

**HORIZONTAL DIRECTIONAL DRILL ANALYSIS
STATE ROUTE 88 (SR-88)/WHEELING AND LAKE ERIE RAILROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E63-674
PA-WA-0171.0000-RR
(SPLP HDD# S1B-0120)**

SR-88/WHEELING AND LAKE ERIE RR CROSSING
PADEP SECTION 105 PERMIT NO.: E63-674
PA-WA-0171.0000-RR
(SPLP HDD# S1B-0120)

This reevaluation of the horizontal directional drill (HDD) installation of a 20-inch diameter pipeline, HDD No. S1B-0120, has been completed in accordance with paragraphs 4 and 5 of the Stipulated Order (Order) issued under Environmental Hearing Board Docket No. 2017-009-L. This HDD is number 1 on the list of HDDs included on Exhibit 2 of the Order.

The first attempted pilot hole for this HDD was initiated on May 27, 2017, from a west entry point towards the east. During the HDD attempt, five IRs were identified between the western entry/exit point and State Route 88, and due to these IRs, the drill was suspended on June 15, 2017. The entire HDD profile is underlain by the Pittsburgh Coal Company's Cincinnati Mine. Following an extensive geologic investigation of the effects of subsidence of the coal mine on the integrity of the overlying geology, the proposed HDD is being abandoned, and being replaced with a conventional construction plan consisting of open trench pipeline lay, one short conventional bore of a private road, and two FlexBors.

PIPE INFORMATION

20-Inch: 0.456 wall thickness; X-65

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

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 20-INCH

- Horizontal length: 2,170 foot (ft)
- Entry/Exit angle: 18 degrees
- Maximum Depth of cover: 190 ft
- Pipe design radius: 2,000 ft

GEOLOGIC AND HYDROGEOLOGIC ANALYSIS

Bedrock in the area of HDD S1B-0120 consists of cyclic sequences of sandstone, shale, claystone, limestone and coal of the Monongahela Group. The Monongahela Group is bounded up-section by the Waynesburg Formation and down-section by the Conemaugh Group. The lowest unit in the Waynesburg Formation is the Waynesburg Coal. The Monongahela Group is divided into two formations consisting of the Uniontown Formation up section and the Pittsburgh Formation, down section. The lowest unit in the Monongahela Group is the Pittsburgh Coal, which outcrops along the banks of Mingo Creek and the Monongahela River south and east of the Site. The Uniontown and Pittsburgh Formations consist of dense limestone and discontinuous shale, siltstone and sandstone (Newport, 1973).

The Benwood Limestone, Fishpot Limestone, and Redstone Limestone were identified in the stratigraphic sequence below HDD S1B-0120. However, karst features such as solution cavities and caves have not been identified in these carbonate beds in this portion of Washington County; therefore, no geophysics surveys were performed.

The Waynesburg Coal and the Uniontown Coal were mapped in the shallow rock sequence at HDD S1B-0120 (Roan, 1970). However, neither coal occurs in an economically viable thickness. Evidence of the coals may only be black or carbonaceous shales. Published documents do not show evidence of strip or deep mining in the area that correlates with these units (USGS, 1979).

The Pittsburgh Coal occurs below HDD S1B-0120 at elevations ranging from 800 ft above mean sea level (amsl) at the western end of HDD S1B-0120 to 760 ft amsl in on the eastern end. The Pittsburgh Coal, ranging from 4.5 feet to 5.5 feet thick across Union Township, was extensively mined across the area.

SR-88/WHEELING AND LAKE ERIE RR CROSSING
PADEP SECTION 105 PERMIT NO.: E63-674
PA-WA-0171.0000-RR
(SPLP HDD# S1B-0120)

The original profile (now abandoned) for HDD S1B-0120 passes over mined out sections of coal.

A review of the PADEP on-line records revealed a mine subsidence complaint was filed with the PADEP in the area of interest on January 1, 2001. The subsidence complaint was mapped between Mingo Church and the HDD S1B-0120 drill path. However, the available records do not indicate if the complaint was the result of a change in well water quality/quantity or an actual subsidence event involving damage to homes or property.

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

Coal Mining and Subsidence

The originally proposed HDD profile is underlain by the Pittsburgh Coal Company's Cincinnati Mine. The Cincinnati Mine operated in Union Township, Washington County in the early 1900's. The primary mining method was room and pillar mining. Mining was completed under the planned horizontal directional drill pipeline prior to 1913. According to an inspection report in the 1913 Bituminous Coal Mining Report of the Department of Mines of Pennsylvania (PA Mines Report, 1914), the Cincinnati Mine extracted the thin-vein Pittsburgh Coal at a mining height between five and six feet thick. Main entries were nine feet wide and production room entries were approximately twenty-four feet wide.

The mining development orientation followed the coal's main Butt and Face cleavage planes. Main entries were primarily used for developing areas for the highly productive rooms. These main entries were also used for men and material movement within the mines, for coal haulage and as air courses for mine ventilation. According to the 1914 report, these entries were nine feet wide. At that time mines did not use any roof bolts and the entries were solely supported by the large adjacent coal pillars that would remain after mine closure. The highly productive rooms were advanced to the right or left from the main entries. The 1914 report states that these entries were twenty-four feet wide. After each room had advanced to its planned length, which was approximately one-half way between main entries, the small support pillar between rooms was systematically removed (mined) as the miners retreated allowing the roof to collapse behind them. When this happened surface subsidence would occur. Most subsidence would occur almost immediately and all ground movements would be completed within a few weeks. The main Butt and Face entries needed to remain open for the duration of mining life and thus relatively large pillars were left between these entries as support. The surface above those pillars should remain stable from subsidence for the long term.

The bedrock above the mined areas behaves differently above the zone where the roof fails due to high extraction of coal or due to pillar failure. These zones depend on the width of the extraction and rock types. A caved zone occurs from the roof of the mined coal and typically extends upwards for 6 to 10 times the mining thickness (Kendorski, 2006). In the case of the Cincinnati Mine where the mined thickness is 5 to 6 feet, this zone would be from 30 to 60 feet above the top of coal. Bedrock in this zone would have extensive fracturing and sizable voids. Above the caved zone and extending for 24 to 30 times the mining thickness, a fractured zone would occur. In this zone, many fractures would be present but the rock strata would remain as a single unit without extensive dislocated rock or voids present. At the Cincinnati Mine, this zone would extend from 30-60 feet to 120-180 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. The dilated zone would have smaller fractures but the bedrock would remain as a single unit. At the Cincinnati Mine, this dilation zone would extend from 120-180 feet to 240-360 feet above the top of the coal. The zone above that is termed the constrained or bending zone where no fracturing would occur.

SR-88/WHEELING AND LAKE ERIE RR CROSSING
PADEP SECTION 105 PERMIT NO.: E63-674
PA-WA-0171.0000-RR
(SPLP HDD# S1B-0120)

Mine Pools

Regional mine pool maps for abandoned Pittsburgh coal mines in southwestern Pennsylvania were published in 2004 by the National Mine Reclamation Center at West Virginia University (<http://www.hrc.nrcce.wvu.edu/>). The area of HDD S1B-0120 appears on the Hackett and Monongahela, PA, Quadrangles overlying an area of abandoned deep Pittsburgh coal mines labeled "Courtney". The shading on the maps indicated the mines in this region are "not flooded or unknown", as opposed to "flooding or flooded" or "active mine". A mine discharge point is shown on the map approximately 1.0 miles east of HDD S1B-0120 near the west shore of the Monongahela River (on the Monongahela 7.5 min. quadrangle map) at an elevation of approximately 768 ft amsl.

The most recent geotechnical borings advanced at the site were performed by Intertek PSI in November 2017. Three borings were advanced beyond the depth of the abandoned Pittsburgh coal mine. In two of the borings (B-02A and B-03) the water levels in the boreholes dropped rapidly as the borings approached the roof of the mine void to an elevation a few feet above the top of the mine void. In the third boring (B-04) water was lost as the boring approached the roof of the mine and was not regained for the rest of the boring. These observations indicate a mine pool is likely present at HDD S1B-0120. The water level elevations in B-02A and B-03 were approximately 805 and 807 ft amsl, respectively. The lowest elevation of the 9/21/17 revision of the profile for HDD S1B-0120 is 818 ft amsl.

Two FlexBors and one road bore, connected by open trench construction, is proposed to replace an HDD at this location. The lowest elevations along the profiles for these borings would be approximately 960 ft amsl. Neither the HDD or alternative conventional borings would encounter the mine pool; therefore, there is no risk for creating a new mine discharge with the open cut/bore construction plan.

In theory, a new mine pool discharge could be created if a large volume loss of drilling fluids were to discharge to the pool and raise the mine pool elevation; however the replacement construction plan of open trench construction, one convention horizontal road bore, and two FlexBors do not used pressurized fluids; therefore there is no means to create a new mine pool discharge.

Subsidence Potential

Tetrattech mine engineers working for SPLP have completed an extensive study of the current conditions of the Cincinnati Mine and overlying geology in this section of the proposed pipeline installation.

As presented and discussed in the Tetrattech report provided as Attachment 2 of the Reevaluation Report, the mine maps are generally a reliable indication of the extent of what was mined. Tetrattech has reviewed several of the different maps available at the PA DEP California, Pennsylvania, mine map repository and the Pennsylvania Mine Map Atlas website. These all indicated the same depiction of the mine workings under the planned pipeline area.

The selected construction alternatives for this area includes open trench and Flexbor construction. Flexbor Crossings will be completed under Patterson Road and the Wheeling and Lake Erie Railroad. The first Crossing is 781 feet long and extends from Station 2+87 to Station 11+76. The second Flexbox crosses under Route 88 and a small stream. The second FlexBor is 189 feet long and extends from Station 17+90 to Station 19+82 as shown in the report. Figure 3 in the report shows the planned construction with the two Flexbor drills under the Wheeling and Lake Erie Railroad and Route 88 and the associated zones of strata fractures during subsidence. To be conservative the top of each zone is shown at the maximum estimated distance above the mine. Both Flexbor drills will pass through the top of the fractured zone. The first crossing however, is mostly in the dilated zone. None of the planned Flexbors will be in the caved zone.

SR-88/WHEELING AND LAKE ERIE RR CROSSING
PADEP SECTION 105 PERMIT NO.: E63-674
PA-WA-0171.0000-RR
(SPLP HDD# S1B-0120)

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 4 in the report. There are two primary areas of potential future subsidence. One area is centered at Station 13+00 and occurs within a retreat mined area that was not completely retreat mined based on the interpretation of seismic data. The increased subsidence at this location was estimated to be about 0.72 foot (8.6 inches). However, this location is under an area of the crossing where the new pipeline will be installed by open trench and falls outside the angle of draw for the Flexbor. The second area of increased subsidence occurs between Stations 19+00 and 26+00. This area is again located in a retreat mined area that was interpreted as not being completely retreat mined. The estimated additional subsidence at this area is estimated to be about 0.34 foot (4 inches), and occurs under a portion of the shorter and shallower Flexbor which is shown at the maximum extent of the fracture zone. The actual limit of the fracture zone may be below the bore elevation. The remainder of the pipeline under the crossings will be open trench installation.

Based upon the data obtained from the subsidence analysis, and the results of a Finite Elements Analysis (pipe stress), the pipeline engineers has concluded "no concern" regarding the open cut/horizontal bore/FlexBor construction plan. The findings by the pipeline engineers is included within the report provided in Attachment 2.

HYDROGEOLOGY, GROUND WATER, AND WELL PRODUCTION ZONES

There is very little primary porosity associated with the sedimentary rocks of western Pennsylvania for the storage and movement of groundwater. The primary occurrence of groundwater in the Monongahela Group is associated with the interconnected network of secondary porosity features characteristic of the bedrock. These include bedrock fractures that developed during folding and faulting (Newport, 1973) and bedding plane partings. Regional systematic joints within the bedrock are generally indicated by northwest and west-northwest trending (Nickelsen, Hough, 1967) fracture traces. In addition, a set of associated non-systematic joints are indicated by a series of fracture traces oriented north-northeast within straight segments of local stream valleys. These joint sets can represent preferred pathways of groundwater flow.

Groundwater was not observed during advancement of recent geotechnical cores. The west core was taken to 255 ft below ground surface (bgs). The east core sampling ended at 180 ft bgs. Water levels in the cores holes were gauged at the beginning of each day, and water was not detected.

A review of records in the Pennsylvania Groundwater Information System (PAGWIS) and PADEP eMAP databases for supply wells in Union Township, Washington County identified two water supply wells in vicinity to HDD S1B-0120. Based on the approximate ground surface elevations and these well records, the regional groundwater table is estimated to occur between approximately 910 and 920 feet amsl. According to Wagner (1975) water well yields in the area are relatively low, ranging from 0.2 to 15 gallons per minute (gpm). While well yields in the area should improve with increased well diameter, the yields generally do not improve with increased well depth. According to the PAGWIS records, both supply wells are 6-inches in diameter and have a maximum yield of 3 gpm.

Attachment 1 provides an extensive discussion on the hydrogeology of this location.

SR-88/WHEELING AND LAKE ERIE RR CROSSING
PADEP SECTION 105 PERMIT NO.: E63-674
PA-WA-0171.0000-RR
(SPLP HDD# S1B-0120)

INADVERTENT RETURNS DISCUSSION

As stated in the introduction of this HDD reanalysis, five IRs occurred during the first pilot hole attempt before the drill was suspended in June 2017. These events prompted the reanalysis of this HDD, with the first step of the reanalysis being the acquisition of new geotechnical cores to below the anticipated depth of HDD profile adjustment.

The pilot hole drill for this HDD crossing was still in the entry profile when abandoned and never progressed to the horizontal run of profile. In the original entry run, the depth of profile had a maximum depth of 51 ft and was at a lesser depth for much of its length.

As stated in the introduction, an extensive investigation of the subsurface geology has revealed that the proposed HDD profile, or any re-designed profile, would pass through extensively fractured bedrock resulting from subsidence of the coal mine. With this information SPLP has concluded that no practicable steps can be taken to meaningfully reduce the risks of an IR. Therefore, this HDD is being abandoned and replaced with a conventional construction open cut/bore/FlexBor construction plan.

ADJACENT FEATURES ANALYSIS

The crossing of stream S27 is located immediately west of and parallel to state route 88 (Union Street), approximately 250 feet north of the intersection with Mingo Church Road. Streams S28 and S127 have a confluence immediately east of Patterson Road, approximately 1,000 feet northeast of the intersection with state route 88, approximately 1.5 miles south of Finleyville, Pennsylvania.

This location is set primarily within agricultural lands, however there are industrial developments in the immediate vicinity. Thirteen homes and a church are located within 450 ft of the HDD profile. Potable water for these homes and facilities is provided by public services and private wells. During the initial planning stages SPLP sent letters to all landowners within 150 feet of the pipeline right-of-way (ROW) offering the opportunity to have any existing water sources (wells and springs) tested prior to the start of construction. No property owners accepted this initial offer of pre-construction sampling.

In accordance with the terms of the Order, SPLP previously identified all landowners with property located within 450 feet of the original HDD alignment. There are twenty-three landowners with property located within 450 feet of the HDD alignment. SPLP sent each of these landowners a notice letter via both certified and first class mail on October 30, 2017, that included an offer to sample the landowner's private water supply/well in accordance with the terms of the Order and the Water Supply Assessment, Preparedness, Prevention and Contingency Plan. The letter also requested that each landowner contact the Right-of-Way agent for the local area and provide SPLP with information regarding: (1) whether the landowner has a well; (2) where that well is located, and its depth and size if known; and (3) whether the landowner would like to have the well sampled. In accordance with paragraph 10 of the Order, copies of the certified mail receipts for the letters sent to landowners have been provided to Karyn Yordy, Executive Assistant, Office of Programs at the Department's Central Office.

As a result of additional geological investigations, the proposed HDD at this location is being abandoned, and will be replaced by a combination of conventional open cut construction, one conventional horizontal bore, and two FlexBors. The intended pilot process in advance of the FlexBor reaming is an "air hammer", therefore no pressurized drilling fluids will be used during the pilot phase. The Flexbor reaming process does not use pressurized bentonite based drilling fluids, but rather high volume air flows with minimal water injection, with the cuttings returning to the entry through an enclosed casing. As a result, the new construction plan substantially reduces the risk that pipeline construction will impact private water supplies.

SR-88/WHEELING AND LAKE ERIE RR CROSSING
PADEP SECTION 105 PERMIT NO.: E63-674
PA-WA-0171.0000-RR
(SPLP HDD# S1B-0120)

ALTERNATIVES ANALYSIS

As required by the Order, the reanalysis of S1B-0120 included an evaluation of conventional open cut alternatives and a re-route analysis. As part of the PADEP Chapter 105 permit process for the Mariner II East Project, SPLP developed and submitted for review a project-wide Alternatives Analysis. During the development and siting of the Project, SPLP considered a number of different routings, locations, and designs to determine whether there was a practicable alternative. SPLP performed this determination through a sequential review of routes and design techniques, which concluded with an alternative that has the least environmental impacts, taking into consideration cost, existing technology, and logistics. The baseline route provided for the pipeline construction was to cross every wetland and stream on the project by open cut construction procedures. The Alternatives Analysis submitted to PADEP conceptually analyzed the potential feasibility of any alternative to baseline route trenched resource crossings (e.g., reroute, conventional bore, HDD).

Open-cut Analysis

There are multiple surface and subsurface features to be considered when evaluating an open cut plan of construction to replace this HDD. In order from west to east, these include stream S27, a public water pipeline, a private gravel road, an Equigas pipeline, State Route 88, an Equitrans pipeline, the Wheeling and Lake Erie Railroad, stream S28, a storm sewer line, Patterson Road, a second Equigas pipeline, and stream S142. Excepting the railroad and the Equitrans pipeline, the majority of these are parallel to the crossings of State Route 88 and Patterson Road. All of these surface features are set below the surrounding topography.

Use of the open cut construction method across the entire current 2,170-foot-long crossing alignment is not technically feasible due to the requirements to use trenchless construction methods to install the 20-inch-diameter pipeline beneath the Wheeling and Lake Erie Railroad, as well as State Route 88 and Mingo Church Road. Therefore, any open cut alternative would require the use of trenchless construction methods to cross these three features at a minimum.

In addition, use of an open cut method across the entire alignment would result in direct but temporary and minor impacts to three streams (streams S27, S28, and S142) that are PADEP Chapter 93 designated Trout Stocked Fisheries. SPLP specifications require a minimum of 48-inches of cover over the installed pipeline beneath the bottom of the watercourse. To meet this cover requirement, during construction through streams S27, S28, and S142, an open cut workspace with a width of 75 feet would be required to accommodate the pipeline and provide sufficient space for trench excavation, spoil storage, and pipeline installation with sufficient separation from the existing 12-inch-diameter pipeline for integrity management. The assessed area of impact by this open cut plan would directly affect approximately 3.755 acres of land (forest and agricultural land), 1,594 square feet of stream, and 0.509 acres of PADEP floodway. This conventional open cut crossing would require damming the stream using an upstream and downstream using a geotube, while simultaneously pumping around all stream flows, and pumping out of all produced groundwater discharge from the excavated shallow soil horizons and water seepage below the geotube dams installed in the channel for the entire duration of the open cut crossing event.

**SR-88/WHEELING AND LAKE ERIE RR CROSSING
PADEP SECTION 105 PERMIT NO.: E63-674
PA-WA-0171.0000-RR
(SPLP HDD# S1B-0120)**

Table 1. Open Cut Alternative Impacts on Waterbodies.

Stream	Crossing Method	Stream Dist. Length in Perm ROW (feet)	Stream Dist. Length in Temp ROW (feet)	Stream Perm Impact (sq. feet) ¹	Stream Temp Impact (sq. feet) ¹	PADEP Perm Floodway Impact (acres) ¹	PADEP Temp Floodway Impact (acres) ¹	Ch. 106 Perm Floodplain Impact (acres) ¹	Ch. 106 Temp Floodplain Impact (acres) ¹
S27	Open Cut	63	16	378	96	0.153	0.067	n/a	n/a
S28	Open Cut	57	27	570	270	0.143	0.068	n/a	n/a
S142	Open Cut	70	0	280	0	0.077	0.001	n/a	n/a

Although the above surface disturbances to the subject streams would be controlled and managed using the measures in SPLP's Impact Avoidance, Minimization, and Mitigation Plan and E&S Plan to a level that is temporary and minor, the preferred method would be to use a trenchless construction method to avoid these surface disturbances.

Conventional Auger Bore (CAB) Alternative

The use of the conventional auger bore (CAB) construction method across the entire current 2,170-foot-long crossing alignment is not technically feasible due to: 1) the length limitations of this existing technology; and 2) the change in elevation (not a horizontal profile) across this crossing alignment, as discussed below.

Horizontal auger boring was initially developed to cross under two-lane roadways with an average crossing width of 40 feet and a maximum crossing width of 70 feet. However, with demand for longer installations increasing, the current maximum extent for a CAB installation of a 20-inch-diameter pipeline is approximately 390 feet. Accordingly, this crossing methodology should only be considered for avoidance of obstacles of somewhat less than 390 feet in length, and therefore would be considered not technically feasible for the current 2,170-foot-long crossing alignment.

Combination Open-Cut/CAB Alternative Analysis

SPLP analyzed a combination open cut/CAB crossing alternative across the entire crossing alignment. This combination open cut/CAB crossing alternative was developed with consideration and incorporation of:

- Best engineering design practices;
- Requirements to use trenchless construction methods to install the 20-inch-diameter pipeline beneath the Wheeling and Lake Erie Railroad, as well as State Route 88 and Mingo Church Road;
- Known areal extent and classification of existing PADEP-regulated wetlands, waterbodies, and floodplains/floodways, and objective to avoid or minimize surface disturbance to these resources;
- Known areal extent and protection requirements of existing agency-regulated significant land use, cultural, and human environment resources, and objective to avoid or minimize surface disturbance to these resources;
- Known existing topographic, geologic, and hydrogeologic conditions and constraints at and below the ground surface along and adjacent to the current 2,170-foot-long crossing alignment based on the *HDD Hydrogeologic Reevaluation Report*; and
- The objective to use the minimum linear extent of the CAB construction method practicable.

**SR-88/WHEELING AND LAKE ERIE RR CROSSING
PADEP SECTION 105 PERMIT NO.: E63-674
PA-WA-0171.0000-RR
(SPLP HDD# S1B-0120)**

Description of Alternative

This theoretical combination alternative along the current 2,170-foot-long alignment crosses multiple surface and subsurface features, including from west to east: stream S27, a public water pipeline, an Equigas pipeline, State Route 88, a private gravel road, an Equitrans pipeline, the Wheeling and Lake Erie Railroad, stream S28, a storm sewer line, Patterson Road, a second Equigas pipeline, and stream S142. Excepting the railroad and the Equitrans pipeline, these features are located in close proximity and parallel to the crossings of State Route 88 and Patterson Road. This alternative includes from west to east:

- An approximately 596-foot-long open cut construction method crossing of uplands (woodlot) and stream S27;
- A 95-foot-long (not including 56-foot-long bore pit and 16-foot-long receiving pit) CAB crossing of State Route 88 that also encompasses a public water pipeline and an Equigas pipeline;
- An approximately 980-foot-long open cut construction method crossing of uplands (forest and agricultural land), including an Equitrans pipeline;
- A 206-foot-long (not including 56-foot-long bore pit and 16-foot-long receiving pit) CAB crossing of the Wheeling and Lake Erie Railroad;
- An approximately 123-foot-long open cut construction method crossing of uplands (forest and open land);
- An 82-foot-long (not including 16-foot-long receiving pit and 56-foot-long bore pit) CAB crossing of Patterson Road that also encompasses stream S28, a storm sewer line, a second Equigas pipeline, and stream S142; and
- An approximately 88-foot-long open cut construction method of uplands (woodlot).

Analysis of Alternative

This theoretical combination alternative was determined to be not technically feasible due to multiple constraints, including, but not necessarily limited to, topography not conducive to conventional auger bore, limitations of available additional temporary workspace (ATWS), and significant safety concerns related to existing infrastructure and construction equipment, materials, and personnel, as described below.

As noted previously due to pipeline installation requirements, the railroad and two public roads cannot be open cut and require use of the CAB construction method. However, all of the surface features noted above are set below the surrounding topography, and the elevated topography on both sides of the railroad and two public roads significantly complicates the design of a CAB. Based on review of the HDD profile cross section, as well as development of theoretical site-specific CAB designs, each crossing would require excavation of large areas on the adjacent slopes to achieve the bore pit depths required to secondarily excavate a trench for the entry, receiving, and pull back phases of a CAB. Specifically, the bore/receiving pit depths would be 12 and 20 ft (State Route 88), 56 and 10 ft (Wheeling and Lake Erie Railroad), and 21 and 31 feet (Patterson Road) to achieve minimum pipeline cover requirements. For comparison purposes, the typical bore/receiving pit depth on the Project and generally considered technically feasible ranges from 10 to 15 feet with a maximum of 20 feet, thus many of the required bore/receiving pit depths would be unacceptable from both a technical and safety perspective. Even with the use of shoring or sheet pile for the bore pit and receiving pit, the back slopes to each side of the bore are required to be cut back at 1:0.75 slopes for worker safety. Therefore, large areas of additional temporary workspace (ATWS), several acres in size would be required outside of (typically adjacent to) the bore pits for temporary storage of excavated spoil.

The theoretical CAB design on the east side of Patterson Road would require removing so much subsurface material that it could expose the existing ME1 pipeline, or installing a sheet pile wall to hold the ME1 pipeline in place. It is not safe to expose an in-service pipeline. Driving sheet pile next to an in-service pipeline has to be done carefully, and a sheet pile wall could interfere with acquiring the depth required inside the

SR-88/WHEELING AND LAKE ERIE RR CROSSING
PADEP SECTION 105 PERMIT NO.: E63-674
PA-WA-0171.0000-RR
(SPLP HDD# S1B-0120)

existing easement to set a boring machine or excavate the receiving pit for laying sections of pipe to be pulled through the bore hole. Furthermore, a CAB design at Patterson Road would require SPLP to acquire an additional permanent easement. The potentially affected private landowner has rejected all offers for an additional permanent easement, and therefore condemnation of the additional land would likely be necessary.

Although the above surface disturbances to the subject streams would be controlled and managed using the measures in SPLP's Impact Avoidance, Minimization, and Mitigation Plan and E&S Plan to a level that is temporary and minor, the preferred method would be to use a trenchless construction method to avoid these surface disturbances.

Combination Open-Cut/FlexBor Alternative Analysis

SPLP analyzed a combination open cut/CAB/FlexBor crossing alternative across the entire crossing alignment. This combination open cut/CAB/FlexBor crossing alternative was developed with consideration and incorporation of:

- Best engineering design practices;
- Requirements to use trenchless construction methods to install the 20-inch-diameter pipeline beneath the Wheeling and Lake Erie Railroad, as well as State Route 88 and Mingo Church Road;
- Known areal extent and classification of existing PADEP-regulated wetlands, waterbodies, and floodplains/floodways, and objective to avoid or minimize surface disturbance to these resources;
- Known areal extent and protection requirements of existing agency-regulated significant land use, cultural, and human environment resources, and objective to avoid or minimize surface disturbance to these resources;
- Known existing topographic, geologic, and hydrogeologic conditions and constraints at and below the ground surface along and adjacent to the current 2,170-foot-long crossing alignment based on the *HDD Hydrogeologic Reevaluation Report*; and
- The practical application of FlexBor technology to avoid impact to natural resources, and complete the crossing under the roads and railroad using minimum entry and receiving pit lengths and depths.

Description of Alternative

This construction combination alternative along the current 2,170-foot-long alignment crosses multiple surface and subsurface features, including from west to east: stream S27, a public water pipeline, an Equigas pipeline, State Route 88, an Equitrans pipeline, a private gravel road, the Wheeling and Lake Erie Railroad, stream S28, a storm sewer line, Patterson Road, a second Equigas pipeline, and stream S142. Excepting the private road, railroad and the Equitrans pipeline, these features are located in close proximity and parallel to the crossings of State Route 88 and Patterson Road. As depicted on the plan view and cross section drawings in Attachment 3, this alternative would necessarily include two (2) FlexBor crossings, whereas the remaining portions of the current pipeline alignment would be installed using the open cut construction method and one short convention horizontal bore. This alternative includes from west to east:

- An approximately 1093-foot-long open cut construction crossing of uplands;
- A 189-foot-long (not including 50-foot-long bore pit and 30-foot-long receiving pit) FlexBor crossing of State Route 88 that also encompasses stream S27, a public water pipeline and an Equigas pipeline;
- An approximately 160-foot-long open cut construction, 50-ft horizontal road bore, then 454-foot of open cut construction crossing of uplands (forest and agricultural land);

**SR-88/WHEELING AND LAKE ERIE RR CROSSING
PADEP SECTION 105 PERMIT NO.: E63-674
PA-WA-0171.0000-RR
(SPLP HDD# S1B-0120)**

- A 781-foot-long (not including 50-foot-long bore entry pit) FlexBor crossing of the Equitrans pipeline; Wheeling and Lake Erie Railroad; Patterson Road; stream S28; a storm sewer line; a second Equigas pipeline, and stream S142; and
- An approximately 287-foot-long open cut construction method crossing of uplands (open land).

Analysis of Alternative

This construction combination alternative was determined to be feasible due to the application of Flexbor technology.

A “FlexBor” does not utilize bentonite as an additive to create a “mud slurry” to carry cuttings during the pilot and reaming phases. Instead, it utilizes high pressure air and water. The pilot phase will be performed using a FlexBor unit driving a 6-inch diameter air hammer (hammer bore) in front of 6-inch diameter casing that houses the drive stem. During the reaming phase, the FlexBor cutter is attached in front of a casing pipe and is pushed/pulled through the designed profile guided by the pilot hole. During the reaming phase, only high pressure air and water is used to carry cuttings; however the FlexBor cutter “ingests” the cuttings which are carried back to the point of entry through the casing pipe where the cutting are collected and removed; therefore the risk of an IR is very low. Bentonite is only used a lubricant on the exterior of the casing pipe (if needed) to prevent binding to the bedrock, therefore there is no potential to discharge a foreign material to the land surface or surrounding geology during the process.

Attachment 3 contains an overview of the alternative construction plan and a set of the Flexbor plan and profiles intended for implementation under the alternative construction plan.

Re-Route Analysis

In accordance with state and federal guidance, SPLP has routed the Project to be co-located with existing pipeline and other utility corridors to avoid new “greenfield” routing alignments, to the maximum extent practicable. This avoids and minimizes new and permanent impacts on previously undisturbed land, land use encumbrance, and site-specific and cumulative impacts on land, environmental, and community resources. The SR-88 and Lake Erie Railroad Crossing HDD is co-located within the existing SPLP 12” pipeline ROW and rerouting would cause new greenfield impacts. In addition, given the size, length, and general perpendicular direction of streams S27, S28, and S142, no practicable re-route option lies to the east or west of the proposed route that would not ultimately cross these streams or the Lake Erie Railroad. No change in subsurface geology can be obtained by reroute. The same geology as described in the geology section of this analysis and within the attached hydrogeologic report, and mine subsidence report continues for miles in all directions; therefore SPLP has concluded that since the Open cut/CAB/FlexBor construction plan is a viable alternative to the HDD, no further consideration of a re-route of the project is required.

CONCLUSION

After the initial pilot hole attempt to cross this location by HDD, SPLP contractors conducted extensive investigations of the subsurface geology, underlying coal mine, and effects of coal mine subsidence across the construction area. In response to a better understanding of the subsurface geology and degree of fracturing, which makes prevention of IRs during an HDD practically impossible, SPLP is abandoning the proposed HDD and is submitting the Pennsylvania Department of Environmental Protection a Chapter 102 and Chapter 105 permit modification package for review and approval. The permit modification package proposes a change in crossing methodology from the original HDD design to a combination of open cut, conventional horizontal bore, and two FlexBors to complete pipeline installation across the area encompassed by the original design of HDD No. S1B-0120.

**SR-88/WHEELING AND LAKE ERIE RR CROSSING
PADEP SECTION 105 PERMIT NO.: E63-674
PA-WA-0171.0000-RR
(SPLP HDD# S1B-0120)**

**ATTACHMENT 1
GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT**



HDD HYDROGEOLOGIC REEVALUATION REPORT

**Mariner East II
Spread 1
HDD S1B-0120
Wheeling and Lake Erie Railroad
Union Township, Washington County, Pennsylvania**

Prepared for:

Sunoco Pipeline, L.P.

Prepared by:

**Groundwater & Environmental Services, Inc.
301 Commerce Park Drive
Cranberry Township, Pennsylvania 16066**

May 2018



HDD HYDROGEOLOGIC REEVALUTION REPORT

**Mariner East II
Spread 1
HDD S1B-0120
Wheeling and Lake Erie Railroad
Union Township, Washington County, Pennsylvania**

May 2018

Prepared for:

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

Prepared by:

A handwritten signature in blue ink, appearing to read 'E.T. Fox'.

Edwin T. Fox, P.G.
Project Hydrogeologist

Reviewed by:

A handwritten signature in blue ink, appearing to read 'Richard T. Wardrop'.

Richard T. Wardrop, P.G.
Principal Hydrogeologist

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 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.



May 10, 2018

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

date



TABLE OF CONTENTS

1.0	INTRODUCTION.....	1
1.1	HDD and Flex Bore/Road Bore/Open Trench Alternative Descriptions.....	2
1.1.1	HDD.....	2
1.2	Historic HDD Activities	3
2.0	HDD GEOLOGY / HYDROGEOLOGY.....	4
2.1	Physiography	4
2.1.1	Topography.....	4
2.1.2	Hydrology	4
2.2	Geology.....	4
2.2.1	Soils	4
2.2.2	Bedrock Lithology	5
2.2.3	Structure.....	6
2.2.4	Fracture Trace Analysis.....	7
2.2.5	Karst.....	7
2.2.6	Mining	8
2.3	Geotechnical Properties	9
2.3.1	2013 Geotechnical Borings.....	9
2.3.2	August 2017 Geotechnical Borings	10
2.3.3	November 2017 Geotechnical Borings.....	12
2.3.4	Compressive Strength.....	13
2.3.5	Rock Engineering Properties	13
2.4	Hydrogeology	13
2.4.1	Occurrence of Groundwater.....	13
2.4.2	Groundwater Water Levels.....	13
2.4.3	Well Yields	15
2.4.4	Water Supply Wells.....	15
2.4.5	450-Foot Water Supply Survey	15
2.4.6	Potential Impact of Mining on Groundwater.....	15
2.4.7	Mine Pools.....	16
3.0	OBSERVATIONS TO DATE	18
3.1	HDD Observations for ME I.....	18
3.2	HDD Observations for ME II	18
4.0	HDD AND FLEX BORE/ROAD BORE OPEN TRENCH ALTERNATIVE.....	19
5.0	CONCLUSIONS AND RECOMMENDATIONS	21
6.0	REFERENCES.....	22

FIGURES

- Figure 1. Site Location Map
- Figure 2. Regional Geology Map
- Figure 3. Local Geology Map
- Figure 4. Structure Contour Map
- Figure 5. Fracture Trace Map
- Figure 6. Mine Map, Cincinnati Coal Mine
- Figure 7. Percent Recovery and RQD with Depth in B1-2W



FIGURES (Continued)

- Figure 8. Percent Recovery and RQD with Depth in B1-2E
- Figure 9. Water Supply Well Locations
- Figure 10. 450-Water Supply Survey Results
- Figure 11. Hydrologic Response Zones
- Figure 12. 2017 IR Location Map

TABLES

- Table 1. PAGWIS Well Records for Wells 148374 and 148364

ATTACHMENTS

- Attachment A. HDD and FlexBor/Road Bore/Open Trench Alternative Plans and Profiles
- Attachment B. Geotechnical Reports

1.0 INTRODUCTION

Sunoco Pipeline, L.P. (SPLP) retained Groundwater & Environmental Services, Inc. (GES) to prepare Hydrogeological Reevaluation Reports for horizontal directional drills (HDDs) associated with the Mariner East II pipeline project and listed on Exhibit 2 of the Stipulated Order, EHB Docket No. 2017-009-L, signed August 10, 2017. This report discusses the hydrogeological reevaluation for HDD S1B-0120, a 20-inch pipeline planned for installation near the intersection of Route 88 with Mingo Church Road in Union Township, Washington County, Pennsylvania. The reevaluation takes into consideration the original HDD plan and profile presented in the IR PPC Plan for Washington County (rev. September 30, 2016). A combined flex bore/road bore/open trench alternative is discussed with the HDD in Sections 1.1, 4.0 and 5.0. Plans and profiles for both the HDD and flex bore/road bore/open trench alternative are provided in **Attachment A**. A topographic map depicting the location of the HDD alignment and surrounding area is presented as **Figure 1**.

