123.00	J	0	P,Sm	DS	T	N	
	8.00									123.40	J	0	P,Sm	DS	VT	N	
	9.00	125.0								124.40	MB						
125 160	6.00	125.0							SHALE, Light to dark gray, very fine grained, fresh, weak to strong, very close to wide spaced discontinuities Calcareous partings throughout	125.10	MB						Loss of water.
										125.60	J	0	P,Sm	FR	PO	N	
	7.90									126.50	J	13	U,Sm	FR	VT	N	
	5.40		R-24	60 100%	58 97%	R4	FR		127.0 MARL, Light gray, very fine grained, fresh, weak to strong, wide spaced discontinuities	127.10	J	6	P,Sm	FR	T	N	
										128.00	J	8	P,Sm	DS	T	N	
	5.40																
	4.90	130.0							130.0								
130	5.40	130.0							ARGILLITE with interbedded Shale, Reddish brown to gray, fine to very fine grained, moderately weathered, weak to strong, close to wide spaced discontinuities	130.40	J						Used up to 400 Gallons for R-24 to R-25. Loss of water.
	5.00																
	4.90		R-25	60 100%	31 52%	R4	M		132.6' - 135' Vertical Fracture with Calcite and Iron infilling	132.90	J						
	5.40																

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Boring No.: **B-65A**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	5.40																
	4.50	135.0															
135 150		135.0							135.0								
	5.50								SHALE with interbedded Argillite, Light to dark gray, very fine to fine grained, moderately weathered, weak to medium strong, close to moderately spaced discontinuities								Loss of water.
	4.75								135' - 140' Calcareous partings present throughout 135' - 135.1' Vertical Fracture with Calcite and Iron infillings	136.30	J	24	U,Sm	DS	O	Ca	
									135.3' - 135.7' Vertical Fracture with Calcite and Iron infillings	136.80	J	18	P,Sm	DS	T	Ca	
	5.25		R-26	60 100%	46 77%	R3	M		136.3' - 136.5' Vertical Fracture with Calcite and Iron infillings	137.10	J	7	P,Sm	DS	T	Ca	
									137.1' - 137.8' Highly Fractured zone	137.80	J	8	P,Sm	DS	T	Ca	
	6.25																
	5.00	140.0								139.00	J	16	U,Sm	DS	T	N	
										139.40	J	20	U,Sm	DS	T	Ca	
140		140.0								139.80	J	8	P,Sm	DS	VT	Ca	
	5.60								SHALE with interbedded Argillite, Light to dark gray, very fine grained, moderately weathered, weak to medium strong, very close to moderately spaced discontinuities	140.30	J	0	P,R	FR	T	N	Used up to 400 Gallons for R-27. Loss of water.
									140' - 140.5' Decomposed Shale to Sand	141.00	J	5	P,R	FR	T	N	
	5.50								140' - 145' Calcareous partings present throughout 141.1' - 142.1' Highly Fractured zone	141.50	J	6	S,R	FR	PO	Ca	
	7.30		R-27	59 98%	44 73%	R3	M			142.30	J	20	U,Sm	FR	T	N	
									142.7' - 143' Highly weathered Gray Clay, high plasticity 143' - 143.5' Highly Fractured zone								
	6.00									143.50	J	4	P,R	FR	T	N	
	5.50	145.0								144.30	J	8	P,Sm	FR	T	N	
145 140		145.0															
	8.00								SHALE with interbedded Argillite, Light to dark gray, very fine to fine grained, slightly weathered, weak to medium strong, very close to moderately spaced discontinuities	145.25	J	15	P,R	DS	T	N	Used up to 400 Gallons for R-28. Loss of water.
									145' - 150' Calcareous partings present throughout	145.70	J	0	P,R	DS	PO	N	Rig chatter.
	13.50								145.7' - 146.5' Highly Fractured zone	146.50	J	0	P,Sm	FR	PO	N	
									147.2								
	14.50		R-28	58 97%	45 75%	R3	SL		ARGILLITE, Light gray to reddish brown, fine grained, slightly weathered, weak to medium strong, very close to wide spaced discontinuities								
	14.25									148.00	J	6	P,R	FR	VT	N	
										148.45	J	8	P,R	DS	T	N	
	10.90	150.0															
150		150.0															
	15.50								ARGILLITE, Reddish brown, fine grained, slightly weathered, medium strong, close to wide spaced discontinuities								Used up to 400 Gallons for R-29. Loss of water.
	14.50																
	14.00		R-29	58 97%	55 92%	R3	SL			152.80	J	16	U,R	FR	T	N	
	17.50									153.30	J	10	P,R	FR	T	N	
										153.80	J	6	P,R	FR	T	N	
	14.00	155.0															
155 130		155.0								154.60	J	45	P,R	FR	T	N	
	4.00								ARGILLITE, Reddish brown, fine grained, fresh, medium strong, close to wide spaced discontinuities								Used up to 400 Gallons for R-30. Loss of water.
	4.40																
	3.50		R-30	60 100%	60 100%	R3	FR										
	3.40								158.4								
									SHALE, Light to dark gray, very fine grained, fresh,	158.30	J	16	U,R	FR	T	N	

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
									medium strong, close to moderately spaced discontinuities	158.70	B	14	P,Sm	FR	PO	N	
	4.50	160.0															
160		160.0							SHALE, Light to dark gray, very fine grained, fresh, weak to medium strong, close to moderately spaced discontinuities 160' - 165' Calcareous partings present throughout								Loss of water. Rig chatter.
	4.00									160.80	J	9	P,Sm	FR	T	N	
	3.75									161.75	J	17	P,Sm	FR	T	N	
	3.25		R-31	58 97%	51 85%	R3	FR										
	2.40									163.40	J	10	S,Sm	FR	T	N	
										163.60	J	10	U,R	FR	PO	N	
	3.60	165.0								164.50	J	3	U,Sm	FR	T	N	
165 120		165.0							165.0 ARGILLITE, Gray to reddish brown, fine grained, slightly weathered, weak to strong, moderate to wide spaced discontinuities								Loss of water. Rig chatter.
	3.40									165.70	J	0	P,R	FR	PO	N	
	2.50																
	2.20		R-32	60 100%	60 100%	R4	SL										
	2.20																
	3.25	170.0															
170		170.0							ARGILLITE, Reddish brown, fine to very fine grained, fresh, weak to medium strong, moderate to wide spaced discontinuities 170' - 175' Calcareous partings present throughout								Used up to 300 Gallons for R-31 and R-32. Loss of water.
	4.50																
	3.00																
	2.90		R-33	60 100%	58 97%	R3	FR										
	2.75																
	3.25	175.0								174.00	J	0	P,R	FR	T	N	
175 110		175.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to strong, wide spaced discontinuities 175' - 180' Calcareous partings present throughout	174.80	B	6	P,Sm	FR	T	N	Loss of water.
	2.40																
	2.50																
	3.00		R-34	60 100%	60 100%	R4	FR										
	2.50																
	3.00	180.0															
180		180.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to strong, moderate to wide spaced discontinuities 180' - 185' Calcareous partings present throughout								Loss of water.
	3.50																
	3.20																
	2.90		R-35	58 97%	58 97%	R4	FR										
	3.25									183.70	J	3	P,R	FR	T	N	
	3.50																

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PROJECT NO.: **353754**

Boring No.: **B-65A**

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.50	185.0															
185 100	3.00	185.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to medium strong, moderate to wide spaced discontinuities								Loss of water.
	2.90																
	3.10		R-36	60 100%	60 100%	R3	FR										
	4.50																
	4.60	190.0								188.90	J	12	P,Sm	DS	PO	N	
190	3.60	190.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to medium strong, wide spaced discontinuities								Loss of water.
	2.50																
	2.90		R-37	60 100%	60 100%	R3	FR										
	3.40																
	3.00	195.0															
195 90	3.25	195.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to medium strong, wide spaced discontinuities								Used up to 400 Gallons for R-36 and R-38. Loss of water.
	2.50																
	3.10		R-38	60 100%	60 100%	R3	FR										
	3.50																
	3.50	200.0															
200	3.00	200.0							ARGILLITE with interbedded Shale, Reddish brown to light gray, fine to very fine grained, fresh, weak to medium strong, close to wide spaced discontinuities								Loss of water.
	3.25									201.20	J	0	S,R	DS	T	N	
	2.90		R-39	60 100%	57 95%	R6	FR			201.45	B	6	U,Sm	DS	PO	N	
	3.00																
	3.20	205.0															
205 80	3.25	205.0							ARGILLITE, Reddish brown, fine grained, fresh, medium strong to strong, wide spaced discontinuities								Used up to 400 Gallons for R-39 and R-41.
	3.60																
	3.75		R-40	60 100%	60 100%	R4	FR										
	3.40																
	3.25	210.0															

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PROJECT NO.: **353754**

Boring No.: **B-65A**

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
210	3.50	210.0							ARGILLITE with interbedded Shale, Reddish brown to light gray, fine to very fine grained, slightly weathered, medium strong, very close to moderately spaced discontinuities								Loss of water. Rig chatter.
	2.50									211.60	B	12	P,R	FR	T	N	
	3.00		R-41	59 98%	55 92%	R3	SL										
	2.50									213.30	J	12	U,R	FR	T	N	
										213.50	J	16	U,R	FR	T	N	
										214.00	B	10	P,Sm	FR	T	N	
	3.25	215.0								214.40	J	11	P,R	FR	T	N	
215 70	2.75	215.0							ARGILLITE with interbedded Shale, Reddish brown to light gray, fine to very fine grained, slightly weathered, medium strong, moderate to wide spaced discontinuities								Loss of water. Rig chatter.
	1.70									215.90	J	28	P,R	FR	T	N	
	2.70		R-42	60 100%	60 100%	R3	SL										
	2.75																
	3.40	220.0															
220	4.50	220.0							ARGILLITE, Reddish brown, fine grained, fresh, medium strong, very close to wide spaced discontinuities 220' - 225' Calcareous partings present throughout	220.80	J	8	P,R	DS	O	N	Used up to 400 Gallons for R-41 and R-43. Loss of water. Rig chatter.
	3.50																
	3.70		R-43	58 97%	55 92%	R3	FR										
	4.10																
	3.70	225.0															
225 60	3.50	225.0							ARGILLITE, Reddish brown, fine grained, fresh, medium strong to strong, close to wide spaced discontinuities 228.2' - 229' Calcite vein								Loss of water.
	2.50																
	2.75		R-44	60 100%	57 95%	R4	FR										
	2.50									228.20	J	6	P,R	FR	O	N	
										228.40	J	0	P,R	FR	O	N	
	3.50	230.0															
230	4.25	230.0							ARGILLITE, Reddish brown, fine grained, fresh, medium strong, wide spaced discontinuities 230' - 235' Calcareous partings present throughout 233' - 235' Interbedded Shale								Loss of water.
	3.90																
	3.90		R-45	60 100%	60 100%	R3	FR										
	3.40																
	2.90	235.0															
235 50		235.0															

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PROJECT NO.: **353754**

Boring No.: **B-65A**

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.00									235.60	J	0	U,Sm	DS		N	
	4.00								ARGILLITE with interbedded Shale, Reddish brown, fine to very fine grained, fresh, strong, very close to moderately spaced discontinuities 235' - 240' Calcareous partings present throughout 235' - 235.6' Fractured zone with Iron infilling								Used up to 400 Gallons for R-45 and R-46. Loss of water.
	4.10		R-46	60 100%	54 90%	R4	FR										
	4.20									238.60	J	20	P,R	FR	PO	N	
	2.75	240.0															
240																	
	4.75	240.0							ARGILLITE with interbedded Shale, Reddish brown, fine to very fine grained, fresh, weak to strong, moderate to wide spaced discontinuities 240' - 245' Calcareous partings present throughout								Loss of water.
	4.50																
	3.40		R-47	60 100%	60 100%	R4	FR										
	2.30									243.30	J	0	P,R	FR	T	N	
	3.00	245.0															
245 40																	
	2.75	245.0							ARGILLITE with interbedded Shale, Reddish brown, fine to very fine grained, fresh, weak to strong, moderate to wide spaced discontinuities 245' - 250' Calcareous partings present throughout								Loss of water.
	3.10									245.70	J	11	U,Sm	FR	PO	N	
	3.00		R-48	60 100%	58 97%	R4	FR										
	3.55									247.70	J	70	P,R	FR	T	N	
	4.50	250.0															
250																	
	3.20	250.0							ARGILLITE, Reddish brown, fine grained, fresh, strong, wide spaced discontinuities								Used up to 400 Gallons for R-47 and R-49. Loss of water.
	3.15																
	3,70		R-49	60 100%	60 100%	R4	FR										
	3.75																
	3.50	255.0															
255 30																	
	4.25	255.0							ARGILLITE with interbedded Shale, Reddish brown, fine to very fine grained, fresh, medium strong, very close to wide spaced discontinuities								Loss of water.
	3.10																
	3.70		R-50	60 100%	59 98%	R3	FR										
	2.90									257.90 258.00	J J	0 0	P,Sm P,Sm	FR FR	PO O	CL N	
	3.50	260.0															
260																	
	4.40	260.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to medium strong, close to moderately spaced discontinuities								Used up to 400 Gallons for R-50 and R-51. Loss of water.

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00																
	3.50		R-51	60 100%	60 100%	R3	FR			262.00	J	3	U,R	FR	T	N	
	4.00																
	4.25	265.0															
265 20	3.50	265.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to medium strong, close to moderately spaced discontinuities 265' - 270' Calcareous partings present throughout								Loss of water.
	3.95																
	3.90		R-52	60 100%	60 100%	R3	FR			266.60	J	4	P,R	DS	PO	N	
										267.00	J	8	P,R	DS	T	N	
	3.60									268.00	J	10	P,R	DS	T	N	
	4.50	270.0								268.60	J	0	P,R	DS	T	N	
270	3.75	270.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to strong, wide spaced discontinuities 270' - 275' Calcareous partings present throughout								Loss of water.
	3.75																
	3.90		R-53	60 100%	60 100%	R4	FR										
	4.25																
	4.75	275.0															
275 10	3.60	275.0							ARGILLITE with interbedded Shale, Reddish brown, fine to very fine grained, fresh, weak to strong, very close to wide spaced discontinuities 275' - 280' Calcareous partings present throughout 279.5' - 279.8' Highly Fractured zone with high weathering and Clay	275.80	J	0	P,Sm	FR	T	N	Used up to 400 Gallons for R-53 and R-54. Loss of water.
	3.10									276.10	J	6	U,Sm	FR	T	N	
	3.75		R-54	60 100%	55 92%	R4	FR										
	3.25																
	4.25	280.0								279.50	J	6	P,R	FR	T	N	
280	4.50	280.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to strong, wide spaced discontinuities 280' - 285' Calcareous partings present throughout	279.80	J	0	P,Sm	FR	O	N	Loss of water.
	4.00																
	4.25		R-55	60 100%	60 100%	R4	FR										
	4.00																
	4.50	285.0															
285 0	4.00	285.0							ARGILLITE with interbedded Shale, Reddish brown, fine to very fine grained, fresh, weak to medium strong, very close to wide spaced discontinuities 287.7' - 287.9' Calcite parting								Loss of water.
	4.40																

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.40																
	3.25		R-56	60 100%	57 95%	R3	FR										
	3.50									287.90	J	0	P,Sm	FR	PO	N	
										288.10	J	3	P,Sm	FR	T	N	
	3.90	290.0								288.90	J	0	U,R	DS	T	N	
290		290.0							ARGILLITE with interbedded Shale, Reddish brown, fine to very fine grained, fresh, weak to strong, close to wide spaced discontinuities								Used up to 400 Gallons for R-55 and R-57. Loss of water.
	2.75																
	3.10																
	4.00		R-57	60 100%	56 93%	R4	FR										
	4.50																
	4.50	295.0															
295 -10	2.90	295.0							ARGILLITE, Reddish brown, fine grained, fresh, very strong, close to wide spaced discontinuities 295' - 300' Calcareous partings present throughout 299.5' Interbedded Shale								Loss of water.
	3.90																
	4.50		R-58	60 100%	56 93%	R5	FR										
	4.00									298.30	J	12	P,R	FR	T	N	
	3.00	300.0								299.60	J	19	U,R	FR	PO	N	
300	4.50	300.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to strong, wide spaced discontinuities 300' - 305' Calcareous partings present throughout 300' - 302.4' Interbedded very fine grained Shale								Used up to 400 Gallons for R-58 and R-59. Loss of water.
	4.50																
	3.40		R-59	60 100%	60 100%	R4	FR										
	3.60																
	3.50	305.0															
305 -20	4.90	305.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to strong, close to wide spaced discontinuities								Loss of water.
	5.50																
	4.25		R-60	60 100%	60 100%	R4	FR										
	5.40																
	4.50	310.0								309.40	J	0	P,Sm	DS		N	
310		310.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to strong, moderate to wide spaced discontinuities								Loss of water.
	3.50																
	5.00																

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-65A**
Page 13 of 13

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.00		R-61	60 100%	60 100%	R4	FR										
	4.00																
	4.45	315.0															
315 -30	4.00	315.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to strong, close to wide spaced discontinuities								
	4.00																
	4.50		R-62	58 97%	58 97%	R4	FR										
	4.50																
	4.50	320.0															
320	4.00	320.0							ARGILLITEwith interbedded Shale, Reddish brown, fine grained, fresh, weak to strong, close to wide spaced discontinuities								
	4.00																
	4.50		R-63	60 100%	60 100%	R4	FR										
	4.50																
	4.00	325.0															
325 -40	4.00	325.0							ARGILLITE, Reddish brown, fine grained, fresh, weak to strong, close to wide spaced discontinuities								
	4.00																
	4.00		R-64	60 100%	60 100%	R4	FR										
	4.00																
	4.00	330.0															
330									330.0 End of Boring at 330 feet BGS. Borehole grouted with cement and bentonite hole plug.								
335 -50																	

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-65A**

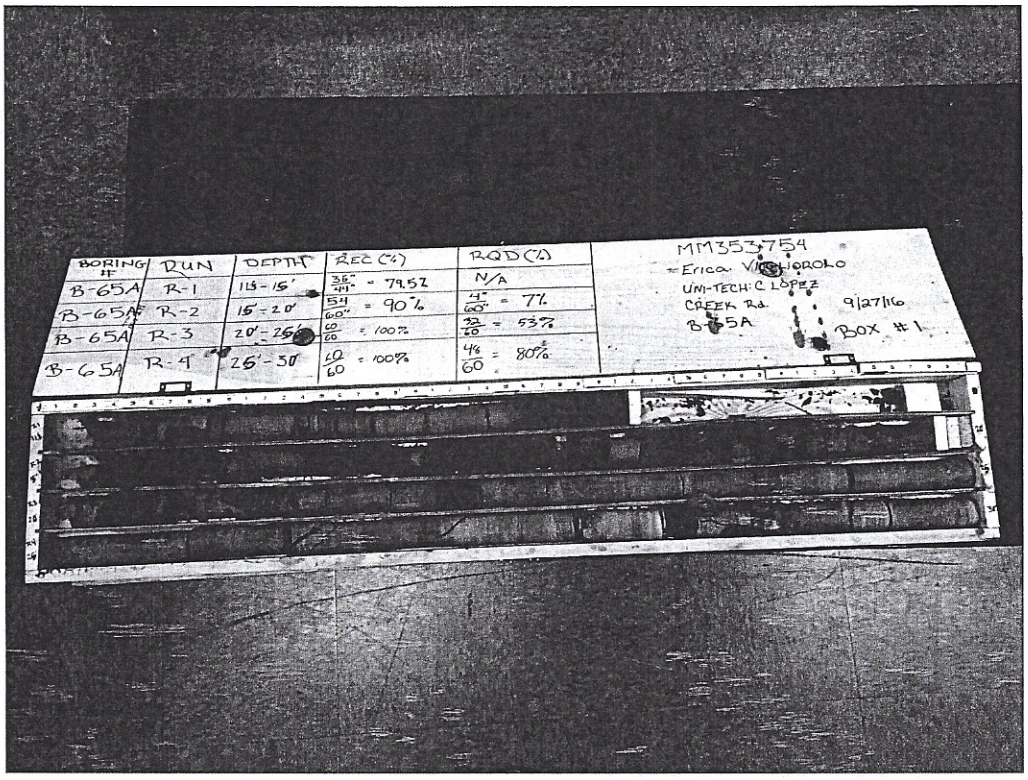


Figure B-65A.1
B-65A Box 1 Runs 1-4 Dry

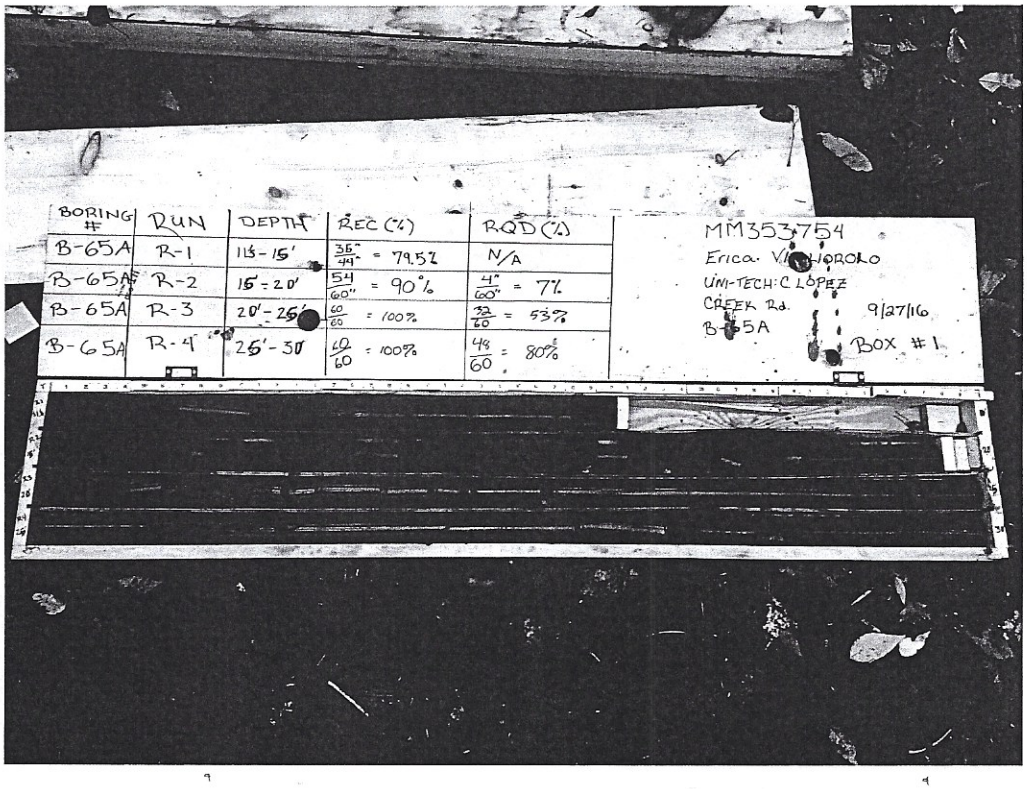


Figure B-65A.2
B-65A Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-65A

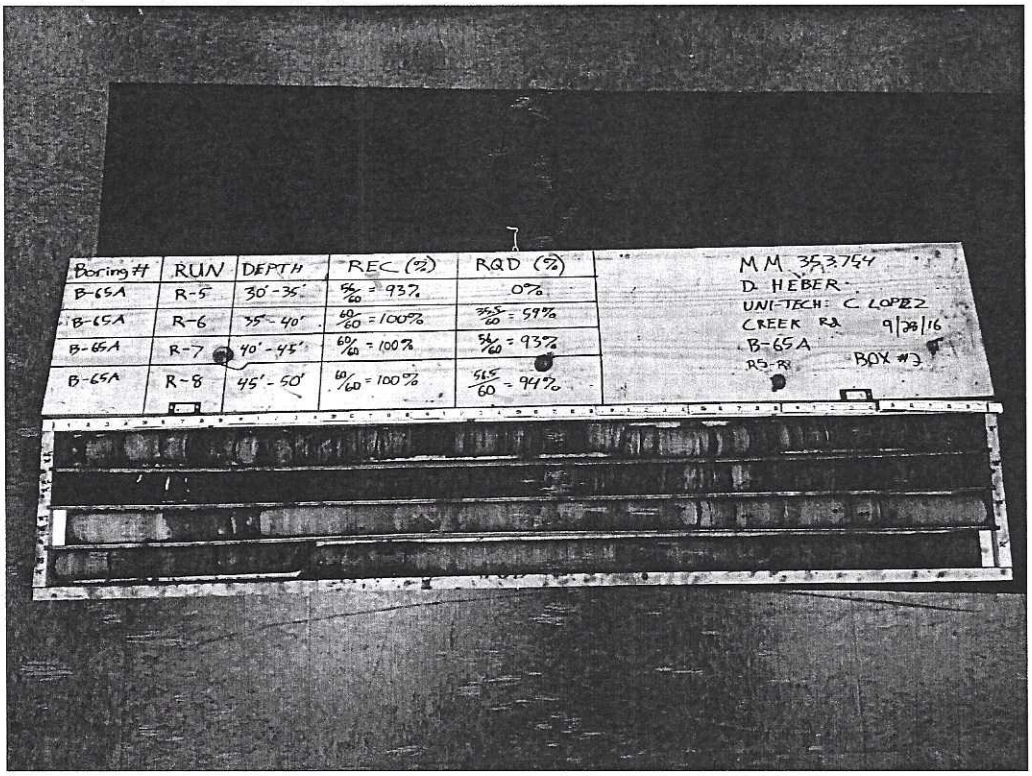


Figure B-65A.3
B-65A Box 2 Runs 5-8 Dry

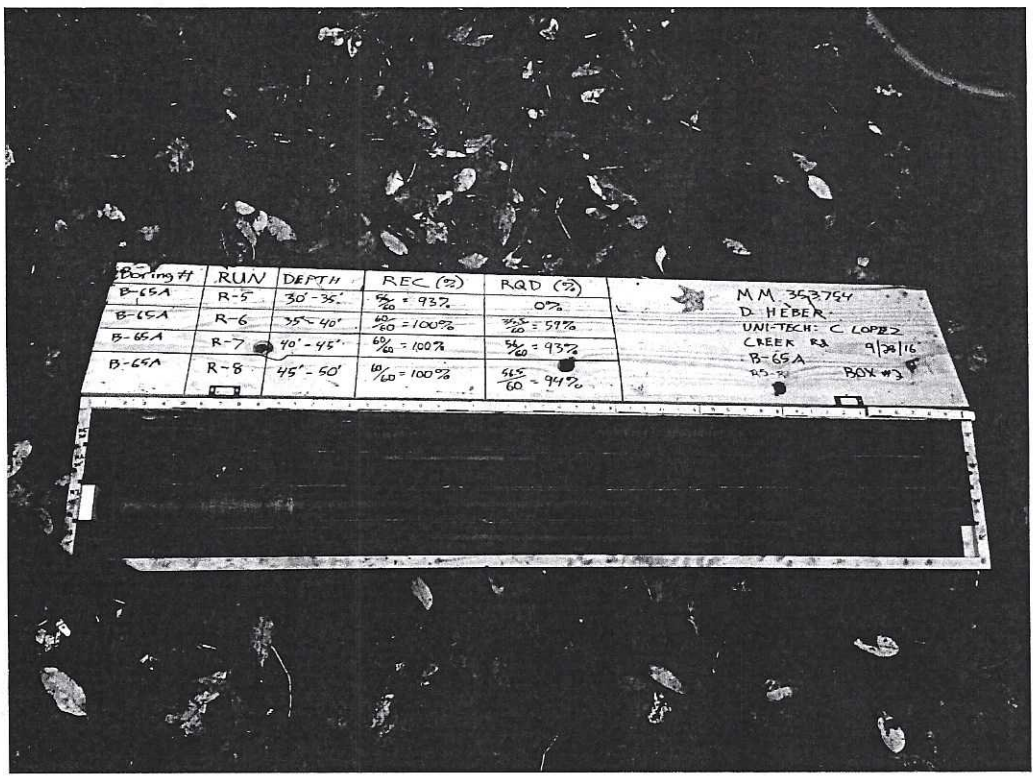


Figure B-65A.4
B-65A Box 2 Runs 5-8 Wet

MOTT MACDONALD	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-65A

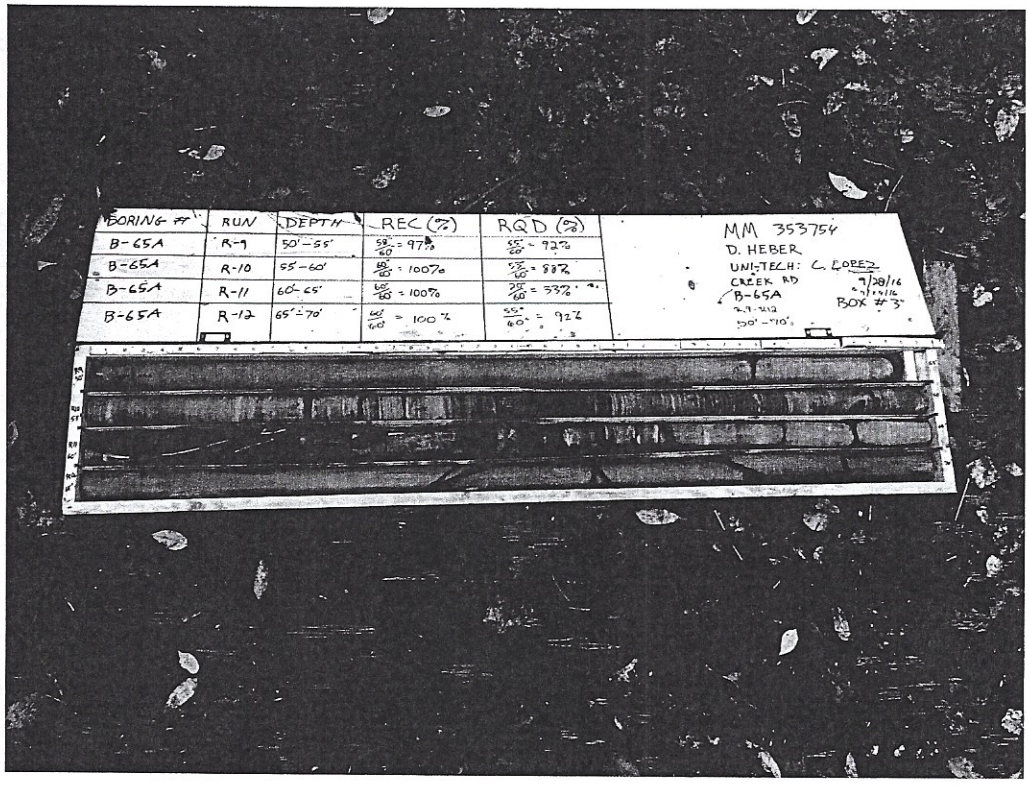


Figure B-65A.5
B-65A Box 3 Runs 9-12 Dry

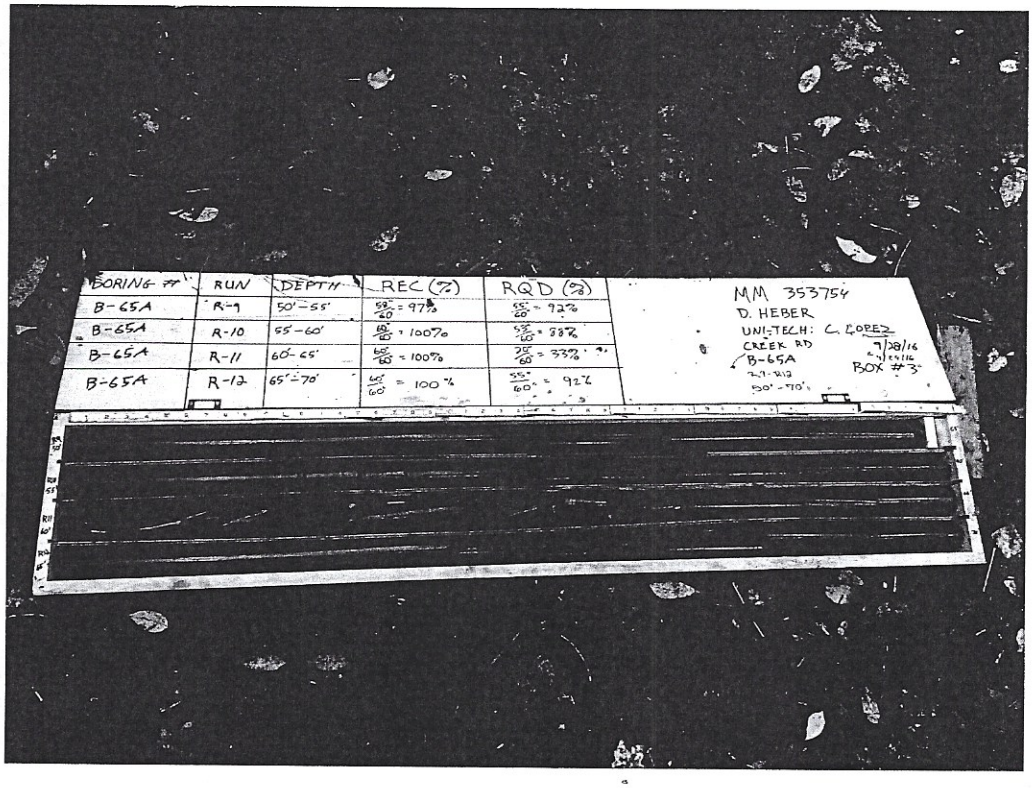


Figure B-65A.6
B-65A Box 3 Runs 9-12 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65A

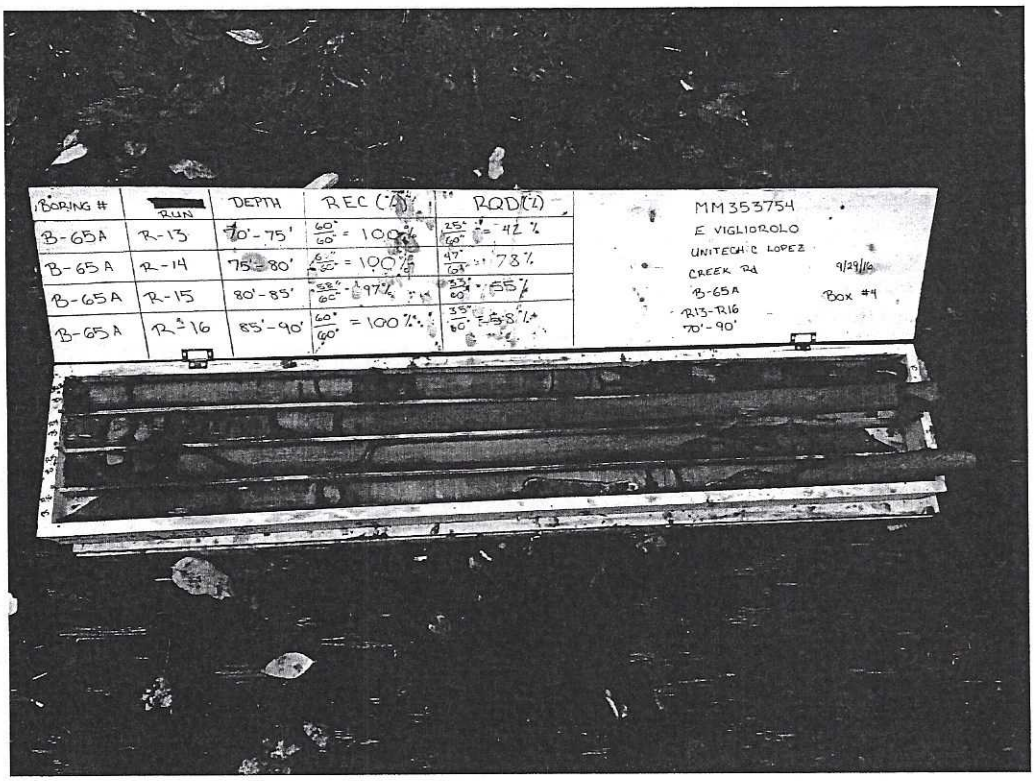


Figure B-65A.7
B-65A Box 4 Runs 13-16 Dry

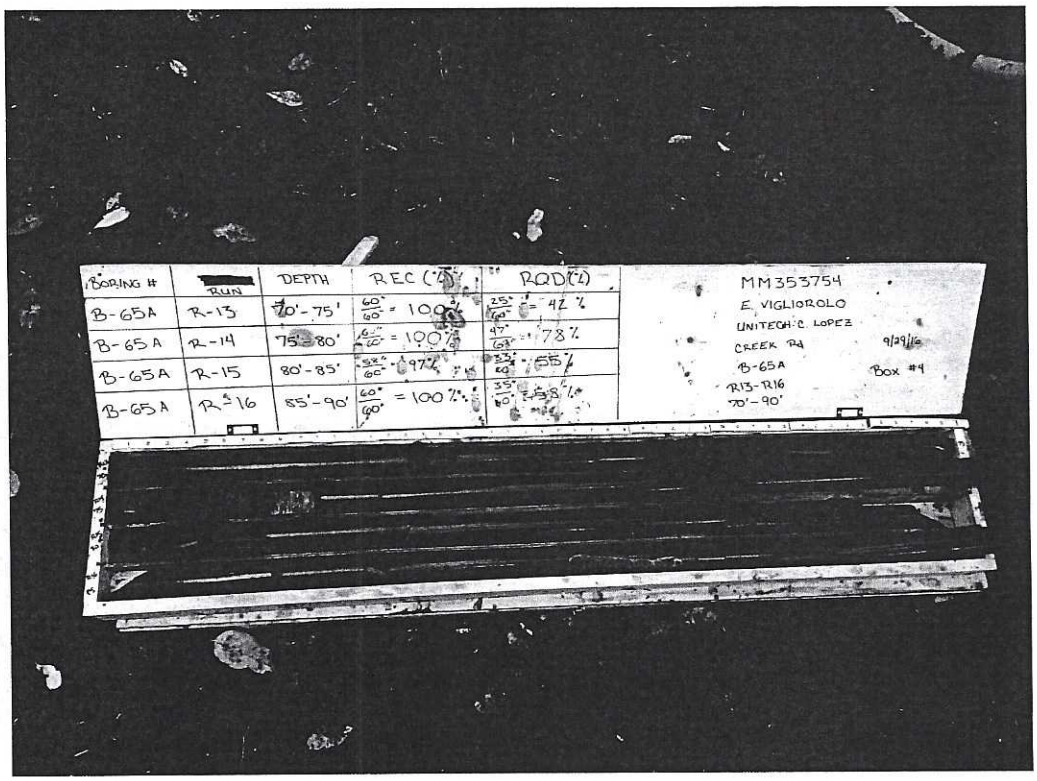


Figure B-65A.8
B-65A Box 4 Runs 13-16 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65A

