HORIZONTAL DIRECTIONAL DRILL ANALYSIS
LIVERMORE ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E65-973
PA-WM2-0093.0000-RD-16
(SPLP HDD# S2-0016-16)

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LIVERMORE ROAD CROSSING
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ATTACHMENT 2

COAL MINE SUBSIDENCE AND STRESS ANALYSIS

SUBSIDENCE POTENTIAL REVIEW
LIVERMORE ROAD
20-INCH HORIZONTAL DIRECTIONAL DRILLED PIPELINE PROJECT
DERRY TOWNSHIP, WESTMORELAND COUNTY, PA
NOVEMBER 2018

PRESENTED FOR

Sunoco Logistics, L.P.
525 Fritztown Road
Sinking Spring, PA

PRESENTED BY

Tetra Tech
661 Andersen Drive
Foster Plaza 7
Pittsburgh, PA 15220

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INTRODUCTION

Tetra Tech, Inc. (Tetra Tech) was retained by Sunoco Logistics L.P. (Sunoco) to review the mining activity and subsidence potential of the abandoned coal mines below the planned Livermore Road horizontal directional drilled pipeline located in Derry Township, Westmoreland County, Pennsylvania. Our report follows.

BACKGROUND

Mine subsidence is defined by Pennsylvania Department of Environmental Protection (PA DEP) as "movement of the ground surface as a result of readjustments of the overburden due to collapse or failure of underground mine workings." Overburden is the soil and rock lying between the coal and the surface. When subsidence occurs at or near the location of an overlying structure, damage to the structure may occur. The potential impacts to surface structures are "generally classified as cosmetic, functional, or structural. Cosmetic damage refers to slight problems where only the physical appearance of the structure is affected, such as cracking in plaster or drywall. Functional damage refers to situations where the structure's use has been impacted, such as jammed doors or windows. A more significant impact on structural integrity is classified as structural damage. This includes situations where entire foundations require replacement due to severe cracking of supporting walls and footings." (PADEP, 2017). When a new structure is designed over areas where potential mine subsidence could result in structural damage, structural engineers can mitigate the damage concerns by improving the structural integrity of the structure or by isolating the structure from the subsidence. When structural improvement or isolation is not possible or is cost prohibitive, the hazards posed by mine subsidence can be mitigated by grouting the remnant mined entries (filling voids with concrete like material to prevent settling) to reduce the potential for subsidence.

The most effective mitigation method is to relocate the structure over areas where the coal has not been mined; however, in Pennsylvania mining regions, this is not always a possibility. When a structure is located over abandoned mine workings, predicting the probability and timing of future subsidence is not a clearly defined science. The probability of future subsidence depends on the remaining stability of the mine pillars, the columns of coal left in place to support the overlying overburden. The timing of any future failure of the pillars would depend on knowing the exact failure strength, the geometry of the mine pillars and the reduction in the strength of the mine pillars over time. There is, however, no way to know exactly when pillar failure will occur. Mining maps are prepared by active mining companies when the mine was operating to indicate where mining occurred and the type of mining conducted. Maps of abandoned mines are used by mining engineers to verify the mine layout and to estimate the size of remaining voids and pillars. These maps often lack complete details of the mining and are sometimes inaccurate. Incomplete or inaccurate knowledge of mine configuration can introduce additional errors into any future subsidence prediction.

Most abandoned mine subsidence impacts to small buildings (such as houses or offices) that result in structural damage have occurred in areas of limited overburden, such as where the mine depth is less than 100 feet. Although the subsidence damage classifications above refer to surface impacts, similar classifications might be applicable for impacts to underground pipelines located below the ground surface. As an example, areas of minor ground movement after a pipeline has been installed within a horizontal drilled borehole may cause movement of the pipeline (similar to cosmetic or functional damage to a surface structure) but may not cause

structural damage such as a break in the pipeline resulting in a loss of fluids or gas. Areas of potential structural damage should be avoided or mitigated.

The Tunnelton Mining Company's Marion Mine operated in Derry Township, Westmoreland County in the late 1980's and early 1990's. The primary mining method used at the mine was room and pillar mining using mechanized continuous mining machines and shuttle car haulage. Mining production was completed under the planned HDDP in 1985. The Marion Mine produced coal from the Upper Freeport coal seam at a mining height of approximately 3.5 feet, with primary development entries (tunnels) that were 18 feet to 20 feet wide and panel and room entries that were 18 feet to 24 feet wide. The pillars in the submains and panels appear to average 50 feet by 50 feet. (Refer to Figure 1)

The room and pillar method of mining consists of entries and pillars that allow for the movement of men and material along with directing air currents that are necessary for ventilating the production areas for the removal of methane gas and coal dust, while providing suitable air quantities for the workforce. The coal pillars that remain after entry development are designed for roof support and ground control for worker safety and for directing the ventilating air currents.

Using the mine maps, obtained from the Pennsylvania Mine Atlas, the mine production plan consisted of a series of mains, submains and panels. The area that the HDDP crosses is considered a five-entry panel with a series of room entries constructed left and right of the panel entries. Under the pipeline, the room entries were developed using similar supporting pillar size as was used with the fie-entry submain.

The mine mapping indicates that the area where the HDDP crosses was developed using similar size pillars and no secondary retreat mining was conducted. The mine mapping also indicates that there had been localized immediate roof falls in this area. The smaller sized pillars that lie to the south of the angle of draw for the HDDP have the highest risk of future subsidence because the pillars in these areas were not necessarily designed to provide long term support. As previously discussed, due to potential inaccuracies in the mine maps the exact pillar sizes cannot be guaranteed.

TYPES OF MINE SUBSIDENCE

Mine subsidence occurs in one of two physical forms, a trough or a sinkhole. A trough is a shallow, often broad, dish-shaped depression that develops when the overburden sags downward into a mine opening in response to roof collapse, the crushing of mine pillars, or the punching (pushing) of pillars into the mine floor. There can also be areas of surface heave around the edges of the subsidence troughs. Trough subsidence typically occurs in areas of deeper overburden, typically in areas of more than 100 feet of overburden. The depth and extent of the trough are closely related to the dimensions and thickness of the extracted coal.

A sinkhole is a depression in the ground surface that occurs due to localized collapse of the overburden directly into a mine opening (a room or entry). This is often called "chimney" type subsidence. Boundaries between the ground surface and the vertical walls of the sinkhole are often abrupt, and because sinkhole diameter generally increases with depth, the sinkhole in profile may initially resemble an open bottle with the top at the ground surface. Erosion of soil at the sinkhole's periphery may increase the diameter near the ground surface to create an hourglass profile. Sinkhole subsidence typically occurs in areas of shallow overburden, primarily 100 feet or less. Sinkhole-prone areas are the primary locations where subsidence causes severe structural damage to buildings on the surface. Sinkhole subsidence in an area of single-seam mining is usually limited to areas where the total thickness of the rock layers above the coal is no

more than 6 to 10 times the thickness of the coal mined in the area. The soil thickness overlying the rock is not included in this estimate. (Kendorski, 2006).

CATEGORIES OF MINE SUBSIDENCE POTENTIAL

Mining-induced subsidence is caused when a seam of coal is extracted and overlying rock layers cave into the voids left by mining such that there is movement on the ground surface. The probability of subsidence is greater in areas where a high percentage of coal is removed. In an analysis of underground mines, subsidence potential can be classified into the following three general categories:

Category 1 – Subsidence probably occurred during or soon after mining.

Category 2 – Support area where subsidence is unlikely.

Category 3 – Area where subsidence may occur in the future if it has not already occurred.

Room and pillar mining, the method of mining commonly used in the project area, is a method of mining where mine entries were excavated through the coal seam. The unmined coal or coal pillars remained in place to support the roof.

Category 1 refers to areas where nearly full extraction of the coal occurred as a result of retreat mining and there is very low probability of extensive future subsidence, although subsidence can occur at the edges of these areas due to failure of adjacent supporting pillars. No retreat mining occurred in the Marion mine within the angle of draw, therefore no category 1 subsidence areas exist.

Category 2 refers to areas where the mine configuration and pillars are adequately designed to provide permanent support to the ground surface. The amount of coal removed in these areas is generally low to moderate. These areas, although mined, generally remain stable over the long term and typically include main entries and haulage routes as well as low-extraction-ratio room and pillar areas of the mines where retreat mining did not occur. Areas of mines delineated as Category 2 would have a relatively low probability of future subsidence.

Category 3 refers to areas underlain by room and pillar mines with a high percentage of coal removed and where retreat mining was not performed. In Category 3 areas, it is uncertain whether subsidence occurred and whether there remains a likelihood of subsidence in the future. In these areas, entries were driven through the coal, and the pillar sizes were smaller than what would generally be required to provide permanent support. In other words, the pillars were designed with a low factor of safety (caused by the high extraction ratio), and there would be an elevated risk of pillar, roof, or floor failure. If subsidence already occurred, the possibility of future subsidence is very unlikely. However, if subsidence has not previously occurred, the possibility of future subsidence remains high. Of the three categories, Category 3 would have the highest probability for future subsidence.

In mining subsidence terms, the extent of the potential area impacted by subsidence can be defined using a specific angle from the coal seam to the ground surface that could be affected if roof failure occurred at the mine level. The potential subsidence affected area can be directly overhead but could also be offset a certain horizontal distance from the roof failure location. The angle, termed the “angle-of-draw,” can vary depending on the overburden rock type (Peng, 1978). PA DEP accepts 20 degrees as the angle-of-draw for the flat-lying coal seams in the bituminous coal region; however, up to 35-degree angle-of-draws have been found to occur, primarily in deeply dipping mining areas. Because mining in the Marion mine was in a flat-lying coal seam, a 20-degree angle-of-draw would be expected. There have also been instances of

higher angles in specific cases, but those cases are extremely rare. The angle-of-draw can also be projected downward from a surface structure to determine what area within a mine could, if pillar or roof failure occurred, cause surface subsidence.

Tetra Tech reviewed the mine maps and the location and elevation of the planned horizontal boring. Figure 1 depicts the areas within the mine that are within the angle-of-draw depicted downward from the level of the HDDP. Both angle-of-draws (20° and 35°) are shown on Figure 1. The area shown was created by using an angle-of-draw from the pipeline's bottom elevation to the top of the coal seam. The areas shown within the extent of the mine within the angle-of-draw have the potential to affect the pipeline if pillar failure occurs. A 15-foot horizontal zone on each side of the pipe (30 feet total) was also included. A total of 4.7 acres lies within the 20° angle of draw influence area, while 8.3 acres lie within a 35° angle of draw influence area. The categories of mine subsidence potential areas are shown on Figure 2 and summarized on Table 1.

TABLE 1 – Summary of Categories of Subsidence Potential within Angle of Draw

Angle of Draw	Subsidence Potential	Area (Acres) 20°	Area (Acres) 35°
Subsidence Category 1	Subsidence probably occurred during or soon after mining	0	0
Subsidence Category 2	Support area where subsidence is unlikely	4.7	8.3
Subsidence Category 3	Area where subsidence may occur in the future if it has not already occurred	0	0
Total		**4.7**	**8.3**

Within the overburden the strata above the coal seam behaves differently when subsidence occurs, based on the distance above the coal seam and the mining thickness. These different zones are classified based on past research. A caved zone occurs from the roof of the mined coal and typically extends upwards for a distance of 6 to 10 times the mining thickness (Kendorski, 2006). In the case of the Marion mine where the mined thickness is three and a half feet, this zone would be from 21 to 35 feet above the top of coal. Rock in this zone would have extensive fracturing and sizable voids. Above the cave zone and extending for 24 to 30 times the mining thickness a fractured zone would occur. In this zone, a lot of fractures would be present but the rock strata would remain as a single unit without extensive dislocated rock or voids present. At the Marion mine, this zone would extend from 21 to 35 feet to 84 to 105 feet above the top of mining. The next zone would extend from the top of the fractured zone to about 60 times the mining thickness. This zone is termed the dilated zone. This zone would have small temporary fractures that would heal over time. The rock again would remain as a single unit. At the Marion mine, this dilation zone would extend from 84 to 105 feet to 210 feet above the top of the coal. The zone above the dilated zone is termed the constrained or bending zone where no significant fracturing would occur. The zones are shown on Table 2.

Table 2: Zones of Strata Fracturing During Subsidence

Zone	Extent Above Coal Seam (ft.) (x mining height)	Impact to Strata	Voids Created
Constrained	Not Applicable	No Fractures	None
Dilation	Up to 60	Small Fractures	Micro
Fracture	Up to 30	Fractured	Minimal
Caved	Up to 10	Fractured	Sizable
Mined Coal Seam			

Determining induced strains from subsidence during active mining has become relatively accurate, especially for longwall mines. Numerous computer models have been developed by mining agencies and universities that use variations in the rock type within the overlying strata, mining thickness, and mine geometry at the coal seam level to predict ground movements at the surface. These models not only predict the extent and amount of subsidence but can predict tilts and strains occurring at ground level. They can also be used to predict maximum strains if subsidence would occur, although their application for abandoned mines is less predictable as to the extent of subsidence. Mine subsidence from an abandoned mine is less uniform and predictable than subsidence during active mining. However, the use of models for actual mining should provide relatively similar results when predicting the potential strains from future subsidence of abandoned mines.

FINDINGS

The mine maps were reviewed by experienced mining engineers. Although the mining shown on the maps covering the area under the HDDP occurred over 30 years ago, the maps were found to be very detailed regarding the mining type and location of mining. The maps were georeferenced by PA DEP. In our opinion, the mine maps are generally a reliable indication of the extent of what was mined.

The horizontal directional boring starts on its western most location at 403 feet above the mined coal. The descending boring will be approximately 240 feet above the mining when it levels about 726 feet horizontally from its start. The boring would then be fairly level for approximately 225 feet to the end of the mine where it will remain approximately 240 feet above the mine. The remainder of the pipeline will lie above unmined coal. Refer to Figure 3 and 4.

Figure 4 was prepared using the planned HDDP profile and adding the top of each fracture zone if subsidence would occur or has occurred. To be conservative, the top of each fracture zone was selected as the maximum value based on the Kendorski's research (Kendorski, 2006). The entire bore will be completed within the constrained zone.

The PA DEP Bureau of Abandoned Mine Land Reclamation (BAMR) is responsible for maintaining an inventory of all abandoned mine related incidents in Pennsylvania. This includes mine subsidence incidents above abandoned mines such as the Marion mine. It is our

understanding that their recording of these incidents began shortly after 1977. There have been no subsidence incidents reported and investigated in the area of the HDDP in the past 40 years.

When the earth subsides, the curvature of the strata can produce a horizontal strain within the strata. Some of this strain can be transferred to a rigid pipeline that is placed within the strata. Strain is defined as the amount of deformation in the direction of applied force divided by the initial length of the material. This results in a unitless number such as inches per inch. Strain can be induced by compression, tension or bending forces. Using historical subsidence data from primarily known conditions during longwall mining, models have been developed to predict strains at the ground surface caused by subsidence. These models, although not perfectly suited for use with abandoned mines, can be adapted to estimate strains within the strata at the elevations where the pipeline will be placed. Because the caved zone would be heavily fractured during subsidence, local strains within the caved zone cannot be accurately estimated. To estimate the strains that may be seen at the pipeline level in the zones above the caved zone, Tetra Tech engaged Dr. Keith Heasley, a mining engineer with experience using subsidence models to predict the possible strains. Dr. Heasley is a professor of mining engineering at West Virginia University. His full report can be found in Appendix A.

Modeling of the Marion mine was conducted using a base coal strength of 900 pounds per square inch (psi) to simulate the strength of the coal at the time of mining. Subsequently, a coal strength of 600 psi was modeled to simulate the coal strength after the mine pillars degrade over time. The predicted subsidence with both coal strengths along the pipeline alignment is shown on Figure 5. The 900-psi coal subsidence plot indicates anticipated ground subsidence directly after mining. The 600-psi plot predicts the subsidence that may occur along the pipeline as the mine conditions degrade over time. It is unknown when or if the 600-psi conditions will ever occur. Predicting the exact condition of the mine at this time, or at any precise time in the future, is not possible. Subsidence may also occur in different areas at different times so that the estimated subsidence in the model may not occur at the same time.

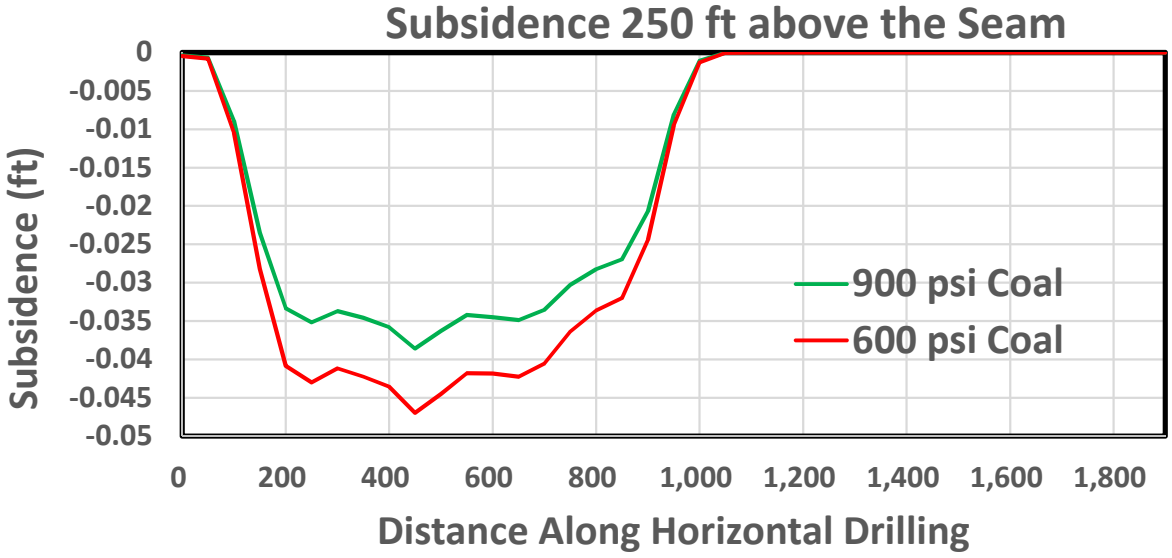


Figure 5-Estimated Subsidence

LaModel was chosen as the mining-induced stress analysis program to estimate strain on the strata at the location of the pipeline within the strata. This program is primarily designed to calculate the seam stress and displacement within an underground mine. The software uses boundary elements for calculating the stresses and displacements in coal mines or other thin tabular seams or veins. During active mining, it can be used to optimize pillar sizes and mine layout by minimizing pillar stress. Multi-seam mining stress can also be reviewed. This program can also reasonably calculate surface subsidence. A medium distance of 250 feet above the Marion mine was chosen for detailed analysis of mine subsidence. In the LaModel program, the overburden is modeled as a continuum. Therefore, the program shows the subsidence directly over the mined areas and within the angle of draw. The magnitude of subsidence decreases as the distance from the mine increases and the subsidence spreads. The program does not model any dilation of the overburden.

The estimated maximum subsidence that the pipeline may experience in the future is the difference between the subsidence estimated using the original strength (900 psi) of coal and the subsidence estimated using degraded strength (600 psi) of coal. This differential subsidence is shown on Figure 6. There is one area of potential future subsidence however minimal. This one area is from Station 1+00 to Station 9+50 and occurs within an area that was not retreat mined. The increased subsidence at this location was estimated to be about 0.009 feet (0.1 inches).

The strains within the strata associated with the estimated future subsidence should the pillars fail are shown on Figure 6. The maximum strain values range from -231 microstrains to +278 microstrains and fluctuate continuously along the pipeline length. The level of strain that the pipeline may experience is a function of the ground movement and a function of how tightly the pipeline is coupled to the ground movement. If the pipeline can slide within the HDDP, then areas of tensile or compressive strain can be reasonably canceled by adjacent areas of the opposite strain.

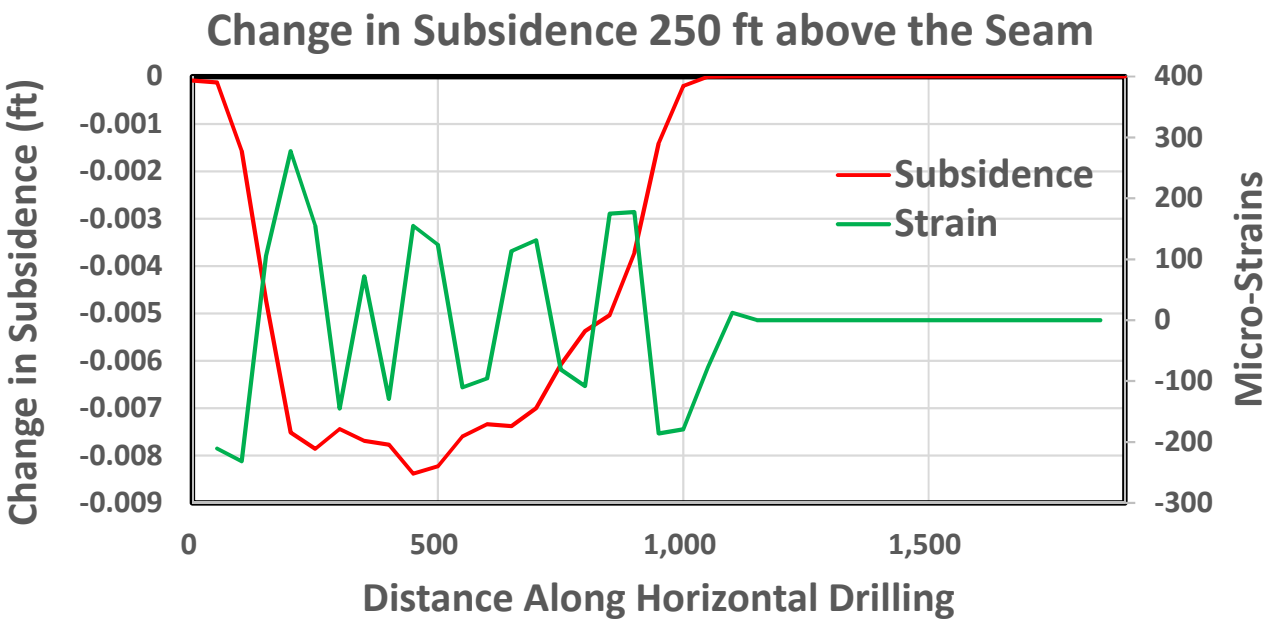
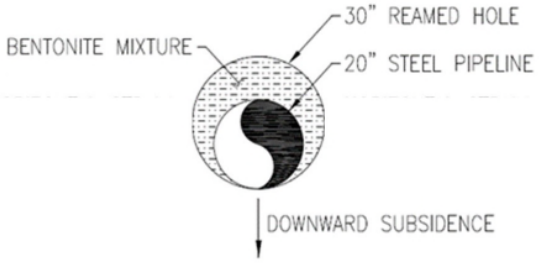


Figure 6 – Change in Subsidence

The modeled strains are in the strata at the location of the pipeline alignment. The bored excavation for the HDDP will be larger than the pipe to be installed. As shown on Figure 7, the strain in the strata encompassing the hole, is not directly correlated to the strain imparted to the pipeline. The overbore (larger diameter of the hole compared to the pipe) leaves room for potential movement of the pipe within the strata. Transmission of the strain from the strata to the pipe associated with this project is being reviewed by pipeline engineers.



HDDP 20”

Figure 7 – Borehole and Pipeline Cross Section

RECOMMENDATIONS

Based on the findings presented above Tetra Tech recommends the following actions:

- Provide the estimated maximum subsidence and strain within the strata to pipeline engineers for their use to assure that the pipeline stresses are within appropriate pipeline design standards, including an adequate factor of safety.
- It does not appear that any significant subsidence may occur in the future, so mitigating the subsidence strain by grouting the underlying abandoned coal mine should not be necessary.

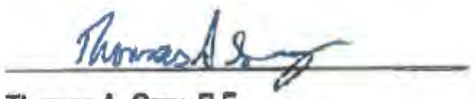
CLOSURE

The subsidence modeling calculates the stress and ground movement throughout the strata, from the coal seam to the surface. Numerical subsidence models have been calibrated both at the mine level (for optimizing pillar design) and at the surface (for subsidence prediction). Obviously, these are the locations where there is relatively simple access for performing the broad area measurements needed for the calibration of the model. Obtaining calibration measurements from within the solid rock mass between the mine and the surface is not very effective, since only limited locations can be practically measured versus wide area measurements in the mine or on the surface. In addition, underground subsidence has been observed in multi-seam mines and every indication is that the strain field is continuous throughout the overburden. Further, the numerical method used for simulating the rock strata is consistent with the physical laws of superposition and interpolation. Therefore, it is entirely reasonable and standard engineering practice to calculate/interpolate the subsidence at the location of the pipeline which is between the calibrated mine and surface locations. The model calculations are based on average subsidence parameters which may certainly have some variable for each individual site and that predicting subsidence from pillar failure and incomplete caving is different than the complete caving subsidence used to develop the subsidence parameters.

In areas where the pipeline is to be located greater than 50 feet below the ground surface, the drill will be over-bored to a diameter larger than the pipeline. This will decrease the frictional drag between the earth and the pipeline, and maintaining this low-friction environment over the life of the pipeline would help decouple the pipeline from any ground movements and subsidence-induced strains.

This report was prepared to assist Sunoco in the evaluation of the subject project. The scope of this report is limited to the specific project, location, and time described herein. The report presents Tetra Tech's understanding of site conditions as discernible from information provided by others and obtained by Tetra Tech. Maps in this report are included only to aid the reader and should not be considered surveys. If additional data concerning this site becomes available, Tetra Tech should be informed so that we may examine the information and, if necessary, modify this report accordingly.

Respectfully submitted,



Thomas A. Gray, P.E.
Mining Engineer

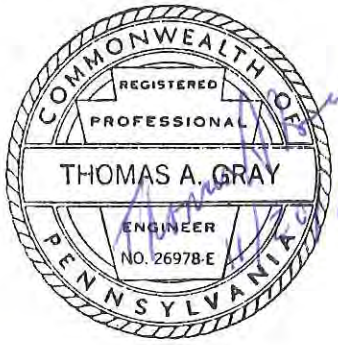
Farley Wood, P.E.
Mining Engineer

Keith Heasley, PhD, P.E.
Mining Engineer

CERTIFICATION

SUBSIDENCE POTENTIAL REVIEW
LIVERMORE ROAD
20-INCH HORIZONTAL DIRECTIONAL DRILLED PIPELINE PROJECT

By affixing my seal to this document I am confirming that the project conditions were reviewed and that accepted engineering practices were used to arrive at the reported results. Subsidence engineering is not an exact science and professional judgement was used to assess the many variables that exist, and is subject to those limitations that may be included in the Subsidence Report and information provided by third parties.



Thomas A Gray

11/20/18

Thomas Gray, P.E. Date

License No. 26978-E

The term certify as used herein is defined as follows: An engineer's certification of condition is a declaration of professional judgement. It does not constitute a warranty or guarantee, either expressed or implied.

TETRA TECH ROONEY

Date: 11/21/2018

To: Mathew Gordon
Project Manager
Sunoco Logistics, L.P.
525 Fritztown Road
Sinking Spring, PA

Subject: **Subsidence Potential Review 20-inch Horizontal Drilled Pipeline Project**
Livermore Rd. – Derry Township, Westmoreland County, PA
Mariner East II TTR Project: 204-3110 1.2 PPP2

Mr. Gordon,

Tetra Tech Rooney has reviewed the above referenced subsidence report in addition to performing a pipe stress analysis and we have confirmed that if the predicted subsidence does in fact occur in the future, the resulting stresses within the pipeline will still be in compliance with ASME B31.4.

Sincerely,

Jeff Lowy, P.E.
Civil Engineer
Tetra Tech Rooney

Attachments:

Geotechnical Report: Subsidence Potential Review Livermore Rd | 20" Horizontal Directional Drilled Pipeline Project – Derry Township, Westmoreland County, PA

CC: Larry Gremminger, CWB, Environmental Project Consultant
Dean Shauers, P.E., President, Tetra Tech Rooney
Thomas A. Gray, P.E., Energy and Natural Resources Manager, Tetra Tech, Inc.