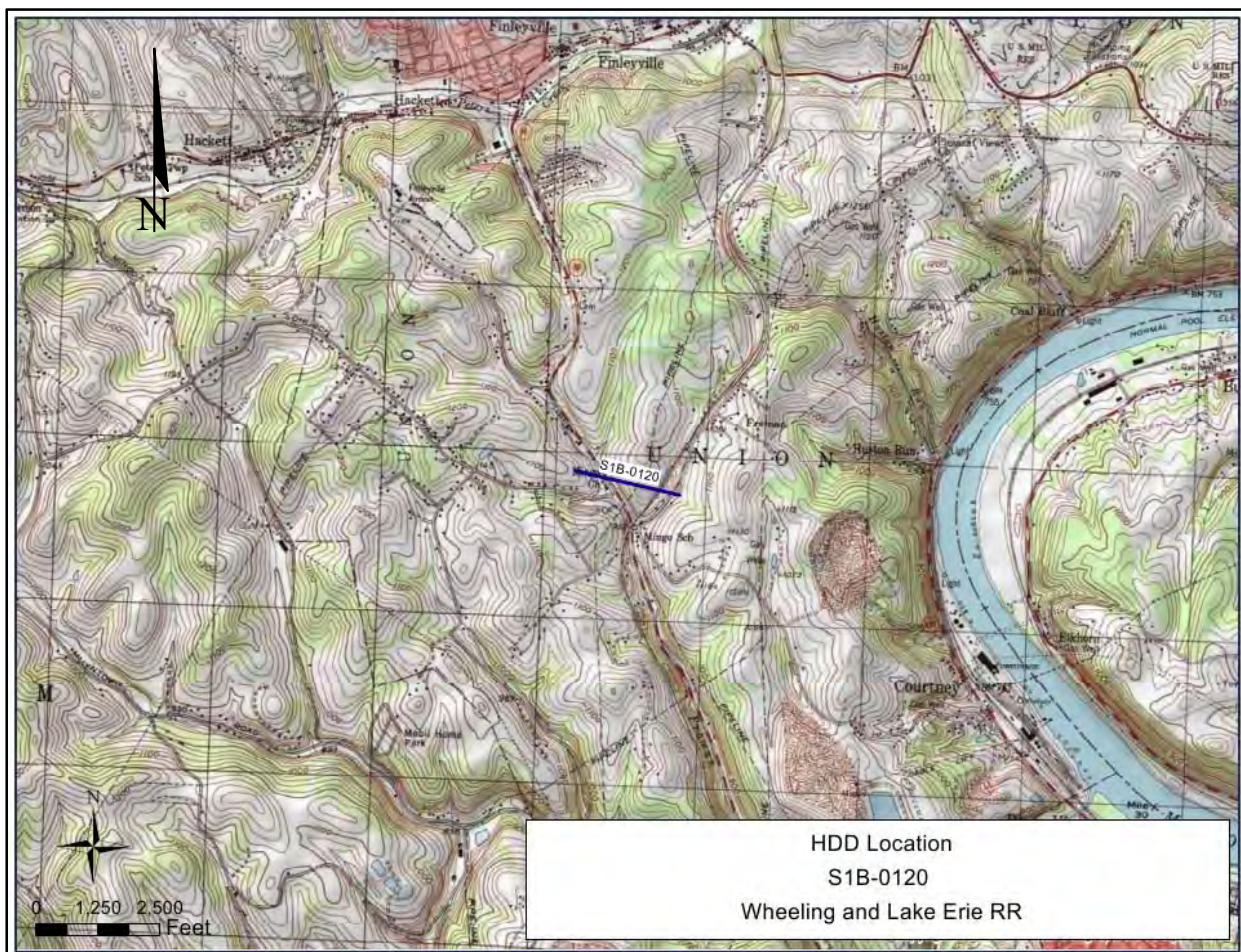


Figure 1: Site Location Map (modified from USGS Monongahela 1:24,000 Topo. Quad., rev. 1979)

This report presents the following information:

- Geologic and hydrogeologic characteristics in the area of HDD S1B-0120;
- 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 June 2013, by Terracon Consultants, Inc. (Terracon) in August 2017 and by Intertek PSI in November 2017 in support of the HDD S1B-0120 reevaluation. Please note that GES did not oversee or direct the geotechnical drilling programs, including, but not limited to, selection of the number and location of borings, determination of surface elevations, target depths, observations of rock cores during drilling operations, or preparation of boring logs. A GES Professional Geologist (PG) observed the work performed during the November 2017 geotechnical drilling program. The geotechnical reports, boring logs, and any core photographs that resulted from these programs were generated by the three SPLP contractors. GES relied on these reports and incorporated their data into the general geologic and hydrogeologic framework for this hydrogeologic reevaluation report.

1.1 HDD and Flex Bore/Road Bore/Open Trench Alternative Descriptions

1.1.1 HDD

The plan and profile, included in **Attachment A**, for HDD S1B-0120 is 2,170 feet long with stationing running east to west. The east entry/exit point is located due east of Patterson Road at a surface elevation of approximately 1,010 feet above mean sea level (ft amsl). The profile shows the boring running above the existing ME I 12-inch pipeline. Moving east to west the 20-inch line passes beneath Patterson Road, streams S142 and S28, the Wheeling Lake Erie Railroad, and the southern end of a north/south trending ridge at surface elevation 1,075 ft amsl at Station 07+15. From the ridge the HDD is designed to run under State Route 88 at Station 15+33, stream S27 at Station 16+42 at an approximate elevation of 970 ft amsl. The HDD profile slopes from Station 12+25 at an elevation of 880 ft amsl upward to the western entry/exit point at Station 21+70 and with an approximate surface elevation of 1,085 ft amsl.

1.1.2 FlexBor/Road Bore/Open Trench Alternative

The plan and profiles for the FlexBor/road bore/open trench alternative are also provided in Attachment A. The alternative proposes that a FlexBor be advanced from an entry pit east of Patterson Road and surface west of the Wheeling Lake Erie Railroad for 20-inch pipe installation. This bore would enter from a pit 17 to 31 feet deep and 50 feet long, pass under steams S28 and S142, pass under Patterson Road and pass under the railroad before surfacing at an elevation of 1,054 ft amsl. The proposed bore is 779 feet long (horizontally) and runs from approximately Station 0+96 to 8+75 on the HDD alignment. This bore would be drilled with air hammer technology using compressed air and water from an approved source and no bentonite-based drilling fluids would be used.

A road bore would be drilled under State Route 88 and stream S27 for 20-inch pipe installation. This bore would be placed approximately between stations 14+75 and 16+50 on the HDD profile. The entry pit would be on the west end, would be 9 to 14 feet deep and 50 feet long. The exit pit would be approximately 22 feet deep and 30 feet long. The road bore would pass under stream S27 and State Route 88. This bore would be drilled with an air hammer pilot and FlexBor ream technology therefore no drilling fluids would be used.

Twenty-inch pipe installation along all parts of the S1B-0120 HDD alignment that are not replaced with by the flex bore or road bore would be accomplished using standard SPLP ME II open trench procedures.



1.2 Historic HDD Activities

IRs observed during the advancement of the ME I HDD included, turbid water entering the cistern for the Mingo Presbyterian Church, located at the intersection of State Route 88 and Mingo Church Road, and an intrusion of drilling liquids into stream S27 along Patterson Road.

Drilling of the first attempted pilot hole for ME II HDD S1B-0120 along the HDD profile was initiated on May 27, 2017, from the west entry/exit point towards the east. Shortly after advancing the drill bit into bedrock, all returns of drilling liquids were lost. In addition, approximately 5,000 gallons of drilling liquids in the mud pit drained into the formation at the western end of the HDD profile. Attempts to regain circulation, while continuing to advance the pilot hole, were met with limited success. Five IRs were subsequently identified between the western entry/exit point and State Route 88. The IRs included turbid groundwater containing bentonite entering the Mingo Church cistern, drilling liquids seeping from the ground surface at the backdoor of Mingo Church, turbid groundwater containing bentonite seeping from the bank of stream S27, and drilling mud flowing from a former water supply well at a residence adjacent to the pipeline. Due to the IRs, the drill was suspended on June 15, 2017.



2.0 HDD GEOLOGY / HYDROGEOLOGY

2.1 Physiography

2.1.1 Topography

HDD S1B-0120 is located in the Pittsburgh Low Plateau Section of the Appalachian Physiographic Province, which consists of a smooth to irregular undulating upland surface. The uplands are cut by relatively shallow valleys (Sevon, 2000) in a dendritic drainage pattern. Local relief between valley floor and the crests of adjacent uplands typically ranges from 100 to 250 feet.

The topography in the area of HDD S1B-0120 consists of rounded ridges cresting at 1,200 ft amsl bisected by the valleys for two tributaries of Froman Run identified as streams S27 and S28. The base of the valleys along the HDD profile are 969 ft amsl for stream S27 and 984 ft amsl for stream S28. The HDD is located between statewide Pipeline Stations 928+00 and 951+00 with an overall length of 2,170 feet. The surrounding area is comprised of mixed residential, commercial and agricultural properties.

2.1.2 Hydrology

The nearest surface water bodies to HDD S1B-0120 include stream S27, which crosses the drill path at boring station 16+40 and stream S28, which crosses the drill path at boring station 1+54. These streams are tributaries to Froman Run, which flows 1.2 miles south before discharging into Mingo Creek. Mingo Creek flows east into the Monongahela River, approximately 2.2 miles southeast of HDD S1B-0120.

The road bore, part of the FlexBor/road bore/open trench alternative passes under stream S27 at 8 feet. The FlexBor passes under stream S28 and stream S142 at approximately 15 feet (see **Attachment A**).

2.2 Geology

Bedrock in the area of HDD S1B-0120 consists of cyclic sequences of sandstone, shale, claystone, limestone and coal of the Monongahela Group. The Monongahela Group is bounded up-section by the Waynesburg Formation and down-section by the Conemaugh Group, as illustrated on **Figure 2**. The lowest unit in the Waynesburg Formation is the Waynesburg Coal. The Monongahela Group is divided into two formations consisting of the Uniontown Formation up section and the Pittsburgh Formation, down section. The lowest unit in the Monongahela Group is the Pittsburgh Coal, which outcrops along the banks of Mingo Creek and the Monongahela River south and east of the Site. The Uniontown and Pittsburgh Formations consist of dense limestone and discontinuous shale, siltstones, sandstones and coal (Newport, 1973).

2.2.1 Soils

The Soil Survey for Washington and Greene Counties indicates soil along the path of HDD S1B-0120 belongs to the Culleoka channery silt loam (CaD) on 15 to 25% slopes, the Dormont silt loam (DoB) on 3 to 15% slopes, Dormont silt loam (DoC) on 15 to 25% slopes, the Dormont-Culleoka complex (DtF) on 25 to 50% slopes, Weikert-Culleoka complex (WeC) on 8 to 15% slopes and Weikert-Culleoka complex (WeD) on 15 to 25% slopes.

DoB, DoC and DtF soils, derived fine-loamy residuum weathered from limestone, sandstone, and shale, are moderately well drained. WeC and WeD soils, derived from residuum weathered from siltstone, are moderately well to excessively well-drained. CaD soils, derived from fine-loamy residuum weathered from sandstone and shale, are moderately deep to deep and moderately well to well drained. Soils in valley of stream S27 along Route 88 are classified as Urban Land (Us). These are soils that have been disturbed by human activities to a point where they cannot be described using standard soil taxonomy. They include areas containing coal mine spoils (USDA, August 2017).

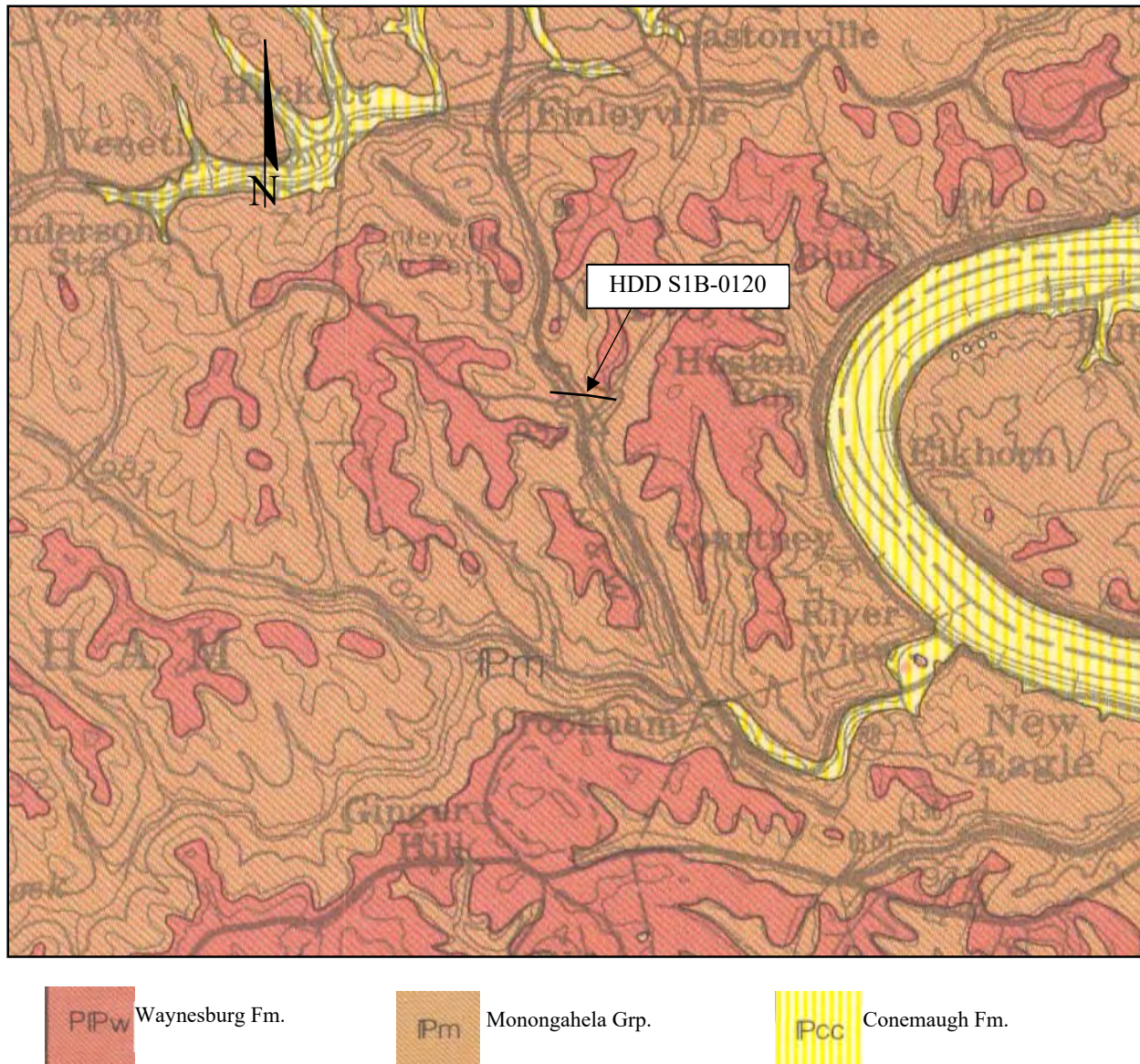


Figure 2: Regional Geology Map (modified from Wagner, et. al, 1975)

2.2.2 Bedrock Lithology

Besides several unnamed shales, siltstones and mudstones, intermediate bedrock units of the Monongahela Group that outcrop along the HDD S1B-0120 path include the Uniontown Coal, the “E” Sandstone of the Pittsburgh Formation, and the Benwood Limestone. The Uniontown Coal in the area consists predominantly of black, carbonaceous shale with coal stringers. Below the Uniontown Coal is the “E” sandstone, which typically ranges from 60 to 90 feet thick. The Benwood Limestone was mapped along the steep portions and base of the S27 stream valley along Route 88. The Benwood Limestone typically ranges from 38 to 54 feet thick. A lithologic map illustrating the bedrock units outcropping along the HDD path is included as **Figure 3**.

Intermediate bedrock units below Benwood Limestone from up-section to down-section include: the Sewickley Coal, Fishpot Sandstone, the Fishpot Limestone, Redstone Coal, Redstone Limestone, Pittsburgh Sandstone and the Pittsburgh Coal. The Pittsburgh Coal, averaging 5.3 feet thick, has been

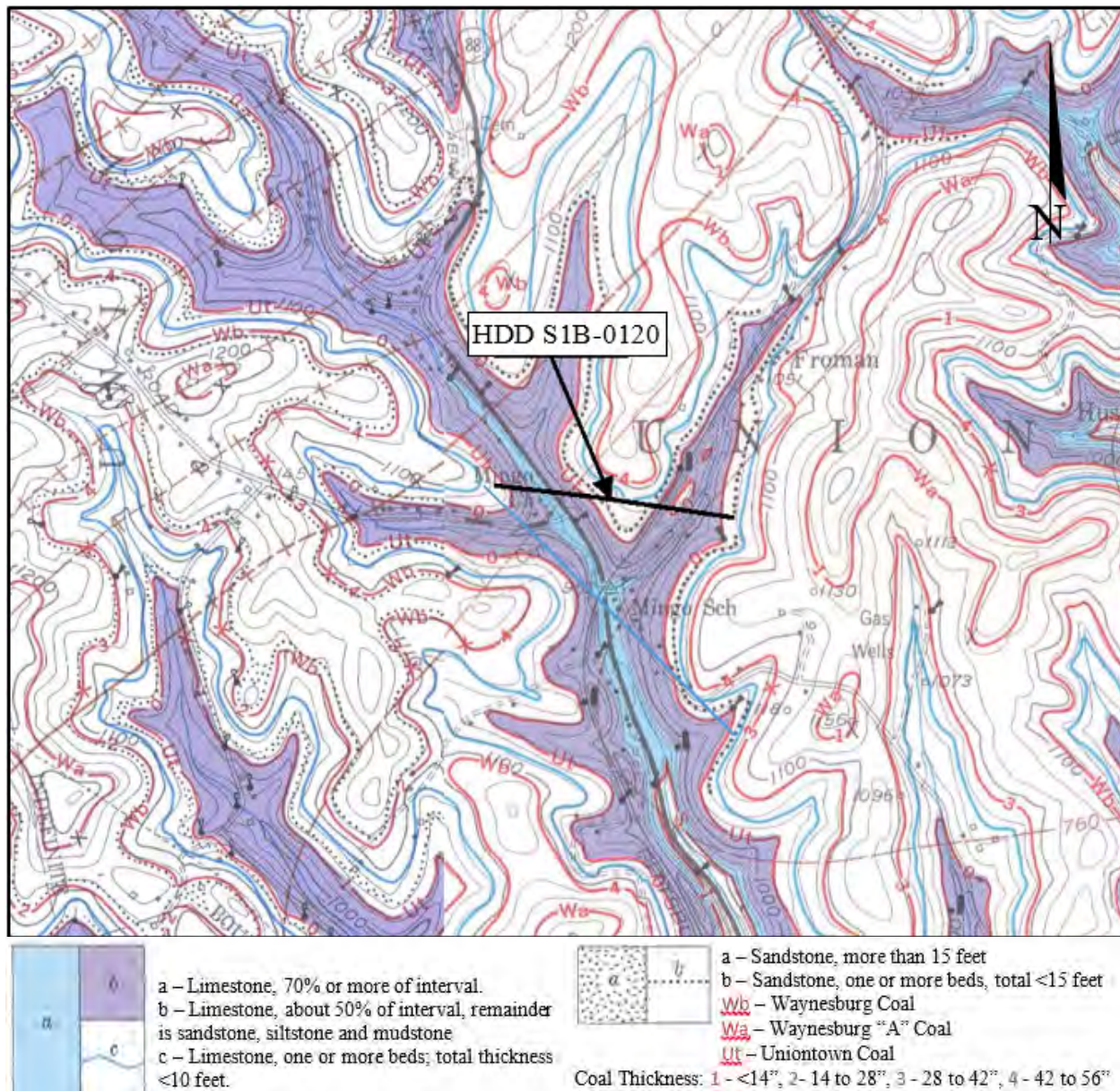


Figure 3: Local Geology Map (modified from Kent and Schweinfurth, 1969; and Roen, et. al., 1970)

mined extensively in the area (**Section 2.2.6**). The base of the coal ranges from 800 ft amsl at the western end of the HDD S1B-0120 to 760 ft amsl at the eastern end. Based on these elevations, the Pittsburgh Coal ranges from 284 to 250 ft bgs across the extent of HDD S1B-0120.

2.2.3 Structure

Skema (1987) published structure contour maps of the coal beds in Washington County, Pennsylvania. A portion of one map is shown on **Figure 4** depicting local structure contours at the base of the Pittsburgh Coal. This map shows that HDD S1B-0120 is located on the southeastern flank of the Amity Anticline. Bedrock dips to the southeast at approximately 1.5 degrees.

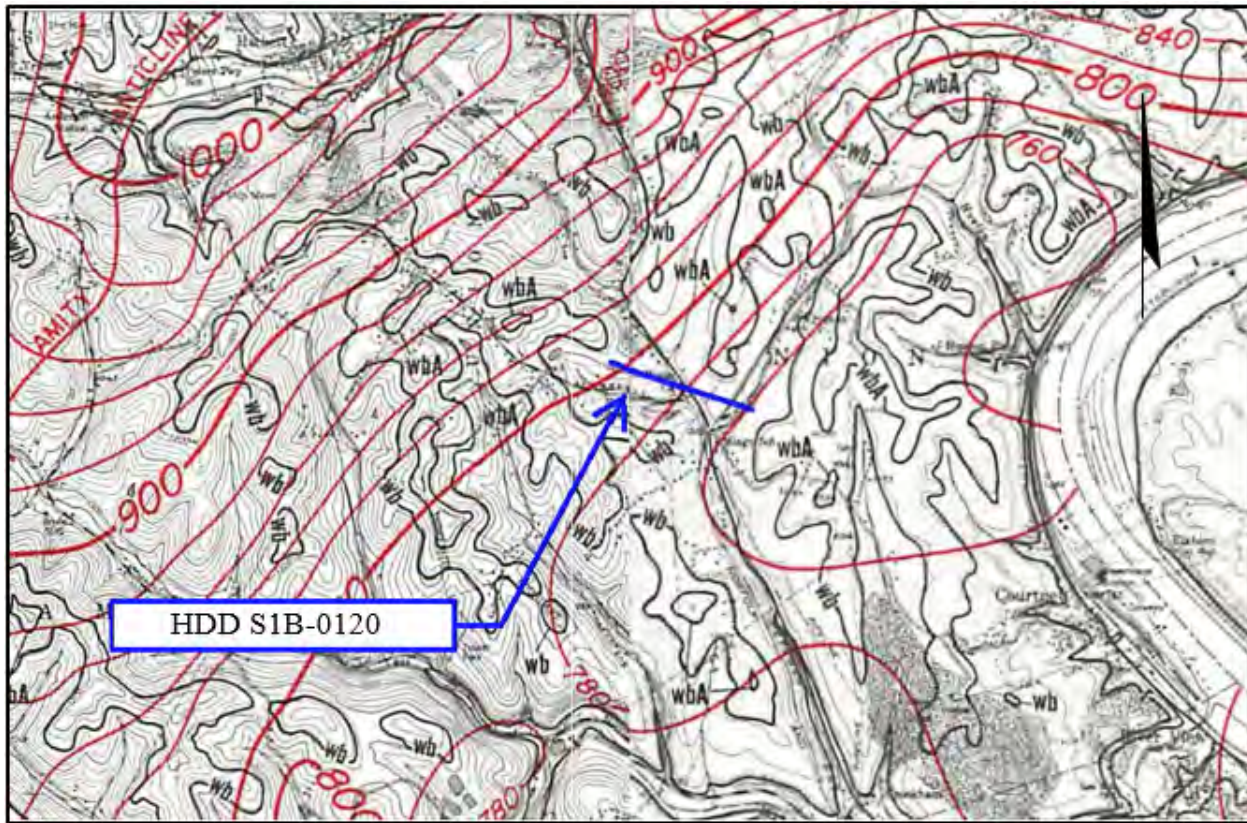


Figure 4: Structure Contour Map (modified from Skema, 1987)

2.2.4 Fracture Trace Analysis

Fracture trace analysis using high altitude aerial photography 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 5 shows a fracture trace map prepared for this reevaluation. This mapping was performed using aerial stereographic pairs flown in the fall of 1938. As such, much of the land surface appears undeveloped; therefore, fracture traces are more easily seen. Three general orientations are present in the set of fracture traces. Two of the orientations generally match the systematic joint alignments mapped by Nickelsen and Hough (1967); a northwest trending set and a east-west trending set (systematic joint sets). The third orientation trends north-northeast and is sub-orthogonal to the east-west trending set.

Because bedrock fractures and jointing systems represent weak points in the bedrock, they are preferential pathways for groundwater infiltration and migration. The 1938 aerial imagery indicates the surrounding area was dominated by agriculture, so it had not been subjected to the property re-development activities more common today. The proposed path of the HDD is shown in red on Figure 5 and transects one northwest trending trace near its eastern entry/exit point.

2.2.5 Karst

The Benwood Limestone, Fishpot Limestone, and Redstone Limestone were identified in the stratigraphic sequence below HDD S1B-0120. However, karst features such as solution cavities and caves have not been identified in these carbonate beds, in this portion of Washington County, Pennsylvania (Miller, 1934).

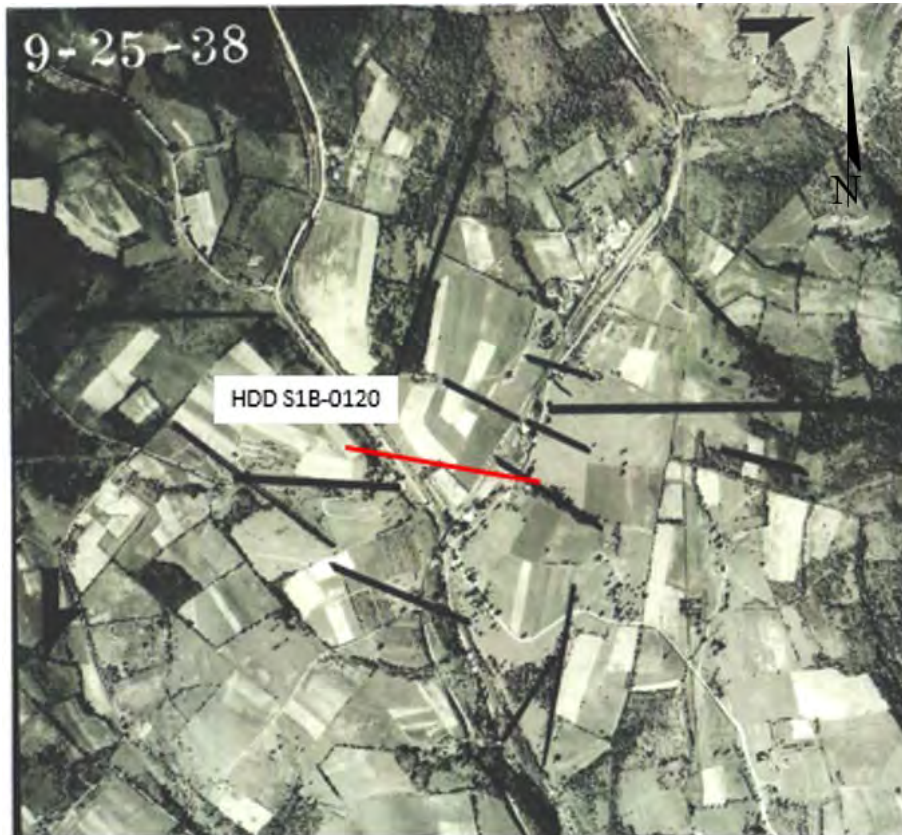


Figure 5: Fracture Trace Map

2.2.6 Mining

The Waynesburg Coal and the Uniontown Coal were mapped in the region in the shallow rock sequence at HDD S1B-0120 (Roen, 1970); however, neither coal occurred in an economically viable thickness. Evidence of the coals may only be black or carbonaceous shales. Published documents do not show evidence of strip or deep mining in the area that correlates with these units (USGS, 1979).

The base of the Pittsburgh Coal occurs below HDD S1B-0120 at elevations ranging from 800 ft amsl at the western end of HDD S1B-0120 to 760 ft amsl in on the eastern end. Contour lines of the base of the Pittsburgh Coal are illustrated on **Figure 3** and **Figure 4**. The Pittsburgh Coal, ranging from 4.5 feet to 5.5 feet thick across Union Township, was extensively mined across the area, as illustrated on **Figure 6**.

As shown on **Figure 6**, the western end of the profile for HDD S1B-0120 passes over a mined out section of coal extending from the western entry/exit point to the east side of State Route 88. This mined section of coal measures approximately 1,045 feet long by 270 feet wide. East of State Route 88, the HDD traverses a southeast trending haulage way supported by coal pillars.

A review of the PADEP on-line records revealed a mine subsidence complaint was filed with the PADEP in the area of interest on January 1, 2001. The subsidence complaint was mapped between Mingo Church and the HDD S1B-0120 drill path. However, the available records do not indicate if the complaint was the result of a change in well water quality/quantity or an actual subsidence event involving damage to homes or property.

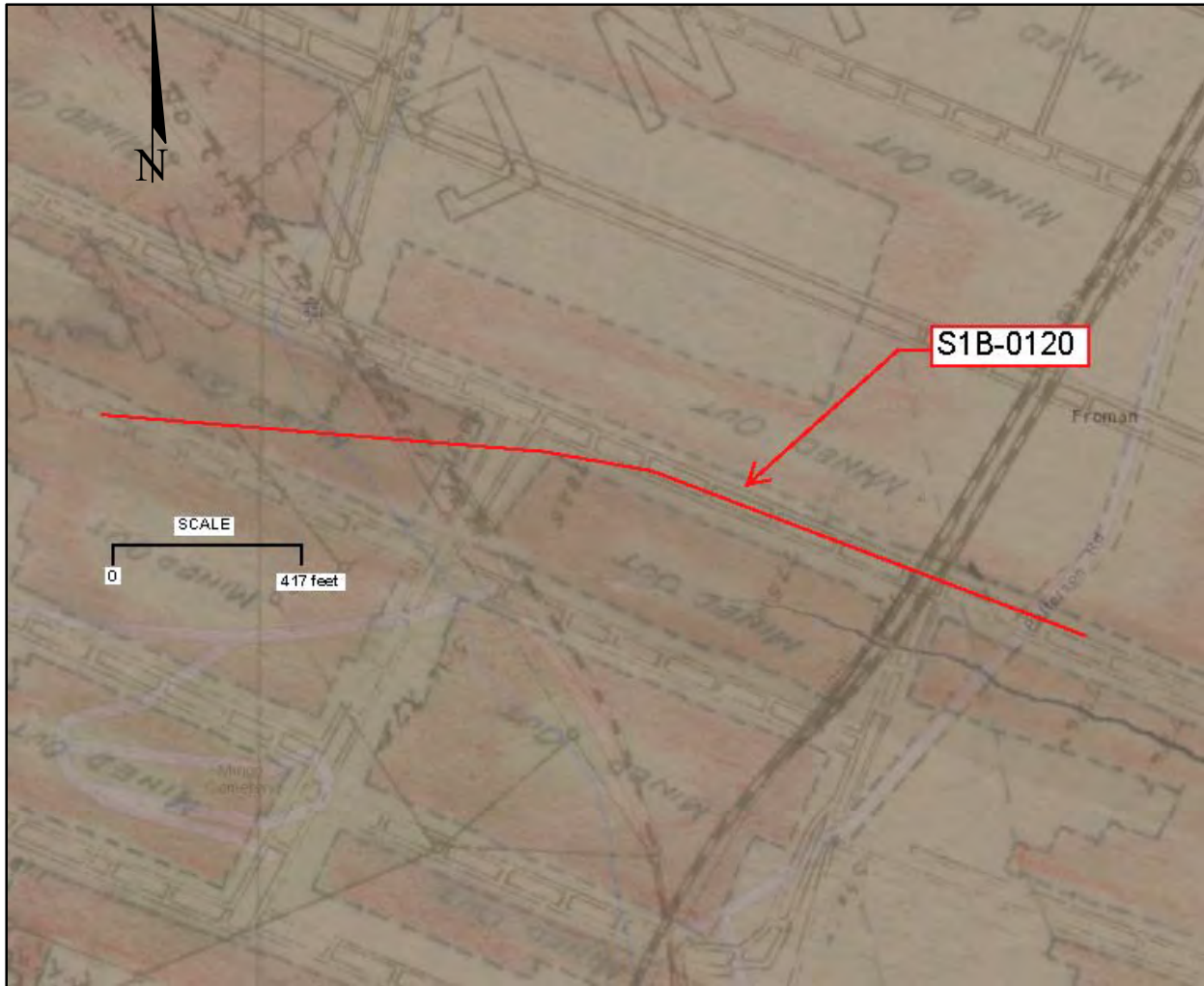


Figure 6: Mine Map, Cincinnati Coal Mine (from Pennsylvania State University, 2017)

2.3 Geotechnical Properties

Two geotechnical borings (HDD-06 and HDD-07) were advanced in 2013 along the profile of HDD S1B-0120 for the design of the ME I pipeline. However, the 2013 borings were terminated at depths of 8 feet and 22 feet (**Attachment B**). Two additional geotechnical borings (B1-2E and B12W) were advanced in August 2017 and three additional geotechnical borings (B-02A, B-03, and B-04) were advanced in November 2017 as part of the reevaluation of the HDD.

2.3.1 2013 Geotechnical Borings

The drilling logs from the 2013 borings were presented in the risk assessment for in the ME II IR PPC Plan for Washington County (**Attachment B**). Boring HDD-06, located along State Route 88, was advanced to bedrock refusal at 8 ft bgs. The overburden was identified as silty clay grading to weathered gray siltstone at bedrock refusal. Boring HDD-07, located along Patterson Road, was advanced to 22 feet. Bedrock refusal was encountered at 12 ft bgs. While the overburden at HDD-07 was not described on the boring log, the bedrock from 12 to 22 feet was identified as interbedded gray shale and limestone.



2.3.2 August 2017 Geotechnical Borings

Two geotechnical borings were advanced in August 2017 by Terracon to further assess subsurface conditions in support of the analysis of alternatives to the HDD pipe installation plan. The geotechnical report covering these two borings is provided in **Attachment B**.

B1-2W

Boring B1-2W was advanced near the entry/exit point on the western extent of HDD S1B-0120. Both the field notes and final drilling log (**Attachment B**) were reviewed. The overburden is described as a medium dense, silty sand with gravel (SM) grading to a very dense, poorly graded sand (SP) from 6 to 13.5 feet below ground surface (ft bgs), overlying 6.5 feet of medium dense, silty clay (CL-ML) to 19.5 ft bgs. Weathered bedrock was observed from 19.5 to 24 ft bgs.

The borehole was advanced using rock coring methods from 24 to 255 ft bgs. The core is representative of the Monongahela Group on the western side of the HDD alignment. The rock type was mostly massive limestone and mudstone with thin interbedded sandstone. The limestone contained several soft clay seams. Coal was observed from 207.5 to 211 ft bgs at an elevation of 870 ft amsl. The elevation of this coal seam and location of the coal within the cored interval correlate with the literature values for the Redstone Coal (Kent, 1969). The boring was not advanced to the Pittsburgh Coal, which would have been encountered approximately 22 to 27 feet below the bottom of the boring.

Rock Quality Determinations (RQDs) generally improved with depth over the cored interval averaging 61% from 24 to 102 ft bgs, 77% from 102 to 202 ft bgs, and 91% from 202 to 255 ft bgs. Vertical to high angle fractures and joints were observed from 57 to 62 ft bgs, 67 to 72 ft bgs, 107 ft bgs, 132 to 137 ft bgs, 140 ft bgs, and 166 ft bgs. **Figure 7** presents a graphical representation of the percent recovery and percent RQD with depth in boring B1-2W. While the average RQD improves with depth, there is a variability to the RQD values throughout the boring, and RQDs less than 60% occurred at multiple intervals.

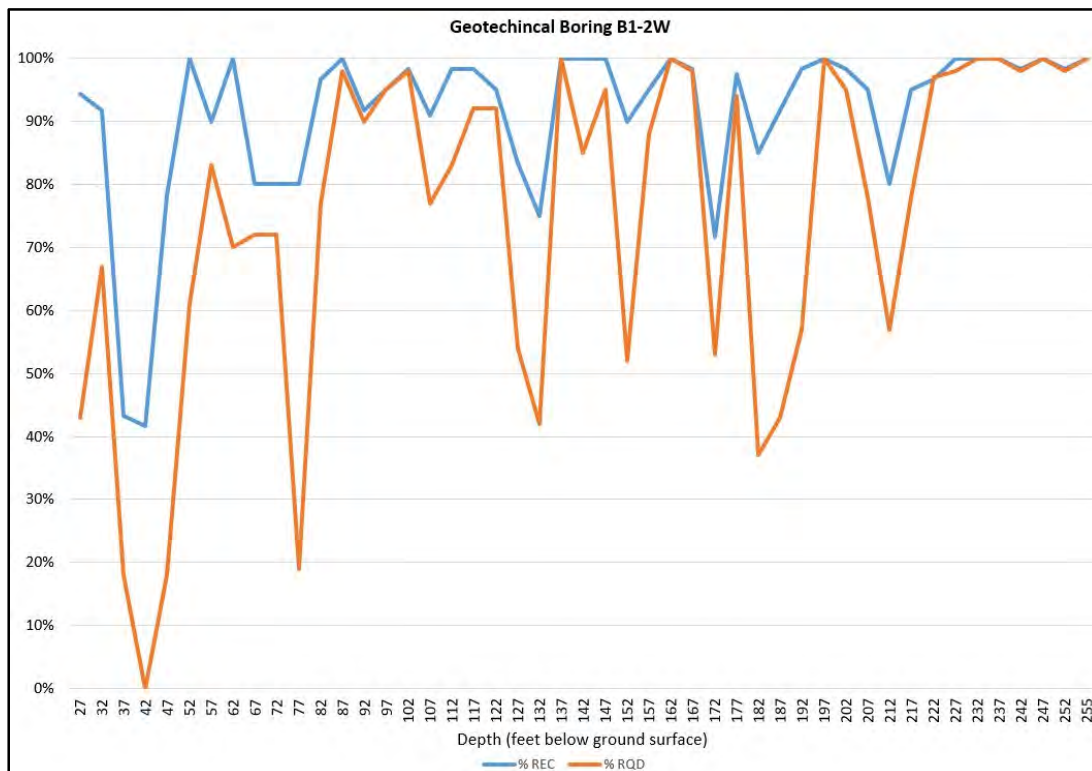


Figure 7: Percent Recovery and RQD with Depth in B1-2W



Groundwater was not observed during advancement of boring B1-2W. Water levels in the boring were gauged at the beginning of each day, and water was not detected. According to the field log for geotechnical boring B1-2W (**Attachment B**), returns of drilling liquids (potable water pumped downhole to cool and lubricate the drill bit) were lost after the bit was advanced to 28.5 ft bgs. Drilling liquids returned to the ground surface briefly at 105.5 ft bgs and 108.5 ft bgs. However, drilling liquids did not return to the ground surface once the bit was advanced beyond 111 ft bgs.