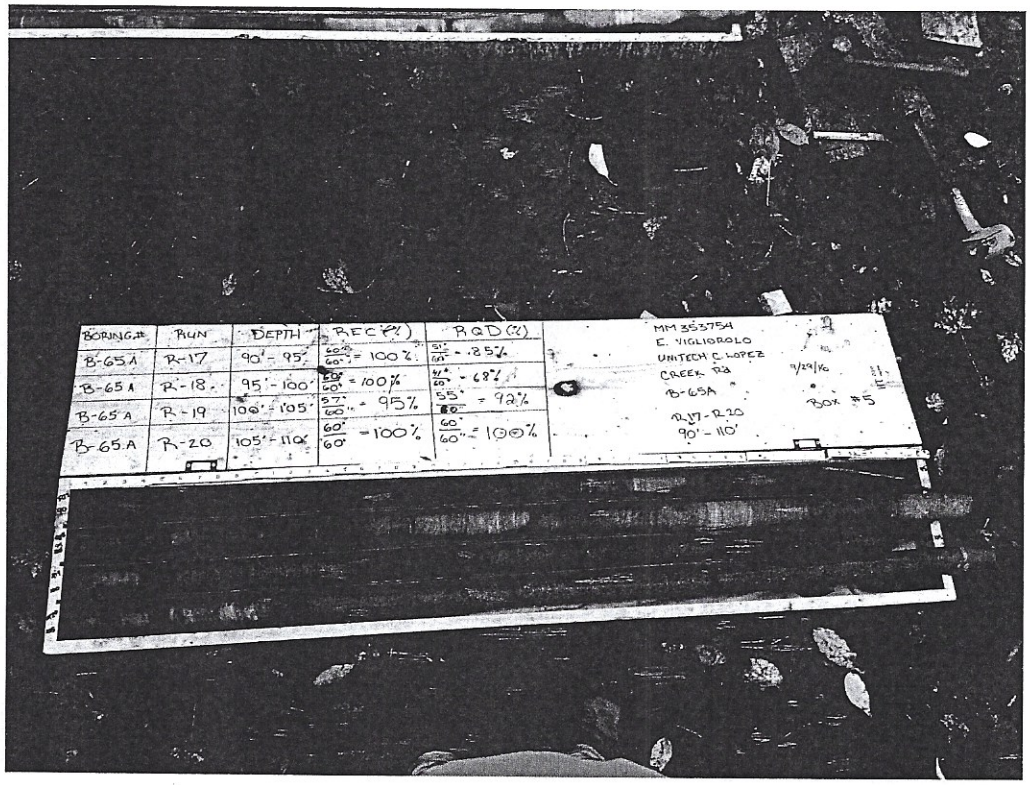


Figure B-65A.9
B-65A Box 5 Runs 17-20 Dry

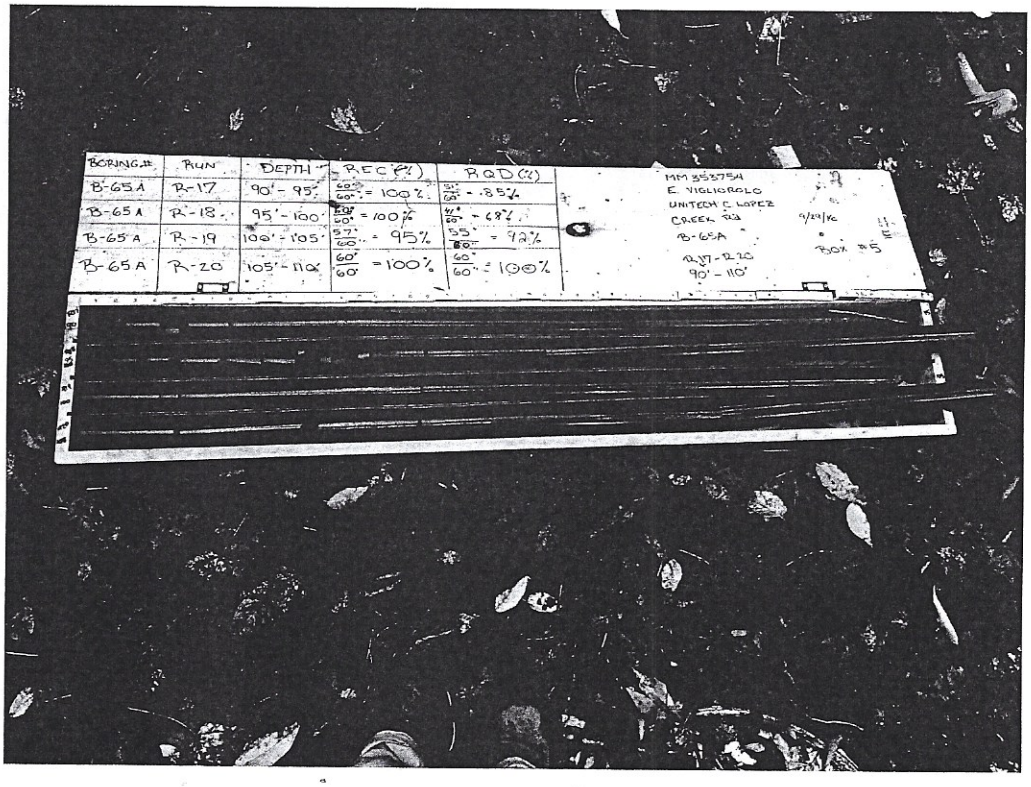


Figure B-65A.10
B-65A Box 5 Runs 17-20 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65A

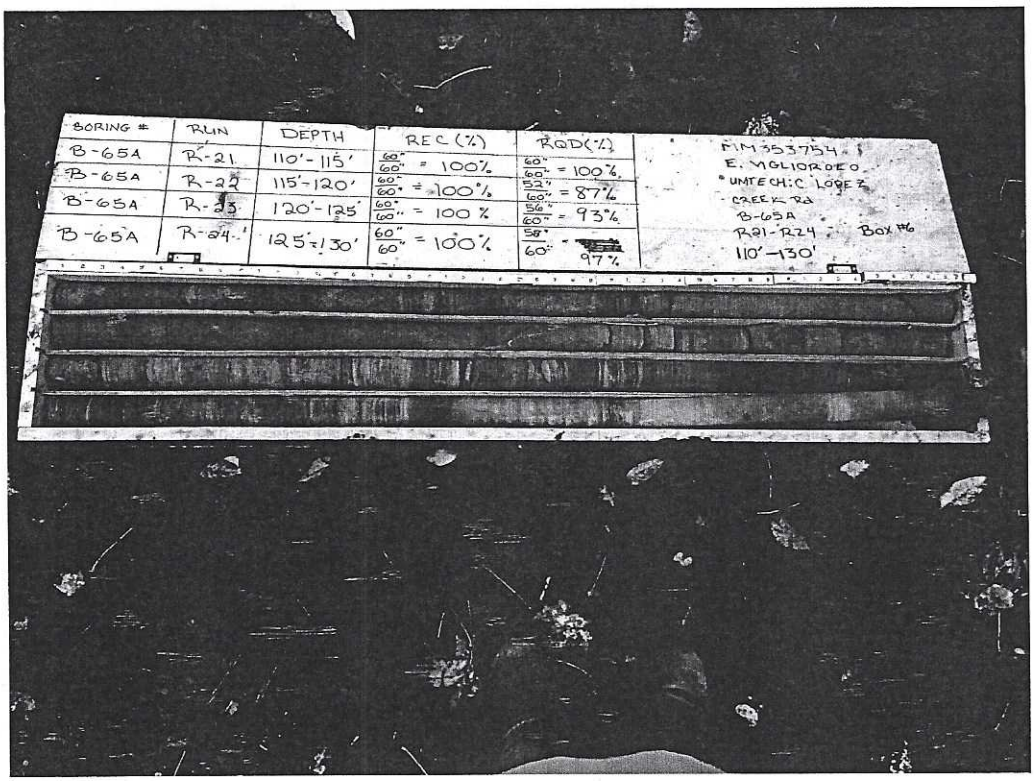


Figure B-65A.11
B-65A Box 6 Runs 21-24 Dry

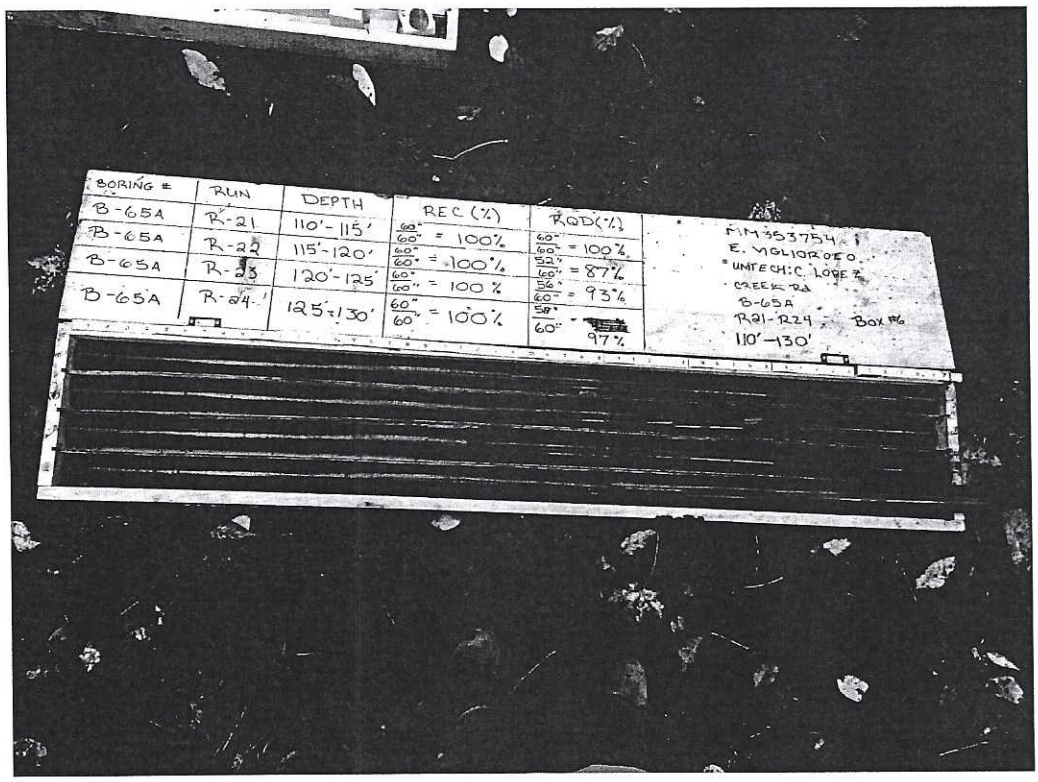


Figure B-65A.12
B-65A Box 6 Runs 21-24 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65A

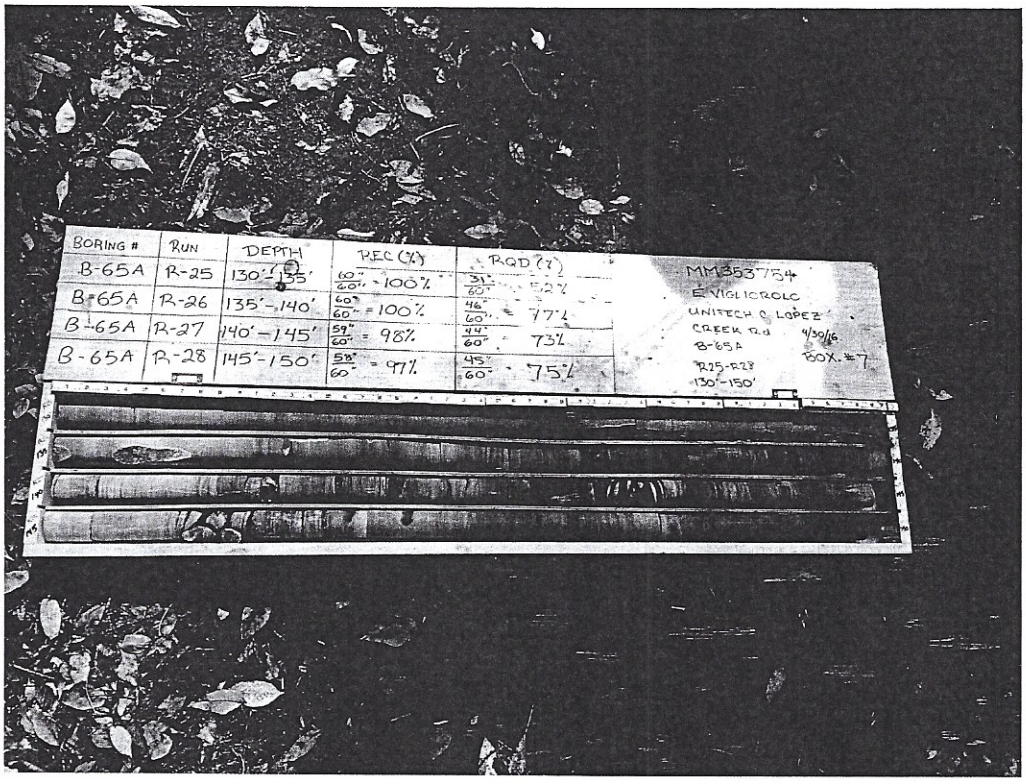


Figure B-65A.13
B-65A Box 7 Runs 25-28 Dry

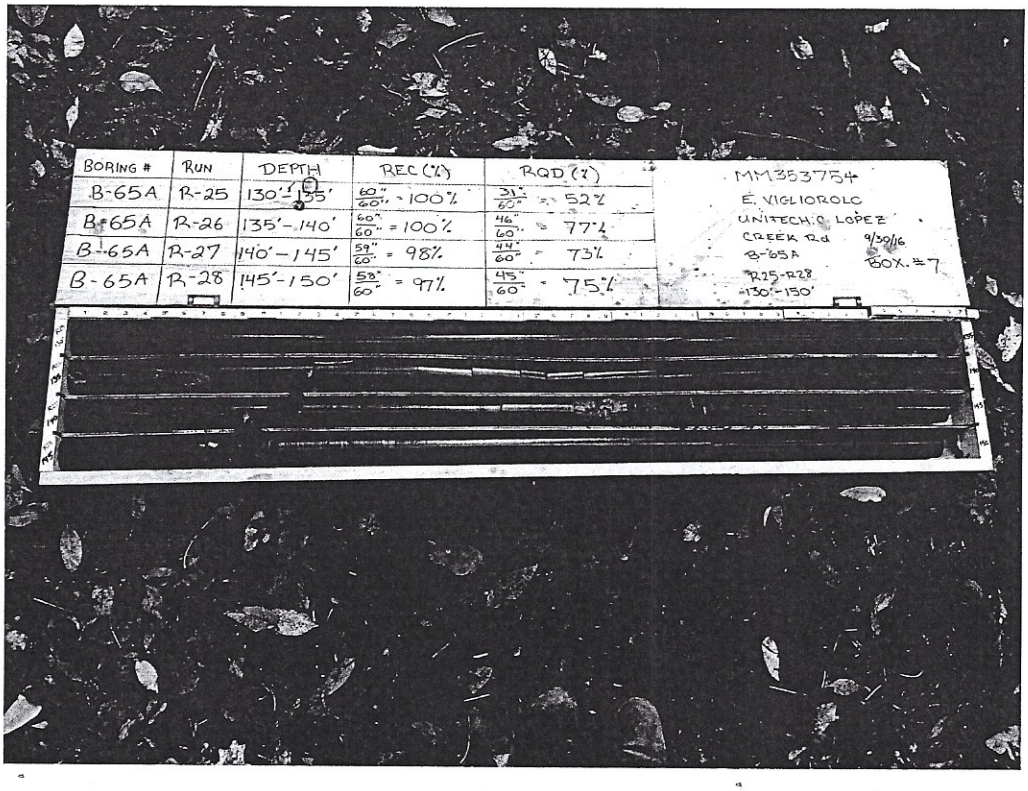


Figure B-65A.14
B-65A Box 7 Runs 25-28 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65A

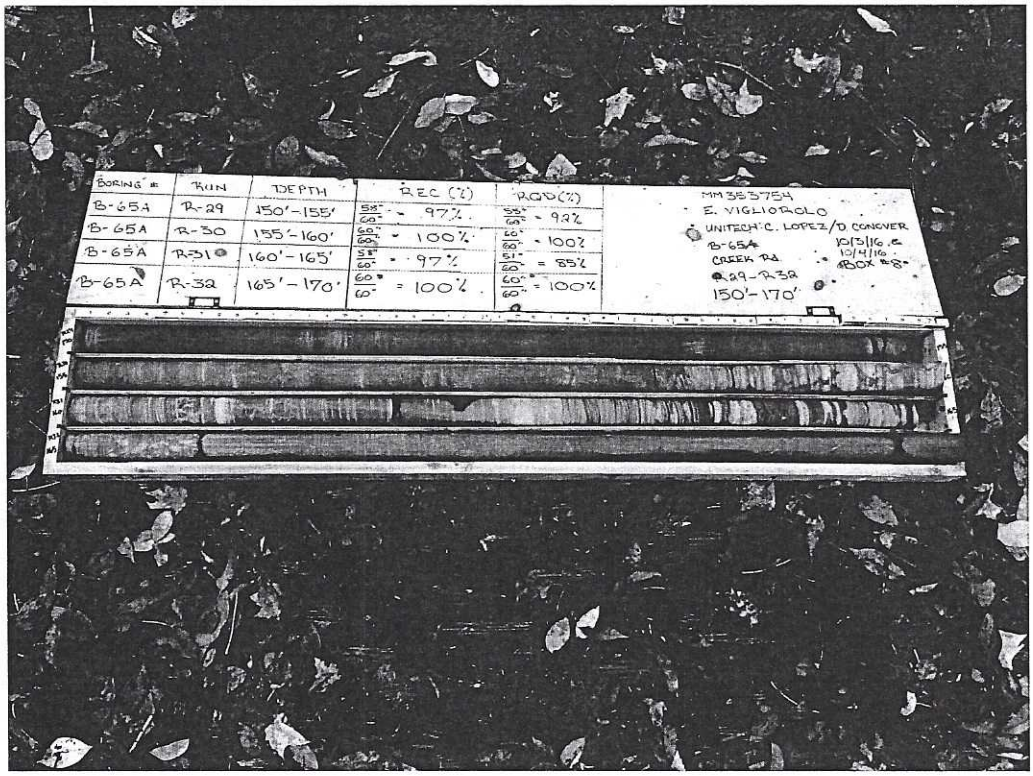


Figure B-65A.15
B-65A Box 8 Runs 29-32 Dry

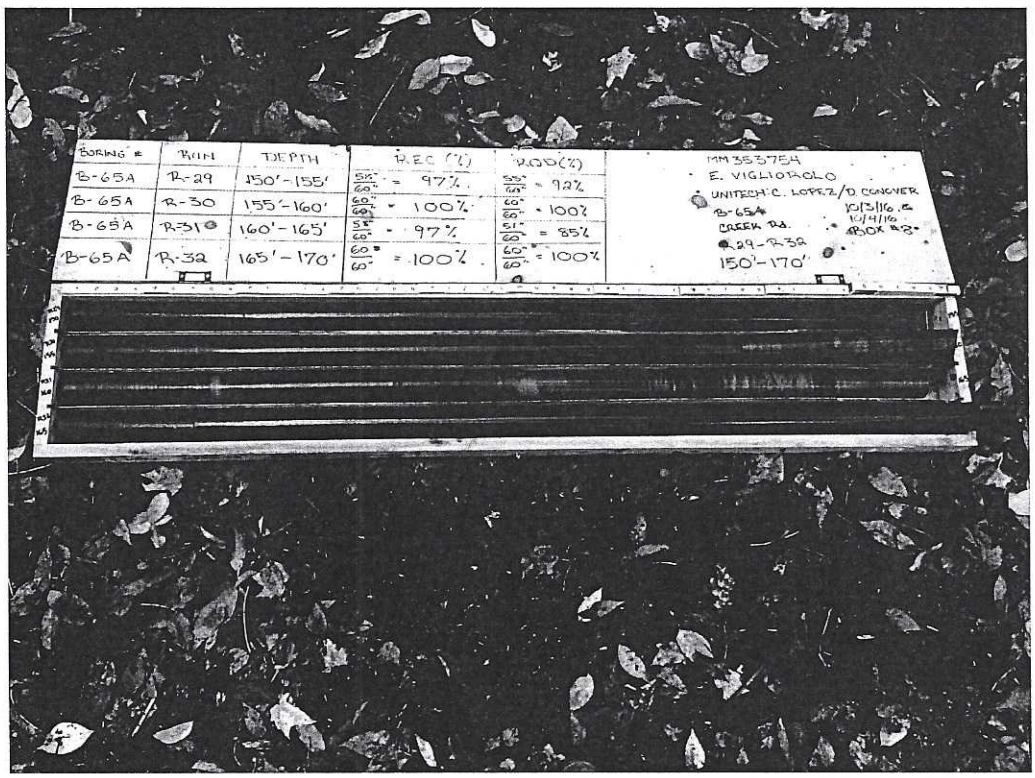


Figure B-65A.16
B-65A Box 8 Runs 29-32 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65A

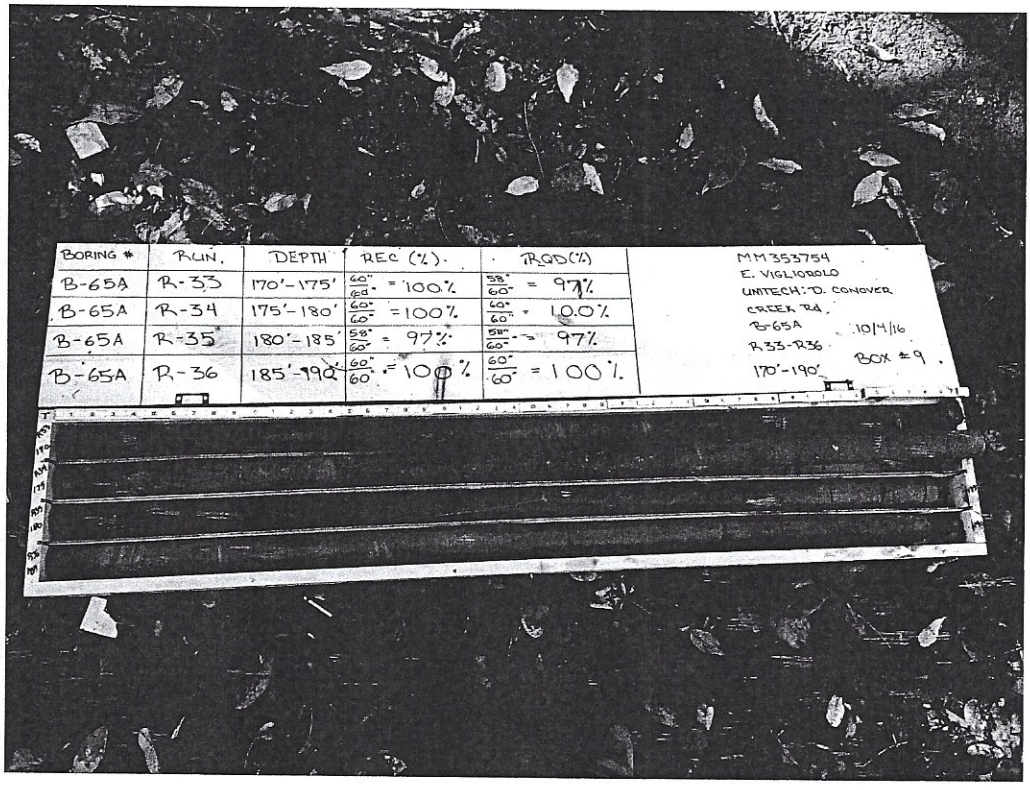


Figure B-65A.17
B-65A Box 9 Runs 33-36 Dry

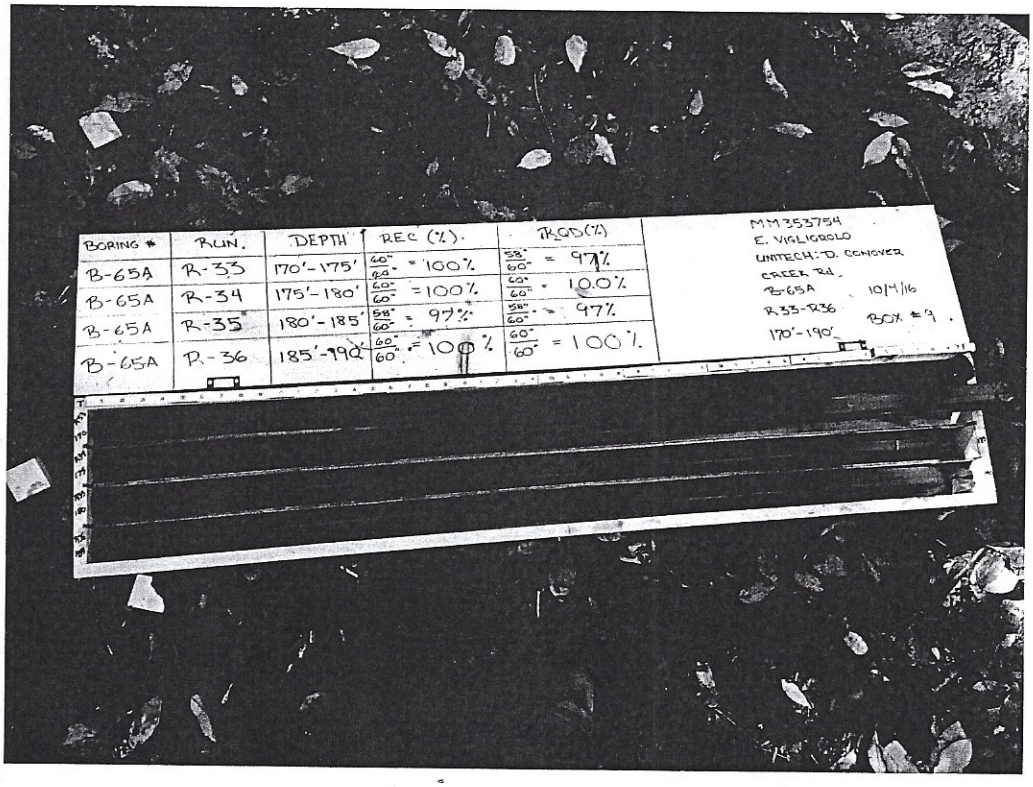


Figure B-65A.18
B-65A Box 9 Runs 33-36 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65A

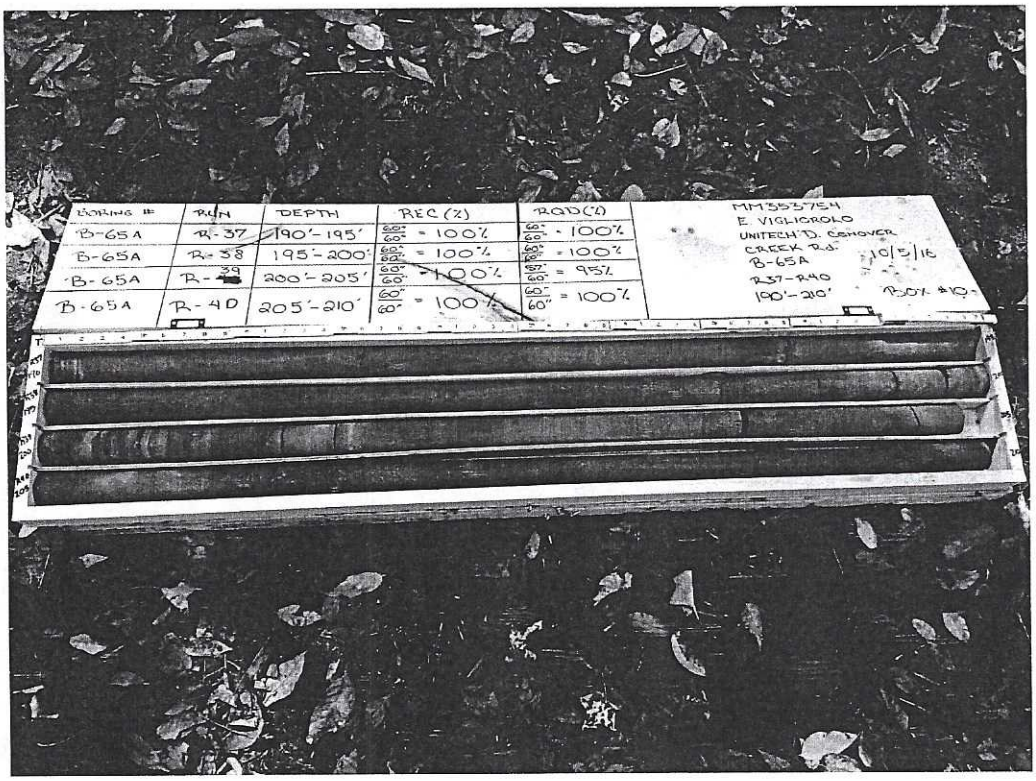


Figure B-65A.19
B-65A Box 10 Runs 37-40 Dry

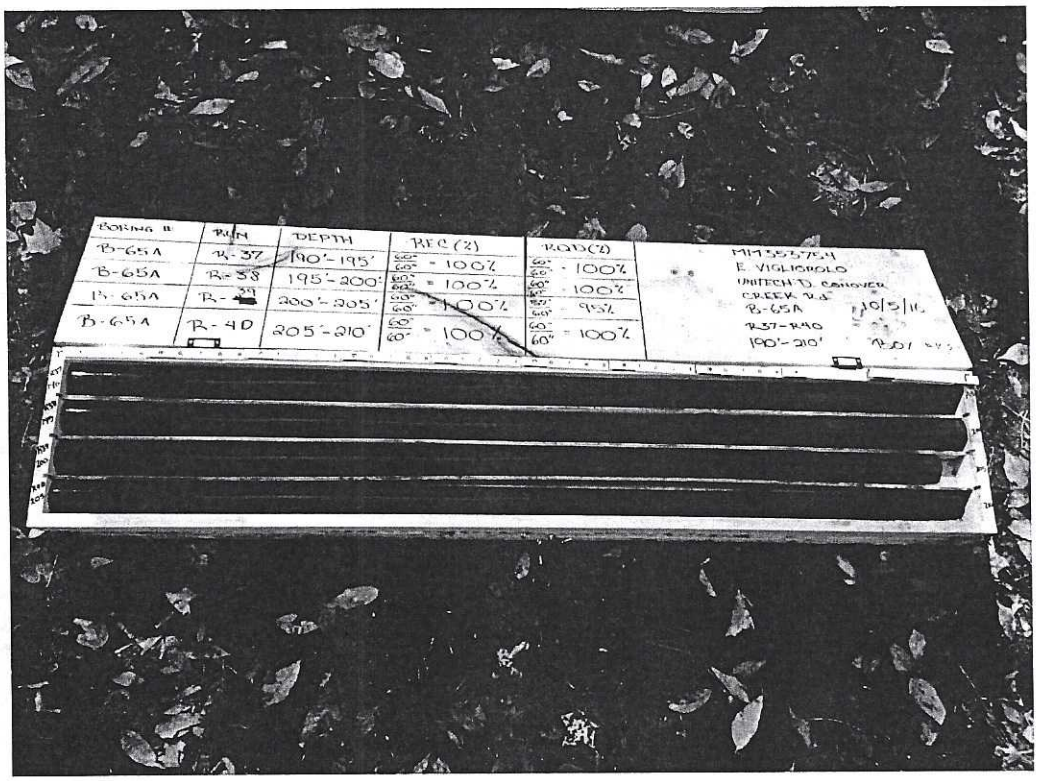


Figure B-65A.20
B-65A Box 10 Runs 37-40 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65A

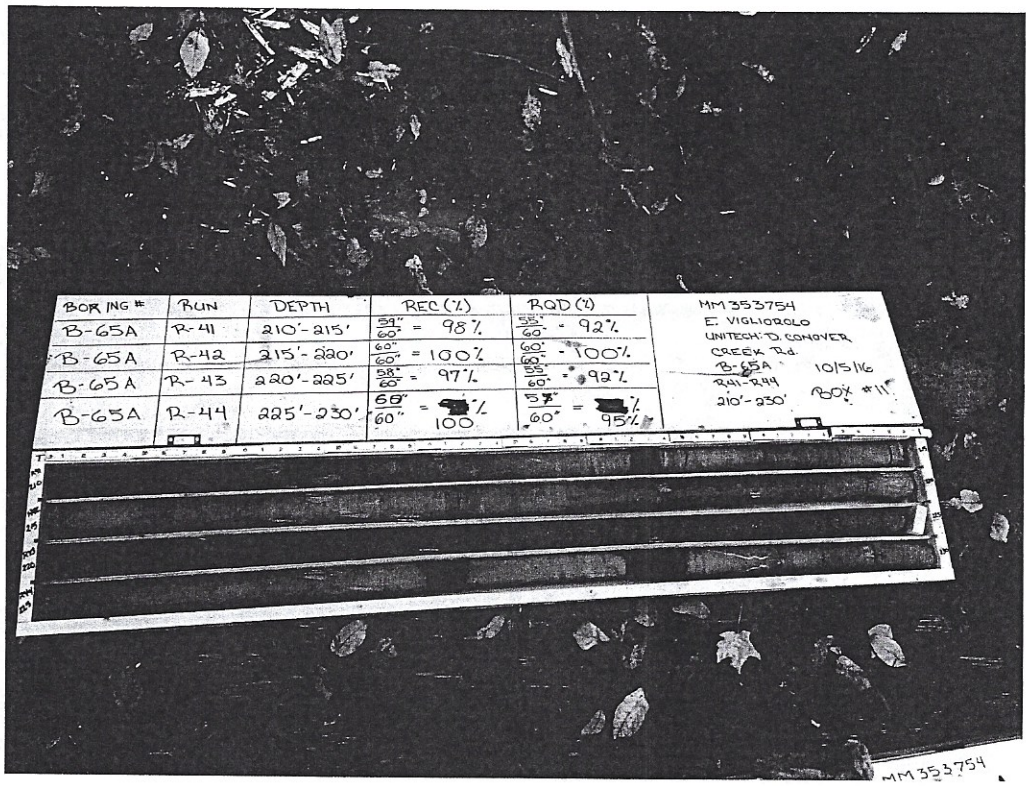


Figure B-65A.21
B-65A Box 11 Runs 41-44 Dry

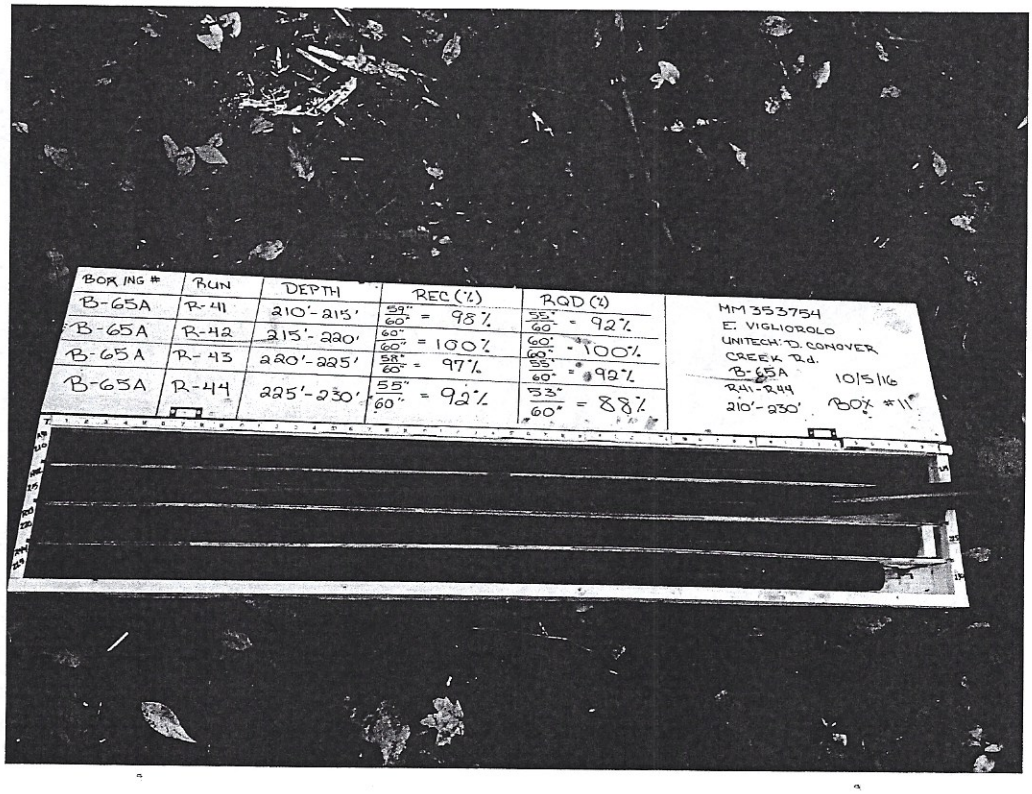


Figure B-65A.22
B-65A Box 11 Runs 41-44 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65A

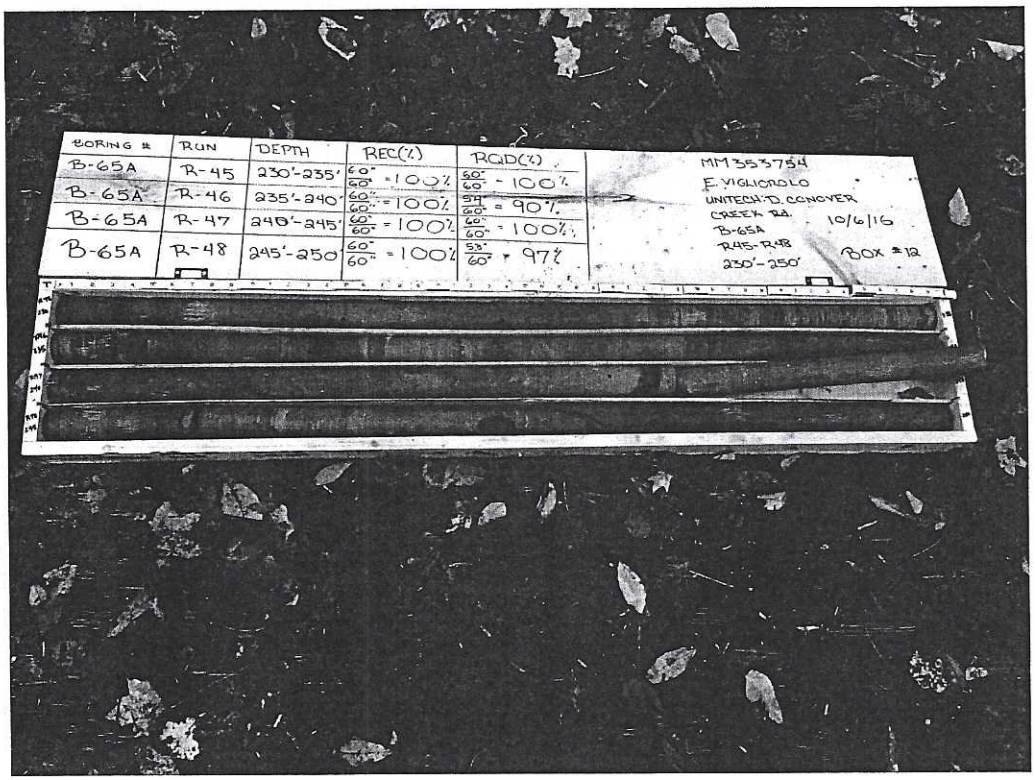


Figure B-65A.23
B-65A Box 12 Runs 45-48 Dry

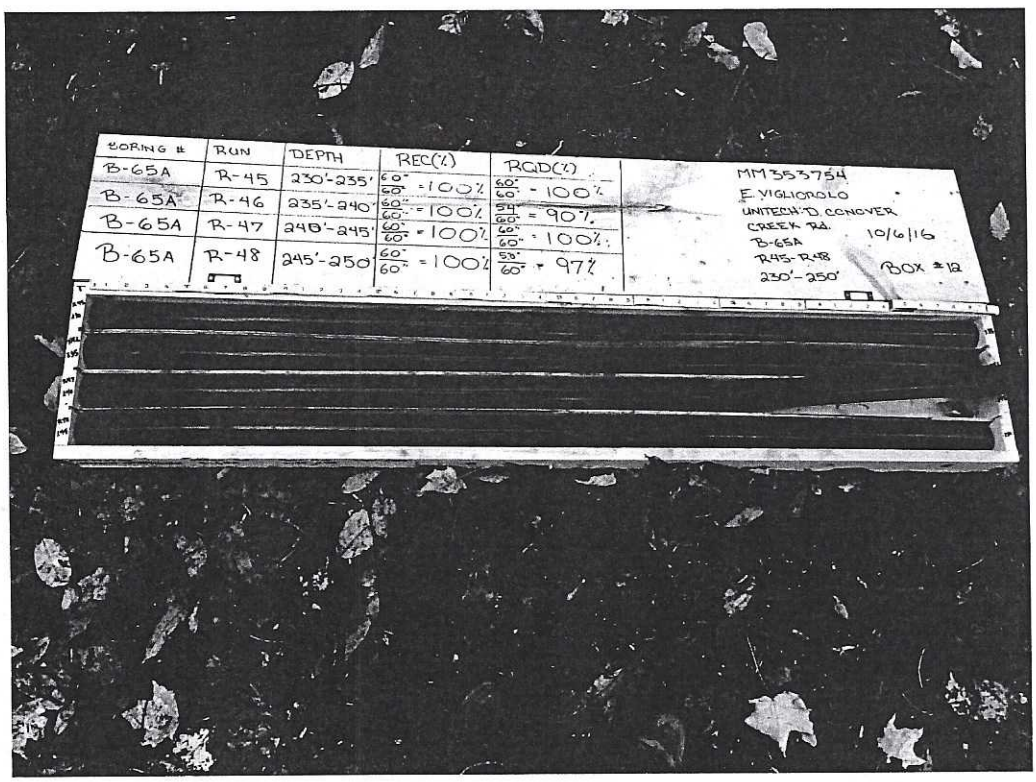


Figure B-65A.24
B-65A Box 12 Runs 45-48 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65A