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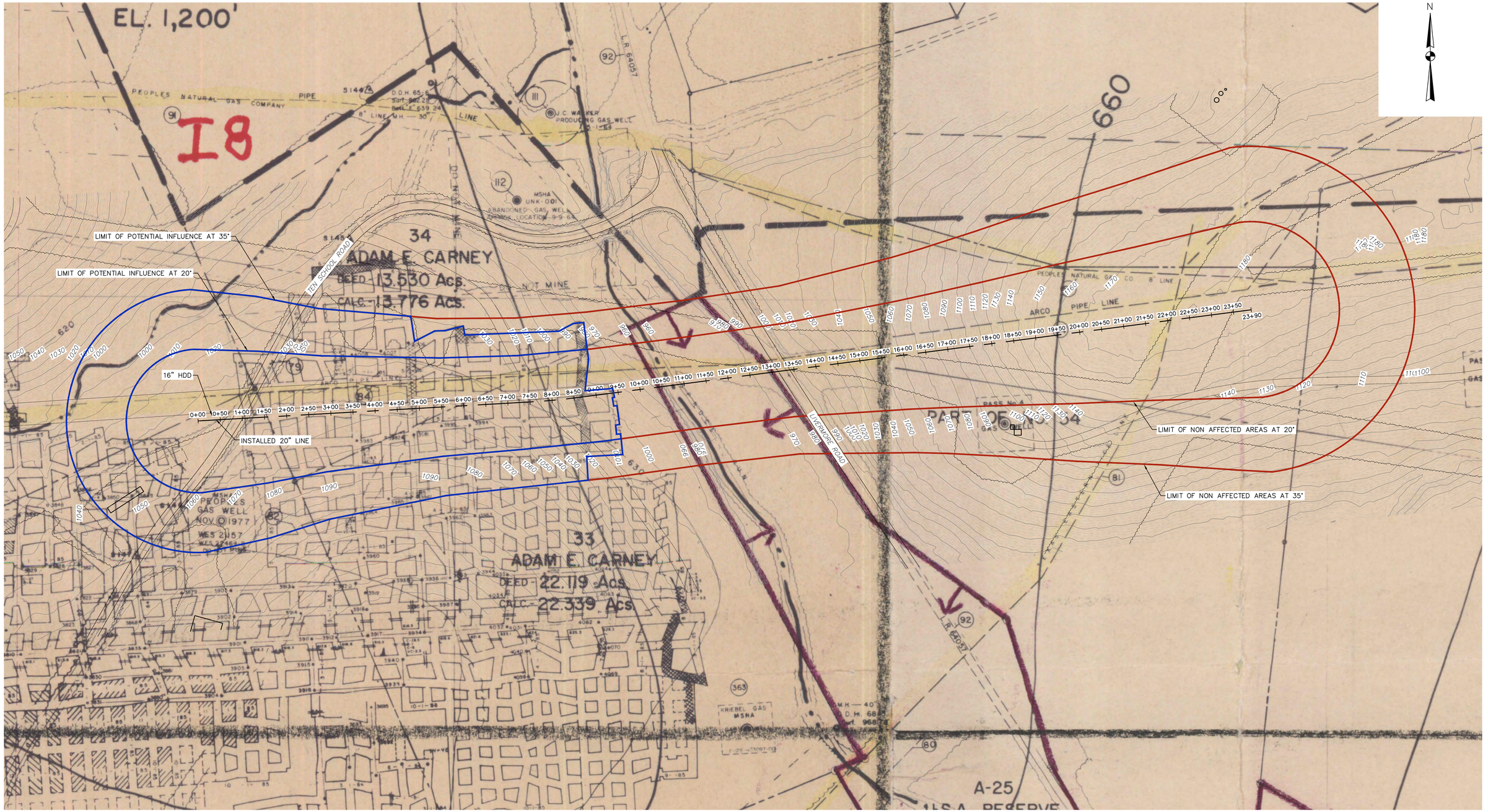

LEGEND

LIMIT OF POTENTIAL INFLUENCE AREA ON PIPELINE

LIMIT OF NON AFFECTED AREAS

REFERENCE: TUNNELTON MINING COMPANY, MARION MINE – OBTAINED FROM PA DEP –UNDATED

0 100 200
SCALE IN FEET

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REVISIONS

NO.	BY	DATE	REMARKS

SUNOCO PIPELINE L.P.
SINKING SPRING, PENNSYLVANIA

PENNSYLVANIA PIPELINE PROJECT

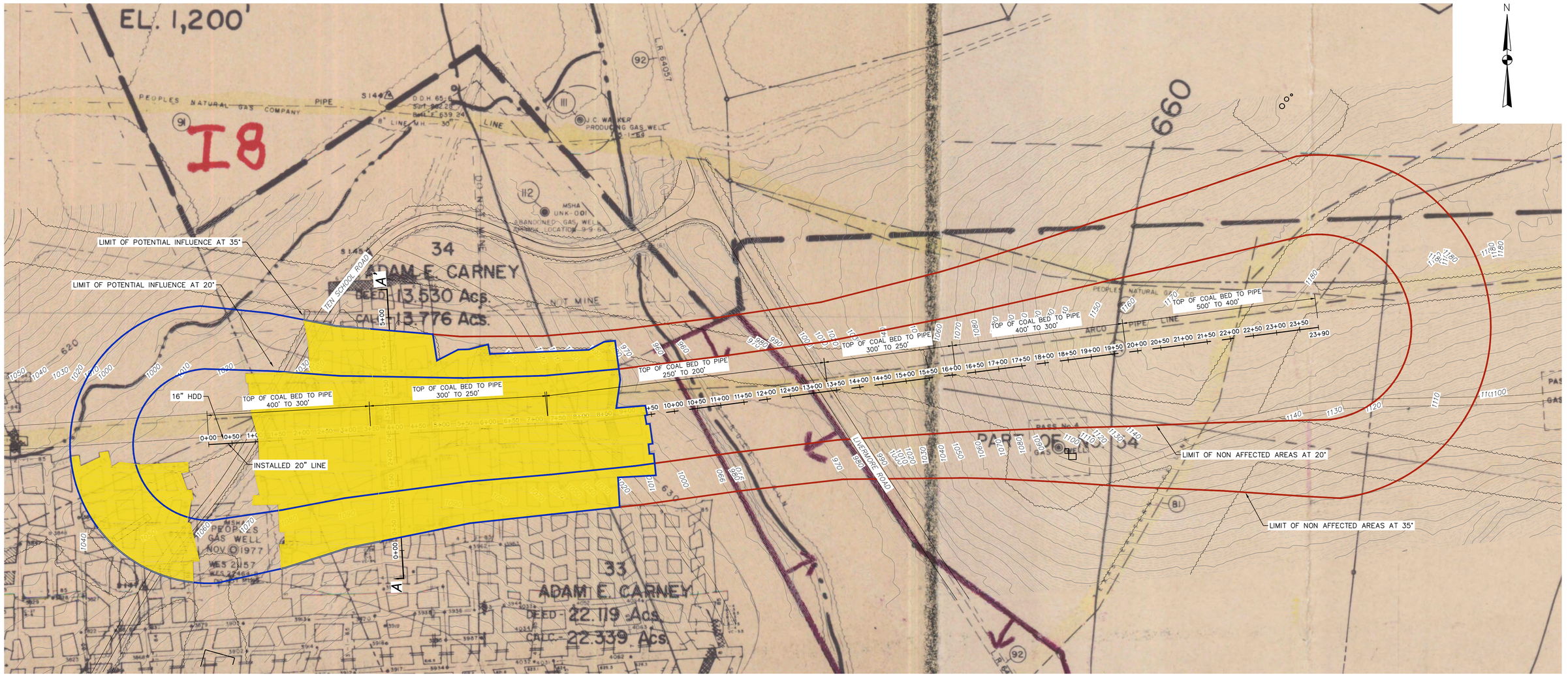
PROJECT LOCATION WITH ANGLE OF DRAW

WESTMORELAND COUNTY
LIVERMORE ROAD
20" HDD
MINE AREA

DATE:	5/31/18
PROJECT NO.:	
DESIGNED BY:	TG
DRAWN BY:	JSM
CHECKED BY:	TG

FIGURE 1

R:_Marcellus Shale Projects\Sunoco\5958 – Penn Pipeline Project\3 – Westmoreland\Spread 2\HDD Mining Review\Figures\PA-WM-HDD-F0028.dwg PIT BEN.HOPPE 8/28/2018 11:54:05 AM



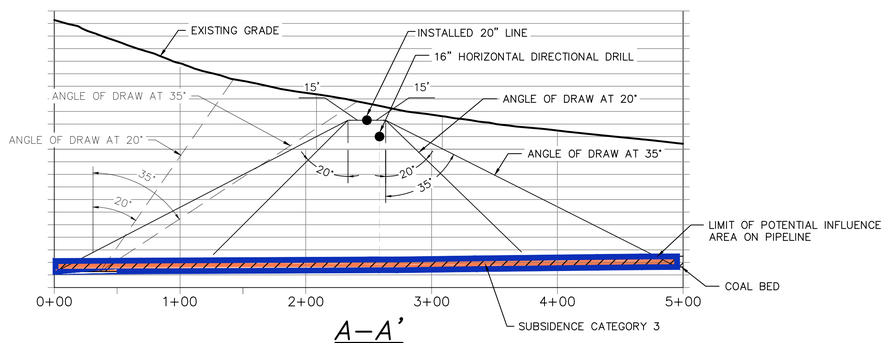
LEGEND

- LIMIT OF POTENTIAL INFLUENCE AREA ON PIPELINE
- LIMIT OF NON AFFECTED AREAS
- SUBSIDENCE CATEGORY 1
- SUBSIDENCE CATEGORY 2
- SUBSIDENCE CATEGORY 3

CATEGORIES OF MINE SUBSIDENCE POTENTIAL

CATEGORY 1: SUBSIDENCE PROBABLY OCCURRED DURING OR SOON AFTER MINING.
CATEGORY 2: SUPPORT AREA WHERE SUBSIDENCE UNLIKELY.
CATEGORY 3: AREAS WHERE SUBSIDENCE MAY HAVE OCCURRED OR MAY OCCUR IN THE FUTURE.

REFERENCE: TUNNELTON MINING COMPANY, MARION MINE – OBTAINED FROM PA DEP –UNDATED



A–A'
NOT TO SCALE

0 100 200
SCALE IN FEET

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REVISIONS			
NO.	BY	DATE	REMARKS

SUNOCO PIPELINE L.P.
SINKING SPRING, PENNSYLVANIA

PENNSYLVANIA PIPELINE PROJECT

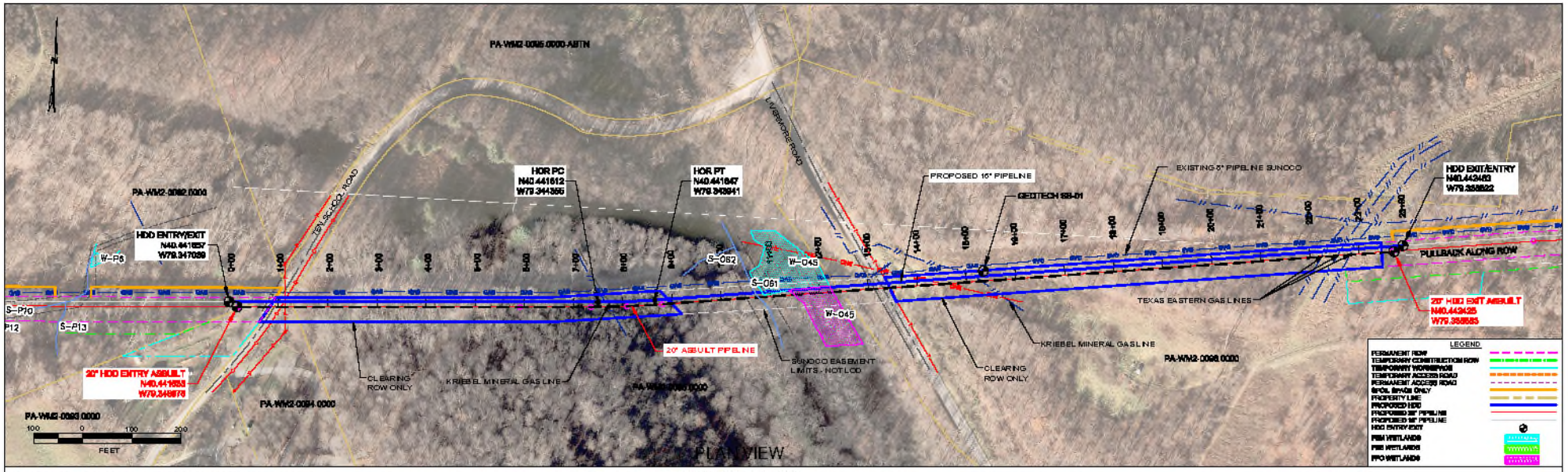
PROJECT LOCATION WITH SUBSIDENCE CATEGORIES

WESTMORELAND COUNTY
LIVERMORE ROAD
20" HDD
MINE AREA

DATE:	5/31/18
PROJECT NO.:	
DESIGNED BY:	TG
DRAWN BY:	JSM
CHECKED BY:	TG

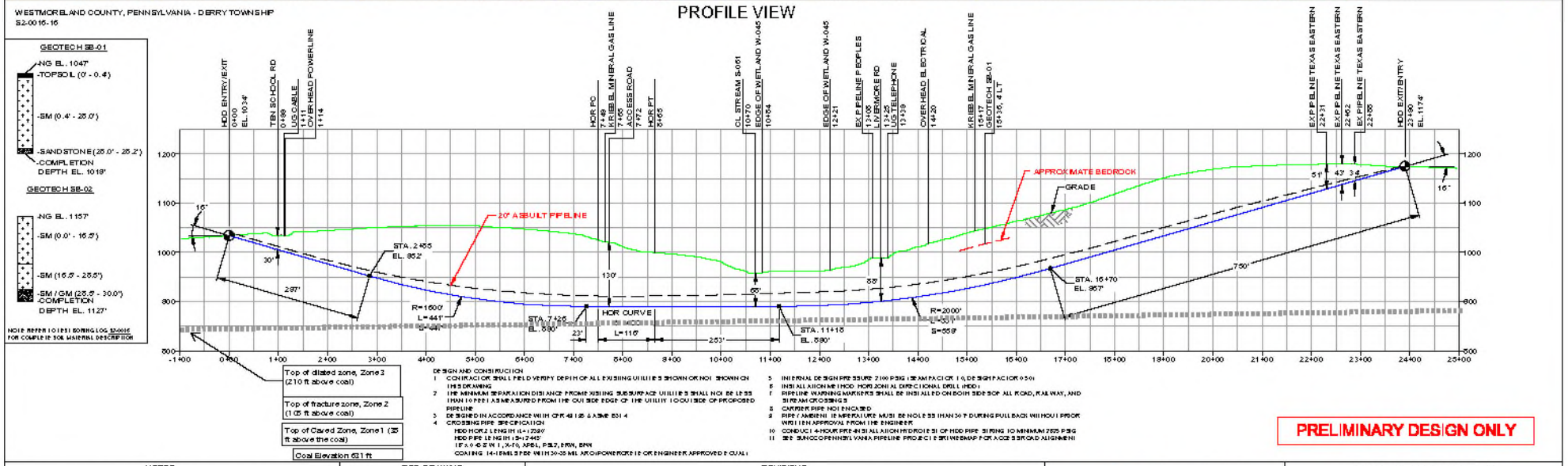
FIGURE 2

R:_Marcellus Shale Projects\Sunoco\5958 – Penn Pipeline Project\3 – Westmoreland\Spread 2\HDD Mining Review\Figures\PA-WM-HDD-FG029.dwg PIT BEN.HOPPE 8/28/2018 11:53:30 AM



WESTMORELAND COUNTY, PENNSYLVANIA - DERRY TOWNSHIP
52-00116-16

PROFILE VIEW



DESIGN AND CONSTRUCTION

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION
   HDD HOR.Z LENGTH (L+12')=2287'
   HDD PIPE LENGTH (L+25')=2465'
   16" X 0.438 W T, X-70, API 5L, PSL2, ERW, BPW
   COATING: 14-18 MILS PER WITH 30-35 MIL ARO EPOXY PER ICE (OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PIPE PRESSURE 2100 PSIG (STEAM PACIFIC 1.0, DESIGN FACTOR 0.50)
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD)
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDE SOF ALL ROAD, RAILWAY, AND STREAM CROSSINGS
8. CARRIER PIPE NOT ENCASED
9. PIPE / AMBIENT TEMPERATURE MUST BE NOT LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER
10. CONDUCT 4-HOUR PRESSURE INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 2625 PSIG
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT

PRELIMINARY DESIGN ONLY

NOTES

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

REF. DRAWING				
SHEET 02	10	SHEET 04	EROSION & SEDIMENT PLAN	
SHEET 05	10	SHEET 07	AERIAL SITE PLAN	
DWG NO		DWG NO	DESCRIPTION	NO.

REVISIONS							
DESCRIPTION	NO.	BY	DATE	CHK	DATE	APP	DATE
INCREASED DRILL DEPTH, UPDATED NOTES AND TOPS INCREASED TEMP - DESIGN CHANGE PER CLIENT	3	MKS	05/21/15	RMS	05/21/15	CAS	05/21/15
REVISED PER PADEP COMMENTS RECEIVED 06-05-15	2	DLM	06/01/15	RMS	06/01/15	AAM	06/01/15
REVISED PER PADEP COMMENTS	1	MKS	05/13/15	RMS	05/13/15	AAM	05/13/15
		DLM	05/25/15	RMS	05/25/15	AAM	05/25/15
ADDED GEOTECH INFO	0	MKS	04/07/15	RMS	04/07/15	AAM	04/07/15
ISSUED FOR BID	A	MKS	03/31/15	RMS	03/31/15	AAM	04/24/15

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

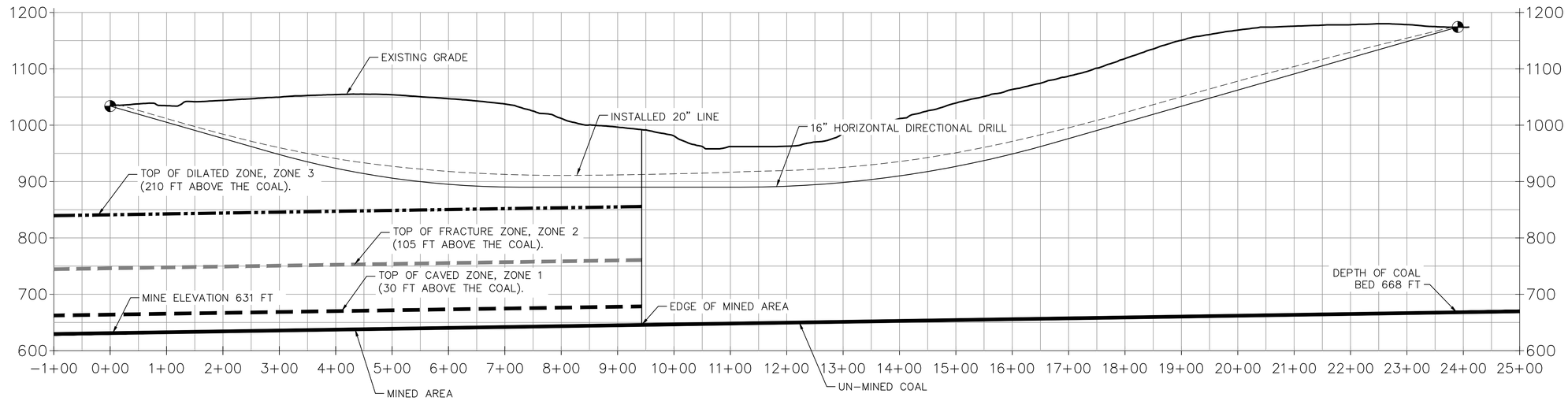
SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
LIVERMORE ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200' | DWG. NO.: PA-WM2-0093.0000-RD-16

Reference: Tetra Tech Rooney Drawing PA_WM2_0093.0000_RD-16

Figure 3 - Plan and Profile



0 100 200
SCALE IN FEET

TETRA TECH
www.tetratech.com
661 ANDERSEN DRIVE – FOSTER PLAZA 7
PITTSBURGH, PA 15220
T: (412) 921-7090 | F: (412) 921-4040

REVISIONS			
NO.	BY	DATE	REMARKS

SUNOCO PIPELINE L.P.
SINKING SPRING, PENNSYLVANIA

PENNSYLVANIA PIPELINE PROJECT

HDD PROFILE WITH ZONES OF STRATA FRACTURING DURING SUBSIDENCE

WESTMORELAND COUNTY
LIVERMORE ROAD
MINE AREA

DATE:	5/31/18
PROJECT NO.:	
DESIGNED BY:	TG
DRAWN BY:	JSM
CHECKED BY:	TG

FIGURE 4

R:_Marcellus Shale Projects\Sunoco\5958 – Penn Pipeline Project\3 – Westmoreland\Spread 2\HDD Mining Review\Figures\PA-WM-HDD-FG027.dwg PIT JOY.SCABILLONI 11/19/2018 3:15:27 PM

LAMODEL ANALYSIS OF SUBSIDENCE POTENTIAL
LIVERMORE ROAD
HORIZONTAL DIRECTIONAL DRILLED PIPELINE PROJECT
DERRY TOWNSHIP, WESTMORELAND COUNTY, PA
August, 2018

PRESENTED FOR

Sunoco Logistics, L.P.
525 Fritztown Road
Sinking Spring, PA

PRESENTED BY

Tetra Tech
661 Andersen Drive
Foster Plaza 7
Pittsburgh, PA 15220

TABLE OF CONTENTS

FIGURES

INTRODUCTION

The Sunoco Logistic L.P. is planning to horizontally directional drill (HDD) a pipeline under Livermore Road and in the strata over the abandoned Tunnelton Mining Company's Marion Mine in Derry Township, Westmoreland County, PA. The HDD section under the road will be about 2,390 ft long and 250-500 ft above the mine level. The objective of this investigation is to utilize the LaModel boundary-element program to analyze the future subsidence potential over the abandoned Marion Mine, and in particular, to determine any potential subsidence and associated strains that may occur along the proposed pipeline alignment.

MINING BACKGROUND

The Tunnelton Mining Corporation operated the underground Marion Mine in Derry Township, Westmoreland County in the late 1980's and early 1990's. The Upper Freeport seam was mined using the room and pillar mining method below the HDDP. No retreat mining was conducted directly under the HDDP. The Upper Freeport seam was mined from Station 01+00 on the western end of the HDDP to about Station 10+00 (1000 ft). The depth of the coal from the surface is about 400 ft above the western portion of the HDDP.

THE LAMODEL PROGRAM

The LaModel program is used to model the stresses and displacements on thin tabular deposits such as coal seams. It uses the displacement-discontinuity (DD) variation of the boundary-element method, and because of this formulation, it is able to analyze large areas of single or multiple-seam coal mines (Heasley, 1998). LaModel is unique among boundary element codes because the overburden material includes laminations which give the model a very realistic flexibility for stratified sedimentary geologies and multiple-seam mines. Using LaModel, the total vertical stresses and displacements in the coal seam are calculated, and optionally, the surface subsidence, or subsidence anywhere in the overburden, can be calculated. Amongst subsidence prediction programs, LaModel has the unique ability of be able to model the highly variable subsidence associated with time-dependent, pillar failure.

Since LaModel's original introduction in 1996, it has continually been upgraded and modernized as operating systems and programming languages have changed. The present program is written in Microsoft Visual C++ and runs in the windows operating system. It can be used to calculate convergence, vertical stress, overburden stress, element safety factors, pillar safety factors, intra-seam subsidence, etc. on single and multiple seams with complex geometries and variable topography. Presently, the program can analyze a 2000 x 2000 grid with 6 different material models and 52 different individual in-seam materials. It uses a forms-based system for inputting model parameters and a graphical interface for creating the mine grid. Also, it includes a utility referred to as a "Wizard" for automatically calculating coal pillars with a Mark-Bienawski pillar strength and another utility to assist with the development of "standard" gob properties. Recently, the LaModel program was interfaced with AutoCAD to allow mine plans and overburden contours

to be automatically imported into the corresponding seam and overburden grids. Also, the output from LaModel can be downloaded into AutoCAD and overlain on the mine map for enhanced analysis and graphical display. Within the last couple of years, new algorithms have been added to the program to help optimize subsidence calculations (Yang, 2016).

LAMODEL MATERIAL PROPERTY INPUT

Mine Grid: The LaModel simulation of the Marion Mine encompassed a fairly large area of the abandoned mine (see the "Mine Grid" area in Figure 1) in order to keep any edge effects from the boundary conditions from affecting the area of interest around the pipeline alignment. This model area was 2,500 ft wide and 2,000 ft high. A relatively small element size of 2 ft was used to best model the given entries and pillars. This smaller element size also facilitates using a thin lamination thickness for the overburden to optimize the subsidence angle-or-draw. With the 2 ft element width, the final grid size was 1250 X 1000 elements. The actual mine grid was automatically generated from the digitized Marion Mine.

Overburden Grid: For inputting the overburden information in order to accurately simulate the overburden stress on the seam, an overburden grid was developed that was 500 ft wider than the mine grid on all four sides. Therefore, the final overburden grid was 3500 ft wide by 2500 ft high and used 10 ft wide elements on a 350 X 300 element grid. The values for the overburden grid were then automatically generated from the AutoCAD topographic lines as shown in Figure 1. The result of the overburden grid generation process is the calculated overburden stress on the coal seam as plotted in Figure 2. In the plotted overburden stress, the lower stress areas under the east of the mine grid and higher stress area under the ridges to the south and north-west can easily be seen. Also, the variable stress under the pipeline can be seen.

Overburden, Gob and Coal Properties: The material properties for the Marion Mine model were generated using the LaModel subsidence optimization routines (Yang, 2016) to provide a subsidence factor (65%) and angle-of-draw consistent with the western Pennsylvania overburden and consistent with the 800 ft wide by 420 ft deep development panel that underlie the pipeline survey stations 01+00 to 10+00 alignment. This resulted in an average rock modulus of 3,000,000 psi and lamination thickness of 2.885 ft. for the overburden, and a final gob modulus of 21,547 psi for the strain-hardening gob model. For the initial model, intended to simulate the coal strength at the time of mining, a NIOSH recommended coal strength of 900 psi as implemented in the Mark-Bieniawski pillar strength formula by the LaModel coal wizard was used. To simulate the maximum potential subsidence that might occur over time after initial mining (assumedly due to coal, roof or floor degradation by oxidation, spalling, moisture, etc.), a 33% reduced coal strength (600 psi) was implemented into a separate "degraded mine" model.

POST-MINING MODEL RESULTS

Seam Convergence: Initially, the model with the 900 psi coal strength intended to simulate the mine conditions immediately after mining was run and analyzed in order to gain an understanding of the post-mining conditions. The first model output to be examined was the seam convergence

as shown in Figure 3. In this output, the overburden convergence over the development panel (under the pipeline stations 01+00 to 10+00) is less than 0.10 ft.

Pillar Safety Factors: Next, the safety factors of the remaining coal pillars were examined as shown in Figure 4. (Note: the scale of this safety factor plot was set to give details on the pillars with safety factors less than 4.0). This Figure shows that the pillars located under survey stations 01+00 to 10+00 are stable and lowest safety pillar factor is approximately 2.8.

Subsidence: The next output from the post-mining model to be examined was the subsidence at the pipeline location (see Figure 5). This subsidence is directly correlated to the seam convergence shown in Figure 3. Similar to the convergence, the negligible increase in surface subsidence due to development pillar mining is evident in Figure 5. Here the original predicted subsidence under the pipeline location can be seen. Subsidence under the survey stations 01+00 to 10+00 ranges from 0.02 ft to 0.04 ft.

The pipeline in the HDD sections ranges from approximately 450-500 ft above the seam, at the entry and exit hillside locations (23+90), to 240 ft above the seam under the survey stations 07+00 to 11+50. In LaModel, an average distance above the seam of 250 ft was used to calculate the subsidence values which are applied to the HDD pipeline. In the LaModel program, the overburden is modeled as a continuum. Therefore, the program does show the subsidence horizontally expand, within the angle-of-draw, and the magnitude decrease as the distance from the mine increases, but the program does not model any vertical dilation of the overburden, which minimizes the change in subsidence with depth.

To examine the details of the previous subsidence along the pipeline alignment, the subsidence above the seam has been interpolated from the output shown in Figure 5 directly to the pipeline coordinates, as shown in Figure 6. In this plot, the subsidence under the pipeline as it crosses over the development pillar areas is clearly visible.