B1-2E

Geotechnical boring B1-2E was advanced near the entry/exit point at the eastern end of HDD S1B-0120. The overburden was described as a medium dense, silty clay (CL-ML) to 12.5 ft bgs. The borehole was advanced via rock coring methods from 12.5 to 180.0 ft bgs. The core is representative of the Monongahela Group on the eastern side of the bore. The sandstone, observed in the core from 12.5 feet to 20 feet, correlates with the lithology map included as **Figure 3**. The remaining bedrock lithology consisted of limestone and mudstone with thin interbedded sandstone. The limestone contained several soft clay seams. Evidence of the Redstone Coal was not observed. The calculated elevation of the Redstone Coal at the B1-2E boring location, using the dip of the rocks, is 826 ft amsl. Boring B1-2E was terminated at an elevation of 827.5 ft amsl. The Pittsburgh Coal would have been encountered approximately 70 feet below the bottom of the boring.

Rock Quality Determinations (RQDs) generally improved with depth over the cored interval averaging 65% from 12.5 to 102 ft bgs and 95% from 102 to 180.0 ft bgs. Vertical to moderate angled fractures and joints were observed from 15 to 17.5 ft bgs, 49 ft bgs, 67.5 to 72.5 ft bgs, and 177.5 to 180 ft bgs. **Figure 8** presents a graphical representation of the percent recovery and percent RQD with depth in boring B1-2E to define the zones where fractures, bedding plane and horizontal fractures, are most common. Note RQDs were high and varied little between 97.5 and 147.5 ft bgs but some variability returned to the RQD values between 147.5 and 182.5 with a value near 50% over the five foot run from 152.5 to 157.5 ft bgs.

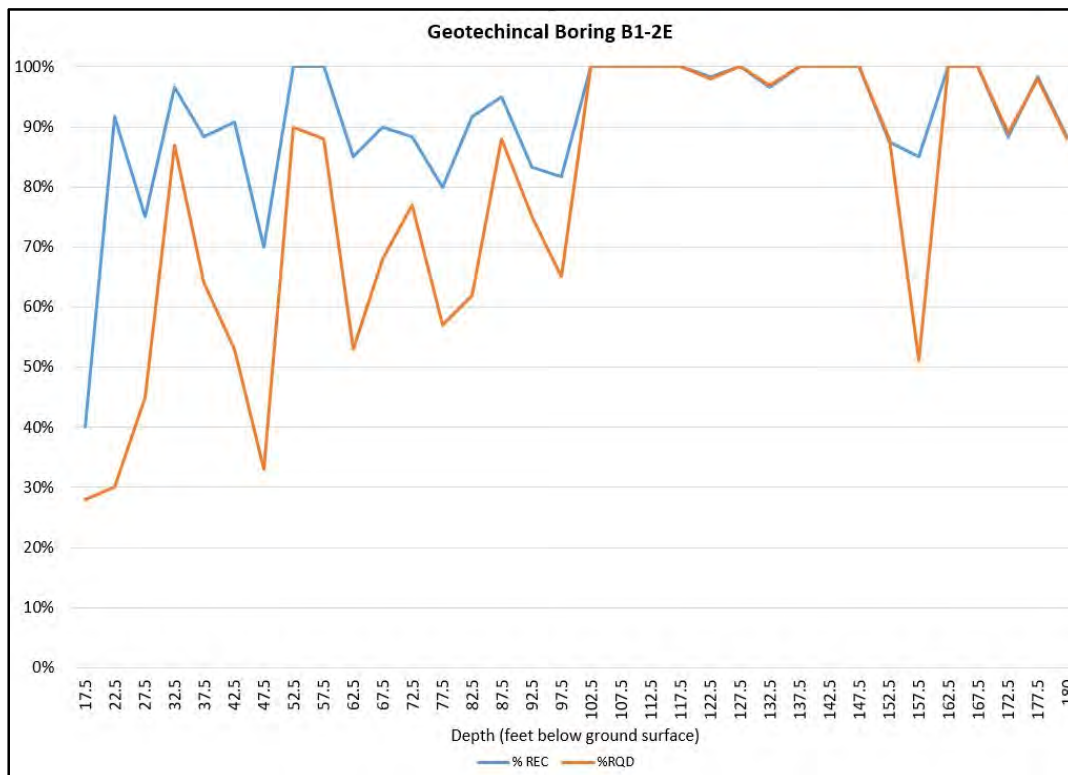


Figure 8: Percent Recovery and RQD with Depth in B1-2E



Groundwater was not observed in boring B1-2E. The water level in the boring at the start of each day of drilling ranged from 4.05 to 4.36 feet below the top of the casing. The relatively consistent depth to water at the start of each day indicates Boring B1-2E did not intersect fractures with significant water bearing capacity, and the observations are representative of retained drilling water.

2.3.3 November 2017 Geotechnical Borings

Three additional geotechnical borings were drilled in November 2017 to assess potential mine voids and the strength of rock overlying mine voids. The boring locations, drilling logs, and laboratory testing results are provided in Attachment B. The following descriptions are based on the observations of GES' PG who was present during the drilling of these geotechnical borings.

B-2A

Boring B-2A was installed along the drill profile due west of Route 88 at approximately Station 15+75 on the HDD plan and profile and was advanced to a depth of 213 feet. Bedrock coring began at a depth of 11.6 feet. Vertical fracturing and clay seams were observed in the upper 50 feet of the core. Two zones of highly weathered shale were encountered from 51 to 55 ft bgs and from 83 to 92 ft bgs. RQD and recovery data reflected extremely weak integrity within the shallower weathered zone, whereas the deeper weathered zone showed near-complete recovery and increasing RQD with depth. The Redstone Coal was encountered from 113 to 118 ft bgs and was observed as carbonaceous shale above and below an interbedded shale and coal unit. The Pittsburgh Coal was encountered from 183 to 188 ft bgs. Two voids were observed 5 feet above the coal, likely the result of mine roof-collapse. A creosote-like odor was observed within this interval which is likely due to former mining operations. During coring, drilling water was lost from 27 to 55 ft bgs and again from 153 to 163 ft bgs. Sediment appeared in Froman Run when drilling reached 100 ft bgs and ceased in response to placing a bentonite grout in the bore and allowing it to set for 24-hours and in response to a loss in circulation at 153 ft bgs. Significant changes in water levels during coring were likely due to hydraulic communication with the abandoned Pittsburgh Coal mine.

B-3

Boring B-3 was located at approximately Station 13+70 along the plan and profile and was advanced to a depth of 258 feet. Bedrock coring began at a depth of 20 feet. A shallower zone of very poor (0 to 25%) to poor (25 to 50%) RQD was encountered in the upper 40 feet of the rock core. A single vertical fracture was observed at 26 ft bgs and clay seams were observed in the upper 85 feet of the core, specifically at 39 and 57 ft bgs where core was absent. One zone of highly weathered shale was encountered from 89 to 95 ft bgs and correlates in elevation to the deeper weathered zone observed in B-2A. The Redstone Coal was encountered from 149 to 153 ft bgs and was observed as interbedded carbonaceous shale and coal. The Pittsburgh Coal was encountered from 217 to 228 ft bgs; and was observed as fractured carbonaceous shale and interbedded coal; no voids were encountered. During coring, core water was lost at 39 ft bgs, regained at 46 ft bgs, and lost again at 57 ft bgs. Water elevations remained constant (approximately 50 ft bgs) until the Pittsburgh Coal unit was encountered at which time the level fell to approximately 208 ft bgs, 9 feet above the coal.

B-4

Boring B-4 was located at approximately Station 9+75 along the plan and profile and was advanced to a depth of 291 feet. Bedrock coring began at a depth of 14.5 feet. Two zones of highly weathered bedrock were encountered in the upper 35 feet of the core and at 161 to 165 ft bgs. Whereas the lower weathered zone is within limestone, the upper is within limestone, claystone, and shale. Neither weathered zone aligns with weathered zones observed in B-2A and B-3. Vertical fractures were observed at 25, 30, 190, 215, 272, and 275 ft bgs. Clay seams were observed in the shallow weathered zone and at 230 ft bgs, at the base of a fair (50 to 75%) RQD interval. The Redstone Coal was encountered from 188 to 192 ft bgs and was observed as interbedded carbonaceous shale and coal. The Pittsburgh Coal was encountered at 252 to 266 ft bgs in the form of a void (no coal was found in this interval). Three feet of gob and coal fragments were

observed from 266 to 269 ft bgs. A significant change in the depth to water, from 18.1 to 88 ft bgs, was observed after coring through the Redstone Coal unit (188-192 ft bgs). In addition, drilling water was lost at 250 ft bgs, immediately above the Pittsburgh Coal mine void.

2.3.4 Compressive Strength

The compressive strength of the core samples collected from geotechnical borings B1-2W and B1-2E was measured in accordance with ASTM Standard Test Method D7012 (Method C). The testing results are included in **Attachment B**. The average compressive strength of the limestone units was 11,716 psi. The average compressive strength for the mudstone/shale units was 7,321 psi. These results are generally consistent with expectations, as rate of advancement at other ME II HDDs has been much slower through limestone than the rate of advancement through shale or mudstone.

2.3.5 Rock Engineering Properties

The Monongahela Group rock properties are as follows (Geyer and Wilshusen, 1982):

- Well developed, thin beds in sandstone and siltstone; thicker beds in limestone; shale is fissile or very thick; claystone very poor bedding.
- Fracture joints are poorly to moderately well developed in sandstone and siltstone; poorly developed in claystone and shale; moderately to well developed in limestone; widely spaced in irregular intervals; blocky or platy pattern; spacing is closer in finer grained rocks; open and vertical.

2.4 Hydrogeology

2.4.1 Occurrence of Groundwater

There is very little primary porosity associated with the sedimentary rocks of western Pennsylvania for the storage and movement of groundwater. The primary occurrence of groundwater in the Monongahela Group is associated with the interconnected network of secondary porosity features characteristic of the bedrock. These include bedrock fractures that developed during folding and faulting (Newport, 1973) and bedding plane partings. Regional systematic joints within the bedrock are generally indicated by northwest and west-northwest trending (Nickelsen and Hough, 1967) fracture traces. In addition, a set of associated non-systematic joints are indicated by a series of fracture traces oriented north-northeast within straight segments of local stream valleys. These joint sets can represent preferred pathways of groundwater flow.

2.4.2 Groundwater Water Levels

No representative groundwater levels were obtained during the drilling of geotechnical borings HDD-06, HDD-07, B1-2E and B1-2W.

After review of records in the Pennsylvania Groundwater Information System (PAGWIS) and eMapPA databases for supply wells in Union Township, Washington County, two water supply wells were identified proximal to HDD S1B-0120. The approximate well locations are illustrated on **Figure 9**. Well 148364 appears to be in the same location as the well identified as ***630-01 by SPLP's 450-foot water supply survey (see Section 2.4.6); well 148374 is not a location where a land owner requested pre-construction testing. Well construction details in the PAGWIS records are summarized on **Table 1**.

Based on the approximate ground surface elevations and these well records, a local shallow or perched water table is estimated to occur between approximately 910 and 920 ft amsl. Considering that the base of HDD S1B-0120 on the plan and profile will be at an elevation of 880 ft amsl, the middle section of the boring would be advanced within saturated zones. The road and FlexBor profiles are higher in elevation and would not pass through this zone.

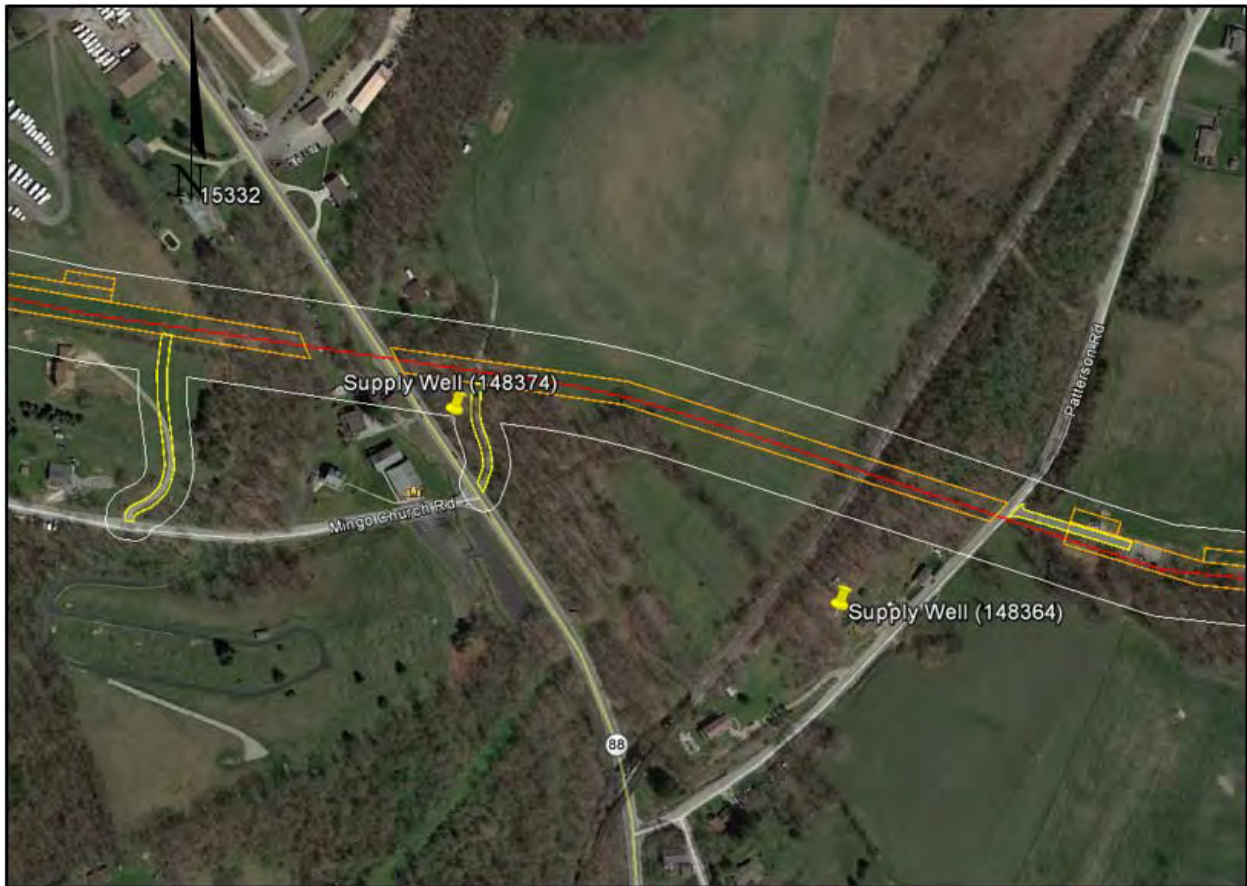


Figure 9. Water Supply Well Locations (well locations may not be accurate, per PAGWIS Files)

Table 1 – PAGWIS Well Records for Wells 148374 and 148364

Well ID#	148374		148364	
	Depth (feet)	Elevation (ft amsl)	Depth (feet)	Elevation (ft amsl)
Ground Surface (approximate)		980		990
Casing Depth	21	959	24	966
Total Depth (feet)	120	860	130	860
Depth to Rock (feet)	12	968	21	969
Depth to Water (feet)	60	920	80	910

Water levels obtained during the drilling of borings B-2A, B-3, and B-4 indicate a shallow water table or perched aquifer can supply water to local water supply wells, but a water table surface a few feet above the abandoned Pittsburgh Coal mine indicates groundwater drains to the mine in the area.

2.4.3 Well Yields

According to Wagner (1975) water well yields in the area are relatively low, ranging from 0.2 to 15 gallons per minute (gpm). While well yields in the area will improve with increased well diameter, the yields generally do not improve with increased well depth. According to the PAGWIS records, both supply wells are 6-inches in diameter and have a maximum yield of 3 gpm.

2.4.4 Water Supply Wells

An initial pre-construction sampling program for domestic wells within 150 feet of the pipeline right-of-way (ROW) was performed by SPLP. All property owners within 150 feet of the ROW were given the opportunity to have any existing water sources (wells and springs) tested prior to the start of construction. A review of property records, using Washington County's Geographic Information System (GIS) Parcel Viewer, was conducted to verify the status of the wells. The records indicate the property where Well #148364 plots is connected to public water supply. However, the adjacent property to the south at 3 Patterson Road, (Parcel ID #640-013-00-00-00030-00) obtains water via private supply well. The properties surrounding Well #148374 are connected to public water, indicating this well may no longer be in use. Of the remaining residences proximal to HDD S1B-0120, only the residence at 541 Mingo Church Road (Parcel #640-011-00-00-00070-01) obtains water via a private supply well. A record for this well was not available through the PAGWIS system. A recent survey of water supply sources within 450 feet of the HDD alignment produced a list of all landowners interested in having pre-construction sampling performed for their water supply. The findings from this effort are presented in **Section 2.4.5**.

2.4.5 450-Foot Water Supply Survey

SPLP performed a preconstruction survey of landowners within 450 feet of the HDD S1B-0120 alignment and six landowners responded positively to an offer to have their wells tested. **Figure 10** illustrates the sampling locations, which include two wells and three springs. A fourth spring is located west of the 450-foot line but was included in the program. No well specific water level or pump depth information was available or could be collected during the sampling of the wells. Well depth information was provided by the property owner for one well (WL-12082017-636-01) located approximately 320 feet from the S1B-0120 alignment (100 ft bgs). Assuming twenty feet of steel surface casing, a conservatively large estimate of the water production zone from 20 to 100 ft bgs. Comparing this estimated production zone depth interval to the elevation of the HDD profile indicates the HDD would be above the groundwater production interval where the HDD passes by the well. For the combined FlexBor/road bore/open trench alternative the pipe installation would be open trench, approximately 320 feet from the well.

2.4.6 Potential Impact of Mining on Groundwater

Mine subsidence in this region causes differing degrees of fracturing within the overburden due to different zones of compressive and tensile stresses. Compressive stresses cause the strata that is generally horizontally bedded to either shift laterally along the bedding planes or rupture, which increases the lateral movement of groundwater along horizontal bedding plane partings. Additional vertical and high angle fracture planes are created by the tensile stresses. The increased secondary porosity creates additional pathways for the vertical movement of groundwater and groundwater storage (Iannacchione, et. al., 2008). **Figure 11** depicts of the hydrologic responses that occur in five zones of deformation above areas of coal extraction and mine subsidence. These zones include (from mine to surface) the caved zone, fractured zone, dilated zone, constrained strata zone, and surface fracture zone (Kendorski, 1993).

The intervals of lower recovery and lower RQD values above the mine seen in geotechnical borings B1-2W, B-2A, B-3, B-4 and B1-2E generally correspond with the Hydrogeologic Response Zones described above, even though evidence of mine subsidence was not observed at the ground surface (i.e. Constrained Zone). A Fracture Zone with vertical fractures, low RQD and low recovery was seen just above the Cincinnati Mine in the three borings that penetrated the mine (B-2A, B-2, and B-4). In general, zones of

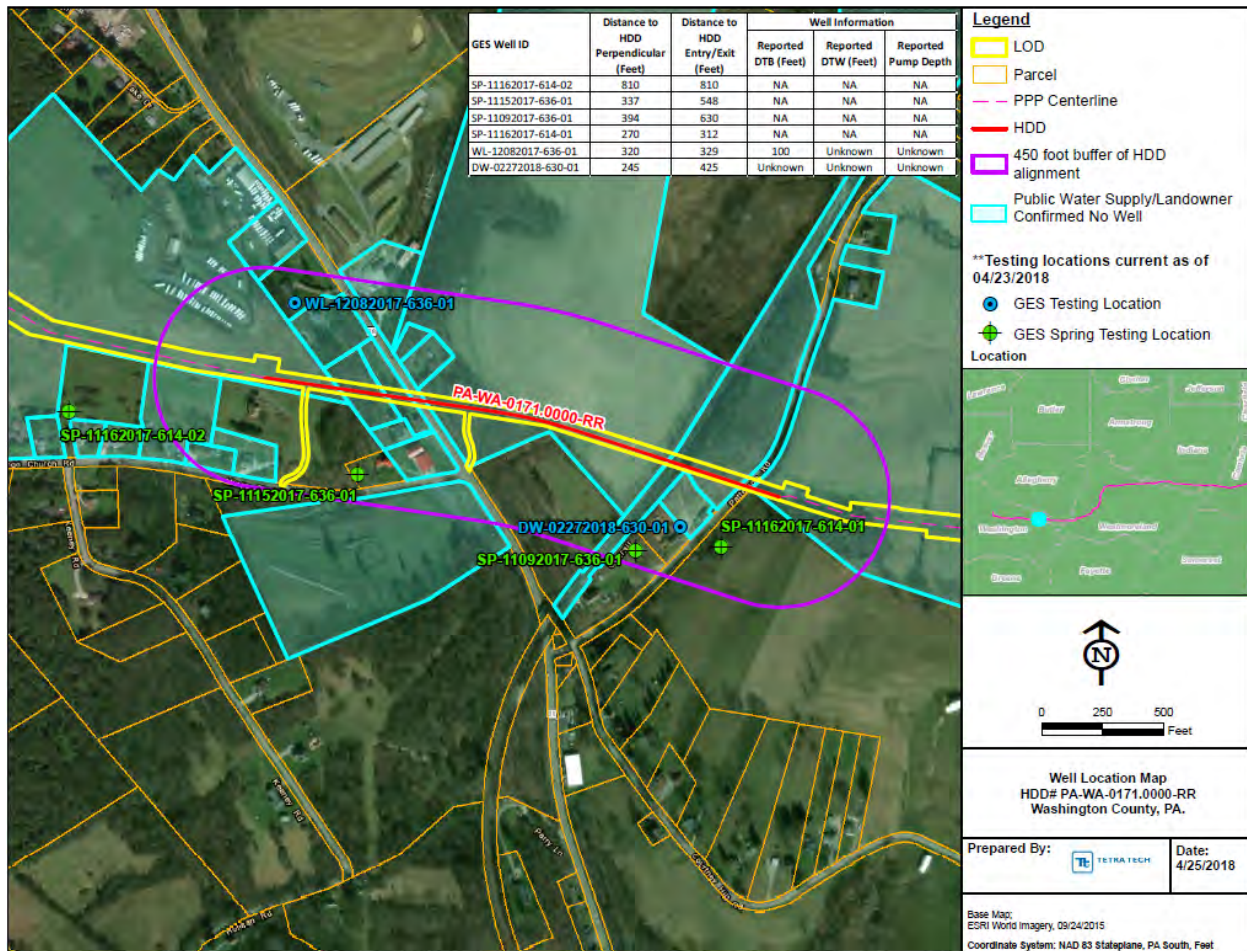


Figure 10. 450-foot Water Supply Survey Results

highly variable RQD due to bedding plane partings and fracturing were seen in all five geotechnical borings for which rock cores were obtained and that section of rock is the Dilated Zone. Cincinnati Mine in the three borings that penetrated the mine (B-2A, B-2, and B-4). In general, zones of highly variable RQD due to bedding plane partings and fracturing were seen in all five geotechnical borings for which rock cores were obtained and that section of rock is the Dilated Zone.

The locations of the 2017 IRs support groundwater flow in the hydrologic response zones from previous deep mine subsidence. The IRs observed at multiple locations during the initial advancement of HDD S1B-0120 up to 370 feet south-southeast of the drill path (see Section 3.2), correlate with increased horizontal flow of groundwater and drilling liquids in the Dilated Zone. The absence of any measureable water level during the advance of B1-2W and permanent loss of drilling liquid returns during advancement of the boring B1-2W past 111 ft bgs is consistent with the presence of a Fractured Zone that drains to the deep mine.

2.4.7 Mine Pools

Regional mine pool maps for abandoned Pittsburgh coal mines in southwestern Pennsylvania were published in 2004 by the National Mine Reclamation Center at West Virginia University (<http://www.hrc.nrcce.wvu.edu/>). The area of HDD S1B-0120 appears on the Hackett and Monongahela, Pennsylvania, Quadrangles overlying an area of abandoned deep Pittsburgh coal mines labeled “Courtney”.

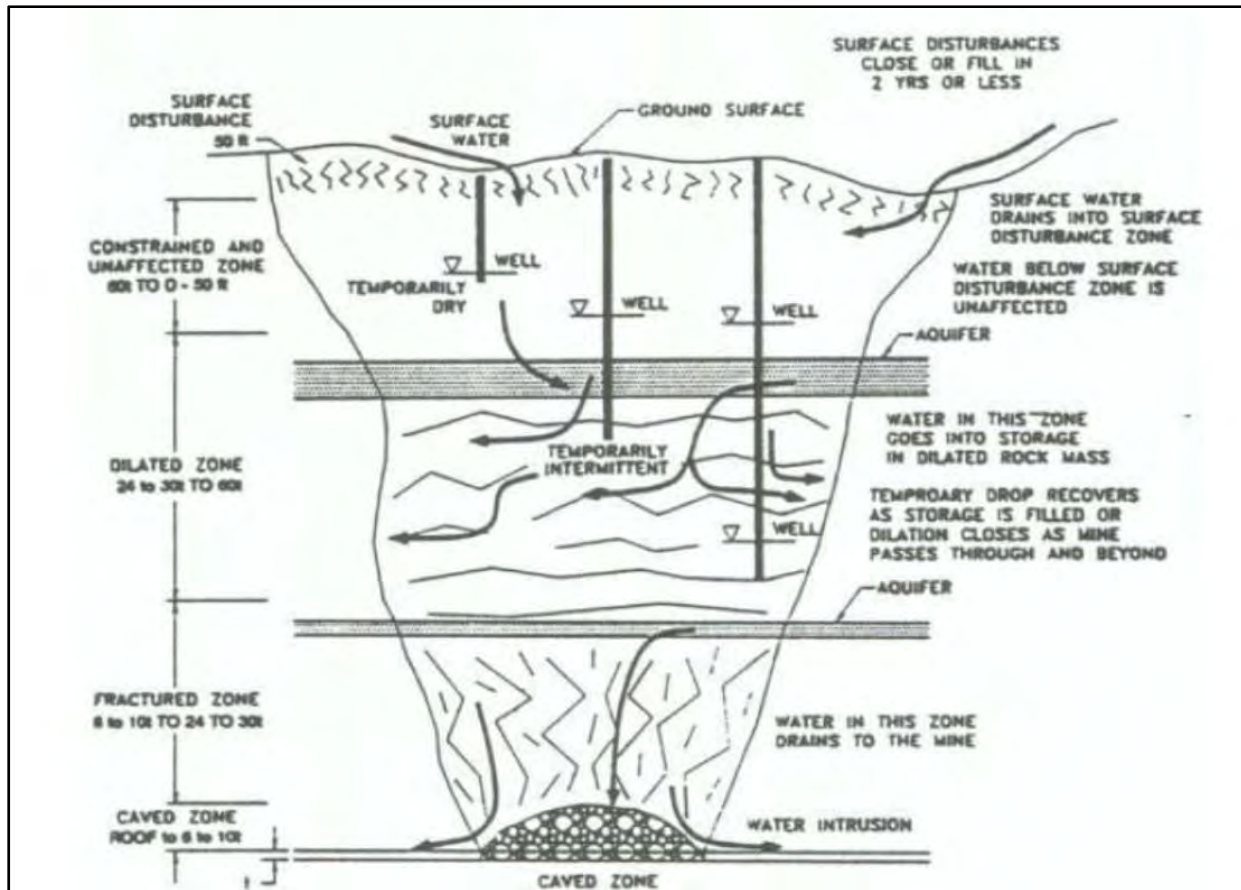


Figure 11. Hydrologic Response Zone (From Kendorski, 1993)

The shading on the maps indicated the mines in this region are “not flooded or unknown”, as opposed to “flooding or flooded” or “active mine”. A mine discharge point is shown on the map approximately 1.0 miles east of HDD S1B-0120 near the west shore of the Monongahela River (on the Monongahela 7.5 min. quadrangle map) at an elevation of approximately 768 ft amsl.

Three geotechnical borings were advanced beyond the depth of the abandoned Pittsburgh coal mine in November 2017. In two of the borings (B-2A and B-3) the water levels in the boreholes dropped rapidly as the borings approached the roof of the mine void to an elevation a few feet above the top of the mine void. In the third boring (B-4) water was lost as the boring approached the roof of the mine and was not regained for the rest of the boring. These observations indicate a mine pool is likely present at HDD S1B-0120. The water level elevations in B-2A and B-3 were approximately 805 and 807 ft amsl, respectively. The lowest elevation of the 9/21/17 revision of the profile for HDD S1B-0120 is 818 ft amsl. Thus, the HDD profile would not encounter the mine pool and there is no risk for creating a new mine discharge in that manner.

3.0 OBSERVATIONS TO DATE

3.1 HDD Observations for ME I

The list of ME I IRs provided in the PPC Plan for Washington County does not identify any IRs at HDD S1B-0120. However, pipeline staff reported that drilling fluid appeared on the land surface at the cistern for the Mingo Presbyterian Church along Mingo Church Road and in the unnamed tributary along Patterson Road near the planned HDD exit point during the ME I project.

3.2 HDD Observations for ME II

From May 27 to June 15, 2017 attempts were made to drill the pilot hole for HDD S1B-0120. During the initial advancement of the pilot hole for HDD S1B-0120, from west to east, drilling fluid returns were lost shortly after advancing the drill bit into bedrock. Loss of drilling fluid began during the advancement of the 2nd joint (approximately 65 feet). In addition, approximately 5,000 gallons of drilling liquids in the mud pit drained into the formation at the western end of the HDD profile. IRs were subsequently identified at five separate locations between the entry point and State Route 88. The locations of the ME II IRs are illustrated on **Figure 12**.

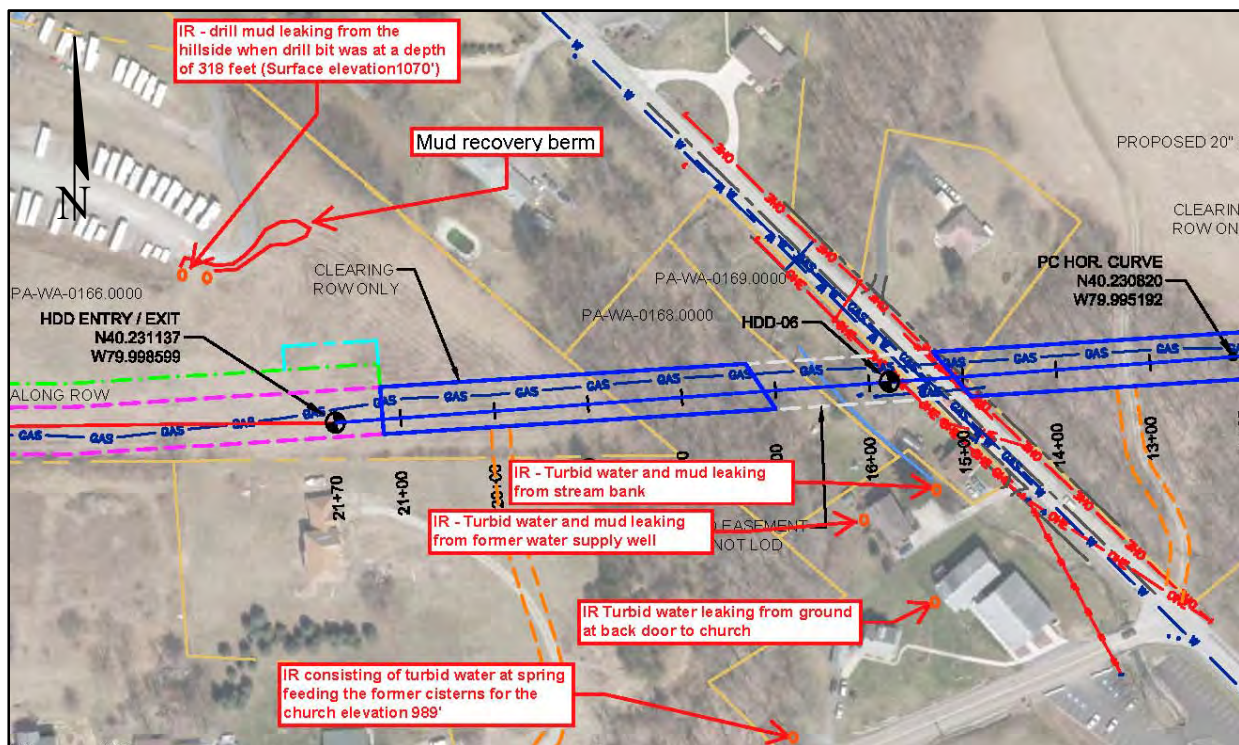


Figure 12: 2017 IR Location Map (Modified from Tetra Tech Rooney April 4, 2017)

Corrective measures included the injection Lost Circulation Materials (LCMs) and the installation of 316 feet of 16-inch casing. Initially, the casing was successful at improving the returns of drilling mud. However, drilling fluid returns were lost when the drill bit was approximately 667 feet from the entry point (moving west to east). Again, LCMs were used to regain drilling fluid returns. During the subsequent advancement of the borehole, IRs occurred at Mingo Creek Church and in the stream S27 along State Route 88. Advancement of the borehole was terminated after drilling mud continued to flow from a former supply well 145 feet south of the borehole.



4.0 HDD AND FLEX BORE/ROAD BORE OPEN TRENCH ALTERNATIVE

The proposed alignment of the considered HDD S1B-0120 is 2,170 linear feet long. The profile is 46 feet below stream S27, 22 feet below stream S28 and seven feet below stream S142. At its deepest part (at elevation 880 ft amsl) the vertical distance to the abandoned Cincinnati Mine is estimated to be approximately 90 feet.

For the FlexBor/road bore/open trench alternative the FlexBor under the Wheeling Lake Erie Railroad and Patterson Road is 779 feet long. The profile for the FlexBor runs 15 feet under streams S28 and S142, and at its deepest part (at elevations 965 ft amsl) is approximately 193 feet above the abandoned Cincinnati Mine. The road bore under State Route 88 is 168 feet long and passes 8 feet under stream S27. The deepest part of the bore is at the western entry pit at approximate elevation 962 ft amsl and here the profile is approximately 166 feet above the abandoned Cincinnati Mine.

As described by Terracon on two geotechnical boring logs (B1-2E and B1-2W, **Attachment B**), overburden consists of silty clay at B1-2E and silty sand with gravel grading to sand and silty clay at B1-2W. Standard HDD entry/exit practices should limit IR risk above bedrock in these relatively cohesive soils. IR risk is substantially reduced under the FlexBor/road bore/open trench alternative as no pressurized drilling fluids will be used.

According to published geologic and hydrogeologic information, and the rock core descriptions for geotechnical borings B1-2W, B1-2E, B-2A, B-3 and B-4, HDD S1B-0120 is underlain by sequences of sedimentary rocks of the Monongahela Group. Limestone and mudstone are prevalent and relatively massive with thin sandstones and siltstones. Rock strength is variable and inconsistent from the roof of the Cincinnati Mine to the top of rock manifested as a fracture zone directly above the mine and a dilated zone above that. A mapped fracture trace intersects the eastern extent of the alignment which may represent a narrow vertical planar zone of fracturing. Other major structural features in close proximity of the bore path are the S27 and S28 stream valleys, which are straight stream segments and appear to be structurally controlled. Due to this pervasive inconsistent rock strength along the HDD alignment there is no one pathway, above the mine, through which an HDD could pass with a low risk of an IR occurring. It is reported that one IR occurred during the installation of ME-I at this location and five IRs occurred during the first attempt to drill the pilot hole for S1B-0120.

In terms of reducing the risk of loss of circulation (LOC) and of IRs, the FlexBor/road bore/open trench alternative is favorable because drilling muds are not used to advance the bores. Under this alternative, the road bore under State Route 88 and stream S27 will be advanced with an air hammer pilot and Flexbor reamer. The FlexBor under Patterson Road, the Wheeling Lake Erie Railroad and stream S142 will be completed east to west. The FlexBor will start with an air hammer pilot in front of a 6-inch casing followed by the FlexBor reamer during which high pressure air flow with low volume water injection cools the drill bit and removes cuttings.

Groundwater was not observed in boring B1-2W, and the minimal loss of drilling fluids in B1-2E indicted significant water-bearing fractures were not intersected. Water level data obtained during the drilling of borings B-2A and B-3 indicate a mine pool is present in the abandoned Pittsburgh Coal mine, but the HDD profile does not intersect the mine and there is no risk of creating a new mine discharge from HDD drilling. The IRs observed at multiple locations during the initial attempt to install HDD S1B-0120, up to 370 feet south-southeast of the HDD S1B-0120 drill path, correlate with increased horizontal movement of drilling fluid and drilling fluid diluted by groundwater in the Dilated Zone. It is expected that the HDD would pass through saturated materials in the middle section of the bore but that the water well production zone for one



water supply well identified during the 450-foot well survey would not be impacted due to distance from the HDD alignment and depth of the profile relative to the well's production zone.

The profiles for both FlexBors are higher in elevation than estimated saturated zones in the bedrock thus there is low risk of affecting these zones under the Flexbor/road bore/open trench alternative. The one water supply well identified during the 450-foot well survey is approximately 320 feet away from an open trench portion of the alternative, therefore there no risk of affecting that well under the alternative.

There is no IR risk for the road bore part of the Flexbor/road bore/open trench alternative because the road bore is drilled without fluids. For the FlexBors, which will be drilled with compressed air and water, there is very little risk of impacting S142 and S28 because no pressurized fluids are used in the air hammer pilot, and the FlexBor reaming process is within an enclosed casing.



5.0 CONCLUSIONS AND RECOMMENDATIONS

Based on this hydrogeologic evaluation the HDD profile would pass through bedrock of variable degrees of fracturing and strength due to the response of the bedrock to mine roof collapse within the abandoned Cincinnati (Pittsburgh Coal) Mine. A previous attempt to install the ME-II 20-inch pipe using HDD technology resulted in multiple IRS and geotechnical studies show that all possible HDD pathways above the Cincinnati Mine have an inherent risk of LOCs and IRs.

