SUNOCO PIPELINE
An ENERGY TRANSFER Company

535 Fritztown Road
Sinking Spring, PA 19608

August 16, 2019

Via Electronic Mail
Mr. Scott R. Williamson
Program Manager, Waterways & Wetlands Program
Pennsylvania Department of Environmental Protection
Southcentral Regional Office
909 Elmerton Avenue
Harrisburg, PA 17110-8200

Re: PA DEP Old Mill Rd. HDD Re-Evaluation Report –
Request for Additional Information
Old Mill Rd. 16-Inch Horizontal Directional Drill (S2-0156-16)
Permit No. E34-136
Lack Township, Juniata County

Dear Mr. Williamson:

In compliance with the Corrected Stipulated Order dated August 10, 2017 (Order) a Re-Evaluation Report of the above-referenced horizontal directional drill (HDD) was submitted to the Pennsylvania Department of Environmental Protection (Department) on February 5, 2019. In a letter dated March 21, 2019, the Department requested further information. Please accept this letter as a response. Your requests are bolded below followed by Sunoco Pipeline, LP (SPLP) responses.

1. **No geophysical investigation was completed in this area that has karst geology and no detailed justification was provided by SPLP for not conducting such studies. The boring log from Boring B-02 identifies multiple solution activity zones with several areas where the tool dropped during boring activities.**

   DEP recommends that additional geophysics be considered along the eastern entry/exit side. SPLP should provide a full explanation for why geophysical surveys would not be necessary to ensure that the HDD minimizes the potential for inadvertent return(s) and impacts to water supplies if SPLP's determination is to not conduct geophysical surveys.

Based on information gathered during the completion of the 20-inch HDD, SPLP is aware that the profile will be completed through karst geology as evident by the full and partial loss of returns which occurred during the 20-inch HDD. Because of the full and partial loss of returns, the 16-inch HDD was redesigned to increase the depth of the profile by 37 feet in an effort to avoid karst features typically occurring at shallow depths near the ground surface. As requested, SPLP contracted RETTEW to perform a geophysical survey along the eastern entry/exit side of the redesigned 16-inch HDD profile. The results of the geophysical survey identified anomalies within the survey area which could be indicative of fractures and potential areas for loss of returns or inadvertent returns. SPLP will inform the drilling contractor in advance of these potential fracture zones. In addition, the frequency of drill path reconnaissance will be increased while the drilling tool is being advanced through the identified anomalies. A copy of the geophysical survey report is attached.

2. **All water supply wells located along fracture trace trends within proximity to the HDD path do not appear to have been considered as part of this re-evaluation. Given the fracture trace analysis, SPLP should include the evaluation of water supplies that may be located along the fracture trace trends. This may include evaluation of available on-line data, field surveys, and evaluation of whether properties along the fracture trace trends are already connected to a public water supply system. Additional information regarding the investigation of those potential supply wells should be included in the re-evaluation. If the risk of minimized impact to these wells cannot be determined, we recommend those water supply owners should be offered the same course of action as if they were located within 450-feet.**

SPLP feels that the justification for additional water supply evaluations is not warranted based solely on the results of the fracture trace analysis, especially since none of the identified fracture traces intersect the redesigned 16-inch profile. However, as a desktop exercise, a second search of the Pennsylvania Groundwater Information System (PaGWIS) was conducted. The search radius was expanded to 1 mile and five (5) water supply wells were identified within the PaGWIS database. Two of the wells have an identified usage of aquaculture and the remaining three are identified as being domestic supply sources. Each of these wells was plotted on the Blairs Mill United States Geologic Survey 7.5-Minute Topographic Map and none of them occur along the identified fracture traces. Further, all five of the identified wells are located hydraulically upgradient of the proposed 16-inch HDD profile. Based on the absence of any fracture traces intersecting the 16-inch bore path, the fact that none of the wells identified within a 1-mile radius search of the PaGWIS database are located on a fracture trace, and all of the wells being located hydraulically upgradient of the proposed 16-inch HDD profile, SPLP does not feel that additional risk evaluation of these water supplies is necessary.

Per the Order, SPLP conducted a survey to identify any water supply wells located within 450 feet of the Old Mill Road HDD prior to initiating construction of the 20-inch HDD. No wells were identified within the 450-foot search radius; however, one water well (WL-09212017-614-01) was identified approximately 1,250 feet from the western entry/exit point. Water quality samples were collected from the residence prior to and during installation of the 20-inch HDD. None of the parameters typically identified in samples impacted by drilling fluids (i.e., turbidity, total suspended solids, iron and manganese) were identified at concentrations higher than those observed in the pre-construction samples.