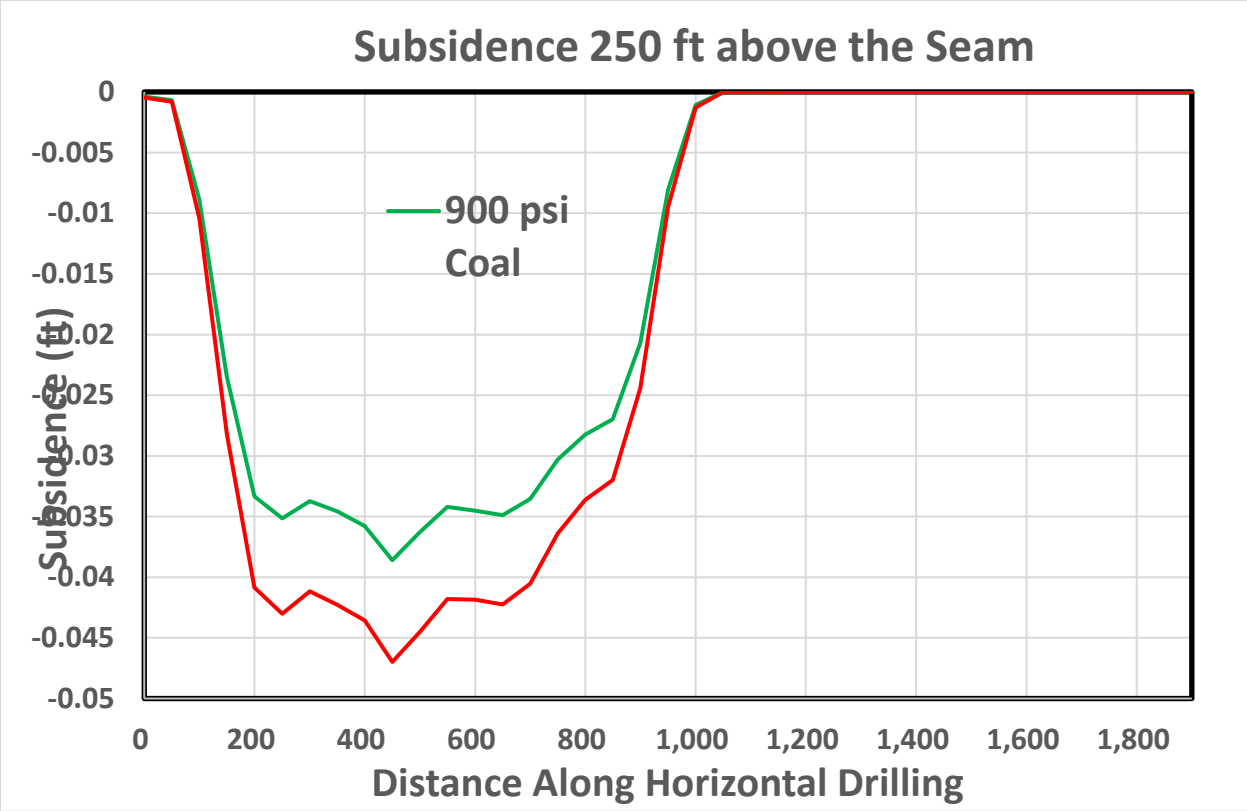


Figure 6. Subsidence prediction along the pipeline alignment at different coal strengths.

DEGRADED MINE MODEL RESULTS

As previously stated, the model with 900 psi coal strength (as shown in Figures 3, 4, and 5) was intended to simulate the mine conditions immediately after mining. The subsidence shown in Figure 5 and the 900 psi coal line in Figure 6 has assumedly already occurred immediately after mining. To simulate the maximum potential subsidence that might occur over time due to degradation of the coal, roof and/or floor by oxidation, spalling, moisture, etc., a model with a coal strength of 600 psi (a 33% strength reduction) was run, analyzed and compared with the post-mining 900 psi model.

Pillar Safety Factors: The first output to be closely examined from the degraded mine model was pillar safety factors as shown in Figure 7. This Figure shows that the pillars under the pipeline are stable with safety factors more than 2.0. Therefore, there is no expected pillar failure under the pipeline, even with the degraded coal strength.

Additional Subsidence: The additional subsidence at the pipeline level generated by degrading the coal strength is shown in Figures 8 and 9. It is clear from these figures, that any additional subsidence is very minimal, only ranging up to 0.008 ft (see Figures 8 and 9).

Strains: The strains associated with the predicted post-mining subsidence are also shown in Figure 9. The maximum strain value at the HDD location due to any additional subsidence is predicted to be only about 100 to 300 micro-strains (0.0001% to 0.0003%), and fluctuates continuously along the pipeline length.

The level of strain that the pipeline may experience is both a function of the ground movement and also a function of how tightly the pipeline is coupled to the ground movement. The pipeline is installed by the horizontal directional drill method which provides for an over-reamed bore hole. If the pipeline can easily slide, then areas of tension or compression in the ground can be reasonably canceled by sliding of the pipe between adjacent areas of the opposite strain. The exact response of the pipeline in the ground is to be analyzed in a separate report.

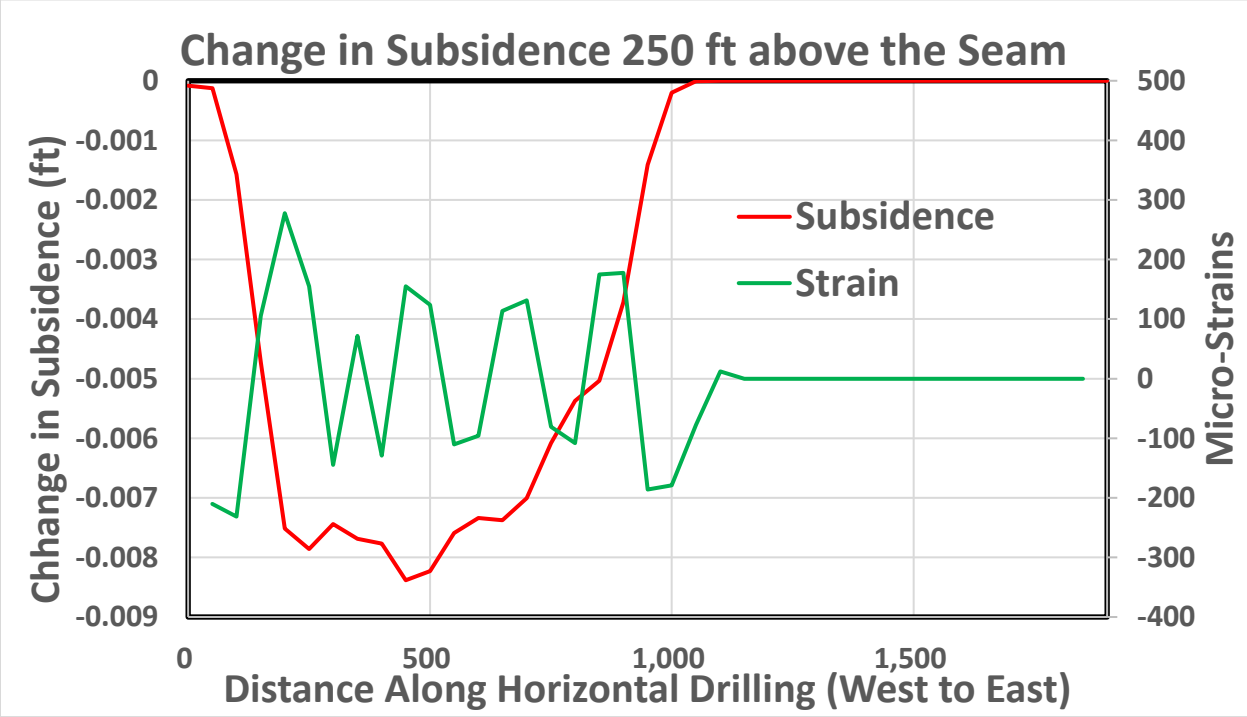


Figure 9. Predicted subsidence and associated strains (tension is negative).

REFERENCES

Heasley, K. A. (1998) Numerical Modeling of Coal Mines with a Laminated Displacement-Discontinuity Code, Ph.D. dissertation, Colorado School of Mines, 187 pp.

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

The Pennsylvania State University (2014) Pennsylvania Mine Map Atlas, http://www.minemaps.psu.edu/

Yang, J. (2016) Calibrating LaModel for Subsidence, M.S. thesis, West Virginia University, 93 pp.

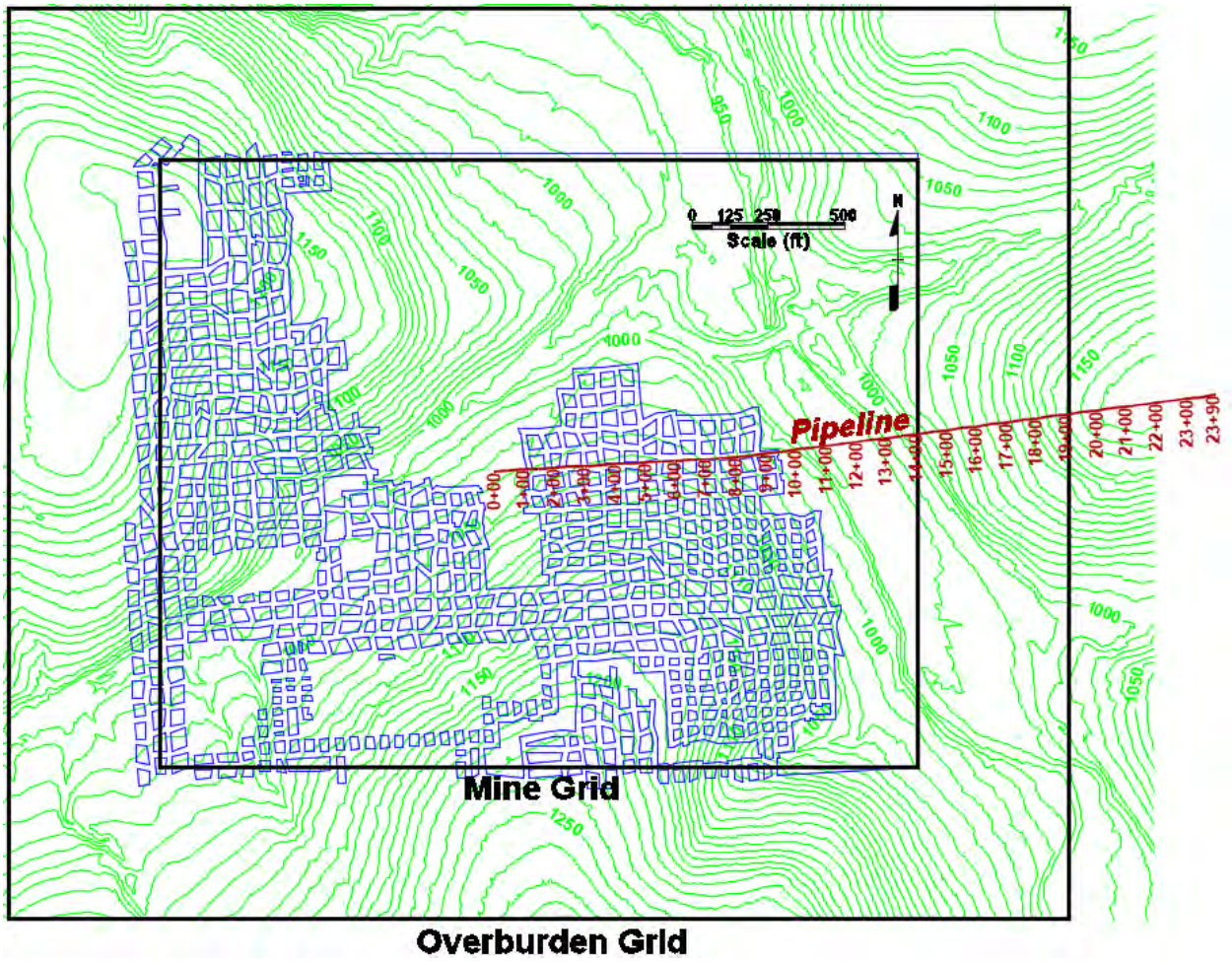


Figure 1. Map of mine and overlying pipeline

.

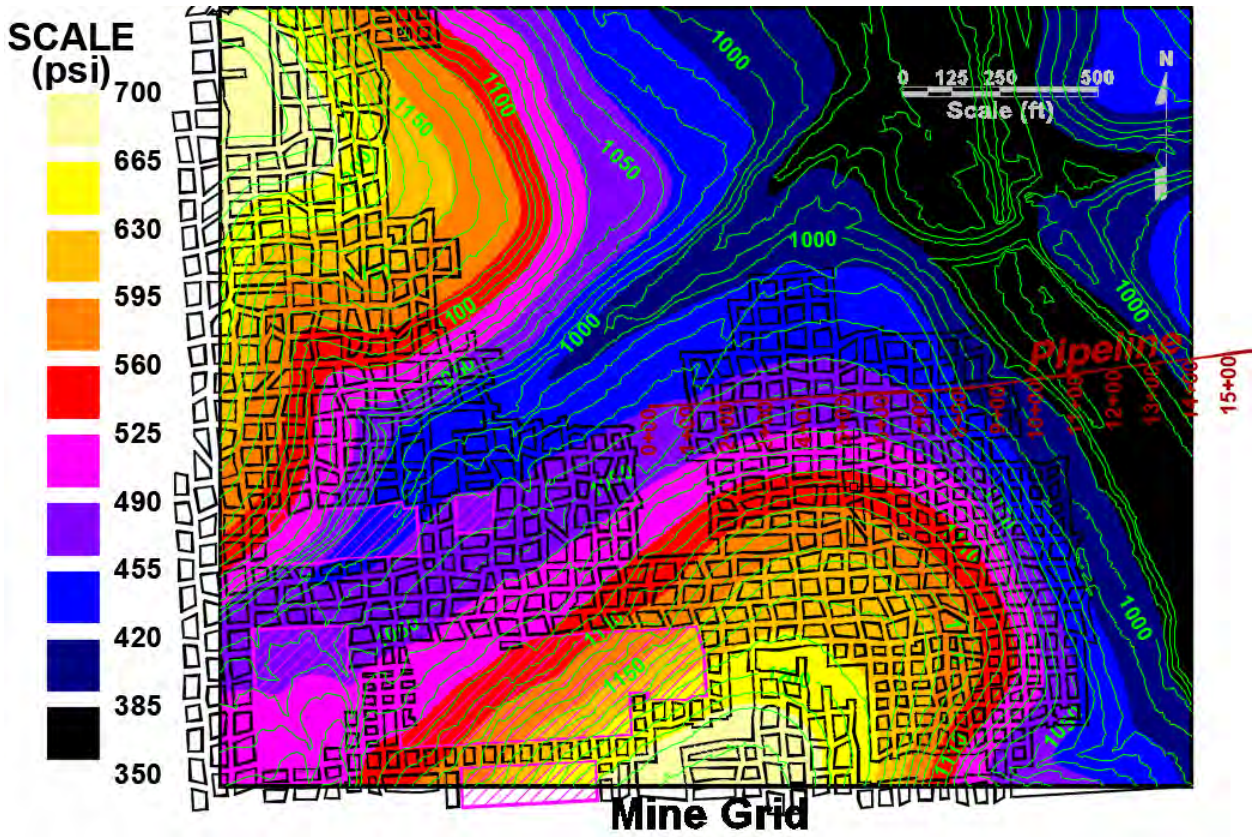


Figure 2. Overburden stress on the seam.

Figure 3. Seam convergence with 900 psi coal strength.

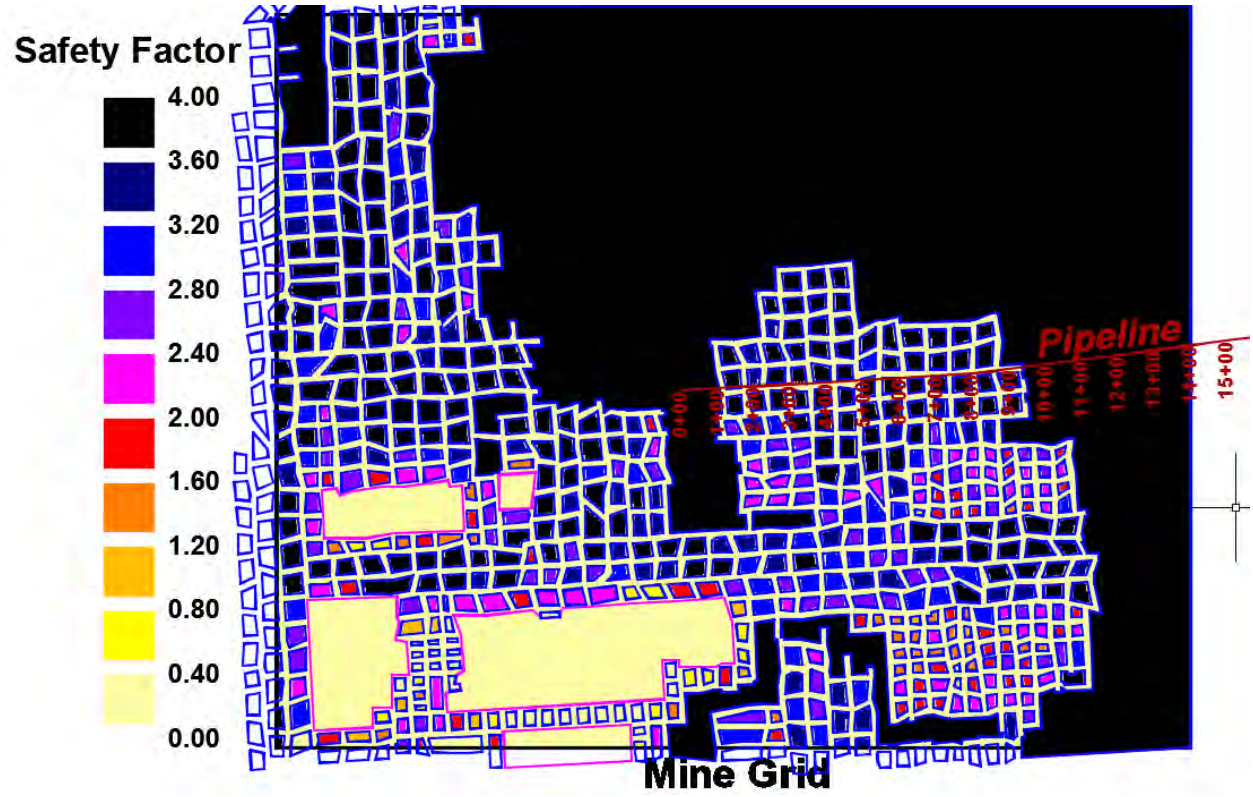


Figure 4. Pillar safety factors with 900 psi coal strength.

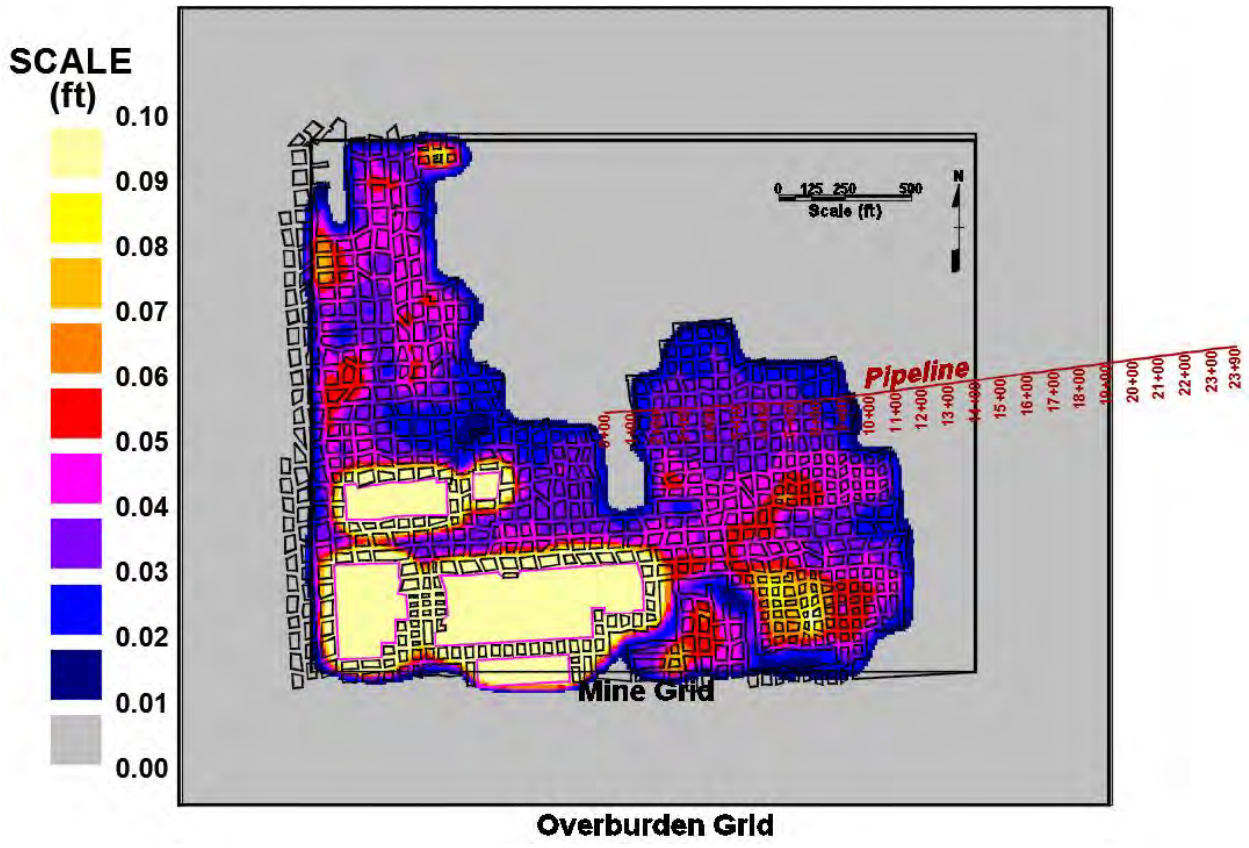


Figure 5. Subsidence at the pipeline for 900 psi coal strength.

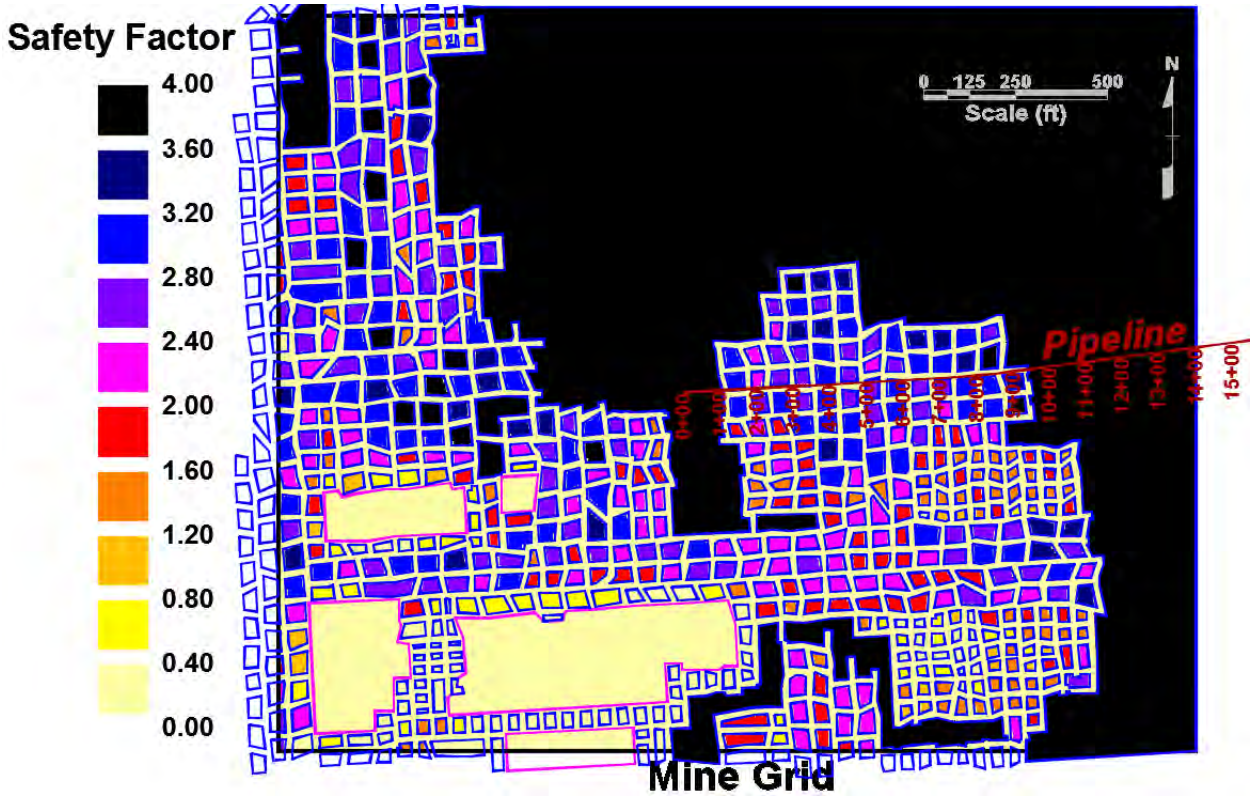


Figure 7. Pillar safety factor with 600 psi coal strength.

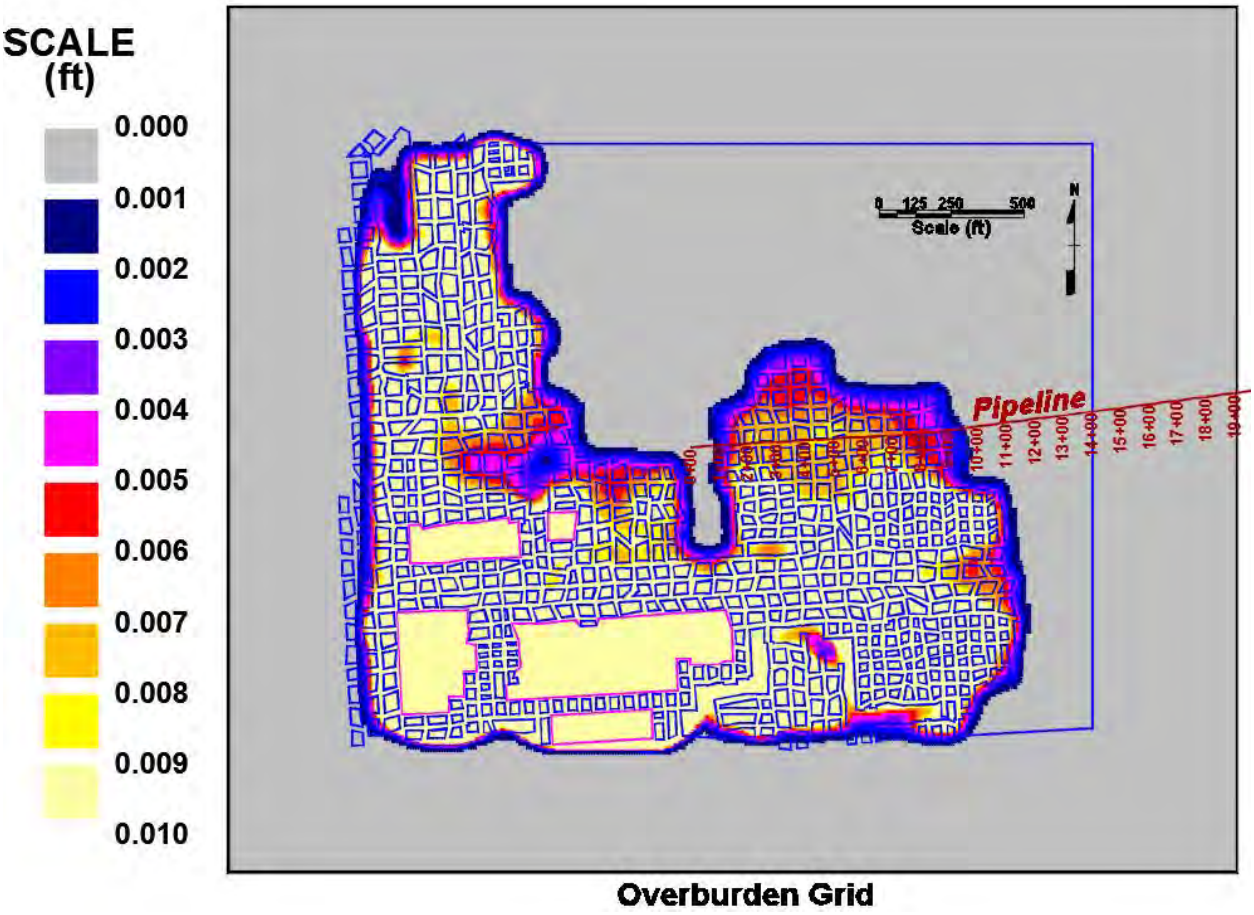


Figure 8. Increase in subsidence going from 900 psi coal to 600 psi coal.