The FlexBor/road bore/open trench alternative eliminates the risk of LOCs and IRs from drilling fluids and appears to a preferred approach for installation of the ME-II 20-inch line at the location of HDD S1B-0120.

6.0 REFERENCES

eMapPA, Pennsylvania Dept. of Env. Prot., <http://www.depgis.state.pa.us/emappa/>

Geyer, A.R. and J.P. Wilshusen (1982), *Engineering Characteristics of Rocks of Pennsylvania*. Department of Natural Resources, Bureau of Topographic and Geologic Survey, EG-01, 4th Ser.

Iannacchione, A., Tonsor, S. J., Witowski, M., and others (2008), *The Effects of Subsidence Resulting from Underground Bituminous Coal Mining on Surface Structures and Features and on Water Resources 2003 to 2008*, Bituminous Mine Subsidence and Land Conservation Act Five-Year Report, The University of Pittsburgh for the Pennsylvania Department of Environmental Protection.

Kendorski, F. (1993), *Effect of High-Extraction Coal Mining on Surface and Ground Waters*, 12th International Conference on Ground Control in Mining, Morgantown, WV, August 3-5, 1993, pp. 412-425.

Kent, B. H. and Schweinfurth S. P. (1969), *Lithologic Map of the Hackett Quadrangle, Pennsylvania*. Commonwealth of Pennsylvania, Department of Natural Resources, Bureau of Topographic and Geologic Survey, Bulletin G56.

Miller B. L. (1934), *Limestones of Pennsylvania*. Commonwealth of Pennsylvania, Department of Internal Affairs, Bureau of Topographic and Geologic Survey, Bulletin M22.

National Mine Reclamation Center (2004), *WV 173 Phase IV EPA Region III Mine Pool Project, Final Technical Report for the project period Jan. 1, 2003 through Oct. 31, 2004*. (<http://www.hrc.nrcce.wvu.edu/>).

Nickelsen, R. P. and Hough, V. D. (1967) *Jointing in the Appalachian Plateau of Pennsylvania*, GSA Bull. v. 78, p. 609-630

Newport, T.G. (1973), *Summary Ground-Water Resources of Washington County, Pennsylvania*. Commonwealth of Pennsylvania Department of Natural Resources, Pennsylvania Geological Survey, Water Sources Report 38.

Pennsylvania Groundwater Information System PAGWIS, Bur. of Topo. and Geol. Surv., <http://www.dcnr.pa.gov/Conservation/Water/Groundwater/PAGroundwaterInformationSystem/Pages/default.aspx>

Pennsylvania State University (2017), *Pennsylvania Historic Underground Mine Map Database*, Department of Environmental Protection, <http://www.minemaps.psu.edu/>.

Roen, J. B., Kent, B. H., and Schweinfurth, S. P., (1970), *Lithologic Map of the Monongahela Quadrangle, Pennsylvania*. Commonwealth of Pennsylvania, Bureau of Topographic and Geologic Survey, in PGS Bulletin G56A.

Sevon, W. D., 2000, *Physiographic Provinces of Pennsylvania*, 4th ed., Pa. Topo. and Geol. Surv., Map 13.

Skema, V.W. (1987), *Coal Resources of Washington County, Pennsylvania*. Commonwealth of Pennsylvania, Bureau of Topographic and Geologic Survey, Mineral Resources Report 93, Part 1.

Tetra Tech Rooney (April 4, 2017), *Drawing Number PA-WA-0171.0000-RR, Wheeling and Lake Erie RR*. Prepared for Sunoco Logistics Partners LP.



United States Department of Agriculture (August 2017), <http://websoilsurvey.nrcs.usda.gov>, Natural Resources Soil Conservation Survey for Washington County, Pennsylvania.

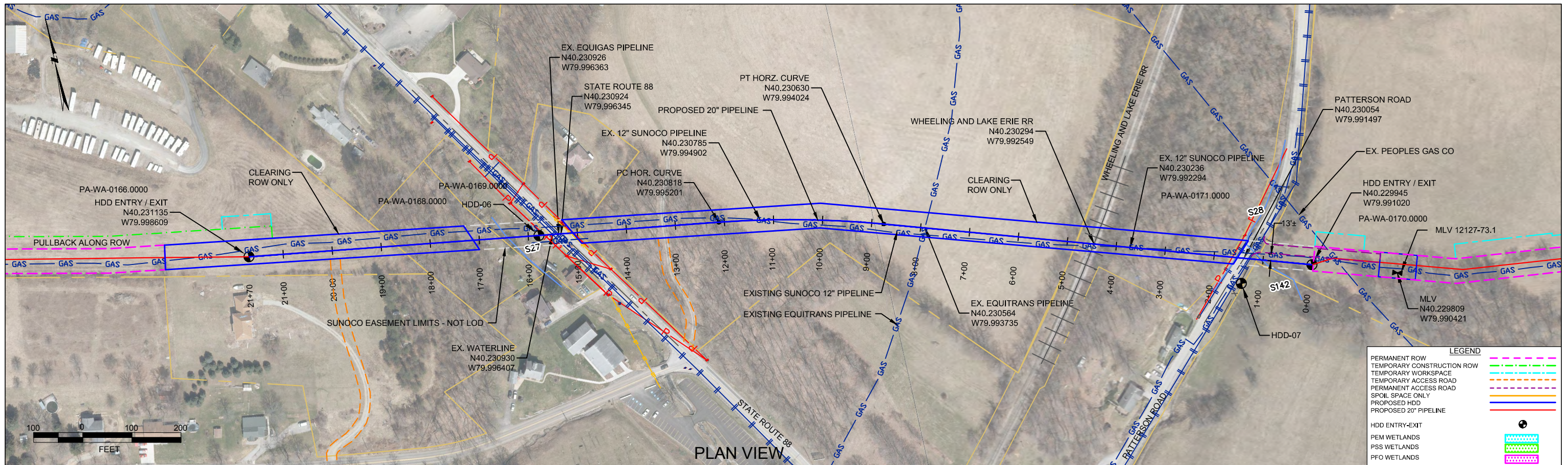
United States Geological Survey (USGS) Monongahela, Pennsylvania 1:24,000 Topographic Quadrangle Map, rev. 1979.

Wagner, W. R., Craft, J. L., Heyman, L., and Harper, J. A.. (1975), *Greater Pittsburgh Region Geologic Map and Cross Sections*. Commonwealth of Pennsylvania, Bureau of Topographic and Geologic Survey, Map 42.



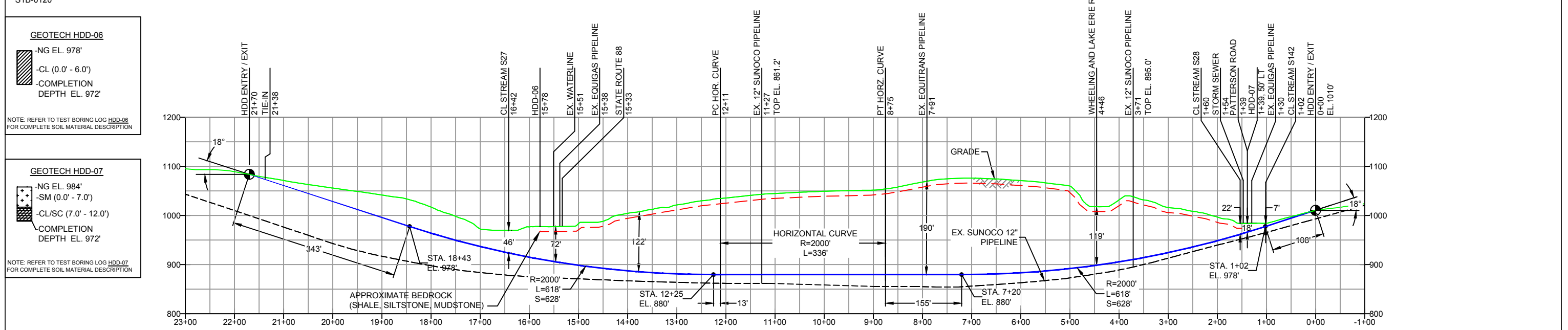
Attachment A

HDD and FlexBor/Road Bore/Open Trench Alternative Plans and Profiles



WASHINGTON COUNTY, PENNSYLVANIA - UNION TOWNSHIP
S1B-0120

PROFILE VIEW



- DESIGN AND CONSTRUCTION:**
- CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
 - THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
 - DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
 - CROSSING PIPE SPECIFICATION:
HDD HORZ. LENGTH (L=): 2170'
HDD PIPE LENGTH (S=): 2212'
20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
 - INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
 - INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
 - PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
 - CARRIER PIPE NOT ENCASED.
 - PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
 - CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
 - PIPELINE AND CROSSING TO BE INSTALLED AND MAINTAINED IN ACCORDANCE WITH LAST APPROVED AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION SPECIFICATIONS FOR PIPELINES CONVEYING FLAMMABLE AND NON-FLAMMABLE SUBSTANCES.
 - BLASTING NOT PERMITTED.
 - SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.

NOTES

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

REF. DRAWING		REVISIONS	
ES-1.55	TO ES-1.56	EROSION & SEDIMENT PLAN	
SHEET 32	TO SHEET 33	AERIAL SITE PLAN	
		EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16
		EP1	REVISED PER PADEP COMMENTS
		EP	
DWG NO	DWG NO	DESCRIPTION	NO.

**Sunoco Logistics
Partners L.P.**

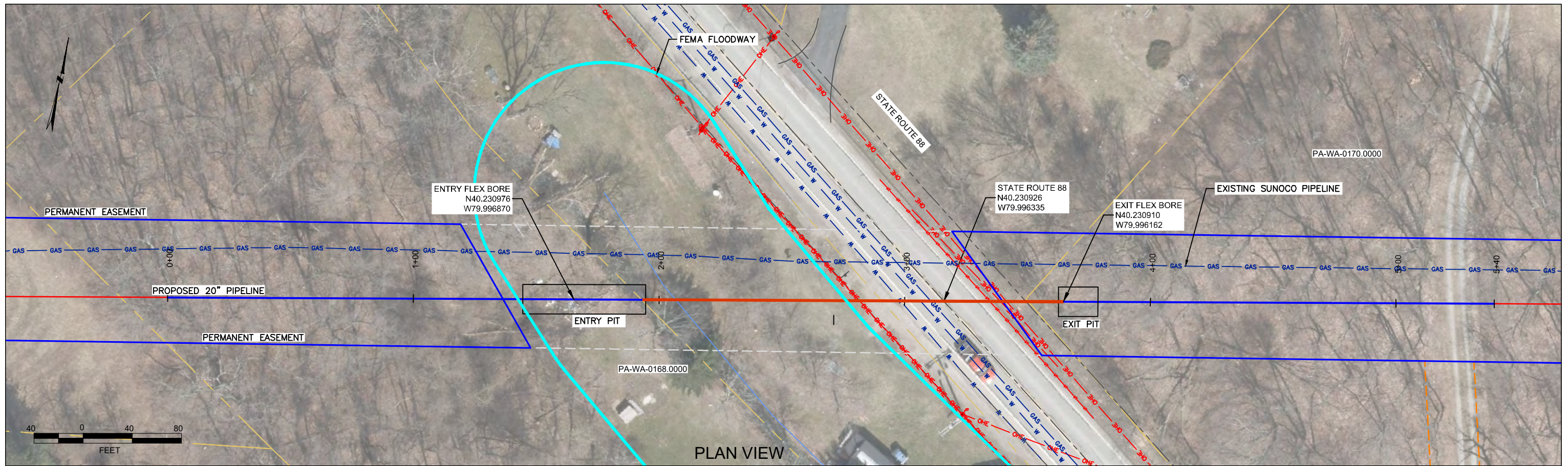
SUNOCO PIPELINE, L.P.

20-INCH HORIZONTAL DIRECTIONAL DRILL
WHEELING AND LAKE ERIE RR
PENNSYLVANIA PIPELINE PROJECT

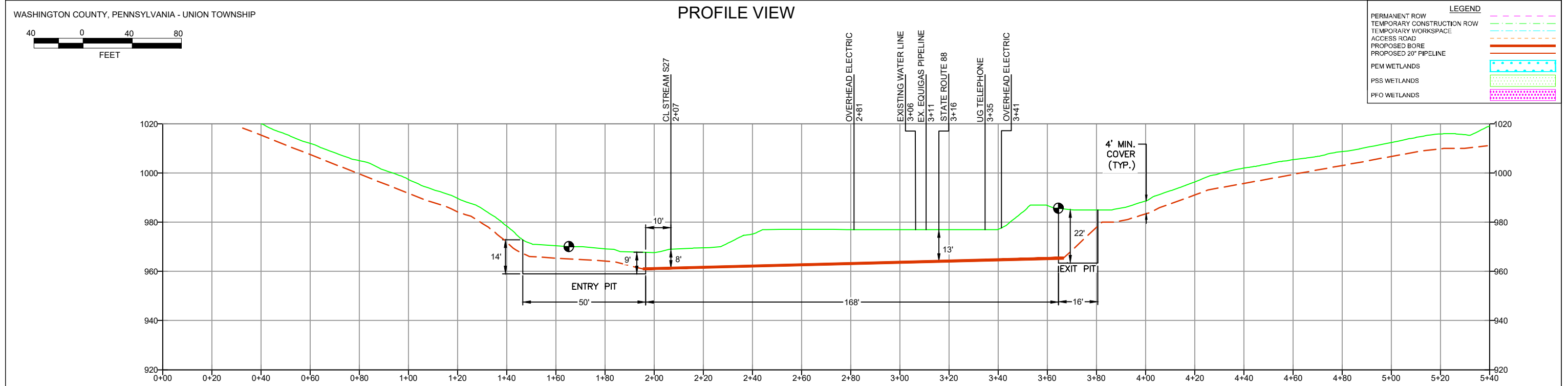
TETRA TECH ROONEY
(303) 792-5911

SCALE: 1"=200'

DWG. NO. PA-WA-0171.0000-RR



PLAN VIEW



PROFILE VIEW

LEGEND

- PERMANENT ROW
- TEMPORARY CONSTRUCTION ROW
- TEMPORARY WORKSPACE
- ACCESS ROAD
- PROPOSED BORE
- PROPOSED 20" PIPELINE
- PEM WETLANDS
- PSS WETLANDS
- PFO WETLANDS

WASHINGTON COUNTY, PENNSYLVANIA - UNION TOWNSHIP

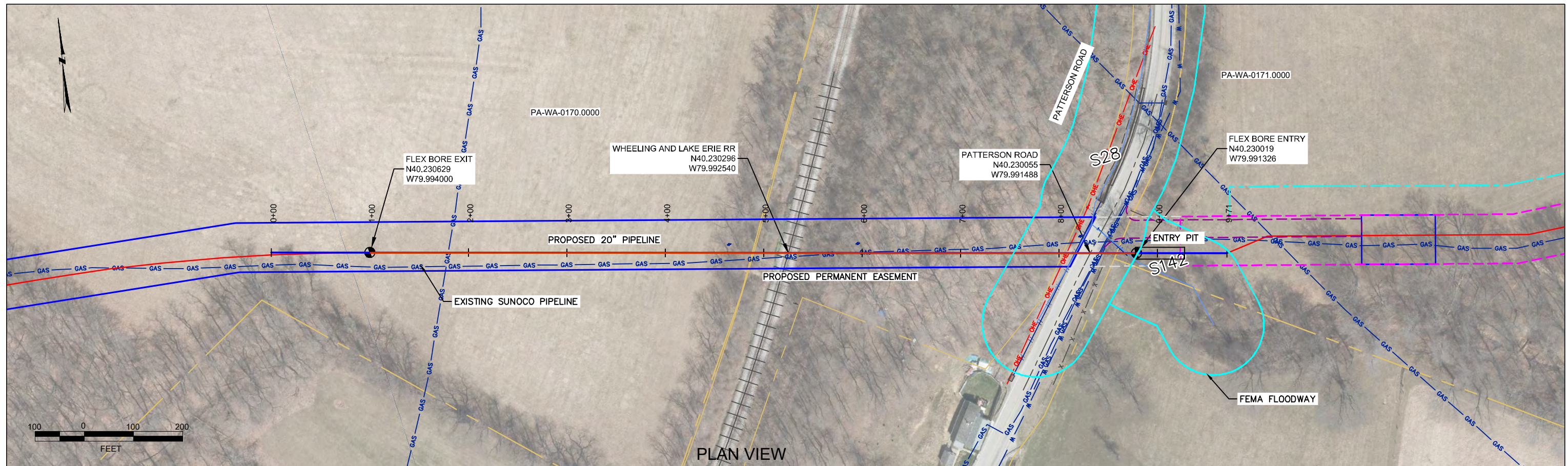


- CONSTRUCTION NOTES**
- 20" WELDED STEEL PIPE: 20" OD x 0.456" WT, X-65, API-5L, PSL2, ERW, BFW, DRL
 - COATING: 14 TO 16 MILS OF 3M SCOTCHKOTE TM 6233 FBE WITH 40 MILS MIN. DFT POWERCRETE R95.
 - DESIGN FACTOR: 0.50 (HOOP STRESS)
 - DESIGN PRESSURE: 1480 PSIG
TEST PRESSURE: 1850 PSIG

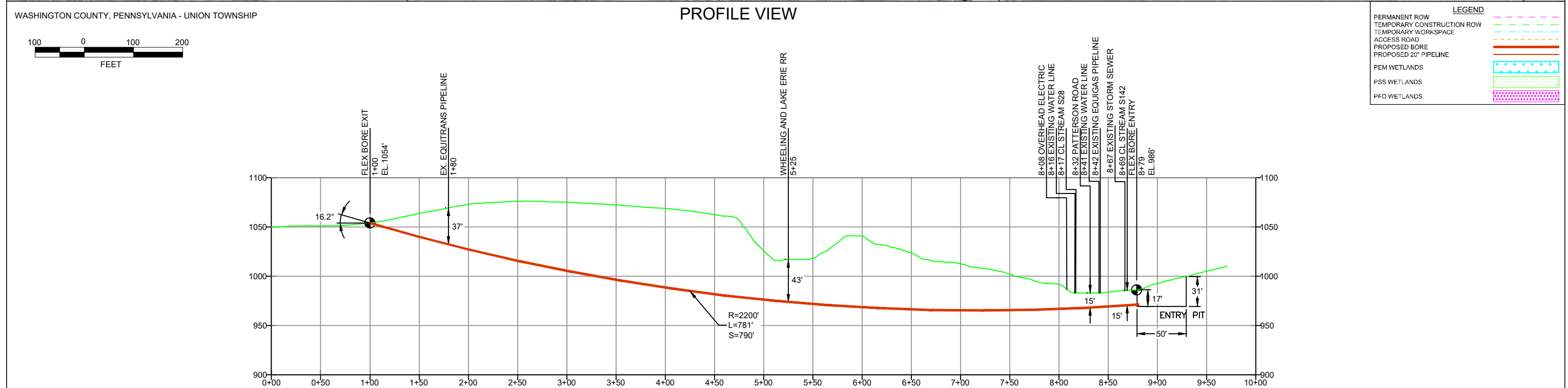
- THE COATING ON THE CARRIER PIPE SHALL BE INSPECTED IMMEDIATELY PRIOR TO ITS INSTALLATION AND ALL DAMAGED COATING SHALL BE REPAIRED IN ACCORDANCE WITH SUNOCO'S PIPELINE COATING SPECIFICATIONS.
- INSTALL CATHODIC PROTECTION TEST LEADS AS SPECIFIED ON THE ALIGNMENT SHEETS OR SUNOCO CORROSION TECHNICIAN.
- WELDED JOINTS INSIDE R.O.W. SHALL BE 100% X-RAYED.
- CONTRACTOR WILL MAINTAIN A MINIMUM 4' OF COVER TO THE TOP OF PIPE USING FIELD BENDS.
- CONTRACTOR WILL MAINTAIN A MINIMUM 24" OF COVER FROM ALL EXISTING UTILITIES.
- CONTRACTOR WILL MAINTAIN A MINIMUM 5' OF COVER FROM BOTTOM OF STREAMS
- IN ADDITION TO THE SITE-SPECIFIC INFORMATION PROVIDED IN THIS DRAWING, GENERAL REQUIREMENTS INCLUDED IN ALIGNMENT SHEETS, PERMITS AND APPROVAL FROM FEDERAL, STATE AND LOCAL AGENCIES ALSO APPLY.

PRELIMINARY DESIGN ONLY

NOTES		REVISIONS						Sunoco Logistics Partners L.P.		SUNOCO PIPELINE, L.P.	
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.										BORE STATE ROUTE 88 PENNSYLVANIA PIPELINE PROJECT	
										SCALE: 1"=40' DWG. NUMBER: PA-WA-0169.0000-RD FLEX BORE	
A	ISSUED FOR REVIEW	MRS	04/10/18	RMB	04/10/18	CAG	04/10/18				
NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE				



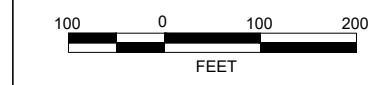
PLAN VIEW



PROFILE VIEW

LEGEND	
PERMANENT ROW	
TEMPORARY CONSTRUCTION ROW	
TEMPORARY WORKSPACE	
ACCESS ROAD	
PROPOSED BORE	
PROPOSED 20" PIPELINE	
FEM WETLANDS	
PSS WETLANDS	
PFO WETLANDS	

WASHINGTON COUNTY, PENNSYLVANIA - UNION TOWNSHIP



- CONSTRUCTION NOTES**
- 20" WELDED STEEL PIPE 20" OD x 0.456" WT, X-65, API-5L, PSL2, ERW, BFW, DRL
 - 16" WELDED STEEL PIPE 16" OD x .438 WT., X-70, API 5L, PSL2, ERW, BFW
 - COATING: 14 TO 16 MILS OF 3M SCOTCHKOTE TM 6233 FBE WITH 40 MILS MIN. DFT POWERCRETE R95.
 - DESIGN FACTOR: 0.50 (HOOP STRESS)
 - DESIGN PRESSURE: 1480 PSIG
TEST PRESSURE: 1850 PSIG

- THE COATING ON THE CARRIER PIPE SHALL BE INSPECTED IMMEDIATELY PRIOR TO ITS INSTALLATION AND ALL DAMAGED COATING SHALL BE REPAIRED IN ACCORDANCE WITH SUNOCO'S PIPELINE COATING SPECIFICATIONS.
- INSTALL CATHODIC PROTECTION TEST LEADS AS SPECIFIED ON THE ALIGNMENT SHEETS OR SUNOCO CORROSION TECHNICIAN.
- WELDED JOINTS INSIDE R.O.W. SHALL BE 100% X-RAYED.
- CONTRACTOR WILL MAINTAIN A MINIMUM 4' OF COVER TO THE TOP OF PIPE USING FIELD BENDS.
- CONTRACTOR WILL MAINTAIN A MINIMUM 24" OF COVER FROM ALL EXISTING UTILITIES.
- CONTRACTOR WILL MAINTAIN A MINIMUM 5' OF COVER FROM BOTTOM OF STREAMS
- IN ADDITION TO THE SITE-SPECIFIC INFORMATION PROVIDED IN THIS DRAWING, GENERAL REQUIREMENTS INCLUDED IN ALIGNMENT SHEETS, PERMITS AND APPROVAL FROM FEDERAL, STATE AND LOCAL AGENCIES ALSO APPLY.

PRELIMINARY DESIGN ONLY

NOTES

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

REVISIONS							
NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
A	ISSUED FOR REVIEW		MRS 04/05/18	CAG	04/05/18	MM	04/05/18

Sunoco Logistics Partners L.P.

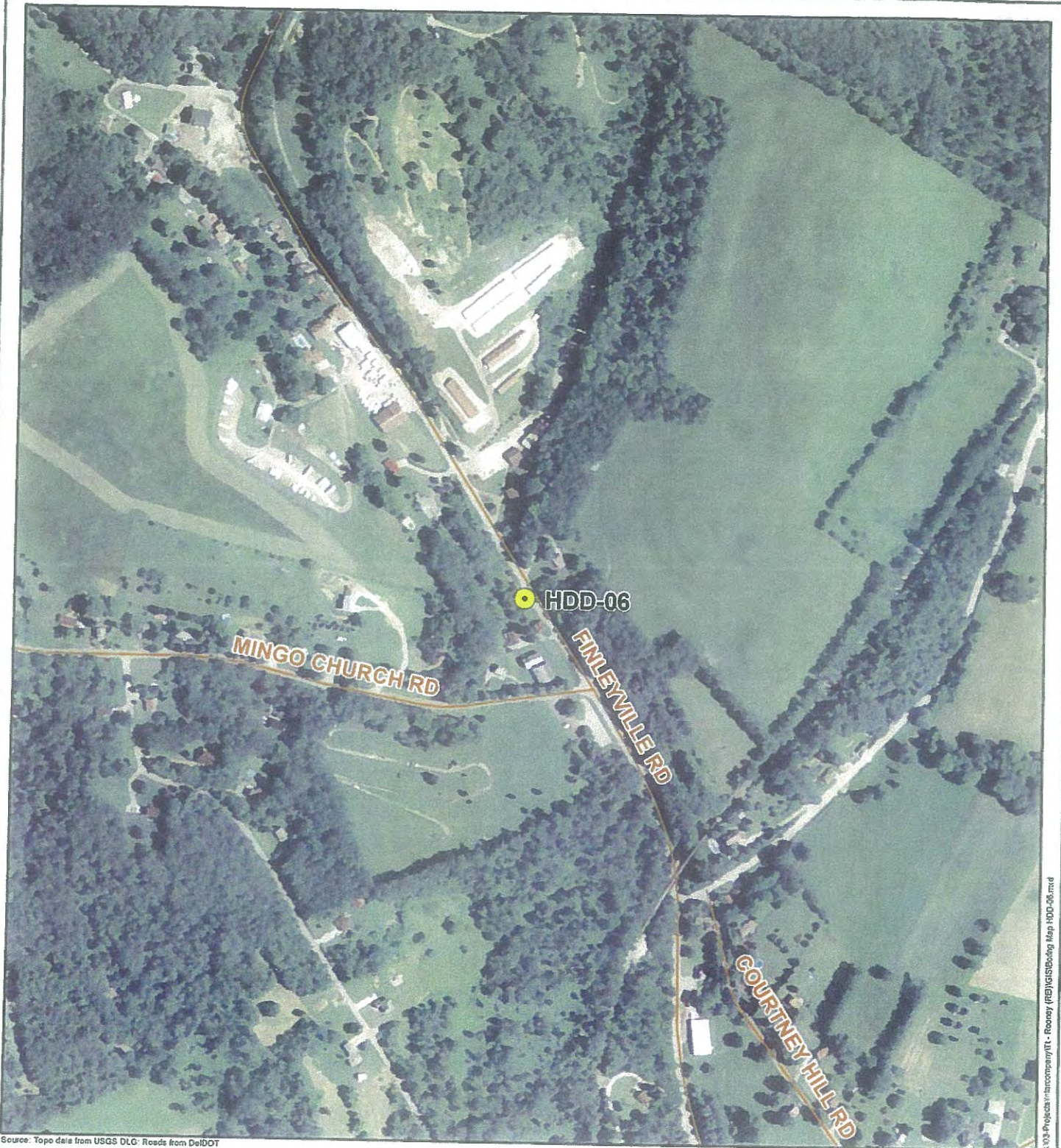
TETRA TECH ROONEY
 (303) 792-5911

SUNOCO PIPELINE, L.P.
 FLEX BORE
 PATTERSON RD
 PENNSYLVANIA PIPELINE PROJECT
 SCALE: 1"=100'
 DWG. NUMBER: PA-WA-0170.0000-RD FLEX BORE COMBO



Attachment B

Geotechnical Reports

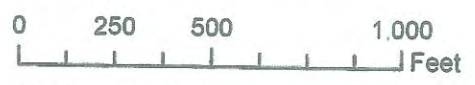


Source: Topo data from USGS DLG; Roads from DelDOT

S:\03-Projects\11\tracomp\11T - Rooney (RE)\GIS\Boring Map HDD-06.mxd



Figure
Boring Location HDD-06
Sunoco Mariner East Project
Washington County, PA



1 inch = 500 feet

Tetra Tech, Inc.
 Phone: (302) 738-7551
 Toll Free: (800) 462-0910
www.tetrattech.com

This map is provided by Tetra Tech solely for display and reference purposes and is subject to change without notice. No claims, either real or assumed, as to the absolute accuracy or precision of any data contained herein are made by Tetra Tech, nor will Tetra Tech be held responsible for any use of this document for purposes other than which it was intended.



Source: *Topo data from USGS DLG Roads from DelDOT

S:\03-Projects\W\tracompany\01 - Rooney (R)\GIS\Boring Map HDD-07.mxd

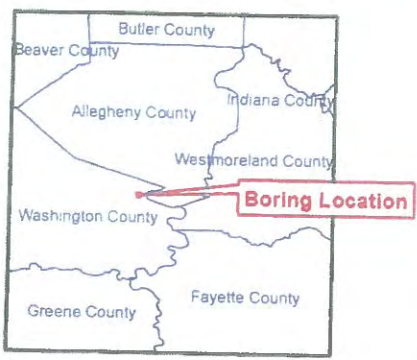


Figure
Boring Location HDD-07
Sunoco Mariner East Project
Washington County, PA



1 inch = 500 feet

Tetra Tech, Inc.
 Phone: (302) 738-7551
 Toll Free: (800) 462-0910
www.tetrattech.com

This map is provided by Tetra Tech solely for display and reference purposes and is subject to change without notice. No claims, either real or assumed, as to the absolute accuracy or precision of any data contained herein are made by Tetra Tech, nor will Tetra Tech be held responsible for any use of this document for purposes other than which it was intended.

October 9, 2017



Directional Project Support, Inc.
33311 Lois Lane, Suite A
Magnolia, TX 77354

Attn: Mr. Robert Sessions
P: (318) 542 6657
E: fielduspl@hotmail.com

Re: Geotechnical Site Characterization
Mariner East 2 Pipeline Project
Spread 1 – Wheeling and Lake Erie RR
Commonwealth of Pennsylvania
Drawing #PA-WA-0171.0000-RR
PO #20170804-7
Terracon Project No. J217P078

Dear Mr. Sessions:

This letter provides a summary of the bedrock characterization for the Mariner East 2 Pipeline Project crossing to be located at Wheeling and Lake Erie RR (Drawing #PA-WA-0171.0000-RR) in the Commonwealth of Pennsylvania. Our services were performed in general accordance with our proposal number PJ2175108 dated July 28, 2017. Our scope of services included advancing two borings, designated as B1-2W and B1-2E, visual classification and photography of the rock core samples, and laboratory testing of representative rock samples.

Test borings, B1-2W and B1-2E were drilled between August 5 and 17, 2017 to depths of 255 and 180 feet, respectively as shown on the attached **Test Boring Location Plan**. Bedrock typically consisted of interlayered sedimentary rock comprised of limestone, mudstone, and sandstone. Final test boring logs documenting overburden soil and bedrock conditions as well as photographs of the rock core samples are attached.

Rock compressive strength testing was performed on samples from approximately 20-foot intervals within the bedrock strata at each boring location. Unconfined compressive strength test results are shown on the attached reports.

Geotechnical Site Characterization

Mariner East 2 Pipeline – Spread 1 Wheeling and Lake Erie RR ■ Pennsylvania
Drawing #PA-WA-0171.0000-RR / PO #20170804-7
October 9, 2017 ■ Terracon Project No. J217P078



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

Sincerely,

Terracon Consultants, Inc.

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

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

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

Attch:

TEST BORING LOCATION PLAN

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

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

TEST BORING LOCATION PLAN



**APPROXIMATE
BORING
LOCATION**

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

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

Terracon
Consulting Engineers & Scientists

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

TEST BORING LOCATION PLAN

Wheeling and Lake Erie RR HDD Cores B1-2W and B1-2E
PA-WA-0171.0000-RR
Washington County, Pennsylvania

Exhibit

A-2

EXPLORATION RESULTS

BORING LOG NO. B1-2W Wheeling & Lake Erie RR West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 1

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.23114° Longitude: -79.9986° Approximate Surface Elev: 1082 (Ft.) +/- ELEVATION (Ft.)								
	0.7 Topsoil SILTY SAND WITH GRAVEL (SM) , brown, medium dense	1081.5+/-							
5	6.0 POORLY GRADED SAND (SP) , trace silt, brown, very dense Oxidation at 9.5 feet	1076+/-							
10	13.5 SILTY CLAY (CL-ML) , trace sand, gray to brown, very stiff to hard, desiccated Weathered rock from 14.8 - 15.0 feet	1068.5+/-							
15	19.5 Weathered rock	1062.5+/-							
20	24.0 Rock at 23.5 feet, start core at 24 feet	1058+/-							
25	Run 1, Moderately hard, slight weathering, yellowish gray, fine-grained, LIMESTONE, horizontal to low angle joints, very close to close spacing, rough to smooth, clay seam 26 to 26.5 feet	1055+/-							
30	Run 2, Similar, very light gray, 1 to 2-inch clay seams between 29.5 and 31.1 feet								

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

Not encountered



Boring Started: 8/5/2017

Boring Completed: 8/10/2017

Drill Rig: Diedrich D-50

Driller: Terra Testing, Inc.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. - GEO SMART LOG-NO WELL - J217P078 - SPREAD 1.GPJ

BORING LOG NO. B1-2W Wheeling & Lake Erie RR West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 1

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.23114° Longitude: -79.9986° Approximate Surface Elev: 1082 (Ft.) +/-								
	DEPTH ELEVATION (Ft.)								
32.0	Run 2, Similar, very light gray, 1 to 2-inch clay seams between 29.5 and 31.1 feet <i>(continued)</i>	1050+/-			55			2.5 2.5	
37.0	Run 3, Similar, yellowish gray to light gray, horizontal to moderately dipping joints, 2-inch clay seam at 35 and 37 feet	1045+/-			26		18	2.5 3 3 2.5 2.5	
42.0	Run 4, Similar, light gray to medium dark gray	1040+/-			25		0	2.5 2.5 3 2 2.5	
47.0	Run 5, Similar	1035+/-			47		18	2 2 2 2.5 2.5	
52.0	Run 6, Similar to 51 feet At 51 feet : Moderately hard, slight weathering, dark greenish gray, fine grained to argillaceous, MUDSTONE, very thin bedding, horizontal joints, very close to close spacing, rough to smooth, discolored	1030+/-			60		61	2 2 2 2 2	
57.0	Run 7, Similar, with 1 to 2-inch limestone nodules between 53 and 54 feet Run 8, Similar, with vertical fractures	1025+/-			54		83	2 2 2 2 2	
60		60			60		70	2 2 2	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

Not encountered



Boring Started: 8/5/2017

Boring Completed: 8/10/2017

Drill Rig: Diedrich D-50

Driller: Terra Testing, Inc.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 1.GPJ

BORING LOG NO. B1-2W Wheeling & Lake Erie RR West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 1

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.23114° Longitude: -79.9986° Approximate Surface Elev: 1082 (Ft.) +/- ELEVATION (Ft.)								
	Run 8, Similar, with vertical fractures (<i>continued</i>)	62.0			60			2 2	
	Run 9, Similar to 63 feet, transitioning into limestone at 62 feet Moderately hard, slight weathering, yellowish gray to light gray, LIMESTONE, horizontal joints, very close to moderately close	67.0			55		87	2 2 2 2 2	
	Run 10, Similar, with moderate dipping to high angle joints, transitioning into mudstone at 71 feet	72.0			48		72	2 2 2 2.25 2.25	
	Run 11, Moderately hard, slight weathering, very dark gray, fine-grained to argillaceous, MUDSTONE, very thin bedding, horizontal joints, very close spacing, smooth At 74 feet : Moderately hard, very slight weathering, light gray, fine-grained, LIMESTONE, horizontal joints, very close to close, 1 to 3-inch beds of mudstone between 74 and 76 feet	77.0			48		19	4 4.5 4.5 5 5.5	
	Run 12, Similar, very close to moderately close, 1-inch bed of mudstone at 79.5 feet	82.0			58		77	2 1.75 1.5 1.5 1.5	
	Run 13, Similar, 7-inch bed of carbonaceous mudstone at 86 feet	87.0			60		98	1.5 1.5 1.5 1.5 1.5	
	Run 14, Similar to 89 feet Moderately hard, fresh to very slight weathering, dark greenish gray,				55		90	1.5 1.5 1.5	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

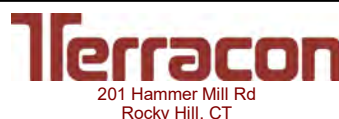
Notes:

Abandonment Method:
Grouted to surface

See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

Not encountered



Boring Started: 8/5/2017

Boring Completed: 8/10/2017

Drill Rig: Diedrich D-50

Driller: Terra Testing, Inc.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 1.GPJ

BORING LOG NO. B1-2W Wheeling & Lake Erie RR West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 1

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.23114° Longitude: -79.9986° Approximate Surface Elev: 1082 (Ft.) +/- ELEVATION (Ft.)								
	DEPTH								
92.0	fine-grained to argillaceous, MUDSTONE, very thin bedding, horizontal joints, very close to close spacing, smooth Run 14, Similar to 89 feet (<i>continued</i>)	990+/-			55			1.5 1.5	
	Run 15, Similar							3 3 3.25 3.25 3.25	
97.0		985+/-			57		95		
	Run 16, Similar, transitioning into limestone at 100 feet							1.5 1.5 1.5 1.5	
102.0		980+/-			59		98		
	Run 17, Moderately hard, fresh to very slight weathering, yellowish gray to light gray, fine-grained LIMESTONE, horizontal to moderately dipping joints, very close to close spacing, smooth to rough				54.5		77	1.75 1.75 1.5 1.5 1.5	
107.0		975+/-							
	Run 18, Similar, occasional mudstone beds				59		83	2 2 1.5 1.5 1.5	
112.0		970+/-						1.75 1.75 1.75 1.75 1.75	
	Run 19, Similar, 2-inch clay seam at 116 feet				59		92		
117.0		965+/-						1.5 1.5 1.5	
	Run 20, Similar				57		92		
		120							