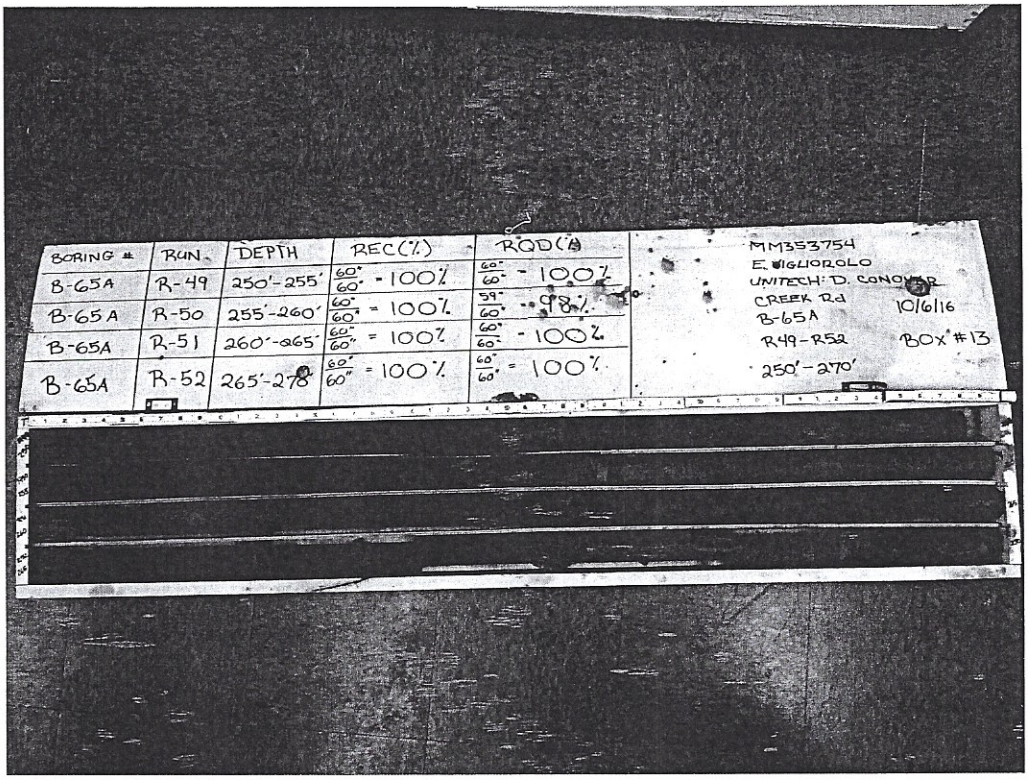


Figure B-65A.25
B-65A Box 13 Runs 49-52 Dry

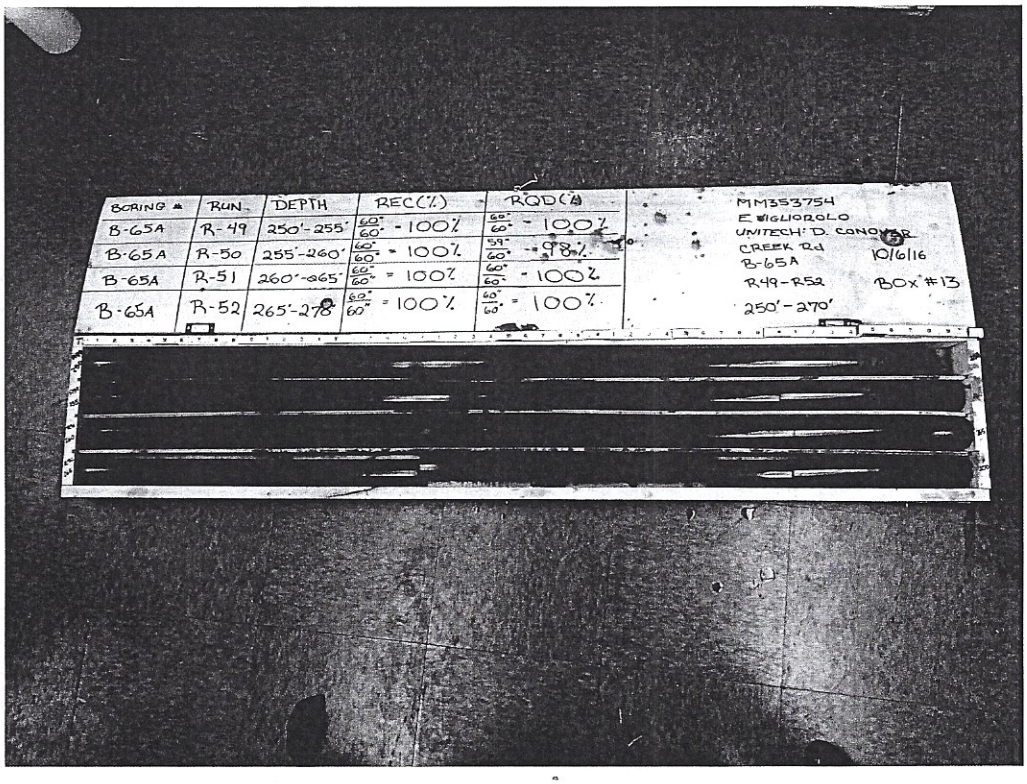


Figure B-65A.26
B-65A Box 13 Runs 49-52 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65A

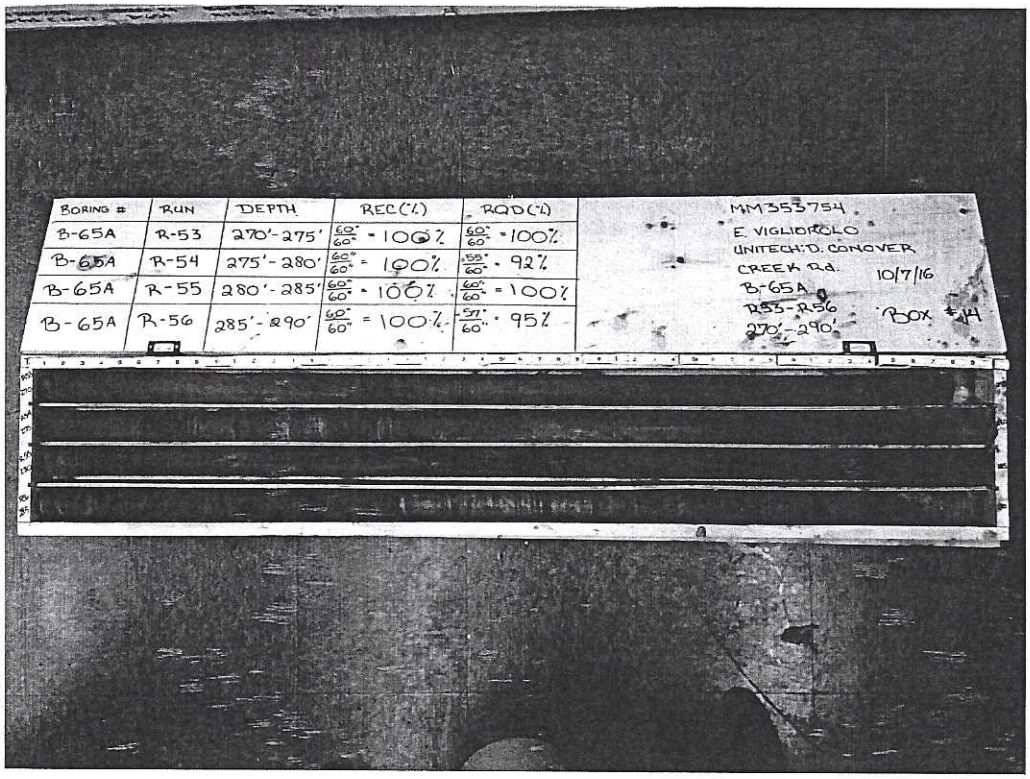


Figure B-65A.27
B-65A Box 14 Runs 53-56 Dry

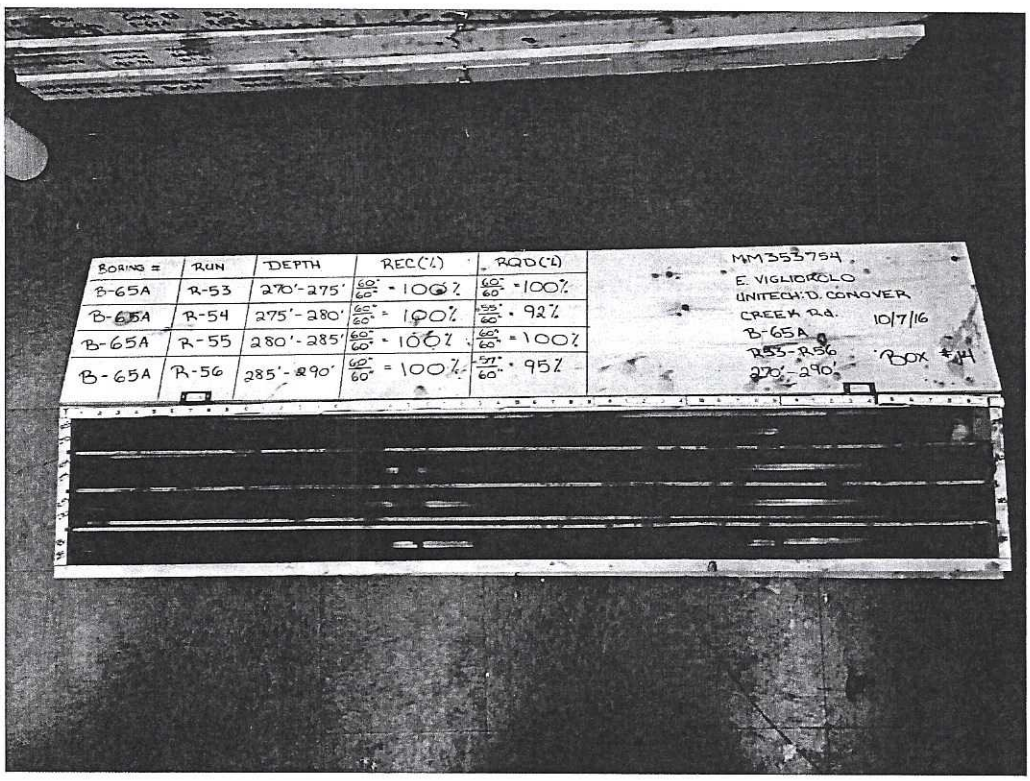


Figure B-65A.28
B-65A Box 14 Runs 53-56 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-65A

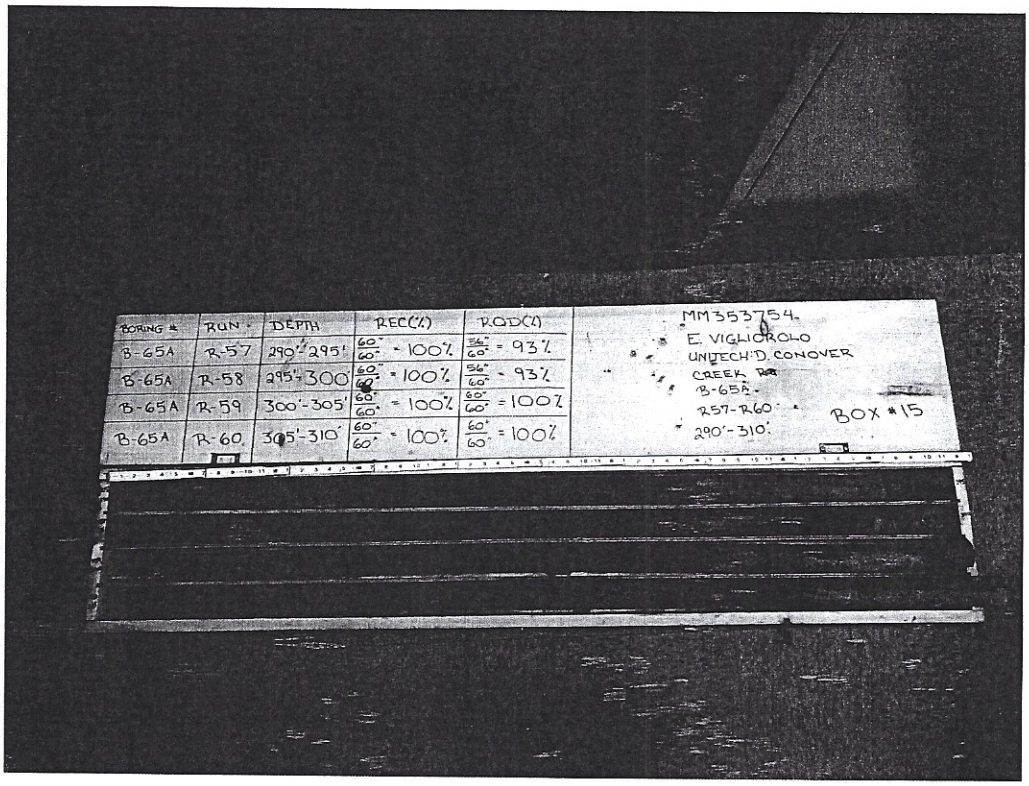


Figure B-65A.29
B-65A Box 15 Runs 57-60 Dry

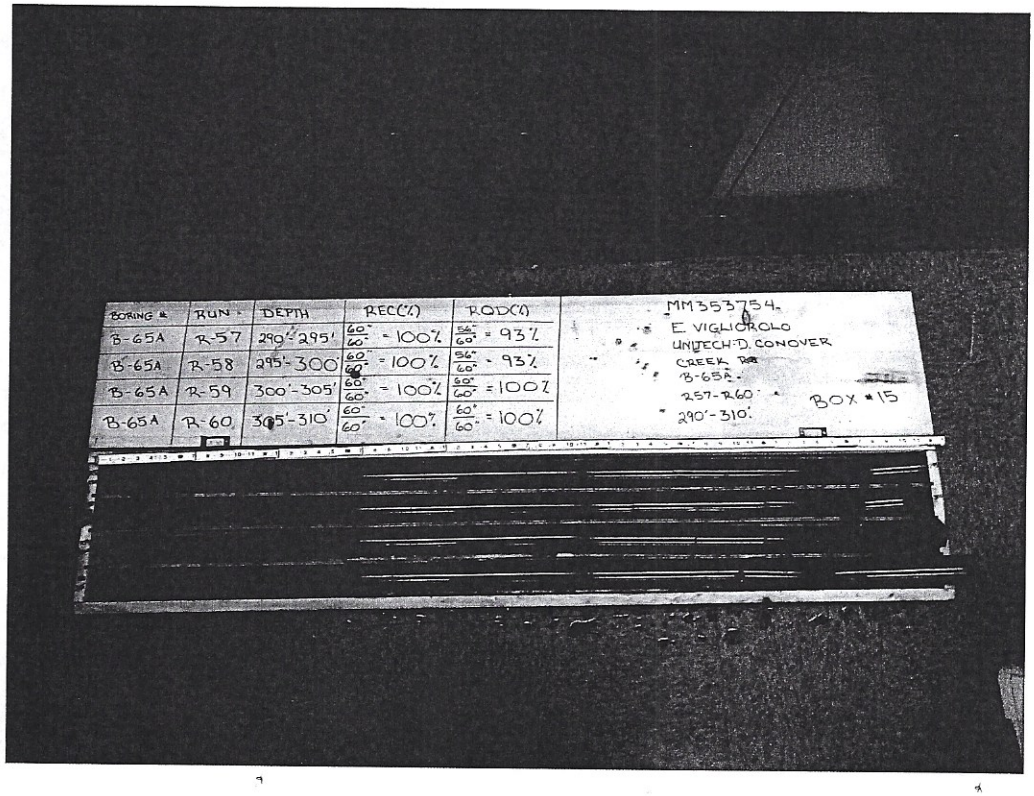


Figure B-65A.30
B-65A Box 15 Runs 57-60 Wet

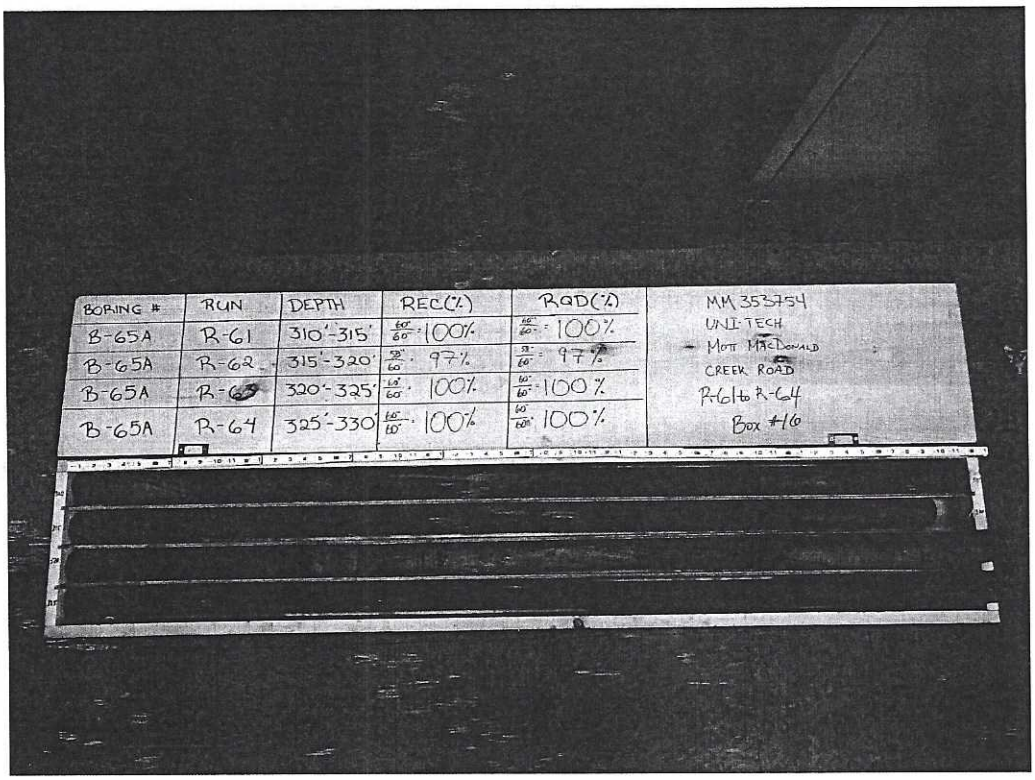


Figure B-65A.31
B-65A Box 16 Runs 61-64 Dry

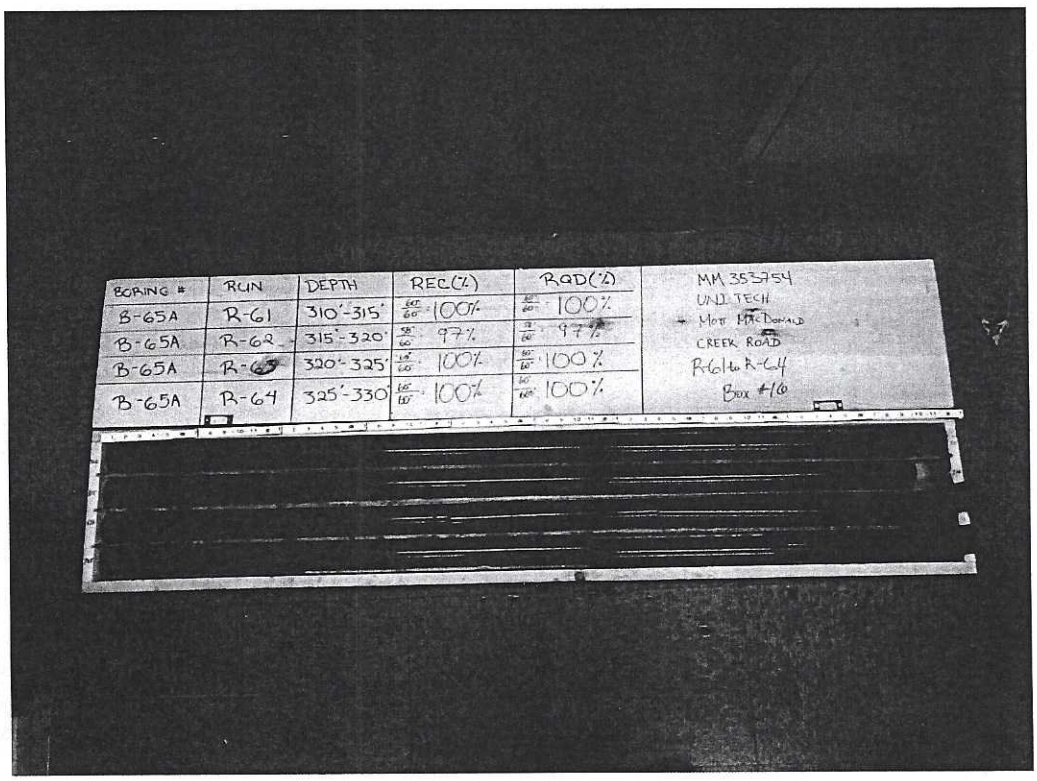


Figure B-65A.32
B-65A Box 16 Runs 61-64 Wet

MOTT MACDONALD	PennEast Pipeline Project	BORING NO.:
	Rock Core Photographs	B-65A

MOTT MACDONALD M M

SOIL BORING LOG

BORING NO.: **B-66**
Page 1 of 1

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Nishisakawick Creek, Hunterdon Co., NJ	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Kyle Hansen
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	February 7, 2019 at 12:45 pm
Driller/Helper:	Nick Beehler / Miles Neipert	**Date/Time Finished:**	February 13, 2019 at 9:15 am

Elevation: 351.6 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** In northern field off Ridge Road **Coord.:** N: **40.532129** E: **-75.044795**
Horizontal Datum: NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HSA	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-55LC

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

Hammer Type

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
350	S-1 0.0'- 2.0'	8	1 50/5"		ML	Hard, brown Clayey SILT with coarse to fine Gravel, trace fine Sand, wet (ML)	-	-	-	-	Decomposed rock in tip of spoon
	2.0'-'						-	-	-	-	Installed 4-inch casing to 2 feet BGS.
▽	3.0'-'					3.5	-	-	-	-	Hard drilling around 3 feet
5	S-2 5.0'- 5.4'	2	50/2"			5.4 Very dense, reddish brown DECOMPOSED ROCK fragments, wet Top of Rock at 5 feet BGS. See Rock Coring Log.	-	-	-	-	Drilled to 5 feet BGS. Permeability: performed permeability falling head test.
340											
10											
15											

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
2/10/19	8:01	-	3.5	15.0	2.95
2/11/19	8:15	-	3.5	75.0	11.65
2/12/19	7:45	-	3.5	145.0	18.65
2/13/19	8:00	-	3.5	205.0	32.93

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-66**

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

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

MOTT MACDONALD M M

CORE BORING LOG

BORING NO.: **B-66**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Nishisakawick Creek, Hunterdon Co., NJ	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Kyle Hansen
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	February 7, 2019 at 12:45 pm
Driller/Helper:	Nick Beehler / Miles Neipert	**Date/Time Finished:**	February 13, 2019 at 9:15 am

Elevation: 351.6 ft. **Vertical Datum:** NAVD 1988

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

Boring Location: In northern field off Ridge Road

Coord.: N: **40.532129** E: **-75.044795**

Horizontal Datum: NAD 1983

Rig Make & Model: CME-55LC

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								
	4.90	5.0							ARGILLITE, reddish brown, fine grained, slightly weathered, medium strong, very close spaced discontinuities 5' - 10' Fractured zone Calcareous inclusions throughout								
	3.30																
	2.50		R-1	60 100%	5 8%	R3	SL			6.90	J	35	S,R	DS	T	N	
	3.00																
	3.00	10.0															
10																	
	3.50	10.0							ARGILLITE with interbedded Shale, reddish brown, very fine grained, moderately weathered, weak, very close to close spaced discontinuities								
340	3.50								11.2' - 12.1' Fractured zone 13.1' - 14.6' Fractured zone	10.80	J	20	U,R	FR	T	N	
	3.95		R-2	54 90%	16 27%	R2	M			12.05	J	20	P,R	FR	T	N	
										12.65	J	10	U,R	DS	T	N	
	3.25																
	4.25	15.0															
15																	
	3.50	15.0							ARGILLITE, reddish brown, fine grained, moderately weathered, weak, very close spaced discontinuities Calcareous inclusions throughout 15.55' - 16.15' Vertical fracture at 90° 16.15' - 16.9' Vertical fracture at 85°								
	3.25																
	3.00		R-3	36 59%	0 0%	R2	M			17.30	J	10	P,R	DS	PO	N	
	5.00																
	6.00	20.0															
20																	
	6.33	20.0							ARGILLITE, reddish brown, fine grained, moderately weathered, weak								21.5' - 22.0' Temporary loss of water every few inches
330	8.25																
	5.00		R-4	4 6%	0 0%	R2	M										
	5.25																
	4.00	25.0															

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
2/10/19	8:01	-	3.5	15.0	3.0
2/11/19	8:15	-	3.5	75.0	11.7
2/12/19	7:45	-	3.5	145.0	18.7
2/13/19	8:00	-	3.5	205.0	32.9

Notes:

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	6.50	25.0							ARGILLITE, reddish brown, fine grained, moderately weathered, weak, very close to moderately spaced discontinuities	25.60	J	10	U,R	FR	O	N	
	6.25								26' - 28.2' Fractured Zone								
	5.50		R-5	60 100%	26 43%	R2	M			28.15	J	10	P,Sm	FR	T	N	
	5.33									28.50	J	5	P,R	DS	T	N	
	4.25	30.0								29.45	J	10	P,Sm	FR	PO	N	
30	4.75	30.0							ARGILLITE, reddish brown, fine grained, fresh, weak to medium strong, wide spaced discontinuities	30.11	J	15	S,R	FR	T	N	
	5.00								Calcareous inclusions throughout	31.35	J	20	P,Sm	FR	T	N	
320	4.25		R-6	60 100%	60 100%	R3	FR										
	4.00																
	3.75	35.0								34.55	J	10	P,Sm	FR	T	N	
35	4.25	35.0							ARGILLITE with interbedded Shale, reddish brown, very fine grained, fresh, medium strong, moderately spaced discontinuities	35.65	J	20	P,R	FR	T	N	
	4.50								Calcareous inclusions throughout								
	4.75		R-7	59 98%	57 94%	R3	FR			37.10	J	10	U,R	FR	T	N	
	4.00									37.90	B	5	U,Sm	FR	T	N	
	4.50	40.0								39.15	B	5	P,Sm	FR	T	N	
40	4.50	40.0								39.38	J	10	P,Sm	FR	O	N	
	4.00								ARGILLITE with interbedded Shale, gray to reddish brown, very fine grained, fresh, weak to medium strong, moderate to wide spaced discontinuities	40.50	J	10	P,Sm	FR	T	Ca	
310	4.25		R-8	60 100%	50 83%	R3	FR		Calcareous inclusions throughout	41.23	J	5	P,Sm	FR	VT	N	
	3.50								41.75' - 42.25' 70° Calcite vein	43.40	J	10	P,Sm	FR	VT	N	
	4.00	45.0								44.45	J	10	S,R	FR	T	N	
45	4.25	45.0							45.0 SHALE, reddish brown, very fine grained, fresh, medium strong to strong, moderately spaced discontinuities	45.90	J	10	P,Sm	FR	T	N	
	4.75								Calcareous inclusions throughout	46.00	J	60	S,R	FR	T	N	
	3.50		R-9	60 100%	50 83%	R4	FR			46.90	J	5	S,R	FR	T	N	
	4.50									48.20	J	10	P,Sm	FR	T	N	
	4.75	50.0							50.0	48.95	J	5	P,Sm	FR	T	N	

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.50	50.0							ARGILLITE with interbedded Shale, reddish brown, very fine grained, fresh, strong, wide spaced discontinuities								
300	3.50																
	4.00		R-10	60 99%	60 99%	R4	FR			52.43	J	50	S,R	FR	T	N	
	4.25																
	3.00									53.94	J	10	U,Sm	FR	T	N	
		55.0								54.55	J	5	U,R	FR	T	N	
55									55.0								
	3.50	55.0							SILTSTONE, reddish brown to gray, very fine grained, fresh, strong, moderate to wide spaced discontinuities	55.27	J	0	U,R	FR	T	N	
	3.33									56.10	J	5	P,Sm	FR	T	N	
	3.25		R-11	60 100%	57 95%	R4	FR										
	4.50																
	3.25																
60		60.0								59.68	J	10	S,R	FR	T	N	
	3.00	60.0							SILTSTONE with interbedded Shale, dark gray to gray, medium strong to strong, fresh, moderate to close spacing Calcareous inclusions throughout 60.32' - 60.95' Vertical fracture from Calcite vein with quartz infill 62.15' - 64.7' Highly fractured zone	61.07	J	5	P,R	FR	T	N	Calcite veins throughout
290	3.25									61.75	J	5	P,Sm	FR	T	N	
	4.50		R-12	58 97%	13 22%	R4	SL										
	3.50																
	9.00																
65		65.0							65.0								
	3.75	65.0							SHALE, gray to dark gray, very fine grained, fresh, medium strong to strong, very close to moderately spaced discontinuities 66.2' - 68' Calcite vein								
	3.00																
	3.00		R-13	60 99%	30 50%	R4	FR			67.55	J	5	P,Sm	DS	T	N	Groundwater color change at 67 feet to brown
	3.00									68.67	J	5	P,Sm	FR	T	N	
	3.50									69.32	J	8	U,Sm	DS	T	N	
70		70.0							70.0								
	3.25	70.0							SILTSTONE, dark gray to gray, fine grained, fresh, medium strong, moderate to wide spaced discontinuities	70.75	J	15	P,Sm	DS	T	N	
280	4.25									71.05	J	10	S,R	DS	O	N	
	3.25		R-14	60 100%	51 85%	R3	FR			71.82	J	20	U,Sm	DS	T	N	
	3.00																
	4.00	75.0							75.0								

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-66**

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	4.00	75.0							ARGILLITE, reddish brown to gray, very fine to fine grained, fresh, strong, wide spaced discontinuities	75.35	J	5	S,R	FR	PO	N	
										75.70	J	5	U,R	FR	T	N	
	4.00																
	4.25		R-15	60 99%	56 93%	R4	FR										
	3.50																
										78.70	J	55	U,R	FR	T	N	
	4.00	80.0															
80																	
	3.50	80.0							ARGILLITE, reddish brown to dark gray, fine grained, fresh, strong, wide spaced discontinuities								5 foot run.
	3.50								Calcareous inclusions throughout								
270																	
	4.00		R-16	59 98%	59 98%	R4	FR										
	3.50																
	3.50	85.0															
85									85.0								
	4.25	85.0							SHALE, gray to dark gray, very fine grained, fresh, weak to medium strong, wide spaced discontinuities	85.05	J	5	U,R	FR	PO	N	
	3.25								Calcareous inclusions throughout								
	4.00		R-17	60 100%	58 97%	R3	FR			87.56	J	5	P,Sm	DS	PO	Fe	
	4.00																
	4.00	90.0								89.38	J	10	P,Sm	FR	T	N	
90																	
	4.00	90.0							SHALE, dark gray to gray, very fine grained, fresh, weak to medium strong, wide spaced discontinuities	90.14	J	10	S,R	FR	O	N	
	3.75								Calcareous inclusions throughout								
260																	
	4.00		R-18	60 100%	56 93%	R3	FR										
	3.75																
										93.80	J	5	P,Sm	FR	PO	N	
	4.00	95.0								94.03	J	10	S,R	FR	PO	N	
95									95.0								
	3.50	95.0							ARGILLITE, gray to reddish brown, fine grained, fresh, strong, wide spaced discontinuities	95.33	J	0	P,R	FR	T	N	
	3.50																
	3.50		R-19	60 99%	60 99%	R4	FR										
										97.65	J	0	U,R	FR	T	N	
	3.75																
	3.75	100.0															

NOTES:

PROJECT NO.: 353754

Boring No.: B-66

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	100.0							ARGILLITE with interbedded Shale, reddish brown, fine to very fine grained, fresh, medium strong to strong, moderate to wide spaced discontinuities	100.32	J	15	U,Sm	FR	T	N	
250	3.50								Calcareous inclusions throughout								
	3.25		R-20	60 100%	56 93%	R4	FR										
	3.75									103.00	J	60	S,R	FR	T	N	
	3.25	105.0								103.85	J	5	P,R	FR	PO	N	
105									105.0								
	3.25	105.0							SHALE, reddish brown, very fine grained, fresh, weak to medium strong, moderately spaced discontinuities	105.30	J	5	S,Sm	FR	T	N	
										105.83	J	5	P,Sm	FR	T	N	
	4.00								106.4								
	4.25		R-21	60 100%	57 94%	R3	FR		ARGILLITE, reddish brown, fine grained, fresh, medium strong to strong, wide spaced discontinuities Calcareous inclusions throughout 106.9' - 107.4' Calcite vein	107.15	V	75	P,R	DS	O	QZ	/FE
	3.00																
	3.50	110.0															
110																	
	3.75	110.0							ARGILLITE, reddish brown, fine grained, fresh, strong, wide spaced discontinuities Calcareous inclusions throughout	110.34	J	20	S,R	FR	W	N	
240	4.00																
	3.50		R-22	60 100%	57 94%	R4	FR										
	4.00																
	3.42	115.0								114.60	J	0	P,R	FR	T	N	
115																	
	3.00	115.0							ARGILLITE, reddish brown, fine grained, fresh to slightly weathered, medium strong to strong, close to wide spaced discontinuities Calcareous inclusions throughout	115.16	J	5	P,Sm	FR	PO	N	
	4.00									116.21	J	5	P,R	FR	T	N	
	4.25		R-23	60 100%	48 80%	R4	SL										
	3.25																
	2.75	120.0								118.73	J	45	P,R	FR	T	N	
120																	
	3.75	120.0							ARGILLITE, reddish brown, fresh to slightly weathered, medium strong to strong, close to moderately spaced discontinuities	120.78	J	10	P,Sm	FR	T	N	
									121.1' - 122.3' Calcite vein	121.01	J	0	P,Sm	FR	T	N	
230	3.25																
	3.00		R-24	60 99%	49 81%	R3	SL										
										122.90	J	0	P,Sm	FR	T	N	
	2.75								123.1' - 123.6' Calcite vein	123.35	V	75	P,R	FR	T	Ca	
	2.50	125.0								124.20	J	15	P,R	FR	PO	N	

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	2.00	125.0							ARGILLITE, reddish brown, fine grained, fresh, strong, moderate to wide spaced discontinuities Calcareous inclusions throughout								
	3.25									126.38	J	10	U,R	FR	T	N	
	2.50		R-25	57 94%	53 88%	R4	FR			127.05 127.30	J J	0 10	P,Sm S,Sm	FR FR	T T	N N	
	3.50									128.25	J	15	P,R	FR	T	N	
	2.50	130.0								129.05	J	10	P,R	FR	T	N	
130	3.75	130.0							ARGILLITE, reddish brown, fine grained, fresh, strong, wide spaced discontinuities Calcareous inclusions throughout								
220	2.75																
	2.75		R-26	59 98%	58 97%	R4	FR										
	3.50																
	3.25	135.0															
135	2.50	135.0							ARGILLITE, reddish brown, fine grained, fresh, strong, wide spaced discontinuities Calcareous inclusions throughout	134.85	J	5	P,R	FR	T	N	
	3.25																
	3.00		R-27	59 98%	55 91%	R4	FR										
	2.75																
	3.50	140.0								139.55	J	5	P,R	FR	T	N	
140	2.50	140.0							ARGILLITE, reddish brown, fine grained, fresh, strong, wide spaced discontinuities Calcareous inclusions throughout								
210	2.50																
	2.75		R-28	60 100%	57 94%	R4	FR										
	3.25									143.40	J	5	U,Sm	FR	T	N	
	1.75	145.0								143.85	J	10	P,R	FR	T	N	
145	3.00	145.0							ARGILLITE, reddish brown, fine grained, fresh, medium strong to strong, wide spaced discontinuities Calcareous inclusions throughout	144.70	J	20	P,R	FR	T	N	
	4.00																
	3.75		R-29	57 94%	56 93%	R4	FR										
	4.00																
	3.00	150.0								149.14	J	5	P,Sm	FR	VT	N	
										149.67	J	5	P,R	FR	T	N	

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-66**

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00	150.0							ARGILLITE, reddish brown, fine to very fine grained, fresh, medium strong to strong, wide spaced discontinuities								
200	3.25									151.65	J	5	P,Sm	FR	T	N	
										151.87	J	10	P,Sm	FR	T	N	
	2.75		R-30	60 100%	55 92%	R4	FR		152.6								
									SHALE, dark gray, very fine grained, fresh, weak to medium strong, close to moderately spaced discontinuities Calcareous inclusions throughout	153.15	J	5	P,Sm	FR	T	Ca	
	3.50									154.18	J	15	U,Sm	FR	T	Ca	
	3.50	155.0															
155		155.0							SHALE, dark gray to gray, very fine grained, fresh, weak to medium strong, wide spaced discontinuities								
	3.00																
	3.75																
	4.00		R-31	58 97%	55 91%	R4	FR										
									158.0								
	2.25								SILTSTONE, gray, fine grained, fresh, medium strong to strong, close to moderately spaced discontiuities 158' - 160' Calcareous inclusions	158.00	J	10	P,Sm	FR	T	N	
										158.33	J	10	U,R	FR	T	N	
	2.50	160.0								159.35	J	10	P,R	FR	T	N	
160		160.0							160.0								
	2.75								ARGILLITE, grayish to reddish brown, fine grained, fresh, strong, wide spaced discontinuities Calcareous inclusions throughout								
190	2.50																
	2.75		R-32	59 98%	59 98%	R4	FR										
	3.25																
	2.50	165.0															
165		165.0							165.0								
	2.50								SHALE, gray to dark gray, very fine grained, fresh, medium strong, close to wide spaced discontinuities Calcareous inclusions throughout								
	2.75																
	2.50		R-33	60 100%	59 98%	R3	FR										
	2.25									168.30	J	15	U,Sm	FR	T	N	
										169.00	J	5	P,Sm	FR	T	N	
	2.50	170.0								169.36	J	5	P,Sm	FR	T	N	
170		170.0								169.85	J	10	P,Sm	FR	T	N	
	2.50								SHALE, gray to dark gray, very fine grained, fresh, medium strong, very close to moderately spaced discontinuities Calcareous inclusions throughout 174.16' - 175' Fractured zone	170.03	J	10	P,Sm	FR	T	N	
										170.72	J	10	P,Sm	FR	T	N	
180	2.75									171.63	J	10	P,Sm	FR	T	N	
	3.25		R-34	59 98%	43 71%	R3	FR										
										173.01	J	10	U,Sm	FR	T	N	
	2.50									173.40	J	5	P,Sm	FR	T	N	
										173.80	J	10	P,Sm	FR	T	N	
	3.00	175.0							175.0								