HORIZONTAL DIRECTIONAL DRILL ANALYSIS
LIVERMORE ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E65-973
PA-WM2-0093.0000-RD-16
(SPLP HDD# S2-0016)

ATTACHMENT 3

LANDOWNER COMMUNICATIONS

SUNOCO PIPELINE
An ENERGY TRANSFER Partnership

P. O. Box 2218
Altoona, PA 16602

February 26, 2018

BY CERTIFIED AND FIRST CLASS MAIL
[redacted]

Re: Mariner East 2 – Pennsylvania Pipeline Project
Horizontal Directional Drilling Construction Notification
and Offer of Alternative Temporary Water Supply

To whom it may concern:

Previously, Sunoco Pipeline L.P. ("SPLP") wrote to inform you that certain construction activity known as Horizontal Directional Drilling ("HDD") for Mariner East 2, also known as the Pennsylvania Pipeline Project, is located within 450 feet of your property boundary. In that letter, SPLP offered private water supply/well testing at SPLP's expense if you have a private water supply/well located within 450 feet of the HDD alignments. If you have not yet requested testing of your qualifying private water supply/well, but now would like SPLP to have your private water supply/well tested, please contact the Sunoco representative for your area by calling Amy Abramowich at (814) 204-0450.

In addition, as part of this construction activity, SPLP is offering landowners with a private water supply/well located within 450 feet of the HDD alignments to be connected to an alternative temporary water supply, such as a water buffalo, that will be installed and maintained at SPLP's expense for the entire period of HDD operations.

If you would like to be connected to an alternative temporary water supply, please contact the Sunoco representative for your area by calling Amy Abramowich at (814) 204-0450.

Thank you for your cooperation.

Mark McConnell
Land Project Manager
Representing Sunoco Pipeline L.P.
Office: (814) 204-0450

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SUNOCO PIPELINE
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February 26, 2018

BY CERTIFIED AND FIRST CLASS MAIL
[redacted]

Re: Mariner East 2 – Pennsylvania Pipeline Project
Horizontal Directional Drilling Construction Notification
and Offer of Alternative Temporary Water Supply

Dear [redacted]

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Land Project Manager
Representing Sunoco Pipeline L.P.
Office: (814) 204-0450

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Total Postage & Fees:	**$3.920**

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X

B. Received By: *(Printed Name)*

C. Date of Delivery

1. Article Addressed to:

D. Is delivery address different from item 1? ☐ Yes
If YES, enter delivery address below: ☐ No

3. Service Type

2. Article Number *(Transfer from service label)*

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(Uses Return Receipt Card)
Instructions
1. Apply address label above to the back of this card.
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SUNOCO PIPELINE
An ENERGY TRANSFER Partnership

P. O. Box 2218
Altoona, PA 16602

February 26, 2018

BY CERTIFIED AND FIRST CLASS MAIL
[redacted]

Re: Mariner East 2 – Pennsylvania Pipeline Project
Horizontal Directional Drilling Construction Notification
and Offer of Alternative Temporary Water Supply

Dear [redacted]

Previously, Sunoco Pipeline L.P. ("SPLP") wrote to inform you that certain construction activity known as Horizontal Directional Drilling ("HDD") for Mariner East 2, also known as the Pennsylvania Pipeline Project, is located within 450 feet of your property boundary. In that letter, SPLP offered private water supply/well testing at SPLP's expense if you have a private water supply/well located within 450 feet of the HDD alignments. If you have not yet requested testing of your qualifying private water supply/well, but now would like SPLP to have your private water supply/well tested, please contact the Sunoco representative for your area by calling Amy Abramowich at (814) 204-0450.

In addition, as part of this construction activity, SPLP is offering landowners with a private water supply/well located within 450 feet of the HDD alignments to be connected to an alternative temporary water supply, such as a water buffalo, that will be installed and maintained at SPLP's expense for the entire period of HDD operations.

If you would like to be connected to an alternative temporary water supply, please contact the Sunoco representative for your area by calling Amy Abramowich at (814) 204-0450.

Thank you for your cooperation.

Mark McConnell
Land Project Manager
Representing Sunoco Pipeline L.P.
Office: (814) 204-0450

Each sheet can be used for one Certified Mail piece, which can be sent without Physical Return Receipt Service (Option A) or with Physical Return Receipt Service (Option B).

CERTIFIED MAIL

Percheron Field Services
Representing Sunoco Logistics
P.O. Box 2218
Altoona PA 16602

9407 1118 9956 0586 9222 77

$3.920
US POSTAGE
FIRST-CLASS
FROM 16652
02/24/2018
stamps endicia

0625000876622O

PS Form 3800 6/02

A Certified Mail
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(No Return Receipt Card)
Instructions

1. Apply this label to the TOP EDGE of the mailpiece.
2. Apply address label below to the CENTER of the mailpiece.
3. Peel the Certified Mail label below and fold it over your envelope, just above the postage so that it covers the existing Certified Mail marking.

Delivery Address when used with A or Return Address when used with B

Top of the page

U.S. Postal Service
Certified Mail Receipt

OUTBOUND TRACKING NUMBER
9407 1118 9956 0586 9222 77

FEES

Postage per piece	$0.470
Certified Fee	$3.450
Total Postage & Fees:	**$3.920**

ARTICLE ADDRESS TO:

[redacted]

Postmark Here

CERTIFIED MAIL

CERTIFIED MAIL

← Fold and Tear →

SENDER: COMPLETE THIS SECTION

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- Attach this card to the back of the mailpiece, or on the front if space permits.

1. Article Addressed to:

2. Article Number *(Transfer from service label)*

COMPLETE THIS SECTION ON DELIVERY

A. Signature: *(☐ Addressee or ☐ Agent)*

X

B. Received By: *(Printed Name)*

C. Date of Delivery

D. Is delivery address different from item 1? ☐ Yes
If YES, enter delivery address below: ☐ No

3. Service Type

CERTIFIED MAIL

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(Uses Return Receipt Card)
Instructions

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★ USA CMF - 134.04/17 ★

SUNOCO PIPELINE
An ENERGY TRANSFER Partnership

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Altoona PA 16602

9407 1118 9956 0586 9227 89

$3.920
US POSTAGE
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FROM 16652
02/24/2018
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PS Form 3800 6/02

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Certified Mail Receipt

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9407 1118 9956 0586 9227 89

FEES

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Certified Fee	$3.450
Total Postage & Fees:	$3.920

ARTICLE ADDRESS TO:

[redacted]

[redacted] Here

[redacted]

Delivery Address when used with A or Return Address when used with B

CERTIFIED MAIL

CERTIFIED MAIL

← Fold and Tear →

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3. Service Type

2. Article Number *(Transfer from service label)*

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(Uses Return Receipt Card)
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3. Peel the Certified Mail label above and fold it over your envelope, just above the postage so that it covers the existing Certified Mail marking.

Certified Mail Labels (3000-3999)
Covered by and/or for use with U.S. Patents 6,244,763; 6,868,406; 7,216,110; 7,236,956; 7,236,970; 7,490,065; 7,567,940; 7,613,639; 7,743,043; 7,882,094; 8,027,926; 8,027,927; 8,027,935; 8,041,644; 8,046,823; 8,103,647; 8,195,579; 8,301,572; 8,392,391; 8,498,943 and 8,843,464.

CERTIFIED MAIL

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★ 1-UP Laser Form ★
★ USA CMF - 134 04/17 ★

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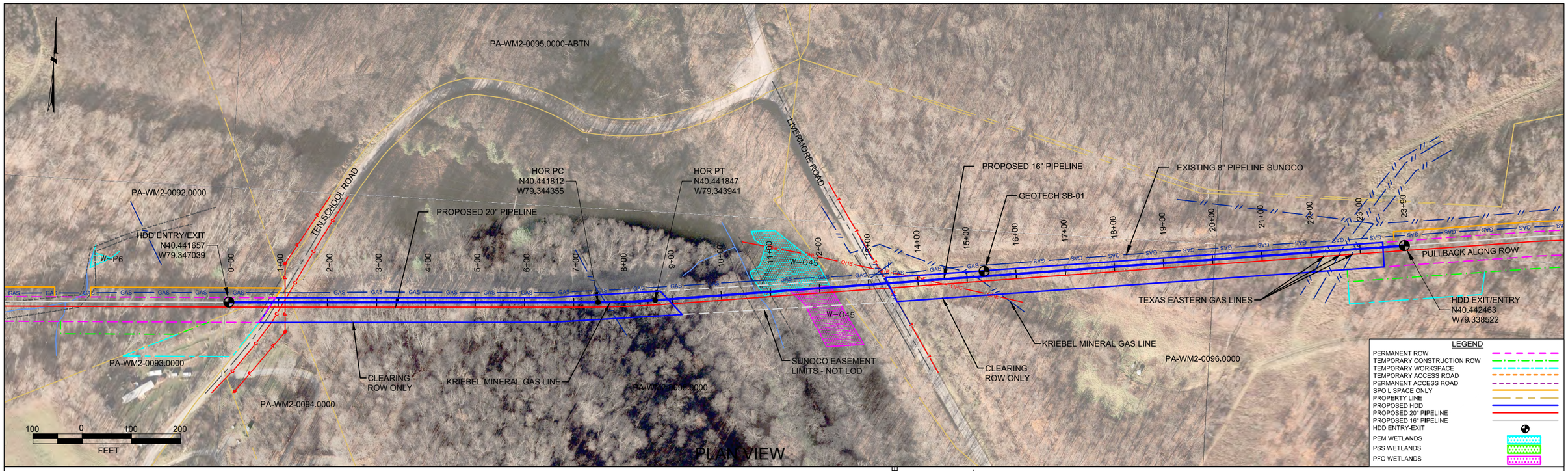
HORIZONTAL DIRECTIONAL DRILL ANALYSIS
LIVERMORE ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E65-973
PA-WM2-0093.0000-RD-16
(SPLP HDD# S2-0016)

ATTACHMENT 4

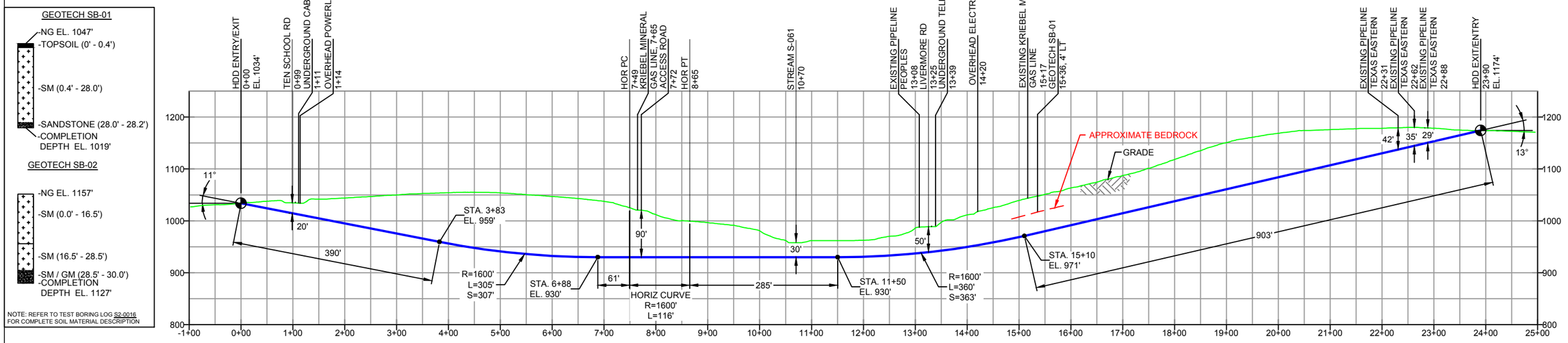
ORIGINAL PERMITTED; 20-INCH IR, AND

REVISED 16-INCH HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES



PROFILE VIEW

WESTMORELAND COUNTY, PENNSYLVANIA - DERRY TOWNSHIP
S2-0016-16



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):2390'
   HDD PIPE LENGTH (S=):2425'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.

Figure 1. Original Permitted 16-Inch HDD Plan and Profile

NOTES

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

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
4	REVISED PROFILE WITH 2017 LIDAR	MRS	03/20/17	RMB	03/20/17	CAG	03/20/17
3	DESIGN CHANGE - RELOCATED HORIZONTAL CURVE AND DRILL DEPTH	MRS	11/01/16	RMB	11/01/16	AAW	11/01/16
2	REVISED PER ENGINEERING COMMENTS	MRS	08/26/16	RMB	08/26/16	AAW	08/26/16
1	ADDED "CLEARING ROW ONLY" ANNOTATION	MRS	03/24/16	RMB	03/24/16	AAW	03/24/16
0	ISSUED FOR CONSTRUCTION	MRS	12/21/15	RMB	12/21/15	AAW	12/21/15

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
LIVERMORE ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200'

DWG. NO: PA-WM2-0093.0000-RD-16

PA-WM2-0095.0000-ABTN

PA-WM2-0092.0000

PA-WM2-0094.0000

PA-WM2-0093.0000

PA-WM2-0096.0000

TEN SCHOOL ROAD

LIVERMORE ROAD

HDD ENTRY/EXIT
16" REDESIGN
N40.441657
W79.347039

W-P6

S-P10

P12

S-P13

HDD ENTRY/EXIT 16" PERMITTED
N40.441657
W79.347039

20" HDD ENTRY ASBUILT
N40.441633
W79.346978

HOR PC
N40.441812
W79.344355

HOR PT
N40.441847
W79.343941

S-062

S-061

W-045

W-045

INADVERTENT RETURN (IR)-1
N40.442130
W79.343050

16" PERMITTED PIPELINE

GEOTECH SB-01

EXISTING 8" PIPELINE SUNOCO

HDD ENTRY/EXIT 16" PERMITTED
N40.442463
W79.338521

HDD EXIT/ENTRY
16" REDESIGN
N40.442463
W79.338522

PULLBACK ALONG ROW

TEXAS EASTERN GAS LINES

20" HDD EXIT ASBUILT
N40.442425
W79.338583

16" PROPOSED HDD REDESIGN

KRIEBEL MINERAL GAS LINE

CLEARING
ROW ONLY

KRIEBEL MINERAL GAS LINE

20" ASBUILT PIPELINE

SUNOCO EASEMENT
LIMITS - NOT LOD

CLEARING
ROW ONLY

0 100 200
FEET

PLAN VIEW

LEGEND

- PERMANENT ROW
- TEMPORARY CONSTRUCTION ROW
- TEMPORARY WORKSPACE
- TEMPORARY ACCESS ROAD
- PERMANENT ACCESS ROAD
- SPOIL SPACE ONLY
- PROPERTY LINE
- PROPOSED HDD
- PROPOSED 20" PIPELINE
- PROPOSED 16" PIPELINE
- HDD ENTRY-EXIT
- PEM WETLANDS
- PSS WETLANDS
- PFO WETLANDS

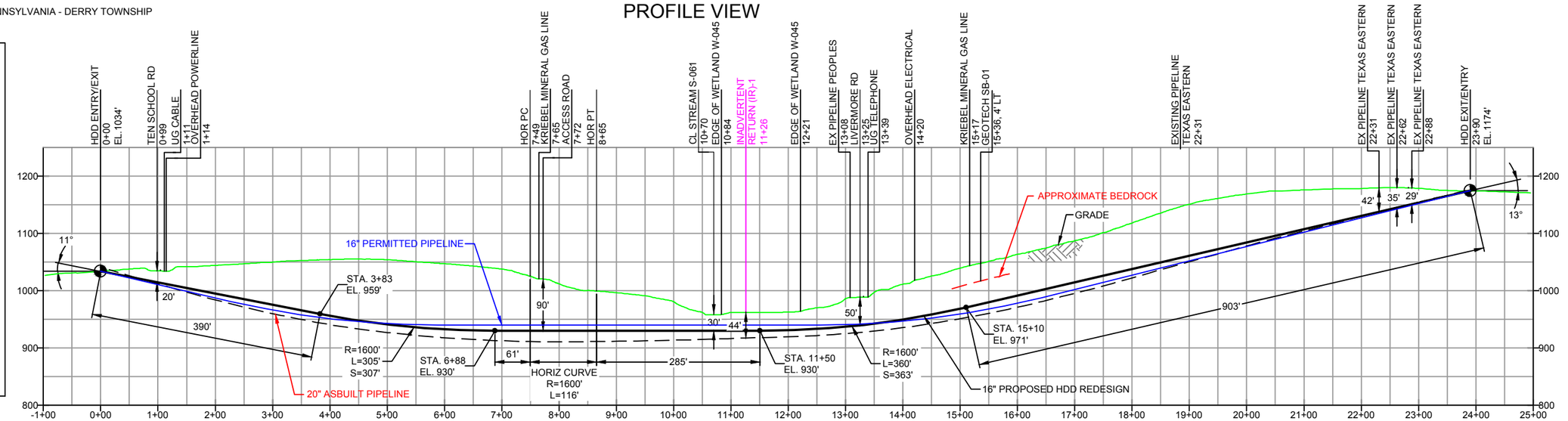
WESTMORELAND COUNTY, PENNSYLVANIA - DERRY TOWNSHIP
S2-0016-16

PROFILE VIEW

GEOTECH SB-01
-NG EL. 1047'
-TOPSOIL (0' - 0.4')
-SM (0.4' - 28.0')
-SANDSTONE (28.0' - 28.2')
-COMPLETION
DEPTH EL. 1019'

GEOTECH SB-02
-NG EL. 1157'
-SM (0.0' - 16.5')
-SM (16.5' - 28.5')
-SM / GM (28.5' - 30.0')
-COMPLETION
DEPTH EL. 1127'

NOTE: REFER TO TEST BORING LOG S2-0016 FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:

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2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):2390'
   HDD PIPE LENGTH (S=):2425'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 2100 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 2625 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.

Figure 2. 20-inch Inadvertent Return HDD Plan and Profile

NOTES

1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
2. STATIONING IS BASED ON HORIZONTAL DISTANCES.
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REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-2.40	TO	ES-2.41	EROSION & SEDIMENT PLAN
SHEET 76	TO	SHEET 77	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	DESIGN CHANGE PER CLIENT REQUEST	MRS	05/21/18	RMB	05/21/18	CAG	05/21/18
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	MRS	05/18/16	RMB	05/18/16	AAW	05/18/16
EP		DLM	03/23/16	RMB	03/23/16	AAW	03/23/16
B	ADDED GEOTECH INFO	MRS	09/07/15	RMB	09/07/15	AAW	09/07/15
A	ISSUED FOR BID	MRS	08/31/15	RMB	08/31/15	AAW	03/24/15

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LIVERMORE ROAD
PENNSYLVANIA PIPELINE PROJECT

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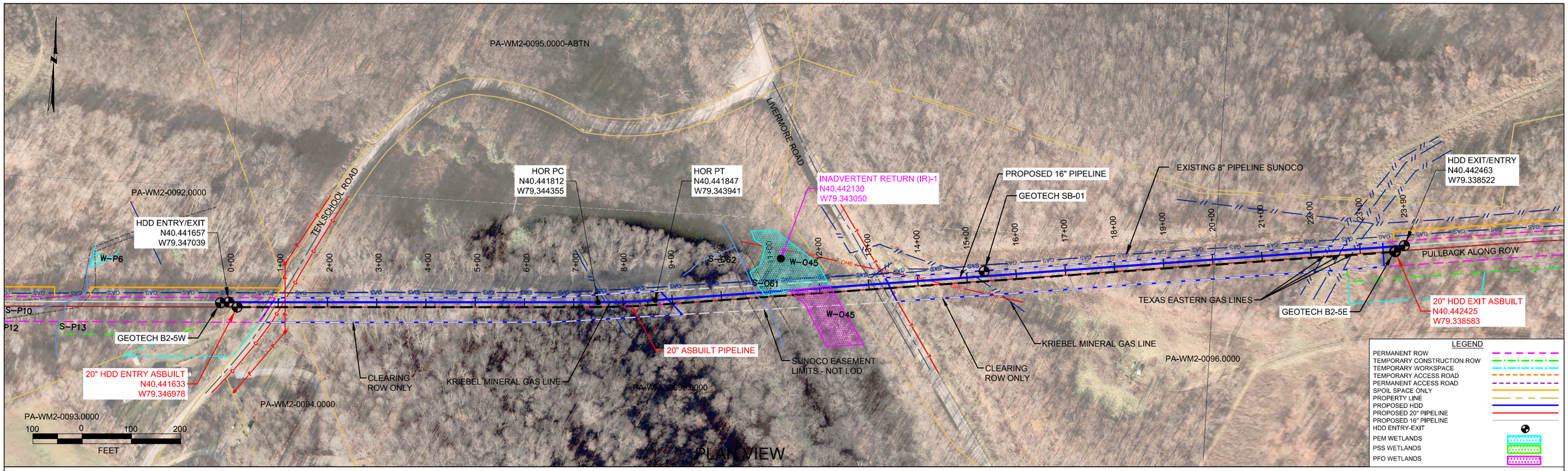
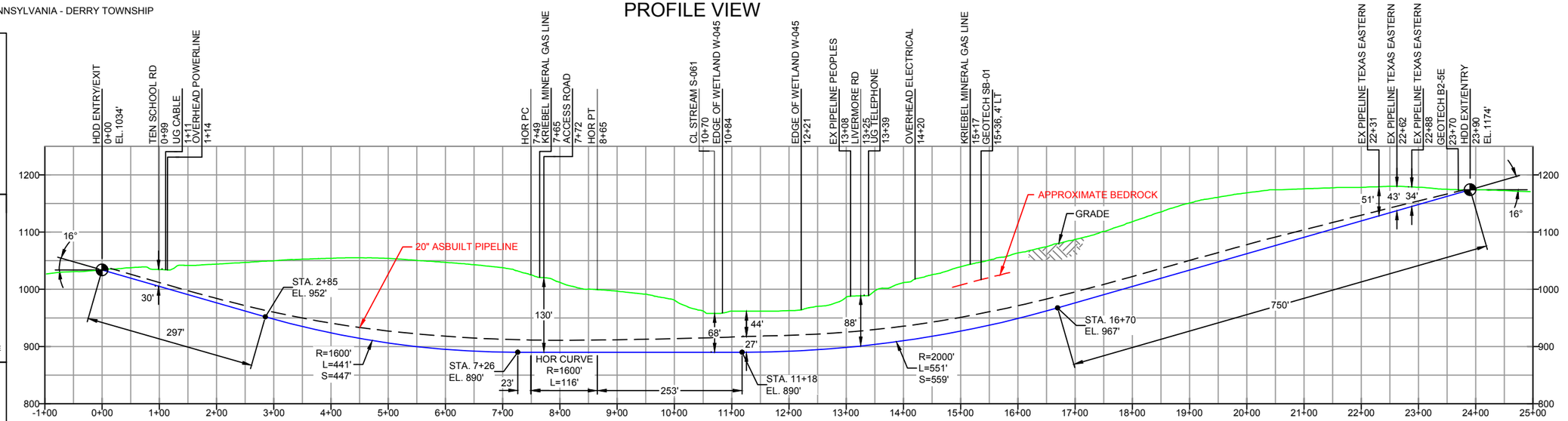
DWG. NO: PA-WM2-0093.0000-RD-16

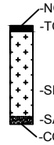


WESTMORELAND COUNTY, PENNSYLVANIA - DERRY TOWNSHIP
S2-0016-16

PROFILE VIEW



GEOTECH SB-01



NOTE: REFER TO TEST BORING LOG S2-0016 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B2-5W

NOTE: REFER TO TEST BORING LOG B2-5W TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B2-5E

NOTE: REFER TO TEST BORING LOG B2-5E TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

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Figure 3. Revised 16-Inch HDD Plan and Profile

NOTES

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

REF. DRAWING

ES-2.40	TO	ES-2.41	EROSION & SEDIMENT PLAN	
SHEET 76	TO	SHEET 77	AERIAL SITE PLAN	
DWG NO		DWG NO	DESCRIPTION	

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP5	ADDED INADVERTENT RETURN INFO	MRS	01/22/19	RMB	01/22/19	CAG	01/22/19
EP4	ADDED GEOTECH INFO	MRS	11/15/18	RMB	11/15/18	CAG	11/15/18
EP3	INCREASED DRILL DEPTH, UPDATED NOTE 5 AND 10 PER INCREASED 16" MOP - DESIGN CHANGE PER CLIENT	MRS	05/21/18	RMB	05/21/18	CAG	05/21/18
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	MRS	05/18/16	RMB	05/18/16	AAW	05/18/16
EP		DLM	03/23/16	RMB	03/23/16	AAW	03/23/16

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
LIVERMORE ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200'

DWG. NO: PA-WM2-0093.0000-RD-16

HORIZONTAL DIRECTIONAL DRILL ANALYSIS
LIVERMORE ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E65-973
PA-WM2-0093.0000-RD-16
(SPLP HDD# S2-0016)

This reanalysis of the horizontal directional drill (HDD) installation of a 16-inch diameter pipeline that traverses Livermore Road in Derry Township, Westmoreland County, Pennsylvania is in accordance with the Stipulated Order issued under Environmental Hearing Board Docket No. 2017-009-L for HDDs listed on Exhibit 3 of the Stipulated Order. This HDD is number 2 on the list of HDDs included on Exhibit 3 of the Order.

The 20-inch HDD was initiated before the temporary injunction issued by the Pennsylvania Department of Environmental Protection (PADEP) Environmental Hearing Board on July 25, 2017. This HDD had inadvertent returns (IRs) on the installation of the first pipe (20-inch) and therefore, the installation of the second pipe (16-inch) requires reanalysis. The IRs associated with the HDD of the 20-inch pipe were remediated and the HDD for the 20-inch pipe was completed.

The 16-inch pipe HDD is referred to herein as HDD S2-0016.

PIPE INFORMATION

16-Inch: 0.438 wall thickness; X-70

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

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 16-INCH

- Horizontal length: 2,390 feet (ft)
- Entry/Exit angle: 13-14 degrees
- Maximum depth of cover: 105 ft
- Maximum depth of cover under Spruce Run (stream S-O61): 20 ft
- Maximum depth of cover under wetland O45: 25 ft
- Pipe design radius: 1,600 ft

ROOT CAUSE ANALYSIS FOR THE 20-INCH PIPE INSTALLATION IR

The occurrence of the IR event during the HDD installation of the 20-inch pipeline was due to the shallow depth of the profile under the stream and adjacent wetland, and lack of competent bedrock above the drill profile to the land surface. The thin and large proportion of unconsolidated overburden and possible zone of bedrock fracture concentration were all potential contributing factors to the IRs that occurred during installation of the 20-inch pipeline. Lastly, the geometry of the 20-inch HDD profile, with elevated ground to the west and east of S-061 and wetland W-045, would result in increased annular pressure on the drilling fluid at this low spot in the profile, which could have contributed to the IRs.

GEOLOGIC AND HYDROGEOLOGIC ANALYSIS

The bedrock underlying the profile for HDD S2-0016-16 belongs to the Pennsylvanian age Casselman and Glenshaw Formations that together form the Conemaugh Group. The Group is stratigraphically defined as the rocks lying between the Upper Freeport coal (below) and the Pittsburgh coal (above). The bedrock underlying hilltops and upper parts of the hillsides is part of the Casselman Formation and bedrock underlying the lower parts of the hillsides and flood plain to Spruce Run are part of the Glenshaw Formation.

In general, the Glenshaw and Casselman Formations are distinguished by the marine beds of the Glenshaw Formation versus the non-marine beds of the Casselman Formation (Edmunds, et. al, 1999). The Casselman Formation is characterized by a few locally persistent red beds, calcareous claystone, freshwater limestones, thin sandstones, shales, siltstones, and generally thin, economically insignificant coal beds. The Glenshaw Formation consists of repeated sequences of sandstone, siltstone, shale, claystone (including red beds), limestone, and coal. It contains four major marine zones that are, from lowest to highest in stratigraphic position, the Brush Creek, Pine Creek, Woods Run, and Ames.

Karst geology is not present at this HDD location; therefore, the use of geophysics assessments was considered but not conducted because the results from these types of assessments would provide no data to assist in the redesign of the 16-inch HDD.

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

Coal Mining and Subsidence

TetraTech mine engineers complete a study and subsidence analysis of the coal mining below the proposed HDD. A copy of the TetraTech Subsidence Report is provided in Attachment 2. The Upper Freeport coal was mined under the profile west of Spruce Run. In the area of the HDD, the bedrock is dipping gently westt at approximately 2.1 degrees.