Additionally, one well owner complaint was received after completion of the 20-inch HDD and a water quality sample was collected (WL-02212019-619-01) as part of the complaint investigation detailed below. On February 21, 2019, SPLP also collected a water quality sample from a well (WL-02212019-604-01) recently identified approximately 2,400 feet from the eastern entry/exit point of the Old Mill Road HDD. None of the parameters typically identified in samples impacted by drilling fluids (i.e., turbidity, total suspended solids, iron and manganese) were identified in this sample at concentrations higher than the Department's established primary and secondary drinking water standards (MCLs/SMCLs). Summary tables containing the analytical results from the various water quality sampling events are attached.

On January 19, 2018, a complaint was made regarding extra sediment buildup in the iron filter in the residence of Mr. David Shearer. Mr. Shearer reported that he first noticed the extra sediment accumulation on January 2, 2018. To assess potential sources for the increased sediment, a water quality sample (WL-02212019-619-01) was collected from the Shearer well on January 31, 2018; however, because the Shearer well is approximately 2,700 feet north of the Old Mill Road HDD location, a pre-construction sample was not collected. Turbidity results were reported at 176 nephelometric turbidity units which exceeds the threshold for visibility. The elevated turbidity concentration is likely the result of suspended sediment in the well. Suspended solids were detected at a concentration of 29.0 milligrams per liter (mg/l). Iron and manganese were detected at concentrations of 21.8 mg/l and 0.319 mg/l, respectively. While both of these concentrations are above their respective Department SMCLs, the elevated iron and manganese concentrations can be attributed to the high levels of turbidity and suspended/dissolved solids. Further evaluation conducted by a Pennsylvania-licensed Professional Geologist has concluded that the Shearer's well was not impacted by the completion of the 20-inch Old Mill Road HDD due to the presence of a hydrologic (groundwater) divide between the Shearer's well and the HDD location. A copy of the well complaint investigation report was submitted to the Department on January 17, 2019. On January 22, 2019, the Department responded that it completed a review of the Report and concurred with the conclusion that the construction activities associated with the Old Mill Road Crossing HDD activities were not responsible for the reported impacts to the Shearer's private water supply.

SPLP submits that we have been, and are, in complete compliance with the agreed terms and analysis requirements of the Order, as agreed to by the Department, and that no further analysis is required for the Department to consent to the start of this HDD. SPLP therefore requests that the Department approve the Re-Evaluation Report for Old Mill Road HDD (S2-0156-16) as soon as possible.

Sincerely,

Larry J. Gremminger, CWB
Geotechnical Evaluation Leader
Vice-President – Environmental, Health & Safety
Energy Transfer Partners
Mariner East 2 Pipeline Project

Pertaining to the practice of geology and information conveyed.

8/16/2019

Douglas J. Hess, P.G.
License No. PG-000186-G
Skelly and Loy, Inc.
Director of Groundwater
and Site Characterization
Geo-Environmental Services

Date

Attachments as stated.

RETTEW | ENVIROSCAN
3020 Columbia Avenue, Lancaster, PA 17603 ● Phone: (800) 738-8395
E-mail: rettew@rettew.com ● Website: rettew.com

Engineers
Environmental Consultants
Surveyors
Landscape Architects
Safety Consultants
Geophysicists

July 29, 2019

Mr. Larry J. Gremminger
Sunoco Logistics, L.P.
535 Fritztown Road
Sinking Spring, PA 19608

RE: Geophysical Survey
Sunoco Pipeline, L.P. Pipeline Project
Horizontal Directional Drill S2-0156 Old Mill Road
PA-JU-0004.0000-WX
Lack Township, Juniata County, Pennsylvania
RETTEW Project No. 096302008

Dear Mr. Gremminger:

RETTEW Associates, Inc. completed a multi-technique geophysical survey at the S2-0156 Old Mill Road horizontal directional drill (HDD) site. The purpose of the survey was to detect and delineate subsurface fracture zones that could contribute to potential inadvertent returns (IRs) and/or a loss of circulation, and to determine the rock profile and rock rippability for possible ease-of-excavation along the HDD path. The following report, figures, and attachments describe the methods and results of the investigation.

EXECUTIVE SUMMARY

The multi-technique geophysical survey was completed on June 25, 2019. Three different geophysical techniques were utilized to detect and delineate subsurface voids or low-density zones and provide a bedrock profile. These methods, and their general results, are as follows:

- Microgravity delineated a laterally-extensive mass-deficient zone in the eastern half of the survey area
- Seismic refraction and multi-spectral analysis of surface waves (MASW) results confirmed the presence of low-velocity zones that could represent fracture zones within the bedrock
- Electrical resistivity imaging (ERI) identified a relatively conductive surface layer over a discontinuous mildly resistive layer, with the discontinuities and deeper conductive anomalies possibly suggesting the presence of fracture zones or mud-filled voids.