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
	2.50	175.0							ARGILLITE with interbedded Shale, dark gray to reddish brown, fine to very fine grained, fresh, medium strong to strong, wide spaced discontinuities	175.10	J	5	P,R	FR	T	N	
	3.25								Calcareous inclusions throughout	176.10	J	5	U,Sm	FR	VT	N	
	3.00		R-35	60 100%	57 94%	R4	FR										
	3.00									178.26	J	5	U,R	DS	O	N	
	4.00	180.0															
180	3.25	180.0							ARGILLITE, reddish brown, fine grained, fresh, strong, wide spaced discontinuities								5 foot run.
									Calcareous inclusions throughout								
170	2.50																
	3.75		R-36	60 100%	60 100%	R4	FR										
	3.00																
	3.50	185.0															
185	3.25	185.0							ARGILLITE, reddish brown, very fine grained, fresh, medium strong to strong, wide spaced discontinuities								
									Calcareous inclusions throughout								
	2.50																
	3.50		R-37	60 100%	60 100%	R4	FR										
	3.25									188.50	J	5	P,R	FR	T	N	
	3.25	190.0															
190									190.0								
	3.50	190.0							SHALE, gray to dark gray, very fine grained, fresh, weak to medium strong, wide spaced discontinuities								
									Calcareous inclusions throughout	190.53	J	20	U,R	FR	T	N	
160	2.50									191.23	J	15	P,Sm	FR	T	N	
	4.00		R-38	60 100%	57 94%	R3	FR										
	3.00																
	3.00	195.0								194.65	J	5	U,Sm	FR	O	N	
195	2.25	195.0							SHALE, gray, very fine grained, fresh, medium strong to strong, close to moderately spaced discontinuities								
	3.25								196.5	196.34	J	5	U,Sm	FR	T	N	
	2.25		R-39	60 100%	60 100%	R4	FR		ARGILLITE, reddish brown, fine grained, fresh, medium strong to strong, wide spaced discontinuities Calcareous inclusions throughout 197.85' - 198.82' Calcite vein	197.48	J	<10	P,R	FR	T	N	
	2.75																
	3.00	200.0															

NOTES:

PROJECT NO.: 353754

Boring No.: B-66

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-66**
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
150	2.75	200.0							ARGILLITE, reddish brown, fine grained, fresh, strong, moderate to wide spaced discontinuities Calcareous inclusions throughout 200.8' - 202.55' Calcite vein								
	2.25																
	1.50		R-40	59 98%	59 98%	R4	FR										
	1.25																
	1.00	205.0								204.00	J	0	P,Sm	FR	T	N	
205	3.00	205.0							ARGILLITE, reddish brown, fine grained, fresh, medium strong to strong, wide spaced discontinuities								
	3.50																
	3.25		R-41	54 90%	51 85%	R4	FR										
	3.00																
	3.25	210.0								209.25	J	0	P,R	FR	O	N	
210									210.0 End of Boring at 210 feet BGS Borehole grouted with portland cement.								
140																	
215																	
220																	
130																	

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-66**

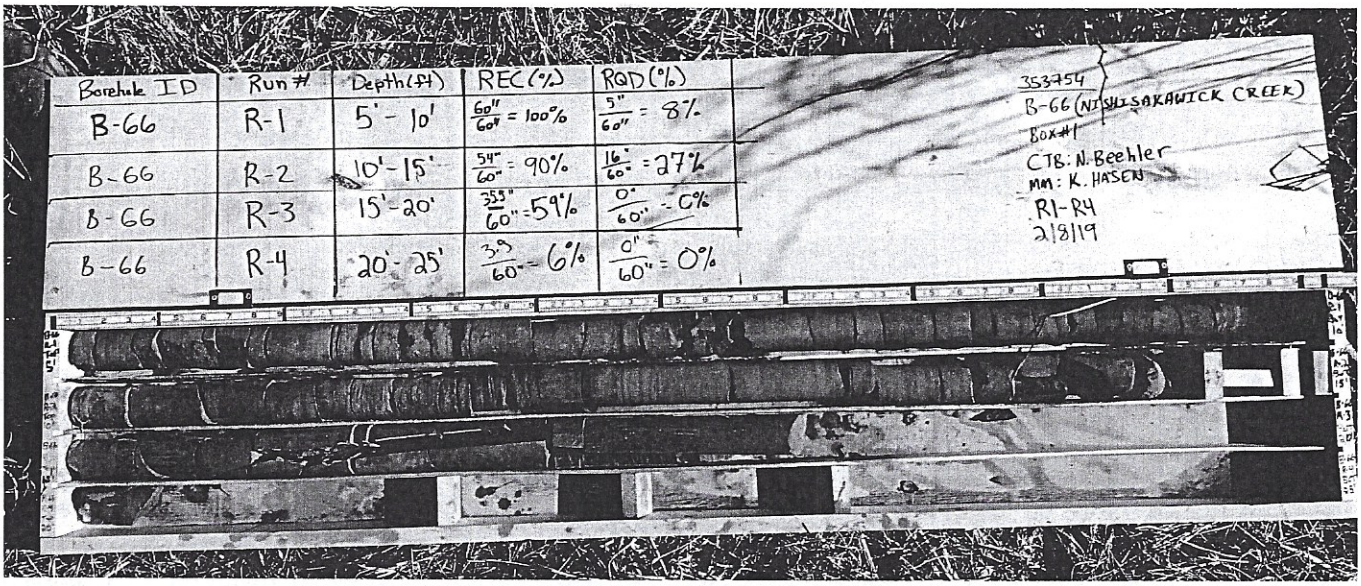


Figure B-66.1
B-66 Box 1 R1-R4 Dry

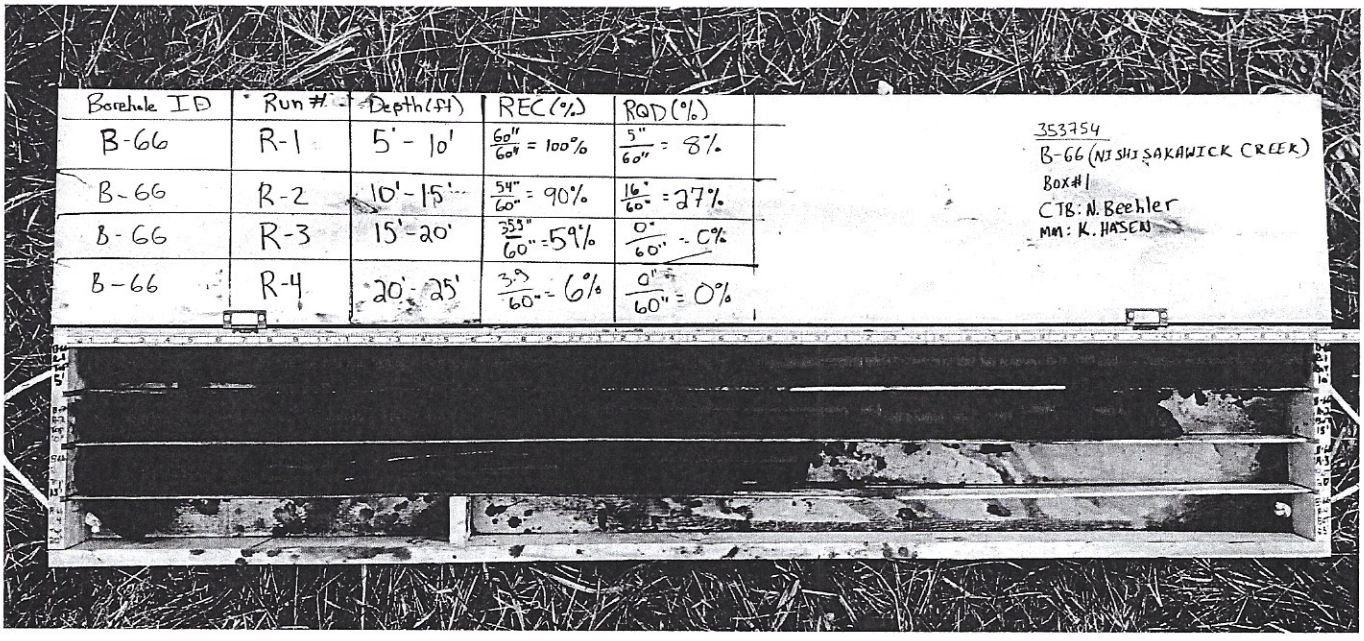


Figure B-66.2
B-66 Box 1 R1-R4 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-66

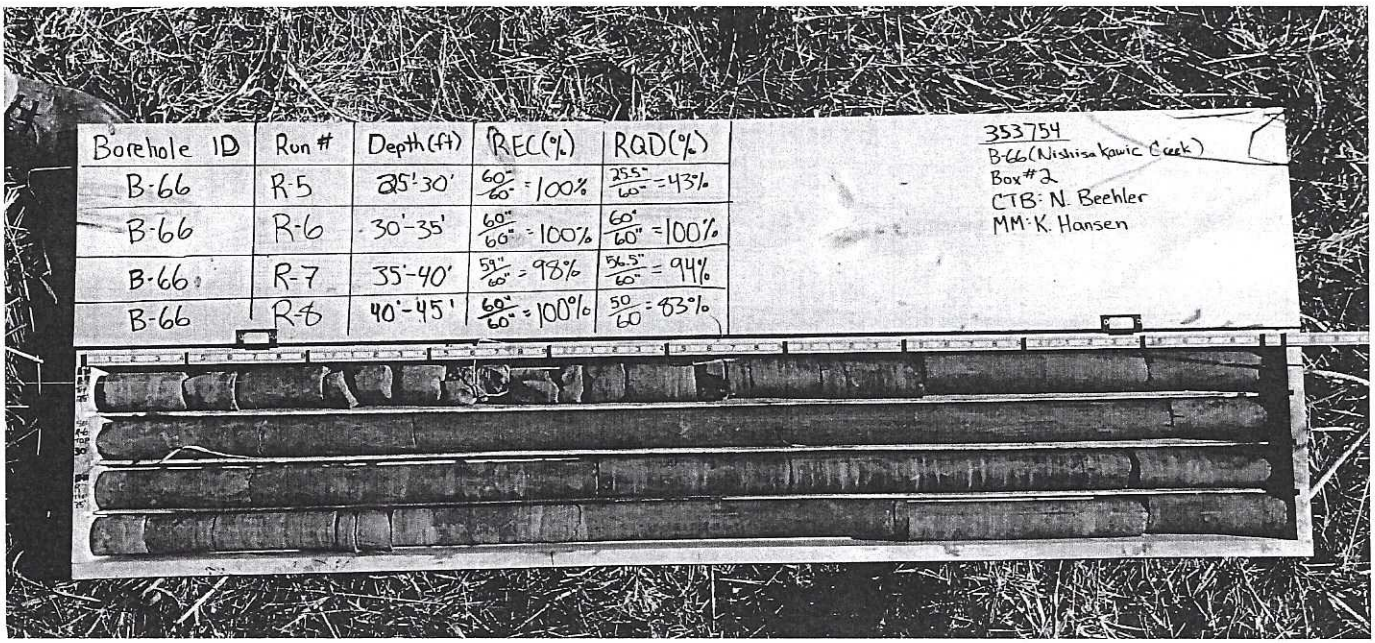


Figure B-66.3
B-66 Box 2 R5-R8 Dry

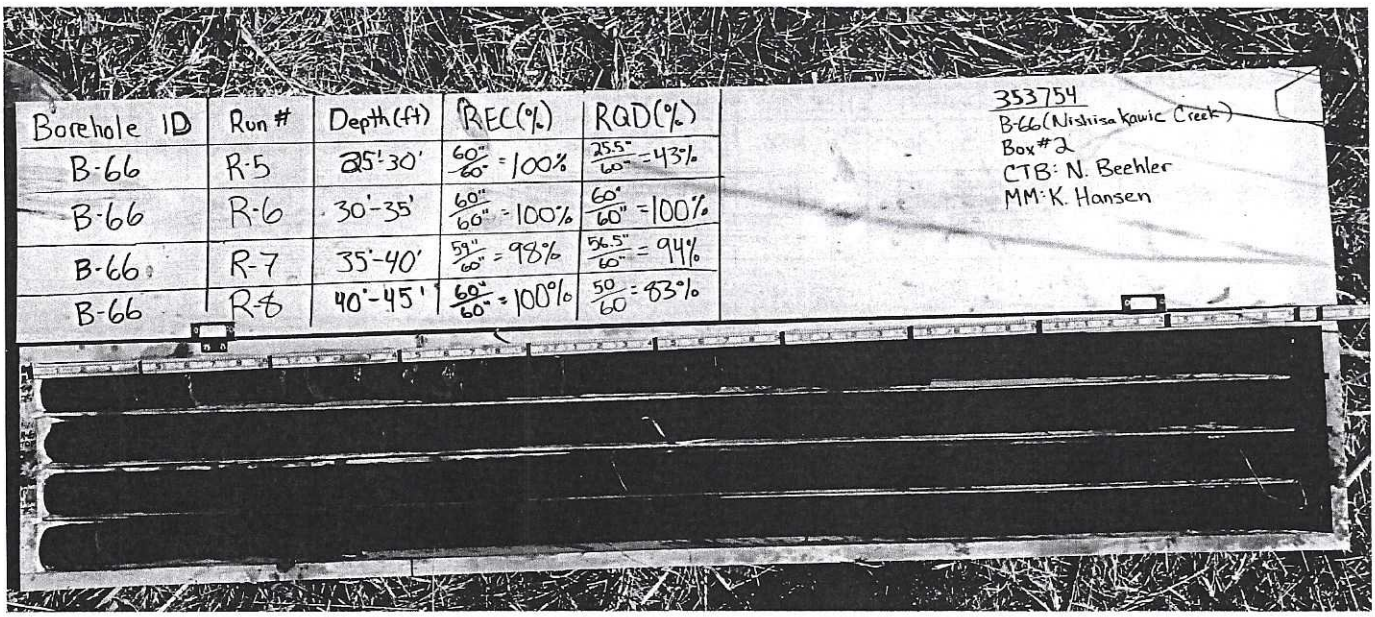


Figure B-66.4
B-66 Box 2 R5-R8 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-66

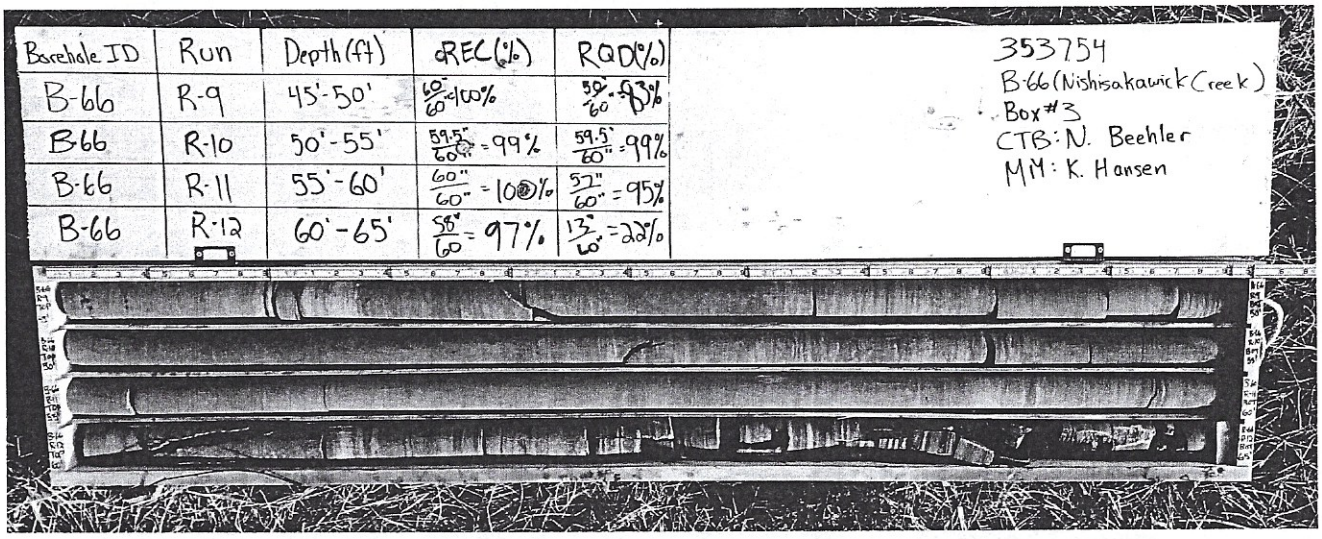


Figure B-66.5
B-66 Box 3 R9-R12 Dry

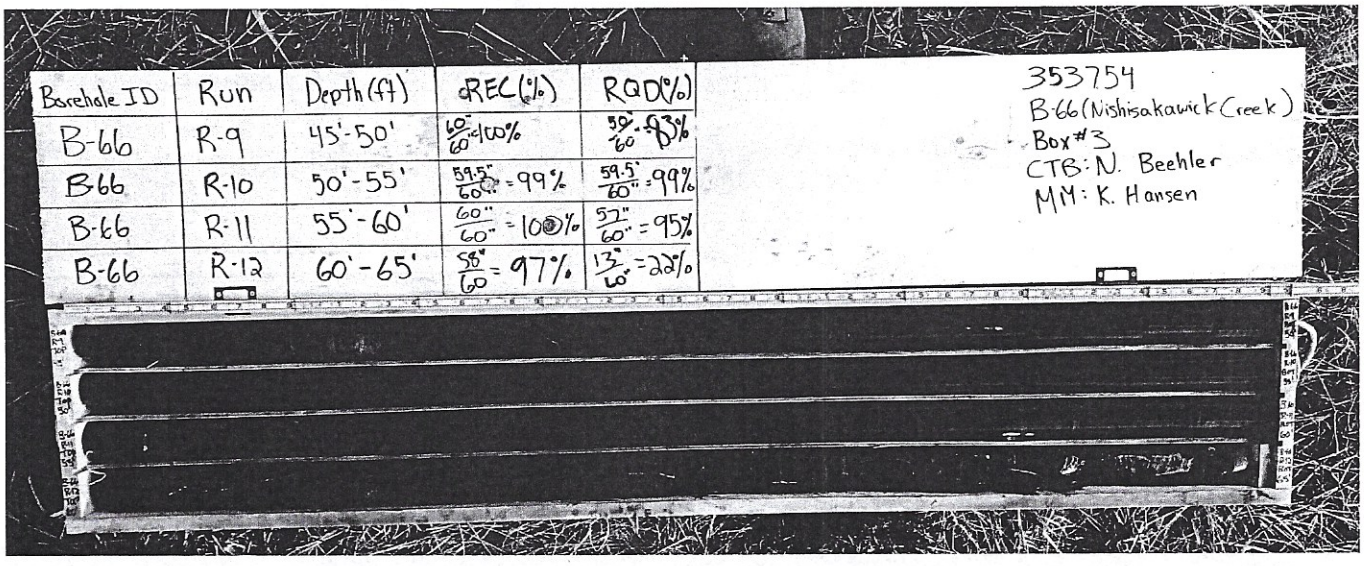


Figure B-66.6
B-66 Box 3 R9-R12 Wet

MOTT MACDONALD	PennEast Pipeline Project	BORING NO.:
	Rock Core Photographs	B-66

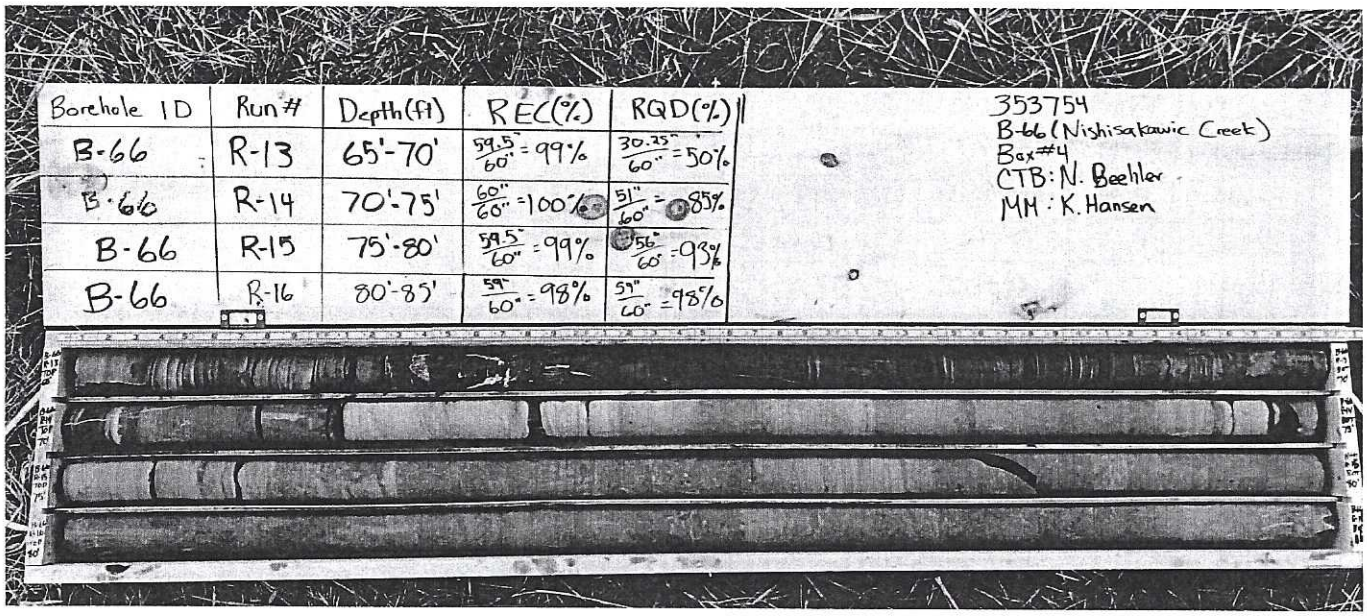


Figure B-66.7
B-66 Box 4 R13-R16 Dry

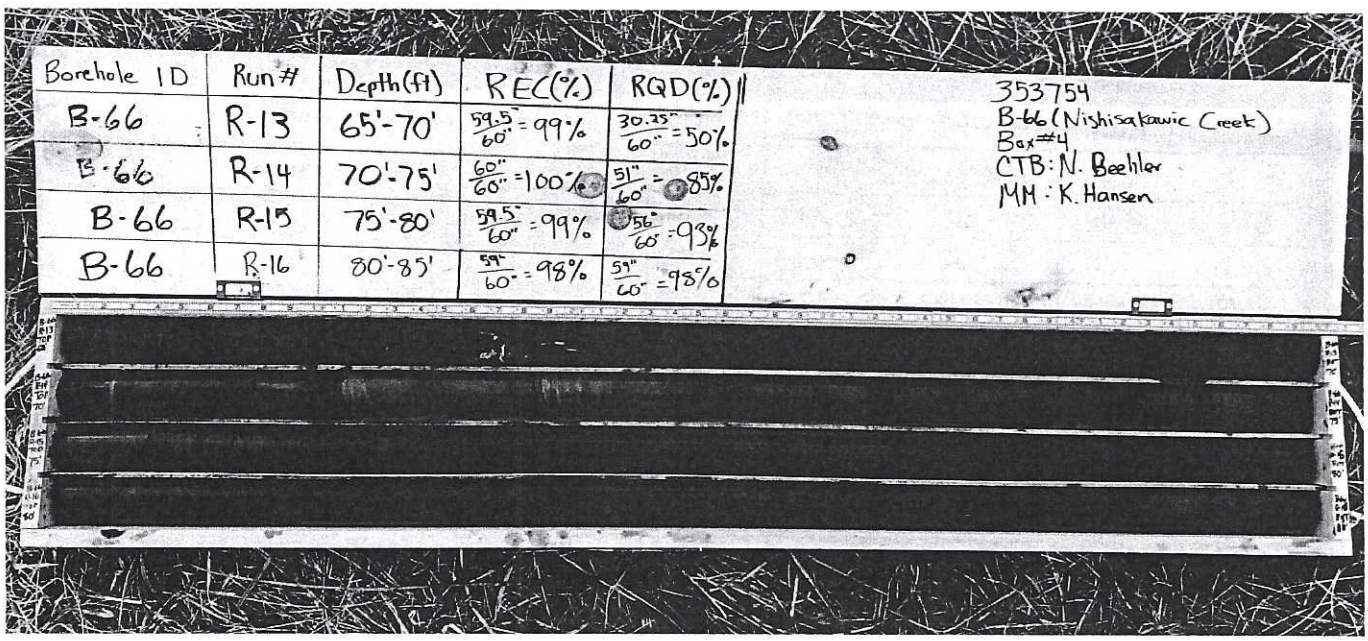


Figure B-66.8
B-66 Box 4 R13-R16 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-66

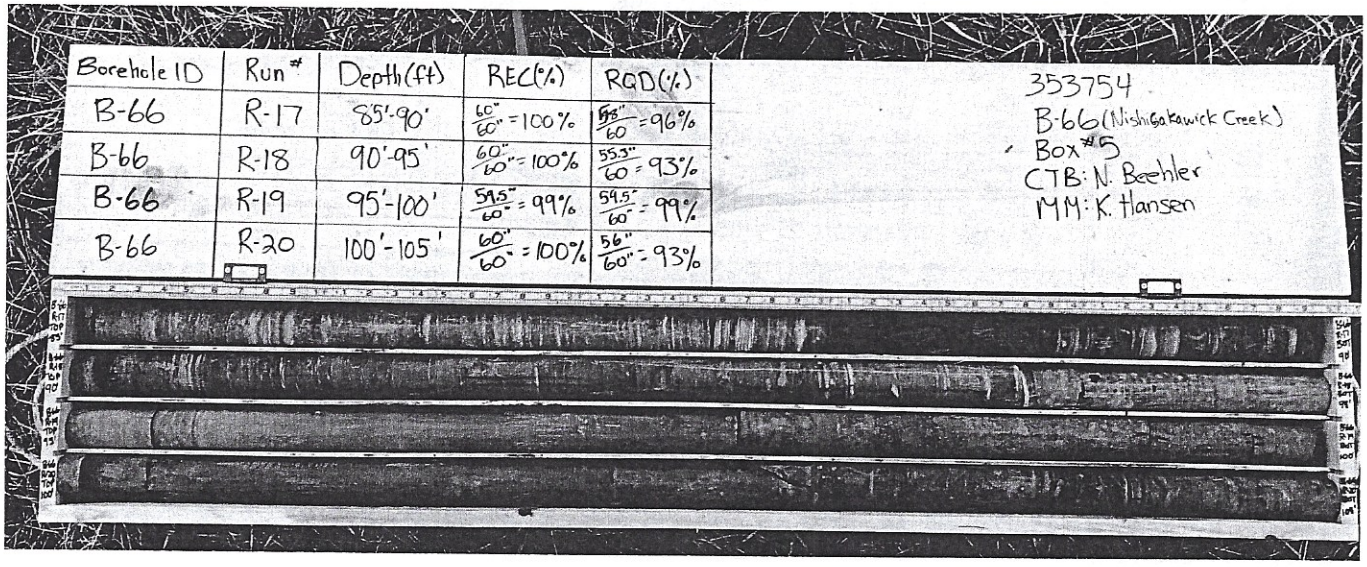


Figure B-66.9
B-66 Box 5 R17-R20 Dry

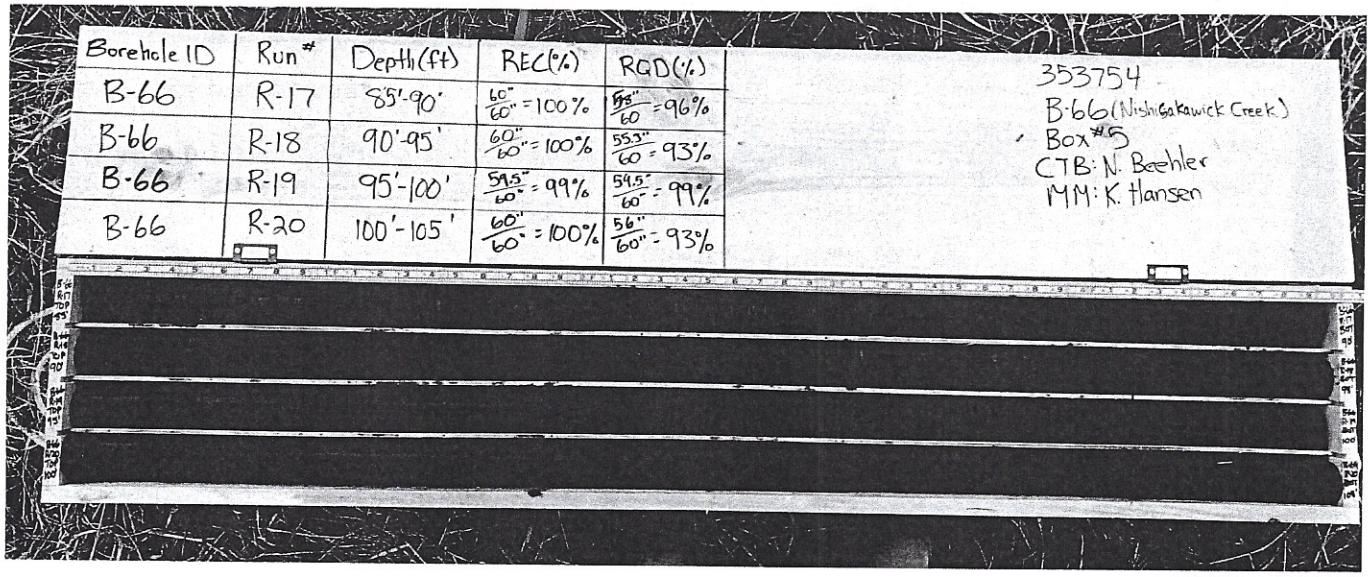


Figure B-66.10
B-66 Box 5 R17-R20 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-66

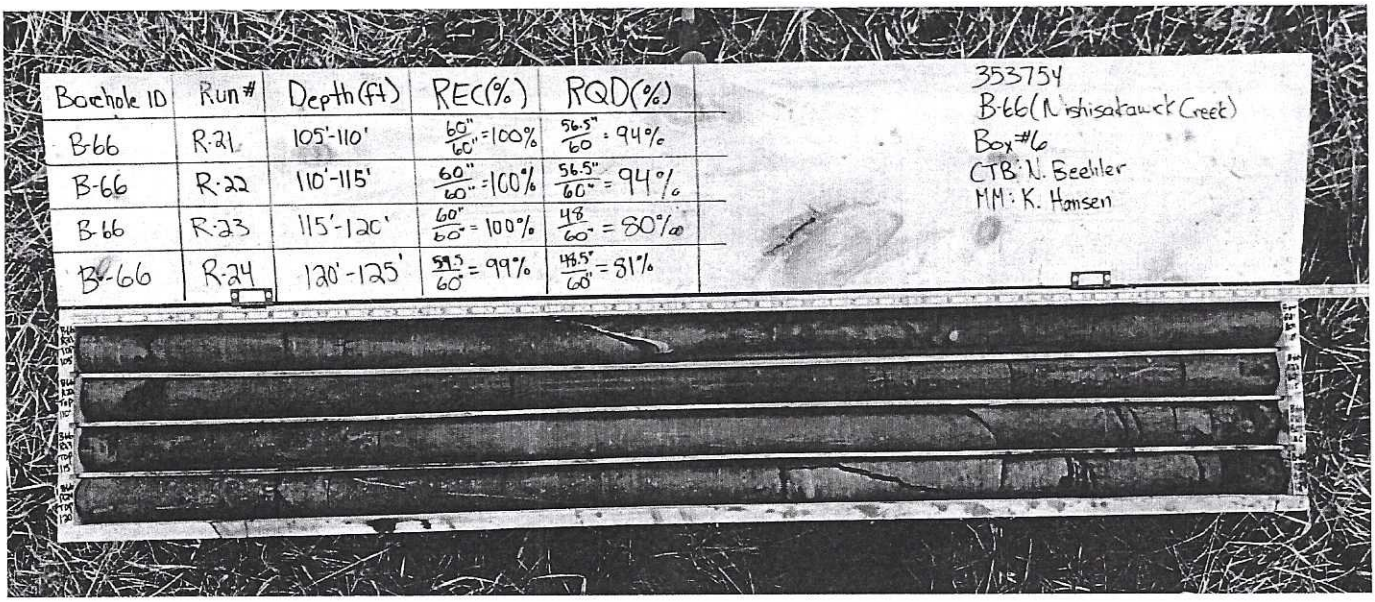


Figure B-66.11
B-66 Box 6 R21-R24 Dry

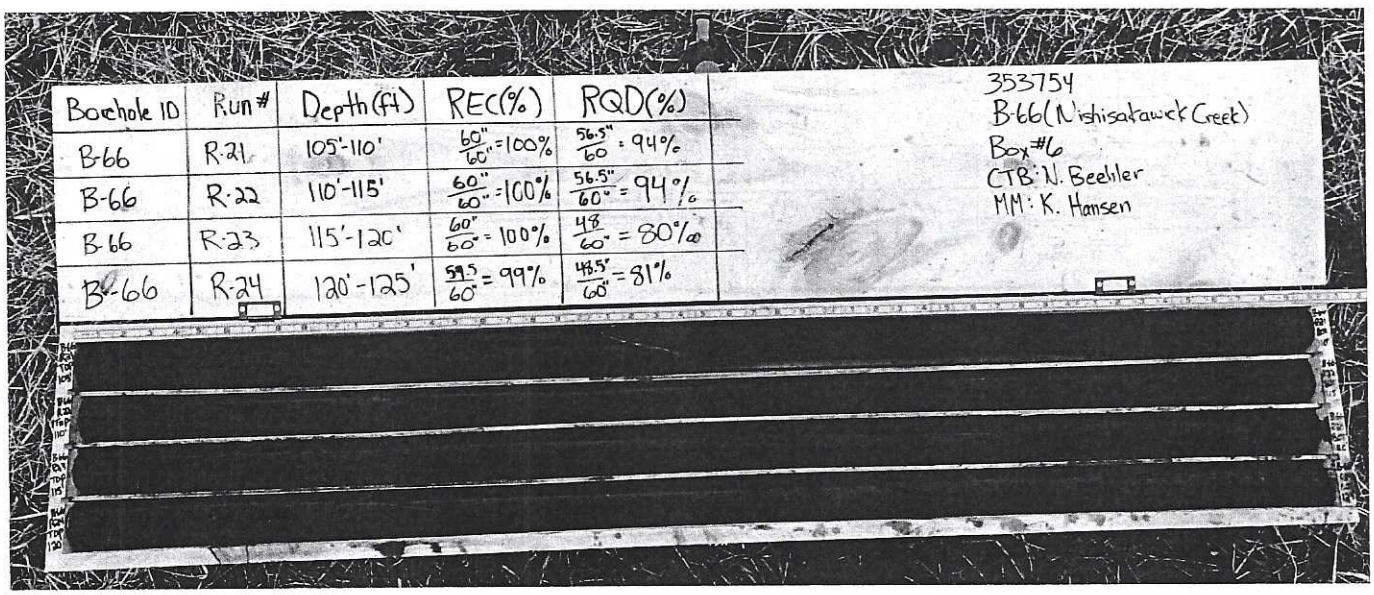


Figure B-66.12
B-66 Box 6 R21-R24 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-66

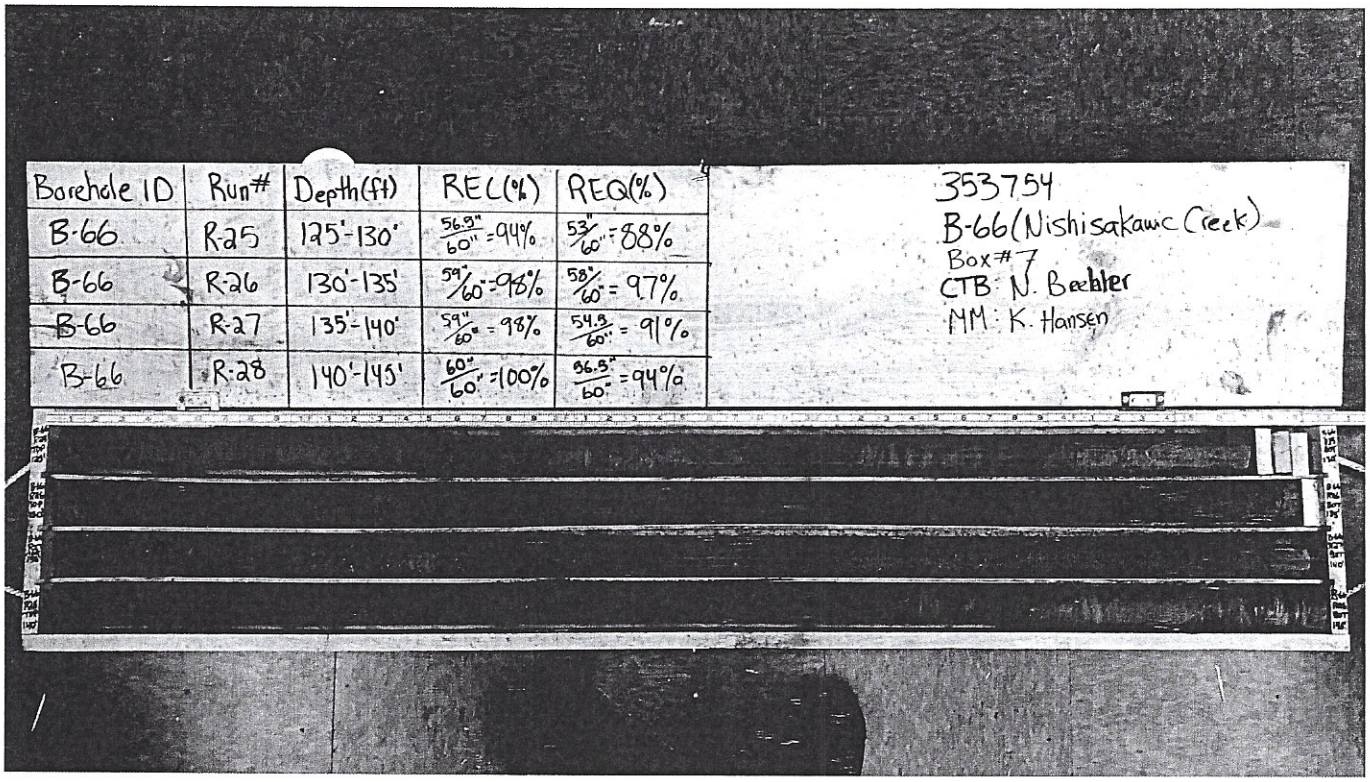


Figure B-66.13
B-66 Box 7 R25-R28 Dry

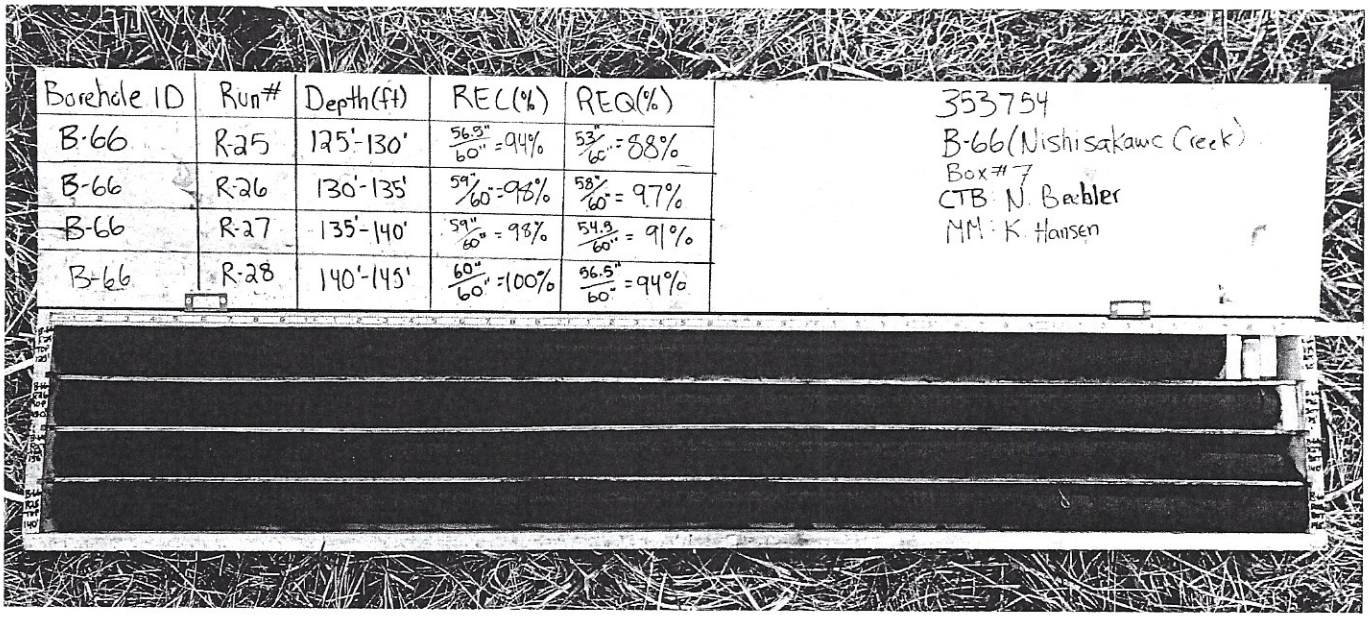


Figure B-66.14
B-66 Box 7 R25-R28 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-66