A review of published mining and geological data indicate that historic deep mining of the Upper Freeport coal occurred in the vicinity of HDD S2-0016-16. HDD S2-0016-16 is within the limits of a former room and pillar Upper Freeport coal mine, a section of the Tunnelton Mining Company's Marion Mine. Base of Upper Freeport coal elevations below the HDD S2-0016-16 profile range from approximately 631 ft above mean sea level (amsl) at the western entry/exit to 646 ft amsl where the mine terminates at approximately HDD Station 9+50. The lowest elevation of HDD S2-0016-16 on the revised profile is 890 ft amsl from Station 7+26 to Station 11+18, which is approximately 244 feet above the highest floor elevation of the mine along the HDD profile, within the limits of the mine footprint. The coal is approximately 3.5-feet thick within the mine therefore the shortest distance from the mine roof to the revised profile is approximately 240 feet.

Kendorksi (2006) delineated estimated extents of four zones of fracturing above deep mines, based on the thickness of extracted coal. From bottom to top these include the Caved Zone (with extensive fracturing and sizeable voids), Fracture Zone (fracturing, without extensive dislocation of rocks or voids), Dilation Zone (small fractures), and the Constrained Zone (with no rock fracturing related to mine subsidence). The maximum estimated extent of the Dilation Zone above the Marion Mine is 210 feet and the lowest part of the revised profile within the limits of the mine footprint is 240 feet above the mine therefore the part of the profile that is within limits of mine's footprint is entirely in the Constrained Zone.

Mine Pool

The risk of a Loss of Circulation (LOC) creating a new mine pool discharge is very small given the standard procedures associated with LOCs implemented by the ME II HDD program in the summer of 2018. The standard procedures call for immediate suspension of drilling activity and assessment at the first signs of fluid loss while drilling. This greatly diminishes the potential volume of fluid that can be lost to mine workings and any associated adverse increase in the pressure head on a mine pool. Based upon a review by the project geologists, a mine outcrop where a discharge might occur at the surface does not exist within the footprint of the workings. Given the extent of the mine workings, volume of natural groundwater recharge being received by the workings, associated natural groundwater pressure heads on the workings, position of the HDD profile within the mine workings, and standard ME II LOC

procedures; the risk of an LOC creating enough to change the current mine hydrology to create a new mine pool discharge is extremely small.

Mine Subsidence

Historic mining information, the elevations of the revised HDD-0016-16 profile, and subsidence and stress modelling were used by Tetra Tech (November 2018) to evaluate potential future stress on the installed pipe due to future subsidence of the abandoned Tunnelton Mining Company's Marion Mine. The available information was sufficient for Tetra Tech and it's subconsultants to perform the analysis therefore geophysical studies were not required.

Based upon the data obtained from the subsidence analysis, and the results of a Finite Elements Analysis (pipe stress), the pipeline engineers has concluded that the potential stress of further subsidence will not exceed allowable limits as established by ASME B31.4-2012, (Pipeline Transportation Systems for Liquids and Slurries, The American Society of Mechanical Engineers, New York, 2012). The findings by the pipeline engineers is included within the TetraTech report provided in Attachment 2.

HYDROGEOLOGY, GROUND WATER, AND WELL PRODUCTION ZONES

Groundwater in the bedrock aquifer below the land surface at HDD S2-0016-16 is stored and moves within a network of rock fractures and bedding plane partings. Regional systematic joints are oriented northwest and west-northwest and may represent preferred pathways for groundwater flow. Based on data contained in the geotechnical borings for HDD S2-0016-16, groundwater was encountered at approximately 49.5 ft bgs in boring B2-5W near the west entry/exit and at 126 ft bgs in B2-5E at the east entry/exit. The groundwater table is expected to be near the surface over the area of wetland W-045 in the flood plain of Spruce Run.

The Pennsylvania Groundwater Information System (PaGWIS) reported two wells within a half mile of the HDD S2-0016-16 alignment. PA Well ID 426067 is a residential well drilled in year 2007 and located approximately 200 feet north of the HDD, near the intersection of Ten School Road and Livermore Road. The well is listed at 245 feet deep and the static water level at time of installation was 35 ft bgs. PA Well ID 648050 is a residential well located approximately 1,115 feet southwest of the west entry/exit for a home along Ten School Road that was drilled in year 2010. The well is listed at 265 feet deep and the static water level at time of installation was 55 ft bgs.

SPLP performed a survey of land owners within 450 feet of the ROW for the revised profile and three land owners along Ten School Road responded positively to an offer to have their residential wells tested. Two land owners reported well depths at 230 feet and at 320 feet, but no water level measurements could be obtained given the construction of the wells. No public water supplies were identified within 450-feet of the alignment.

Pre and post-construction water quality sampling results for three residential wells demonstrate that none were impacted by the installation of the 20-inch line therefore the risk of impacting any of these supplies while installing the 16-inch line is small. These wells are located south of the west entry/exit and western part of the profile where the profile is shallow. By comparison the depths of the two of the three wells are large at 230 and 320 ft bgs, greatly reducing any risk of a water quality impact from the HDD.

Published median well yields for the Conemaugh Group range from 1 to 357 gallons per minute (gpm) with the higher yields coming from wells in sandstones (Newport, 1973). The well yields estimated at the time of well installation for the two wells within 0.5 miles of the HDD, reported in the PaGWIS data base, were relatively low at 4 and 5 gpm.

HORIZONTAL DIRECTIONAL DRILL ANALYSIS
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Attachment 1 provides an extensive discussion on the hydrogeology, and results of the geotechnical investigations performed at this location.

INADVERTENT RETURN (IR) DISCUSSION

Pilot drilling for the ME II 20-inch line at HDD-0016 began on 4/29/17 drilling west to east. Operations continued without incident until 5/5/17 when the pilot reached 1,061 ft (under Spruce Run) and a loss of returns was noted. The next day the driller was tripping in to the cutting face and advanced 10 feet when an IR occurred in wetland W-045, due north of Spruce Run. A containment and pumping system was quickly established. Drilling fluids captured in the containment were pumped up the slope to Livermore Road where vac trucks were staged to receive and transport fluids back to the HDD recycling unit at the west entry/exit along Ten School Road. Until the pulling of the 20-inch pipe, the IR remained active and was managed in this manner. On 5/24/18 the 20-inch reamer exited on the east side and the crew began tripping out drill rod to the west side in preparation for starting the 30-inch ream. At that time a second IR occurred in the same general area along the north bank of Spruce Run where approximately 30 gallons of drilling fluid surfaced and entered Spruce Run. Another IR surfaced due northwest of the first IR on the flood plain of wetland W-045. The new IRs were contained and cleaned up. Drilling fluids were contained along the stream bank and managed by pumping back into the initial IR containment. Drilling fluids coating the stream bottom were cleaned up by agitating the stream bottom and vacuuming the turbid fluid. The new IRs were only active for a short time and all IR activity was returned to the original IR containment and removed.

As stated above, the occurrence of the IR event during the HDD installation of the 20-inch pipeline was due to the shallow depth of the profile under the stream and adjacent wetland, and lack of competent bedrock above the drill profile to the land surface. The thin and large proportion of unconsolidated overburden and possible zone of bedrock fracture concentration were all potential contributing factors to the IRs that occurred during installation of the 20-inch pipeline. Lastly, the geometry of the 20-inch HDD profile, with elevated ground to the west and east of S-061 and wetland w-045, would result in increased annular pressure on the drilling fluid at this low spot in the profile, which could have contributed to the IRs.

ADJACENT FEATURES ANALYSIS

The crossing of Livermore Road is located in Westmoreland County, approximately 4.4 miles west/northwest of the community of Blairsville. The HDD crosses under Livermore Road from approximately 460 ft south to intersection of Livermore Road and Number 10 Road, in Derry Township.

This pipeline route follows parallel to an existing SPLP pipeline and is set under one stream, one wetland, and a portion occurs within the United States Army Corps of Engineers (USACE) Conemaugh Recreation Area. Wetland O45 is not designated as a high quality or exceptional value wetland; however, a portion of it is forested wetland. Stream S-O61, Spruce Run, is designated a high quality coldwater fishery in accordance with Chapter 93. This HDD avoids surficial impacts to wetland O45, stream S-O61 (Spruce Run), and the associated floodway of stream S-O61. Additionally, this HDD avoids surficial impacts to Number 10 Road, the floodway of stream S-O62, a Federal Emergency Management Agency (FEMA) 100-year floodplain (Chapter 106 area) located west of Livermore Road, Livermore Road, forested woodlands, an overhead powerline, and existing underground utilities (e.g., cable line, gas lines, telephone line, and electric lines), parallel to and crossing perpendicular to the easement.

SPLP performed a survey of land owners within 450 feet of the ROW for the revised profile and three land owners along Ten School Road responded positively to an offer to have their residential wells tested. These wells are located south of the west entry/exit and western part of the profile where the profile is shallow. Pre and post-construction water quality sampling results for these three residential wells

demonstrate that none were impacted by the installation of the 20-inch line therefore the risk of impacting any of these supplies while installing the 16-inch line is small. By comparison the depths of the two of the three wells are large at 230 and 320 ft bgs., greatly reducing any risk of a water quality impact from the HDD. The depth of the third well is unknown.

SPLP does not believe any potential private water wells are of concern for this HDD. A copy of SPLP's landowner communications is provided with this Reevaluation Report as Attachment 3.

ALTERNATIVES ANALYSIS

The HDD as permitted is an alternative plan of installation to a conventional open trench construction plan. Using the HDD method avoids direct impacts to two streams and their associated floodways, a forested wetland, associated forested woodlands and riparian habitats, a FEMA 100-year floodplain (Chapter 106 area), USACE public lands, an overhead powerline, and existing underground utilities. Alteration of the current permitted route and plans for installation would require major modifications of the state Chapter 102 and Chapter 105 permits, and authorization issued by the USACE.

Open-cut and Conventional Bore Analysis

The pipeline route as currently permitted follows an existing utility easement. SPLP specifications require a minimum of 48-inches of cover over the installed pipelines below ground and below the bottom of watercourses. To meet this cover requirement, construction through the one stream and one wetland at this location would require a minimum authorized open cut work space 75 ft in width to accommodate the 16-inch pipeline, allowing for the pipeline to be installed with sufficient separation for integrity management. The assessed area of impact by this open cut plan would directly affect 1,702 square feet of state water bottoms, 0.056 acres of forested wetlands, 0.149 acres of emergent wetlands, 0.337 acres of floodway, and 0.240 acres of a FEMA 100-year floodplain (Chapter 106 area).

Due to the existing perennial nature of Spruce Run (stream S-O61) and saturated soils of wetland O45, a significant volume of surface water and produced groundwater is anticipated to fill all the excavations during the open cut process. These water volumes can be pumped to a discharge filtration structure; however, the current feasible filtration ability does not exceed 50 microns, therefore, cloudy water (from suspended fine clay and silt particles) will be discharged downstream during the entire duration of this crossing until completion regardless of all control methods employed.

A conventional auger bore is a practical means of pipeline installation where the topography is conducive, groundwater is manageable, and the length is ideally less than 200 ft, varying by substrate conditions at the location. The horizontal length of this crossing (2,390 ft) is beyond the technically practicable limits of an auger bore to complete regardless of substrate conditions, and the large changes in elevation on both sides of the stream and wetland makes use of a conventional bore unworkable due to the need to set the entry and exit pits into the adjacent hillsides. These changes in elevation also prohibit pulling of the pipe string into the bored receiving hole.

Re-Route Analysis

This pipeline route as currently permitted follows an existing SPLP pipeline easement. This HDD not only avoids impacts to one stream, an associated floodway wetland, and forested woodlands, but also avoids direct effects on Livermore Road, Number 10 Road, USACE public lands, an overhead powerline, and existing underground utilities, parallel to and crossing perpendicular to the easement.

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No practicable re-route option lies to the north or south of the proposed route that would not transect Spruce Run (stream S-O61), its associated floodway, other riparian forested wetlands, and forested woodlands. Although existing utility easements are located to the north and south of this pipeline route, a shift to the north in an existing utility easement would locate the pipeline closer to the Conemaugh River, result in additional impacts to the FEMA 100-year floodplain in this area, and lengthen this span of pipeline without avoiding any additional resources. A shift to the south in an existing utility easement would result in the same impacts to Spruce Run (stream S-O61), its associated floodway, other riparian forested wetlands, and forested woodlands.

During the PADEP Chapter 105 permit process for the Pennsylvania Pipeline Project, SPLP created and submitted for review a project-wide alternatives analysis. The baseline route provided for the pipeline construction to cross every wetland and stream on the project by open trench construction procedures. The alternatives analysis submitted to PADEP conceptually analyzed the feasibility of any alternative to trenched resource crossings (e.g., reroute, bore, HDD). The decision making processes for switching from an open cut to HDD is discussed thoroughly in the submitted alternatives analysis and was an important part of the overall PADEP approval of HDD plans as currently permitted. Where HDDs are planned and received PADEP Chapter 105 and 102 authorizations, they have already been evaluated to be the preferred alternative based on several variables that led the SPLP and PADEP to believe there would be less impacts on the environment in general, and aquatic and upland natural resources specifically, if these resources were drilled rather than trenched.

In summary, due to the largely similar (i.e., crossing Spruce Run, its floodway, forested wetland riparian areas, and forested woodlands) or increased impacts to resources (i.e., FEMA 100-year floodplain that widens to the north of this crossing), there is no alternative route that would result in less impacts to aquatic resources, including Spruce Run, floodways, forested wetlands, and the FEMA 100-year floodplain, and forested woodland resources.

This re-route analysis conducted for the Livermore HDD confirms the conclusions reached in the alternatives analysis previously submitted to PADEP.

HORIZONTAL DIRECTIONAL DRILL REDESIGN

HDD specialists and geologists have utilized additional geologic investigations and coal mine analysis in the redesign of the planned HDD. This redesign adjusts the HDD profile deeper to minimize the risk of drilling fluid loss, drilling difficulties, and IRs. A summary of the redesign factors is provided below. The original permitted, 20-inch IR, and redesigned 16-inch HDD plan and profile drawings are provided in Attachment 4.

Revised Horizontal Directional Drill Design Summary: 16-inch

- Horizontal length: 2,390 foot ft
- Entry/Exit angle: 16 degrees
- Maximum Depth of cover: 150 ft
- Maximum depth of cover under Spruce Run (stream S-O61): 68 ft
- Maximum depth of cover under wetland O45: 70
- Pipe design radius: 1,600 – 2,000 ft

CONCLUSION

Based on the original and revised profiles for HDD S2-0016-16, the revised profile is deeper into bedrock than the original profile. As such, the revised profile greatly reduces the risk of IRs. Procedures

established and documented in SPLP's revised IR Assessment, Preparedness, Prevention, and Contingency (PPC) Plan (April 2018 plan) across all ME II spreads have proven to be very effective in eliminating IRs and minimizing the extent of IRs.

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

- SPLP will provide the drilling crew and company inspectors the location(s) data on potential zones of higher risk for fluid loss and IRs, including the area related to previous IRs, and potential zones of fracture concentration identified by the fracture trace analysis, so that monitoring can be enhanced when drilling through these locations.

- SPLP will require and enforce the use of annular pressure (AP) monitoring during the drilling of the pilot holes, which assists in immediate identification of pressure changes indicative of loss of return flows or over pressurization of the annulus to manage development of pressures that can induce an IR;

- SPLP inspectors will ensure that an appropriate diameter pilot tool, relative to the diameter of the drilling pipe, is used to ensure adequate "annulus spacing" around the drilling pipe exits to allow good return flows during the pilot drilling;

- SPLP will implement short-tripping of the reaming tools as return flow monitoring indicates to ensure an open annulus is maintained to manage the potential inducement of IRs;

- SPLP will require monitoring of the drilling fluid viscosity, such that fissures and fractures in the subsurface are sealed during the drilling process;

- During all drilling phases, the use of Loss Control Materials (LCMs) will be implemented if indications of a potential IR are noted or an IR is observed. The use of LCMs, however, is less effective below 70 ft of the ground surface. The AP below that depth can exceed the effective stabilization capability of LCMs. Accordingly, the preferred corrective action needed to address the presence of fractures or unstable geology at greater depths below ground will require grouting of the HDD annulus. Two types of grouting will be utilized for corrective actions to seal fractures and stabilize zones of weak geology. These are: 1) grouting using "neat cement"; and 2) grouting using a sand/cement mix. Neat cement grout is a slurry of Portland cement and water. The sand/cement grout mix is a slurry of mostly sand with a small percentage of Portland cement and activators that after setup results in a material having the competency of a friable sandstone or mortar. Both grouting actions require tripping out the drilling tool, and then tripping in with an open-ended drill stem to apply or inject the grout mixes.

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FEASIBILITY DETERMINATION

Based on the information reviewed by the Geotechncial Evaluation Leader, Professional Geologists, Professional Engineers, and HDD specialists, the HDD Reevaluation Team's opinion is that the proposed HDD design and implementation of the management measures contained within this re-revaluation report will minimize the risk of IRs and impacts to public and private water supplies during the construction phases of the HDD.

Pertaining to Horizontal Directional Drilling Practices and Procedures; Conventional Construction; Alternatives; and Environmental Effects

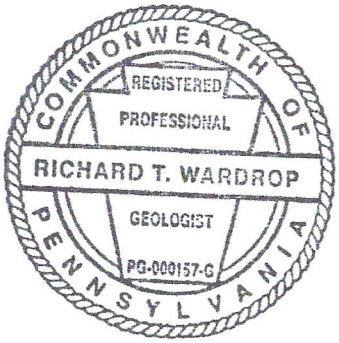
2/1/2019
Date

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

Pertaining to the practice of geology

1/31/19
Date

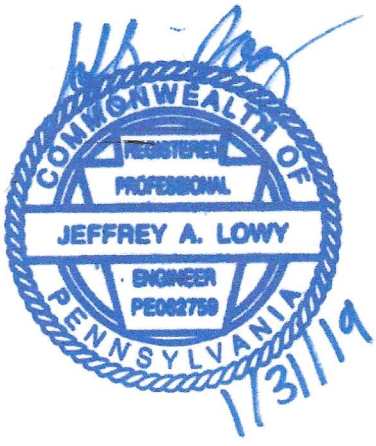
Richard T. Wardrop, P.G.
License No. PG-000157-G
Groundwater & Environmental Services, Inc.
Lead Hydrogeologist



Pertaining to the pipeline stress and HDD geometry

1/31/19
Date

Jeffery A. Lowy, P.E.
Lic. No. PE082759
Rooney Engineering, Inc.
Civil Engineer



HORIZONTAL DIRECTIONAL DRILL ANALYSIS
LIVERMORE ROAD CROSSING
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ATTACHMENT 1

GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT

HDD HYDROGEOLOGIC REEVALUATION REPORT

Mariner East II
Spread 2
HDD S2-0016-16
Livermore Road
Derry Township, Westmoreland County, Pennsylvania

Prepared for:

Sunoco Pipeline, L.P.

Prepared by:

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

January 2019

HDD HYDROGEOLOGIC REEVALUTION REPORT

Mariner East II
Spread 2
HDD S2-0016-16
Livermore Road
Derry Township, Westmoreland County, Pennsylvania

January 2019

Prepared for:

Sunoco Pipeline, L.P.
535 Fritztown Road
Sinking Spring, Pennsylvania 19608

Prepared by:

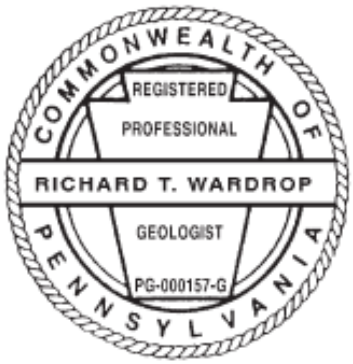
Richard T. Wardrop, P.G.
Lead Hydrogeologist

Reviewed by:

Jack Vasalani, P.G.
Principal Geologist

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

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



January 31, 2019

Richard T. Wardrop, P. G.
Lic. No. PG000157G

date

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FIGURES

ATTACHMENTS

1.0 INTRODUCTION

Sunoco Pipeline, L.P., (SPLP) retained Groundwater & Environmental Services, Inc. (GES) to prepare horizontal directional drill (HDD) Hydrogeologic Reevaluation Reports (HRRs) for HDDs listed on Exhibit 3 of the Stipulated Order EHB Docket No. 2017-009-L signed August 10, 2017. This report discusses the hydrogeologic reevaluation for HDD S2-0016-16 (the 16-inch HDD for this location). The planned alignment for HDD S2-0016-16 runs west to east from a location due west of Ten School Road to it eastern end approximately 1,000 feet east of Livermore Road in Derry Township, Westmoreland County, Pennsylvania (see Figure 1). The discussion presented in this report is based on an alignment and profile developed by Tetra Tech/Rooney, revised on October 7, 2016 (permitted profile). GES has also been provided a proposed alternative profile for HDD S2-0016-16, revised January 22, 2019 (revised profile) (see Attachment A). The revised profile was developed to increase the depth of the profile within competent bedrock beneath Spruce Run and the wetland on the stream's flood plain. For the purpose of this assessment, GES utilized both HDD designs to evaluate the hydrogeologic conditions at HDD S2-0016-16. The origin and direction of stationing for both profiles is identical running from Station 0+00 at the western entry/exit to Station 23+90 at the eastern entry/exit.

As described in the Stipulated Order (pages 3 and 4), the HRRs will provide information to eliminate, reduce, or control the release or inadvertent return (IR) of HDD drilling fluids to the surface of the ground or impact to water supplies at the location during HDD operations.

This report presents the following information:

- Geologic and hydrogeologic characteristics in the area of HDD S2-0016-16;
- Summaries of studies performed pertinent to reevaluation, including fracture trace analysis and geotechnical borings;
- A site conceptual model; and
- A reevaluation summary with conclusions.

The contents of this report were developed from interpretation of published information, field observations, and related field studies. Site geotechnical boring programs were conducted by Tetra Tech in April 2015 and by Terracon Consultants, Inc. (Terracon) in September 2017, in support of the HDD S2-0016-16 design. Please note that GES did not oversee or direct either geotechnical drilling program, including, but not limited to, the selection of number and location of borings, determination of surface elevations, target depths, observations of rock cores during drilling operations, or preparation of boring logs. The geotechnical reports, boring logs, and any core photographs that resulted from these programs were generated by SPLP's contractors. GES relied on these reports and incorporated their data into the general geologic and hydrogeologic framework for this HRR.

Figure 1. Site Location Map (modified from PAGEODE)

2.0 HDD GEOLOGY / HYDROGEOLOGY

2.1 Physiography

HDD S2-0016-16 is located within the Pittsburgh Low Plateau Section of the Appalachian Plateaus Physiographic Province, which is characterized by smooth to irregular, undulating surface; narrow, relatively shallow valleys; strip mines and reclaimed land. Locally the Upper Freeport coal has been deep mined. Spruce Run flows northwest across the alignment to a confluence with the Conemaugh River approximately 0.8 miles northwest of the HDD.

2.1.1 Topography

The topography along the surface overlying HDD S2-0016-16 is variable. Moving west to east the first 700 feet is relatively flat along an upland, then the terrane steepens over the next 350 feet to western bank of Spruce Creek (S-061) and its flood plain holding wetland W-045. The flood plain extends to approximately Station 12+21 at which point the terrane becomes steep again, moving east across Livermore Road to Station 19+50. The land surface is again relatively flat along an upland from Station 19+50 to the eastern entry/exit point at Station 23+90. The maximum difference in elevation over the profile is approximately 222 feet between the topographic high due west of the eastern entry/exit at 1,180 feet above mean sea level (ft amsl) and S-061 at 958 ft amsl. The surface elevation of the topographic high within the western part of the profile is approximately 1,055 ft amsl at Station 4+50 (see Attachment A).

2.1.2 Hydrology

The nearest surface water body to the HDD S2-0016-16 location is stream S-061 (Spruce Run) which flows northwest across the alignment at Station 10+70. The HDD passes under one wetland W-045 that occurs between Stations 10+84 and 12+21. On the permitted profile the HDD is shown approximately 20 feet below S-061. The revised profile shows the HDD would be approximately 68 feet below S-061. These depths are similar under wetland W-045 due east of the stream.

2.2 Geology

2.2.1 Soils

Information about the soil characteristics along the alignment were obtained from the National Resource Conservation Service Web Soil Survey database for Westmoreland County (NRCS-WSS). Upland and hillside soils represent 85% of the surface materials along the profile. These include the Chilpin channery silt loam (3 to 8% slopes), Gilpin-Usher complex (8 to 25% slopes), Shelocta-Gilpin channery silt loam (25 to 75% slopes) and Wharton silt loam (8 to 15% slopes). These soils are derived from acid shale, siltstone and sandstone parent bedrock that occurs at depths from 30 to 79 inches from surface. They are moderately well-drained to well-drained with most water tables at depths greater than 80 inches. The soils in the flood plain associated with Spruce Run are Lobdell silt loam (0 to 3% slopes) derived from fine-loamy alluvium coming from the shales, siltstones and sandstones on the surrounding hillsides and ridges. These soils are moderately well-drained with water tables 16 to 30 inches from the surface.

2.2.2 Bedrock Lithology

The bedrock underlying the profile for HDD S2-0016-16 belongs to the Pennsylvanian age Casselman and Glenshaw Formations that together form the Conemaugh Group (see Figure 2). The Group is stratigraphically defined as the rocks lying between the Upper Freeport coal (below) and the Pittsburgh coal (above). The bedrock underlying hilltops and upper parts of the hillsides is part of the Casselman Formation and bedrock underlying the lower parts of the hillsides and flood plain to Spruce Run are part of the

Figure 2. Site Geology Map (modified from PA GEODE)

Glenshaw Formation. The Upper Freeport coal was mined under the profile west of Spruce Run (see Section 2.2.6).

In general, the Glenshaw and Casselman Formations are distinguished by the marine beds of the Glenshaw Formation versus the non-marine beds of the Casselman Formation (Edmunds, et. al, 1999). The Casselman Formation is characterized by a few locally persistent red beds, calcareous claystone, freshwater limestones, thin sandstones, shales, siltstones, and generally thin, economically insignificant coal beds. The Glenshaw Formation consists of repeated sequences of sandstone, siltstone, shale, claystone (including red beds), limestone, and coal. It contains four major marine zones that are, from lowest to highest in stratigraphic position, the Brush Creek, Pine Creek, Woods Run, and Ames.

2.2.3 Structure

Skema (1988) provides structure contour maps for the Upper Freeport coal beds in Westmoreland County. As shown on Figure 3, HDD S2-0016-16 is located due east of the structural axis of the Greensburg Syncline. Here the bedrock is dipping gently west at approximately 2.1 degrees.

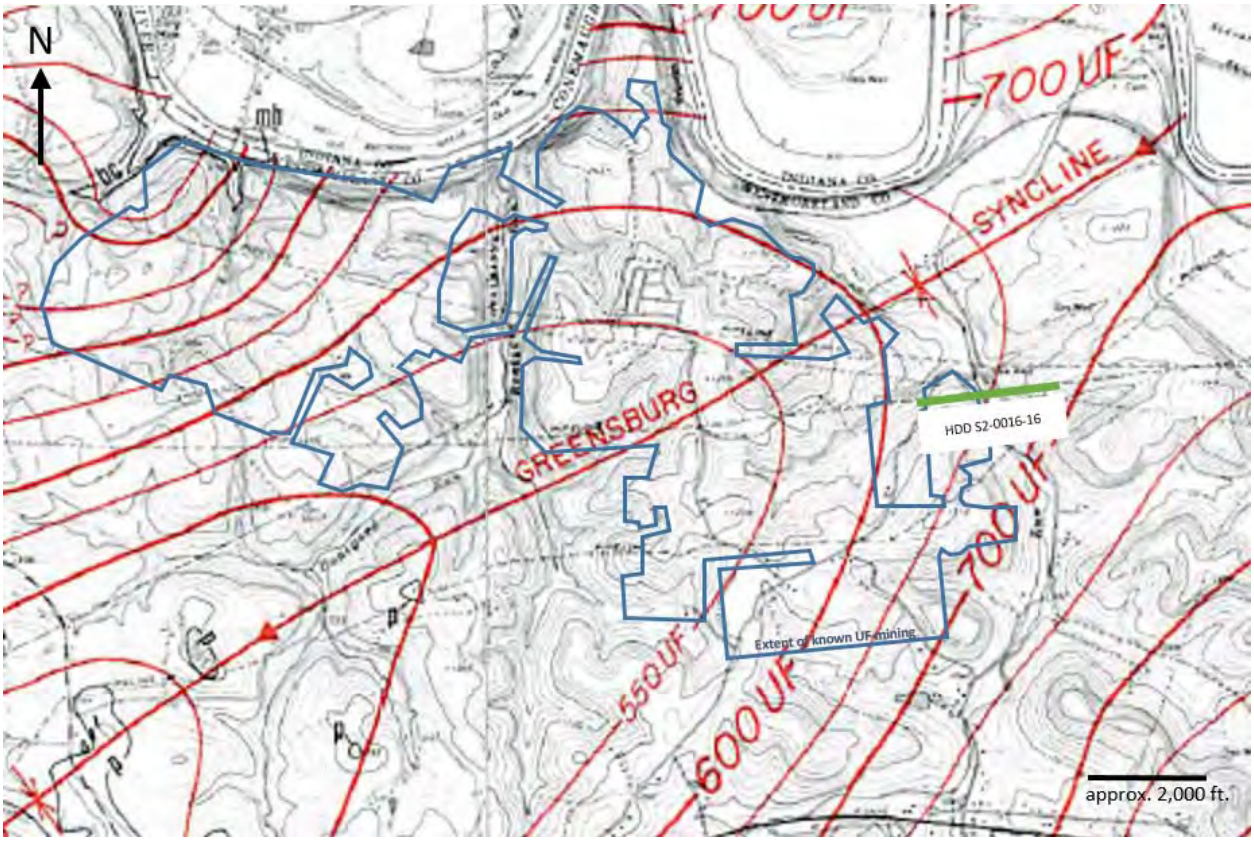

Figure 3. Structure Contour Map of the Upper Freeport Coal (mod. from Skema, 1988)

Discontinuities in the form of joints and faults are imprinted in the broadly folded bedrock in the region. These fractures can act as conduits for groundwater movement and/or represent areas of weakness in the rock. Nickelsen and Hough (1967) conducted regional mapping of joints in shale, coal and sandstone in the Appalachian Plateau. In the vicinity of HDD S2-0016-16, two systematic joint sets were mapped with approximate trends of west-northwest and northwest. Less frequent non-systematic joints were mapped approximately orthogonal to the systematic joints.