Results from the seismic methods are consistent with each other, and with the geology as mapped by the PA Geological Survey; all suggesting that the local bedrock is fractured, with several potential anomalous zones. The top-of-rock is expected to be only slightly irregular with a thin weathered zone above competent rock. Within the survey limits, the HDD path lies at a depth that is entirely within non-rippable rock.

SITE DESCRIPTION

The Old Mill Road HDD site is located west of State Route 75, along Cross Keys Road/Old Mill Road in Lack Township, Juniata County, Pennsylvania (see **Figure 1**). A geophysical survey was conducted over accessible areas of the path between the HDD exit/entry locations (**Figure 2**). Site access was limited due to standing water as well as streams that cross the HDD profile.

The site bedrock geology consists primarily of the Devonian-aged Onondaga and Old Port Formations (The Geologic Map of Pennsylvania, PA Department of Conservation and Natural Resources Geology Interactive Map, 2019 – see **Figure 2**). The formations include, in order of increasing age, the Onondaga Formation, Ridgeley Member of Old Port Formation, and Shriver, Mandata, Corriganville, and New Creek Members of Old Port Formation, undivided. Lithology consists of limestone and sandstone (calcareous sandstone) and some chert and shale (Berg et at., 1980). The western portion of the survey consists of the Hamilton Group which includes the Mahantango and Marcellus Formations. The Hamilton Group consists primarily of clastic mudstone, shale, and black-shale beds (Ibid).

MICROGRAVITY SURVEY

Microgravity meters measure very small local variations in gravity. Several factors can locally affect the acceleration of gravity. One factor is the local density or mass distribution of the bedrock or soils beneath the meter. Gravity highs (mass excesses) commonly represent locally shallow bedrock pinnacles or float blocks in the soil profile or zones of particularly massive bedrock. Gravity lows (mass deficiencies) may represent locally deep bedrock cutters, or clay seams where soil displaces bedrock; air-, water- or mud-filled voids within bedrock; stoping voids in the soil above bedrock; or zones where soils have been made less dense by removal of fines.

The residual microgravity data are shown on **Figure 3**. The values depict the general plan-view shallow mass distribution beneath the survey area. Lower values (red) represent local mass deficiencies (air- or clay-filled voids, fracture zones, or deeper soils). Higher values (blue) represent local mass excesses (shallow bedrock, bedrock pinnacles, or float blocks). Specific microgravity survey parameters are listed in **Appendix A**.

SEISMIC MASW AND REFRACTION SURVEY

Seismic Multi-Spectral Analysis of Surface Waves (MASW) and refraction methods utilize the speed of seismic waves through various geologic layers and features to characterize the subsurface geologic conditions. The methods enable determination of the general material types, and the approximate depth to bedrock or rock profile. MASW can detect low-velocity zones in soils that might represent developing sinkholes, or low velocities below the top of rock that might be associated with karst dissolution features or bedrock fractures. The principles of seismic refraction are summarized in **Appendix B**.

The seismic survey consisted of one profile along the HDD center line, with a gap over standing water (see blue triangles, upper panel, **Figure 2**). Color-contour velocity models of the seismic profiles for the seismic refraction and MASW are presented on **Figure 4**. The vertical scale represents relative elevation in feet, and the horizontal axis represents an along-profile distance in feet. The color contours represent average seismic velocity variations; compressional or Primary (P-wave) velocities for refraction, and shear or secondary (S-wave) velocities for MASW. Increasing velocities grade from blue to yellow to orange to brown for refraction (upper cross section), and purple to grey to tan to brown for MASW (lower cross section). Please note that high- and low-velocity data along the first and last fifteen feet of any profile have higher uncertainty. Specific seismic refraction and MASW survey parameters are listed in **Appendix A**.

ERI SURVEY

Electrical resistivity measurements involve driving an electrical current in the ground using current electrodes at the ground surface. The apparent resistivity of the subsurface is determined by measuring the potential difference, or voltage, between two potential electrodes with a known separation and position/orientation relative to the current electrodes. The depth and volume of the subsurface zone represented by the measured apparent resistivity is a function of the geometry of the current and potential electrodes. Apparent resistivities are converted to model or true resistivities by performing a joint inversion of all of the measured apparent resistivities along a profile (or profiles in the case of 3D resistivity).

The resistivity survey consisted of three linear profiles centered on the HDD alignment (see orange dots, **Figure 2**). The apparent resistivity data were mathematically inverted using both EarthImager 2D by AGI to provide a cross-sectional image of each individual profile. **Figure 5** shows individual 2D profiles. The vertical scale represents relative elevation in feet, and the horizontal axis represents an along-profile distance in feet. The color contours represent average resistivity variations with increasing resistivity from purple, blue to green to yellow to orange to red. Specific ERI survey parameters are listed in **Appendix A**.