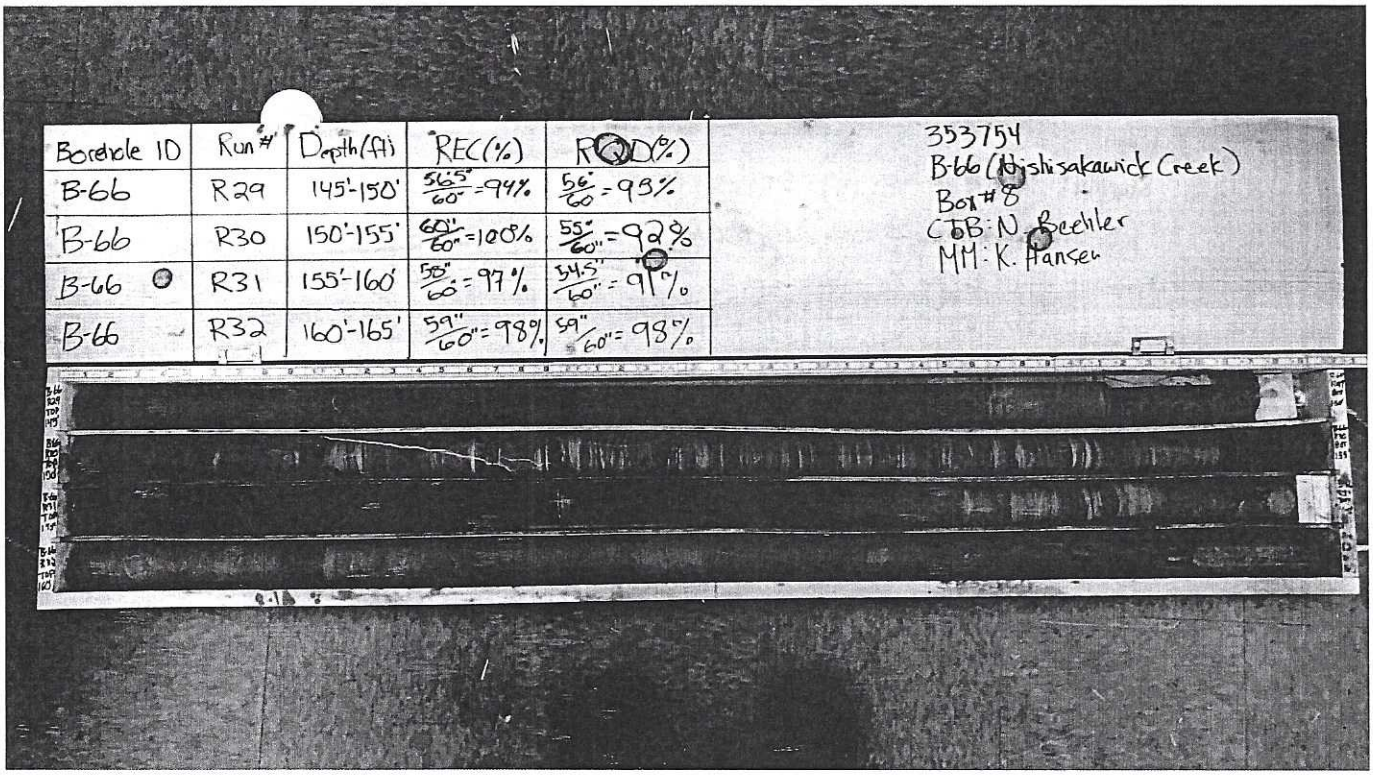


Figure B-66.15
B-66 Box 8 R29-R32 Dry

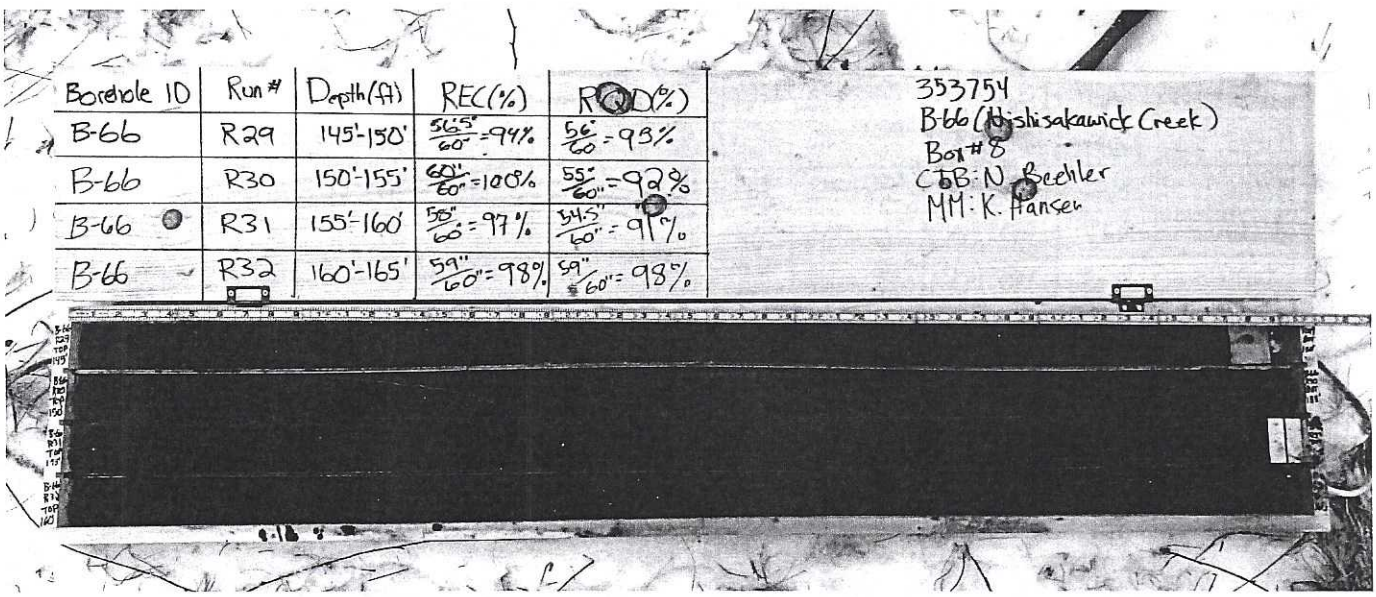


Figure B-66.16
B-66 Box 8 R29-R32 Wet

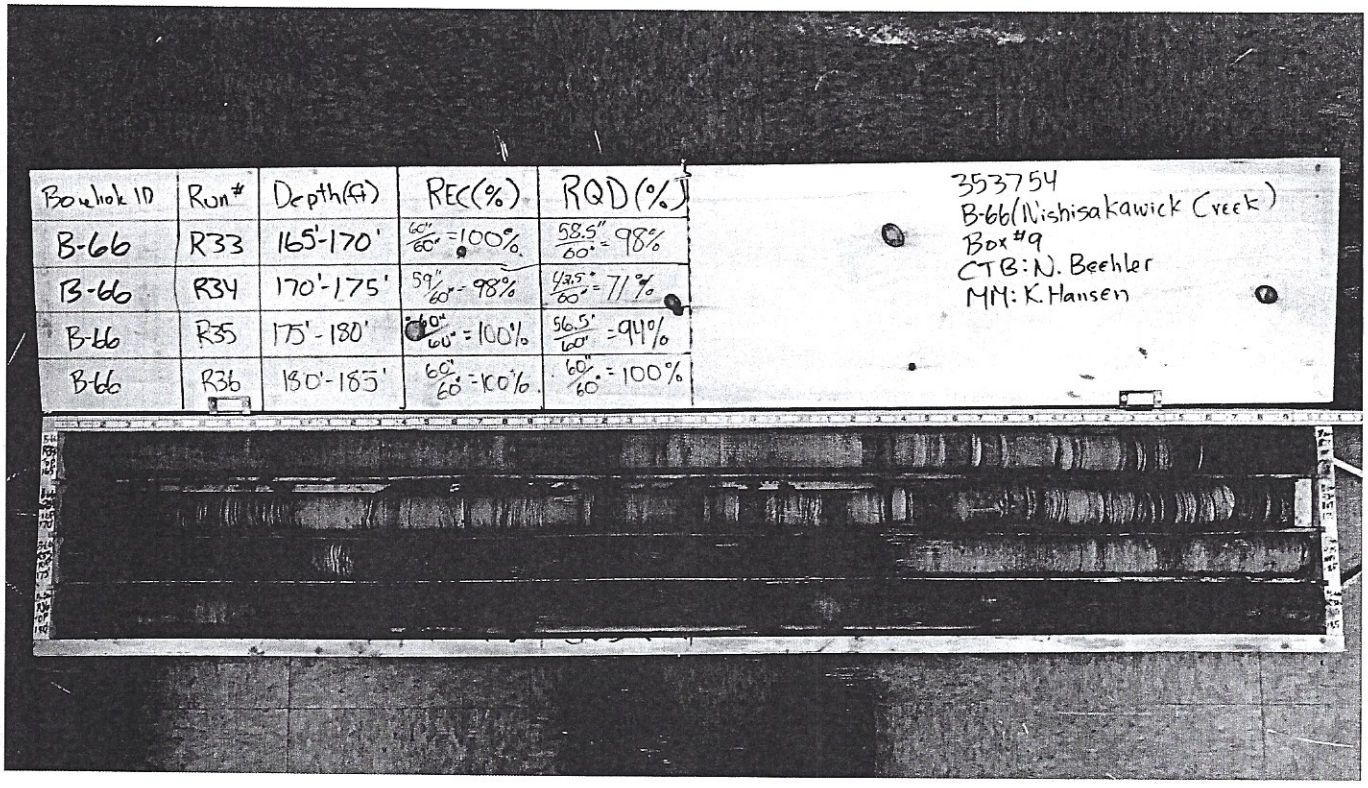


Figure B-66.17
B-66 Box 9 R33-R36 Dry

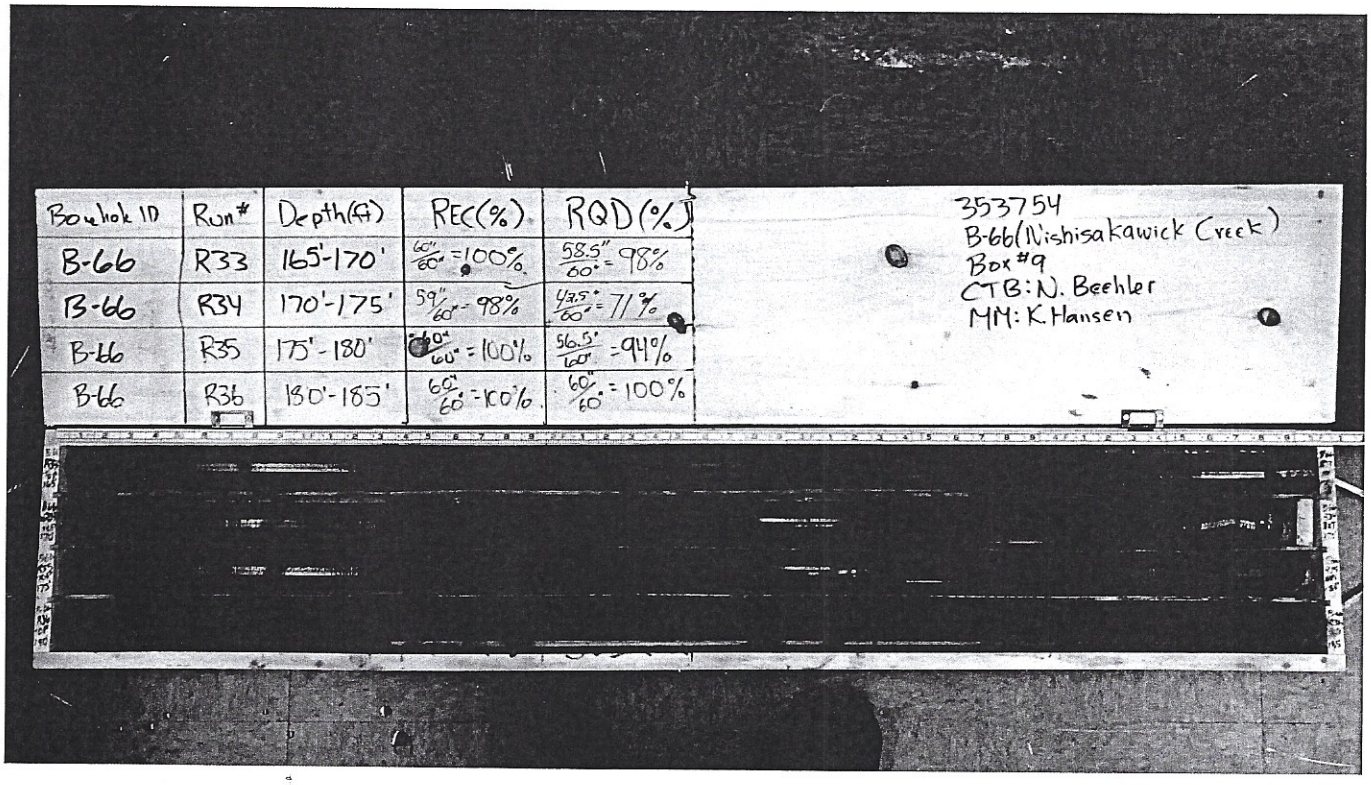


Figure B-66.18
B-66 Box 9 R33-R36 Wet

MOTT MACDONALD	PennEast Pipeline Project	BORING NO.:
	Rock Core Photographs	B-66

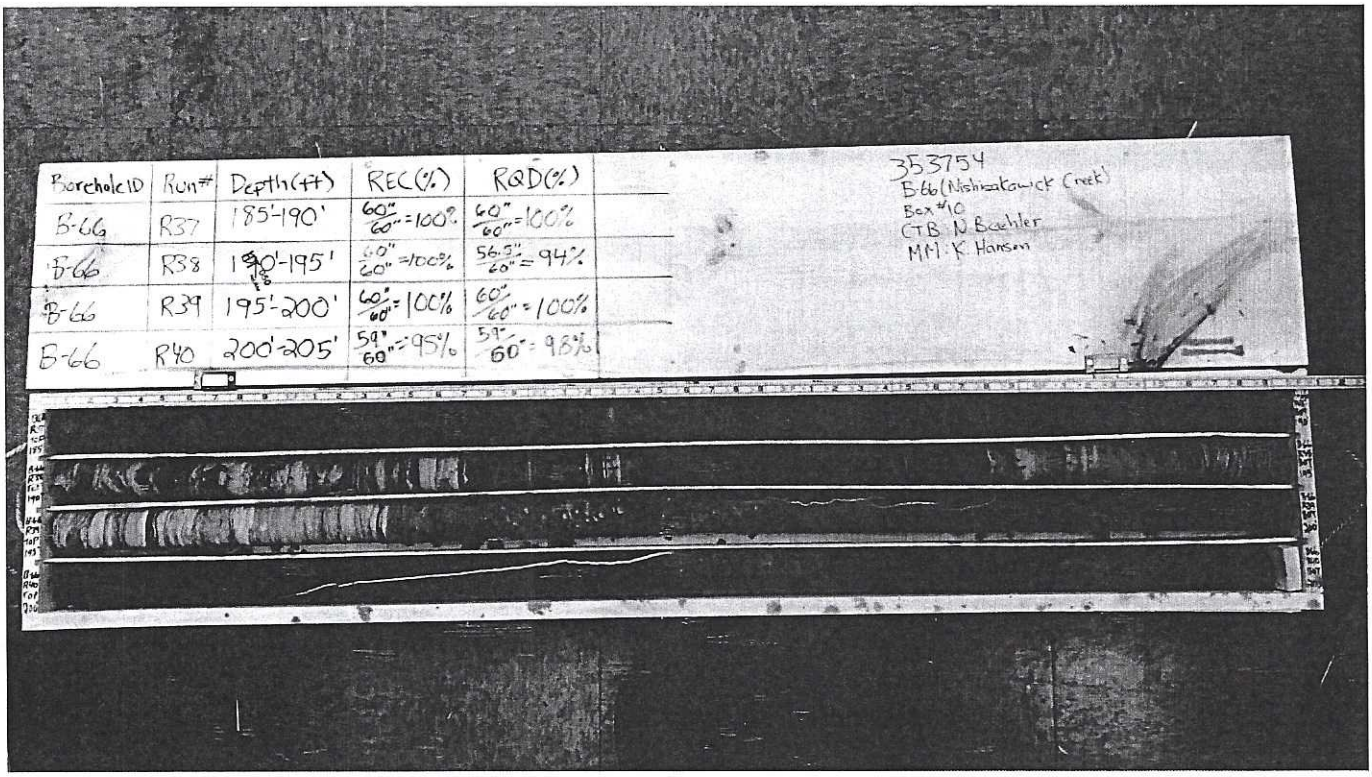


Figure B-66.19
B-66 Box 10 R37-R40 Dry

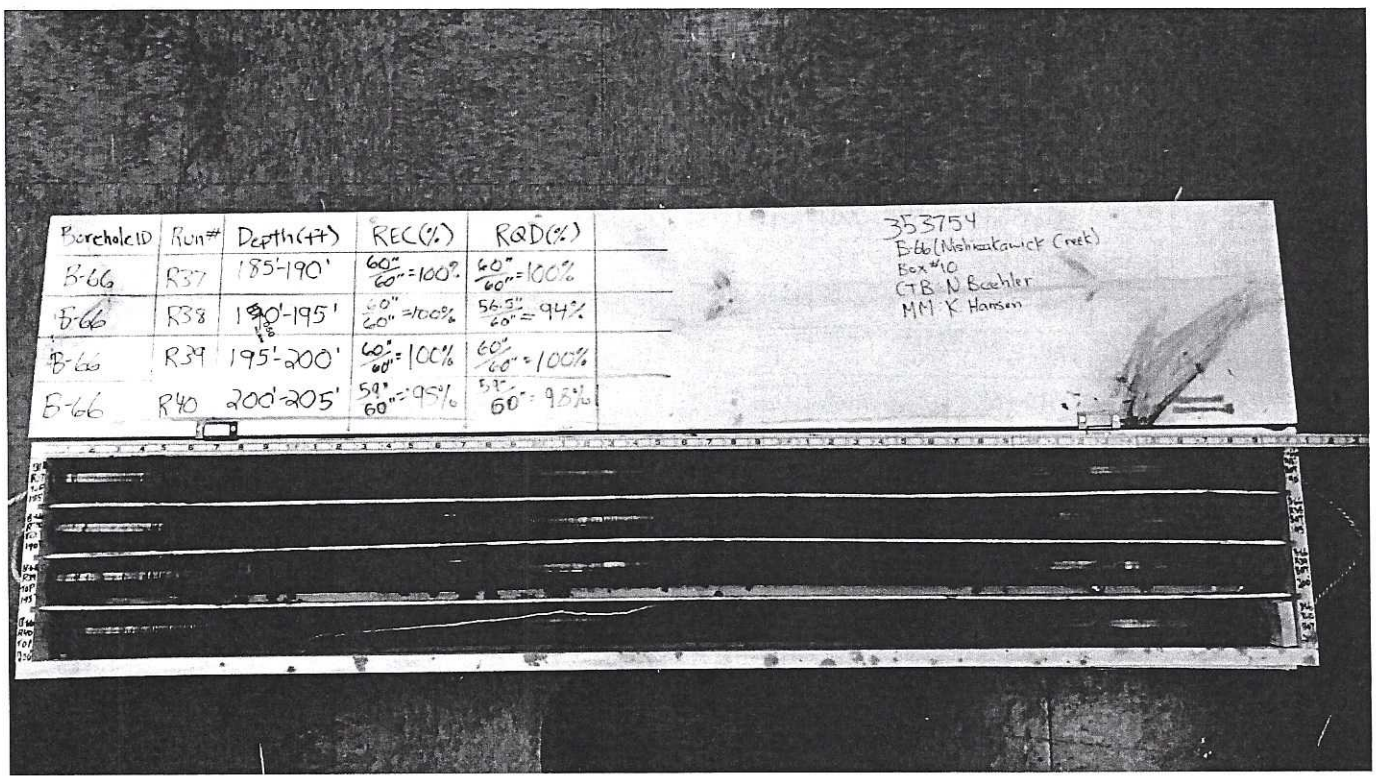


Figure B-66.20
B-66 Box 10 R37-R40 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-66

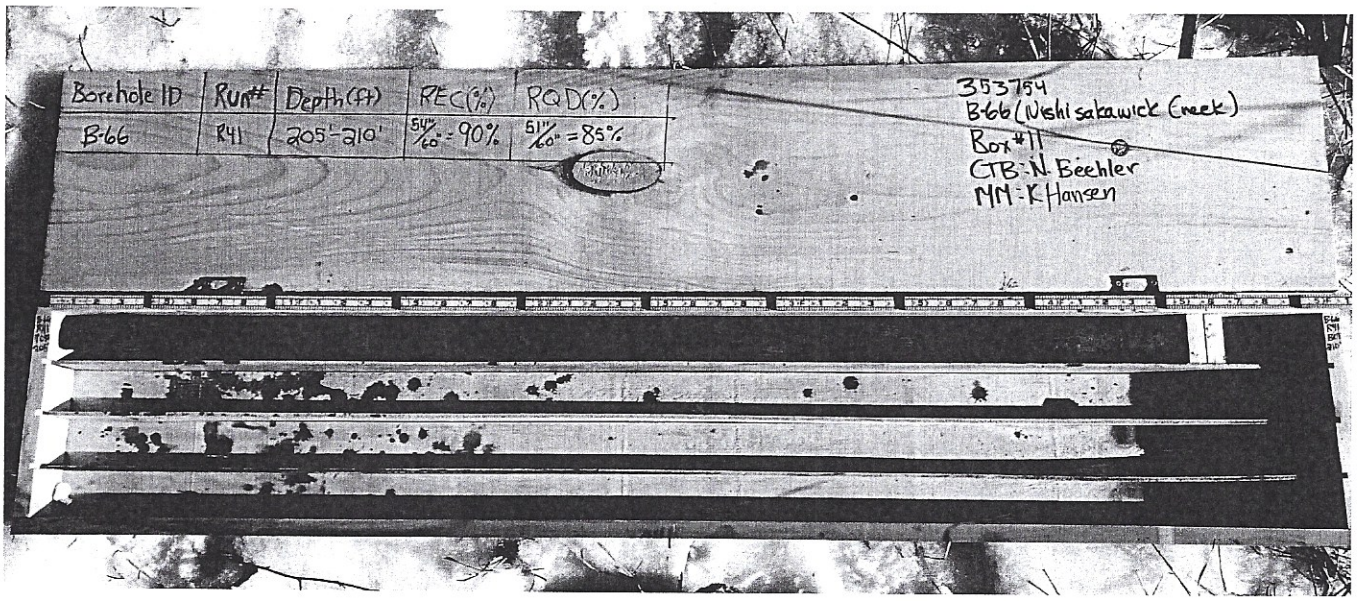


Figure B-66.21
B-66 Box 11 R41 Dry

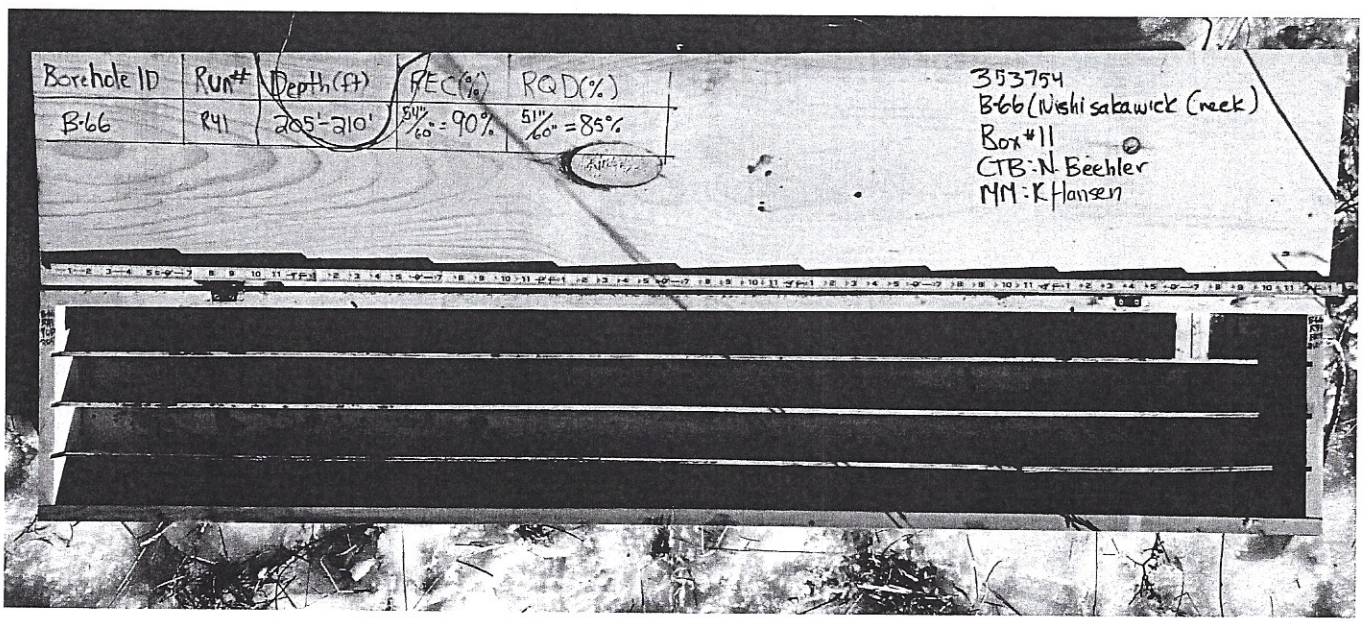


Figure B-66.22
B-66 Box 11 R41 Wet

MOTT MACDONALD M M	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-66

Appendix C

Installation Load and Stress Evaluation

MOTT MACDONALD

Horizontal Directional Drilling
Operating Stress Analysis - MAOP Based

Project Name:	PennEast Pipeline Project	**By:**	M. Eakins
Project No:	353754	**Checked:**	G. Duyvestyn
HDD Name:	Nishisackawick Creek	**Owner:**	Penn East Pipeline Company
Location:	Luzerne (PA) to Mercer County (NJ)	**Date:**	3/12/2019

References:

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

Design Parameters

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

Longitudinal Stress from Bending

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

Hoop Stress

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

Longitudinal Tensile Stress from Hoop Stress

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

Longitudinal Stress from Thermal Expansion

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

Net Longitudinal Stress (Compression Side of Curve)

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

Net Longitudinal Stress Tension Side of Curve)

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

Maximum Shear Stress

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

Combined Biaxial Stress Check

Combined Biaxial Stress Check		55,554	psi	
	Percent SMYS	79.4%		Limited to 90% SMYS by ASME/ANSI B31.8 section 833.4

MOTT MACDONALD

Calculated by: M. Eakins
Checked by: G. Duyvestyn
Date: 3/14/2019
Project No: 353754

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

PROJECT: PennEast Pipeline Project

HDD CROSSING LOCATION: Nishisakawick Creek (No Buoyancy - 10PPG Drilling Fluid)

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		33+01	1+006	0.0	0.0	341.0	103.9	--	--		99,380 lb	49.7 tons
straight		32+36	0+987	64.6	19.7	325.4	99.2	48.0	1219.2	0.3	110,239 lb	55.1 tons
straight		31+75	0+968	129.2	39.4	309.8	94.4	48.0	1219.2	0.3	121,061 lb	60.5 tons
straight		31+13	0+949	193.8	59.1	294.1	89.7	48.0	1219.2	0.3	131,931 lb	66.0 tons
straight		30+50	0+930	258.4	78.8	278.5	84.9	48.0	1219.2	0.3	142,762 lb	71.4 tons
straight		29+87	0+911	323.0	98.4	262.9	80.1	48.0	1219.2	0.3	153,532 lb	76.8 tons
straight		29+25	0+891	387.6	118.1	247.2	75.4	48.0	1219.2	0.3	164,483 lb	82.2 tons
straight		28+62	0+872	452.2	137.8	231.6	70.6	48.0	1219.2	0.3	175,333 lb	87.7 tons
straight		27+99	0+853	516.8	157.5	216.0	65.8	48.0	1219.2	0.3	186,184 lb	93.1 tons
straight		27+36	0+834	581.4	177.2	200.4	61.1	48.0	1219.2	0.3	197,034 lb	98.5 tons
straight		26+74	0+815	646.0	196.9	184.7	56.3	48.0	1219.2	0.3	207,855 lb	103.9 tons
straight		26+11	0+796	710.6	216.6	169.1	51.5	48.0	1219.2	0.3	218,736 lb	109.4 tons
straight		25+48	0+777	775.2	236.3	153.5	46.8	48.0	1219.2	0.3	229,586 lb	114.8 tons
curve	vertical	24+96	0+761	827.1	252.1	141.3	43.1	48.0	1219.2	0.3	256,654 lb	128.3 tons
curve	vertical	24+47	0+746	879.0	267.9	129.9	39.6	48.0	1219.2	0.3	278,072 lb	139.0 tons
curve	vertical	23+98	0+730	930.9	283.7	119.3	36.4	48.0	1219.2	0.3	279,451 lb	139.7 tons
curve	vertical	23+46	0+715	982.8	299.6	109.4	33.4	48.0	1219.2	0.3	285,248 lb	142.5 tons
curve	vertical	22+94	0+699	1,034.8	315.4	100.3	30.6	48.0	1219.2	0.3	292,651 lb	146.3 tons
curve	vertical	22+43	0+684	1,086.7	331.2	92.1	28.1	48.0	1219.2	0.3	300,775 lb	150.4 tons
curve	vertical	21+92	0+668	1,138.6	347.1	84.8	25.8	48.0	1219.2	0.3	309,223 lb	154.6 tons
curve	vertical	21+40	0+652	1,190.5	362.9	77.8	23.7	48.0	1219.2	0.3	317,791 lb	158.9 tons
curve	vertical	20+89	0+637	1,242.5	378.7	71.9	21.9	48.0	1219.2	0.3	326,357 lb	163.2 tons
curve	vertical	20+37	0+621	1,294.4	394.5	66.8	20.3	48.0	1219.2	0.3	334,832 lb	167.4 tons
curve	vertical	19+85	0+605	1,346.3	410.4	62.4	19.0	48.0	1219.2	0.3	343,294 lb	171.6 tons
curve	vertical	19+33	0+589	1,398.2	426.2	58.8	17.9	48.0	1219.2	0.3	351,574 lb	175.8 tons
curve	vertical	18+82	0+574	1,450.2	442.0	56.1	17.1	48.0	1219.2	0.3	359,704 lb	179.9 tons
curve	vertical	18+30	0+558	1,502.1	457.8	54.1	16.5	48.0	1219.2	0.3	367,674 lb	183.8 tons
curve	vertical	17+78	0+542	1,554.0	473.7	52.9	16.1	48.0	1219.2	0.3	448,022 lb	224.0 tons
curve	vertical	17+26	0+526	1,605.9	489.5	52.5	16.0	48.0	1219.2	0.3	460,310 lb	230.2 tons
straight		16+86	0+515	1,643.4	500.9	52.5	16.0	48.0	1219.2	0.3	466,536 lb	233.3 tons
straight		16+51	0+503	1,680.9	512.4	52.5	16.0	48.0	1219.2	0.3	472,763 lb	236.4 tons
straight		16+13	0+492	1,718.4	523.8	52.5	16.0	48.0	1219.2	0.3	478,989 lb	239.5 tons
straight		15+76	0+480	1,755.9	535.2	52.5	16.0	48.0	1219.2	0.3	485,216 lb	242.6 tons
curve	vertical	15+21	0+464	1,810.9	552.0	52.9	16.1	48.0	1219.2	0.3	532,026 lb	266.0 tons
curve	vertical	14+66	0+447	1,865.9	568.7	54.2	16.5	48.0	1219.2	0.3	557,613 lb	278.8 tons
curve	vertical	14+11	0+430	1,920.9	585.5	56.3	17.2	48.0	1219.2	0.3	558,153 lb	279.1 tons
curve	vertical	13+56	0+413	1,975.8	602.2	59.2	18.0	48.0	1219.2	0.3	565,502 lb	282.8 tons
curve	vertical	13+01	0+397	2,030.8	618.9	63.0	19.2	48.0	1219.2	0.3	575,395 lb	287.7 tons
curve	vertical	12+47	0+380	2,085.8	635.8	67.6	20.6	48.0	1219.2	0.3	586,398 lb	293.2 tons
curve	vertical	11+92	0+363	2,140.8	652.5	73.0	22.3	48.0	1219.2	0.3	597,896 lb	298.9 tons
curve	vertical	11+37	0+347	2,195.8	669.3	79.3	24.2	48.0	1219.2	0.3	609,599 lb	304.8 tons
curve	vertical	10+83	0+330	2,250.7	686.0	86.4	26.3	48.0	1219.2	0.3	621,315 lb	310.7 tons
curve	vertical	10+28	0+313	2,305.7	702.8	94.4	28.8	48.0	1219.2	0.3	632,989 lb	316.5 tons
curve	vertical	9+74	0+297	2,360.7	719.5	103.2	31.4	48.0	1219.2	0.3	644,562 lb	322.3 tons
curve	vertical	9+20	0+280	2,415.7	736.3	112.8	34.4	48.0	1219.2	0.3	656,007 lb	328.0 tons
curve	vertical	8+66	0+264	2,470.6	753.1	123.2	37.6	48.0	1219.2	0.3	667,310 lb	333.7 tons
curve	vertical	8+12	0+248	2,525.6	769.8	134.5	41.0	48.0	1219.2	0.3	678,461 lb	339.2 tons
curve	vertical	7+58	0+231	2,580.6	786.6	146.5	44.7	48.0	1219.2	0.3	689,457 lb	344.7 tons
curve	vertical	7+05	0+215	2,635.6	803.3	159.4	48.6	48.0	1219.2	0.3	700,295 lb	350.1 tons
straight		6+46	0+197	2,696.1	821.8	174.1	53.1	48.0	1219.2	0.3	706,580 lb	353.3 tons
straight		5+87	0+179	2,756.7	840.2	188.7	57.5	48.0	1219.2	0.3	712,865 lb	356.4 tons
straight		5+29	0+161	2,817.2	858.7	203.4	62.0	48.0	1219.2	0.3	719,150 lb	359.6 tons
straight		4+70	0+143	2,877.8	877.2	218.0	66.5	48.0	1219.2	0.3	725,435 lb	362.7 tons
straight		4+11	0+125	2,938.3	895.6	232.7	70.9	48.0	1219.2	0.3	731,720 lb	365.9 tons
straight		3+52	0+107	2,998.9	914.1	247.3	75.4	48.0	1219.2	0.3	738,005 lb	369.0 tons
straight		2+94	0+090	3,059.4	932.5	262.0	79.8	48.0	1219.2	0.3	744,290 lb	372.1 tons
straight		2+35	0+072	3,120.0	951.0	276.6	84.3	48.0	1219.2	0.3	750,575 lb	375.3 tons
straight		1+76	0+054	3,180.5	969.4	291.3	88.8	48.0	1219.2	0.3	756,860 lb	378.4 tons
straight		1+17	0+036	3,241.1	987.9	305.9	93.2	48.0	1219.2	0.3	763,145 lb	381.6 tons
straight		0+59	0+018	3,301.6	1,006.3	320.6	97.7	48.0	1219.2	0.3	769,430 lb	384.7 tons
HDD Rig Location		0+00	0+000	3,362.2	1,024.8	335.2	102.2	48.0	1219.2	0.3	775,715 lb	387.9 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				
1,178	8.12	1.68%	0	0.00	0.00%	0.0	0.00	0.00%	0.02	Yes	0.00	Yes
1,307	9.01	1.87%	0	0.00	0.00%	191.8	1.32	0.27%	0.02	Yes	0.00	Yes
1,435	9.90	2.05%	0	0.00	0.00%	383.5	2.64	0.55%	0.03	Yes	0.00	Yes
1,564	10.78	2.23%	0	0.00	0.00%	575.3	3.97	0.82%	0.03	Yes	0.01	Yes
1,693	11.67	2.42%	0	0.00	0.00%	767.0	5.29	1.10%	0.03	Yes	0.01	Yes
1,821	12.56	2.60%	0	0.00	0.00%	958.8	6.61	1.37%	0.03	Yes	0.02	Yes
1,950	13.44	2.79%	0	0.00	0.00%	1,150.5	7.93	1.64%	0.03	Yes	0.03	Yes
2,078	14.33	2.97%	0	0.00	0.00%	1,342.3	9.25	1.92%	0.04	Yes	0.03	Yes
2,207	15.22	3.15%	0	0.00	0.00%	1,534.0	10.58	2.19%	0.04	Yes	0.04	Yes
2,336	16.10	3.34%	0	0.00	0.00%	1,725.8	11.90	2.47%	0.04	Yes	0.05	Yes
2,464	16.99	3.52%	0	0.00	0.00%	1,917.5	13.22	2.74%	0.04	Yes	0.07	Yes
2,593	17.88	3.70%	0	0.00	0.00%	2,109.3	14.54	3.01%	0.05	Yes	0.08	Yes
2,722	18.76	3.89%	0	0.00	0.00%	2,301.0	15.86	3.29%	0.05	Yes	0.10	Yes
3,043	20.98	4.35%	12,882	88.82	18.40%	2,450.4	16.90	3.50%	0.34	Yes	0.22	Yes
3,296	22.73	4.71%	12,882	88.82	18.40%	2,590.4	17.85	3.70%	0.35	Yes	0.24	Yes
3,313	22.84	4.73%	12,882	88.82	18.40%	2,720.8	18.75	3.89%	0.35	Yes	0.25	Yes
3,381	23.31	4.83%	12,882	88.82	18.40%	2,841.7	19.59	4.06%	0.36	Yes	0.27	Yes
3,469	23.92	4.96%	12,882	88.82	18.40%	2,953.0	20.36	4.22%	0.35	Yes	0.28	Yes
3,556	24.59	5.09%	12,882	88.82	18.40%	3,054.7	21.06	4.36%	0.35	Yes	0.29	Yes
3,666	25.27	5.24%	12,882	88.82	18.40%	3,146.8	21.70	4.50%	0.35	Yes	0.31	Yes
3,767	25.97	5.38%	12,882	88.82	18.40%	3,229.3	22.27	4.61%	0.36	Yes	0.32	Yes
3,869	26.68	5.53%	12,882	88.82	18.40%	3,302.1	22.77	4.72%	0.36	Yes	0.33	Yes
3,970	27.37	5.67%	12,882	88.82	18.40%	3,365.2	23.20	4.81%	0.36	Yes	0.34	Yes
4,070	28.06	5.81%	12,882	88.82	18.40%	3,418.7	23.57	4.89%	0.36	Yes	0.35	Yes
4,168	28.74	5.95%	12,882	88.82	18.40%	3,462.4	23.87	4.95%	0.36	Yes	0.35	Yes
4,264	29.40	6.09%	12,882	88.82	18.40%	3,496.5	24.11	4.99%	0.36	Yes	0.36	Yes
4,359	30.05	6.23%	12,882	88.82	18.40%	3,520.8	24.28	5.03%	0.37	Yes	0.36	Yes
5,311	36.62	7.59%	12,882	88.82	18.40%	3,464.1	23.88	4.95%	0.38	Yes	0.38	Yes
5,457	37.62	7.80%	12,882	88.82	18.40%	3,469.0	23.92	4.96%	0.39	Yes	0.38	Yes
5,531	38.13	7.90%	0	0.00	0.00%	3,469.0	23.92	4.96%	0.10	Yes	0.24	Yes
5,604	38.64	8.01%	0	0.00	0.00%	3,469.0	23.92	4.96%	0.10	Yes	0.24	Yes
5,678	39.15	8.11%	0	0.00	0.00%	3,469.0	23.92	4.96%	0.10	Yes	0.24	Yes
5,752	39.66	8.22%	0	0.00	0.00%	3,469.0	23.92	4.96%	0.10	Yes	0.24	Yes
6,307	43.48	9.01%	12,167	83.89	17.38%	3,463.8	23.88	4.95%	0.38	Yes	0.38	Yes
6,610	45.58	9.44%	12,167	83.89	17.38%	3,448.4	23.78	4.93%	0.39	Yes	0.39	Yes
6,617	45.62	9.45%	12,167	83.89	17.38%	3,422.6	23.60	4.89%	0.39	Yes	0.38	Yes
6,704	46.22	9.58%	12,167	83.89	17.38%	3,386.6	23.35	4.84%	0.39	Yes	0.38	Yes
6,821	47.03	9.74%	12,167	83.89	17.38%	3,340.3	23.03	4.77%	0.39	Yes	0.38	Yes
6,951	47.93	9.93%	12,167	83.89	17.38%	3,283.7	22.64	4.69%	0.40	Yes	0.37	Yes
7,088	48.87	10.13%	12,167	83.89	17.38%	3,216.8	22.18	4.60%	0.40	Yes	0.36	Yes
7,226	49.82	10.32%	12,167	83.89	17.38%	3,139.7	21.65	4.49%	0.40	Yes	0.36	Yes
7,365	50.78	10.52%	12,167	83.89	17.38%	3,052.4	21.05	4.36%	0.40	Yes	0.35	Yes
7,504	51.74	10.72%	12,167	83.89	17.38%	2,954.9	20.37	4.22%	0.41	Yes	0.34	Yes
7,641	52.68	10.92%	12,167	83.89	17.38%	2,847.1	19.63	4.07%	0.41	Yes	0.33	Yes
7,777	53.62	11.11%	12,167	83.89	17.38%	2,729.3	18.82	3.90%	0.41	Yes	0.32	Yes
7,911	54.54	11.30%	12,167	83.89	17.38%	2,601.3	17.94	3.72%	0.41	Yes	0.30	Yes
8,043	55.45	11.49%	12,167	83.89	17.38%	2,463.2	16.98	3.52%	0.42	Yes	0.29	Yes
8,173	56.35	11.68%	12,167	83.89	17.38%	2,315.0	15.96	3.31%	0.42	Yes	0.28	Yes
8,302	57.24	11.86%	12,167	83.89	17.38%	2,156.8	14.87	3.08%	0.42	Yes	0.26	Yes
8,376	57.75	11.97%	0	0.00	0.00%	1,977.1	13.63	2.82%	0.15	Yes	0.11	Yes
8,451	58.27	12.07%	0	0.00	0.00%	1,797.4	12.39	2.57%	0.15	Yes	0.10	Yes
8,525	58.78	12.18%	0	0.00	0.00%	1,617.6	11.15	2.31%	0.15	Yes	0.09	
8,600	59.29	12.29%	0	0.00	0.00%	1,437.9	9.91	2.05%	0.15	Yes	0.07	
8,674	59.81	12.39%	0	0.00	0.00%	1,258.2	8.67	1.80%	0.15	Yes	0.07	
8,749	60.32	12.50%	0	0.00	0.00%	1,078.4	7.44	1.54%	0.16	Yes	0.05	
8,823	60.83	12.60%	0	0.00	0.00%	898.7	6.20	1.28%	0.16	Yes	0.05	
8,898	61.35	12.71%	0	0.00	0.00%	719.0	4.96	1.03%	0.16	Yes	0.04	Yes
8,972	61.86	12.82%	0	0.00	0.00%	539.2	3.72	0.77%	0.16	Yes	0.04	Yes
9,047	62.37	12.92%	0	0.00	0.00%	359.5	2.48	0.51%	0.16	Yes	0.03	Yes
9,121	62.89	13.03%	0	0.00	0.00%	179.7	1.24	0.26%	0.16	Yes	0.03	Yes
9,196	63.40	13.14%	0	0.00	0.00%	0.0	0.00	0.00%	0.16	Yes	0.03	Yes