2.2.4 Fracture Trace Analysis

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

Figure 4 is the fracture trace map prepared for this reevaluation. This mapping was performed using aerial stereographic pairs flown in the spring of 1939 and a USGS topographic map for the Blairsville 7.5 minute quadrangle. Three general orientations are present in the set of fracture traces: a northwestern trending set, a north-northeastern trending set and a northeastern set. One trace is oriented north-northwest.

As shown on Figure 4, one of the northwest trending fracture traces is partly defined by a straight stream segment of Spruce Run (S-061) and crosses the alignment at approximately Station 10+70. A north-north eastern trending trace crosses the HDD alignment at approximately Station 18+38. These two traces

parallel one of the systematic joint sets and one of the non-systematic joints sets mapped by Nickelsen and Hough (1967), respectively.

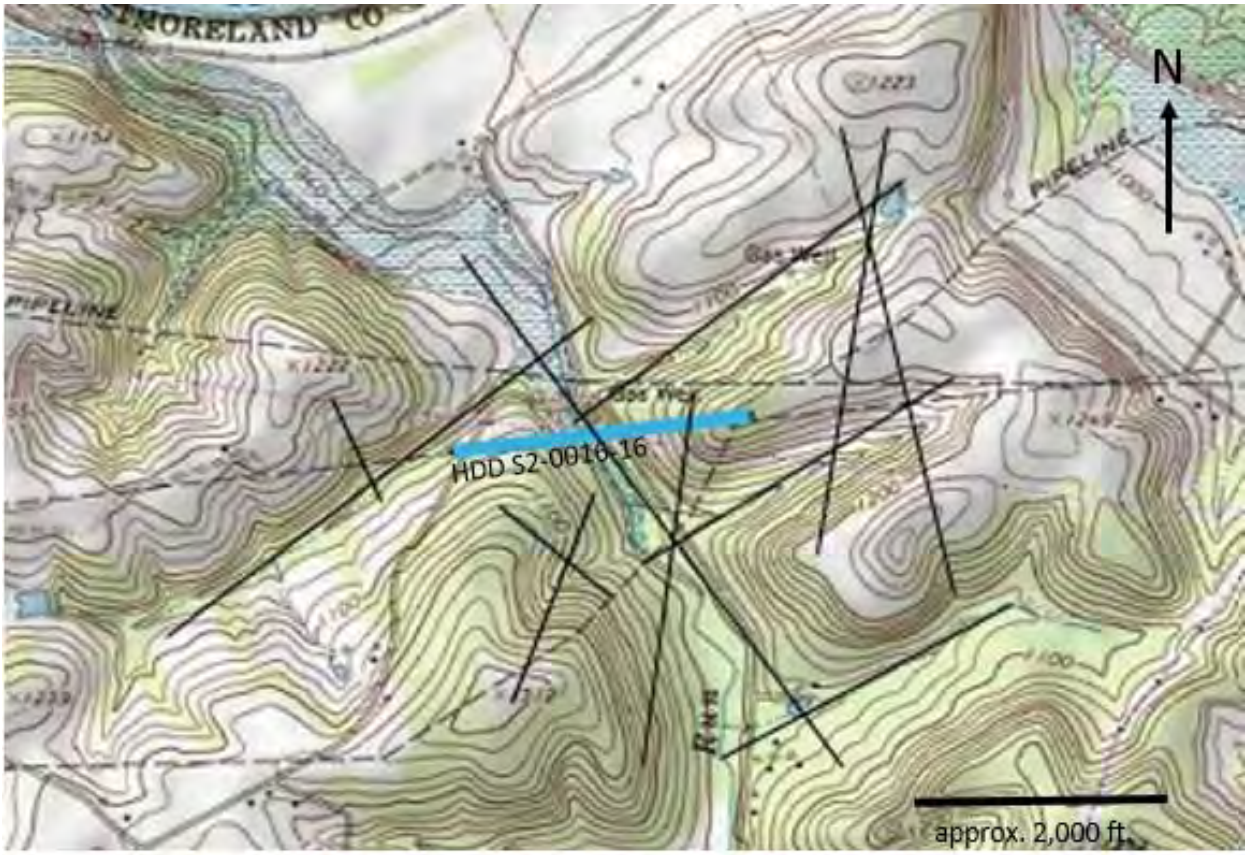

Figure 4. Fracture Trace Map

2.2.5 Karst

Based on published geologic data, no karst features are anticipated within the region of HDD S2-0016-16 as limestone units are relatively thin and discontinuous.

2.2.6 Mining

A review of published mining and geological data indicate that historic deep mining of the Upper Freeport coal occurred in the vicinity of HDD S2-0016-16 (see Figure 5).

The Penn State Mine Atlas shows that HDD S2-0016-16 is within the limits of a former room and pillar Upper Freeport coal mine, a section of the Tunnelton Mining Company's Marion Mine. Base of Upper Freeport coal elevations below the HDD S2-0016-16 profile range from approximately 631 ft amsl at the western entry/exit to 646 ft amsl where the mine terminates at approximately Station 9+50. The lowest elevation of HDD S2-0016-16 on the revised profile is 890 ft amsl from Station 6+88 to Station 11+50, which is approximately 244 feet above the highest floor elevation of the mine along the HDD S2-0016-16 drill path, within the limits of the mine footprint. The coal is approximately 3.5-feet thick within the mine therefore the shortest distance from the mine roof to the revised profile is approximately 240 feet.

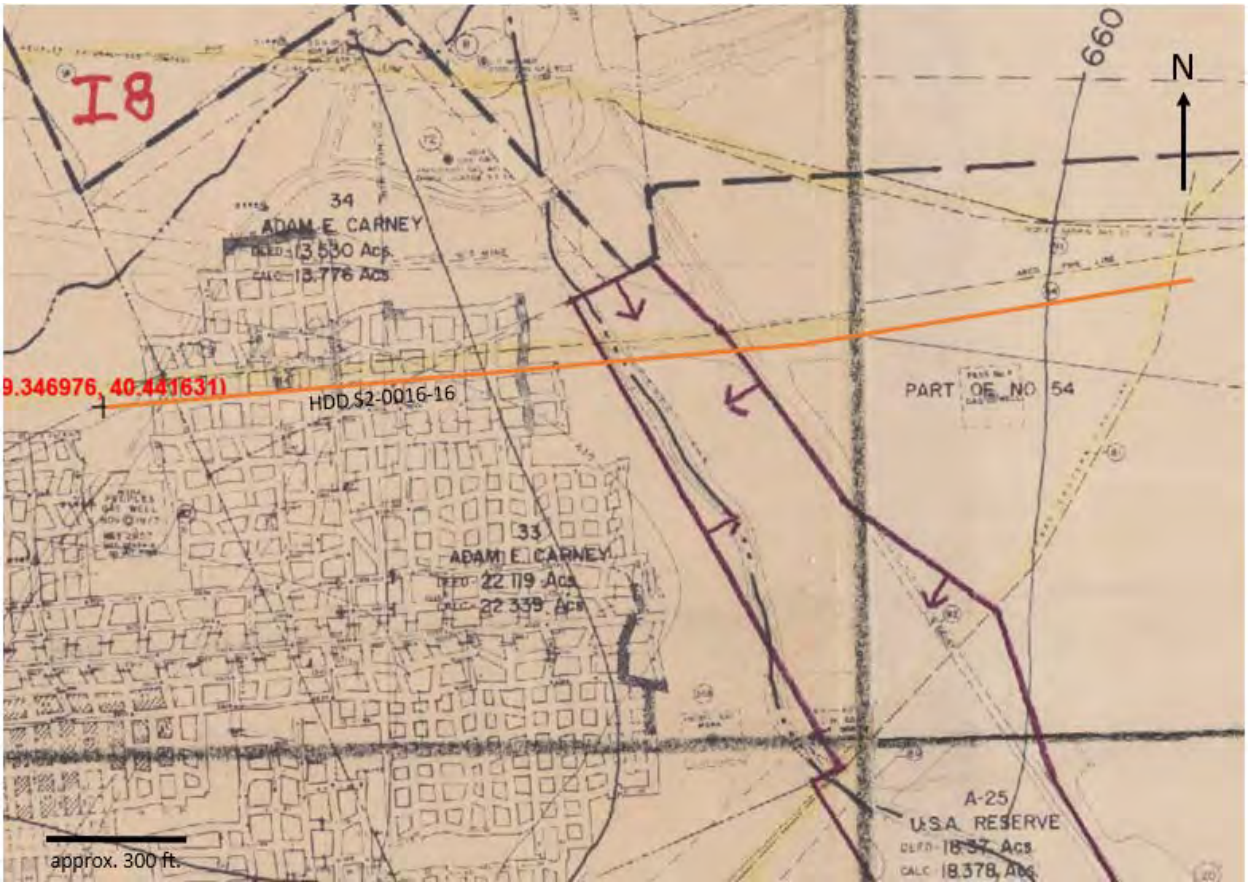

Figure 5. Limits of Upper Freeport Coal Seam Deep Mining Near HDD S2-0016-16
(modified from Penn State Mine Atlas)

Kendorksi (2006) delineated estimated extents of four zones of fracturing above deep mines, based on the thickness of extracted coal. From bottom to top these include the Caved Zone (with extensive fracturing and sizeable voids), Fracture Zone (fracturing, without extensive dislocation of rocks or voids), Dilation Zone (small fractures), and the Constrained Zone (with no rock fracturing related to mine subsidence). The maximum estimated extent of the Dilation Zone above the Marion Mine is 210 feet and the lowest part of the revised profile within the limits of the mine footprint is 240 feet above the mine therefore the part of the profile that is within limits of mine's footprint is entirely in the Constrained Zone.

The risk of an LOC to create a new mine pool discharge is very small given the standard procedures associated with LOCs implemented by the ME II HDD program in the summer of 2018. The standard procedures call for immediate suspension of drilling activity and assessment at the first signs of fluid loss. This greatly diminishes the volume of fluid that can be lost to mine workings and any associated adverse increase in the pressure head on a mine pool. Figure 3 shows the limits of the local continuous interconnected Upper Freeport coal mine working associated with the Marion Mine. From the location of the HDD, the local mine workings extend north to the southern shore of the Conemaugh River, west approximately 2.7 miles, and south approximately 0.8 miles. The workings lie within the Greensburg Syncline. Mine roof elevations range from approximately 545 ft amsl to 805 ft amsl within the continuous mine workings. The surface elevations within the footprint of the mine workings range from 860 ft amsl to 1260 ft amsl with the lowest elevations near the western limit of mining at a tributary to the Conemaugh River. A mine outcrop, where a discharge might occur at the surface, does not exist within the footprint of the workings. Given the extent of the mine workings, volume of natural groundwater recharge being received by the workings, associated natural groundwater pressure heads on the workings, position of the

HDD profile within the mine workings, and standard ME II LOC procedures; the risk of an LOC creating enough change in the current mine hydrology to create a new mine pool discharge is extremely small.

2.2.7 Rock Engineering Properties

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

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

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

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

2.2.8 Results of Geotechnical Borings

Original Borings

Two geotechnical borings (SB-01 and SB-02) were installed by Tetra Tech in September 2014 in support of the original HDD design. The location of SB-01 is shown on both the original and revised plan and profiles in Attachment A. SB-01 was drilled on the alignment at approximately Station 15+36. Split spoon soil samples were obtained to a depth of 28 feet and the hole was advanced to auger refusal at 30 feet. The material in the upper 28 feet was described as a fine silty sand with gravel and the material after 28 feet was described as weathered sandstone. No groundwater was encountered in the boring. SB-02 was located over 700 feet east of the east entry/exit and the log is not considered representative of materials underlying HDD S2-0016-16.

Recent Borings

Two additional geotechnical borings (B2-5W and B2-5E) were installed by Terracon in September 2017 in support of the HDD reevaluation.

.*B2-5E*

Boring B2-5E was advanced at the eastern entry/exit location on the revised profile. This boring was located at a surface elevation of approximately 1,173 ft amsl and installed to a depth of 302.8 feet below ground surface (ft bgs). Unconsolidated overburden was comprised of lean clay with gravel to 13.0 ft bgs. Weathered bedrock occurred from approximately 13.0 to 48.0 feet ft bgs, prior to encountering competent bedrock. Bedrock cores were obtained from 13 ft bgs to the total depth and contained shale, mudstone, siltstone, and sandstone, with minor interbeds of limestone, characteristic of the Casselman Formation. Core recoveries below 38 ft bgs, were high, ranging from 83 to 100 percent. Regarding rock quality index determination (RQD), after the weathered bedrock zone RQD varied from 20 to 100 percent with no correlation between depth and RQD. Relatively high RQD zones are noted from 48 to 98 feet and from 218 to 283 ft bgs. The most representative water level measurements obtained for this boring were at approximately 126 ft bgs.

B2-5W

Boring B2-5W was advanced at the western entry/exit location on the profiles. This boring was located at

a surface elevation of approximately 1,037 ft amsl and installed to a depth of 167.2 ft bgs. Unconsolidated overburden was comprised of lean clay and gravel with sand to 18.5 ft bgs. Weathered bedrock occurred from approximately 18.5 to 32 ft bgs, prior to encountering relatively competent bedrock. Bedrock cores were obtained from 23 ft bgs to the total depth and contained shale, mudstone, siltstone, sandstone and limestone characteristic of the Glenshaw Formation. Core recoveries varied from 47 to 100 percent to a depth of 117 ft bgs, but were 100 percent for the remainder of the boring. The RQD varied greatly from the upper most cores to a depth of 122 feet, after which the values were consistently much higher between 95 to 100 percent. The most representative water level measurements obtained for this boring were at approximately 49.5 ft bgs

2.3 Hydrogeology

2.3.1 Occurrence of Groundwater

Groundwater in the bedrock aquifer below the land surface at HDD S2-0016-16 in Westmoreland County is stored and moves within a network of rock fractures and bedding plane partings. Regional systematic joints are oriented northwest and west-northwest and may represent preferred pathways for groundwater flow.

Based on data contained in the geotechnical borings for HDD S2-0016-16, groundwater was encountered at approximately 49.5 ft bgs in boring B2-5W near the west entry/exit and at 126 ft bgs in B2-5E at the east entry/exit. The groundwater table is expected to be near the surface over the area of wetland W-045 in the flood plain of Spruce Run.

2.3.2 Groundwater Levels and HDD entry/exit elevations

The surface elevation of the west entry/exit for the both profiles at Station 0+00 is 1,034 ft amsl. The surface elevation of the eastern entry/exit on both profiles, at Station 23+90, is 1,174 ft amsl. If the water level elevations measured at the geotechnical borings are representative of groundwater levels in the area than the revised profile will be within groundwater for approximately 67 percent of the drill. Given the entry/exit elevations on the profiles there is little risk of the HDD creating a groundwater discharge at one of the entry/exits. Taking into consideration the geometry of the revised profile and the water level data from geotechnical borings B2-5W and B2-5E there will be approximately 27 feet of groundwater head between the west entry/exit and stream S-061 and approximately 92 feet of head between the east entry/exit and S-061 which could facilitate a groundwater discharge in the valley bottom if a pathway is present between the HDD borehole and the surface.

Pennsylvania Groundwater Information System (PaGWIS) reported two wells within a half mile of the HDD S2-0016-16 alignment. PA Well ID 426067 is a residential well drilled in year 2007 and located approximately 200 feet north of Station 9+00, near the intersection of Ten School Road and Livermore Road. The well is listed at 245 feet deep and the static water level at time of installation was 35 ft bgs. PA Well ID 648050 is a residential well located approximately 1,115 feet southwest of the west entry/exit for a home along Ten School Road that was drilled in year 2010. The well is listed at 265 feet deep and the static water level at time of installation was 55 ft bgs.

2.3.3 Well Yields

Published median well yields for the Conemaugh Group range from 1 to 357 gallons per minute (gpm) with the higher yields coming from wells in sandstones (Newport, 1973). The well yields estimated at the time of well installation for the two wells within 0.5 miles of the HDD, reported in the PaGWIS data base, were 4 and 5 gpm.

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2.3.4 SPLP Water Supply Surveys

SPLP performed a survey of land owners within 450 feet of the ROW for the revised profile and three land owners along Ten School Road responded positively to an offer to have their residential wells tested (see Figure 6).

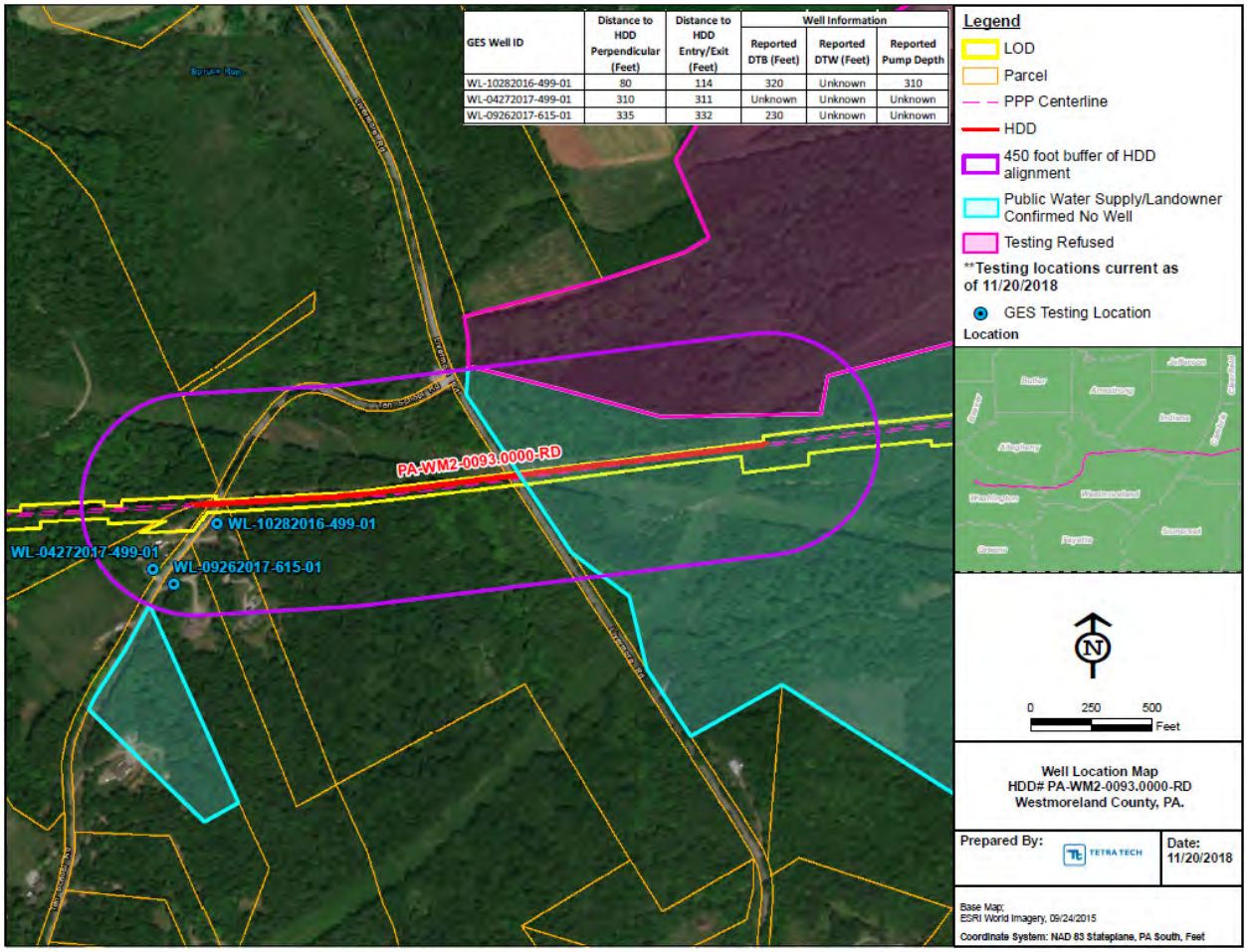

Figure 6. Water Supply Wells Sampled within 450 feet of HDD Alignment

These wells are identified as WL-10282016-499-01, WL-04272017-499-01, and WL-09262017-615-01. Two land owners reported well depths; WL-09262017-615-01 at 230 feet and WL-10282016-499-01 at 320 feet, but no water level measurements could be obtained given the construction of the wells. No public water supplies were identified within 450-feet of the alignment.

Pre and post-construction water quality sampling results for three residential wells demonstrate that none were impacted by the installation of the 20-inch line therefore the risk of impacting any of these supplies while installing the 16-inch line is small. These wells are located south of the west entry/exit and western part of the profile where the profile is shallow. By comparison the depths of the two of the three wells are large at 230 and 320 ft bgs., greatly reducing any risk of a water quality impact from the HDD. The depth of the third well is unknown.

2.4 Summary of Geophysical Studies

No geophysical studies were conducted for this reevaluation as there is no indication of karst development in the area. Historic mining information, the elevations of the revised HDD-0016-16 profile, and

subsidence and stress modelling were used by Tetra Tech (November 2018) to evaluate potential future stress on the installed pipe due to future subsidence of the abandoned Tunnelton Mining Company's Marion Mine. The available information was sufficient for Tetra Tech and it's subconsultants to perform the analysis therefore geophysical studies were not required.

3.0 OBSERVATIONS TO DATE

3.1 On This HDD Alignment

3.1.1 ME I

No IRs were reported along the alignment of the HDD S2-0016-16 drill on the list of IRs for ME I documented in the IR PPC Plan for Westmoreland County.

3.1.2 ME II

Pilot drilling for the 20-inch line at HDD-0016 began on 4/29/17 drilling west to east. Operations continued without incident until 5/5/17 when the pilot reached 1,061 ft (under Spruce Run) and a loss of returns was noted. The driller began tripping out. The next day the driller tripped back into the cutting face and advanced 10 feet when an IR occurred in wetland W-045, due north of Spruce Run. A containment and pumping system was quickly established. Drilling fluids captured in the containment were pumped up the slope to Livermore Road where vac trucks were staged to receive and transport fluids back to the mud plant at the west entry/exit along Ten School Road. From that point in time until the pulling of the 20-inch pipe, the managed IR was frequently active and contained. On 5/24/18 the 20-inch reamer exited on the east side and the crew began tripping out drill rod to the west side in preparation for starting the 30-inch ream. At that time a second IR occurred along the north bank of Spruce Run where approximately 30 gallons of drilling fluid surfaced and entered Spruce Run. Another IR surfaced due northwest of the first IR on the flood plain of wetland W-045. The new IRs were contained and cleaned up. Drilling fluids were contained along the stream bank and managed by pumping back into the primary IR containment. Drilling fluids coating the stream bottom were cleaned up by agitating the stream bottom and vacuuming the turbid fluid. The new IRs were only active for a short time and all IR activity returned to the original IR and managed containment.

The overburden was relatively thick over most of the 20-inch line profile. The thinnest overburden occurred where the drill passed below Spruce Run (S-061) and wetland W-045. At this location the as-built profile for the installed 20-inch line shows the overburden to be approximately 42 feet (see Attachment A). Unconsolidated materials are usually thicker in valley bottom settings. Often stream valleys in the Appalachian Plateau are developed along vertical zones of fracture concentration where weathering is enhanced by a relatively higher density of bedrock fractures than on the surrounding hillsides and hill tops. HDD S2-0016-20 crossed Spruce Run, wetland W-045 and a fracture trace indicated by a straight section of the stream (see Figure 4). Thus, the relatively thin overburden, relatively large proportion of unconsolidated overburden and possible zone of bedrock fracture concentration were all potential contributing factors to the IRs that occurred during installation of the 20-inch pipe. Additionally, given the geometry of the profile, with elevated ground to the west and east of S-061 and wetland w-045, the increased annular pressure on the drilling fluid at this low spot in the profile could have contributed to the IRs.

No instances of LOCs or IRs occurred outside the zone beneath Spruce Run and wetland W-045 during drilling and construction of the 20-inch line at HDD S2-0016.

3.2 On Other HDD Alignments in Similar Hydrogeologic Settings

3.2.1 ME I

One IR location was reported on the list of IRs for ME I documented in the IR PPC Plan that is underlain by Casselman Formation bedrock. This was the PA-WM-0088.0000-RR, Norfolk Southern Railway near the town of Jeanette in Westmoreland County. None of the IRs listed for ME I were underlain by the Glenshaw Formation.

3.2.2 ME II

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

4.0 SUMMARY AND CONCLUSIONS

4.1 HDD Site Conceptual Model

One major IR and two minor IRs occurred on the flood plain of Spruce Run, due east of the stream, during drilling activities associated with installation of the 20-inch line at HDD S2-0016. Factors contributing to the IRs included relatively thin overburden, a relatively large proportion of the overburden comprised of unconsolidated materials, a potential vertical zone of bedrock fracture concentration as indicated by the mapped fracture trace coincident with Spruce Run and elevated annular pressures. The revised profile for the 16-inch line increases the depth to the profile in the area of the IRs by 48 feet when compared to the permitted profile and by 26 feet when compared to the as-built profile for the 20-inch line. In general, increasing the depth of the profile at this location increases the strength of the overburden reducing the risk of IRs. An increase in the proportion of overburden comprised of competent bedrock may contribute to the strength of the overburden; however, a vertical bedrock fracture zone, manifested as the fracture trace coincident to Spruce Run, may represent a preferred pathway for fluid migration at this location.

A second fracture trace intersecting the eastern portion of the revised profile and variability in the RQD for bedrock at geotechnical borings B2-5W and B2-5E indicate other zones of bedrock weakness may be present, however such zones did not cause LOCs or IRs in areas other than wetland W-045 during drilling and construction of the 20-inch line.

The Tunnelton Mining Company's Marion Upper Freeport deep coal mine underlies approximately 40 percent of the HDD, due west of Spruce Run. At the deepest portion of the revised profile the abandoned mine is 240 feet below the profile, placing the revised profile within the Constrained Zone, as defined by Kendorski (2006), with no additional bedrock fracturing caused by mine subsidence.

Three domestic supply wells were identified within 450-feet of the revised alignment based on SPLP's water well survey results. None of these wells were impacted by the installation of the 20-inch line therefore the risk of impacting any of these supplies while installing the 16-inch line is small. These wells are located south of the west entry/exit and western part of the profile where the profile is shallow. By comparison the depths of the two of the three wells are large at 230 and 320 ft bgs, greatly reducing any risk of a water quality impact from the HDD. The depth of the third well is unknown.