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

Not encountered



Boring Started: 8/5/2017

Boring Completed: 8/10/2017

Drill Rig: Diedrich D-50

Driller: Terra Testing, Inc.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 1.GPJ

BORING LOG NO. B1-2W Wheeling & Lake Erie RR West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 1

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.23114° Longitude: -79.9986° Approximate Surface Elev: 1082 (Ft.) +/- ELEVATION (Ft.)								
	Run 20, Similar (continued)	122.0			57			1.5 1.25	
	Run 21, Similar	127.0			50		54	3.5 3.5 4 4 2.75	
	Run 22, Similar. 2-inch clay seams at 127.5 and 128 feet	132.0			45		42	2.75 2 2 2	
	Run 23, Similar, with moderately dipping joints	137.0			60		100	1.75 1.5 1.5 1.5	
	Run 24, Similar, with clay seams between 137 and 139 feet	142.0			60		85	2 2.25 2 2 2	
	Run 25, Similar	147.0			60		95	2.5 2.5 2.25 2.25 1.5	
	Run 26, Moderately hard, fresh to very slight weathering, very dark gray to light gray, argillaceous to fine-grained MUDSTONE, very thin to thin bedding with sandstone, horizontal joints, very close to close spacing, rough to smooth, 1-inch clay seam at 147.5 feet	150			54		52	2.5 3.25 3.5	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

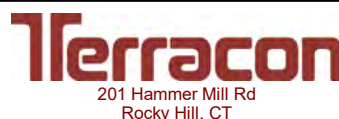
Notes:

Abandonment Method:
Grouted to surface

See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

Not encountered



Boring Started: 8/5/2017

Boring Completed: 8/10/2017

Drill Rig: Diedrich D-50

Driller: Terra Testing, Inc.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 1.GPJ

BORING LOG NO. B1-2W Wheeling & Lake Erie RR West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 1

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.23114° Longitude: -79.9986° Approximate Surface Elev: 1082 (Ft.) +/- ELEVATION (Ft.)								
	DEPTH								
152.0	Run 27, Similar	930+/-			54			3.5 2.5	
157.0	Run 28, Similar	925+/-			57		88	2.75 1.5 .75 .75 1.25	
162.0	Run 29, Similar, vertical fracture at 166 feet	920+/-			60		100	1 1 1.25 1.25 1.5	
167.0	Run 30, Similar	915+/-			59		98	1.5 2.25 2 1.5 1.75	
172.0	Run 31, Similar	910+/-			43		53	2.25 2 2.75 2.5 2.25	
177.0	Run 32, Similar	905+/-			58.5		94	1.25 1 1.25 1.25 1.25	
180					51		37	2.25 2.5 2	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

Not encountered



Boring Started: 8/5/2017

Boring Completed: 8/10/2017

Drill Rig: Diedrich D-50

Driller: Terra Testing, Inc.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 1.GPJ

BORING LOG NO. B1-2W Wheeling & Lake Erie RR West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 1

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.23114° Longitude: -79.9986° Approximate Surface Elev: 1082 (Ft.) +/- ELEVATION (Ft.)								
	Run 32, Similar (continued)	182.0			51			2.25 2.25	
	Run 33, Similar, clay seams between 182 and 185 feet	187.0			55		43	1.75 1.75 1.75 1.75	
	Run 34, Similar, 2-inch clay seams at 188 and 190 feet	192.0			59		57	1.5 1.5 1.75 1.75	
	Run 35, Similar	197.0			60		100	1.75 1.5 1.5 1.25	
	Run 36, Similar	202.0			59		95	1 1.25 1.25 1.25	
	Run 37, Similar, dark gray to black	207.0			57		78	2.5 3.5 2.5 1.75 2.25	
	Run 38, Similar, coal seam from 207.5 to 211 feet	210			48		57	2.25 1.5 1.5	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

Not encountered



Boring Started: 8/5/2017

Boring Completed: 8/10/2017

Drill Rig: Diedrich D-50

Driller: Terra Testing, Inc.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 1.GPJ

BORING LOG NO. B1-2W Wheeling & Lake Erie RR West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 1

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.23114° Longitude: -79.9986° Approximate Surface Elev: 1082 (Ft.) +/- ELEVATION (Ft.)								
	Run 38, Similar, coal seam from 207.5 to 211 feet (<i>continued</i>)				48			1.25 3.5	
	212.0 870+/-								
	Run 39, Similar, horizontal to low angle Greenish gray from 216 to 219 feet	215			57		78	2 1.5 2.75 1.25 1.5	
	217.0 865+/-								
	Run 40, Similar	220			58		97	1 1 1.5 1.5 1.5	
	222.0 860+/-								
	Run 41, Similar	225			60		98	2 1.25 1.25 1 1.25	
	227.0 855+/-								
	Run 42, Similar, increased thin bedding sandstone between 228 and 230 feet	230			60		100	1.5 1.25 .75 1 1.25	
	232.0 850+/-								
	Run 43, Similar	235			60		100	1.5 1.25 1.5 1.25 1.25	
	237.0 845+/-								
	Run 44, Similar	240			59		98	1 1 1.25	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

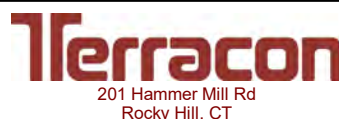
Notes:

Abandonment Method:
Grouted to surface

See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

Not encountered



Boring Started: 8/5/2017

Boring Completed: 8/10/2017

Drill Rig: Diedrich D-50

Driller: Terra Testing, Inc.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 1.GPJ

BORING LOG NO. B1-2W Wheeling & Lake Erie RR West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 1

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.23114° Longitude: -79.9986° Approximate Surface Elev: 1082 (Ft.) +/- ELEVATION (Ft.)								
	Run 44, Similar (continued)				59			1 1	
	242.0 840+/- Run 45, Similar	245			60		100	1.75 1.5 1.25 1.5 2	
	247.0 835+/- Run 46, Similar	250			59		98	1.25 1 1 1.25 1	
	252.0 830+/- Run 47, Similar to 253 feet	255			36		100	1 1.5 1.5	
	255.0 827+/- At 253 feet : Moderately hard, fresh, light gray, fine-grained, SANDSTONE, very thin bedding, horizontal joint, close spacing, rough to smooth								
	Boring Terminated at 255 Feet								

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

Not encountered



Boring Started: 8/5/2017

Boring Completed: 8/10/2017

Drill Rig: Diedrich D-50

Driller: Terra Testing, Inc.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 1.GPJ

BORING LOG NO. B1-2E Wheeling & Lake Erie RR East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 1

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.229954° Longitude: -79.991° Approximate Surface Elev: 1010 (Ft.) +/- ELEVATION (Ft.)								
SILTY CLAY (CL-ML) , brown with light brown streaking, very stiff		5	4.36'	X	14	4-8-12 N=20			
Trace weathered rock from 9.5 - 10 feet		10		X	12	7-8-8 N=16			
12.5 Roller bit resistance at 12.5 feet, begin rock core at 12.5 feet Run 1, Hard, very slight to moderate weathering, light gray, fine-grained, SANDSTONE, very thin bedding, low angle joints at very close to close spacing, rough, discolored joints, severely weathered from 15 to 17.5 feet	997.5+/-	15		24			28	0.25 1.25 1.75 2.5 2.5	
17.5 Run 2, 17.5 - 20.0 feet: Similar 19.7 - 22.5 feet: Moderately hard, slight weathering, medium gray, argillaceous, MUDSTONE, very fine bedding, horizontal joints at very close spacing, smooth, discolored joints	992.5+/-	20		55			30	2.5 2.5 2.75 2.75 2.5	
22.5 Run 3, 22.5 - 26.5 feet: Similar, medium gray to grayish black, very close to close spacing 26.5 - 27.5 feet: Moderately hard, very slight weathering very light gray, argillaceous, LIMESTONE, horizontal joints at close spacing, smooth	987.5+/-	25		45			45	2.75 3.25 3.75 1.25 2	
27.5 Run 4, 27.5 - 29.0 feet: Similar to MUDSTONE in Runs 2 and 3 29.0 - 32.5 feet: Similar to LIMESTONE in Run 3	982.5+/-	30		58			87	5.5 2 1.75 1.25 1.25	
32.5 Run 5, Similar to LIMESTONE in Run 4, very light gray to medium gray, very close to close spacing	977.5+/-	35		53				1.75 3.5	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS

- ▽ 4.05' on 8/14/17
- ▽ 4.11' on 8/15/17
- ▽ 4.36' on 8/16/17



Boring Started: 8/12/2017

Boring Completed: 8/17/2017

Drill Rig: Diedrich D-50

Driller: Terra Testing, Inc.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 1.GPJ

BORING LOG NO. B1-2E Wheeling & Lake Erie RR East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 1

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.229954° Longitude: -79.991° Approximate Surface Elev: 1010 (Ft.) +/- ELEVATION (Ft.)								
	Run 5, Similar to LIMESTONE in Run 4, very light gray to medium gray, very close to close spacing (<i>continued</i>)	37.5			53		64	3.75 3.75 3.5	
	Run 6, Similar, LIMESTONE with beds of MUDSTONE	42.5			54.5		53	2.5 2.25 2.25 2	
	Run 7, Similar, LIMESTONE with beds of MUDSTONE	47.5			42		33	7 3.5 5 1.75 1.5	
	Run 8, Similar, LIMESTONE, high angle joint at 49 feet	52.5			60		90	2.25 2 2.25 2.25 2.5	
	Run 9, Similar to 56 feet, LIMESTONE transitioning to MUDSTONE from 56 to 57.5 feet, medium gray to greenish gray, close spacing	57.5			60		88	1.5 1.5 1.25 1.75 1.75	
	Run 10, Moderately hard, very slight weathering, medium gray to greenish gray, argillaceous, MUDSTONE, very thin bedding, horizontal joints at very close to close spacing, smooth	62.5			51		53	1.75 2.25 2.25 2 2.25	
	Run 11, Similar	67.5			54		68	2.5 2.75 3.25 3.75 3.75	
	Run 12, Moderately hard, slight weathering, very light gray to gray, argillaceous, LIMESTONE, horizontal to moderately dipping joints at very close to close spacing, rough to smooth	70			53			2.75 2.75	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

- ▽ 4.05' on 8/14/17
- ▽ 4.11' on 8/15/17
- ▽ 4.36' on 8/16/17



Boring Started: 8/12/2017

Boring Completed: 8/17/2017

Drill Rig: Diedrich D-50

Driller: Terra Testing, Inc.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL -J217P078 - SPREAD 1.GPJ

BORING LOG NO. B1-2E Wheeling & Lake Erie RR East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 1

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.229954° Longitude: -79.991° Approximate Surface Elev: 1010 (Ft.) +/- ELEVATION (Ft.)								
	Run 12, Moderately hard, slight weathering, very light gray to gray, argillaceous, LIMESTONE, horizontal to moderately dipping joints at very close to close spacing, rough to smooth (<i>continued</i>)	72.5			53		77	1.25 2 1.5	
	Run 13, Similar, LIMESTONE with carbonaceous MUDSTONE from 75 to 77.5 feet	77.5			48		57	2.75 3 2.75 3 3.25	
	Run 14, Similar, LIMESTONE with carbonaceous MUDSTONE from 77.5 to 79.5 feet	82.5			55		62	2.75 1.5 2 2.25 2.25	
	Run 15, Moderately hard, slight weathering, yellowish gray, argillaceous, LIMESTONE, horizontal joints at very close to moderately close spacing, rough	87.5			57		88	3 2.5 2.5 2.25 1.75	
	Run 16, Similar	92.5			50		75	2 2.25 2.5 2.25 2.25	
	Run 17, 92.5 - 93.3 feet: Similar 94 - 97.5 feet: Moderately hard, slight weathering, medium gray, argillaceous, MUDSTONE, very thin bedding, horizontal joints at very close to close spacing, smooth	97.5			49		65	2.25 2.5 3.25 2 3	
	Run 18, Similar, medium gray to dark greenish gray, very close spacing, carbonaceous from 101 to 102.5 feet	102.5			60		100	1.5 1.5 1.75 1.75 1.75	
		105			60			1.25 1.25	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

- ▽ 4.05' on 8/14/17
- ▽ 4.11' on 8/15/17
- ▽ 4.36' on 8/16/17



Boring Started: 8/12/2017

Boring Completed: 8/17/2017

Drill Rig: Diedrich D-50

Driller: Terra Testing, Inc.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL -J217P078 - SPREAD 1.GPJ

BORING LOG NO. B1-2E Wheeling & Lake Erie RR East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 1

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.229954° Longitude: -79.991° Approximate Surface Elev: 1010 (Ft.) +/- ELEVATION (Ft.)								
DEPTH									
107.5	Run 19, 102.5 - 106.2 feet: Similar, carbonaceous MUDSTONE 106.2 - 107.5 feet: Moderately hard, very slight weathering, yellowish gray to medium gray, argillaceous, LIMESTONE, horizontal to low angle joints at close to moderately close spacing, rough to smooth <i>(continued)</i>	902.5+/-			60		100	1 1.25 1.5	
112.5	Run 20, Similar, dark gray to black bands at 108 to 108.1 feet and 108.5 to 108.9 feet	897.5+/-			60		100	1.5 1.25 1 1.25	
117.5	Run 21, Similar, light gray to medium gray	892.5+/-			60		100	3 1.25 1.5 1.25 1.25	
122.5	Run 22, Similar, LIMESTONE with carbonaceous MUDSTONE beds	887.5+/-			59		98	2.5 2.25 2.25 2.75 2.75	
127.5	Run 23, Similar, LIMESTONE with carbonaceous MUDSTONE beds	882.5+/-			60		100	2 1.75 1.75 1.5	
132.5	Run 24, Similar, LIMESTONE with carbonaceous MUDSTONE beds, argillaceous to coarse, close to moderately close spacing	877.5+/-			58		97	1.5 1.25 1.5 1.5 1.25	
137.5	Run 25, Similar, LIMESTONE, yellowish gray to very dark gray, argillaceous to coarse	872.5+/-			60		100	2 2 1.75 2 2	
140	Run 26, Similar, yellowish gray to medium gray, fewer MUDSTONE beds				60			2 1.75	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

- ▽ 4.05' on 8/14/17
- ▽ 4.11' on 8/15/17
- ▽ 4.36' on 8/16/17



Boring Started: 8/12/2017

Boring Completed: 8/17/2017

Drill Rig: Diedrich D-50

Driller: Terra Testing, Inc.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 1.GPJ

BORING LOG NO. B1-2E Wheeling & Lake Erie RR East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 1

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.229954° Longitude: -79.991° Approximate Surface Elev: 1010 (Ft.) +/-								
	DEPTH ELEVATION (Ft.)								
142.5	Run 26, Similar, yellowish gray to medium gray, fewer MUDSTONE beds <i>(continued)</i>	145			60		100	1.75 1.75 2	
147.5	Run 27, Similar, LIMESTONE with MUDSTONE bed from 144.5 to 145.3 feet, very close to moderately close spacing	150			60		100	1.75 1.5 1.5 1.25	
152.5	Run 28, Similar, close to moderately close	155			52.5		88	1.5 1.5 1.25 1.25	
157.5	Run 29, Moderately hard, slight weathering, light gray to dark gray, argillaceous, MUDSTONE, very thin bedding, horizontal joints at very close to close spacing, smooth	160			51		51	3.5 3.75 3.5 3.5	
162.5	Run 30, Similar	165			60		100	2.5 2.25 2 2	
167.5	Run 31, Similar	170			60		100	2.25 2 2 2.25 2	
172.5	Run 32, Similar	175			53		89	1.5 2 2 1.75 2	
					59			1.75 1.75	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

- ▽ 4.05' on 8/14/17
- ▽ 4.11' on 8/15/17
- ▽ 4.36' on 8/16/17



Boring Started: 8/12/2017

Boring Completed: 8/17/2017

Drill Rig: Diedrich D-50

Driller: Terra Testing, Inc.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 1.GPJ

BORING LOG NO. B1-2E Wheeling & Lake Erie RR East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 1

GRAPHIC LOG	LOCATION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Latitude: 40.229954° Longitude: -79.991° Approximate Surface Elev: 1010 (Ft.) +/- ELEVATION (Ft.)								
	Run 33, 172.5 - 174 feet: Similar, MUDSTONE transitioning into LIMESTONE				59		98	2 2	
	174 - 177.5 feet: Moderately hard, slight weathering, light gray to medium gray, fine-grained LIMESTONE, horizontal joints at very close to moderately close spacing, smooth <i>(continued)</i>							1.75	
	Run 34, Similar, medium gray, low angle to moderately dipping joints				26.5		88	1.75 2 1	
	Boring Terminated at 180 Feet	180							

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

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

Notes:

Abandonment Method:
Grouted to surface

See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS	
▽	4.05' on 8/14/17
▽	4.11' on 8/15/17
▽	4.36' on 8/16/17



Boring Started: 8/12/2017

Boring Completed: 8/17/2017

Drill Rig: Diedrich D-50

Driller: Terra Testing, Inc.

Project No.: J217P078

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 1.GPJ

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

Boring No.: B1-2W
 Sample No.: 1
 Sample Depth: 44 feet
 Sampling Date: 8/5/17

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

Diameter: 1.98 in
 Length: 3.94 in
 L/D: 1.99
 End Area: 3.08 in²

Maximum Axial Load at Failure: 46,900 lb
 Compressive Strength: 15,232 psi
 Compressive Strength: 105.02 Mpa
 Unit Weight 165 pcf

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


Before the Test

After the Test

Photograph before the test is not available

Photograph after the test is not available

Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	W. Shedd
Project No.	J217P078		Test Date:	10/6/2017
Location:	Spread 1		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

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

Boring No.: B1-2W
 Sample No.: 1c
 Sample Depth: 44 feet
 Sampling Date: 8/5/17

Lithology : Limestone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 15 min

Diameter: 1.97 in
 Length: 4.21 in
 L/D: 2.14
 End Area: 3.05 in²

Maximum Axial Load at Failure: 49,100 lb
 Compressive Strength: 16,109 psi
 Compressive Strength: 111.07 Mpa
 Unit Weight 170 pcf

Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline
Project No:	J217P078
Location:	Spread 1
Client :	Directional Project Support Inc.

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

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

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

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

Boring No.: B1-2W
 Sample No.: 2
 Sample Depth: 63 feet
 Sampling Date: 8/5/17

Lithology : Limestone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 10 min

Diameter: 1.97 in
 Length: 4.09 in
 L/D: 2.08
 End Area: 3.05 in²

Maximum Axial Load at Failure: 34,180 lb
 Compressive Strength: 11,214 psi
 Compressive Strength: 77.32 Mpa
 Unit Weight 157 pcf


Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No:	J217P078		Test Date:	9/13/2017
Location:	Spread 1		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

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

Boring No.: B1-2W
 Sample No.: 3
 Sample Depth: 83 feet
 Sampling Date: 8/5/17

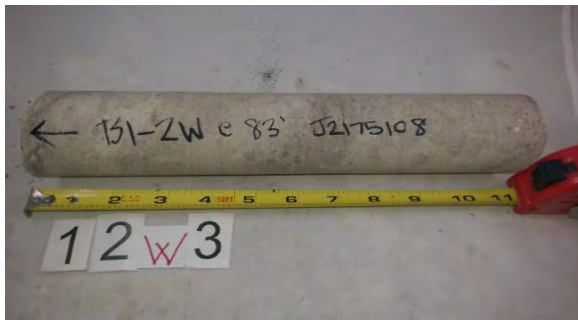
Lithology : Limestone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 12 min

Diameter: 1.98 in
 Length: 4.18 in
 L/D: 2.11
 End Area: 3.08 in²


Maximum Axial Load at Failure: 40,730 lb
 Compressive Strength: 13,228 psi
 Compressive Strength: 91.20 Mpa
 Unit Weight 148 pcf

Before the Test

After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No:	J217P078		Test Date:	9/13/2017
Location:	Spread 1		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

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

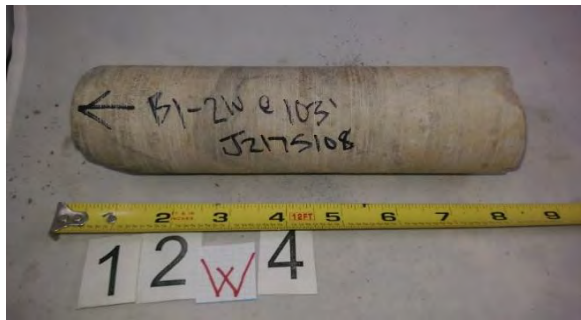
Boring No.: B1-2W
 Sample No.: 4
 Sample Depth: 103 feet
 Sampling Date: 8/5/17

Lithology : Limestone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 8 min

Diameter: 1.97 in
 Length: 4.41 in
 L/D: 2.24
 End Area: 3.05 in²

Maximum Axial Load at Failure: 26,850 lb
 Compressive Strength: 8,809 psi
 Compressive Strength: 60.74 Mpa
 Unit Weight 158 pcf

Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 1
Client :	Directional Project Support Inc.

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

Performed by:	A. Suprunenko
Test Date:	9/13/2017
Reviewed By :	L. Dwyer
Review Date :	10/9/2017

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

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

Boring No.: B1-2W
 Sample No.: 5
 Sample Depth: 122 feet
 Sampling Date: 8/5/17

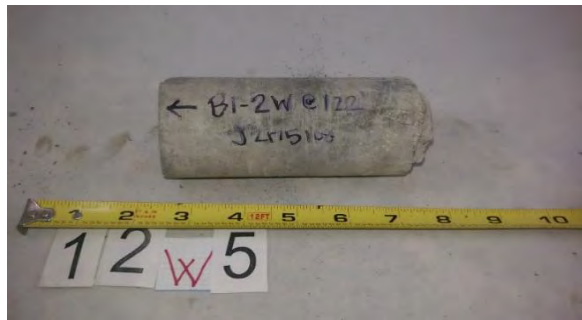
Lithology : Limestone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 8 min

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

Maximum Axial Load at Failure: 26,620 lb
 Compressive Strength: N/A psi
 Compressive Strength: N/A Mpa
 Unit Weight N/A pcf

Specimen dimensions are not available

Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 1
Client :	Directional Project Support Inc.

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

Performed by:	A. Suprunenko
Test Date:	9/13/2017
Reviewed By :	L. Dwyer
Review Date :	10/9/2017

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

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

Boring No.: B1-2W
 Sample No.: 6
 Sample Depth: 143 feet
 Sampling Date: 8/5/17

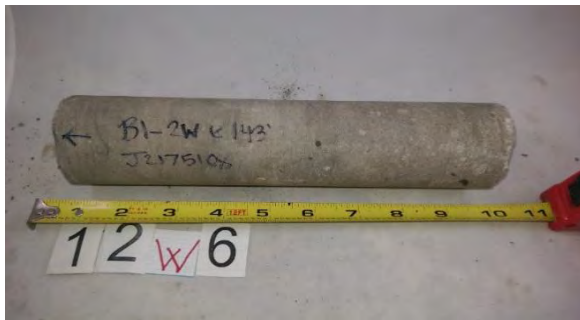
Lithology : Limestone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 14 min

Diameter: 1.97 in
 Length: 4.41 in
 L/D: 2.24
 End Area: 3.05 in²

Maximum Axial Load at Failure: 47,030 lb
 Compressive Strength: 15,429 psi
 Compressive Strength: 106.38 Mpa
 Unit Weight 159 pcf

Before the Test

After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline
Project No:	J217P078
Location:	Spread 1
Client :	Directional Project Support Inc.

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

Performed by:	A. Suprunenko
Test Date:	9/13/2017
Reviewed By :	L. Dwyer
Review Date :	10/9/2017

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

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

Boring No.: B1-2W
 Sample No.: 7
 Sample Depth: 163 feet
 Sampling Date: 8/5/17

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

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

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

Specimen broke during preparation

Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 1
Client :	Directional Project Support Inc.

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

Performed by:	A. Suprunenko
Test Date:	9/13/2017
Reviewed By :	L. Dwyer
Review Date :	10/9/2017

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

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

Boring No.: B1-2W
 Sample No.: 8
 Sample Depth: 183 feet
 Sampling Date: 8/5/17

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

Diameter: 1.97 in
 Length: 4.31 in
 L/D: 2.19
 End Area: 3.05 in²

Maximum Axial Load at Failure: 19,110 lb
 Compressive Strength: 6,270 psi
 Compressive Strength: 43.23 Mpa
 Unit Weight 172 pcf

Before the Test

After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 1
Client :	Directional Project Support Inc.

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

Performed by:	A. Suprunenko
Test Date:	9/13/2017
Reviewed By :	L. Dwyer
Review Date :	10/9/2017

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

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

Boring No.: B1-2W
 Sample No.: 9
 Sample Depth: 202 feet
 Sampling Date: 8/5/17

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

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

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

Specimen broke during preparation

Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline	<p style="margin: 0;">77 Sundial Ave., Suite 401 W Manchester, New Hampshire</p>	Performed by:	A. Suprunenko
Project No:	J217P078		Test Date:	9/13/2017
Location:	Spread 1		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

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

Boring No.: B1-2W
 Sample No.: 9c
 Sample Depth: 215 feet
 Sampling Date: 8/5/17

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

Diameter: 1.98 in
 Length: 4.22 in
 L/D: 2.13
 End Area: 3.08 in²

Maximum Axial Load at Failure: 19,880 lb
 Compressive Strength: 6,456 psi
 Compressive Strength: 44.52 Mpa
 Unit Weight 169 pcf


Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	W. Shedd
Project No:	J217P078		Test Date:	10/7/2017
Location:	Spread 1		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

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

Boring No.: B1-2W
 Sample No.: 10
 Sample Depth: 223 feet
 Sampling Date: 8/5/17

Lithology : Mudstone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 3 min

Diameter: 1.97 in
 Length: 4.42 in
 L/D: 2.24
 End Area: 3.05 in²

Maximum Axial Load at Failure: 10,390 lb
 Compressive Strength: 3,409 psi
 Compressive Strength: 23.50 Mpa
 Unit Weight 172 pcf


Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No:	J217P078		Test Date:	9/13/2017
Location:	Spread 1		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

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

Boring No.: B1-2W
 Sample No.: 11
 Sample Depth: 243 feet
 Sampling Date: 8/5/17

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

Diameter: 1.97 in
 Length: 3.51 in
 L/D: 1.78
 End Area: 3.05 in²

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

Comments : Specimen broke during preparation.


Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No:	J217P078		Test Date:	9/13/2017
Location:	Spread 1		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

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

Boring No.: B1-2W
 Sample No.: 11c
 Sample Depth: 242.5 feet
 Sampling Date: 8/5/17

Lithology : Mudstone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 12 min

Diameter: 1.95 in
 Length: 3.58 in
 L/D: 1.84
 End Area: 2.99 in²

Maximum Axial Load at Failure: 39,270 lb
 Compressive Strength: 13,149 psi
 Compressive Strength: 90.66 Mpa
 Unit Weight 173 pcf

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


Before the Test

After the Test

Photograph before the test is not available



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	W. Shedd
Project No:	J217P078		Test Date:	10/7/2017
Location:	Spread 1		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

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

Boring No.: B1-2W
 Sample No.: 12
 Sample Depth: 254 feet
 Sampling Date: 8/5/17

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

Diameter: 1.98 in
 Length: 4.51 in
 L/D: 2.28
 End Area: 3.08 in²

Maximum Axial Load at Failure: 17,320 lb
 Compressive Strength: 5,625 psi
 Compressive Strength: 38.78 Mpa
 Unit Weight 166 pcf


Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No:	J217P078		Test Date:	9/13/2017
Location:	Spread 1		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

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

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

Boring No.: B1-2E
 Sample No.: 1
 Sample Depth: 12.5 feet
 Sampling Date: 8/12/17

Lithology : Sandstone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 10 min

Diameter: 1.98 in
 Length: 4.33 in
 L/D: 2.19
 End Area: 3.08 in²

Maximum Axial Load at Failure: 34,220 lb
 Compressive Strength: 11,114 psi
 Compressive Strength: 76.63 Mpa
 Unit Weight 157 pcf

Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline
Project No:	J217P078
Location:	Spread 1
Client :	Directional Project Support Inc.

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

Performed by:	A. Suprunenko
Test Date:	10/3/2017
Reviewed By :	L. Dwyer
Review Date :	10/8/2017

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

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

Boring No.: B1-2E
 Sample No.: 2
 Sample Depth: 32.5 feet
 Sampling Date: 8/12/17

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

Diameter: 1.98 in
 Length: 4.26 in
 L/D: 2.15
 End Area: 3.08 in²

Maximum Axial Load at Failure: 29,970 lb
 Compressive Strength: 9,733 psi
 Compressive Strength: 67.11 Mpa
 Unit Weight 158 pcf

Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 1
Client :	Directional Project Support Inc.

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

Performed by:	A. Suprunenko
Test Date:	10/3/2017
Reviewed By :	L. Dwyer
Review Date :	10/8/2017

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

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

Boring No.: B1-2E
 Sample No.: 3
 Sample Depth: 52 feet
 Sampling Date: 8/12/17

Lithology : Limestone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 8 min

Diameter: 1.95 in
 Length: 3.92 in
 L/D: 2.01
 End Area: 2.99 in²

Maximum Axial Load at Failure: 28,040 lb
 Compressive Strength: 9,389 psi
 Compressive Strength: 64.73 Mpa
 Unit Weight 171 pcf


Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	W. Shedd
Project No.	J217P078		Test Date:	10/7/2017
Location:	Spread 1		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/8/2017

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

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

Boring No.: B1-2E
 Sample No.: 4
 Sample Depth: 71 feet
 Sampling Date: 8/12/17

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

Diameter: 1.98 in
 Length: 4.29 in
 L/D: 2.17
 End Area: 3.08 in²

Maximum Axial Load at Failure: 29,220 lb
 Compressive Strength: 9,490 psi
 Compressive Strength: 65.43 Mpa
 Unit Weight 168 pcf

Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline
Project No:	J217P078
Location:	Spread 1
Client :	Directional Project Support Inc.

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

Performed by:	A. Suprunenko
Test Date:	10/3/2017
Reviewed By :	L. Dwyer
Review Date :	10/8/2017

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

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

Boring No.: B1-2E
 Sample No.: 5
 Sample Depth: 91 feet
 Sampling Date: 8/12/17

Lithology : Limestone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 15 min

Diameter: 2.00 in
 Length: 4.16 in
 L/D: 2.08
 End Area: 3.14 in²

Maximum Axial Load at Failure: 50,780 lb
 Compressive Strength: 16,164 psi
 Compressive Strength: 111.45 Mpa
 Unit Weight 163 pcf

Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline	<p style="margin: 0;">77 Sundial Ave., Suite 401 W Manchester, New Hampshire</p>	Performed by:	A. Suprunenko
Project No:	J217P078		Test Date:	10/3/2017
Location:	Spread 1		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/8/2017

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

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

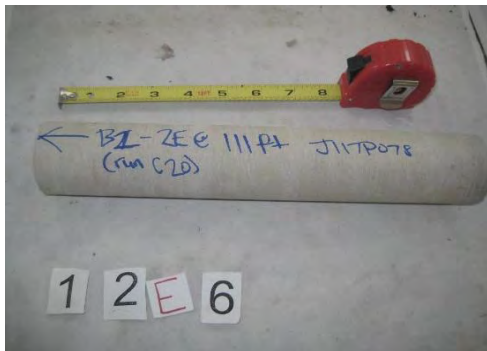
Boring No.: B1-2E
 Sample No.: 6
 Sample Depth: 111 feet
 Sampling Date: 8/12/17

Lithology : Limestone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 17 min

Diameter: 1.98 in
 Length: 4.06 in
 L/D: 2.05
 End Area: 3.08 in²

Maximum Axial Load at Failure: 56,300 lb
 Compressive Strength: 18,285 psi
 Compressive Strength: 126.07 Mpa
 Unit Weight 157 pcf

Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline
Project No:	J217P078
Location:	Spread 1
Client :	Directional Project Support Inc.

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

Performed by:	A. Suprunenko
Test Date:	10/3/2017
Reviewed By :	L. Dwyer
Review Date :	10/8/2017

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

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

Boring No.: B1-2E
 Sample No.: 7
 Sample Depth: 132 feet
 Sampling Date: 8/12/17

Lithology : Limestone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 8 min

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

Maximum Axial Load at Failure: 26,250 lb
 Compressive Strength: 8,525 psi
 Compressive Strength: 58.78 Mpa
 Unit Weight 160 pcf


Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No:	J217P078		Test Date:	10/3/2017
Location:	Spread 1		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/8/2017

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

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

Boring No.: B1-2E
 Sample No.: 8
 Sample Depth: 152 feet
 Sampling Date: 8/12/17

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

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

Maximum Axial Load at Failure: 14,820 lb
 Compressive Strength: 4,862 psi
 Compressive Strength: 33.52 Mpa
 Unit Weight 169 pcf


Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 1		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/8/2017

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

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

Boring No.: B1-2E
 Sample No.: 9
 Sample Depth: 176 feet
 Sampling Date: 8/12/17

Lithology : Limestone
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 8 min

Diameter: 1.97 in
 Length: 3.76 in
 L/D: 1.91
 End Area: 3.05 in²

Maximum Axial Load at Failure: 24,900 lb
 Compressive Strength: 8,169 psi
 Compressive Strength: 56.32 Mpa
 Unit Weight 165 pcf

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


Before the Test



After the Test



Drawing # : PA-WA-0171.0000-RR
 PO # : 20170804-7
 Crossing : Wheeling and Lake Erie RR
 Spread : Spread 1

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No:	J217P078		Test Date:	10/3/2017
Location:	Spread 1		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/8/2017

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

Figure 1 - Site Vicinity Plan

Make online reservations at
www.visitPAparks.com
or call toll-free 888-PA-PARKS

Visit us at <http://www.dcnr.state.pa.us>

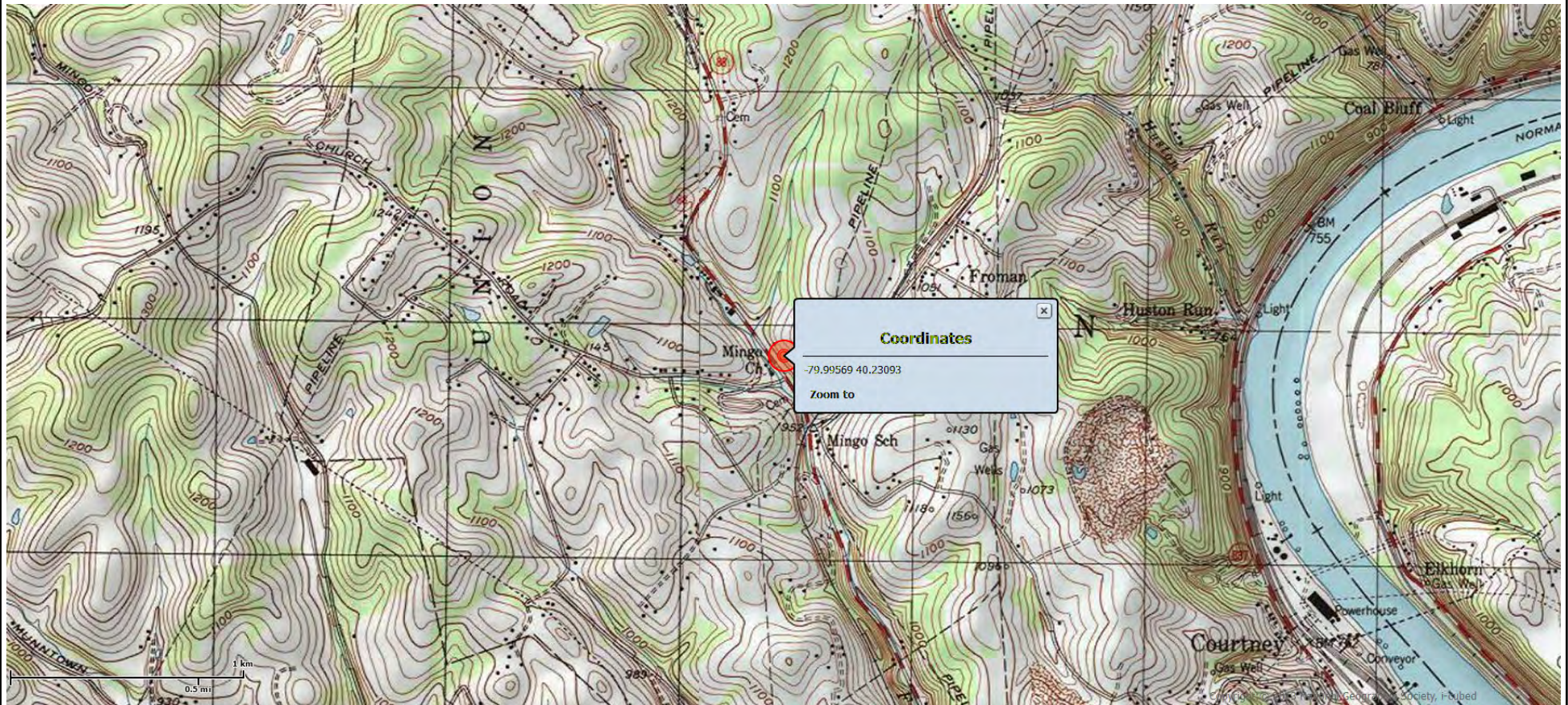
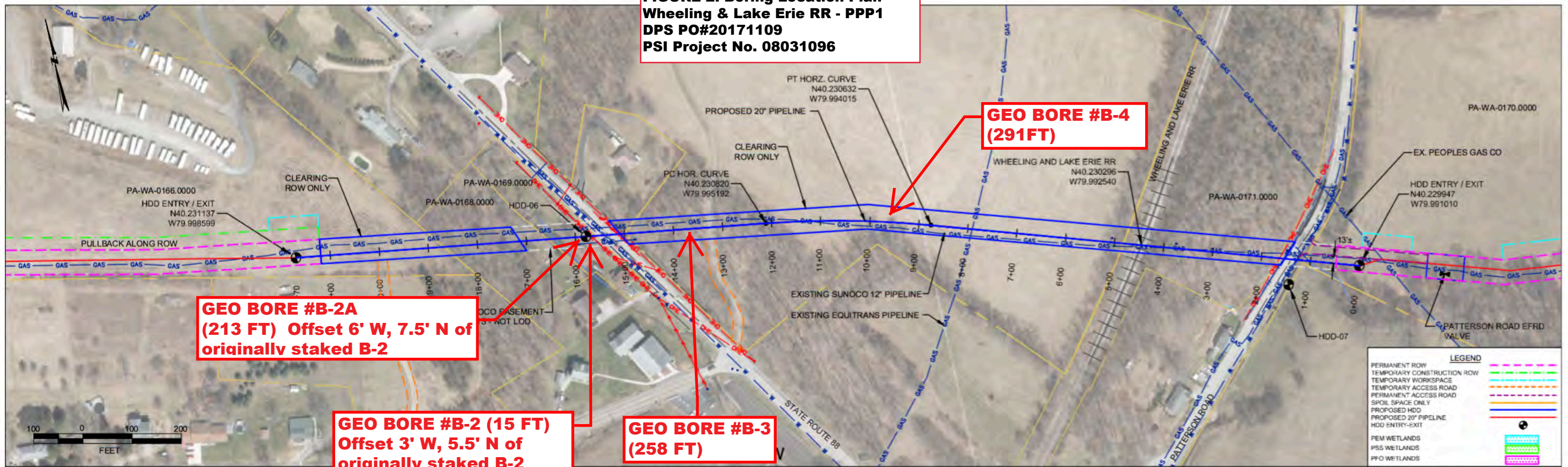
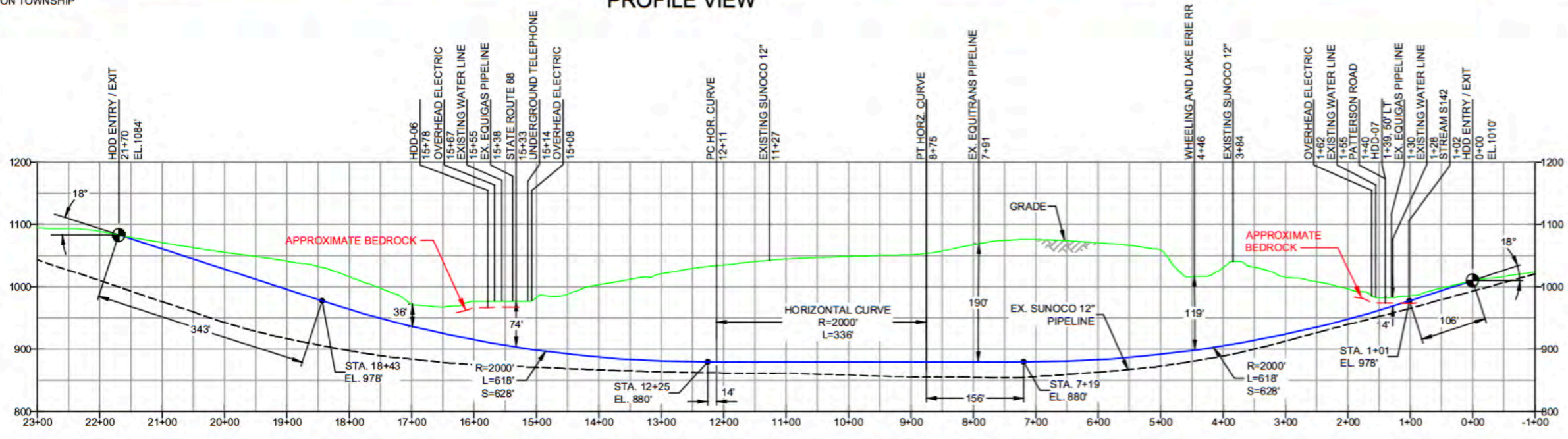


FIGURE 2: Boring Location Plan
Wheeling & Lake Erie RR - PPP1
DPS PO#20171109
PSI Project No. 08031096



PROFILE VIEW



GEO TECH HDD-06

- NG EL. 978'
- CL (0.0' - 8.0')
- SILT STONE (8.0' - 8.1') (AUGER REFUSAL)
- COMPLETION DEPTH EL. 970'

NOTE: REFER TO TEST BORING LOG HDD-06 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEO TECH HDD-07

- NG EL. 984'
- SM (0.0' - 7.0')
- CL/SC (7.0' - 12.0')
- SILT STONE / SAND STONE (12.0') (AUGER REFUSAL)
- COMPLETION DEPTH EL. 972'

NOTE: REFER TO TEST BORING LOG HDD-07 FOR COMPLETE SOIL MATERIAL DESCRIPTION

- DESIGN AND CONSTRUCTION:**
- CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
 - THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
 - DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
 - CROSSING PIPE SPECIFICATION:
 HDD HORZ. LENGTH (L)=217'
 HDD PIPE LENGTH (S)=221'
 20" x 0.456" W.T., X-65, API-5L, PSL2, ERW, BFW, DRL
 COATING: 14-16 MILS OF 3M SCOTCH-KOTE TM 6233 FBE WITH 40 MILS MIN. DFT POWERCRETE R95
 - SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)
 - DESIGN PRESSURE: 1480 PSIG, TEST PRESSURE: 1850 PSIG
 - INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD)
 - PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
 - CARRIER PIPE NOT ENCASED.
 - PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
 - CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
 - SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.