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

Ground Elevation at Pipe Entry	341.01	feet
	103.94	metres
Ground Elevation at Pipe Exit	335.20	feet
	102.17	metres

	TOTAL PULL LOADS	
Maximum Values	775,715lb	387.9tons

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		
9,196	63.4	13.14%	12,882	88.8	18.40%	3,521	24.3	5.03%	0.42	0.39

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
	428.09	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	775,715	lb
	3,451	kN
Factor of Safety	4.6	

Start-Up Load Factor	1.5	
Maximum Calculated Start-Up Pipe Pull Load	1,163,572	lb
	5,176	kN
Factor of Safety	3.0	

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)	0.1	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	22.5	lb/100ft² (Based on HDD experience from previous installations)
	107.73	dyne/cm²
Plastic Viscosity	15	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	m³/min
Drilling mud pumping rate	1129	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.273	m³/min
Pipe Pullback Rate	10	feet/min (Based on HDD experience)
	3.05	m/min

MOTT MACDONALD

Calculated by: M. Eakins
Checked by: G. Duyvestyn
Date: 3/14/2019
Project No: 353754

ontal Directional Drilling
ulation of Pull Loads and Stresses during Pipe Installation

PROJECT: PennEast Pipeline Project

HDD CROSSING LOCATION: Nishisakawick Creek (Buoyancy - 10PPG Drilling Fluid)

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		33+01	1+006	0.0	0.0	341.0	103.9	--	--		99,380	lb	49.7 tons
straight		32+38	0+987	64.6	19.7	325.4	99.2	48.0	1219.2	0.3	102,426	lb	51.2 tons
straight		31+75	0+968	129.2	39.4	309.8	94.4	48.0	1219.2	0.3	105,472	lb	52.7 tons
straight		31+13	0+949	193.8	59.1	294.1	89.7	48.0	1219.2	0.3	108,519	lb	54.3 tons
straight		30+50	0+930	258.4	78.8	278.5	84.9	48.0	1219.2	0.3	111,565	lb	55.8 tons
straight		29+87	0+911	323.0	98.4	262.9	80.1	48.0	1219.2	0.3	114,611	lb	57.3 tons
straight		29+25	0+891	387.6	118.1	247.2	75.4	48.0	1219.2	0.3	117,658	lb	58.8 tons
straight		28+62	0+872	452.2	137.8	231.6	70.6	48.0	1219.2	0.3	120,704	lb	60.4 tons
straight		27+99	0+853	516.8	157.5	216.0	65.8	48.0	1219.2	0.3	123,751	lb	61.9 tons
straight		27+35	0+834	581.4	177.2	200.4	61.1	48.0	1219.2	0.3	126,797	lb	63.4 tons
straight		26+74	0+815	646.0	196.9	184.7	56.3	48.0	1219.2	0.3	129,843	lb	64.9 tons
straight		26+11	0+796	710.6	216.6	169.1	51.5	48.0	1219.2	0.3	132,890	lb	66.4 tons
straight		25+48	0+777	775.2	236.3	153.5	46.8	48.0	1219.2	0.3	135,936	lb	68.0 tons
curve	vertical	24+98	0+761	827.1	252.1	141.3	43.1	48.0	1219.2	0.3	160,340	lb	80.2 tons
curve	vertical	24+47	0+746	879.0	267.9	129.9	39.6	48.0	1219.2	0.3	158,390	lb	79.2 tons
curve	vertical	23+96	0+730	930.9	283.7	119.3	36.4	48.0	1219.2	0.3	147,145	lb	73.6 tons
curve	vertical	23+46	0+715	982.8	299.6	109.4	33.4	48.0	1219.2	0.3	140,525	lb	70.3 tons
curve	vertical	22+94	0+699	1,034.8	315.4	100.3	30.6	48.0	1219.2	0.3	139,021	lb	69.5 tons
curve	vertical	22+43	0+684	1,086.7	331.2	92.1	28.1	48.0	1219.2	0.3	143,904	lb	72.0 tons
curve	vertical	21+92	0+668	1,138.6	347.1	84.6	25.8	48.0	1219.2	0.3	148,371	lb	74.2 tons
curve	vertical	21+40	0+652	1,190.5	362.9	77.8	23.7	48.0	1219.2	0.3	152,613	lb	76.3 tons
curve	vertical	20+89	0+637	1,242.5	378.7	71.9	21.9	48.0	1219.2	0.3	156,732	lb	78.4 tons
curve	vertical	20+37	0+621	1,294.4	394.5	66.8	20.3	48.0	1219.2	0.3	160,793	lb	80.4 tons
curve	vertical	19+85	0+605	1,346.3	410.4	62.4	19.0	48.0	1219.2	0.3	164,833	lb	82.4 tons
curve	vertical	19+33	0+589	1,398.2	426.2	58.8	17.9	48.0	1219.2	0.3	168,879	lb	84.4 tons
curve	vertical	18+82	0+574	1,450.2	442.0	56.1	17.1	48.0	1219.2	0.3	172,947	lb	86.5 tons
curve	vertical	18+30	0+558	1,502.1	457.8	54.1	16.5	48.0	1219.2	0.3	177,052	lb	88.5 tons
curve	vertical	17+78	0+542	1,554.0	473.7	52.9	16.1	48.0	1219.2	0.3	202,916	lb	101.5 tons
curve	vertical	17+26	0+526	1,605.9	489.5	52.5	16.0	48.0	1219.2	0.3	208,564	lb	104.3 tons
straight		16+88	0+515	1,643.4	500.9	52.5	16.0	48.0	1219.2	0.3	213,236	lb	106.6 tons
straight		16+51	0+503	1,680.9	512.4	52.5	16.0	48.0	1219.2	0.3	217,912	lb	109.0 tons
straight		16+13	0+492	1,718.4	523.8	52.5	16.0	48.0	1219.2	0.3	222,586	lb	111.3 tons
straight		15+76	0+480	1,755.9	535.2	52.5	16.0	48.0	1219.2	0.3	227,260	lb	113.6 tons
curve	vertical	15+21	0+464	1,810.9	552.0	52.9	16.1	48.0	1219.2	0.3	265,359	lb	133.2 tons
curve	vertical	14+66	0+447	1,865.9	568.7	54.2	16.5	48.0	1219.2	0.3	265,957	lb	133.0 tons
curve	vertical	14+11	0+430	1,920.9	585.5	56.3	17.2	48.0	1219.2	0.3	259,093	lb	129.5 tons
curve	vertical	13+56	0+413	1,975.8	602.2	59.2	18.0	48.0	1219.2	0.3	241,422	lb	120.7 tons
curve	vertical	13+01	0+397	2,030.8	619.0	63.0	19.2	48.0	1219.2	0.3	243,545	lb	121.8 tons
curve	vertical	12+47	0+380	2,085.8	635.8	67.6	20.6	48.0	1219.2	0.3	253,030	lb	126.5 tons
curve	vertical	11+92	0+363	2,140.8	652.5	73.0	22.3	48.0	1219.2	0.3	261,729	lb	130.9 tons
curve	vertical	11+37	0+347	2,195.8	669.3	79.3	24.2	48.0	1219.2	0.3	269,939	lb	135.0 tons
curve	vertical	10+83	0+330	2,250.7	686.0	86.4	26.3	48.0	1219.2	0.3	277,826	lb	138.9 tons
curve	vertical	10+28	0+313	2,305.7	702.8	94.4	28.8	48.0	1219.2	0.3	285,488	lb	142.7 tons
curve	vertical	9+74	0+297	2,360.7	719.5	103.2	31.4	48.0	1219.2	0.3	292,991	lb	146.5 tons
curve	vertical	9+20	0+280	2,415.7	736.3	112.8	34.4	48.0	1219.2	0.3	300,378	lb	150.2 tons
curve	vertical	8+66	0+264	2,470.6	753.1	123.2	37.6	48.0	1219.2	0.3	307,681	lb	153.8 tons
curve	vertical	8+12	0+248	2,525.6	769.8	134.5	41.0	48.0	1219.2	0.3	314,925	lb	157.5 tons
curve	vertical	7+58	0+231	2,580.6	786.6	146.5	44.7	48.0	1219.2	0.3	322,127	lb	161.1 tons
curve	vertical	7+05	0+215	2,635.6	803.3	159.4	48.6	48.0	1219.2	0.3	329,302	lb	164.7 tons
straight		6+46	0+197	2,695.1	821.6	174.1	53.1	48.0	1219.2	0.3	339,081	lb	169.5 tons
straight		5+87	0+179	2,756.7	840.2	189.7	57.8	48.0	1219.2	0.3	348,860	lb	174.4 tons
straight		5+29	0+161	2,817.2	858.7	203.4	62.0	48.0	1219.2	0.3	358,638	lb	179.3 tons
straight		4+70	0+143	2,877.8	877.2	218.0	66.5	48.0	1219.2	0.3	368,417	lb	184.2 tons
straight		4+11	0+125	2,938.3	895.6	232.7	70.9	48.0	1219.2	0.3	378,195	lb	189.1 tons
straight		3+53	0+107	2,998.9	914.1	247.3	75.4	48.0	1219.2	0.3	387,974	lb	194.0 tons
straight		2+94	0+090	3,059.4	932.5	262.0	79.8	48.0	1219.2	0.3	397,753	lb	198.9 tons
straight		2+35	0+072	3,120.0	951.0	276.6	84.3	48.0	1219.2	0.3	407,531	lb	203.8 tons
straight		1+76	0+054	3,180.5	969.4	291.3	88.8	48.0	1219.2	0.3	417,310	lb	208.7 tons
straight		1+17	0+036	3,241.1	987.9	305.9	93.2	48.0	1219.2	0.3	427,088	lb	213.5 tons
straight		0+59	0+018	3,301.6	1,006.3	320.6	97.7	48.0	1219.2	0.3	436,867	lb	218.4 tons
HDD Rig Location		0+00	0+000	3,362.2	1,024.8	335.2	102.2	48.0	1219.2	0.3	446,646	lb	223.3 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				
1,178	8.12	1.68%	0	0.00	0.00%	0.0	0.00	0.00%	0.02	Yes	0.00	Yes
1,214	8.37	1.73%	0	0.00	0.00%	31.8	0.22	0.05%	0.02	Yes	0.00	Yes
1,250	8.62	1.79%	0	0.00	0.00%	63.6	0.44	0.09%	0.02	Yes	0.00	Yes
1,286	8.87	1.84%	0	0.00	0.00%	95.4	0.66	0.14%	0.02	Yes	0.00	Yes
1,323	9.12	1.89%	0	0.00	0.00%	127.2	0.88	0.18%	0.02	Yes	0.00	Yes
1,359	9.37	1.94%	0	0.00	0.00%	158.9	1.10	0.23%	0.02	Yes	0.00	Yes
1,395	9.62	1.99%	0	0.00	0.00%	190.7	1.32	0.27%	0.02	Yes	0.00	Yes
1,431	9.87	2.04%	0	0.00	0.00%	222.5	1.53	0.32%	0.03	Yes	0.00	Yes
1,467	10.11	2.10%	0	0.00	0.00%	254.3	1.75	0.36%	0.03	Yes	0.00	Yes
1,503	10.36	2.15%	0	0.00	0.00%	286.1	1.97	0.41%	0.03	Yes	0.00	Yes
1,539	10.61	2.20%	0	0.00	0.00%	317.9	2.19	0.45%	0.03	Yes	0.00	Yes
1,575	10.86	2.25%	0	0.00	0.00%	349.7	2.41	0.50%	0.03	Yes	0.00	Yes
1,611	11.11	2.30%	0	0.00	0.00%	381.5	2.63	0.54%	0.03	Yes	0.00	Yes
1,901	13.11	2.72%	12,882	88.82	18.40%	406.2	2.80	0.58%	0.32	Yes	0.08	Yes
1,878	12.95	2.68%	12,882	88.82	18.40%	429.4	2.96	0.61%	0.32	Yes	0.08	Yes
1,744	12.03	2.49%	12,882	88.82	18.40%	451.0	3.11	0.64%	0.32	Yes	0.08	Yes
1,666	11.49	2.38%	12,882	88.82	18.40%	471.1	3.25	0.67%	0.32	Yes	0.08	Yes
1,648	11.35	2.35%	12,882	88.82	18.40%	489.5	3.38	0.70%	0.32	Yes	0.08	Yes
1,706	11.76	2.44%	12,882	88.82	18.40%	506.4	3.49	0.72%	0.32	Yes	0.08	Yes
1,759	12.13	2.51%	12,882	88.82	18.40%	521.7	3.60	0.75%	0.32	Yes	0.08	Yes
1,809	12.47	2.58%	12,882	88.82	18.40%	535.3	3.69	0.76%	0.32	Yes	0.08	Yes
1,858	12.81	2.65%	12,882	88.82	18.40%	547.4	3.77	0.78%	0.32	Yes	0.08	Yes
1,906	13.14	2.72%	12,882	88.82	18.40%	557.9	3.85	0.80%	0.32	Yes	0.08	Yes
1,954	13.47	2.79%	12,882	88.82	18.40%	566.7	3.91	0.81%	0.32	Yes	0.08	Yes
2,002	13.80	2.86%	12,882	88.82	18.40%	574.0	3.96	0.82%	0.32	Yes	0.09	Yes
2,050	14.14	2.93%	12,882	88.82	18.40%	579.6	4.00	0.83%	0.32	Yes	0.09	Yes
2,099	14.47	3.00%	12,882	88.82	18.40%	583.7	4.02	0.83%	0.33	Yes	0.09	Yes
2,405	16.59	3.44%	12,882	88.82	18.40%	574.3	3.96	0.82%	0.33	Yes	0.09	Yes
2,472	17.05	3.53%	12,882	88.82	18.40%	575.1	3.96	0.82%	0.33	Yes	0.09	Yes
2,528	17.43	3.61%	0	0.00	0.00%	575.1	3.96	0.82%	0.05	Yes	0.01	Yes
2,583	17.81	3.69%	0	0.00	0.00%	575.1	3.96	0.82%	0.05	Yes	0.01	Yes
2,639	18.19	3.77%	0	0.00	0.00%	575.1	3.96	0.82%	0.05	Yes	0.01	Yes
2,694	18.57	3.85%	0	0.00	0.00%	575.1	3.96	0.82%	0.05	Yes	0.01	Yes
3,158	21.77	4.51%	12,167	83.89	17.38%	574.2	3.96	0.82%	0.33	Yes	0.09	Yes
3,153	21.74	4.50%	12,167	83.89	17.38%	571.7	3.94	0.82%	0.33	Yes	0.09	Yes
2,965	20.44	4.24%	12,167	83.89	17.38%	567.4	3.91	0.81%	0.33	Yes	0.09	Yes
2,852	19.73	4.09%	12,167	83.89	17.38%	561.4	3.87	0.80%	0.32	Yes	0.09	Yes
2,887	19.91	4.12%	12,167	83.89	17.38%	553.7	3.82	0.79%	0.32	Yes	0.09	Yes
3,000	20.68	4.29%	12,167	83.89	17.38%	544.3	3.75	0.78%	0.33	Yes	0.09	Yes
3,103	21.39	4.43%	12,167	83.89	17.38%	533.3	3.68	0.76%	0.33	Yes	0.09	Yes
3,200	22.06	4.57%	12,167	83.89	17.38%	520.5	3.59	0.74%	0.33	Yes	0.09	Yes
3,293	22.71	4.70%	12,167	83.89	17.38%	506.0	3.49	0.72%	0.33	Yes	0.09	Yes
3,384	23.33	4.83%	12,167	83.89	17.38%	489.8	3.38	0.70%	0.33	Yes	0.09	Yes
3,473	23.95	4.96%	12,167	83.89	17.38%	472.0	3.25	0.67%	0.33	Yes	0.09	Yes
3,561	24.55	5.09%	12,167	83.89	17.38%	452.4	3.12	0.65%	0.34	Yes	0.09	Yes
3,647	25.15	5.21%	12,167	83.89	17.38%	431.2	2.97	0.62%	0.34	Yes	0.09	Yes
3,733	25.74	5.33%	12,167	83.89	17.38%	408.3	2.82	0.58%	0.34	Yes	0.09	Yes
3,819	26.33	5.46%	12,167	83.89	17.38%	383.8	2.65	0.55%	0.34	Yes	0.09	Yes
3,904	26.92	5.58%	12,167	83.89	17.38%	357.6	2.47	0.51%	0.34	Yes	0.09	Yes
4,020	27.71	5.74%	0	0.00	0.00%	327.8	2.26	0.47%	0.07	Yes	0.01	Yes
4,136	28.51	5.91%	0	0.00	0.00%	298.0	2.05	0.43%	0.07	Yes	0.01	Yes
4,251	29.31	6.07%	0	0.00	0.00%	268.2	1.85	0.38%	0.08	Yes	0.01	Yes
4,367	30.11	6.24%	0	0.00	0.00%	238.4	1.64	0.34%	0.08	Yes	0.01	Yes
4,483	30.91	6.40%	0	0.00	0.00%	208.6	1.44	0.30%	0.08	Yes	0.01	Yes
4,599	31.71	6.57%	0	0.00	0.00%	178.8	1.23	0.26%	0.08	Yes	0.01	Yes
4,715	32.51	6.74%	0	0.00	0.00%	149.0	1.03	0.21%	0.08	Yes	0.01	Yes
4,831	33.31	6.90%	0	0.00	0.00%	119.2	0.82	0.17%	0.09	Yes	0.01	Yes
4,947	34.11	7.07%	0	0.00	0.00%	89.4	0.62	0.13%	0.09	Yes	0.01	Yes
5,063	34.91	7.23%	0	0.00	0.00%	59.6	0.41	0.09%	0.09	Yes	0.01	Yes
5,179	35.71	7.40%	0	0.00	0.00%	29.8	0.21	0.04%	0.09	Yes	0.01	Yes
5,295	36.51	7.56%	0	0.00	0.00%	0.0	0.00	0.00%	0.09	Yes	0.01	Yes

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

Ground Elevation at Pipe Entry	341.01	feet
	103.94	metres
Ground Elevation at Pipe Exit	335.20	feet
	102.17	metres

	TOTAL PULL LOADS		
Maximum Values	446,646	lb	223.3 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		
5,295	36.5	7.56%	12,882	88.8	18.40%	584	4.0	0.83%	0.34	0.09

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	446,646	lb
	1,987	kN
Factor of Safety	7.9	
Start-Up Load Factor	1.5	
Maximum Calculated Start-Up Pipe Pull Load	669,968	lb
	2,980	kN
Factor of Safety	5.3	

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)	0.1	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	22.5	lb/100ft² (Based on HDD experience from previous installations)
	107.73	dyne/cm²
Plastic Viscosity	15	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	m³/min
Drilling mud pumping rate	1129	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.273	m³/min
Pipe Pullback Rate	10	feet/min (Based on HDD experience)
	3.05	m/min

MOTT MACDONALD

Calculated by: M. Eakins
Checked by: G. Duyvestyn
Date: 3/14/2019
Project No: 353754

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

PROJECT: PennEast Pipeline Project

HDD CROSSING LOCATION: Nishisakawick Creek (No Buoyancy - 11PPG Drilling Fluid)

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		33+01	1+006	0.0	0.0	341.0	103.9	--	--		99,380 lb	49.7 tons
straight		32+39	0+987	64.6	19.7	325.4	99.2	48.0	1219.2	0.3	112,051 lb	56.0 tons
straight		31+75	0+968	129.2	39.4	309.8	94.4	48.0	1219.2	0.3	124,722 lb	62.4 tons
straight		31+13	0+949	193.8	59.1	294.1	89.7	48.0	1219.2	0.3	137,392 lb	68.7 tons
straight		30+50	0+930	258.4	78.8	278.5	84.9	48.0	1219.2	0.3	150,063 lb	75.0 tons
straight		29+87	0+911	323.0	98.4	262.9	80.1	48.0	1219.2	0.3	162,734 lb	81.4 tons
straight		29+25	0+891	387.6	118.1	247.2	75.4	48.0	1219.2	0.3	175,405 lb	87.7 tons
straight		28+62	0+872	452.2	137.8	231.6	70.6	48.0	1219.2	0.3	188,076 lb	94.0 tons
straight		27+99	0+853	516.8	157.5	216.0	65.8	48.0	1219.2	0.3	200,747 lb	100.4 tons
straight		27+36	0+834	581.4	177.2	200.4	61.1	48.0	1219.2	0.3	213,418 lb	106.7 tons
straight		26+74	0+815	646.0	196.9	184.7	56.3	48.0	1219.2	0.3	226,089 lb	113.0 tons
straight		26+11	0+796	710.6	216.6	169.1	51.5	48.0	1219.2	0.3	238,760 lb	119.4 tons
straight		25+48	0+777	775.2	236.3	153.5	46.8	48.0	1219.2	0.3	251,431 lb	125.7 tons
curve	vertical	24+86	0+761	827.1	252.1	141.3	43.1	48.0	1219.2	0.3	278,473 lb	139.2 tons
curve	vertical	24+47	0+746	879.0	267.9	129.9	39.6	48.0	1219.2	0.3	303,424 lb	151.7 tons
curve	vertical	23+96	0+730	930.9	283.7	119.3	36.4	48.0	1219.2	0.3	306,534 lb	153.3 tons
curve	vertical	23+46	0+715	982.8	299.6	109.4	33.4	48.0	1219.2	0.3	313,960 lb	157.0 tons
curve	vertical	22+94	0+699	1,034.8	315.4	100.3	30.6	48.0	1219.2	0.3	322,979 lb	161.5 tons
curve	vertical	22+43	0+684	1,086.7	331.2	92.1	28.1	48.0	1219.2	0.3	332,669 lb	166.3 tons
curve	vertical	21+92	0+668	1,138.6	347.1	84.6	25.8	48.0	1219.2	0.3	342,632 lb	171.3 tons
curve	vertical	21+40	0+652	1,190.5	362.9	77.8	23.7	48.0	1219.2	0.3	352,665 lb	176.3 tons
curve	vertical	20+89	0+637	1,242.5	378.7	71.9	21.9	48.0	1219.2	0.3	362,651 lb	181.3 tons
curve	vertical	20+37	0+621	1,294.4	394.5	66.8	20.3	48.0	1219.2	0.3	372,525 lb	186.3 tons
curve	vertical	19+85	0+605	1,346.3	410.4	62.4	19.0	48.0	1219.2	0.3	382,244 lb	191.1 tons
curve	vertical	19+33	0+589	1,398.2	426.2	58.8	17.9	48.0	1219.2	0.3	391,781 lb	195.9 tons
curve	vertical	18+82	0+574	1,450.2	442.0	56.1	17.1	48.0	1219.2	0.3	401,120 lb	200.6 tons
curve	vertical	18+30	0+558	1,502.1	457.8	54.1	16.5	48.0	1219.2	0.3	410,250 lb	205.1 tons
curve	vertical	17+78	0+542	1,554.0	473.7	52.9	16.1	48.0	1219.2	0.3	504,773 lb	252.4 tons
curve	vertical	17+26	0+526	1,605.9	489.5	52.5	16.0	48.0	1219.2	0.3	519,010 lb	259.5 tons
straight		16+68	0+515	1,643.4	500.9	52.5	16.0	48.0	1219.2	0.3	526,277 lb	263.1 tons
straight		16+51	0+503	1,680.9	512.4	52.5	16.0	48.0	1219.2	0.3	533,544 lb	266.8 tons
straight		16+13	0+492	1,718.4	523.8	52.5	16.0	48.0	1219.2	0.3	540,812 lb	270.4 tons
straight		15+76	0+480	1,755.9	535.2	52.5	16.0	48.0	1219.2	0.3	548,079 lb	274.0 tons
curve	vertical	15+21	0+464	1,810.9	552.0	52.9	16.1	48.0	1219.2	0.3	595,618 lb	297.8 tons
curve	vertical	14+66	0+447	1,865.9	568.7	54.2	16.5	48.0	1219.2	0.3	625,430 lb	312.7 tons
curve	vertical	14+11	0+430	1,920.9	585.5	56.3	17.2	48.0	1219.2	0.3	628,362 lb	314.2 tons
curve	vertical	13+56	0+413	1,975.8	602.2	59.2	18.0	48.0	1219.2	0.3	638,623 lb	319.0 tons
curve	vertical	13+01	0+397	2,030.8	619.0	63.0	19.2	48.0	1219.2	0.3	650,141 lb	325.1 tons
curve	vertical	12+47	0+380	2,085.8	635.8	67.6	20.6	48.0	1219.2	0.3	663,279 lb	331.6 tons
curve	vertical	11+92	0+363	2,140.8	652.5	73.0	22.3	48.0	1219.2	0.3	676,625 lb	338.4 tons
curve	vertical	11+37	0+347	2,195.8	669.3	79.3	24.2	48.0	1219.2	0.3	690,485 lb	345.2 tons
curve	vertical	10+83	0+330	2,250.7	686.0	86.4	26.3	48.0	1219.2	0.3	704,108 lb	352.1 tons
curve	vertical	10+28	0+313	2,305.7	702.8	94.4	28.8	48.0	1219.2	0.3	717,613 lb	358.8 tons
curve	vertical	9+74	0+297	2,360.7	719.5	103.2	31.4	48.0	1219.2	0.3	730,990 lb	365.5 tons
curve	vertical	9+20	0+280	2,415.7	736.3	112.8	34.4	48.0	1219.2	0.3	744,127 lb	372.1 tons
curve	vertical	8+66	0+264	2,470.6	753.1	123.2	37.6	48.0	1219.2	0.3	757,102 lb	378.6 tons
curve	vertical	8+12	0+248	2,525.6	769.8	134.5	41.0	48.0	1219.2	0.3	769,681 lb	384.9 tons
curve	vertical	7+58	0+231	2,580.6	786.6	146.5	44.7	48.0	1219.2	0.3	782,460 lb	391.2 tons
curve	vertical	7+05	0+215	2,635.6	803.3	159.4	48.6	48.0	1219.2	0.3	794,638 lb	397.4 tons
straight		6+46	0+197	2,696.1	821.8	174.1	53.1	48.0	1219.2	0.3	801,979 lb	401.0 tons
straight		5+87	0+179	2,756.7	840.2	188.7	57.5	48.0	1219.2	0.3	809,120 lb	404.6 tons
straight		5+29	0+161	2,817.2	858.7	203.4	62.0	48.0	1219.2	0.3	816,261 lb	408.1 tons
straight		4+70	0+143	2,877.8	877.2	219.0	66.8	48.0	1219.2	0.3	823,403 lb	411.7 tons
straight		4+11	0+125	2,938.3	895.6	232.7	70.9	48.0	1219.2	0.3	830,544 lb	415.3 tons
straight		3+52	0+107	2,998.9	914.1	247.3	75.4	48.0	1219.2	0.3	837,685 lb	418.8 tons
straight		2+94	0+090	3,059.4	932.5	262.0	79.8	48.0	1219.2	0.3	844,827 lb	422.4 tons
straight		2+35	0+072	3,120.0	951.0	276.6	84.3	48.0	1219.2	0.3	851,968 lb	426.0 tons
straight		1+76	0+054	3,180.5	969.4	291.3	88.8	48.0	1219.2	0.3	859,109 lb	429.6 tons
straight		1+17	0+036	3,241.1	987.9	305.9	93.2	48.0	1219.2	0.3	866,251 lb	433.1 tons
straight		0+59	0+018	3,301.6	1,006.3	320.6	97.7	48.0	1219.2	0.3	873,392 lb	436.7 tons
HDD Rig Location		0+00	0+000	3,362.2	1,024.8	335.2	102.2	48.0	1219.2	0.3	880,533 lb	440.3 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				
1,176	8.12	1.68%	0	0.00	0.00%	0.0	0.00	0.00%	0.02	Yes	0.00	Yes
1,328	9.16	1.90%	0	0.00	0.00%	210.9	1.45	0.30%	0.02	Yes	0.00	Yes
1,479	10.19	2.11%	0	0.00	0.00%	421.9	2.91	0.60%	0.03	Yes	0.00	Yes
1,629	11.23	2.33%	0	0.00	0.00%	632.8	4.36	0.90%	0.03	Yes	0.01	Yes
1,779	12.27	2.54%	0	0.00	0.00%	843.7	5.82	1.21%	0.03	Yes	0.01	Yes
1,929	13.30	2.76%	0	0.00	0.00%	1,054.6	7.27	1.51%	0.03	Yes	0.02	Yes
2,079	14.34	2.97%	0	0.00	0.00%	1,265.6	8.73	1.81%	0.04	Yes	0.03	Yes
2,230	15.37	3.19%	0	0.00	0.00%	1,476.5	10.18	2.11%	0.04	Yes	0.04	Yes
2,380	16.41	3.40%	0	0.00	0.00%	1,687.4	11.63	2.41%	0.04	Yes	0.05	Yes
2,530	17.44	3.61%	0	0.00	0.00%	1,898.3	13.09	2.71%	0.05	Yes	0.07	Yes
2,680	18.48	3.83%	0	0.00	0.00%	2,109.3	14.54	3.01%	0.05	Yes	0.08	Yes
2,830	19.51	4.04%	0	0.00	0.00%	2,320.2	16.00	3.31%	0.05	Yes	0.10	Yes
2,981	20.55	4.26%	0	0.00	0.00%	2,531.1	17.45	3.62%	0.05	Yes	0.12	Yes
3,301	22.76	4.72%	12,882	88.82	18.40%	2,695.5	18.58	3.85%	0.35	Yes	0.25	Yes
3,597	24.80	5.14%	12,882	88.82	18.40%	2,849.4	19.65	4.07%	0.35	Yes	0.27	Yes
3,834	25.65	5.19%	12,882	88.82	18.40%	2,992.9	20.64	4.28%	0.35	Yes	0.29	Yes
3,722	25.66	5.32%	12,882	88.82	18.40%	3,125.8	21.55	4.47%	0.35	Yes	0.30	Yes
3,829	26.40	5.47%	12,882	88.82	18.40%	3,248.3	22.40	4.64%	0.36	Yes	0.32	Yes
3,944	27.19	5.63%	12,882	88.82	18.40%	3,360.2	23.17	4.80%	0.36	Yes	0.34	Yes
4,062	28.00	5.80%	12,882	88.82	18.40%	3,461.5	23.87	4.95%	0.36	Yes	0.35	Yes
4,181	28.82	5.97%	12,882	88.82	18.40%	3,552.2	24.49	5.07%	0.36	Yes	0.36	Yes
4,299	29.64	6.14%	12,882	88.82	18.40%	3,632.3	25.04	5.19%	0.37	Yes	0.38	Yes
4,416	30.45	6.31%	12,882	88.82	18.40%	3,701.8	25.52	5.29%	0.37	Yes	0.39	Yes
4,531	31.24	6.47%	12,882	88.82	18.40%	3,760.6	25.93	5.37%	0.37	Yes	0.40	Yes
4,644	32.02	6.63%	12,882	88.82	18.40%	3,808.7	26.26	5.44%	0.37	Yes	0.41	Yes
4,755	32.79	6.79%	12,882	88.82	18.40%	3,846.1	26.52	5.49%	0.37	Yes	0.41	Yes
4,863	33.53	6.95%	12,882	88.82	18.40%	3,872.9	26.70	5.53%	0.38	Yes	0.42	Yes
5,984	41.26	8.55%	12,882	88.82	18.40%	3,810.5	26.27	5.44%	0.40	Yes	0.44	Yes
6,153	42.42	8.79%	12,882	88.82	18.40%	3,815.9	26.31	5.45%	0.40	Yes	0.44	Yes
6,239	43.01	8.91%	0	0.00	0.00%	3,815.9	26.31	5.45%	0.11	Yes	0.29	Yes
6,325	43.61	9.04%	0	0.00	0.00%	3,815.9	26.31	5.45%	0.11	Yes	0.29	Yes
6,411	44.20	9.16%	0	0.00	0.00%	3,815.9	26.31	5.45%	0.11	Yes	0.29	Yes
6,497	44.80	9.28%	0	0.00	0.00%	3,815.9	26.31	5.45%	0.12	Yes	0.29	Yes
7,061	48.68	10.09%	12,157	83.89	17.38%	3,810.2	26.27	5.44%	0.40	Yes	0.45	Yes
7,414	51.12	10.59%	12,157	83.89	17.38%	3,793.2	26.15	5.42%	0.40	Yes	0.45	Yes
7,449	51.36	10.64%	12,157	83.89	17.38%	3,764.9	25.96	5.30%	0.41	Yes	0.45	Yes
7,563	52.15	10.80%	12,157	83.89	17.38%	3,725.2	25.68	5.32%	0.41	Yes	0.44	Yes
7,707	53.14	11.01%	12,157	83.89	17.38%	3,674.3	25.33	5.25%	0.41	Yes	0.44	Yes
7,863	54.21	11.23%	12,157	83.89	17.38%	3,612.0	24.90	5.16%	0.41	Yes	0.43	Yes
8,023	55.32	11.46%	12,157	83.89	17.38%	3,538.5	24.40	5.05%	0.42	Yes	0.42	Yes
8,165	56.44	11.69%	12,157	83.89	17.38%	3,453.7	23.81	4.93%	0.42	Yes	0.41	Yes
8,347	57.55	11.92%	12,157	83.89	17.38%	3,357.6	23.15	4.80%	0.42	Yes	0.40	Yes
8,507	58.65	12.15%	12,157	83.89	17.38%	3,250.3	22.41	4.64%	0.42	Yes	0.39	Yes
8,665	59.74	12.38%	12,157	83.89	17.38%	3,131.9	21.59	4.47%	0.43	Yes	0.38	Yes
8,821	60.82	12.60%	12,157	83.89	17.38%	3,002.2	20.70	4.29%	0.43	Yes	0.37	Yes
8,975	61.88	12.82%	12,157	83.89	17.38%	2,861.4	19.73	4.09%	0.43	Yes	0.35	Yes
9,127	62.93	13.04%	12,157	83.89	17.38%	2,709.5	18.68	3.87%	0.44	Yes	0.34	Yes
9,276	63.95	13.25%	12,157	83.89	17.38%	2,546.5	17.56	3.64%	0.44	Yes	0.32	Yes
9,422	64.97	13.46%	12,157	83.89	17.38%	2,372.5	16.36	3.39%	0.44	Yes	0.30	Yes
9,567	65.55	13.58%	0	0.00	0.00%	2,174.8	14.99	3.11%	0.17	Yes	0.13	Yes
9,592	66.13	13.70%	0	0.00	0.00%	1,977.1	13.63	2.82%	0.17	Yes	0.12	Yes
9,676	66.72	13.82%	0	0.00	0.00%	1,779.4	12.27	2.54%	0.17	Yes	0.11	
9,761	67.30	13.94%	0	0.00	0.00%	1,581.7	10.91	2.26%	0.17	Yes	0.09	
9,846	67.88	14.07%	0	0.00	0.00%	1,384.0	9.54	1.98%	0.18	Yes	0.08	
9,930	68.47	14.19%	0	0.00	0.00%	1,186.3	8.18	1.69%	0.18	Yes	0.07	
10,015	69.05	14.31%	0	0.00	0.00%	988.5	6.82	1.41%	0.18	Yes	0.08	
10,100	69.63	14.43%	0	0.00	0.00%	790.8	5.45	1.13%	0.18	Yes	0.09	Yes
10,184	70.22	14.55%	0	0.00	0.00%	593.1	4.09	0.85%	0.18	Yes	0.05	Yes
10,269	70.80	14.67%	0	0.00	0.00%	395.4	2.73	0.56%	0.18	Yes	0.04	Yes
10,354	71.39	14.79%	0	0.00	0.00%	197.7	1.36	0.28%	0.18	Yes	0.04	Yes
10,438	71.97	14.91%	0	0.00	0.00%	0.0	0.00	0.00%	0.19	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	341.01	feet
	103.94	metres
Ground Elevation at Pipe Exit	335.20	feet
	102.17	metres

	TOTAL PULL LOADS	
Maximum Values	880,533lb	440.3tons

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		
10,438	72.0	14.91%	12,882	88.8	18.40%	3,873	26.7	5.53%	0.44	0.45

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
	428.09	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	880,533	lb
	3,917	kN
Factor of Safety	4.0	

Start-Up Load Factor	1.5	
Maximum Calculated Start-Up Pipe Pull Load	1,320,800	lb
	5,875	kN
Factor of Safety	2.7	

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 Coefficient (GS or rollers)	0.1	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	22.5	lb/100ft² (Based on HDD experience from previous installations)
	107.73	dyne/cm²
Plastic Viscosity	15	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	m³/min
Drilling mud pumping rate	1129	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.273	m³/min
Pipe Pullback Rate	19	feet/min (Based on HDD experience)
	3.05	m/min