4.2 Conclusions and Recommendations

The risk of LOCs and IRs associated with the revised profile for HDD S2-0016-16 are constrained to the section where the profile passes beneath Spruce Run and wetland W-045. As described above, deepening the profile in this area increases the strength of the overburden. Potentially an increase in the proportion of competent bedrock in the overburden contributes to that increase in strength; however, a bedrock fracture zone, as indicated by a mapped fracture trace, might represent a preferred pathway for fluid migration to the surface. As such, the drilling plan should emphasize the potential risk of LOCs and IRs in this section of the profile and plan accordingly. Steps available to control potential or actual LOCs include:

- Reducing drilling fluid density to maintain a clean borehole and control annular pressure
- Controlling penetration rates to maintain a clean borehole and control annular pressure.
- Suspending drilling activities and performing an assessment at the initial sign for fluid loss that was implemented by the ME II HDD program in the summer of 2018.
- "Squeeze grouting" before resuming after an LOC.

- Re-establishing drilling fluid circulation slowly before advancing after placement of pills or grout plugs.

Three residential supply wells were identified within 450-feet of the revised alignment based on SPLP's water well survey results. None of these wells were impacted by the installation of the 20-inch line. The three wells are located south of the west entry/exit and western part of the profile where the profile is shallow. By comparison the depths of the two of the three wells are large at 230 and 320 ft bgs, reducing the risk of a water quality impact from the HDD.

Based on information provided by, and the expertise of, the HDD team, as well as our experience with the relevant hydrogeology and geology, GES believes that the implementation of the measures described above in Section 4.2 will minimize the likelihood of harm to the environment. Furthermore, based on such information, expertise and experience, GES believes that implementation of these measures is a practicable means, in conjunction with the positions of known water private water supplies in the area, to prevent impacts to such water supplies. In the unlikely event of an impact to a private water supply, SPLP should implement procedures provided the IR PPC Plan

5.0 REFERENCES

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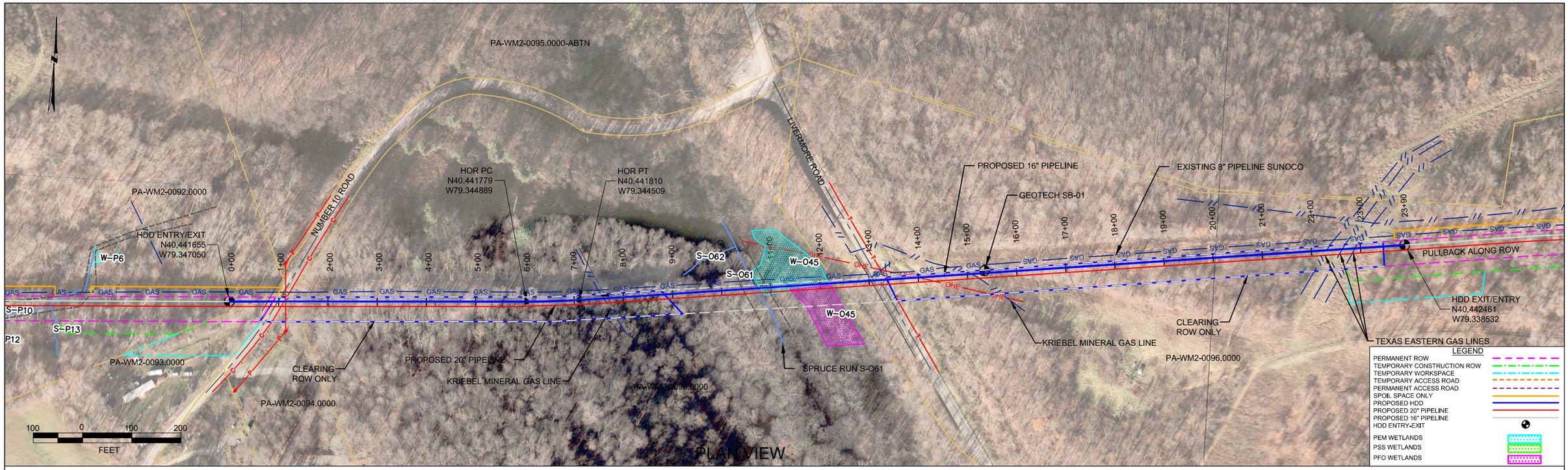
(https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx).

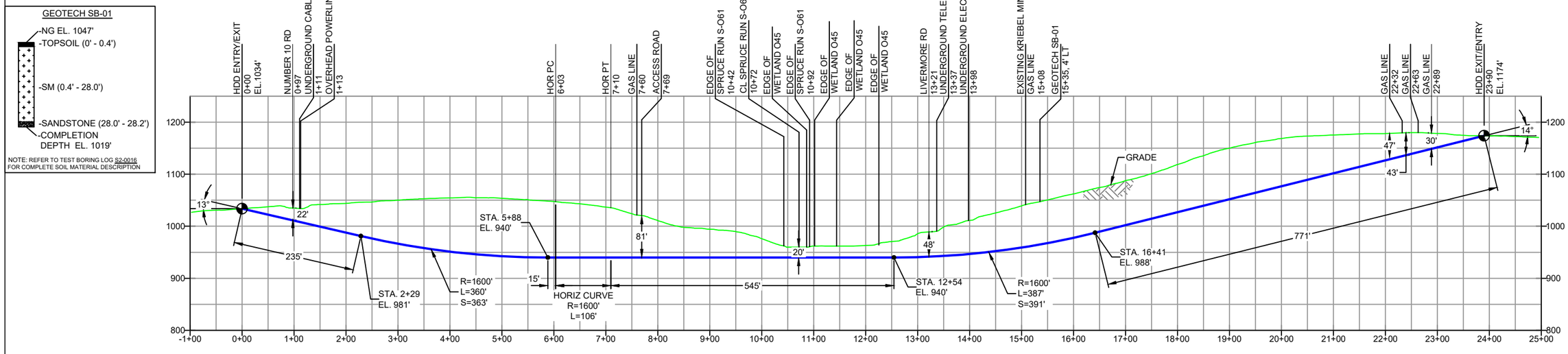
Attachment A

Original and Revised Plans and Profiles



WESTMORELAND COUNTY, PENNSYLVANIA - DERRY TOWNSHIP
S2-0016-16

PROFILE VIEW



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXITING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):2390'
   HDD PIPE LENGTH (S=):2426'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

NOTES

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

REF. DRAWING

ES-2.40	TO	ES-2.41	EROSION & SEDIMENT PLAN
SHEET 76	TO	SHEET 77	AERIAL SITE PLAN
DWG NO		DWG NO	DESCRIPTION

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	MRS	05/18/16	RMB	05/18/16	AAW	05/18/16
EP		DLM	03/23/16	RMB	03/23/16	AAW	03/23/16
B	ADDED GEOTECH INFO	MRS	09/07/15	RMB	09/07/15	AAW	09/07/15
A	ISSUED FOR BID	MRS	08/31/15	RMB	08/31/15	AAW	03/24/15

Sunoco Logistics Partners L.P.

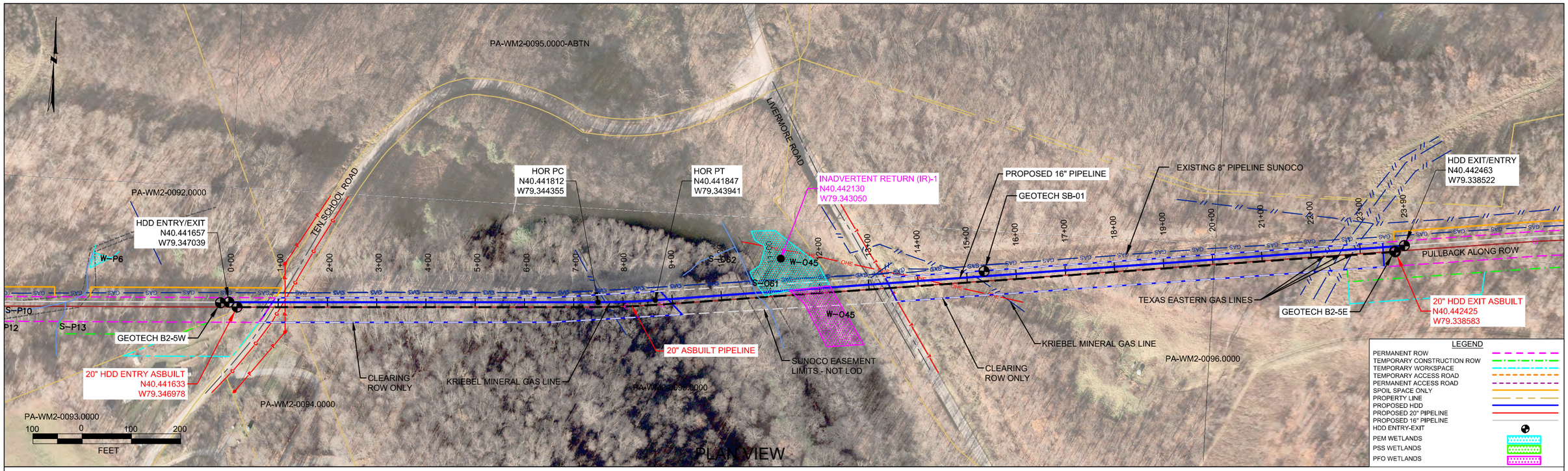
TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

16-INCH HORIZONTAL DIRECTIONAL DRILL
LIVERMORE ROAD
PENNSYLVANIA PIPELINE PROJECT

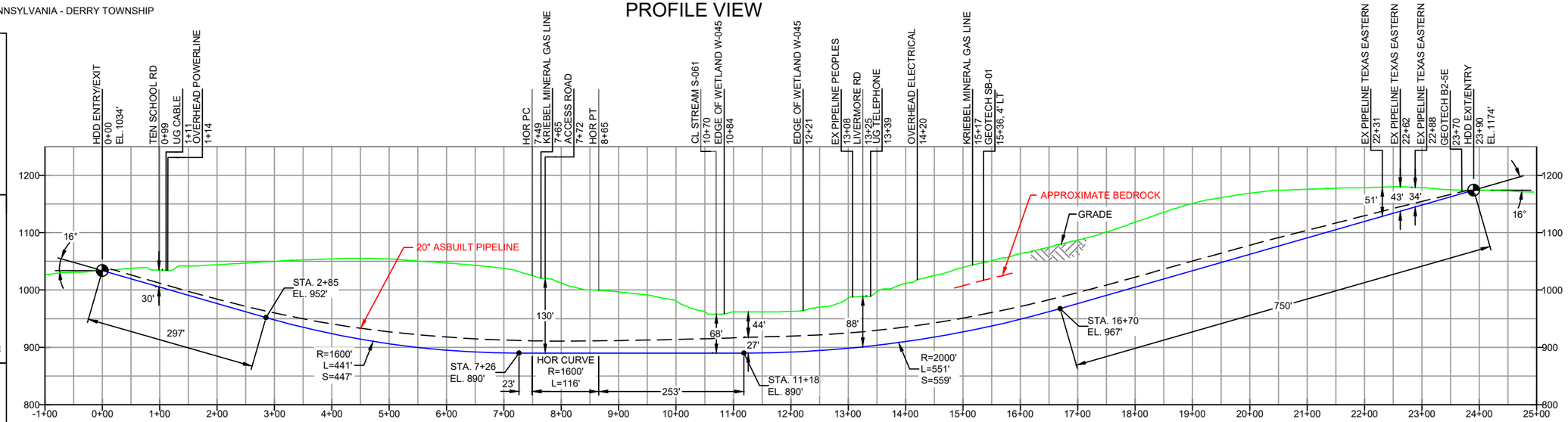
SCALE: 1"=200'

DWG. NO: PA-WM2-0093.0000-RD-16

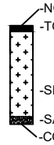


WESTMORELAND COUNTY, PENNSYLVANIA - DERRY TOWNSHIP
S2-0016-16

PROFILE VIEW



GEOTECH SB-01



NOTE: REFER TO TEST BORING LOG S2-0016 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B2-5W

NOTE: REFER TO TEST BORING LOG B2-5W TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B2-5E

NOTE: REFER TO TEST BORING LOG B2-5E TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):2390'
   HDD PIPE LENGTH (S=):2445'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 2100 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 2625 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.

NOTES

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

REF. DRAWING

ES-2.40	TO	ES-2.41	EROSION & SEDIMENT PLAN	
SHEET 76	TO	SHEET 77	AERIAL SITE PLAN	
DWG NO		DWG NO	DESCRIPTION	

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP5	ADDED INADVERTENT RETURN INFO	MRS	01/22/19	RMB	01/22/19	CAG	01/22/19
EP4	ADDED GEOTECH INFO	MRS	11/15/18	RMB	11/15/18	CAG	11/15/18
EP3	INCREASED DRILL DEPTH, UPDATED NOTE 5 AND 10 PER INCREASED 16" MOP - DESIGN CHANGE PER CLIENT	MRS	05/21/18	RMB	05/21/18	CAG	05/21/18
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	MRS	05/18/16	RMB	05/18/16	AAW	05/18/16
EP		DLM	03/23/16	RMB	03/23/16	AAW	03/23/16

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

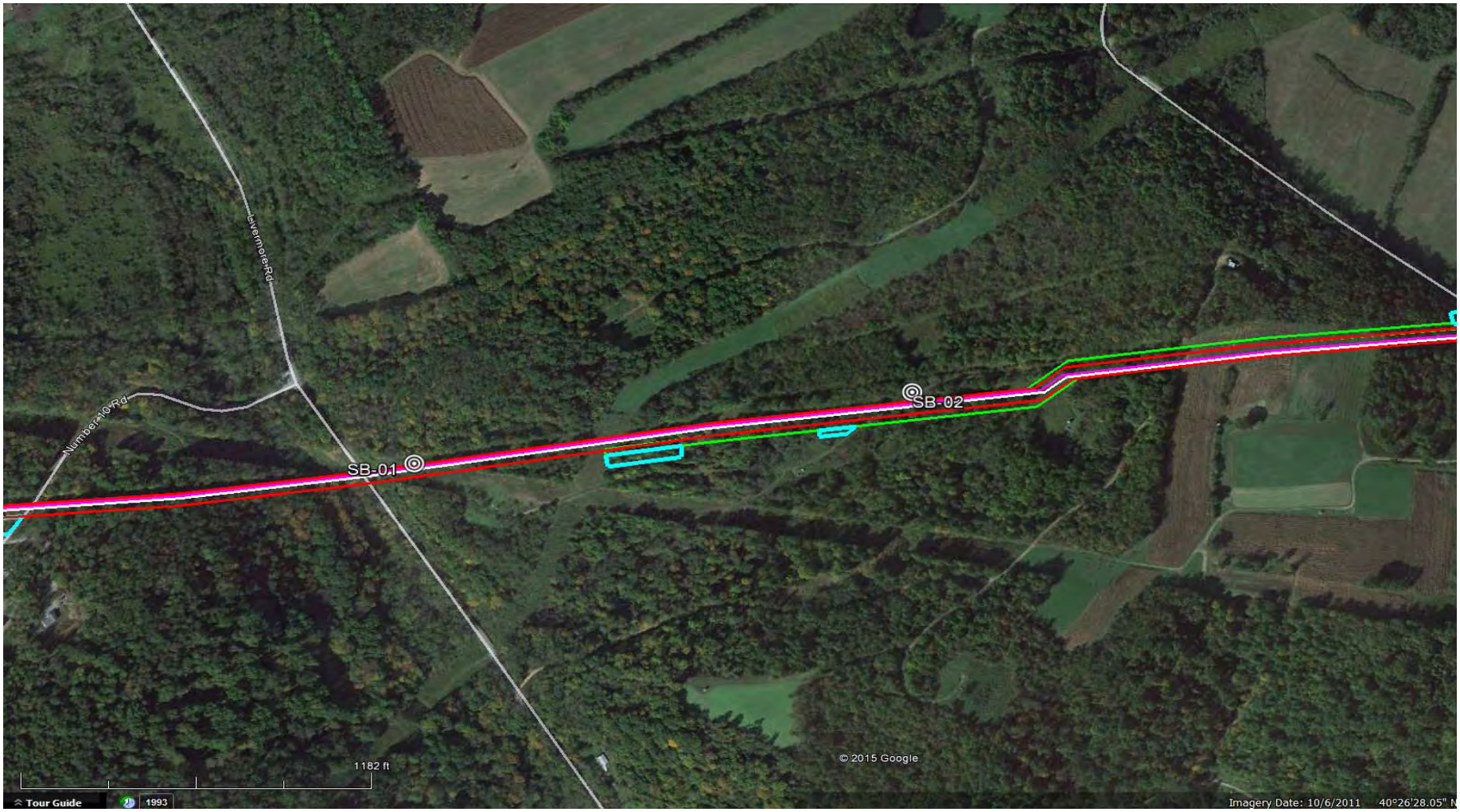
SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
LIVERMORE ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200' | DWG. NO: PA-WM2-0093.0000-RD-16

Attachment B

Geotechnical Reports



LEGEND:

Geotechnical Soil Boring (SB) Locations

TETRA TECH

GEOTECHNICAL BORING LOCATIONS
HDD S2-0016
WESTMORELAND COUNTY, DERRY TOWNSHIP, PA
SUNOCO PENNSYLVANIA PIPELINE PROJECT

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

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT		Project No.: 103IP3406
Project Location:	LIVERMORE ROAD, BLAIRSVILLE, PA		Page 1 of 1
HDD No.:	S2-0016	Dates(s) Drilled: 04-13-15	Inspector: E. WATT
Boring No.:	SB-01	Drilling Method: SPT - ASTM D1586	Driller: S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED	Total Depth (ft): 30.0
Boring Location Coordinates:		40° 26' 31.720" N	79° 20' 29.629" W

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.4			TOPSOIL (5")					
1	3.0	4.9	0.4		24	SM	DARK BROWN AND GRAY MICACEOUS FINE SILTY SAND WITH A	3	21	30	50/5"	**51**
							LITTLE FINE TO COARSE GRAVEL (WEATHERED SANDSTONE).					
2	8.0	10.0			20		DARK BROWN AND GRAY MICACEOUS FINE SILTY SAND WITH A	5	16	26	33	**42**
							LITTLE FINE TO COARSE GRAVEL (WEATHERED SANDSTONE).					
3	13.0	14.0			12		DARK BROWN AND GRAY MICACEOUS FINE SILTY SAND WITH A	9	50/6"			**>50**
							LITTLE FINE TO COARSE GRAVEL (WEATHERED SANDSTONE).					
4	18.0	18.9			11		GRAY AND DARK GRAY MICACEOUS FINE SILTY SAND WITH A	7	50/5"			**>50**
							LITTLE FINE TO COARSE GRAVEL (WEATHERED SANDSTONE).					
5	23.0	23.9			11		GRAY AND DARK GRAY MICACEOUS FINE SILTY SAND WITH A	10	50/5"			**>50**
				28.0			LITTLE FINE TO COARSE GRAVEL (WEATHERED SANDSTONE).					
6	28.0	28.2	28.0	28.2	<1		PARTIALLY WEATHERED GRAY SANDSTONE.	50/2"				**>50**
							AUGERED TO 30'.					
							DRY AND CAVED AT 26'.					
							STARTED GRINDING BETWEEN 20' AND 21'.					

Notes/Comments:

Pocket Pentrometer Testing

BORING IS IN SUNOCO ROW, 110' EAST OF PROPOSED LOCATION. NEW LOCATION APPROXIMATEL 15' TO 20' HIGHER IN ELEVATION.

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

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

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

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT		Project No.: 103IP3406
Project Location:	LIVERMORE ROAD, BLAIRSVILLE, PA		Page 1 of 1
HDD No.:	S2-0016	Dates(s) Drilled: 04-11-15	Inspector: E. WATT
Boring No.:	SB-02	Drilling Method: SPT - ASTM D1586	Driller: S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED	Total Depth (ft): 30.0
Boring Location Coordinates:		40° 26' 34.571" N	79° 20' 5.555" W

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.0			NO TOPSOIL					
1	3.0	5.0	0.0		16	SM	MOTTLED LIGHT BROWN AND GRAY FINE SAND WITH SOME SILT, WITH	10	18	19	13	**37**
							A LITTLE F-C GRAVEL.					
2	8.0	10.0			22		MOTTLED LIGHT BROWN AND GRAY FINE SAND WITH A LITTLE SILT,	2	6	8	9	**14**
							AND A LITTLE F-C GRAVEL.					
3	13.0	15.0			24		VARIEGATED FINE SAND AND CLAYEY SILT, WITH A LITTLE	1	15	19	25	**34**
				16.5			FINE GRAVEL (USCS: SM).					
4	18.0	19.3	16.5		10	SM	VARIEGATED FINE SAND WITH SOME CLAYEY SILT, WITH A LITTLE	4	26	50/3"		**>50**
							FINE GRAVEL.					
5	23.0	24.9			23		ORANGE BROWN TO GRAY FINE SAND WITH SOME CLAYEY SILT,	8	34	43	50/5"	**77**
				28.5			AND WITH A LITTLE FINE GRAVEL. (USCS: SM).					
6	28.0	28.9	28.5		10	SM/ GM	LIGHT GRAY AND LIGHT BROWN FINE SILTY SAND AND FINE TO	15	50/5"			**>50**
				30.0			COARSE GRAVEL.					
							AUGERED TO 30'.					

Notes/Comments:

Pocket Pentrometer Testing

BORING IS 250' EAST OF PROPOSED LOCATION PER REQUIREMENT OF LANDOWNER. NEW LOCATION IS APPROXIMATELY 15' TO 20' HIGHER IN ELEVATION.

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

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

GEOTECHNICAL LABORATORY TESTING SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S2-0016

HDD No.	Test Boring No.	Sample No.	Depth of Sample (ft.) From	Depth of Sample (ft.) To	Water Content, % (ASTM D2216)	Percent Silts/Clays, % (ASTM D1140)	Atterburg Limits (ASTM D4318) Liquid Limit, %	Atterburg Limits (ASTM D4318) Plastic Limit, %	Atterburg Limits (ASTM D4318) Plasticity Index, %	USCS Classif. (ASTM D2487)
S2-0016	SB-01	1	3.0	4.9	7.0	36.4	-	-	-	-
		2	8.0	10.0	9.0	39.4	32	25	7	SM
		3	13.0	14.0	5.3	32.5	-	-	-	-
		4	18.0	18.9	7.0	40.9	33	25	8	SM
		5	23.0	23.9	7.4	38.2	-	-	-	-
	SB-02	1	3.0	5.0	6.1	24.2	-	-	-	-
		2	8.0	10.0	9.2	13.4	-	-	-	-
		3	13.0	15.0	15.1	46.0	34	26	8	SM
		4	18.0	19.3	10.6	28.1	-	-	-	-
		5	23.0	24.9	11.2	44.2	36	26	10	SM
		6	28.0	28.9	6.7	45.2	-	-	-	-

Notes:

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

REGIONAL GEOLOGY SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S2-0016

HDD No.	NAME	BORING NO.	REGIONAL GEOLOGY DESCRIPTION	GENERAL TOPOGRAPHIC SETTING	BEDROCK FORMATION	GENERAL ROCK TYPE	APPROX MAX FM THICKNESS (FT)	DEPTH TO ROCK (Ft bgs) based on nearby well drilling logs	NOTES / COMMENTS
S2-0016	Livermore	SB-01	**Glenshaw Formation** - Cyclic sequences of shale, sandstone, red beds, and thin limestone and coal; includes four marine limestone or shale horizons; red beds are involved in landslides; base is at top of Upper Freeport coal.	Downward slope	Glenshaw	Shale-sandstone with limestone-clastic-coal	280-375	10-30	
		SB-02	**Casselman Formation** - Cyclic sequences of shale, siltstone, sandstone, red beds, thin, impure limestone, and thin, nonpersistent coal; red beds are associated with landslides; base is at top of Ames limestone.	Upland	Casselman	Shale-sandstone with limestone-clastic-coal	236-525	7-14	Yields range from 5-10 gpm (note: only 3 wells within 1-2 mile radius)

TEST BORING LOCATION PLAN

N

APPROXIMATE BORING LOCATION

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

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

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

TEST BORING LOCATION PLAN

Livermoore Road HDD Cores B2-5W and B2-5E
PA-WM2-0093.0000-RD
Westmoreland County, Pennsylvania

Exhibit

A-2

EXPLORATION RESULTS

BORING LOG NO. B2-5W Livermoore Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION PA-WM2-0093.0000-RD
20170912
Latitude: 40.44165° Longitude: -79.3471°

Approximate Surface Elev: 1037 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
		GRAVELLY LEAN CLAY WITH SAND (CL), with sandstone fragments, reddish brown, stiff to very stiff					
			16	9-10-11 N=21			2.5
			14	7-10-11 N=21			1.0
			14	6-8-9 N=17			0.5
18.5	1018.5+/-						
		Weathered rock	2	50/2"			
20.3	1016.5+/-						
		Run 1, Moderately hard, slightly weathered, dark gray, SHALE interbedded with sandstone, carbonaceous, very thin bedding, primary joint set, low angle, very close to close spacing, rough, planar, fresh,	23		28	3.25 3.5	
22.2	1015+/-	slightly open; secondary joint set, high angle, moderately close spacing, rough, undulating, open, iron-stained					
		Run 2, Similar	54		7	0.75 1.25 1.5 2 2.25	
27.2	1010+/-						
		Run 3, Similar From 29.1 to 30.9 feet: Calcareous zone	45		25	4.25 3.25 2.75	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:
Offset 35 feet west to avoid pipeline

Additional water level observation:
49.4' AB

WATER LEVEL OBSERVATIONS

- *10.5' on 9/26/17*
- *25.2' on 9/27/17*
- *49.9' on 9/28/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-25-2017 | Boring Completed: 09-28-2017

Drill Rig: Diedrich D-50 | Driller: Terra Testing, Inc.

Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B2-5W Livermoore Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION PA-WM2-0093.0000-RD
20170912
Latitude: 40.44165° Longitude: -79.3471°
Approximate Surface Elev: 1037 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
Run 3, Similar From 29.1 to 30.9 feet: Calcareous zone *(continued)*					45			2.75 3.25	
32.2	1005+/-								
Run 4, Similar to 32.8 feet At 32.8 feet: Moderately hard, slightly weathered, dark gray, SHALE interbedded with occasional calcareous nodules, very thin bedding, primary joint set, low angle, rough, planar, fresh, slightly open		35			60		58	3 2.5 3.25 2.25 2	
37.2	1000+/-								
Run 5, Similar to 37.5 feet At 37.5 feet: Soft, severely weathered, gray to reddish brown, MUDSTONE, very thin bedding, primary joint set, moderately dipping, close to moderately close spacing, rough, planar, slightly weathered, tight, clay-filled; secondary joint set, low angle, close to very close spacing, planar, rough, slightly open, clay-filled		40			43		25	2.5 2.25 2.25 2.25 2	
42.2	995+/-								
Run 6, Similar		45			54		60	2.5 3 2.75 3.25 3.25	
47.2	990+/-								
Run 7, Similar		50	▼		47		33	3.25 3 3.75 3.25 4.25	
52.2	985+/-								
Run 8, Similar		55			47		63	3.5 3 3 2.75 3.25	
57.2	980+/-								
		60			28		0	4.75 6.25 3.75	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:
Additional water level observation:
49.4' AB

WATER LEVEL OBSERVATIONS

- *10.5' on 9/26/17*
- *25.2' on 9/27/17*
- *49.9' on 9/28/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-25-2017 | Boring Completed: 09-28-2017
Drill Rig: Diedrich D-50 | Driller: Terra Testing, Inc.
Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B2-5W Livermoore Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION PA-WM2-0093.0000-RD
20170912
Latitude: 40.44165° Longitude: -79.3471°
Approximate Surface Elev: 1037 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Run / Description	RECOVERY (In.)	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
62.2	975+/-	Run 9, Soft, very severely weathered, reddish brown to gray, MUDSTONE, very thin bedding, primary joint set, low angle, close to very close spacing, planar, rough, fresh, slightly open; secondary joint set, moderately dipping, close spacing, fresh, planar, tight to slightly open *(continued)*	28		4.75 4	
67.2	970+/-	Run 10, Similar	42	8	3.25 3.25 3.25 3.75 3.25	
72.2	965+/-	Run 11, Similar to 67.4 feet At 67.4 feet: Moderately hard, slightly weathered, gray, MUDSTONE interbedded with shale, thin bedding, primary joint set, low angle, close to very close spacing, rough, planar, fresh, slightly open	60	63	2.5 2.25 2.25 1.5 1.75	
77.2	960+/-	Run 12, Similar From 76.1 to 76.4 feet: High angle joint, rough, fresh, open	60	90	1.75 1.25 2 1.75 2.25	
82.2	955+/-	Run 13, Similar to 78.6 feet From 77.6 to 78.1 and 78.2 to 78.6 feet: High angle joints, rough, fresh, open At 78.6 feet: Moderately hard, slightly weathered, gray, fine to medium-grained SANDSTONE, thin bedding, primary joint set, low angle, close spacing, rough, planar, fresh, slightly open; secondary joint set, high angle, rough, stepped, fresh, open	60	23	2 2 1.75 1.25 1.75	
87.2	950+/-	At 81.7 feet: Soft to moderately hard, moderately to severely weathered, gray, SHALE, very thin bedding, primary joint set, low angle, close to very close spacing, planar, smooth, tight, clay-filled Run 14, Similar	43	7	3.75 5.75 5.25 3.25 3.75	
			54	58	3.25 3 3	

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

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:
Additional water level observation:
49.4' AB

WATER LEVEL OBSERVATIONS

- *10.5' on 9/26/17*
- *25.2' on 9/27/17*
- *49.9' on 9/28/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-25-2017 | Boring Completed: 09-28-2017
Drill Rig: Diedrich D-50 | Driller: Terra Testing, Inc.
Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B2-5W Livermoore Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION PA-WM2-0093.0000-RD
20170912
Latitude: 40.44165° Longitude: -79.3471°
Approximate Surface Elev: 1037 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Run / Description	DEPTH (Ft.)	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
		Run 15, Similar to 88.0 feet		54		3.25 3.75
92.2	945+/-	At 88.0 feet: Moderately hard, slightly weathered, gray, SHALE interbedded with siltstone, very thin bedding, primary joint set, low angle, close to moderately close spacing, planar, smooth, clay-filled *(continued)*	95	60	15	3.75 4.5 5 5.25 4.75
97.2	940+/-	At 91.9 feet: Soft to moderately hard, severely weathered, reddish brown to gray, MUDSTONE, very thin bedding, primary joint set, low angle, close to very close spacing, planar, smooth, tight, clay-filled; secondary joint set, moderately dipping, moderately close, rough, planar, fresh, slightly open				
		Run 16, Similar				
		Run 17, Similar	100	36	13	5.75 6.25 5.25 4.5 8.75
102.2	935+/-					
		Run 18, Similar	105	42	25	5.25 4.25 5 5 5.25
107.2	930+/-					
		Run 19, Similar to 109.6 feet				
112.2	925+/-	At 109.6 feet: Moderately hard, slightly weathered, gray, SILTSTONE interbedded with shale and occasional calcareous nodules, thin bedding, primary joint set, low angle, close spacing, planar, rough, fresh, slightly open	110	56	50	3.5 2.75 2.75 2.25 2.5
		Run 20, Similar	115	58	43	3.75 3.25 3.25 2.75 3.25
117.2	920+/-					
		Run 21, Similar	120	60	73	2.5 2.25 2.25

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:
Additional water level observation:
49.4' AB

WATER LEVEL OBSERVATIONS

- *10.5' on 9/26/17*
- *25.2' on 9/27/17*
- *49.9' on 9/28/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-25-2017 | Boring Completed: 09-28-2017
Drill Rig: Diedrich D-50 | Driller: Terra Testing, Inc.
Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B2-5W Livermoore Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION PA-WM2-0093.0000-RD
20170912
Latitude: 40.44165° Longitude: -79.3471°
Approximate Surface Elev: 1037 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
	Run 21, Similar *(continued)*				2 1.25
122.2	915+/-		60		
	Run 22, Similar to 124.3 feet At 124.3 feet: Moderately hard, fresh, gray, fine-grained, SANDSTONE, thin bedding, primary joint set, low angle, wide to moderately close spacing, planar, rough, fresh, moderately open	125	60	95	1.5 1.25 0.75 1 0.75
127.2	910+/-				
	Run 23, Similar	130	60	100	0.75 1 1 1.25 1
132.2	905+/-				
	Run 24, Similar	135	60	100	1.25 1 1 1 1
137.2	900+/-				
	Run 25, Similar	140	60	100	1.75 1.5 1.25 1.75 1.25
142.2	895+/-				
	Run 26, Similar to 146.4 feet At 146.4 feet: Moderately hard, fresh, dark gray, SHALE interbedded with siltstone, carbonaceous, intact	145	60	100	1.5 1.25 1.25 1 1.75
147.2	890+/-				
	Run 27, Similar	150	60	100	1.5 1.25 1.25

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:
Additional water level observation:
49.4' AB

WATER LEVEL OBSERVATIONS

- *10.5' on 9/26/17*
- *25.2' on 9/27/17*
- *49.9' on 9/28/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-25-2017 | Boring Completed: 09-28-2017
Drill Rig: Diedrich D-50 | Driller: Terra Testing, Inc.
Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B2-5W Livermoore Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION PA-WM2-0093.0000-RD
20170912
Latitude: 40.44165° Longitude: -79.3471°
Approximate Surface Elev: 1037 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
Run 27, Similar *(continued)*									
152.2	885+/-				60			1.25 1.25	
Run 28, Similar		155							
157.2	880+/-				60		100	1.75 1.25 1.25 1.25 1	
Run 29, Similar		160							
162.2	875+/-				60		100	1.5 1.5 1.75 1.25 1.25	
Run 30, Similar		165							
167.2	870+/-				60		100	2 1.5 1.25 1.25 1.5	
Boring Terminated at 167.2 Feet									

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

Additional water level observation:
49.4' AB

WATER LEVEL OBSERVATIONS

- *10.5' on 9/26/17*
- *25.2' on 9/27/17*
- *49.9' on 9/28/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-25-2017 | Boring Completed: 09-28-2017

Drill Rig: Diedrich D-50 | Driller: Terra Testing, Inc.

Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B2-5E Livermoore Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION PA-WM2-0093.0000-RD
20170912
Latitude: 40.442428° Longitude: -79.33859°
Approximate Surface Elev: 1173 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
		LEAN CLAY (CL), with rock fragments, trace organic matter, orange-brown, stiff to hard								
			5			17	5-12-20 N=32			3.25
			10			18	6-6-6 N=12			
12.8	1160+/-	**POORLY GRADED SAND (SP)**, with clay, brown to gray				2	50/2"			
		Run 1, Medium to hard, moderately to moderately severely weathered, gray with reddish brown, fine-grained SANDSTONE, thin bedding, moderately dipping to vertical joints, close spacing, slightly open to open	15			55		7	2 1 1 0.75 1	
17.8	1155+/-									
		Run 2, Medium to hard, moderately severely to severely weathered, gray with reddish brown, fine-grained SANDSTONE, thin bedding, very close to close spacing, slightly open to moderately wide	20			50		0	4.75 3.5 3.75 4.5 2.25	
22.8	1150+/-									
		Run 3, Similar	25			38		0	3.75 3.25 2.75 3 5	
27.8	1145+/-									
			30			47			5 3	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:
Additional water level observation:
126' on 9/22/17

WATER LEVEL OBSERVATIONS

- 34' on 9/19/17
- 119.4' on 9/20/17
- 127' on 9/21/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-16-2017 | Boring Completed: 09-22-2017
Drill Rig: Diedrich D-50 | Driller: Terra Testing, Inc.
Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B2-5E Livermoore Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION PA-WM2-0093.0000-RD
20170912
Latitude: 40.442428° Longitude: -79.33859°
Approximate Surface Elev: 1173 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
		Run 4, Similar to 28.4 feet From 28.4 to 31.2 feet: Soft, severely weathered, gray MUDSTONE, very thin bedding, close spacing, open to moderately wide				47		10	3 1.5 2.5	
32.8	1140+/-	From 31.2 to 32.8 feet: Hard, moderately weathered, gray SILTSTONE interbedded with limestone, thin bedding, close spacing, moderately open *(continued)*		▽						
		Run 5, Hard, moderately to severely weathered, gray SILTSTONE interbedded with limestone, very thin bedding, primary joint set, moderately dipping, close spacing, open to moderately wide; secondary joint set, high angle to vertical, close spacing, moderately wide, iron staining	35			45		23	4.75 5.25 3 3.5 3.25	
37.8	1135+/-	At 33.6 feet: 1-inch clay seam Run 6, Similar, primary joint set, low angle								
42.8	1130+/-		40			57		20	3.25 3 2.5 3 3	
		Run 7, Soft to hard, moderately to severely weathered, gray with black, interbedded SILTSTONE and MUDSTONE, close joint spacing, moderately open to open At 43.0 and 44.2 feet: Gray clay seams From 45.4 to 47.8 feet: Weathered MUDSTONE	45			56		7	4 2.5 2.5 2.75 2.5	
47.8	1125+/-	Run 8, Hard, slightly weathered, gray SILTSTONE, moderately dipping, close joint spacing, slightly to moderately open				60		86	1.5 1.25 1.5 1 1.25	
52.8	1120+/-	Run 9, Similar From 54.5 to 54.8 feet: High angled joints, iron stained	50							
			55			60		88	1.75 1.25 1.5 1.25 1.25	
57.8	1115+/-	Run 10, Similar, close to moderately close joint spacing At 57.9, 60.1, and 60.4 feet: Iron stained joints				60			1.75 0.75	
			60							

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:
Additional water level observation:
126' on 9/22/17

WATER LEVEL OBSERVATIONS

- ▽ *34' on 9/19/17*
- ▽ *119.4' on 9/20/17*
- ▼ *127' on 9/21/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-16-2017 | Boring Completed: 09-22-2017
Drill Rig: Diedrich D-50 | Driller: Terra Testing, Inc.
Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B2-5E Livermoore Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION PA-WM2-0093.0000-RD
20170912
Latitude: 40.442428° Longitude: -79.33859°
Approximate Surface Elev: 1173 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
	Run 10, Similar, close to moderately close joint spacing At 57.9, 60.1, and 60.4 feet: Iron stained joints *(continued)*		60	85	2 1 2
62.8	1110+/-				
	Run 11, Similar, low angle, close to moderately close joint spacing	65	60	100	1.25 1.5 1.5 1 1.5
67.8	1105+/-				
	Run 12, Similar, close to moderately close spacing At 67.8 feet: High angled joint, iron stained	70	60	80	1.5 1 2.75 1.5 1..5
72.8	1100+/-				
	Run 13, Similar to 73.5 feet At 73.5 feet: Hard, slightly weathered, gray and gray with black SILTSTONE interbedded with shale, low angle to high angle, close to moderately close joint spacing, slightly open to open	75	59	92	2.75 1.5 2.75 1.5 1.5
77.8	1095+/-				
	Run 14, Hard, slightly weathered, black with gray seams, carbonaceous SHALE interbedded with siltstone, very thin bedding, close to moderately close joint spacing, slightly open	80	60	100	1.25 1.25 1.25 1 1
82.8	1090+/-				
	Run 15, Similar	85	60	95	1 1 1.25 1 0.75
87.8	1085+/-				
	Run 16, Similar, moderately dipping	90	59		1.25 1

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:
Additional water level observation:
126' on 9/22/17

WATER LEVEL OBSERVATIONS

- 34' on 9/19/17
- 119.4' on 9/20/17
- 127' on 9/21/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-16-2017 | Boring Completed: 09-22-2017
Drill Rig: Diedrich D-50 | Driller: Terra Testing, Inc.
Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B2-5E Livermoore Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION PA-WM2-0093.0000-RD
20170912
Latitude: 40.442428° Longitude: -79.33859°
Approximate Surface Elev: 1173 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
Run 16, Similar, moderately dipping *(continued)*									
92.8	1080+/-				59		93	1 1 1	
Run 17, Similar		95			60		100	1.25 1 1 1 1	
97.8	1075+/-								
Run 18, Similar		100			60		100	2.25 1 1 1 1	
102.8	1070+/-								
Run 19, Similar		105			60		75	2 1 1 2 1.75	
107.8	1065+/-								
Run 20, Similar At 112.5 feet: High angled joint, iron stained		110			58		33	2.25 2.5 1.5 1 1.25	
112.8	1060+/-								
Run 21, Medium to hard, severely to slightly weathered, gray, fine-grained SANDSTONE, thin bedding, close to moderately close joint spacing, moderately open to moderately wide From 112.8 to 113.8 and 114.3 to 114.8 feet: Vertical joints, iron stained		115			55		56	4 2 2 1.5 1.25	
117.8	1055+/-								
Run 22, Hard, slightly weathered, light gray with dark gray, fine-grained SANDSTONE interbedded with black shale, thin bedding, close to moderately close joint spacing, slightly open		120	▽		60			1.75 1	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:
Additional water level observation:
126' on 9/22/17

WATER LEVEL OBSERVATIONS

- ▽ *34' on 9/19/17*
- ▽ *119.4' on 9/20/17*
- ▼ *127' on 9/21/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-16-2017 | Boring Completed: 09-22-2017
Drill Rig: Diedrich D-50 | Driller: Terra Testing, Inc.
Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B2-5E Livermoore Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION PA-WM2-0093.0000-RD
20170912
Latitude: 40.442428° Longitude: -79.33859°
Approximate Surface Elev: 1173 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
	Run 22, Hard, slightly weathered, light gray with dark gray, fine-grained SANDSTONE interbedded with black shale, thin bedding, close to moderately close joint spacing, slightly open *(continued)*	60	43	1 1.5 1
122.8	1050+/-			
	Run 23, Similar	60	86	2.25 1.25 1.75 1.5 1.25
127.8	1045+/-			
	Run 24, Similar	60	86	2 1 1 1 1
132.8	1040+/-			
	Run 25, Soft to hard, slightly to moderately weathered, gray, SILTSTONE interbedded with limestone and gray clay seams, thin bedding, primary joint set, moderately dipping, close spacing, slightly open; secondary joint set, high angle, close spacing, slightly to moderately open	60	75	1.25 1 1 2 1
137.8	1035+/-			
	Run 26, Similar to 138.6 feet At 138.6 feet: Soft to hard, moderately to severely weathered, gray SILTSTONE with gray clay seams, very thin bedding, primary joint set, high angle, very close to close spacing, slightly to moderately open; secondary joint set, low angle to horizontal, close spacing, moderately open to open	60	20	1.5 2.5 1 2 2.5
142.8	1030+/-			
	Run 27, Similar to 146.2 feet At 146.2 feet: Hard, moderately to severely weathered, very dark gray MUDSTONE interbedded with limestone, very thin bedding, primary joint set, vertical, close spacing, moderately open to open; secondary joint set, high angle, close spacing, moderately open to open From 143 to 143.6 and at 145.1 feet: Clay seams less than 1-inch thick	60	62	2.75 2 1.75 2.25 3.75
147.8	1025+/-			
		57		4.75 2.25

DEPTH (Ft.): 125, 130, 135, 140, 145, 150

WATER LEVEL OBSERVATIONS: ▼

SAMPLE TYPE: solid bar

FIELD TEST RESULTS:

Penetrometer Test (tsf):

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:
Additional water level observation:
126' on 9/22/17

WATER LEVEL OBSERVATIONS

- 34' on 9/19/17
- 119.4' on 9/20/17
- 127' on 9/21/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-16-2017 | Boring Completed: 09-22-2017
Drill Rig: Diedrich D-50 | Driller: Terra Testing, Inc.
Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B2-5E Livermoore Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION PA-WM2-0093.0000-RD
20170912
Latitude: 40.442428° Longitude: -79.33859°
Approximate Surface Elev: 1173 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
		Run 28, Medium hard, moderately weathered, gray SILTSTONE interbedded with limestone, thin bedding, primary joint set, horizontal, close spacing, slightly to moderately open; secondary joint set, moderately dipping, close spacing, slightly open	57	68	1.75 1.5 2
152.8	1020+/-				
		At 151.6 feet: Clay seam less than 1-inch thick *(continued)*			
		Run 29, Soft to medium, moderately to moderately severely weathered, gray MUDSTONE interbedded with limestone, thin bedding, primary joint set, moderately dipping, close to moderately close spacing, moderately open to open; secondary joint set, vertical, close spacing, slightly open to open	60	82	3 3.25 3 1.25 2.5
157.8	1015+/-				
		Run 30, Similar, primary joint set, horizontal, very close to close spacing, moderately open to open; secondary joint set, moderately dipping, very close spacing, moderately open From 157.8 to 158.3 feet: Clay seams less than 1-inch thick	53	30	4.5 3.75 4.75 3 3
162.8	1010+/-				
		Run 31, Similar, primary joint set, horizontal, close spacing, moderately open to moderately wide; secondary joint set, moderately dipping, close spacing, moderately open to open From 163.1 to 163.3 and at 163.6 and 163.8 feet: Clay seams less than 1-inch thick	59	35	5.25 5 4.25 3.75 3.75
167.8	1005+/-				
		Run 32, Similar to 170.3 feet From 170.3 to 172.8 feet: SILTSTONE	50	40	8 7 5.5 2.5 2
172.8	1000+/-				
		Run 33, Hard, slightly to moderately weathered, bluish gray, fine-grained SANDSTONE, thin bedding, primary joint set, horizontal, close to moderately close spacing, slightly open to moderately wide; secondary joint set, high angle, close spacing, slightly open to open	60	90	1.5 2 1.5 1.25 1.25
177.8	995+/-				
		Run 34, Similar, interbedded with siltstone, primary joint set, horizontal, slightly open, close spacing, slightly open	58		2 3

DEPTH (Ft.): 155, 160, 165, 170, 175, 180

WATER LEVEL OBSERVATIONS | SAMPLE TYPE | FIELD TEST RESULTS | Penetrometer Test (tsf)

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:
Additional water level observation:
126' on 9/22/17

WATER LEVEL OBSERVATIONS

- 34' on 9/19/17
- 119.4' on 9/20/17
- 127' on 9/21/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-16-2017 | Boring Completed: 09-22-2017
Drill Rig: Diedrich D-50 | Driller: Terra Testing, Inc.
Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B2-5E Livermoore Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION PA-WM2-0093.0000-RD
20170912
Latitude: 40.442428° Longitude: -79.33859°
Approximate Surface Elev: 1173 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
		Run 34, Similar, interbedded with siltstone, primary joint set, horizontal, slightly open, close spacing, slightly open *(continued)*				58		92	2.75 1.5 1.5	
182.8	990+/-									
		Run 35, Hard, slightly weathered, bluish gray with red seams SILTSTONE, thin bedding, primary joint set, horizontal, close to moderately close spacing, slightly open	185			60		100	2 1.5 1.75 1.5 1.5	
187.8	985+/-									
		Run 36, Medium to hard, slightly to moderately weathered, red with gray MUDSTONE, thin bedding, primary joint set, horizontal, close spacing, moderately open to open; secondary joint set, low angle, very close to close, moderately open to open	190			58		67	3.5 4 4.75 3 3	
192.8	980+/-									
		Run 37, Similar, moderately to severely weathered	195			46		25	7.25 6 5 3.5 4	
197.8	975+/-									
		Run 38, Similar, moderately to severely weathered	200			50		25	9.75 8.5 5.5 3.25 3.75	
202.8	970+/-									
		Run 39, Medium to soft, moderately to severely weathered, red with gray MUDSTONE, thin bedding, primary joint set, horizontal, close spacing, moderately open to open; secondary joint set, high angle, very close to close, moderately open to moderately wide	205			60		72	8 8 3 5 3.5	
207.8	965+/-									
		Run 40, Similar, secondary joints, close to moderately close spacing	210			60			4.25 3	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:
Additional water level observation:
126' on 9/22/17

WATER LEVEL OBSERVATIONS

- 34' on 9/19/17
- 119.4' on 9/20/17
- 127' on 9/21/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-16-2017 | Boring Completed: 09-22-2017
Drill Rig: Diedrich D-50 | Driller: Terra Testing, Inc.
Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B2-5E Livermoore Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION PA-WM2-0093.0000-RD
20170912
Latitude: 40.442428° Longitude: -79.33859°
Approximate Surface Elev: 1173 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description	DEPTH (Ft.)	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
		Run 40, Similar, secondary joints, close to moderately close spacing *(continued)*		60	65	2.25 2.5 3
212.8	960+/-					
		Run 41, Hard, slightly weathered, gray, fine-grained SANDSTONE with interbedded limestone, thin bedding, primary joint set, low angle, moderately close spacing, slightly open	215	60	98	1.5 1 1 1 1
217.8	955+/-					
		Run 42, Similar, primary joint set, horizontal, close spacing, slightly open to open; secondary joint set, low angle, close spacing, slightly open From 220.6 to 220.8 feet: Vertical joint	220	60	70	2 1.75 1 0.75 1.5
222.8	950+/-					
		Run 43, Similar, primary joint set, horizontal, close to moderately close, slightly open	225	60	100	2.5 2 1 1 1.25
227.8	945+/-					
		Run 44, Similar, primary joint set, horizontal, moderately close, slightly open	230	60	100	2 1.25 1 1 1.25
232.8	940+/-					
		Run 45, Hard, slightly weathered, gray, fine-grained SANDSTONE, thin bedding, wide spacing, tight	235	60	100	1 1.25 1.25 1 1
237.8	935+/-					
		Run 46, Hard, slightly weathered, gray, fine-grained SANDSTONE, thin bedding, primary joint set, horizontal, close to moderately close spacing, slightly to moderately open	240	58		1.25 1.25

Penetrometer Test (tsf)

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:
Additional water level observation:
126' on 9/22/17

WATER LEVEL OBSERVATIONS

- 34' on 9/19/17
- 119.4' on 9/20/17
- 127' on 9/21/17

Terracon
201 Hammer Mill Rd
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Run 46, Hard, slightly weathered, gray, fine-grained SANDSTONE, thin bedding, primary joint set, horizontal, close to moderately close spacing, slightly to moderately open *(continued)*			58	92	1 1 1
242.8	930+/-				
Run 47, Similar		245	60	93	1.5 1 1.25 1 0.75
247.8	925+/-				
Run 48, Similar, primary joint set, high angle, close to moderately close spacing, slightly to moderately open		250	60	100	1.25 1.5 1.25 1 1
252.8	920+/-				
Run 49, Similar		255	60	60	1.5 1 1 1 1.5
257.8	915+/-				
Run 50, Hard, slightly to moderately weathered, black, SILTSTONE interbedded with shale, medium bedding, primary joint set, horizontal, close spacing, slightly to moderately open At 260.3 feet: Seam of gray clay less than 1-inch thick		260	60	77	5 2.75 2.25 3.75 2.25
262.8	910+/-				
Run 51, Similar, moderately close spacing		265	57	95	2.5 1.5 3 2 2
267.8	905+/-				
Run 52, Similar, very close to wide spacing		270	60		3 1.75

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Notes:
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DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
	Run 52, Similar, very close to wide spacing *(continued)*				2 1.5 1.25
272.8	900+/-		60	95	
	Run 53, Similar, moderately close spacing	275			2.25 1.25 1.75 1.5 1.25
277.8	895+/-		60	100	
	Run 54, Similar, primary joint set, horizontal, close to moderately close spacing, slightly open; secondary joint set, high angle, moderately close, open	280			2.25 1.75 2 1.5 1.5
282.8	890+/-		60	100	
	Run 55, From 282.8 to 286.3 feet: Hard, slightly to moderately weathered, black with gray, SHALE with interbedded siltstone, very thin to medium bedding From 286.3 to 287.8 feet: SILTSTONE with interbedded shale, primary joint set, horizontal, very close to moderately close spacing, slightly open to open, secondary joint set, high angle, close spacing, moderately open	285			3.5 1.25 2 2.5 4
287.8	885+/-		59	83	
	At 286.7 feet: Seam of clay less than 1-inch thick Run 56, Soft to hard, slightly to severely weathered, gray with black, SILTSTONE with interbedded shale and sandstone and gray clay seams, very thin bedding, primary joint set, horizontal, close spacing, slightly to moderately open Complete loss of water circulation from 287.8 to 302.8 feet	290			3 2.75 2 3.25 3
292.8	880+/-		60	63	
	Run 57, Medium to hard, slightly to severely weathered, gray with black, SILTSTONE with interbedded shale, very thin to thin bedding, primary joint set, horizontal, very close to close spacing, slightly to moderately open; secondary joint set, moderately dipping, very close to close, moderately open to open	295			2.75 3.25 4.25 4.5 4.25
297.8	875+/-		51	27	
		300	60		4.25 2.25

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

Hammer Type: Automatic

Advancement Method:
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Abandonment Method:
Grouted to surface

Notes:
Additional water level observation:
126' on 9/22/17

WATER LEVEL OBSERVATIONS

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DEPTH	ELEVATION (Ft.)	GRAPHIC LOG	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
						60		63	2.75 3 1.75	
302.8	870+/-									

Run 58, Soft to hard, slightly to severely weathered, gray with black, fine-grained SANDSTONE, thin bedding, primary joint set, low angle, very close to close spacing, slightly open to open

From 297.8 to 298.5 and at 299.4 feet: Gray clay seams less than 1-inch thick *(continued)*

Boring Terminated at 302.8 Feet

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

Additional water level observation:
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WATER LEVEL OBSERVATIONS

- *34' on 9/19/17*
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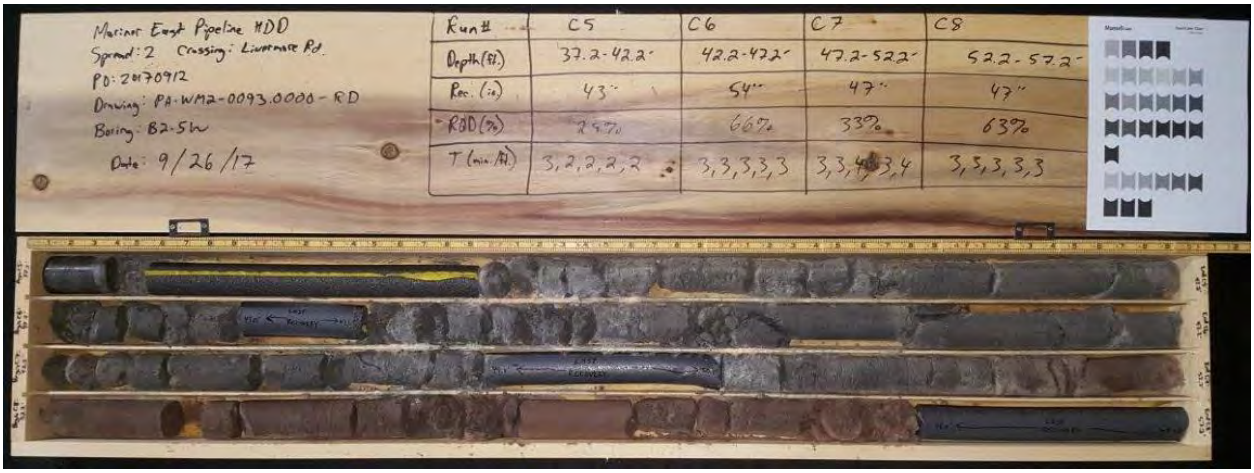
Photograph 1: B2-5W, Samples C-1 to C-4 (20.3 to 37.2 feet)



Photograph 2: B2-5W, Samples C-5 to C-8 (37.2 to 57.2 feet)

Photograph 3: B2-5W, Samples C-9 to C-12 (57.2 to 77.2 feet)

Photograph 4: B2-5W, Samples C-13 to C-16 (77.2 to 97.2 feet)

Photograph 5: B2-5W, Samples C-17 to C-20 (97.2 to 117.2 feet)

Photograph 6: B2-5W, Samples C-21 to C-24 (117.2-137.2 feet)

Photograph 7: B2-5W, Samples C-25 to C-28 (137.2 to 157.2 feet)

Photograph 8: B2-5W, Samples C-29 to C-30 (157.2 to 167.2 feet)

Photograph 1: B2-5E, Samples C-1 to C-4 (12.8 to 32.8 feet)

Photograph 2: B2-5E, Samples C-5 to C-8 (32.8 to 52.8 feet)

Photograph 3: B2-5E, Samples C-9 to C-12 (52.8 to 72.8 feet)

Photograph 4: B2-5E, Samples C-13 to C-16 (72.8 to 92.8 feet)

Photograph 5: B2-5E, Samples C-17 to C-20 (92.8 to 112.8 feet)

Photograph 6: B2-5E, Samples C-21 to C-24 (112.8 to 132.8 feet)

Photograph 7: B2-5E, Samples C-25 to C-28 (132.8 to 152.8 feet)

Photograph 8: B2-5E, Samples C-29 to C-32 (152.8 to 172.8 feet)

Photograph 9: B2-5E, Samples C-33 to C-36 (172.8 to 192.8 feet)

Photograph 10: B2-5E, Samples C-37 to C-40 (192.8 to 212.8 feet)

Photograph 11: B2-5E, Samples C-41 to C-44 (212.8 to 232.8 feet)

Photograph 12: B2-5E, Samples C-45 to C-48 (232.8 to 252.8 feet)

Photograph 13: B2-5E, Samples C-49 to C-52 (252.8 to 272.8 feet)

Photograph 14: B2-5E, Samples C-53 to C-56 (272.8 to 292.8 feet)

Photograph 15: B2-5E, Samples C-57 to C-58 (292.8 to 302.8 feet)