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

REVISIONS		BY	DATE	CHK	DATE	APP	DATE
8	DRILL ENTRY / EXIT LAT LONG UPDATE	MRS	04/03/17	RMB	04/03/17	CAG	04/03/17
7	REVISED PROFILE WITH 2017 LIDAR	MRS	03/13/17	RMB	03/13/17	CAG	03/13/17
6	DESIGN CHANGE - ADJUSTED DRILL ENTRY / EXIT ANGLE	MRS	03/08/17	RMB	03/08/17	CAG	03/08/17
5	UPDATE TO ROW	DLM	02/03/17	RMB	02/03/17	AAW	02/03/17
4	REVISED PER ENGINEERING COMMENTS	MRS	08/19/16	RMB	08/19/16	AAW	08/19/16
3	UPDATED MLV NAME	DLM	04/06/16	RMB	04/06/16	AAW	04/06/16

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
 (303) 792-5911

SUNOCO PIPELINE, L.P.

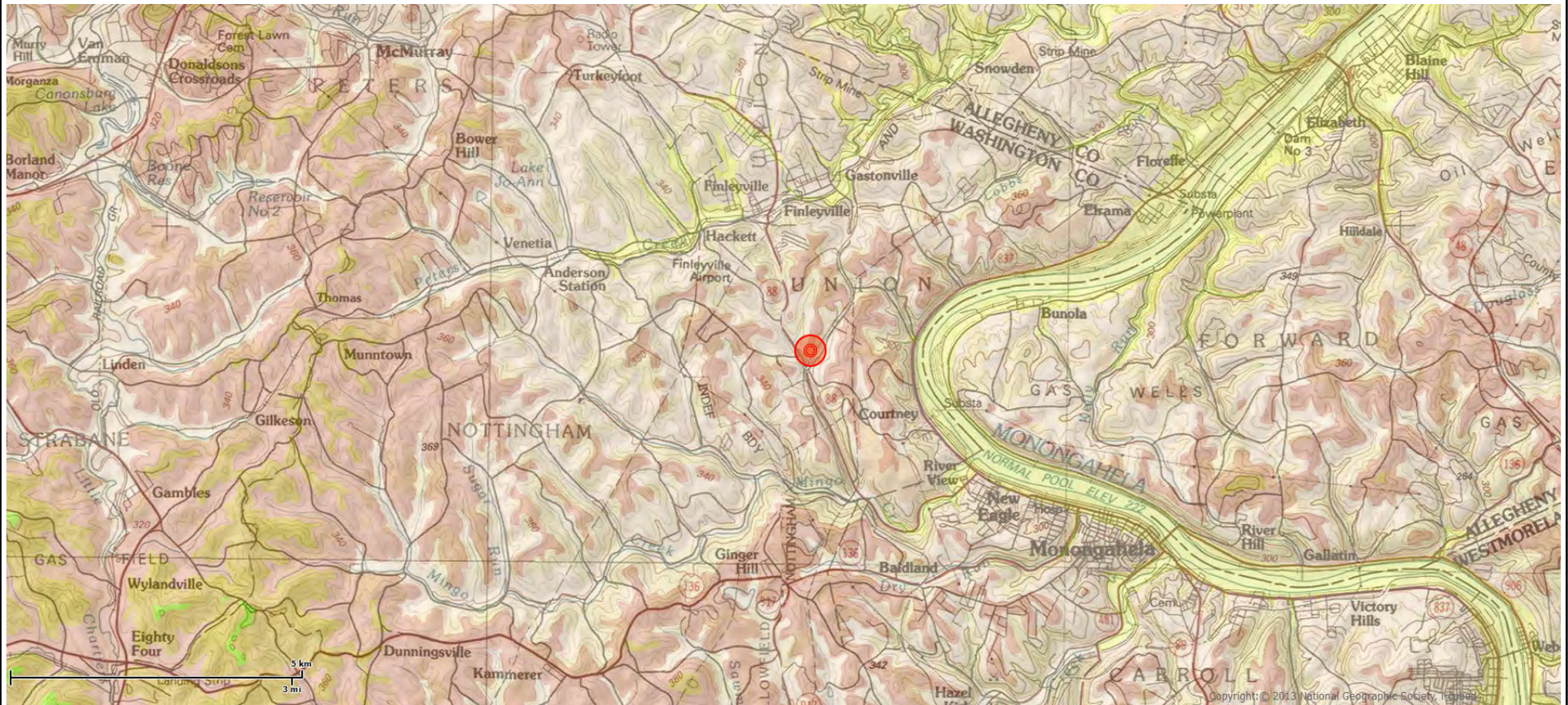
HORIZONTAL DIRECTIONAL DRILL
 WHEELING AND LAKE ERIE RR
 PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200' DWG. NUMBER: PA-WA-0171.0000-RR

Figure 3: Site Geology Plan

Make online reservations at
www.visitPAparks.com
or call toll-free 888-PA-PARKS

Visit us at <http://www.dcnr.state.pa.us>



DATE STARTED: 11/15/17 **DRILL COMPANY:** Terra Testing, Inc.
DATE COMPLETED: 11/16/17 **DRILLER:** T. Canton **LOGGED BY:** W. Thiry
COMPLETION DEPTH: 15.0 ft **DRILL RIG:** Diedrich D-50 Track
BENCHMARK: N/A **DRILLING METHOD:** Hollow Stem Auger
ELEVATION: N/A **SAMPLING METHOD:** SS, 3' Centers
LATITUDE: **HAMMER TYPE:** Automatic
LONGITUDE: **EFFICIENCY:** N/A
STATION: N/A **OFFSET:** N/A **REVIEWED BY:** S. Simonette

BORING B-02

Water During Augering None Enc.
 PreCore Dry

BORING LOCATION:
 Refer to Figure 2 - Boring Location Plan

REMARKS: Ground elevation estimated based on information contained on Google Earth

Elevation (feet)	Depth (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft @				Additional Remarks
										X Moisture PL LL STRENGTH, tsf ▲ Qu * Qp				
0				S-1	20	Approximately 5 inches of TOPSOIL	CL	2-4-7-4 N=11	24					Non-Plastic Fines=32.9%
				S-2	5	FILL - Stiff, damp, brown, Lean CLAY , little Silt, little to trace Sand	GP	4-9-50/3"						
				S-3	13	RESIDUUM - Loose, moist, gray and light brown, Silty SAND , with Gravel, trace Organics, homogenous	SM	2-8-50/3"						
				S-4	0	WEATHERED ROCK - Very dense, dry, gray, LIMESTONE , little Sand, trace Silt and Clay, angular, homogenous (Sampled as a Poorly Graded Gravel)	GP	50/0"						
				R-1	34	BEDROCK - Gray, LIMESTONE , medium bedded, weathered, very broken to blocky, medium hard to hard (0 - 2), water stained at joints Fracture Angles = 0 to 3 Degrees Lost water return at 14 feet Boring terminated at approximately 15 feet due to casing being out of plumb appx. 3 degrees from vertical		RQD=79 Rec=100%						>>



Professional Service Industries, Inc.
 850 Poplar Street
 Pittsburgh, PA 15220
 Telephone: (412) 922-4000

PROJECT NO.: 08031096
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Wheeling & Lake Erie RR (PPP1)
 Washington Co., PA
 PA-WA-0171.0000-RR/PO#20171109

DATE STARTED: 11/15/17 **DRILL COMPANY:** Terra Testing, Inc.
DATE COMPLETED: 11/22/17 **DRILLER:** T. Canton **LOGGED BY:** W. Thiry
COMPLETION DEPTH: 213.2 ft **DRILL RIG:** Diedrich D-50 Track
BENCHMARK: N/A **DRILLING METHOD:** Hollow Stem Auger
ELEVATION: 975 ft **SAMPLING METHOD:** SS, 3' Centers
LATITUDE: **HAMMER TYPE:** Automatic
LONGITUDE: **EFFICIENCY:** N/A
STATION: N/A **OFFSET:** N/A **REVIEWED BY:** S. Simonette

BORING B-02A

Water
 During Augering: None Enc.
 PreCore: Dry

BORING LOCATION:
 Refer to Figure 2 - Boring Location Plan

REMARKS: Ground elevation estimated based on information contained on Google Earth

Elevation (feet)	Depth (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS)	Moisture, %	STRENGTH, tsf	Additional Remarks
0	0					Approximately 5 inches of TOPSOIL FILL - Dry, gray, GRAVEL , little Sand, little to trace Silt and Clay	GP				
970	5										>>⊙
965	10					RESIDUUM - Moist, gray, CLAY , some Silt, little Sand, trace Gravel	CL				
						RESIDUUM - Dry, gray, GRAVEL , little Sand, trace Clay and Silt Auger refusal encountered at approximately 11.6 feet	GP				>>⊙ 2 min.
960	15			R-1	41	BEDROCK - Light gray to medium gray, LIMESTONE , very fine grained, thin to medium bedded, highly to slightly weathered, very broken to massive, soft to hard (0 - 3) Fractures Angles = 3 - 90 Degrees Soft clay seam from 12.2 to 12.3 feet Occasionally Shaley, fossiliferous water stained at joints from 12.4 to 12.9 feet Soft clay seam from 12.7 to 12.9 feet Vertical fracture from 14.2 to 14.8 feet		RQD=100 Rec=100%			>>⊙ 1 min.
											>>⊙ 1 min.
				R-2	56			RQD=88 Rec=94%			>>⊙ 2 min.
											>>⊙ 1 min.
955	20			R-3	55	Carbonaceous lamination from 30.3 to 30.6 feet		RQD=70 Rec=92%			>>⊙ 1 min.
											>>⊙ 1 min.
950	25			R-4	60			RQD=96 Rec=100%			>>⊙ 1 min.
											>>⊙ 1 min.
945	30										>>⊙ 1 min.

Continued Next Page



Professional Service Industries, Inc.
 850 Poplar Street
 Pittsburgh, PA 15220
 Telephone: (412) 922-4000

PROJECT NO.: 08031096
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Wheeling & Lake Erie RR (PPP1)
 Washington Co., PA
 PA-WA-0171.0000-RR/PO#20171109

DATE STARTED: 11/15/17 **DRILL COMPANY:** Terra Testing, Inc.
DATE COMPLETED: 11/22/17 **DRILLER:** T. Canton **LOGGED BY:** W. Thiry
COMPLETION DEPTH: 213.2 ft **DRILL RIG:** Diedrich D-50 Track
BENCHMARK: N/A **DRILLING METHOD:** Hollow Stem Auger
ELEVATION: 975 ft **SAMPLING METHOD:** SS, 3' Centers
LATITUDE: _____ **HAMMER TYPE:** Automatic
LONGITUDE: _____ **EFFICIENCY:** N/A
STATION: N/A **OFFSET:** N/A **REVIEWED BY:** S. Simonette

BORING B-02A

Water	▽	During Augering	None Enc.
	▼	PreCore	Dry
	▽		

BORING LOCATION:
Refer to Figure 2 - Boring Location Plan

REMARKS: Ground elevation estimated based on information contained on Google Earth

Elevation (feet)	Depth (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft @	Additional Remarks	
									X Moisture ◻ PL ◻ LL 0 25 50			
									STRENGTH, tsf ▲ Qu * Qp 0 2.0 4.0			
90				R-17	60	BEDROCK - Light gray to medium gray, SILTSTONE , clayey with calcareous inclusions, thinly to medium bedded, highly to slightly weathered, very broken to massive (averaging blocky), soft to hard (1.5 - 2.5) Fracture Angles = 0 - 5 Degrees		RQD=84 Rec=100%			2 min. 2 min. 2 min. 2 min. >> ◉ 2 min. 2 min.	
880	95		R-18	59		Soft, highly weathered zone from 99.7 to 100 feet		RQD=86 Rec=98%			2 min. >> ▲ Q _u = 333.3 tsf 460.0 pcf 2 min. >> ◉ 2 min.	
875	100		R-19	60		Soft, highly weathered zone from 102.6 to 102.8 feet Soft, highly weathered zone from 103 to 103.2 feet		RQD=48 Rec=100%			3 min. 3 min. 3 min. >> ◉ 3 min.	
870	105		R-20	60		45 Degree angle fracture from 105.6 to 105.7 feet Soft, highly weathered zone from 108.1 to 108.5 feet 45 Degree angle fracture from 108.4 to 108.5 feet 45 Degree angle fracture from 109.2 to 109.5 feet		RQD=48 Rec=100%			3 min. >> ▲ Q _u = 166.1 tsf 168.3 pcf 3 min. >> ◉ 3 min.	
865	110		R-21	37		BEDROCK - Black, COAL , thinly bedded, weathered, very broken to broken, soft to medium hard, with interbedded carbonaceous Shale BEDROCK - Gray, Silty SHALE , very thinly to thinly bedded, highly to slightly weathered, very broken to blocky, soft to hard (1 - 2) Slightly Calcareous Slickensides Fracture Angles = 0 - 45 Degrees		RQD=34 Rec=97%			3 min. >> ◉ 3 min.	
860	115		R-22	55				RQD=52 Rec=92%				3 min. >> ◉ 3 min.
855	120											3 min.

Continued Next Page

<p>Intertek PSI Total Quality. Assured.</p>	Professional Service Industries, Inc. 850 Poplar Street Pittsburgh, PA 15220 Telephone: (412) 922-4000	PROJECT NO.: 08031096 PROJECT: Energy Transfer HDD (DPS) LOCATION: Wheeling & Lake Erie RR (PPP1) Washington Co., PA PA-WA-0171.0000-RR/PO#20171109
---	---	--

DATE STARTED: 11/15/17 **DRILL COMPANY:** Terra Testing, Inc.
DATE COMPLETED: 11/22/17 **DRILLER:** T. Canton **LOGGED BY:** W. Thiry
COMPLETION DEPTH: 213.2 ft **DRILL RIG:** Diedrich D-50 Track
BENCHMARK: N/A **DRILLING METHOD:** Hollow Stem Auger
ELEVATION: 975 ft **SAMPLING METHOD:** SS, 3' Centers
LATITUDE: **HAMMER TYPE:** Automatic
LONGITUDE: **EFFICIENCY:** N/A
STATION: N/A **OFFSET:** N/A **REVIEWED BY:** S. Simonette

BORING B-02A

Water During Augering None Enc.
 PreCore Dry

BORING LOCATION:
 Refer to Figure 2 - Boring Location Plan

REMARKS: Ground elevation estimated based on information contained on Google Earth

Elevation (feet)	Depth (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS)	Moisture, %	STRENGTH, tsf	Additional Remarks
120				R-23	60	BEDROCK - Gray LIMESTONE , medium bedded, weathered to slightly weathered, medium hard to hard (3), with interbedded Siltstone Fracture Angles = 0 to 30 Degrees		RQD=82 Rec=100%			>>⊙ 1 min. 1 min. 1 min. 1 min.
850	125			R-24	60	BEDROCK - Gray SILTSTONE , medium to thinly bedded, slightly weathered, medium hard to hard (0 - 3), Clayey with calcareous streaks and inclusions, Few Slickensides Fracture Angles = 3 to 90 Degrees Vertical fracture from 126.9 to 128.6 feet		RQD=52 Rec=100%			>>⊙ 2 min. 2 min. $Q_u = 211.1$ tsf 2 min. $Q_p = 267.4$ pcf 2 min. 2 min.
845	130			R-25	60	BEDROCK - Gray, SANDSTONE , fine to medium grained, cross bedded, slightly weathered, very broken to massive, hard (2 - 3)		RQD=64 Rec=100%			>>⊙ 2 min. 1 min. 1 min. 1 min.
840	135			R-26	60	BEDROCK - Light gray to gray, SANDSTONE , fine to medium grained, cross bedded, slightly weathered, very broken to massive, medium hard to hard (2 - 3), interbedded with Shale silty interbeds		RQD=88 Rec=100%			>>⊙ 1 min. $Q_u = 402.9$ tsf >>⊙ 1 min. $Q_p = 166.6$ pcf 1 min. 1 min.
835	140			R-27	60			RQD=96 Rec=100%			>>⊙ 1 min. 1 min. 1 min. 1 min.
830	145		R-28	60			RQD=96 Rec=100%			>>⊙ 1 min. $Q_u = 430.3$ tsf >>⊙ 1 min. $Q_p = 166.8$ pcf 1 min. 1 min.	

Continued Next Page

<p>Intertek PSI Total Quality. Assured.</p>	Professional Service Industries, Inc. 850 Poplar Street Pittsburgh, PA 15220 Telephone: (412) 922-4000	PROJECT NO.: 08031096 PROJECT: Energy Transfer HDD (DPS) LOCATION: Wheeling & Lake Erie RR (PPP1) Washington Co., PA PA-WA-0171.0000-RR/PO#20171109
---	---	--

DATE STARTED: 11/15/17 **DRILL COMPANY:** Terra Testing, Inc.
DATE COMPLETED: 11/22/17 **DRILLER:** T. Canton **LOGGED BY:** W. Thiry
COMPLETION DEPTH: 213.2 ft **DRILL RIG:** Diedrich D-50 Track
BENCHMARK: N/A **DRILLING METHOD:** Hollow Stem Auger
ELEVATION: 975 ft **SAMPLING METHOD:** SS, 3' Centers
LATITUDE: **HAMMER TYPE:** Automatic
LONGITUDE: **EFFICIENCY:** N/A
STATION: N/A **OFFSET:** N/A **REVIEWED BY:** S. Simonette


BORING B-02A

Water During Augering None Enc.
 PreCore Dry

BORING LOCATION:
 Refer to Figure 2 - Boring Location Plan

REMARKS: Ground elevation estimated based on information contained on Google Earth

Elevation (feet)	Depth (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft @	Additional Remarks
150				R-29	59	BEDROCK - Light gray to gray, SANDSTONE , fine to medium grained, cross bedded, slightly weathered, very broken to massive, medium hard to hard (2 - 3), interbedded with Shale silty interbeds Clear gel material covering rock core encountered from 153.2 to 153.5 feet		RQD=90 Rec=98%		X Moisture <input checked="" type="checkbox"/> PL <input checked="" type="checkbox"/> LL	1 min. >>⊙ 1 min. 1 min. 1 min. 1 min.
820	155			R-30	60	Carbonaceous laminations from 156.9 to 161.7 feet		RQD=92 Rec=100%		▲ Qu = 287.8 tsf * Qp = 167.4 pcf	1 min. >>⊙ 1 min. 1 min. 1 min.
815	160			R-31	56	BEDROCK - Gray to light gray, Silty SHALE , slightly weathered, very broken to massive, medium hard to hard (1 - 2) Fracture Angles = 0 to 3 Degrees		RQD=92 Rec=94%			1 min. >>⊙ 1 min. 2 min. 2 min.
810	165			R-32	60	BEDROCK - Gray, SANDSTONE , fine to medium grained, slightly weathered, very broken to massive, hard (2 - 3) Fracture Angles = 0 to 3 Degrees		RQD=96 Rec=100%		▲ Qu = 496.1 tsf * Qp = 160.9 pcf	2 min. >>⊙ 1 min. 1 min. 1 min.
805	170			R-33	60	BEDROCK - Gray, Silty SHALE , thinly laminated to thinly bedded, slightly weathered, very broken to massive, medium hard to hard (1 - 3), interbedded with fine grained Sandstone seams Fracture Angles = 0 to 45 Degrees Diagonal fractures from 170.8 to 171.1 feet		RQD=82 Rec=100%			1 min. >>⊙ 1 min. 1 min. 1 min.
800	175			R-34	40	Tool drop from 175 to 176.5 feet BEDROCK - Dark gray, Carbonaceous SHALE , very thinly bedded, highly weathered to weathered, very broken to blocky, soft to medium hard (1) Tool drop from 179.2 to 180.2 feet		RQD=44 Rec=66%		▲ Qu = 256.0 tsf * Qp = 168.6 pcf	1 min. >>⊙ 2 min. 2 min. 2 min.
795	180					Continued Next Page					

 <p> Intertek PSI Total Quality. Assured. </p>	Professional Service Industries, Inc. 850 Poplar Street Pittsburgh, PA 15220 Telephone: (412) 922-4000	PROJECT NO.: 08031096 PROJECT: Energy Transfer HDD (DPS) LOCATION: Wheeling & Lake Erie RR (PPP1) Washington Co., PA PA-WA-0171.0000-RR/PO#20171109
---	---	--

**SR-88/WHEELING AND LAKE ERIE RR CROSSING
PADEP SECTION 105 PERMIT NO.: E63-674
PA-WA-0171.0000-RR
(SPLP HDD# S1B-0120)**

ATTACHMENT 2

MINE SUBSIDENCE REPORT AND PIPELINE RISK ANALYSIS

**SUBSIDENCE POTENTIAL REVIEW
WHEELING AND LAKE ERIE
FLEXBOR CROSSINGS
UNION TOWNSHIP, WASHINGTON COUNTY, PA
May 2018**

PRESENTED FOR

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

PRESENTED BY

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



TABLE OF CONTENTS

INTRODUCTION.....	1
BACKGROUND	1
TYPES OF MINE SUBSIDENCE.....	3
CATEGORIES OF MINE SUBSIDENCE POTENTIAL	3
FINDINGS	6
RECOMMENDATIONS.....	9
CLOSURE.....	10
REFERENCES.....	13

FIGURES

1	Project Location with Angle of Draw
2	Project Location with Subsidence Categories
3	Plan and Profile
4	Estimated Subsidence
5	Change in Subsidence
6	Borehole and Pipeline Cross Section

TABLE

1	Summary of Categories of Subsidence Potential with Angle of Draw
2	Zones of Subsidence Impact Above Coal Seam

APPENDICES

A	Dr. Heasley Subsidence Report
---	-------------------------------

INTRODUCTION

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 Wheeling and Lake Erie Railroad Crossing located in Union Township, Washington 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 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 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 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 Cincinnati Mine operated in Union Township, Washington County in the early 1900s. Mining under the area of the planned Crossing was completed prior to 1913. According to an inspection report in the 1913 Bituminous Coal Mining Report of the Department of Mines of Pennsylvania (PA Mines Report, 1914), the Cincinnati Mine extracted the thin-vein Pittsburgh Coal seam at a seam thickness between 5 and 6 feet thick. Main entries were 9 feet wide, and production rooms entries were about 24 feet wide. To our knowledge, there is no water pooled in the mine under the pipeline area. This information was further confirmed by recent drilling for this project.

The mining method employed at the Cincinnati Mine was room and pillar mining utilizing hand loading (the coal was broken loose using explosives and loaded into carts manually). Main entries were primarily used for developing areas for the rooms. The rooms were more productive (higher tons per manhour) and recovered a higher percentage of the in place coal. The main entries were also used for men and material movement within the mines, for coal haulage, for air courses for mine ventilation and were configured to be stable for an extended period of time. The rooms were areas utilized exclusively for coal recovery, and were only configured for short term stability. They were designed to protect the miners while they were working there, but not for long term stability. At that time, mines did not use any mechanical roof support as used in today's mines. The main entries were supported primarily by the large adjacent coal pillars that would remain after mine closure. Rooms were advanced to the right or left of the main entries. After each room had advanced to its planned length, which was approximately one-half of the way between main entries, the small support pillar between rooms was systematically removed (mined) as the miners retreated, allowing the roof to collapse behind them. When this happened, surface subsidence would occur. Most subsidence would occur almost immediately, and all ground movements would be completed within a few weeks. The main entries needed to remain open for the duration of mining activities and thus relatively large pillars were left between these entries as support. The surface above those pillars should remain stable from subsidence for the long term. Areas between the caved production rooms and the large main entry support pillars or areas where the rooms were not retreated for whatever reason (poor mining condition, mine closures, etc.) have the highest risk of future subsidence because the pillars in these areas were not designed to provide long-term support. These medium-sized pillars are the primary areas of concern regarding potential for future subsidence. Based on the mine map, there are also a few areas where mining did not occur and solid coal remains. Assuming that the mine map is accurate, those areas should be safe from future subsidence. As previously discussed, due to potential inaccuracies in the mine map, this 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. As the mine workings reach the extent of the mine boundaries, some areas are “retreat mined.” In areas where retreat mining is employed, coal pillars are extracted for nearly full recovery (generally 80 to 90 percent recovery) of the coal seam. To accomplish full recovery in a safe manner, the roof of the mine is allowed to cave in a predictable controlled manner following coal extraction. This controlled caving process systematically relieves built-up stresses caused by the cantilever action of the mine roof thereby reducing the risk of catastrophic strata failure where men are working. The limits and extents of

the subsidence are relatively predictable where retreat mining is employed because subsidence normally occurs soon after mining.

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.

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 Cincinnati 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 map and the location and elevations of the planned Crossing. Figure 1 depicts the areas within the mine that are within the angle of draw depicted downward from the level of the planned Crossing. Both angles of draw (20 and 35 degrees) are shown on Figure 1. The areas shown was created by projecting downward using the 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 that if failure occurred the potential to affect the pipeline exists. A 15-foot horizontal zone on each side of the pipe (30 feet total) was also included. A total of 6.8 acres lies within the 20-degree angle of draw influence area, and 11.3 acres lie within

a 35-degree angle of draw influence area. The categories of mine subsidence potential areas are shown on Figure 2 and summarized in Table 1.

Table 1: Summary of Categories of Subsidence Potential with Angle of Draw

Subsidence Category	Subsidence Potential	20° Angle of Draw (Acres)	35° Angle of Draw (Acres)
1	Subsidence probably occurred during or soon after mining	5.0	8.1
2	Support area where subsidence is unlikely	1.1	1.9
3	Area where subsidence may occur in the future if it has not already occurred	0.7	1.3
Total		6.84	11.3

Within the overburden the strata can behave differently when subsidence occurs and depend on the distance above the coal seam and the mining thickness. These different zones are classified based on past research. A caved zone typically extends from the roof of the mined coal seam upward for a distance of 6 to 10 times the mining thickness (Kendorski, 2006). In the case of the Cincinnati Mine, where the mined thickness is 5 to 6 feet, this zone would be from 30 to 60 feet above the top of coal. Rock in this zone would have extensive fracturing and sizable voids. Above the caved zone and extending for 24 to 30 times the mining thickness, a fractured zone would occur. In this zone, many fractures would be present, but the rock strata would remain as a single unit without extensive dislocated rock or voids present. At the Cincinnati Mine, this zone would extend from 30 to 60 feet to 120 to 180 feet above the top of the mined area. The next zone would extend from the top of the fractured zone to about 60 times the mining thickness. This zone, termed the dilated zone, would have smaller fractures that would be less permeable than the fractured zone. The rock in this zone would also remain as a single unit. At the Cincinnati Mine, the dilation zone would extend from 120 to 180 feet to 240 to 360 feet above the top of the coal. The zone above the dilated zone is termed the constrained or bending zone where no fracturing would occur. The zones are shown in 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 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 Crossing occurred over 100 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. We have reviewed several of the different maps available at the PA DEP California, Pennsylvania, mine map repository and the Pennsylvania Mine Map Atlas website. They all indicated the same depiction of the mine workings under the planned pipeline area. There is a couple of potential areas of uncertainty – at retreat mined areas we are not certain if all of the coal was removed and at an area shown as cross-hatched it was assumed that the area was solid coal but we are not certain of that.

The selected construction alternatives for this area includes open trench and Flexbor construction. Flexbor Crossings will be completed under Patterson Road and the Wheeling and Lake Erie Railroad. The first Crossing is 781 feet long and extends from Station 2+87 to Station 11+76. The second Flexbox crosses under Route 88 and a small stream. The second Crossing is 189 feet long and extends from Station 17+90 to Station 19+82.

Figure 3 shows the planned construction with the two Flexbor drills under the Wheeling and Lake Erie Railroad and Route 88 and the associated zones of strata fractures during subsidence. To be conservative the top of each zone is shown at the maximum estimated distance above the mine. Both Flexbor drills will pass through the top of the fractured zone. The first Crossing however, is mostly in the dilated zone. None of the planned Flexbor drills will be in the caved 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 Cincinnati Mine. It is our understanding that their recording of these incidents began shortly after 1977. There have been two subsidence incidents reported and investigated above the Cincinnati Mine. Both of those incidents were not found to be mining related. Thus, there have been no confirmed reported mining-related subsidence events over the Cincinnati mine 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 Cincinnati 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 4. 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. Mine subsidence at this site may have already occurred, may occur at some time in the future, or may never 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.

Tetra Tech employed 3D seismic technology to gain a better understanding of the strata fracturing and anomalies at mine level. The subsidence model was run to reflect this information.

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 200 feet above the Cincinnati 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.

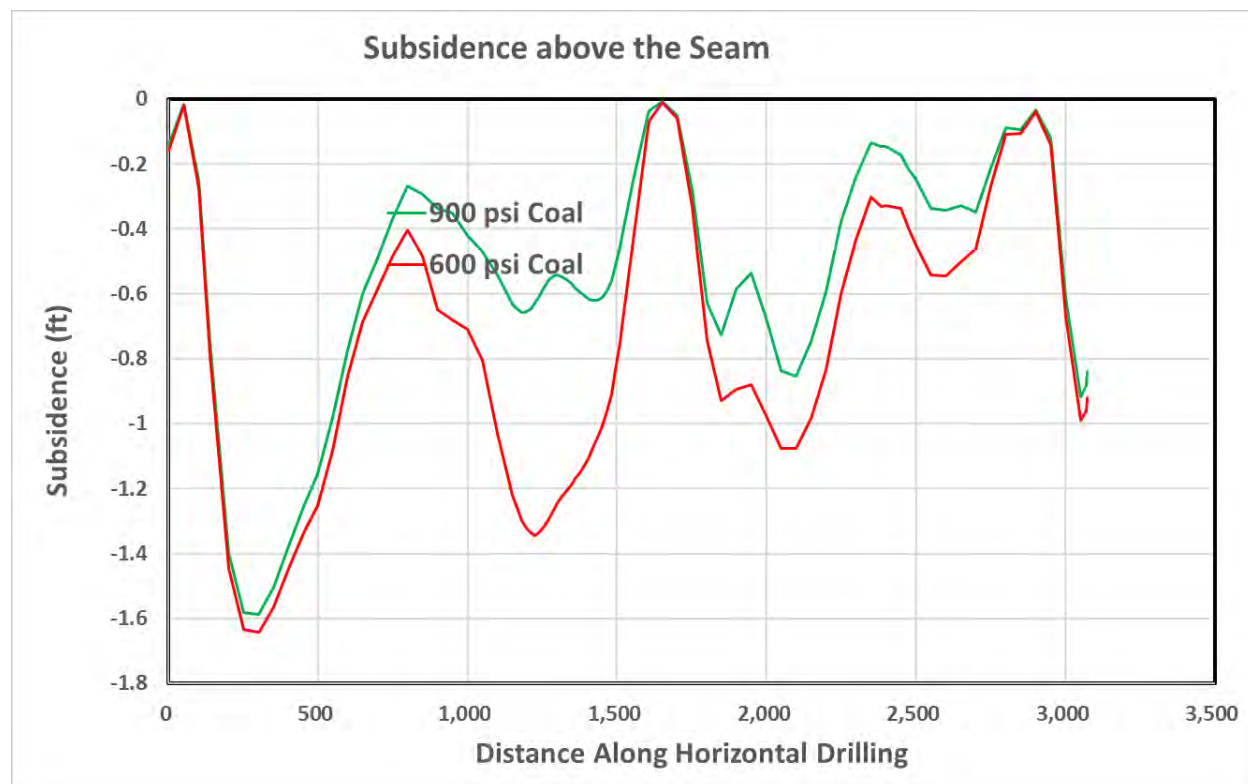


Figure 4. Estimated Subsidence

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 4. There are two primary areas of potential future subsidence. One area is centered at Station 13+00 and occurs within a retreat mined area that was not completely retreat mined based on our interpretation of the 3D seismic data. The increased subsidence at this location was estimated to be about 0.72 foot (8.6 inches). However, this location is under an area of the crossing where the new pipeline will be installed by open trench and falls outside the angle of draw for the Flexbor. The second area of increased subsidence occurs between Stations 19+00 and 26+00. This area is again located in a retreat mined area that was interpreted as not being completely retreat mined. The estimated additional subsidence at this area is estimated to be about 0.34 foot (4 inches), and occurs under a portion of the shorter and shallower Flexbor which is shown at the maximum extent of the fracture zone. The actual limit of the fracture zone may be below the bore elevation. The remainder of the pipeline under the crossings will be open trench installation.

The strains within the strata associated with the estimated future subsidence should the pillars fail are shown on Figure 5. The maximum strain values range from 0.0014 to 0.0021 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 Flexbox, then areas of tensile or compressive strain can be reasonably canceled by adjacent areas of the opposite strain.

The modeled strains are in the strata at the location of the pipeline alignment. The bored excavation for both Flexbors will be larger than the pipe to be installed. As shown on Figure 6, 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.