MOTT MACDONALD

Calculated by: M. Eakins
Checked by: G. Duyvestyn
Date: 3/14/2019
Project No: 353754

ontal Directional Drilling
ulation of Pull Loads and Stresses during Pipe Installation

PROJECT: PennEast Pipeline Project

HDD CROSSING LOCATION: Nishisakawick Creek (Buoyancy - 11PPG Drilling Fluid)

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		33+01	1+006	0.0	0.0	341.0	103.9	--	--		99,380 lb	49.7 tons
straight		32+38	0+987	64.6	19.7	325.4	99.2	48.0	1219.2	0.3	102,258 lb	51.1 tons
straight		31+75	0+968	129.2	39.4	309.8	94.4	48.0	1219.2	0.3	105,136 lb	52.6 tons
straight		31+13	0+949	193.8	59.1	294.1	89.7	48.0	1219.2	0.3	108,015 lb	54.0 tons
straight		30+50	0+930	258.4	78.8	278.5	84.9	48.0	1219.2	0.3	110,893 lb	55.4 tons
straight		29+87	0+911	323.0	98.4	262.9	80.1	48.0	1219.2	0.3	113,772 lb	56.9 tons
straight		29+25	0+891	387.6	118.1	247.2	75.4	48.0	1219.2	0.3	116,650 lb	58.3 tons
straight		28+62	0+872	452.2	137.8	231.6	70.6	48.0	1219.2	0.3	119,529 lb	59.8 tons
straight		27+99	0+853	516.8	157.5	216.0	65.8	48.0	1219.2	0.3	122,407 lb	61.2 tons
straight		27+36	0+834	581.4	177.2	200.4	61.1	48.0	1219.2	0.3	125,286 lb	62.6 tons
straight		26+74	0+815	646.0	196.9	184.7	56.3	48.0	1219.2	0.3	128,164 lb	64.1 tons
straight		26+11	0+796	710.6	216.6	169.1	51.5	48.0	1219.2	0.3	131,043 lb	65.5 tons
straight		25+48	0+777	775.2	236.3	153.5	46.8	48.0	1219.2	0.3	133,921 lb	67.0 tons
curve	vertical	24+98	0+761	827.1	252.1	141.3	43.1	48.0	1219.2	0.3	159,228 lb	79.6 tons
curve	vertical	24+47	0+746	879.0	267.9	129.5	39.6	48.0	1219.2	0.3	159,621 lb	79.8 tons
curve	vertical	23+95	0+730	930.9	283.7	119.3	36.4	48.0	1219.2	0.3	149,953 lb	75.0 tons
curve	vertical	23+46	0+715	982.8	299.6	109.4	33.4	48.0	1219.2	0.3	144,878 lb	72.4 tons
curve	vertical	22+94	0+699	1,034.8	315.4	100.3	30.6	48.0	1219.2	0.3	141,692 lb	70.8 tons
curve	vertical	22+43	0+684	1,086.7	331.2	92.1	28.1	48.0	1219.2	0.3	139,495 lb	69.7 tons
curve	vertical	21+92	0+668	1,138.6	347.1	84.6	25.8	48.0	1219.2	0.3	143,132 lb	71.6 tons
curve	vertical	21+40	0+652	1,190.5	362.9	77.5	23.7	48.0	1219.2	0.3	146,773 lb	73.4 tons
curve	vertical	20+89	0+637	1,242.5	378.7	71.9	21.9	48.0	1219.2	0.3	150,261 lb	75.1 tons
curve	vertical	20+37	0+621	1,294.4	394.5	66.8	20.3	48.0	1219.2	0.3	153,659 lb	76.8 tons
curve	vertical	19+85	0+605	1,346.3	410.4	62.4	19.0	48.0	1219.2	0.3	157,056 lb	78.5 tons
curve	vertical	19+33	0+589	1,398.2	426.2	58.8	17.9	48.0	1219.2	0.3	160,334 lb	80.2 tons
curve	vertical	18+82	0+574	1,450.2	442.0	56.1	17.1	48.0	1219.2	0.3	163,654 lb	81.8 tons
curve	vertical	18+30	0+558	1,502.1	457.8	54.1	16.5	48.0	1219.2	0.3	166,982 lb	83.5 tons
curve	vertical	17+78	0+542	1,554.0	473.7	52.9	16.1	48.0	1219.2	0.3	182,189 lb	91.1 tons
curve	vertical	17+26	0+526	1,605.9	489.5	52.5	16.0	48.0	1219.2	0.3	186,466 lb	93.2 tons
straight		16+88	0+515	1,643.4	500.9	52.5	16.0	48.0	1219.2	0.3	190,099 lb	95.0 tons
straight		16+51	0+503	1,680.9	512.4	52.5	16.0	48.0	1219.2	0.3	193,733 lb	96.9 tons
straight		16+13	0+492	1,718.4	523.8	52.5	16.0	48.0	1219.2	0.3	197,366 lb	98.7 tons
straight		15+76	0+480	1,755.9	535.2	52.5	16.0	48.0	1219.2	0.3	200,999 lb	100.5 tons
curve	vertical	15+21	0+464	1,810.9	552.0	52.9	16.1	48.0	1219.2	0.3	241,438 lb	120.7 tons
curve	vertical	14+66	0+447	1,865.9	568.7	54.2	16.5	48.0	1219.2	0.3	242,942 lb	121.5 tons
curve	vertical	14+11	0+430	1,920.9	585.5	56.3	17.2	48.0	1219.2	0.3	228,646 lb	114.3 tons
curve	vertical	13+56	0+413	1,975.8	602.2	59.2	18.0	48.0	1219.2	0.3	221,500 lb	110.8 tons
curve	vertical	13+01	0+397	2,030.8	619.0	63.0	19.2	48.0	1219.2	0.3	217,286 lb	108.6 tons
curve	vertical	12+47	0+380	2,085.8	635.8	67.6	20.6	48.0	1219.2	0.3	216,496 lb	108.2 tons
curve	vertical	11+92	0+363	2,140.8	652.5	73.0	22.3	48.0	1219.2	0.3	223,450 lb	111.7 tons
curve	vertical	11+37	0+347	2,195.8	669.3	79.3	24.2	48.0	1219.2	0.3	229,812 lb	115.0 tons
curve	vertical	10+83	0+330	2,250.7	686.0	86.4	26.3	48.0	1219.2	0.3	236,050 lb	118.0 tons
curve	vertical	10+28	0+313	2,305.7	702.8	94.4	28.8	48.0	1219.2	0.3	241,961 lb	121.0 tons
curve	vertical	9+74	0+297	2,360.7	719.5	103.2	31.4	48.0	1219.2	0.3	247,710 lb	123.9 tons
curve	vertical	9+20	0+280	2,415.7	736.3	112.8	34.4	48.0	1219.2	0.3	253,339 lb	126.7 tons
curve	vertical	8+66	0+264	2,470.6	753.1	123.2	37.6	48.0	1219.2	0.3	258,879 lb	129.4 tons
curve	vertical	8+12	0+248	2,525.6	769.8	134.5	41.0	48.0	1219.2	0.3	264,353 lb	132.2 tons
curve	vertical	7+58	0+231	2,580.6	786.6	146.5	44.7	48.0	1219.2	0.3	269,776 lb	134.9 tons
curve	vertical	7+05	0+215	2,635.6	803.3	159.4	48.6	48.0	1219.2	0.3	275,163 lb	137.5 tons
straight		6+46	0+197	2,696.1	821.8	174.1	53.1	48.0	1219.2	0.3	282,536 lb	141.3 tons
straight		5+87	0+179	2,756.7	840.2	188.7	57.5	48.0	1219.2	0.3	289,909 lb	145.0 tons
straight		5+29	0+161	2,817.2	858.7	203.4	62.0	48.0	1219.2	0.3	297,283 lb	148.6 tons
straight		4+70	0+143	2,877.8	877.2	218.0	66.5	48.0	1219.2	0.3	304,656 lb	152.3 tons
straight		4+11	0+125	2,938.3	895.6	232.7	70.9	48.0	1219.2	0.3	312,029 lb	156.0 tons
straight		3+52	0+107	2,998.9	914.1	247.3	75.4	48.0	1219.2	0.3	319,403 lb	159.7 tons
straight		2+94	0+090	3,059.4	932.5	262.0	79.8	48.0	1219.2	0.3	326,776 lb	163.4 tons
straight		2+35	0+072	3,120.0	951.0	276.6	84.3	48.0	1219.2	0.3	334,149 lb	167.1 tons
straight		1+76	0+054	3,180.5	969.4	291.3	88.8	48.0	1219.2	0.3	341,523 lb	170.8 tons
straight		1+17	0+036	3,241.1	987.9	305.9	93.2	48.0	1219.2	0.3	348,896 lb	174.4 tons
straight		0+59	0+018	3,301.6	1,006.3	320.6	97.7	48.0	1219.2	0.3	356,269 lb	178.1 tons
HDD Rig Location		0+00	0+000	3,362.2	1,024.8	335.2	102.2	48.0	1219.2	0.3	363,642 lb	181.8 tons

HDD Installation Stress Analysis

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	CombinedTensile and Bending <1.0	Combined Tensile, Bending and Hoop Factor	Combined Tensile, Bending and Hoop <1.0
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS				
1,178	8.12	1.68%	0	0.00	0.00%	0.0	0.00	0.00%	0.02	Yes	0.00	Yes
1,212	8.36	1.73%	0	0.00	0.00%	51.0	0.35	0.07%	0.02	Yes	0.00	Yes
1,246	8.59	1.78%	0	0.00	0.00%	101.9	0.70	0.15%	0.02	Yes	0.00	Yes
1,280	8.83	1.83%	0	0.00	0.00%	152.9	1.05	0.22%	0.02	Yes	0.00	Yes
1,315	9.06	1.88%	0	0.00	0.00%	203.9	1.41	0.29%	0.02	Yes	0.00	Yes
1,349	9.30	1.93%	0	0.00	0.00%	254.8	1.76	0.36%	0.02	Yes	0.00	Yes
1,383	9.53	1.98%	0	0.00	0.00%	305.8	2.11	0.44%	0.02	Yes	0.00	Yes
1,417	9.77	2.02%	0	0.00	0.00%	356.7	2.46	0.51%	0.03	Yes	0.00	Yes
1,451	10.00	2.07%	0	0.00	0.00%	407.7	2.81	0.58%	0.03	Yes	0.00	Yes
1,485	10.24	2.12%	0	0.00	0.00%	458.7	3.16	0.66%	0.03	Yes	0.00	Yes
1,519	10.48	2.17%	0	0.00	0.00%	509.6	3.51	0.73%	0.03	Yes	0.01	Yes
1,553	10.71	2.22%	0	0.00	0.00%	560.6	3.87	0.80%	0.03	Yes	0.01	Yes
1,588	10.95	2.27%	0	0.00	0.00%	611.6	4.22	0.87%	0.03	Yes	0.01	Yes
1,888	13.01	2.70%	12,882	88.82	18.40%	651.3	4.49	0.93%	0.32	Yes	0.09	Yes
1,892	13.05	2.70%	12,882	88.82	18.40%	688.5	4.75	0.98%	0.32	Yes	0.09	Yes
1,778	12.26	2.54%	12,882	88.82	18.40%	723.1	4.99	1.03%	0.32	Yes	0.09	Yes
1,717	11.84	2.45%	12,882	88.82	18.40%	755.2	5.21	1.08%	0.32	Yes	0.09	Yes
1,660	11.58	2.40%	12,882	88.82	18.40%	784.6	5.41	1.12%	0.32	Yes	0.09	Yes
1,654	11.40	2.36%	12,882	88.82	18.40%	811.9	5.60	1.16%	0.32	Yes	0.09	Yes
1,697	11.70	2.42%	12,882	88.82	18.40%	836.3	5.77	1.19%	0.32	Yes	0.09	Yes
1,740	12.00	2.49%	12,882	88.82	18.40%	858.3	5.92	1.23%	0.32	Yes	0.09	Yes
1,781	12.28	2.54%	12,882	88.82	18.40%	877.6	6.05	1.25%	0.32	Yes	0.10	Yes
1,822	12.56	2.60%	12,882	88.82	18.40%	894.4	6.17	1.28%	0.32	Yes	0.10	Yes
1,861	12.83	2.65%	12,882	88.82	18.40%	908.6	6.26	1.30%	0.32	Yes	0.10	Yes
1,901	13.10	2.72%	12,882	88.82	18.40%	920.2	6.34	1.31%	0.32	Yes	0.10	Yes
1,940	13.38	2.77%	12,882	88.82	18.40%	929.3	6.41	1.33%	0.32	Yes	0.10	Yes
1,979	13.65	2.83%	12,882	88.82	18.40%	935.7	6.45	1.34%	0.32	Yes	0.10	Yes
2,190	14.89	3.09%	12,882	88.82	18.40%	920.7	6.35	1.32%	0.33	Yes	0.10	Yes
2,210	15.24	3.16%	12,882	88.82	18.40%	922.0	6.36	1.32%	0.33	Yes	0.10	Yes
2,254	15.54	3.22%	0	0.00	0.00%	922.0	6.36	1.32%	0.04	Yes	0.02	Yes
2,297	15.83	3.28%	0	0.00	0.00%	922.0	6.36	1.32%	0.04	Yes	0.02	Yes
2,340	16.13	3.34%	0	0.00	0.00%	922.0	6.36	1.32%	0.04	Yes	0.02	Yes
2,383	16.43	3.40%	0	0.00	0.00%	922.0	6.36	1.32%	0.04	Yes	0.02	Yes
2,862	19.73	4.09%	12,167	83.89	17.38%	920.6	6.35	1.32%	0.32	Yes	0.10	Yes
2,880	19.86	4.11%	12,167	83.89	17.38%	916.5	6.32	1.31%	0.32	Yes	0.10	Yes
2,710	18.69	3.87%	12,167	83.89	17.38%	909.6	6.27	1.30%	0.32	Yes	0.10	Yes
2,626	18.10	3.75%	12,167	83.89	17.38%	900.1	6.21	1.29%	0.32	Yes	0.10	Yes
2,576	17.76	3.68%	12,167	83.89	17.38%	887.8	6.12	1.27%	0.32	Yes	0.10	Yes
2,566	17.70	3.67%	12,167	83.89	17.38%	872.7	6.02	1.25%	0.32	Yes	0.10	Yes
2,649	18.26	3.78%	12,167	83.89	17.38%	854.9	5.89	1.22%	0.32	Yes	0.10	Yes
2,728	18.79	3.89%	12,167	83.89	17.38%	834.5	5.75	1.19%	0.32	Yes	0.10	Yes
2,798	19.29	4.00%	12,167	83.89	17.38%	811.2	5.59	1.16%	0.32	Yes	0.10	Yes
2,868	19.78	4.10%	12,167	83.89	17.38%	785.3	5.41	1.12%	0.32	Yes	0.10	Yes
2,936	20.25	4.19%	12,167	83.89	17.38%	756.7	5.22	1.08%	0.32	Yes	0.10	Yes
3,003	20.71	4.29%	12,167	83.89	17.38%	725.4	5.00	1.04%	0.33	Yes	0.09	Yes
3,069	21.16	4.38%	12,167	83.89	17.38%	691.4	4.77	0.99%	0.33	Yes	0.09	Yes
3,134	21.61	4.48%	12,167	83.89	17.38%	654.7	4.51	0.94%	0.33	Yes	0.09	Yes
3,198	22.05	4.57%	12,167	83.89	17.38%	615.3	4.24	0.88%	0.33	Yes	0.09	Yes
3,262	22.49	4.66%	12,167	83.89	17.38%	573.2	3.95	0.82%	0.33	Yes	0.09	Yes
3,349	23.09	4.78%	0	0.00	0.00%	525.5	3.62	0.75%	0.06	Yes	0.01	Yes
3,437	23.70	4.91%	0	0.00	0.00%	477.7	3.29	0.68%	0.06	Yes	0.01	Yes
3,524	24.30	5.03%	0	0.00	0.00%	429.9	2.96	0.61%	0.06	Yes	0.01	Yes
3,612	24.90	5.16%	0	0.00	0.00%	382.2	2.63	0.55%	0.06	Yes	0.01	Yes
3,699	25.50	5.28%	0	0.00	0.00%	334.4	2.31	0.48%	0.07	Yes	0.01	Yes
3,786	26.11	5.41%	0	0.00	0.00%	286.6	1.98	0.41%	0.07	Yes	0.01	Yes
3,874	26.71	5.53%	0	0.00	0.00%	238.8	1.65	0.34%	0.07	Yes	0.01	Yes
3,961	27.31	5.65%	0	0.00	0.00%	191.1	1.32	0.27%	0.07	Yes	0.01	Yes
4,049	27.91	5.78%	0	0.00	0.00%	143.3	0.99	0.20%	0.07	Yes	0.01	Yes
4,136	28.52	5.91%	0	0.00	0.00%	95.5	0.66	0.14%	0.07	Yes	0.01	Yes
4,223	29.12	6.03%	0	0.00	0.00%	47.8	0.33	0.07%	0.08	Yes	0.01	Yes
4,311	29.72	6.16%	0	0.00	0.00%	0.0	0.00	0.00%	0.08	Yes	0.01	Yes

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

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	Combined Tensile, Bending and Hoop Factor
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS		
4,311	29.7	6.16%	12,882	88.8	18.40%	936	6.5	1.34%	0.33	0.10

	TOTAL PULL LOADS	
Maximum Values	363,642 lb	181.8 tons

Ground Elevation at Pipe Entry	341.01	feet
	103.94	metres
Ground Elevation at Pipe Exit	335.20	feet
	102.17	metres

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
	428.05	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	363,642	lb
	1,618	kN
Factor of Safety	9.7	
Start-Up Load Factor	1.5	
Maximum Calculated Start-Up Pipe Pull Load	545,464	lb
	2,426	kN
Factor of Safety	6.5	

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)	0.1	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	22.5	lb/100ft² (Based on HDD experience from previous installations)
	107.73	dyne/cm²
Plastic Viscosity	15	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)
	2.27	m³/min
Drilling mud pumping rate	1129	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.273	m³/min
Pipe Pullback Rate	10	feet/min (Based on HDD experience)
	3.05	m/min

MOTT MACDONALD

Calculated by: M. Eakins
Checked by: G. Duyvestyn
Date: 3/14/2019
Project No: 353754

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

PROJECT: PennEast Pipeline Project

HDD CROSSING LOCATION: Nishisakawick Creek (No Buoyancy - 12PPG Drilling Fluid)

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		33+91	1+006	0.0	0.0	341.0	103.9	--	--		99,380 lb	49.7 tons
straight		32+38	0+987	64.6	19.7	325.4	99.2	48.0	1219.2	0.3	113,871 lb	56.9 tons
straight		31+75	0+968	129.2	39.4	309.8	94.4	48.0	1219.2	0.3	128,362 lb	64.2 tons
straight		31+13	0+949	193.8	59.1	294.1	89.7	48.0	1219.2	0.3	142,854 lb	71.4 tons
straight		30+50	0+930	258.4	78.8	278.5	84.9	48.0	1219.2	0.3	157,345 lb	78.7 tons
straight		29+87	0+911	323.0	98.4	262.9	80.1	48.0	1219.2	0.3	171,837 lb	85.9 tons
straight		29+25	0+891	387.6	118.1	247.2	75.4	48.0	1219.2	0.3	186,328 lb	93.2 tons
straight		28+62	0+872	452.2	137.8	231.6	70.6	48.0	1219.2	0.3	200,820 lb	100.4 tons
straight		27+99	0+853	516.8	157.5	216.0	65.8	48.0	1219.2	0.3	215,311 lb	107.7 tons
straight		27+36	0+834	581.4	177.2	200.4	61.1	48.0	1219.2	0.3	229,802 lb	114.9 tons
straight		26+74	0+815	646.0	196.9	184.7	56.3	48.0	1219.2	0.3	244,294 lb	122.1 tons
straight		26+11	0+796	710.6	216.6	169.1	51.5	48.0	1219.2	0.3	258,785 lb	129.4 tons
straight		25+48	0+777	775.2	236.3	153.5	46.8	48.0	1219.2	0.3	273,277 lb	136.6 tons
curve	vertical	24+98	0+761	827.1	252.1	141.3	43.1	48.0	1219.2	0.3	300,293 lb	150.1 tons
curve	vertical	24+47	0+746	879.0	267.9	129.9	39.6	48.0	1219.2	0.3	328,775 lb	164.4 tons
curve	vertical	23+96	0+730	930.9	283.7	119.3	36.4	48.0	1219.2	0.3	333,584 lb	166.8 tons
curve	vertical	23+46	0+715	982.8	299.6	109.4	33.4	48.0	1219.2	0.3	342,667 lb	171.3 tons
curve	vertical	22+94	0+699	1,034.8	315.4	100.3	30.6	48.0	1219.2	0.3	353,296 lb	176.6 tons
curve	vertical	22+43	0+684	1,086.7	331.2	92.1	28.1	48.0	1219.2	0.3	364,546 lb	182.3 tons
curve	vertical	21+92	0+668	1,138.6	347.1	84.5	25.8	48.0	1219.2	0.3	376,917 lb	188.0 tons
curve	vertical	21+40	0+652	1,190.5	362.9	77.8	23.7	48.0	1219.2	0.3	387,503 lb	193.8 tons
curve	vertical	20+89	0+637	1,242.5	378.7	71.9	21.9	48.0	1219.2	0.3	398,890 lb	199.4 tons
curve	vertical	20+37	0+621	1,294.4	394.5	66.8	20.3	48.0	1219.2	0.3	410,112 lb	205.1 tons
curve	vertical	19+85	0+605	1,346.3	410.4	62.4	19.0	48.0	1219.2	0.3	421,126 lb	210.6 tons
curve	vertical	19+33	0+589	1,398.2	426.2	58.8	17.9	48.0	1219.2	0.3	431,910 lb	216.0 tons
curve	vertical	18+82	0+574	1,450.2	442.0	56.1	17.1	48.0	1219.2	0.3	442,447 lb	221.2 tons
curve	vertical	18+30	0+558	1,502.1	457.8	54.1	16.5	48.0	1219.2	0.3	544,955 lb	272.5 tons
curve	vertical	17+78	0+542	1,554.0	473.7	52.9	16.1	48.0	1219.2	0.3	561,326 lb	280.7 tons
curve	vertical	17+26	0+526	1,605.9	489.5	52.5	16.0	48.0	1219.2	0.3	577,497 lb	288.7 tons
straight		16+88	0+515	1,643.4	500.9	52.5	16.0	48.0	1219.2	0.3	585,405 lb	292.9 tons
straight		16+51	0+503	1,680.9	512.4	52.5	16.0	48.0	1219.2	0.3	594,114 lb	297.1 tons
straight		16+13	0+492	1,718.4	523.8	52.5	16.0	48.0	1219.2	0.3	602,422 lb	301.2 tons
straight		15+76	0+480	1,755.9	535.2	52.5	16.0	48.0	1219.2	0.3	610,730 lb	305.4 tons
curve	vertical	15+21	0+464	1,810.9	552.0	52.9	16.1	48.0	1219.2	0.3	658,997 lb	329.5 tons
curve	vertical	14+66	0+447	1,865.9	568.7	54.2	16.5	48.0	1219.2	0.3	651,879 lb	325.9 tons
curve	vertical	14+11	0+430	1,920.9	585.5	56.3	17.2	48.0	1219.2	0.3	678,668 lb	339.3 tons
curve	vertical	13+56	0+413	1,975.9	602.2	59.2	18.0	48.0	1219.2	0.3	681,087 lb	340.5 tons
curve	vertical	13+01	0+397	2,030.8	619.0	63.0	19.2	48.0	1219.2	0.3	701,641 lb	350.8 tons
curve	vertical	12+47	0+380	2,085.8	635.8	67.6	20.6	48.0	1219.2	0.3	710,473 lb	355.2 tons
curve	vertical	11+92	0+363	2,140.8	652.5	73.0	22.3	48.0	1219.2	0.3	728,534 lb	364.3 tons
curve	vertical	11+37	0+347	2,195.8	669.3	79.3	24.2	48.0	1219.2	0.3	740,751 lb	370.4 tons
curve	vertical	10+83	0+330	2,250.7	686.0	86.4	26.3	48.0	1219.2	0.3	757,628 lb	378.8 tons
curve	vertical	10+28	0+313	2,305.7	702.8	94.4	28.8	48.0	1219.2	0.3	771,295 lb	385.6 tons
curve	vertical	9+74	0+297	2,360.7	719.5	103.2	31.4	48.0	1219.2	0.3	787,235 lb	393.6 tons
curve	vertical	9+20	0+280	2,415.7	736.3	112.8	34.4	48.0	1219.2	0.3	801,555 lb	400.8 tons
curve	vertical	8+66	0+264	2,470.6	753.1	123.2	37.6	48.0	1219.2	0.3	846,450 lb	423.2 tons
curve	vertical	8+12	0+248	2,525.6	769.8	134.5	41.0	48.0	1219.2	0.3	860,845 lb	430.4 tons
curve	vertical	7+58	0+231	2,580.6	786.5	146.5	44.7	48.0	1219.2	0.3	874,998 lb	437.5 tons
curve	vertical	7+05	0+215	2,635.6	803.3	159.4	48.6	48.0	1219.2	0.3	888,909 lb	444.5 tons
straight		6+46	0+197	2,696.1	821.8	174.1	53.1	48.0	1219.2	0.3	898,906 lb	448.5 tons
straight		5+87	0+179	2,756.7	840.2	188.7	57.5	48.0	1219.2	0.3	904,904 lb	452.5 tons
straight		5+29	0+161	2,817.2	858.7	203.4	62.0	48.0	1219.2	0.3	912,902 lb	456.5 tons
straight		4+70	0+143	2,877.8	877.2	218.0	66.5	48.0	1219.2	0.3	920,899 lb	460.4 tons
straight		4+11	0+125	2,938.3	895.6	232.7	70.9	48.0	1219.2	0.3	928,897 lb	464.4 tons
straight		3+52	0+107	2,998.9	914.1	247.3	75.4	48.0	1219.2	0.3	936,894 lb	468.4 tons
straight		2+94	0+090	3,059.4	932.5	262.0	79.8	48.0	1219.2	0.3	944,892 lb	472.4 tons
straight		2+35	0+072	3,120.0	951.0	276.6	84.3	48.0	1219.2	0.3	952,890 lb	476.4 tons
straight		1+76	0+054	3,180.5	969.4	291.3	88.8	48.0	1219.2	0.3	960,887 lb	480.4 tons
straight		1+17	0+036	3,241.1	987.9	305.9	93.2	48.0	1219.2	0.3	968,885 lb	484.4 tons
straight		0+59	0+018	3,301.6	1,006.3	320.6	97.7	48.0	1219.2	0.3	976,883 lb	488.4 tons
HDD Rig Location		0+00	0+000	3,362.2	1,024.8	335.2	102.2	48.0	1219.2	0.3	984,880 lb	492.4 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				
1,178	8.12	1.66%	0	0.00	0.00%	0.0	0.00	0.00%	0.02	Yes	0.00	Yes
1,359	9.31	1.93%	0	0.00	0.00%	230.1	1.59	0.33%	0.02	Yes	0.00	Yes
1,522	10.49	2.17%	0	0.00	0.00%	460.2	3.17	0.66%	0.03	Yes	0.00	Yes
1,693	11.68	2.42%	0	0.00	0.00%	690.3	4.76	0.99%	0.03	Yes	0.01	Yes
1,865	12.86	2.66%	0	0.00	0.00%	920.4	6.35	1.31%	0.03	Yes	0.02	Yes
2,037	14.04	2.91%	0	0.00	0.00%	1,150.5	7.93	1.64%	0.04	Yes	0.03	Yes
2,209	15.23	3.16%	0	0.00	0.00%	1,380.6	9.52	1.97%	0.04	Yes	0.04	Yes
2,381	16.41	3.40%	0	0.00	0.00%	1,610.7	11.11	2.30%	0.04	Yes	0.05	Yes
2,552	17.60	3.65%	0	0.00	0.00%	1,840.8	12.69	2.63%	0.05	Yes	0.06	Yes
2,724	18.78	3.89%	0	0.00	0.00%	2,070.9	14.28	2.96%	0.05	Yes	0.08	Yes
2,896	19.97	4.14%	0	0.00	0.00%	2,301.0	15.86	3.29%	0.05	Yes	0.10	Yes
3,068	21.15	4.38%	0	0.00	0.00%	2,531.1	17.45	3.62%	0.05	Yes	0.12	Yes
3,240	22.34	4.63%	0	0.00	0.00%	2,761.2	19.04	3.94%	0.06	Yes	0.14	Yes
3,590	24.54	5.09%	12,882	88.82	18.40%	2,940.5	20.27	4.20%	0.35	Yes	0.26	Yes
3,697	26.87	5.57%	12,882	88.82	18.40%	3,108.4	21.43	4.44%	0.36	Yes	0.30	Yes
3,954	27.27	5.65%	12,882	88.82	18.40%	3,264.9	22.51	4.66%	0.36	Yes	0.32	Yes
4,062	28.01	5.80%	12,882	88.82	18.40%	3,410.0	23.51	4.87%	0.36	Yes	0.34	Yes
4,188	28.88	5.98%	12,882	88.82	18.40%	3,543.5	24.43	5.06%	0.36	Yes	0.36	Yes
4,322	29.80	6.17%	12,882	88.82	18.40%	3,665.7	25.27	5.24%	0.37	Yes	0.38	Yes
4,457	30.73	6.37%	12,882	88.82	18.40%	3,776.2	26.04	5.39%	0.37	Yes	0.40	Yes
4,594	31.67	6.56%	12,882	88.82	18.40%	3,875.1	26.72	5.54%	0.37	Yes	0.42	Yes
4,729	32.60	6.76%	12,882	88.82	18.40%	3,962.5	27.32	5.66%	0.37	Yes	0.43	Yes
4,862	33.52	6.95%	12,882	88.82	18.40%	4,038.3	27.84	5.77%	0.38	Yes	0.44	Yes
4,992	34.42	7.13%	12,882	88.82	18.40%	4,102.4	28.29	5.86%	0.38	Yes	0.46	Yes
5,120	35.30	7.31%	12,882	88.82	18.40%	4,154.9	28.65	5.94%	0.38	Yes	0.47	Yes
5,245	36.16	7.49%	12,882	88.82	18.40%	4,195.8	28.93	5.99%	0.38	Yes	0.47	Yes
6,460	44.54	9.23%	12,882	88.82	18.40%	4,139.4	28.54	5.91%	0.40	Yes	0.50	Yes
6,654	45.88	9.51%	12,882	88.82	18.40%	4,156.9	28.66	5.94%	0.41	Yes	0.51	Yes
6,846	47.20	9.78%	12,882	88.82	18.40%	4,162.8	28.70	5.95%	0.41	Yes	0.51	Yes
6,944	47.88	9.92%	0	0.00	0.00%	4,162.8	28.70	5.95%	0.12	Yes	0.34	Yes
7,043	48.56	10.06%	0	0.00	0.00%	4,162.8	28.70	5.95%	0.13	Yes	0.34	Yes
7,141	49.24	10.20%	0	0.00	0.00%	4,162.8	28.70	5.95%	0.13	Yes	0.34	Yes
7,240	49.92	10.34%	0	0.00	0.00%	4,162.8	28.70	5.95%	0.13	Yes	0.35	Yes
7,812	53.86	11.16%	12,167	83.89	17.38%	4,156.6	28.66	5.94%	0.41	Yes	0.51	Yes
7,728	53.28	11.04%	12,167	83.89	17.38%	4,138.0	28.53	5.91%	0.41	Yes	0.51	Yes
8,045	55.47	11.49%	12,167	83.89	17.38%	4,107.1	28.32	5.87%	0.42	Yes	0.51	Yes
8,074	55.67	11.53%	12,167	83.89	17.38%	4,063.9	28.02	5.81%	0.42	Yes	0.50	Yes
8,318	57.35	11.88%	12,167	83.89	17.38%	4,008.3	27.64	5.73%	0.42	Yes	0.50	Yes
8,422	58.07	12.03%	12,167	83.89	17.38%	3,940.4	27.17	5.63%	0.42	Yes	0.49	Yes
8,036	59.55	12.34%	12,167	83.89	17.38%	3,860.2	26.61	5.51%	0.43	Yes	0.48	Yes
8,761	60.54	12.54%	12,167	83.89	17.38%	3,767.6	25.98	5.38%	0.43	Yes	0.47	Yes
8,980	61.92	12.83%	12,167	83.89	17.38%	3,662.9	25.25	5.23%	0.43	Yes	0.46	Yes
9,143	63.04	13.06%	12,167	83.89	17.38%	3,545.8	24.45	5.07%	0.44	Yes	0.44	Yes
9,332	64.34	13.33%	12,167	83.89	17.38%	3,416.6	23.56	4.88%	0.44	Yes	0.43	Yes
9,502	65.51	13.57%	12,167	83.89	17.38%	3,275.1	22.58	4.68%	0.44	Yes	0.41	Yes
10,034	69.18	14.33%	12,167	83.89	17.38%	3,121.5	21.52	4.46%	0.45	Yes	0.40	Yes
10,205	70.36	14.58%	12,167	83.89	17.38%	2,955.8	20.38	4.22%	0.45	Yes	0.38	Yes
10,373	71.52	14.82%	12,167	83.89	17.38%	2,778.0	19.15	3.97%	0.46	Yes	0.37	Yes
10,538	72.65	15.05%	12,167	83.89	17.38%	2,588.2	17.85	3.70%	0.46	Yes	0.35	Yes
10,932	73.31	15.19%	0	0.00	0.00%	2,372.5	16.36	3.39%	0.19	Yes	0.16	Yes
10,727	73.96	15.32%	0	0.00	0.00%	2,156.8	14.87	3.08%	0.19	Yes	0.14	Yes
10,922	74.62	15.46%	0	0.00	0.00%	1,941.2	13.38	2.77%	0.19	Yes	0.13	
10,917	75.27	15.60%	0	0.00	0.00%	1,725.5	11.90	2.46%	0.19	Yes	0.11	
11,012	75.92	15.73%	0	0.00	0.00%	1,509.8	10.41	2.16%	0.20	Yes	0.10	
11,106	76.56	15.87%	0	0.00	0.00%	1,294.1	8.92	1.85%	0.20	Yes	0.09	
11,201	77.23	16.00%	0	0.00	0.00%	1,078.4	7.44	1.54%	0.20	Yes	0.08	
11,296	77.88	16.14%	0	0.00	0.00%	862.7	5.95	1.23%	0.20	Yes	0.07	Yes
11,391	78.54	16.27%	0	0.00	0.00%	647.1	4.46	0.92%	0.20	Yes	0.06	Yes
11,486	79.19	16.41%	0	0.00	0.00%	431.4	2.97	0.62%	0.21	Yes	0.05	Yes
11,580	79.84	16.54%	0	0.00	0.00%	215.7	1.49	0.31%	0.21	Yes	0.05	Yes
11,675	80.50	16.68%	0	0.00	0.00%	0.0	0.00	0.00%	0.21	Yes	0.04	Yes

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

	Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	Combined Tensile, Bending and Hoop Factor
	psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS		
Maximum Values	11,675	80.5	16.68%	12,882	88.8	18.40%	4,196	28.9	5.99%	0.46	0.51

Ground Elevation at Pipe Entry	341.01	feet
	103.94	metres
Ground Elevation at Pipe Exit	335.20	feet
	102.17	metres

	TOTAL PULL LOADS	
Maximum Values	984,880 lb	492.4 tons

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	984,880	lb
	4,381	kN
Factor of Safety	3.6	
Start-Up Load Factor	1.5	
Maximum Calculated Start-Up Pipe Pull Load	1,477,320	lb
	6,571	kN
Factor of Safety	2.4	

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)	0.1	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	22.5	lb/100ft² (Based on HDD experience from previous installations)
	107.73	dyne/cm²
Plastic Viscosity	15	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	m³/min
Drilling mud pumping rate	1129	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.273	m³/min
Pipe Pullback Rate	10	feet/min (Based on HDD experience)
	3.05	m/min

MOTT MACDONALD

ontal Directional Drilling
ulation of Pull Loads and Stresses during Pipe Installation

Calculated by: M. Eakins
Checked by: G. Duyvestyn
Date: 3/14/2019
Project No: 353754

PROJECT: PennEast Pipeline Project

HDD CROSSING LOCATION: Nishisakawick Creek (Buoyancy - 12PPG Drilling Fluid)