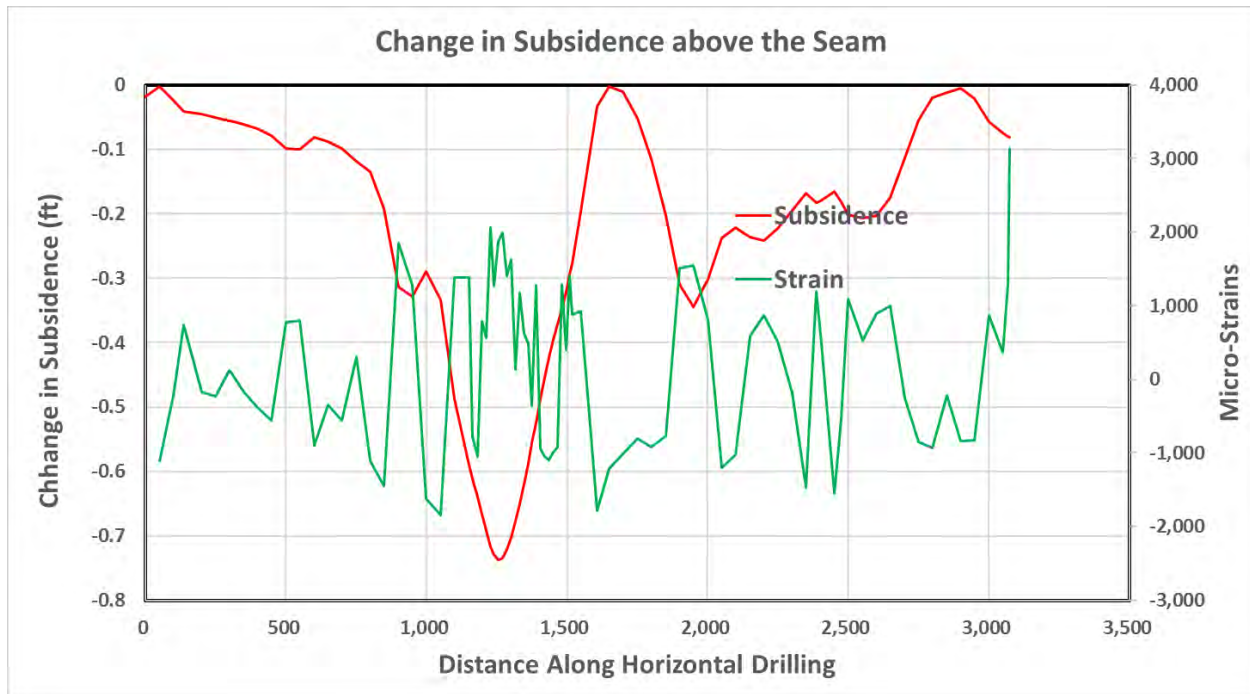
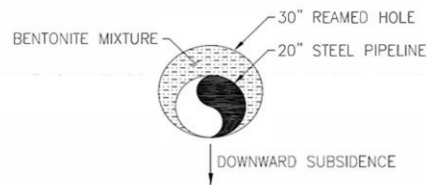


Figure 5. Change in Subsidence



Flexbor 20"

Figure 6 – 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.
- Consider mitigating the subsidence strain by grouting the underlying abandoned coal mine if the pipeline stresses exceed appropriate pipeline design standards.

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

Thomas A. Gray, P.E.
Mining Engineer

Farley Wood

Farley Wood, P.E.
Mining Engineer

Keith A. Heasley

Keith Heasley, PhD, P.E.
Mining Engineer

CERTIFICATION

**SUBSIDENCE POTENTIAL REVIEW
WHEELING AND LAKE ERIE
FLEXBOR CROSSINGS**

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

5/9/18

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.

Date: May 9, 2018

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

Subject: **Subsidence Potential Review Wheeling and Lake Erie Flexbor Crossings –
Union Township, Washington County, PA
Mariner East II TTR Project: 204-3110 1.1 PPP1**

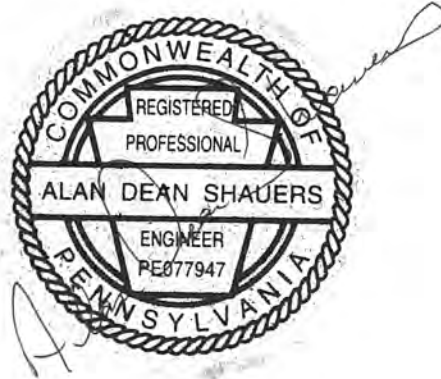
Mr. Gordon,

Tetra Tech Rooney has reviewed the above referenced subsidence report in addition to a Finite Element Analysis (FEA) model 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,



Dean Shauers, P.E.
Tetra Tech Rooney



Attachments:

Geotechnical Report: Subsidence Potential Review Wheeling and Lake Erie Flexbor Crossings –
Union Township, Washington 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.

REFERENCES

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 West Virginia.

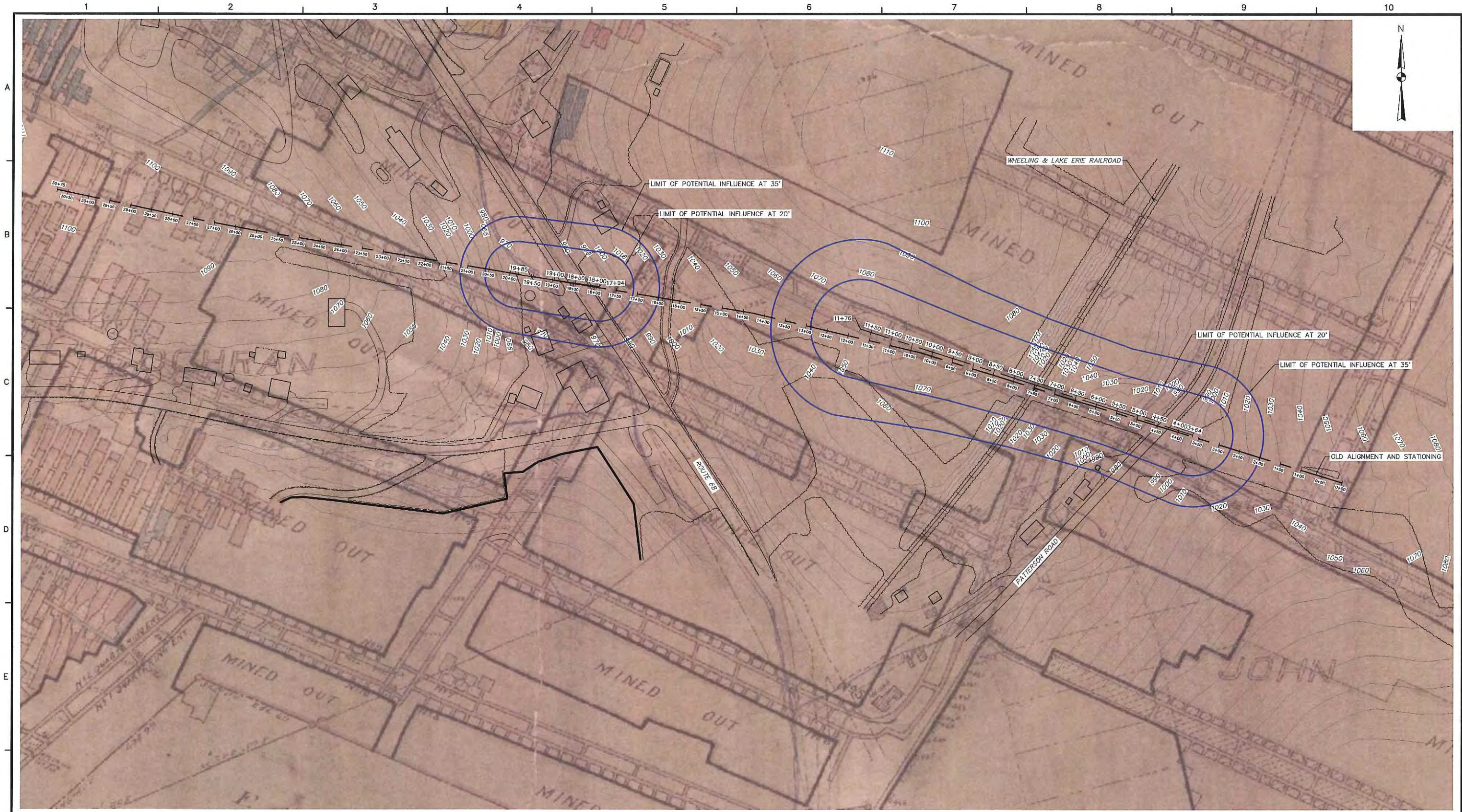
PA DEP, 2017. Technical Guide to Mine Subsidence, Pennsylvania Department of the Environment Website <http://www.dep.state.pa.us/msi/technicalguidetoms.html>.

Peng, Syd S., 1978. Coal Mine Ground Control, John Wiley and Sons, Inc.

Pennsylvania State University, 2014. Pennsylvania Mine Map Atlas, <http://www.minemaps.psu.edu/>.

PA Mines Report, 1914. Commonwealth of Pennsylvania Report on the Department of Mines of Pennsylvania, 1914, Bituminous Coal

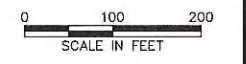
Figures



LEGEND

LIMIT OF POTENTIAL INFLUENCE AREA ON PIPELINE

REFERENCE: CINCINNATI MINE MAP - OBTAINED FROM PA DEP - UNDATED



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

REVISIONS			
NO.	BY	DATE	REMARKS

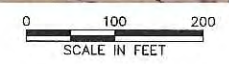
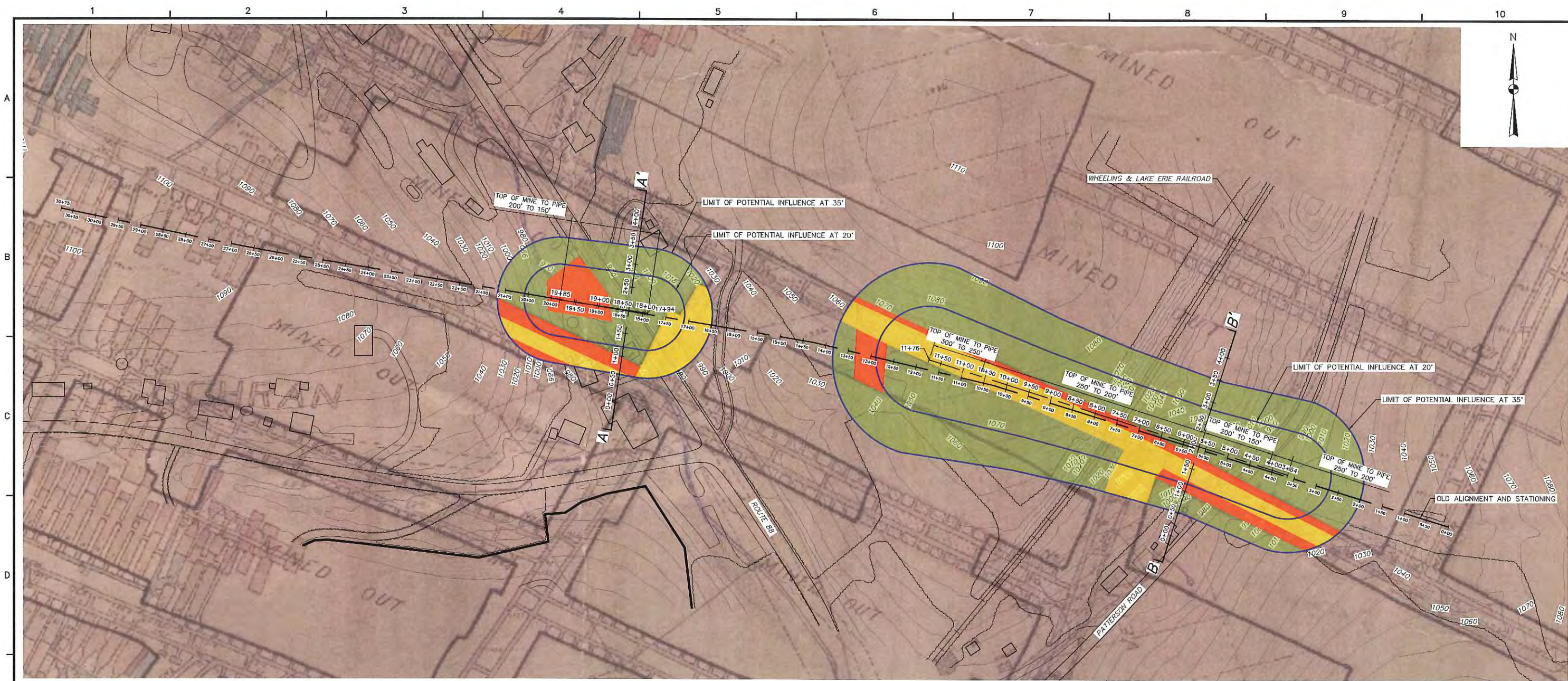
SUNOCO PIPELINE L.P.
SINKING SPRING, PENNSYLVANIA

PENNSYLVANIA PIPELINE PROJECT

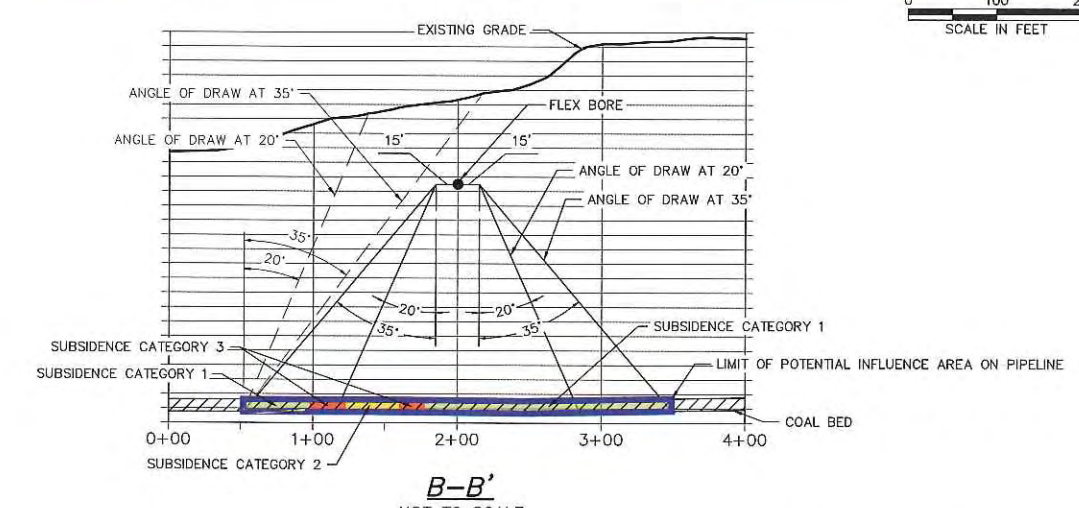
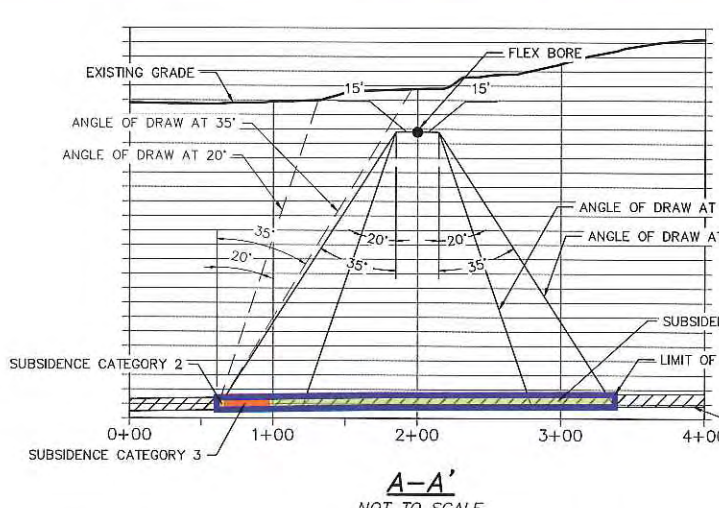
PROJECT LOCATION WITH SUBSIDENCE CATEGORIES
WASHINGTON COUNTY
WHEELING AND LAKE ERIE RAILROAD
MINE AREA

DATE:	5/04/16
PROJECT NO.:	
DESIGNED BY:	TG
DRAWN BY:	JSM
CHECKED BY:	TG
COPYRIGHT TETRA TECH INC.	

FIGURE 1



- LEGEND**
- LIMIT OF POTENTIAL INFLUENCE AREA ON PIPELINE —
 - 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: CINCINNATI MINE MAP - OBTAINED FROM PA DEP - UNDATED



661 ANDERSON DRIVE - FOSTER PLAZA 7
PITTSBURGH, PA 15220
T: (412) 921-7090 | F: (412) 921-4040

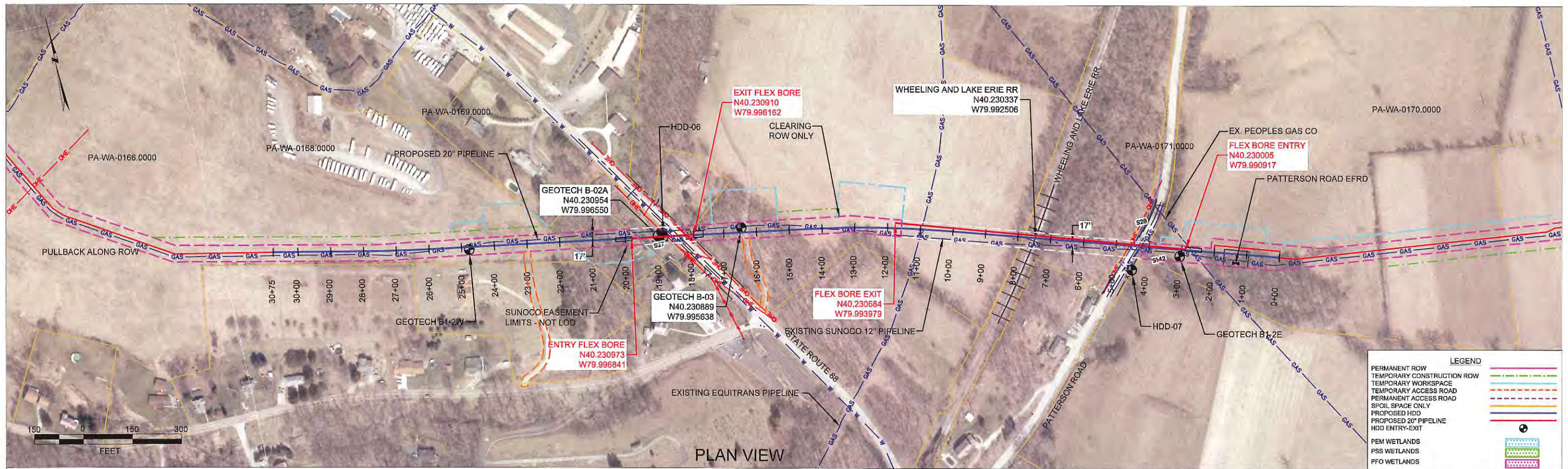
REVISIONS			
NO.	BY	DATE	REMARKS

SUNOCO PIPELINE L.P.
SINKING SPRING, PENNSYLVANIA

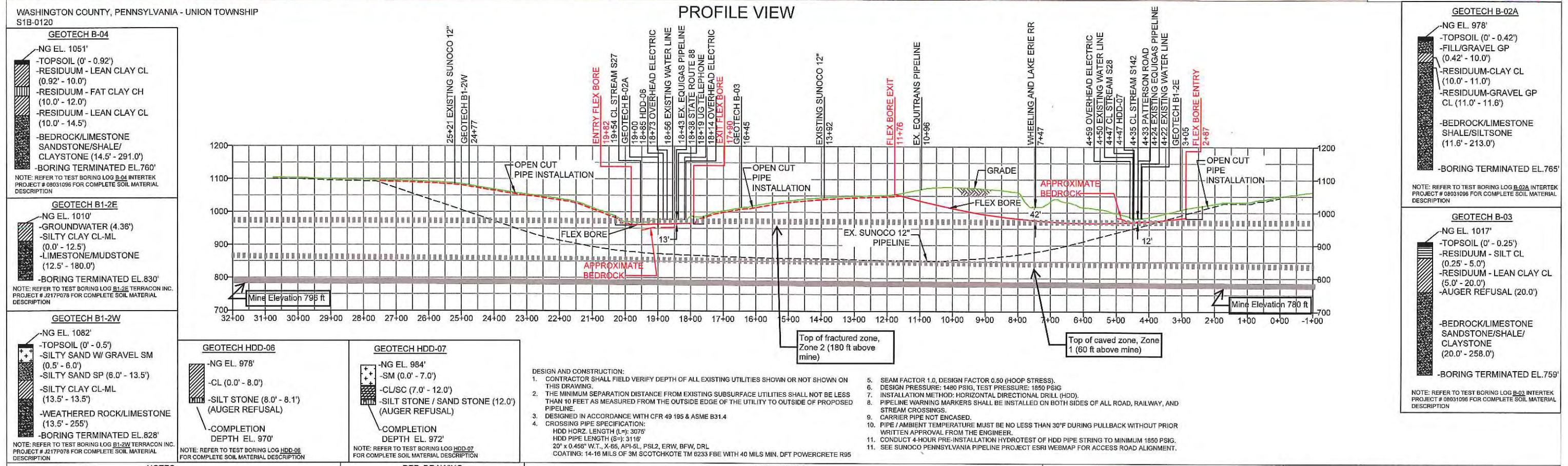
PENNSYLVANIA PIPELINE PROJECT

PROJECT LOCATION WITH SUBSIDENCE CATEGORIES
WASHINGTON COUNTY
WHEELING AND LAKE ERIE RAILROAD
MINE AREA

DATE:	5/04/18
PROJECT NO.:	
DESIGNED BY:	TG
DRAWN BY:	JSM
CHECKED BY:	TG
COPYRIGHT TETRA TECH INC.	
FIGURE 2	



PLAN VIEW



PROFILE VIEW

WASHINGTON COUNTY, PENNSYLVANIA - UNION TOWNSHIP
S1B-0120

GEOTECH B-04
 -NG EL. 1051'
 -TOPSOIL (0' - 0.92')
 -RESIDUUM - LEAN CLAY CL (0.92' - 10.0')
 -RESIDUUM - FAT CLAY CH (10.0' - 12.0')
 -RESIDUUM - LEAN CLAY CL (10.0' - 14.5')
 -BEDROCK/LIMESTONE SANDSTONE/SHALE/CLAYSTONE (14.5' - 291.0')
 -BORING TERMINATED EL. 760'
 NOTE: REFER TO TEST BORING LOG B-04 INTERTEK PROJECT # 08031096 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B1-2E
 -NG EL. 1010'
 -GROUNDWATER (4.36')
 -SILTY CLAY CL-ML (0.0' - 12.5')
 -LIMESTONE/MUDSTONE (12.5' - 180.0')
 -BORING TERMINATED EL. 830'
 NOTE: REFER TO TEST BORING LOG B1-2E TERRACON INC. PROJECT # J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B1-2W
 -NG EL. 1082'
 -TOPSOIL (0' - 0.5')
 -SILTY SAND W/ GRAVEL SM (0.5' - 6.0')
 -SILTY SAND SP (6.0' - 13.5')
 -SILTY CLAY CL-ML (13.5' - 13.5')
 -WEATHERED ROCK/LIMESTONE (13.5' - 255')
 -BORING TERMINATED EL. 828'
 NOTE: REFER TO TEST BORING LOG B1-2W TERRACON INC. PROJECT # J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH HDD-06
 -NG EL. 978'
 -CL (0.0' - 8.0')
 -SILT STONE (8.0' - 8.1') (AUGER REFUSAL)
 -COMPLETION DEPTH EL. 970'

GEOTECH HDD-07
 -NG EL. 984'
 -SM (0.0' - 7.0')
 -CL/SC (7.0' - 12.0')
 -SILT STONE / SAND STONE (12.0') (AUGER REFUSAL)
 -COMPLETION DEPTH EL. 972'

GEOTECH B-02A
 -NG EL. 978'
 -TOPSOIL (0' - 0.42')
 -FILL/GRAVEL GP (0.42' - 10.0')
 -RESIDUUM-CLAY CL (10.0' - 11.0')
 -RESIDUUM-GRAVEL GP CL (11.0' - 11.6')
 -BEDROCK/LIMESTONE SHALE/SILTSTONE (11.6' - 213.0')
 -BORING TERMINATED EL. 765'
 NOTE: REFER TO TEST BORING LOG B-02A INTERTEK PROJECT # 08031096 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B-03
 -NG EL. 1017'
 -TOPSOIL (0' - 0.25')
 -RESIDUUM - SILT CL (0.25' - 5.0')
 -RESIDUUM - LEAN CLAY CL (5.0' - 20.0')
 -AUGER REFUSAL (20.0')
 -BEDROCK/LIMESTONE SANDSTONE/SHALE/CLAYSTONE (20.0' - 258.0')
 -BORING TERMINATED EL. 759'
 NOTE: REFER TO TEST BORING LOG B-03 INTERTEK PROJECT # 08031096 FOR COMPLETE SOIL MATERIAL DESCRIPTION

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-1.55	TO	ES-1.56	EROSION & SEDIMENT PLAN
SHEET 32	TO	SHEET 33	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

BORE CROSSINGS OVERLAY
WHEELING AND LAKE ERIE RR
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=300'
DWG. NUMBER: PA-WA-0171.0000-RR

Appendix A
Dr. Heasley Subsidence Report

LAMODEL ANALYSIS OF SUBSIDENCE POTENTIAL
WHEELING AND LAKE ERIE
HORIZONTAL DIRECTIONAL DRILLED PIPELINE PROJECT
UNION TOWNSHIP, WASHINGTON COUNTY, PA
May 2018

PRESENTED FOR

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

PRESENTED BY

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



TABLE OF CONTENTS

INTRODUCTION.....	1
MINING BACKGROUND.....	1
THE LAMODEL PROGRAM	1
LAMODEL MATERIAL PROPERTY INPUT.....	2
POST-MINING MODEL RESULTS	3
DEGRADED MINE MODEL RESULTS.....	5
REFERENCES.....	7

FIGURES

- 1 Map of mine and overlying pipeline.
- 2 Overburden stress on the seam
- 3 Seam convergence with 900 psi coal strength
- 4 Pillar safety factors with 900 psi coal strength
- 5 Subsidence at the pipeline for 900 psi coal strength
- 6 Subsidence prediction along the pipeline alignment at different coal strengths
- 7 Drop in pillar safety factor between 900 psi and 600 psi coal strength
- 8 Increase in subsidence going from 900 psi coal to 600 psi coal
- 9 Predicted worst case subsidence and associated strains (tension is negative)

INTRODUCTION

The Sunoco Logistic L.P. is planning to horizontally directional drill (HDD) a pipeline at two locations (under the Wheeling & Lake Erie Railroad (W&LE RR) grade and under state route 88) in the strata over the abandoned Cincinnati Mine in Union Township, Washington County, PA. The HDD section under the W&LE RR will be about 892 ft long and 170 ft above the mine. The HDD section under state route 88 will be about 192 ft long and also about 170 ft above the mine. The objective of this investigation is to utilize the LaModel boundary-element program to analyze the future subsidence potential over the abandoned Cincinnati Mine, and in particular, to determine any potential subsidence and associated strains that may occur along the proposed pipeline alignment.

MINING BACKGROUND

The Cincinnati Mine operated in Union Township, Washington County in the early 1900's. Their primary mining method was room and pillar mining. All active mining was completed under the planned horizontal directional drilled pipelines prior to 1913. According to an inspection report in the 1913 Bituminous Coal Mining Report of the Department of Mines of Pennsylvania (PA Mines Report, 1914), the Cincinnati Mine extracted the thin-vein Pittsburgh Coal at a mining height between five and six feet thick. Main entries were nine feet wide and production room entries were about twenty-four feet wide. To our knowledge there is not any water pooled under the pipeline area. This information was further confirmed by recent drilling for this project.

The mining method employed at the Cincinnati Mine was hand loading. The mining development orientation followed the coal's main Butt and Face cleavage planes. Main entries were primarily used for developing areas for the highly productive rooms. These main entries were also used for men and material movement within the mines, for coal haulage and for air courses for mine ventilation. According to the 1914 report, these entries were nine feet wide. At that time mines did not use any roof bolts and the entries were solely supported by the large adjacent coal pillars that would remain after mine closure. The highly productive rooms were advanced to the right or left from the main entries. The 1914 report states that these entries were retreated twenty-four feet wide. After each room had advanced to its planned length, which was approximately one-half way between main entries, the small support pillar between rooms was systematically removed (mined) as the miners retreated allowing the roof to collapse behind them. When this happened, surface subsidence would occur. Most subsidence would occur almost immediately and all ground movements would be completed within a few weeks. The Main entries needed to remain open for the duration of mining life and thus relatively large pillars were left between these entries as support. The surface above those pillars should remain generally stable from subsidence for the long term. Areas in between the caved production rooms and the large main entry support pillars or areas where the rooms were not retreated for whatever reason (poor mining condition, mine closures, etc.) have the highest risk of future subsidence since their pillars were not planned for long term support. In particular to the Cincinnati Mine, these medium sized pillars are the primary areas of concern regarding the potential for future subsidence. There are

also a few areas where mining did not occur and solid coal remains. Those areas, if not mined as shown on the mine maps, should be safe from future subsidence. As previously discussed, due to potential inaccuracies in the mine map, the final mining plan cannot be guaranteed.

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 being 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 Cincinnati Mine area 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 5,400 ft long and 2,400 ft high. A relatively small element size of 4 ft was used to best model the given narrow entries and relatively narrow pillars. This smaller element size also facilitates using a thin lamination thickness for the overburden to optimize the subsidence angle-or-draw. With the 4 ft element width, the final grid size was 1,350 X 600 elements. Based on the mine map, the east, west and south boundaries of the model were simulated with symmetric boundary conditions and the north boundary was simulated with a rigid

boundary condition. The actual mine grid was automatically generated from a digitized version of the Cincinnati 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 on all 4 sides than the model grid and which used 25 ft wide elements on a 260 X 136 element grid. This overburden grid was 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 stream valleys and the higher stress areas under the ridges can easily be seen. In particular, the variable stress under the pipeline can be seen as it: starts on a hill top on the eastern end, travels across a smaller valley, crosses under the end of a ridge, then crosses under a deeper, wider valley before moving to a ridge top at the western extent.

Overburden, Gob and Coal Properties: The material properties for the Cincinnati 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 Pittsburgh Seam overburden and consistent with the 250-350 ft wide, 150-350 ft deep extraction panels that are adjacent to the pipeline alignment. This resulted in an average rock modulus of 3,000,000 psi and lamination thickness of 2.5 ft. for the overburden, and a final gob modulus of 13,000 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 various size and shaped gobs is clearly visible. In particular, the panels adjacent to the pipeline show 2 to 3+ ft of convergence.

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 2.5). This figure shows that some of the “larger” pillars which are located adjacent to gob areas and/or under the deeper cover had marginal safety factors, even directly after mining. This analysis indicates that some of these larger pillars may not be as stable as initially assumed. In particular, a number of pillars under the pipeline directional drilling alignment at a plus of approximately 7+00 show marginal safety factors. Also, the remaining rib pillars at a plus of 13+00 to 16+00 and 19+00 to 20+00 show very low safety factors.

Subsidence: The third output from the post-mining model to be examined was the near surface subsidence (see Figure 5). This subsidence is directly correlated to the seam convergence shown in Figure 3. Similar to the convergence, the increase in surface subsidence due to wider and/or deeper panels is evident in Figure 5. Here the original predicted subsidence under the pipeline location can be seen. Generally, the pipeline just crosses the very edges of the subsidence troughs, and does not overlies the highest subsidence magnitudes.

The depth of the pipeline in the bored sections is not very deep, so the surface subsidence values are applied to the underground 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 in the near surface overburden 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 edge of the adjacent gob areas is clearly visible.

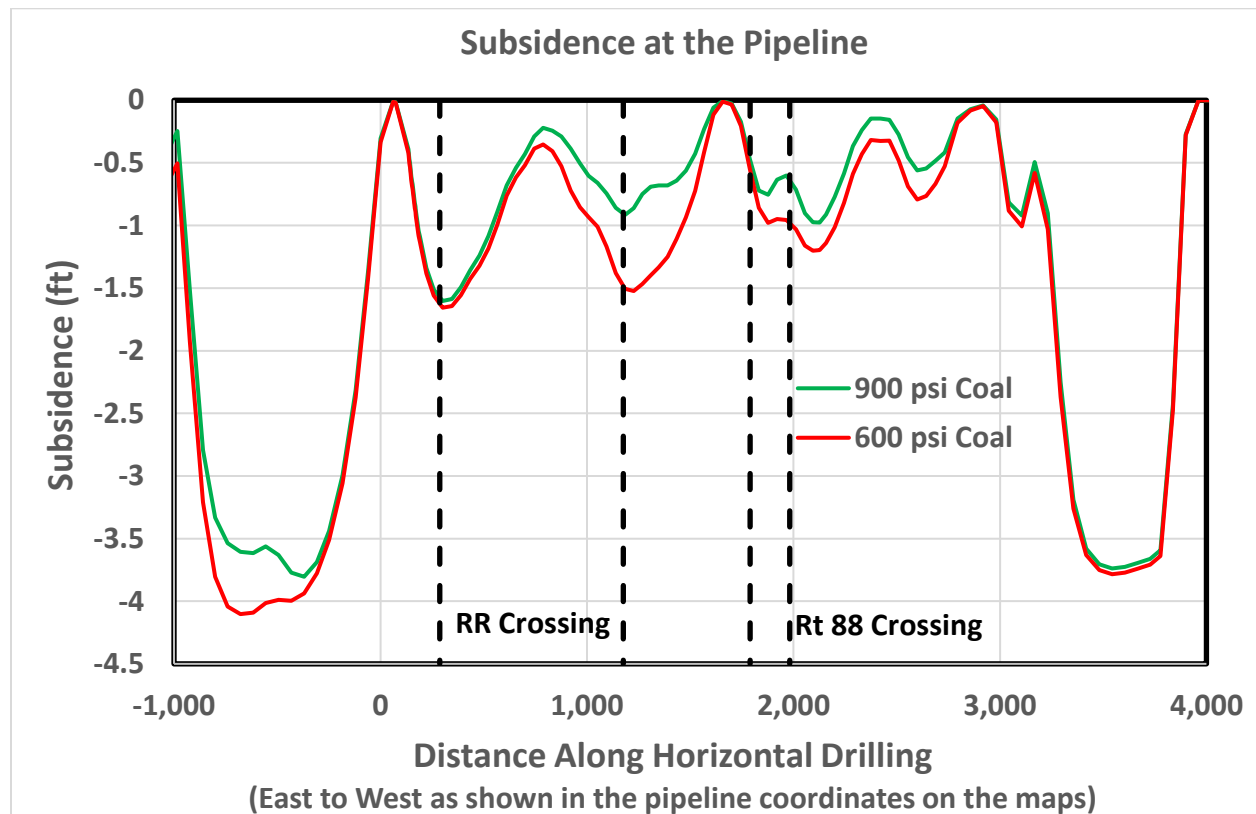


Figure 6. Subsidence prediction along the pipeline alignment at different coal strengths.

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 the change in pillar safety factors as shown in Figure 7. In this figure, it is clear that many of the larger pillars in between two gob areas or adjacent to a gob will fail if the coal/mine strength degrades significantly. In this worst case scenario, many of the pillars, in particular many under the pipeline, are shown to lose significant structural integrity as their strength degrades over time.

Additional Subsidence: When the pillars fail, they cause convergence directly over the pillar, thereby putting additional loading and associate convergence on the adjacent gob. The ground reaction to the pillar failures then results in additional overburden subsidence as shown in Figure 8. With a reduction in coal strength to 600 psi, many of the pillars in between adjacent gob areas go from stable to failed and cause additional subsidence of approximately 0.70 ft (8 in) over these areas. In particular, the proposed pipeline alignment goes directly over one of these areas at a plus of about 12+00 to 16+00 (see Figure 6, 8 and 9).

The details of the potential additional subsidence along the pipeline alignment are show in Figure 9. The Figure shows that there are three areas of potential increased subsidence. One area is centered under the pipeline at minus 8+00 and occurs at a major gob area and over the some smaller main line pillars (see Figure 8). This increased subsidence shows a magnitude of 0.50 ft. The second area of increased subsidence occurs between the pipeline pluses of 8+00 and 18+00 (see Figure 9). This second subsidence area is above an area of thin pillars that have not yet collapsed, but are calculated to collapse with mine degradation. This area is associated with 0.70 ft. of possible additional subsidence. The third are of possible subsidence is centered around a plus of 20+00 and has a subsidence of 0.35 ft.

The degraded mine subsidence predicted in this model may have already occurred, may occur at some time in the future, or may never reach this level. Predicting the actual condition of the mine at this time, and at any given time in the future, is difficult.

Strains: The strains associated with the predicted post-mining subsidence are also shown in Figure 9. The maximum strain values range from 0.0015 to 0.0018, or 0.15% to 0.18%, and fluctuate 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. If the pipe is

tight within the horizontal borehole due to the drilling mud confining the pipe or collapse of the borehole, then it may be assumed that the pipe will experience the full ground strain as shown in Figure 9. If the pipeline is simply lying in the open horizontal borehole and 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.

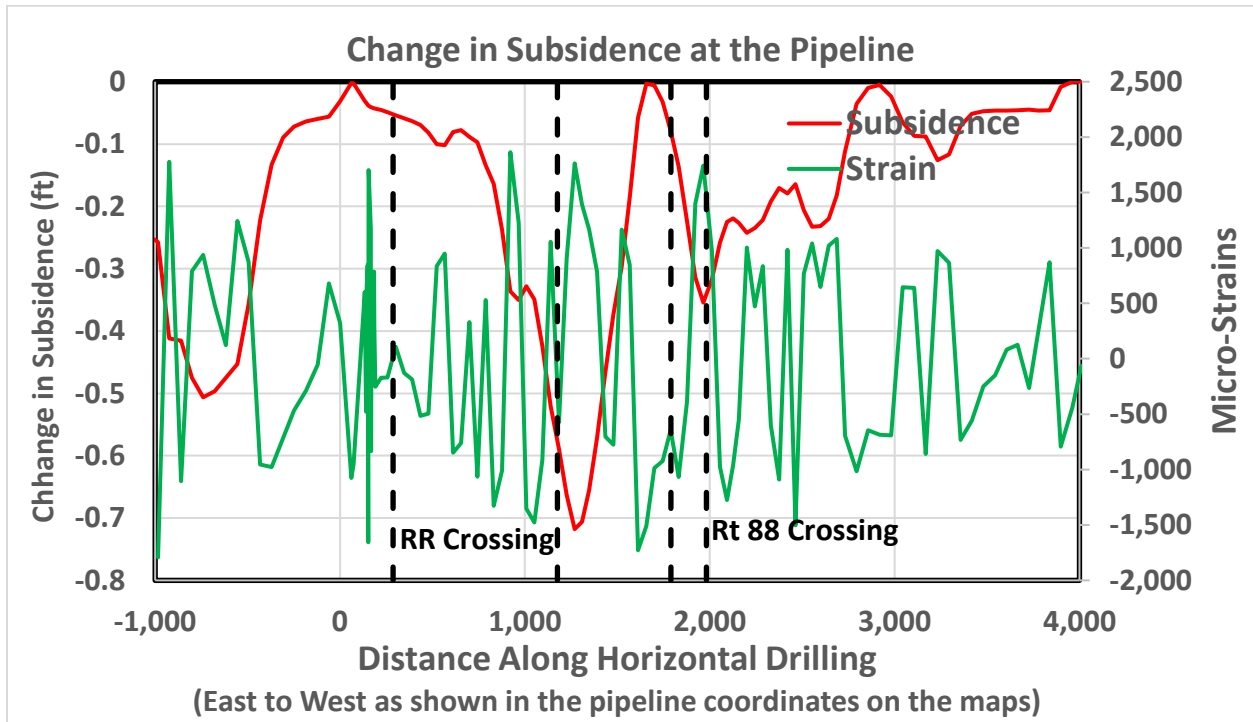


Figure 9. Predicted worst case subsidence and associated strains (tension is negative).

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.

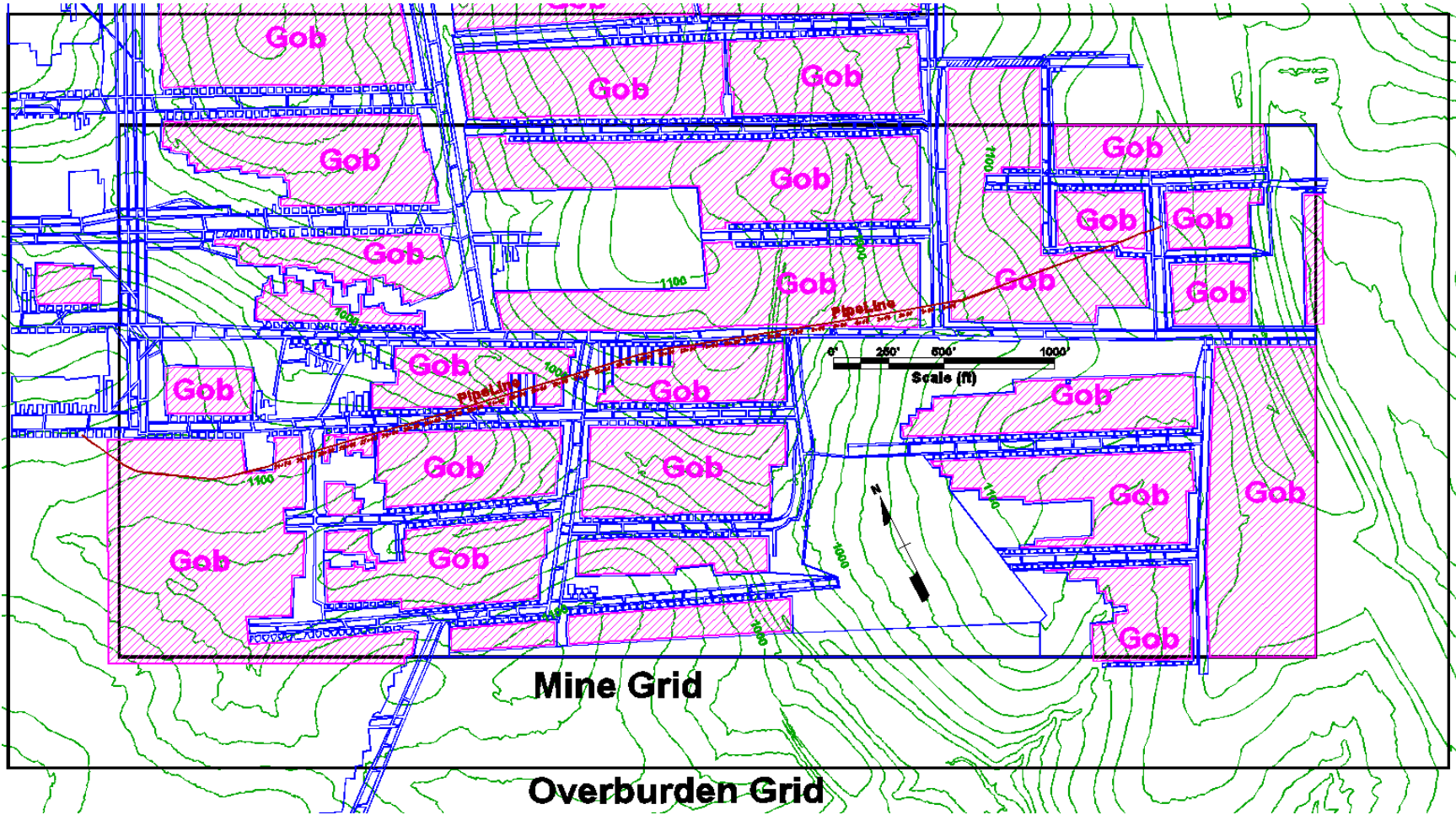


Figure 1. Map of mine and overlying pipeline.

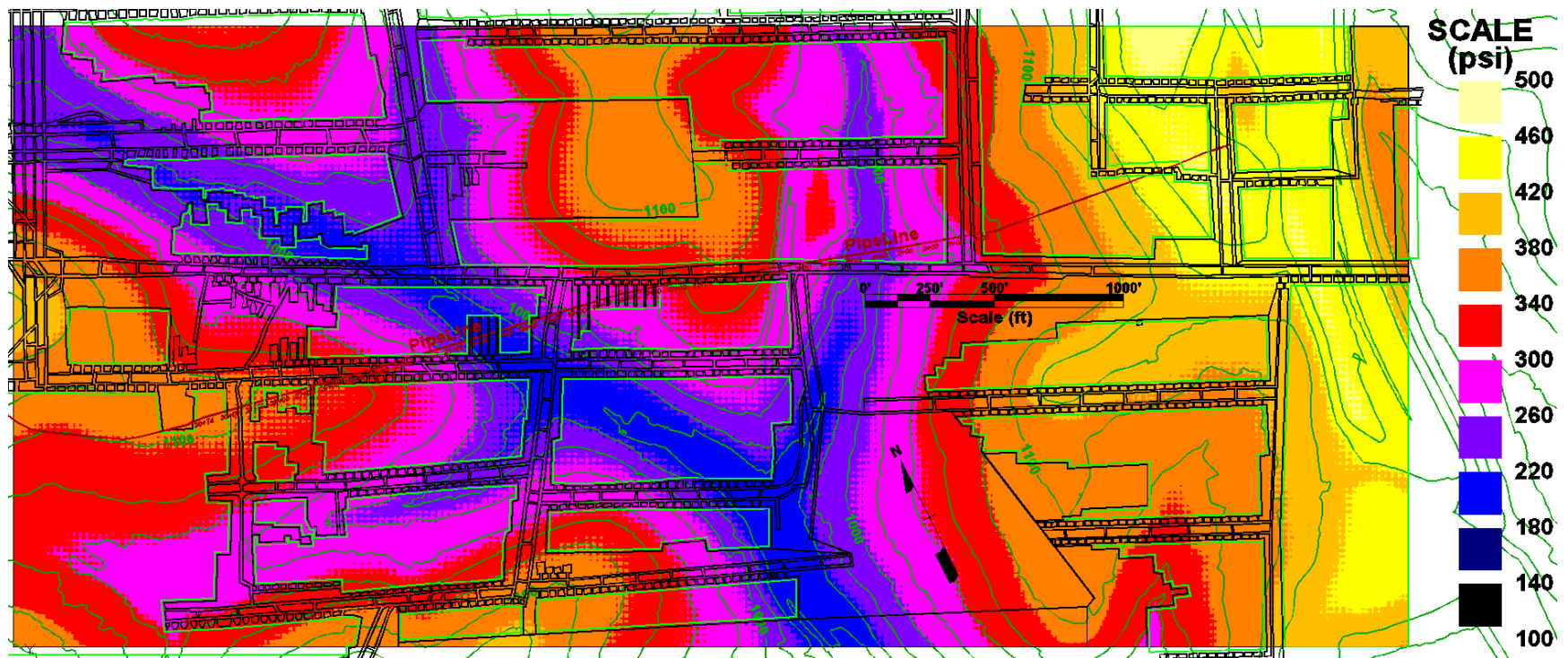


Figure 2. Overburden stress on the seam.

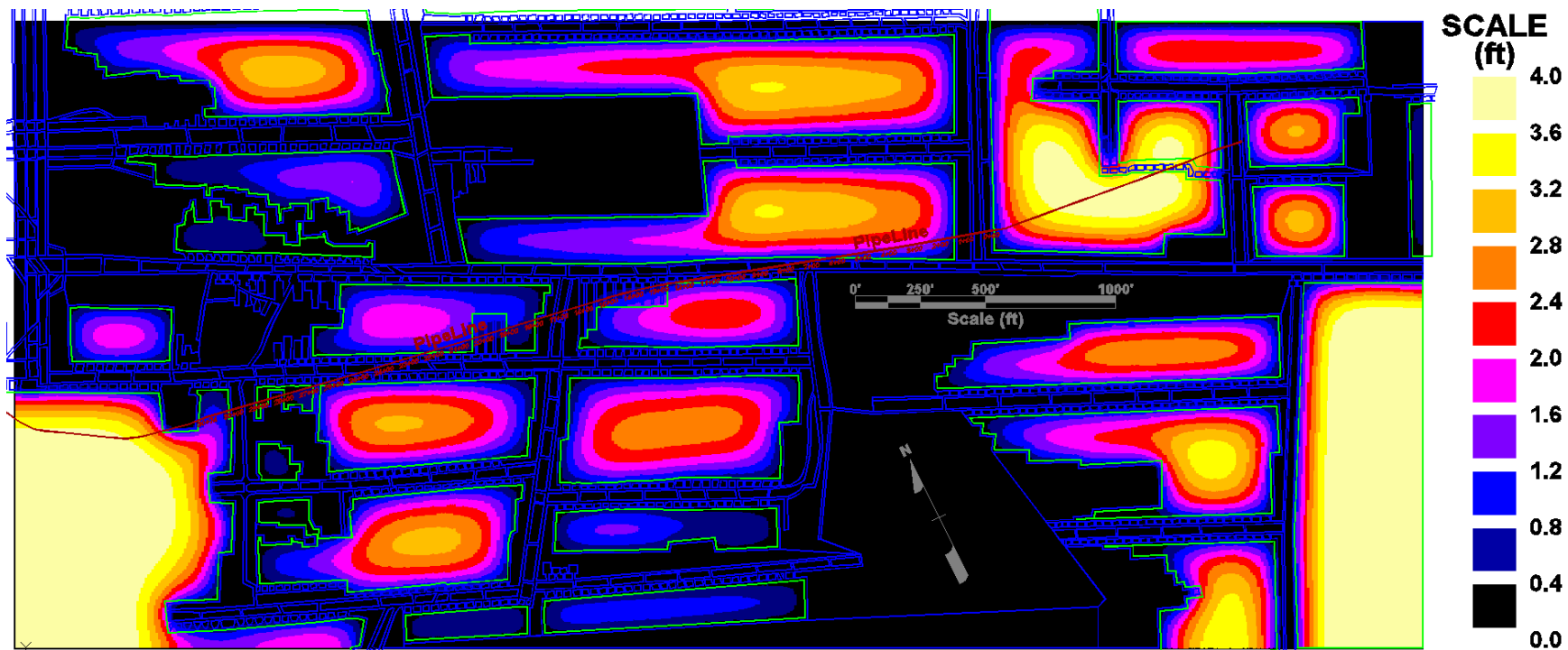


Figure 3. Seam convergence with 900 psi coal strength.

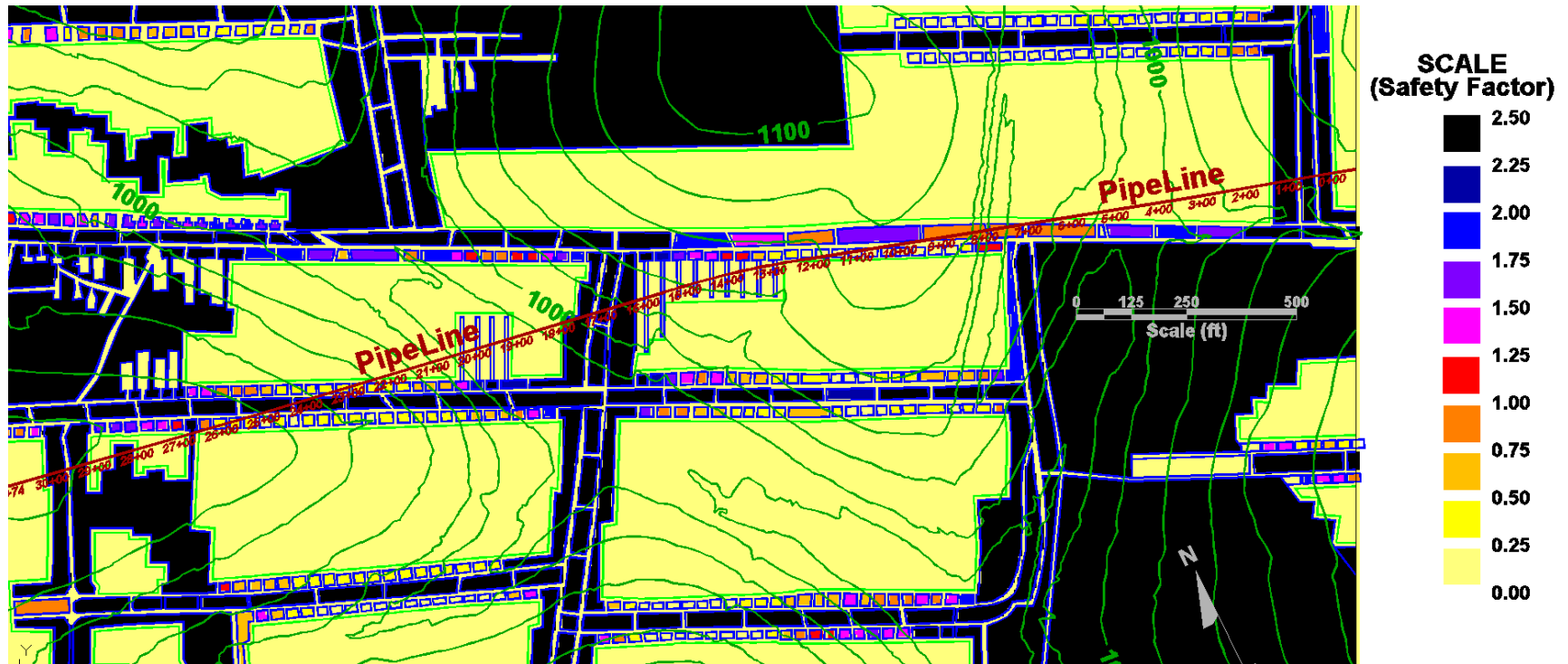


Figure 4. Pillar safety factors with 900 psi coal strength.

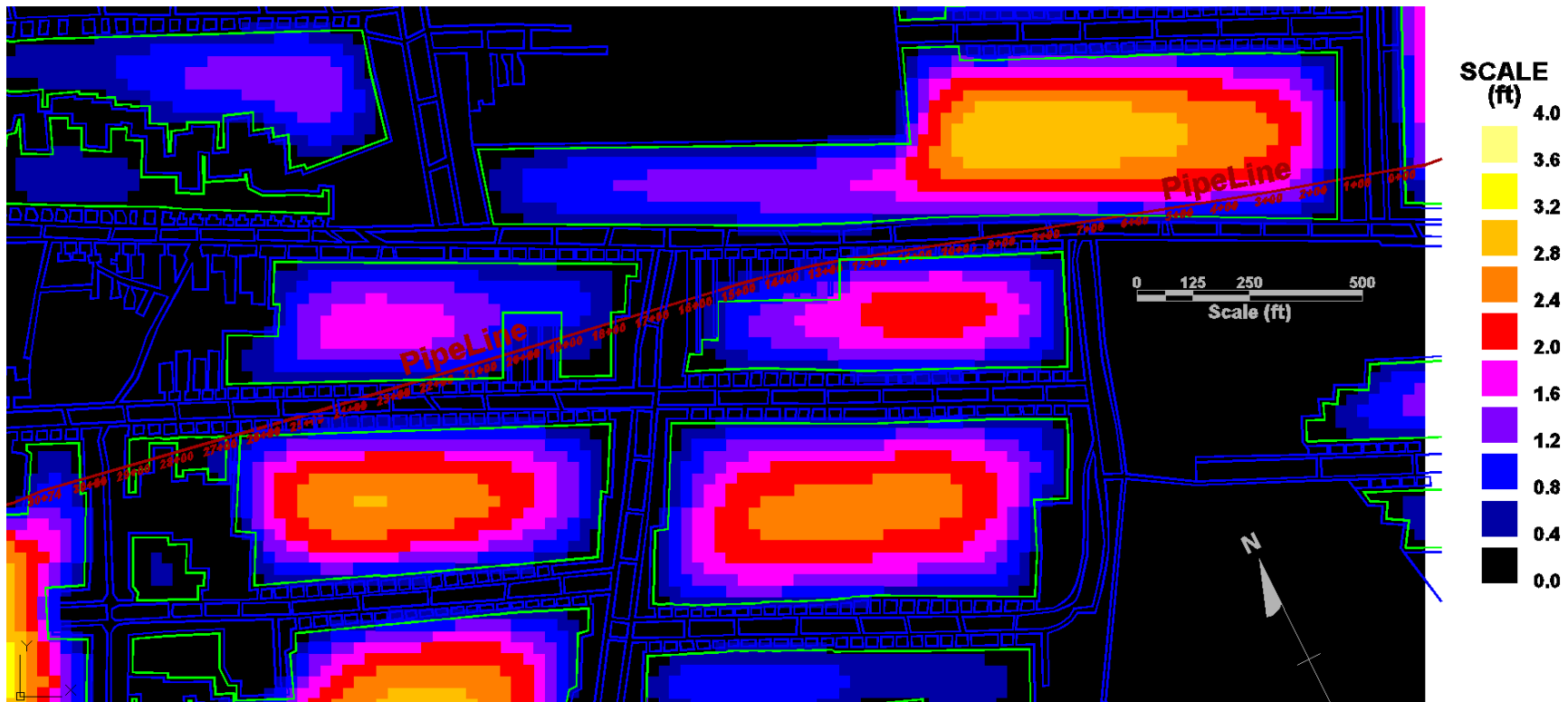


Figure 5. Subsidence at the pipeline for 900 psi coal strength.



Figure 7. Drop in pillar safety factor between 900 psi and 600 psi coal strength.

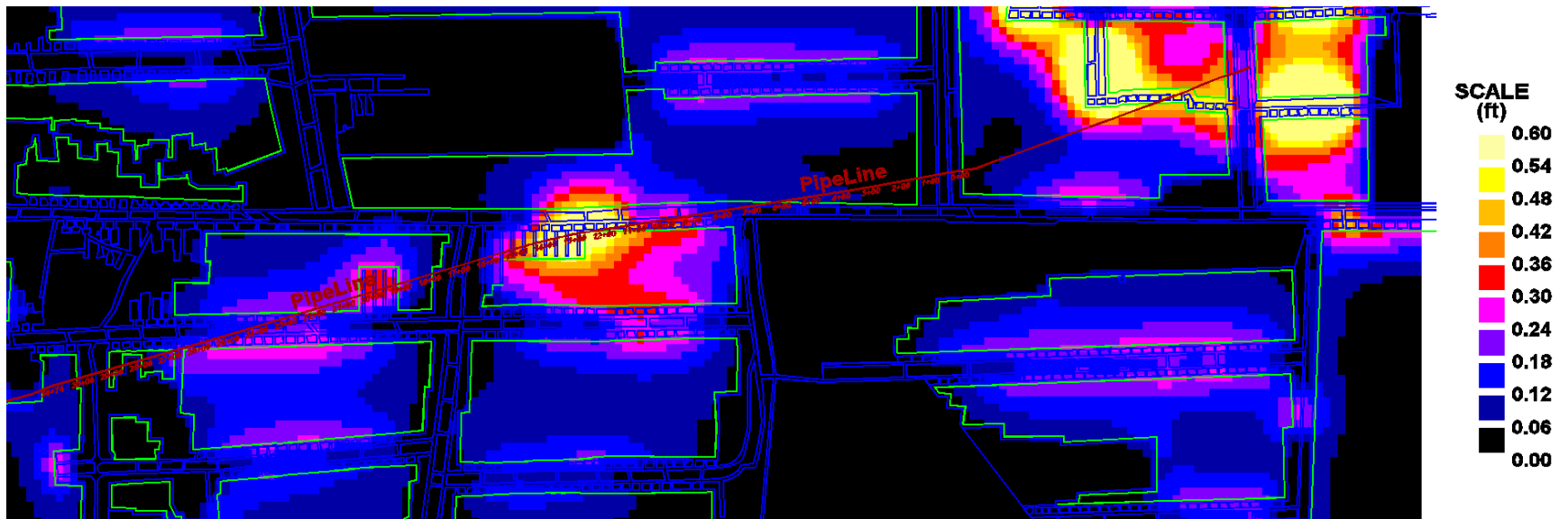
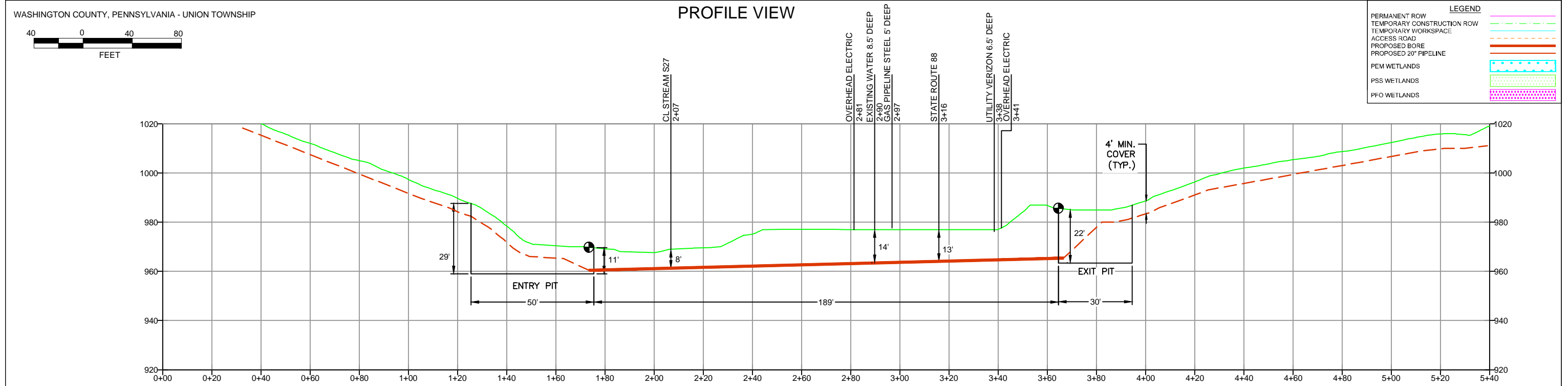
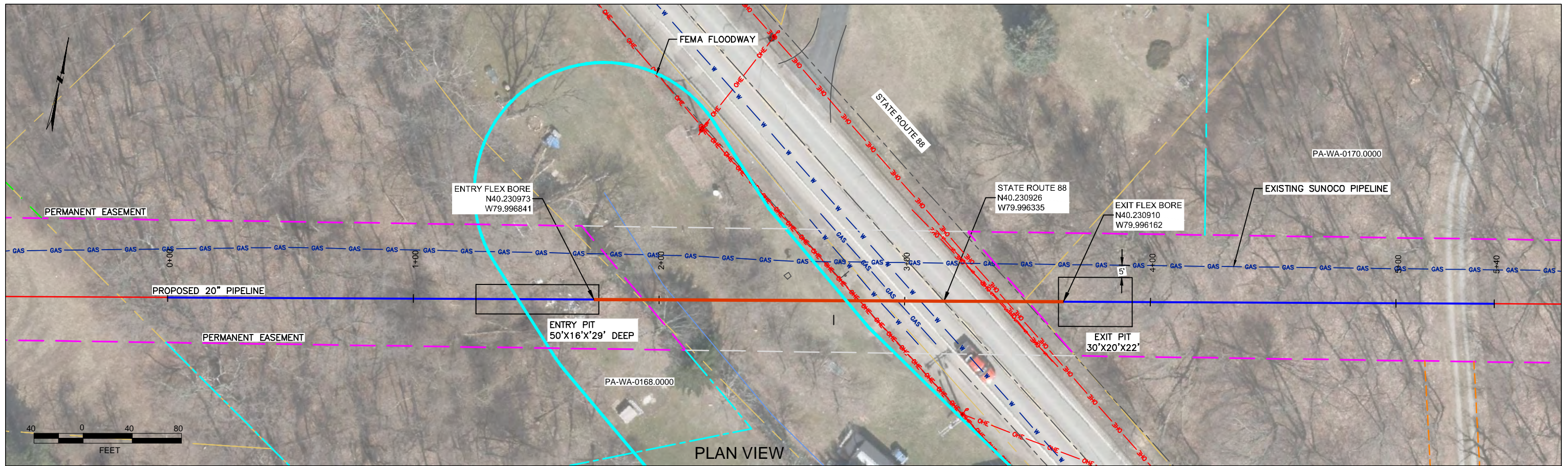


Figure 8. Increase in subsidence going from 900 psi coal to 600 psi coal.

**SR-88/WHEELING AND LAKE ERIE RR CROSSING
PADEP SECTION 105 PERMIT NO.: E63-674
PA-WA-0171.0000-RR
(SPLP HDD# S1B-0120)**

ATTACHMENT 3

ALTERNATIVE CONSTRUCTION PLAN OVERVIEW AND FLEXBOR PROFILES



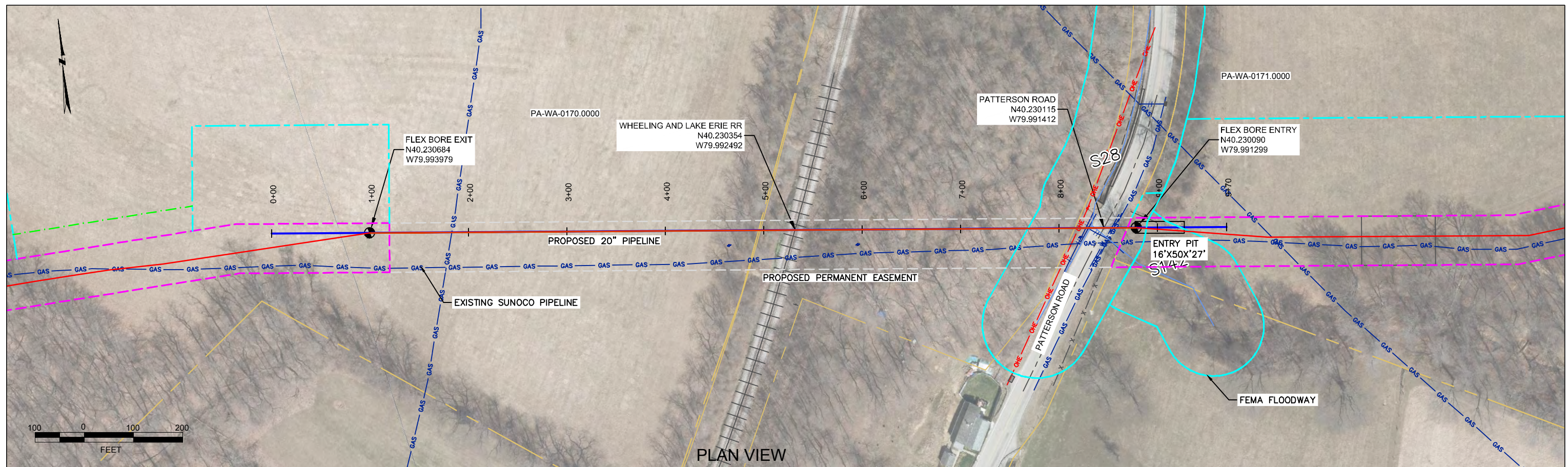
- CONSTRUCTION NOTES**
- 20" WELDED STEEL PIPE: 20" OD x 0.456" WT, X-65, API-5L, PSL2, ERW, BFW, DRL
 - COATING: 14 TO 16 MILS OF 3M SCOTCHKOTE TM 6233 FBE WITH 40 MILS MIN. DFT POWERCRETE R95.
 - DESIGN FACTOR: 0.50 (HOOP STRESS)
 - DESIGN PRESSURE: 1480 PSIG
TEST PRESSURE: 1850 PSIG

- THE COATING ON THE CARRIER PIPE SHALL BE INSPECTED IMMEDIATELY PRIOR TO ITS INSTALLATION AND ALL DAMAGED COATING SHALL BE REPAIRED IN ACCORDANCE WITH SUNOCO'S PIPELINE COATING SPECIFICATIONS.
- INSTALL CATHODIC PROTECTION TEST LEADS AS SPECIFIED ON THE ALIGNMENT SHEETS OR SUNOCO CORROSION TECHNICIAN.
- WELDED JOINTS INSIDE R.O.W. SHALL BE 100% X-RAYED.
- CONTRACTOR WILL MAINTAIN A MINIMUM 4' OF COVER TO THE TOP OF PIPE USING FIELD BENDS.
- CONTRACTOR WILL MAINTAIN A MINIMUM 24" OF COVER FROM ALL EXISTING UTILITIES.
- CONTRACTOR WILL MAINTAIN A MINIMUM 5' OF COVER FROM BOTTOM OF STREAMS
- IN ADDITION TO THE SITE-SPECIFIC INFORMATION PROVIDED IN THIS DRAWING, GENERAL REQUIREMENTS INCLUDED IN ALIGNMENT SHEETS, PERMITS AND APPROVAL FROM FEDERAL, STATE AND LOCAL AGENCIES ALSO APPLY.

Figure 2. State Route 88 FlexBor Crossing Plan

PRELIMINARY DESIGN ONLY

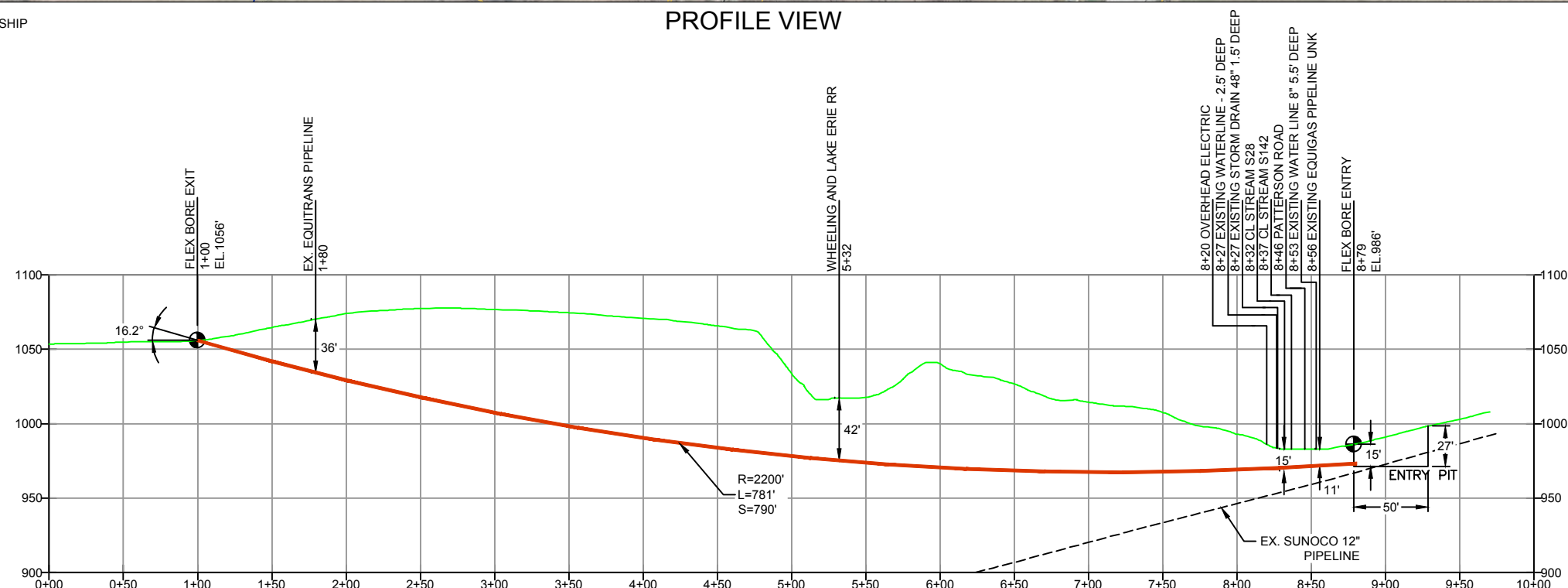
NOTES		REVISIONS						Sunoco Logistics Partners L.P.		SUNOCO PIPELINE, L.P.																	
1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83 2. STATIONING IS BASED ON HORIZONTAL DISTANCES 3. ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP ARE NOT RESPONSIBLE FOR 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.		<table border="1"> <tr> <th>NO.</th> <th>DESCRIPTION</th> <th>BY</th> <th>DATE</th> <th>CHK</th> <th>DATE</th> <th>APP</th> <th>DATE</th> </tr> <tr> <td>A</td> <td>ISSUED FOR REVIEW</td> <td>MRS</td> <td>04/10/18</td> <td>RMB</td> <td>04/10/18</td> <td>CAG</td> <td>04/10/18</td> </tr> </table>						NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE	A	ISSUED FOR REVIEW	MRS	04/10/18	RMB	04/10/18	CAG	04/10/18			BORE STATE ROUTE 88 PENNSYLVANIA PIPELINE PROJECT	
NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE																				
A	ISSUED FOR REVIEW	MRS	04/10/18	RMB	04/10/18	CAG	04/10/18																				
								SCALE: 1"=40'		DWG. NUMBER: PA-WA-0169.0000-RD FLEX BORE																	



WASHINGTON COUNTY, PENNSYLVANIA - UNION TOWNSHIP



PROFILE VIEW



LEGEND	
PERMANENT ROW	
TEMPORARY CONSTRUCTION ROW	
TEMPORARY WORKSPACE	
ACCESS ROAD	
PROPOSED BORE	
PROPOSED 20" PIPELINE	
FEM WETLANDS	
PSS WETLANDS	
PFO WETLANDS	

- CONSTRUCTION NOTES**
- 20" WELDED STEEL PIPE: 20" OD x 0.456" WT, X-65, API-5L, PSL2, ERW, BFW, DRL
 - 16" WELDED STEEL PIPE 16" OD X .438 WT., X-70, API 5L, PSL2, ERW, BFW
 - COATING: 14 TO 16 MILS OF 3M SCOTCHKOTE TM 6233 FBE WITH 40 MILS MIN. DFT POWERCRETE R95.
 - DESIGN FACTOR: 0.50 (HOOP STRESS)
 - DESIGN PRESSURE: 1480 PSIG
TEST PRESSURE: 1850 PSIG

- THE COATING ON THE CARRIER PIPE SHALL BE INSPECTED IMMEDIATELY PRIOR TO ITS INSTALLATION AND ALL DAMAGED COATING SHALL BE REPAIRED IN ACCORDANCE WITH SUNOCO'S PIPELINE COATING SPECIFICATIONS.
- INSTALL CATHODIC PROTECTION TEST LEADS AS SPECIFIED ON THE ALIGNMENT SHEETS OR SUNOCO CORROSION TECHNICIAN.
- WELDED JOINTS INSIDE R.O.W. SHALL BE 100% X-RAYED.
- CONTRACTOR WILL MAINTAIN A MINIMUM 4' OF COVER TO THE TOP OF PIPE USING FIELD BENDS.
- CONTRACTOR WILL MAINTAIN A MINIMUM 24" OF COVER FROM ALL EXISTING UTILITIES.
- CONTRACTOR WILL MAINTAIN A MINIMUM 5' OF COVER FROM BOTTOM OF STREAMS
- IN ADDITION TO THE SITE-SPECIFIC INFORMATION PROVIDED IN THIS DRAWING, GENERAL REQUIREMENTS INCLUDED IN ALIGNMENT SHEETS, PERMITS AND APPROVAL FROM FEDERAL, STATE AND LOCAL AGENCIES ALSO APPLY.

Figure 3. Wheeling Lake Erie RR/Patterson Rd FlexBor Plan

PRELIMINARY DESIGN ONLY

NOTES

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

REVISIONS							
NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
A	ISSUED FOR REVIEW						

(303) 792-5911

SUNOCO PIPELINE, L.P.

FLEX BORE
WHEELING & LAKE ERIE RR/PATTERSON RD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=100'
DWG. NUMBER: PA-WA-0170.0000-RR FLEX BORE COMBO