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		33+01	1+008	0.0	0.0	341.0	103.9	--	--		99,380	lb	49.7 tons
straight		32+38	0+987	64.6	19.7	325.4	99.2	48.0	1219.2	0.3	102,090	lb	51.0 tons
straight		31+75	0+968	129.2	39.4	309.8	94.4	48.0	1219.2	0.3	104,801	lb	52.4 tons
straight		31+13	0+949	193.8	59.1	294.1	89.7	48.0	1219.2	0.3	107,511	lb	53.8 tons
straight		30+50	0+930	258.4	78.8	278.5	84.9	48.0	1219.2	0.3	110,222	lb	55.1 tons
straight		29+87	0+911	323.0	98.4	262.9	80.1	48.0	1219.2	0.3	112,932	lb	56.5 tons
straight		29+25	0+891	387.6	118.1	247.2	75.4	48.0	1219.2	0.3	115,643	lb	57.8 tons
straight		28+62	0+872	452.2	137.8	231.6	70.6	48.0	1219.2	0.3	118,353	lb	59.2 tons
straight		27+99	0+853	516.8	157.5	216.0	65.8	48.0	1219.2	0.3	121,064	lb	60.5 tons
straight		27+36	0+834	581.4	177.2	200.4	61.1	48.0	1219.2	0.3	123,774	lb	61.9 tons
straight		26+74	0+815	646.0	196.9	184.7	56.3	48.0	1219.2	0.3	126,485	lb	63.2 tons
straight		26+11	0+796	710.6	216.6	169.1	51.5	48.0	1219.2	0.3	129,195	lb	64.6 tons
straight		25+48	0+777	775.2	236.3	153.5	46.8	48.0	1219.2	0.3	131,906	lb	66.0 tons
curve	vertical	24+98	0+761	827.1	252.1	141.3	43.1	48.0	1219.2	0.3	158,116	lb	79.1 tons
curve	vertical	24+47	0+746	879.0	267.9	129.9	39.6	48.0	1219.2	0.3	160,852	lb	80.4 tons
curve	vertical	23+96	0+730	930.9	283.7	119.3	36.4	48.0	1219.2	0.3	152,761	lb	76.4 tons
curve	vertical	23+46	0+715	982.8	299.6	109.4	33.4	48.0	1219.2	0.3	149,231	lb	74.6 tons
curve	vertical	22+94	0+699	1,034.8	315.4	100.3	30.6	48.0	1219.2	0.3	147,555	lb	73.8 tons
curve	vertical	22+43	0+684	1,086.7	331.2	92.1	28.1	48.0	1219.2	0.3	146,833	lb	73.4 tons
curve	vertical	21+92	0+668	1,138.6	347.1	84.6	25.8	48.0	1219.2	0.3	146,679	lb	73.3 tons
curve	vertical	21+40	0+652	1,190.5	362.9	77.8	23.7	48.0	1219.2	0.3	146,900	lb	73.5 tons
curve	vertical	20+89	0+637	1,242.5	378.7	71.9	21.9	48.0	1219.2	0.3	147,391	lb	73.7 tons
curve	vertical	20+37	0+621	1,294.4	394.5	66.8	20.3	48.0	1219.2	0.3	148,088	lb	74.0 tons
curve	vertical	19+85	0+605	1,346.3	410.4	62.4	19.0	48.0	1219.2	0.3	149,167	lb	74.6 tons
curve	vertical	19+33	0+589	1,398.2	426.2	58.8	17.9	48.0	1219.2	0.3	151,768	lb	75.9 tons
curve	vertical	18+82	0+574	1,450.2	442.0	56.1	17.1	48.0	1219.2	0.3	154,335	lb	77.2 tons
curve	vertical	18+30	0+558	1,502.1	457.8	54.1	16.5	48.0	1219.2	0.3	158,424	lb	79.2 tons
curve	vertical	17+78	0+542	1,554.0	473.7	52.9	16.1	48.0	1219.2	0.3	161,352	lb	80.7 tons
curve	vertical	17+26	0+526	1,605.9	489.5	52.5	16.0	48.0	1219.2	0.3	164,238	lb	82.1 tons
straight		16+88	0+515	1,643.4	500.9	52.5	16.0	48.0	1219.2	0.3	166,830	lb	83.4 tons
straight		16+51	0+503	1,680.9	512.4	52.5	16.0	48.0	1219.2	0.3	169,422	lb	84.7 tons
straight		16+13	0+492	1,718.4	523.8	52.5	16.0	48.0	1219.2	0.3	172,015	lb	86.0 tons
straight		15+76	0+480	1,755.9	535.2	52.5	16.0	48.0	1219.2	0.3	174,607	lb	87.3 tons
curve	vertical	15+21	0+464	1,810.0	552.0	52.9	16.1	48.0	1219.2	0.3	216,366	lb	108.2 tons
curve	vertical	14+66	0+447	1,865.9	568.7	54.2	16.5	48.0	1219.2	0.3	219,794	lb	109.9 tons
curve	vertical	14+11	0+430	1,920.0	585.5	56.3	17.2	48.0	1219.2	0.3	207,068	lb	103.5 tons
curve	vertical	13+56	0+413	1,975.8	602.2	59.2	18.0	48.0	1219.2	0.3	201,452	lb	100.7 tons
curve	vertical	13+01	0+397	2,030.8	619.0	63.0	19.2	48.0	1219.2	0.3	198,724	lb	99.4 tons
curve	vertical	12+47	0+380	2,085.8	635.8	67.6	20.6	48.0	1219.2	0.3	197,479	lb	98.7 tons
curve	vertical	11+92	0+363	2,140.8	652.5	73.0	22.3	48.0	1219.2	0.3	197,113	lb	98.6 tons
curve	vertical	11+37	0+347	2,195.8	669.3	79.3	24.2	48.0	1219.2	0.3	197,329	lb	98.7 tons
curve	vertical	10+83	0+330	2,250.7	686.0	86.4	26.3	48.0	1219.2	0.3	197,961	lb	99.0 tons
curve	vertical	10+28	0+313	2,305.7	702.8	94.4	28.8	48.0	1219.2	0.3	198,909	lb	99.5 tons
curve	vertical	9+74	0+297	2,360.7	719.5	103.2	31.4	48.0	1219.2	0.3	202,145	lb	101.1 tons
curve	vertical	9+20	0+280	2,415.7	736.3	112.8	34.4	48.0	1219.2	0.3	205,985	lb	103.0 tons
curve	vertical	8+65	0+264	2,470.6	753.1	123.2	37.6	48.0	1219.2	0.3	209,730	lb	104.9 tons
curve	vertical	8+12	0+248	2,525.6	769.8	134.5	41.0	48.0	1219.2	0.3	213,402	lb	106.7 tons
curve	vertical	7+58	0+231	2,580.6	786.6	146.5	44.7	48.0	1219.2	0.3	217,016	lb	108.5 tons
curve	vertical	7+05	0+215	2,635.6	803.3	159.4	48.6	48.0	1219.2	0.3	220,585	lb	110.3 tons
straight		6+46	0+197	2,696.1	821.8	174.1	53.1	48.0	1219.2	0.3	225,553	lb	112.8 tons
straight		5+87	0+179	2,756.7	840.2	188.7	57.5	48.0	1219.2	0.3	230,521	lb	115.3 tons
aight		5+29	0+161	2,817.2	858.7	203.4	62.0	48.0	1219.2	0.3	235,489	lb	117.7 tons
aight		4+70	0+143	2,877.8	877.2	218.0	66.5	48.0	1219.2	0.3	240,457	lb	120.2 tons
aight		4+11	0+125	2,938.3	895.6	232.7	70.9	48.0	1219.2	0.3	245,425	lb	122.7 tons
aight		3+52	0+107	2,998.9	914.1	247.3	75.4	48.0	1219.2	0.3	250,393	lb	125.2 tons
straight		2+94	0+090	3,059.4	932.5	262.0	79.8	48.0	1219.2	0.3	255,361	lb	127.7 tons
straight		2+35	0+072	3,120.0	951.0	276.6	84.3	48.0	1219.2	0.3	260,329	lb	130.2 tons
straight		1+76	0+054	3,180.5	969.4	291.3	88.8	48.0	1219.2	0.3	265,297	lb	132.6 tons
straight		1+17	0+036	3,241.1	987.9	305.9	93.2	48.0	1219.2	0.3	270,265	lb	135.1 tons
straight		0+59	0+018	3,301.6	1,006.3	320.6	97.7	48.0	1219.2	0.3	275,233	lb	137.6 tons
HDD Rig Location		0+00	0+000	3,362.2	1,024.8	335.2	102.2	48.0	1219.2	0.3	280,201	lb	140.1 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				
1,178	8.12	1.68%	0	0.00	0.00%	0.0	0.00	0.00%	0.02	Yes	0.00	Yes
1,210	8.34	1.73%	0	0.00	0.00%	70.1	0.48	0.10%	0.02	Yes	0.00	Yes
1,242	8.57	1.77%	0	0.00	0.00%	140.3	0.97	0.20%	0.02	Yes	0.00	Yes
1,274	8.79	1.82%	0	0.00	0.00%	210.4	1.45	0.30%	0.02	Yes	0.00	Yes
1,307	9.01	1.87%	0	0.00	0.00%	280.6	1.93	0.40%	0.02	Yes	0.00	Yes
1,339	9.23	1.91%	0	0.00	0.00%	350.7	2.42	0.50%	0.02	Yes	0.00	Yes
1,371	9.45	1.96%	0	0.00	0.00%	420.8	2.90	0.60%	0.02	Yes	0.00	Yes
1,403	9.67	2.00%	0	0.00	0.00%	491.0	3.39	0.70%	0.03	Yes	0.01	Yes
1,435	9.90	2.05%	0	0.00	0.00%	561.1	3.87	0.80%	0.03	Yes	0.01	Yes
1,467	10.12	2.10%	0	0.00	0.00%	631.2	4.35	0.90%	0.03	Yes	0.01	Yes
1,499	10.34	2.14%	0	0.00	0.00%	701.4	4.84	1.00%	0.03	Yes	0.01	Yes
1,532	10.56	2.19%	0	0.00	0.00%	771.5	5.32	1.10%	0.03	Yes	0.01	Yes
1,564	10.78	2.23%	0	0.00	0.00%	841.7	5.80	1.20%	0.03	Yes	0.01	Yes
1,874	12.92	2.68%	12,882	88.82	18.40%	896.3	6.18	1.28%	0.32	Yes	0.10	Yes
1,907	13.15	2.72%	12,882	88.82	18.40%	947.5	6.53	1.35%	0.32	Yes	0.10	Yes
1,811	12.49	2.59%	12,882	88.82	18.40%	995.2	6.86	1.42%	0.32	Yes	0.10	Yes
1,769	12.20	2.53%	12,882	88.82	18.40%	1,039.4	7.17	1.48%	0.32	Yes	0.10	Yes
1,749	12.06	2.50%	12,882	88.82	18.40%	1,080.1	7.45	1.54%	0.32	Yes	0.10	Yes
1,741	12.00	2.49%	12,882	88.82	18.40%	1,117.3	7.70	1.60%	0.32	Yes	0.11	Yes
1,739	11.99	2.48%	12,882	88.82	18.40%	1,151.0	7.94	1.64%	0.32	Yes	0.11	Yes
1,741	12.01	2.49%	12,882	88.82	18.40%	1,181.2	8.14	1.69%	0.32	Yes	0.11	Yes
1,747	12.05	2.50%	12,882	88.82	18.40%	1,207.8	8.33	1.73%	0.32	Yes	0.11	Yes
1,756	12.10	2.51%	12,882	88.82	18.40%	1,230.9	8.49	1.76%	0.32	Yes	0.11	Yes
1,768	12.19	2.53%	12,882	88.82	18.40%	1,250.5	8.62	1.79%	0.32	Yes	0.11	Yes
1,799	12.40	2.57%	12,882	88.82	18.40%	1,266.5	8.73	1.81%	0.32	Yes	0.11	Yes
1,830	12.61	2.51%	12,882	88.82	18.40%	1,278.9	8.82	1.83%	0.32	Yes	0.12	Yes
1,878	12.95	2.68%	12,882	88.82	18.40%	1,287.7	8.70	1.80%	0.32	Yes	0.12	Yes
1,913	13.19	2.73%	12,882	88.82	18.40%	1,287.1	8.74	1.81%	0.32	Yes	0.12	Yes
1,947	13.42	2.78%	12,882	88.82	18.40%	1,288.9	8.75	1.81%	0.32	Yes	0.12	Yes
1,978	13.64	2.83%	0	0.00	0.00%	1,288.9	8.75	1.81%	0.04	Yes	0.03	Yes
2,008	13.85	2.87%	0	0.00	0.00%	1,288.9	8.75	1.81%	0.04	Yes	0.03	Yes
2,039	14.06	2.91%	0	0.00	0.00%	1,288.9	8.75	1.81%	0.04	Yes	0.03	Yes
2,070	14.27	2.96%	0	0.00	0.00%	1,288.9	8.75	1.81%	0.04	Yes	0.03	Yes
2,565	17.69	3.66%	12,157	83.89	17.38%	1,287.0	8.74	1.81%	0.32	Yes	0.12	Yes
2,606	17.96	3.72%	12,157	83.89	17.38%	1,281.3	8.70	1.80%	0.32	Yes	0.12	Yes
2,455	16.92	3.51%	12,157	83.89	17.38%	1,251.9	8.63	1.79%	0.32	Yes	0.12	Yes
2,388	16.47	3.41%	12,157	83.89	17.38%	1,238.7	8.54	1.77%	0.31	Yes	0.11	Yes
2,356	16.24	3.37%	12,157	83.89	17.38%	1,221.8	8.42	1.75%	0.31	Yes	0.11	Yes
2,341	16.14	3.34%	12,157	83.89	17.38%	1,201.1	8.28	1.72%	0.31	Yes	0.11	Yes
2,337	16.11	3.34%	12,157	83.89	17.38%	1,176.6	8.11	1.68%	0.31	Yes	0.11	Yes
2,339	16.13	3.34%	12,157	83.89	17.38%	1,148.4	7.92	1.64%	0.31	Yes	0.11	Yes
2,347	16.18	3.35%	12,157	83.89	17.38%	1,116.5	7.70	1.59%	0.31	Yes	0.11	Yes
2,358	16.26	3.37%	12,157	83.89	17.38%	1,080.8	7.45	1.54%	0.31	Yes	0.10	Yes
2,396	16.52	3.42%	12,157	83.89	17.38%	1,041.4	7.18	1.49%	0.32	Yes	0.10	Yes
2,442	16.84	3.49%	12,157	83.89	17.38%	998.3	6.88	1.43%	0.32	Yes	0.10	Yes
2,486	17.14	3.55%	12,157	83.89	17.38%	951.5	6.56	1.36%	0.32	Yes	0.10	Yes
2,530	17.44	3.61%	12,157	83.89	17.38%	901.0	6.21	1.29%	0.32	Yes	0.10	Yes
2,573	17.74	3.68%	12,157	83.89	17.38%	846.8	5.84	1.21%	0.32	Yes	0.10	Yes
2,615	18.03	3.74%	12,157	83.89	17.38%	788.9	5.44	1.13%	0.32	Yes	0.09	Yes
2,674	18.44	3.82%	0	0.00	0.00%	723.2	4.99	1.03%	0.05	Yes	0.01	Yes
2,733	18.84	3.90%	0	0.00	0.00%	657.4	4.53	0.94%	0.05	Yes	0.01	Yes
2,792	19.25	3.99%	0	0.00	0.00%	591.7	4.08	0.85%	0.05	Yes	0.01	Yes
2,851	19.65	4.07%	0	0.00	0.00%	525.9	3.63	0.75%	0.05	Yes	0.01	Yes
2,909	20.06	4.16%	0	0.00	0.00%	460.2	3.17	0.66%	0.05	Yes	0.01	Yes
2,968	20.47	4.24%	0	0.00	0.00%	394.5	2.72	0.56%	0.05	Yes	0.01	Yes
3,027	20.87	4.32%	0	0.00	0.00%	328.7	2.27	0.47%	0.05	Yes	0.01	Yes
3,086	21.28	4.41%	0	0.00	0.00%	263.0	1.81	0.38%	0.06	Yes	0.01	Yes
3,145	21.68	4.49%	0	0.00	0.00%	197.2	1.36	0.28%	0.06	Yes	0.00	Yes
3,204	22.09	4.58%	0	0.00	0.00%	131.5	0.91	0.19%	0.06	Yes	0.00	Yes
3,263	22.50	4.66%	0	0.00	0.00%	65.7	0.45	0.09%	0.06	Yes	0.00	Yes
3,322	22.90	4.75%	0	0.00	0.00%	0.0	0.00	0.00%	0.06	Yes	0.00	Yes

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

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	Combined Tensile, Bending and Hoop Factor
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS		
3,322	22.9	4.75%	12,882	88.8	18.40%	1,279	8.8	1.83%	0.32	0.12

		TOTAL PULL LOADS	
Maximum Values	280,201	lb	140.1 tons

Ground Elevation at Pipe Entry	341.01	feet
	103.94	metres
Ground Elevation at Pipe Exit	335.20	feet
	102.17	metres

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	280,201	lb
	1,246	kN
Factor of Safety	12.6	
Start-Up Load Factor	1.5	
Maximum Calculated Start-Up Pipe Pull Load	420,302	lb
	1,870	kN
Factor of Safety	8.4	

Soil and Mud Properties

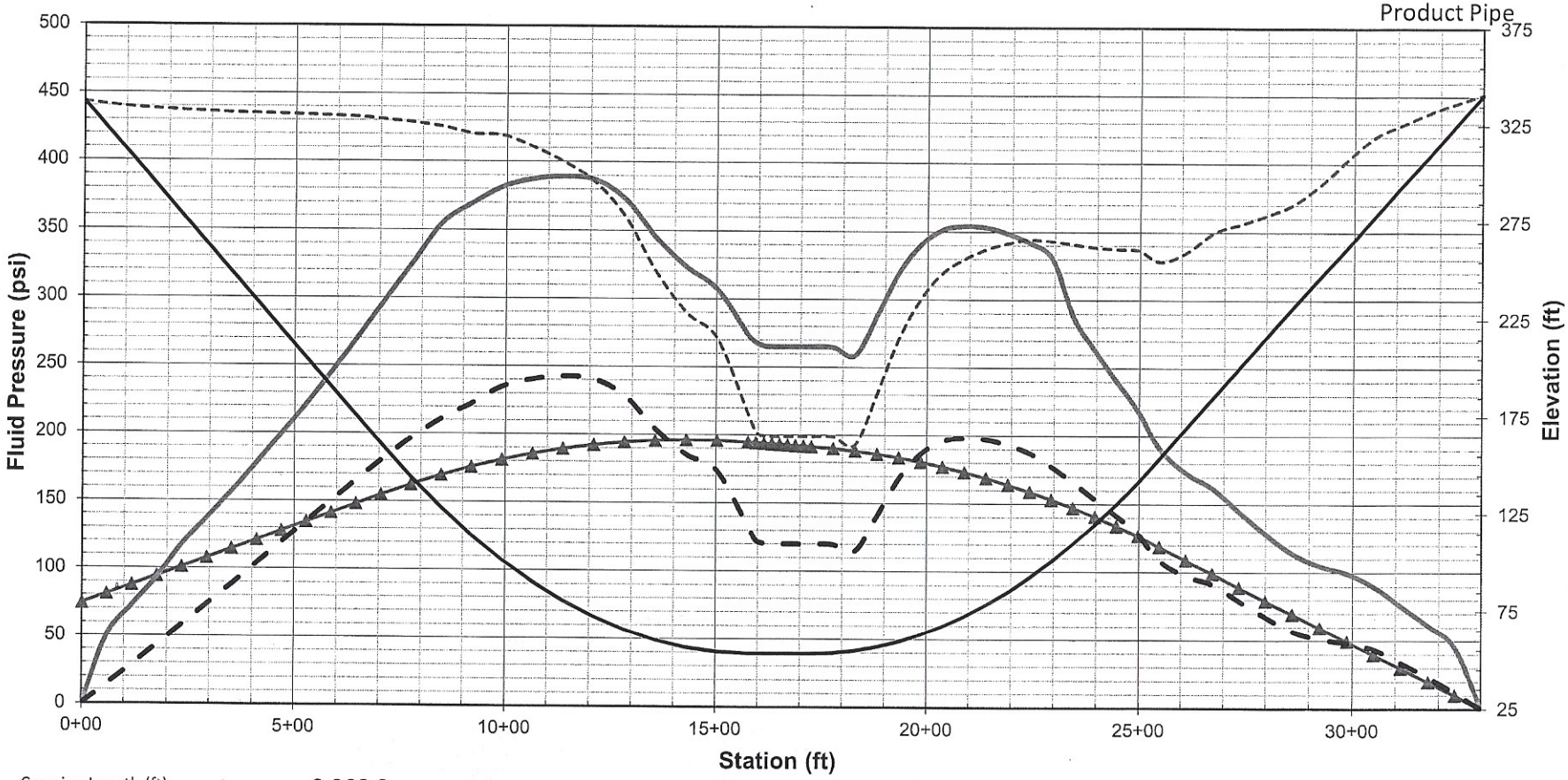
Mud Weight	12	ppg of drill fluid and solids (typically 9.5 to 11 lb/gal)
	1,439	Specific Gravity
Friction Coeff. (GS or rollers)	0.1	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	22.5	lb/100ft² (Based on HDD experience from previous installations)
	107.73	dyne/cm²
Plastic Viscosity	15	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	m³/min
Drilling mud pumping rate	1129	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.273	m³/min
Pipe Pullback Rate	10	feet/min (Based on HDD experience)
	3.05	m/min

Appendix D

Hydraulic Fracture Evaluation

Exit Bore

Drill Rig Side
Product Pipe



Crossing Length (ft)	3,362.2
Bore Diameter (in)	12.250
Drill Pipe O.D. (in)	6.625
Drilling Fluid Weight (ppg)	10.5
Plastic Viscosity (cP)	15
Yield Point (lb/100SF)	22.5

- Required Drilling Fluid Pressure
- Recommended Maximum Allowable Drilling Fluid Pressure
- Overburden Stress
- Ground Surface Profile
- HDD Bore Profile

PennEast
HORIZONTAL DIRECTIONAL DRILLING EVALUATION

MOTT MACDONALD

PennEast Pipeline Project
Nishisakawick Creek Crossing
DRILLING FLUID PRESSURE EVALUATION

Pilot Bore Drilling Fluid Pressure Evaluation

MOTT MACDONALD

Horizontal Directional Drilling
Drilling Fluid Hydraulic Fracture Calculations

Calculated by: M. Eakins
Checked by: G. Duyvestyn
Date: 3/12/2019
Project No: 353754

PROJECT: PennEast Pipeline Project

CROSSING LOCATION: Nishisakawick Creek

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

Soil Properties	Soil Type 1	Soil Type 2	Soil Type 3	Soil Type 4	Soil Type 5
c, soil cohesion (psf)	6000				
c, soil cohesion (N/m^2 or Pa)	287,282	0	0	0	0
ϕ, soil internal friction angle (deg)	6.0				
ϕ, soil internal friction angle (rad)	0.10	0.00	0.00	0.0	0.0
Equivalent SPT Blow Count N60 (blows per 12 inch)	40				
E, Young's Modulus based on blow count (lb/ft^2)	1,200,000	0	0	0	0
E, Young's Modulus (kPa)	50,000				
E, Young's Modulus (lb/ft^2)	1,044,272	0	0	0	0
v, Poisson's ratio	0.30				
G, soil shear modulus (ksf)	402	0	0	0	0
G, soil shear modulus (kPa)	19,231	0	0	0	0
G, soil shear modulus (Pa)	19,230,769	0	0	0	0
γ_s soil total unit weight (pcf) below water table	155				
γ_s soil total unit weight (kN/m^3) below water table	24.4	0.0	0.0	0.0	0.0
γ_s soil total unit weight (pcf) above water table	150				
γ_s soil total unit weight (kN/m^3) above water table	23.6	0.0	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	
Target Drill and Intersect Location	2+00	
	0+061	
Drill Rig setup on Pipe Side (Single Rig Option Only). For Drill and Intersect, this must be "no"	yes	
Drill Rig #1 Elevation	341.0	feet
	103.9	metre
Drill Rig #2 Elevation (Pipe Entry Location)	N/A	feet
	N/A	metre
Recommended Allowable Pressure Factor	2.00	Factor applied
Total Horizontal Installation Length	3,300.6	feet
	1,006.0	metre
True Installation Length	3,362.2	feet
	1,024.8	metre
Pilot Bore Diameter	12.250	inch
	311.15	mm
Drill Pipe Diameter	6.625	inch
	168.28	mm
Yield Point	22.5	$lb/100ft^2$
Plastic Viscosity	15	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	0.021	psi per ft of bore
	0.145	kPa per metre of bore
	0.633	psi per 30 ft drill pipe
Drilling Fluid Mud Weight	10.5	ppg
	78.5	lb/ft^3
	1.26	specific gravity

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
	feet	metre	feet	metre	feet	metre	feet	metre	feet	metre	feet	metre	
Pipe Exit Side	0+00	0+000	3,362.2	1,024.8	335.2	102.2	335.2	102.2	285.2	86.9	0.0	0.0	Type 1
	0+59	0+018	3,301.8	1,006.3	320.6	97.7	333.6	101.7	283.6	86.5	13.1	4.0	Type 1
	1+17	0+036	3,241.1	987.9	305.9	93.2	332.3	101.3	282.3	86.0	26.4	8.0	Type 1
	1+76	0+054	3,180.5	969.4	291.3	88.8	331.5	101.0	281.5	85.8	40.2	12.3	Type 1
	2+35	0+072	3,120.0	951.0	276.6	84.3	330.9	100.8	280.9	85.6	54.2	16.5	Type 1
	2+94	0+090	3,059.4	932.5	262.0	79.8	330.2	100.7	280.2	85.4	68.3	20.8	Type 1
	3+52	0+107	2,998.9	914.1	247.3	75.4	329.7	100.5	279.7	85.2	82.3	25.1	Type 1
	4+11	0+125	2,938.3	895.6	232.7	70.9	328.4	100.1	279.4	85.2	95.7	29.2	Type 1
	4+70	0+143	2,877.8	877.2	218.0	66.5	326.0	100.3	279.0	85.0	111.0	33.8	Type 1
	5+29	0+161	2,817.2	858.7	203.4	62.0	328.7	100.2	278.7	84.9	125.3	38.2	Type 1
	5+87	0+179	2,756.7	840.2	188.7	57.5	328.3	100.1	278.3	84.8	139.6	42.5	Type 1
	6+46	0+197	2,696.1	821.8	174.1	53.1	327.8	99.9	277.8	84.7	153.7	46.8	Type 1
	7+05	0+215	2,635.6	803.3	159.4	48.6	326.8	99.6	277.8	84.6	167.2	51.0	Type 1
	7+76	0+237	2,562.3	781.0	142.4	43.4	325.1	99.1	276.1	84.2	182.7	55.7	Type 1
	8+48	0+258	2,489.0	758.6	126.9	38.7	322.9	98.4	275.9	84.1	196.0	59.7	Type 1
	9+20	0+280	2,415.7	736.3	112.8	34.4	319.3	97.3	272.3	83.0	205.5	63.0	Type 1
	9+92	0+302	2,342.4	714.0	100.1	30.5	318.4	97.0	271.4	82.7	218.2	66.5	Type 1
	10+65	0+324	2,269.1	691.6	89.0	27.1	312.3	95.2	270.3	82.4	223.3	68.1	Type 1
	11+37	0+347	2,195.8	669.3	79.3	24.2	304.7	92.8	269.7	82.2	225.3	68.7	Type 1
	12+10	0+369	2,122.5	646.9	71.1	21.7	294.6	89.8	269.6	78.1	223.4	68.1	Type 1
	12+83	0+391	2,049.1	624.6	64.4	19.6	276.7	84.3	251.7	76.7	212.2	64.7	Type 1
	13+56	0+413	1,975.8	602.2	59.2	18.0	248.8	75.8	228.8	69.7	189.4	57.7	Type 1
	14+29	0+436	1,902.5	579.9	55.5	16.9	227.7	69.4	217.7	66.3	172.2	52.5	Type 1
	15+03	0+458	1,829.2	557.6	53.2	16.2	214.4	65.3	204.4	62.3	161.1	49.1	Type 1
	15+76	0+480	1,755.9	535.2	52.5	16.0	175.6	53.5	185.6	56.5	123.3	37.6	Type 1
	15+95	0+486	1,737.2	529.5	52.5	16.0	166.9	50.7	154.5	50.1	114.0	34.7	Type 1
	16+13	0+492	1,718.4	523.8	52.5	16.0	164.4	50.1	182.4	49.5	111.9	34.1	Type 1
	16+32	0+497	1,699.7	518.1	52.5	16.0	164.0	50.0	182.0	49.4	111.5	34.0	Type 1
	16+51	0+503	1,680.9	512.4	52.5	16.0	164.0	50.0	182.0	49.4	111.5	34.0	Type 1
	16+70	0+509	1,662.2	506.6	52.5	16.0	164.0	50.0	182.0	49.4	111.5	34.0	Type 1
	16+88	0+515	1,643.4	500.9	52.5	16.0	164.0	50.0	182.0	49.4	111.5	34.0	Type 1
	17+07	0+520	1,624.7	495.2	52.5	16.0	164.0	50.0	182.0	49.4	111.5	34.0	Type 1
	17+26	0+526	1,605.9	489.5	52.5	16.0	164.0	50.0	182.0	49.4	111.5	34.0	Type 1
	17+78	0+542	1,554.0	473.7	52.9	16.1	164.0	50.0	182.0	49.4	111.1	33.9	Type 1
Water Body	18+30	0+558	1,502.1	457.8	54.1	16.5	162.0	49.4	162.0	49.4	105.9	32.3	Type 1
	18+82	0+574	1,450.2	442.0	58.1	17.1	168.2	58.9	183.7	56.0	130.6	39.8	Type 1
	19+33	0+589	1,398.2	426.2	58.8	17.9	215.2	65.6	212.2	64.7	156.3	47.7	Type 1
	19+85	0+605	1,346.3	410.4	62.4	19.0	235.6	71.8	232.6	70.9	173.2	52.8	Type 1
	20+37	0+621	1,294.4	394.5	66.8	20.3	248.6	75.8	245.8	74.9	182.0	55.5	Type 1
	20+89	0+637	1,242.5	378.7	71.9	21.9	256.0	78.0	253.0	77.1	184.1	56.1	Type 1
	21+40	0+652	1,190.5	362.9	77.8	23.7	261.0	79.5	258.0	78.6	183.2	55.8	Type 1
	21+92	0+668	1,138.6	347.1	84.0	25.6	264.0	80.5	261.0	79.5	179.5	54.7	Type 1
	22+43	0+684	1,086.7	331.2	92.1	28.1	265.0	81.0	262.9	80.1	173.8	53.0	Type 1
	22+94	0+699	1,034.8	315.4	100.3	30.6	265.1	80.8	262.1	79.9	164.7	50.2	Type 1
	23+46	0+715	982.8	299.6	109.4	33.4	263.4	80.3	260.4	79.4	154.0	46.9	Type 1
	23+96	0+730	930.9	283.7	119.3	36.4	261.9	79.8	258.9	78.9	142.6	43.5	Type 1
	24+47	0+746	879.0	267.9	129.9	39.6	261.2	79.6	258.2	78.7	131.3	40.0	Type 1
	24+98	0+761	827.1	252.1	141.3	43.1	260.4	79.4	257.4	78.5	119.1	36.3	Type 1
	25+48	0+777	775.2	236.3	153.5	46.8	254.6	77.6	251.6	76.7	101.2	30.8	Type 1
	26+11	0+798	710.8	216.6	169.1	51.5	259.6	79.1	256.6	78.2	90.5	27.6	Type 1
	26+74	0+815	646.0	196.9	184.7	56.3	269.8	82.2	266.8	81.3	84.9	25.9	Type 1
	27+36	0+834	581.6	177.2	200.4	61.1	274.0	83.5	271.0	82.6	73.7	22.5	Type 1
	27+99	0+853	516.8	157.5	218.0	66.5	278.7	84.9	275.7	84.0	62.7	19.1	Type 1
	28+62	0+872	452.2	137.8	231.8	70.6	284.5	86.7	281.5	85.8	52.9	16.1	Type 1
	29+25	0+891	387.6	118.1	247.2	75.4	284.8	86.8	281.8	85.9	47.5	14.5	Type 1
	29+87	0+911	323.0	98.4	262.9	80.1	307.8	93.8	304.8	92.9	44.9	13.7	Type 1
	30+50	0+930	258.4	78.8	278.5	84.9	319.2	97.3	316.2	96.4	40.6	12.4	Type 1
	31+13	0+949	193.8	59.1	294.1	89.7	325.4	99.2	322.4	98.3	31.3	9.5	Type 1
	31+75	0+968	129.2	39.4	308.8	94.4	331.6	101.1	328.6	100.1	21.8	6.6	Type 1
	32+38	0+987	64.8	19.7	325.4	99.2	336.6	102.6	333.6	101.7	11.1	3.4	Type 1
Pipe Entry Side	33+01	1+006	0.0	0.0	341.0	103.9	341.0	103.9	338.0	103.0	0.0	0.0	Type 1

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	Recommended Upper Drilling Fluid Pressure Limit			Factor of Safety	Total Stress Evaluation	
psi	kPa	psi	kPa		psi	kPa		psi	kPa		Factor	psi	kPa		psi	kPa
0.0	0.0	70.92	489.0	–	3.17	510.81	–	74.09	510.8	–		0.0	510.8	–	0.0	0.0
255.7	1763.2	69.6	480.2	3.67	11.2	79.9	22.92	80.8	557.1	3.16	6.75	49.9	343.9	0.62	14.1	97.1
291.9	2012.9	68.4	471.4	4.27	15.1	132.0	15.25	87.5	603.4	3.34	6.00	72.3	498.5	0.83	28.4	195.6
317.3	2187.7	67.1	462.5	4.73	27.1	187.1	11.69	94.2	649.6	3.37	5.50	93.1	642.1	0.99	43.3	298.6
339.8	2342.8	65.8	453.7	5.16	35.1	242.2	9.67	100.9	695.9	3.37	4.75	117.5	811.9	1.17	58.4	402.6
359.6	2479.7	64.5	444.9	5.57	43.1	297.3	8.34	107.6	742.2	3.34	4.50	137.1	945.1	1.27	73.5	506.6
379.3	2615.3	63.3	436.1	6.00	51.1	352.4	7.42	114.4	788.5	3.32	4.25	157.0	1,082.7	1.37	88.6	611.1
399.3	2752.8	62.0	427.3	6.44	59.1	407.4	6.76	121.1	834.8	3.30	4.00	177.9	1,226.6	1.47	104.1	717.9
419.0	2888.8	60.7	418.5	6.90	67.1	462.5	6.25	127.8	881.0	3.28	3.75	199.4	1,374.5	1.56	119.5	823.9
438.6	3024.3	59.4	409.7	7.38	75.1	517.6	5.84	134.5	927.3	3.26	3.50	221.7	1,528.3	1.65	134.9	929.8
458.2	3159.5	58.1	400.9	7.88	83.1	572.7	5.52	141.2	973.6	3.25	3.25	245.0	1,689.3	1.74	150.2	1,035.8
477.6	3292.9	56.9	392.1	8.40	91.1	627.8	5.25	147.9	1019.9	3.23	3.00	269.5	1,858.0	1.82	165.4	1,140.6
495.9	3418.6	55.6	383.3	8.92	99.0	682.9	5.01	154.6	1066.2	3.21	2.75	294.8	2,032.7	1.91	179.9	1,240.6
517.0	3564.9	54.0	372.6	9.57	106.3	746.8	4.77	162.4	1119.5	3.18	2.50	324.8	2,239.4	2.00	195.6	1,355.7
534.8	3687.5	52.5	362.0	10.19	116.8	805.3	4.58	169.3	1167.3	3.16	2.25	354.9	2,447.0	2.10	211.0	1,454.5
549.2	3785.6	51.0	351.3	10.78	124.5	858.3	4.41	175.4	1209.6	3.13	2.22	369.6	2,548.0	2.11	222.3	1,532.7
565.2	3896.7	49.4	340.7	11.44	131.4	905.8	4.30	180.8	1246.4	3.13	2.25	381.7	2,631.7	2.11	234.9	1,619.7
571.1	3937.8	47.9	330.0	11.93	137.5	947.7	4.16	185.3	1277.7	3.08	2.25	387.4	2,670.9	2.09	240.4	1,657.4
572.5	3947.4	46.3	319.3	12.36	142.7	984.1	4.01	189.0	1303.4	3.03	2.25	389.2	2,683.5	2.06	242.6	1,672.3
570.0	3929.7	44.8	308.7	12.73	147.2	1014.9	3.87	192.0	1323.9	2.97	2.25	386.9	2,667.8	2.02	240.5	1,658.3
552.7	3811.1	43.2	298.0	12.79	150.9	1040.1	3.66	194.1	1338.1	2.85	2.25	372.6	2,568.9	1.92	228.4	1,575.1
520.5	3589.0	41.7	287.4	12.49	153.7	1059.7	3.39	195.4	1347.1	2.66	2.25	344.6	2,375.8	1.76	203.8	1,405.3
495.1	3413.5	40.1	276.7	12.34	155.7	1073.8	3.18	195.9	1350.5	2.53	2.25	323.0	2,227.0	1.65	185.3	1,277.9
480.0	3309.1	38.6	266.0	12.44	157.0	1082.2	3.06	195.5	1348.2	2.45	2.30	306.7	2,114.7	1.57	173.5	1,195.9
428.0	2950.8	37.0	255.4	11.56	157.4	1085.0	2.72	194.4	1340.4	2.20	2.10	273.3	1,884.6	1.41	132.8	915.4
415.5	2865.7	36.6	252.6	11.28	157.4	1085.0	2.63	194.0	1337.6	2.13	2.00	268.1	1,848.3	1.38	122.7	845.9
410.6	2831.1	36.2	249.9	11.33	157.4	1085.0	2.61	193.6	1334.9	2.12	2.00	265.5	1,830.8	1.37	120.5	830.6
410.0	2827.1	35.9	247.2	11.44	157.4	1085.0	2.61	193.2	1332.2	2.12	2.00	265.0	1,827.4	1.37	120.0	827.5
410.0	2827.1	35.5	244.5	11.56	157.4	1085.0	2.61	192.8	1329.5	2.13	2.00	265.0	1,827.4	1.37	120.0	827.5
410.0	2827.1	35.1	241.7	11.70	157.4	1085.0	2.61	192.4	1326.7	2.13	2.00	265.0	1,827.4	1.38	120.0	827.5
410.0	2827.1	34.7	239.0	11.83	157.4	1085.0	2.61	192.0	1324.0	2.14	2.00	265.0	1,827.4	1.38	120.0	827.5
410.0	2827.1	34.3	236.3	11.97	157.4	1085.0	2.61	191.6	1321.3	2.14	2.00	265.0	1,827.4	1.38	120.0	827.5
410.0	2827.1	33.9	233.6	12.10	157.4	1085.0	2.61	191.2	1318.5	2.14	2.00	265.0	1,827.4	1.39	120.0	827.5
409.5	2823.4	32.8	226.0	12.49	157.1	1083.5	2.61	189.9	1309.5	2.15	2.00	264.5	1,824.0	1.39	119.6	824.6
402.8	2777.1	31.7	218.5	12.71	156.5	1079.0	2.57	188.2	1297.5	2.14	2.00	258.8	1,784.6	1.38	114.9	792.1
436.8	3010.0	30.6	210.9	14.27	155.4	1071.6	2.81	186.0	1282.5	2.35	2.00	288.6	1,989.6	1.55	140.6	969.2
472.0	3254.2	29.5	203.3	16.00	153.9	1061.1	3.07	183.4	1264.5	2.57	2.00	320.1	2,207.3	1.75	168.3	1,160.3
495.1	3413.9	28.4	195.8	17.44	152.0	1047.7	3.28	180.4	1243.5	2.75	2.00	340.8	2,349.8	1.89	186.5	1,285.6
507.2	3496.8	27.3	188.2	18.58	149.6	1031.4	3.39	176.9	1219.6	2.87	2.00	351.5	2,423.6	1.99	195.9	1,350.8
510.0	3516.3	26.2	180.7	19.46	146.8	1012.0	3.47	173.0	1192.7	2.95	2.00	354.1	2,441.2	2.05	198.1	1,366.2
508.7	3507.6	25.1	173.1	20.26	143.5	989.7	3.54	168.7	1162.8	3.02	2.00	352.9	2,433.5	2.09	197.1	1,359.3
503.7	3473.0	24.0	165.6	20.97	139.9	964.4	3.60	163.9	1130.0	3.07	2.00	348.5	2,402.5	2.13	193.2	1,332.1
495.9	3419.4	22.9	158.0	21.64	135.8	936.2	3.65	158.7	1094.2	3.12	2.00	341.5	2,354.7	2.15	187.1	1,290.0
483.5	3333.3	21.8	150.5	22.15	131.3	905.0	3.68	153.1	1055.5	3.16	2.00	330.4	2,277.9	2.16	177.3	1,222.4
466.8	3232.1	20.7	142.9	22.61	126.3	870.9	3.71	147.0	1013.8	3.19	2.50	287.0	1,978.6	1.95	155.8	1,143.0
453.1	3123.9	19.6	135.4	23.07	120.9	833.8	3.75	140.6	969.2	3.22	2.75	262.4	1,809.4	1.87	153.5	1,058.3
437.5	3016.4	18.5	127.8	23.80	115.1	793.9	3.80	133.7	921.7	3.27	3.00	240.0	1,654.9	1.80	141.3	974.1
420.8	2901.1	17.4	120.3	24.12	108.9	751.0	3.86	126.4	871.3	3.33	3.25	218.2	1,504.7	1.73	128.2	884.1
395.9	2729.6	16.4	112.7	24.21	102.3	705.2	3.97	118.6	817.9	3.34	3.50	190.9	1,316.2	1.61	108.9	750.7
381.1	2627.9	15.0	103.3	25.43	93.8	646.4	4.07	108.7	749.8	3.50	3.75	173.1	1,193.4	1.59	97.4	671.7
373.3	2574.1	13.6	93.9	27.49	85.2	587.7	4.38	98.9	681.6	3.78	4.00	161.9	1,116.1	1.64	91.4	630.1
357.7	2465.9	12.3	84.5	29.17	76.7	528.9	4.66	89.0	613.4	4.02	4.25	144.8	998.3	1.63	79.3	546.8
342.2	2359.4	10.9	75.2	31.39	68.2	470.1	5.02	79.1	545.3	4.33	4.50	128.5	886.3	1.63	67.5	465.4
328.2	2262.7	9.5	65.8	34.41	59.7	411.4	5.50	69.2	477.1	4.74	4.75	114.0	786.1	1.65	58.9	392.4
320.4	2209.0	8.2	56.4	39.19	51.1	352.6	6.26	59.3	409.0	5.40	5.00	105.0	723.8	1.77	51.1	352.5
316.6	2182.8	6.8	47.0	46.47	42.6	293.8	7.43	49.4	340.8	6.40	5.25	99.4	685.6	2.01	48.3	333.3
310.2	2139.9	5.5	37.6	56.92	34.1	235.1	9.10	39.5	272.6	7.85	5.50	90.1	621.2	2.28	43.8	301.7
295.5	2037.6	4.1	28.2	72.30	25.6	176.3	11.56	29.7	204.5	9.98	5.75	75.6	521.0	2.55	33.7	232.1
278.2	1918.4	2.7	18.8	102.10	17.0	117.5	16.32	19.8	136.3	14.07	6.00	61.2	422.1	3.10	23.5	161.9
244.8	1686.7	1.4	9.4	179.54	8.5	58.8	28.70	9.9	68.2	24.75	6.25	45.2	311.7	5.41	12.0	82.6
0.0	0.0	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	6.50	0.0	0.0	–	0.0	0.0