RESULTS

The microgravity data are depicted on **Figure 3** as color contours representing the relative density of the subsurface, with blue for high-density, green for “site normal,” and red for locally low-density areas. The microgravity display alternating high-density and low-density “stripes” roughly parallel to the strike of bedrock areas across the survey area. This is consistent with steeply-dipping bedrock units with differing densities, resistance to weathering, or degree of karstification for carbonate units. Areas of low density (red) could represent broken material in fracture zones, deeper weathering of the rock surface at fracture zones, or swarms of karstic voids in carbonates.

The seismic refraction data are presented as a cross-sectional profile on **Figure 4** (top panel). The data indicate a general three-layer stratigraphy consisting of a residual soil mantle, a transition (weathered) zone, and competent bedrock. The uppermost layer has average P-wave velocities generally less than 5,000 feet per second (fps) with a thickness of approximately 5-15 feet. This is consistent with a relatively compact residual clay soil mantle (shaded blue to yellow). The deepest layers have velocities over 10,000 fps (shaded orange to brown) consistent with competent bedrock (Carmichael, R. S., 1989). The zone between roughly the 5,000 and 10,000 fps contours is consistent with a saprolite (weathered bedrock), and is not really a “layer” in the stratigraphic sense. Instead, it contains material that is undergoing various degrees of weathering. This transition zone contains both competent rock, float material, and/or dipping lithologic layers that may stick-up or cut-across the smoothed contours and may impede excavation (see **Appendix B**).

The MASW seismic cross section is presented below the seismic refraction cross section (**Figure 4**, bottom panel). The MASW velocity model shows velocity changes within the bedrock layer across the profile. Velocity lows below the bedrock surface could indicate fracture features which might be potential pathways for IRs.

The seismic velocity models from the ray-tracing method (not shown) were compared to standard ripping charts (see **Appendix C**, Caterpillar, Inc., 1995) using the inferred/assumed layer compositions to determine the general rippability of each stratum. In general, the surficial layer down to about the top of inferred epikarst (wavy dashed contour) should be readily to marginally rippable with a D9 multi- or single-shank ripper doing open field ripping, based on a weighted average velocity of about less than 5,000 fps. Below the 5,000-fps contour, ripping will get more difficult with depth, with the transition zone expected to become non-rippable below the 10,000-fps contour (based on the average ray-trace velocity of over 12,000 fps and Caterpillar charts). The 5,000-fps contour represents the top of the epikarst/weathered rock and not the actual surface which is often non-resolvable in karst terranes. For trenching (as opposed to open field ripping), material below approximately the 3500-fps contour color (greenish blue) may become non-rippable (for a CAT-330 tracked excavator or equivalent). The selection of the contour cut-off for trenching is based on correlations between the ray-tracing models (not shown), material properties, and various excavation strategies investigated by Kirsten (1982). The Limitations section contains additional important information regarding rippability estimation by seismic and other means.

The electrical resistivity results are shown in **Figure 5.** The electrical profiles show a general two-layer model with a conductive upper layer over a more resistive lower layer, indicative of moist, conductive unconsolidated material over more resistive low-porosity bedrock. The upper layer is relatively discontinuous, with some irregularities that could represent near-surface disturbances given the site development history and drainage pattern. The deep conductive anomalies below the inferred top-of-rock may represent fractures or mud-filled voids within bedrock.

CONCLUSIONS

In general, the geophysical survey results display anomalies indicative of fractures that are possible locations for IRs and/or loss of circulation along portions of the HDD alignment. The microgravity results depict a few mass-deficient areas through the western portion of the survey area, and a laterally-extensive mass-deficiency in the eastern portion. **Figure 6** summarizes the anomalous areas with various colored double-arrows. Overlapping and/or adjacent arrows indicate the highest risk of IR, but any anomalous areas might have an enhanced risk.

LIMITATIONS

The survey described above was completed using standard and/or routinely accepted practices of the geophysical industry, and the equipment employed represents, in RETTEW's professional opinion, the best available technology. RETTEW does not accept responsibility for survey limitations due to inherent technological limitations or unforeseen site-specific conditions. We will notify you of such limitations or conditions, when they are identifiable.

The survey is based on observation of current subsurface conditions. Therefore, while the results of this survey can be used to guide further investigations, RETTEW cannot make any warranties concerning future sinkhole occurrence — particularly under the influence of altered surface and subsurface drainage patterns due to grading and construction activities.

Rippability, while historically closely-correlated with seismic P-wave velocity, also depends on geotechnical properties of the material, on the specific method of excavation, and on the variety and size of equipment employed. For mechanical excavation, the teeth or other cutting elements must be forced into discontinuities of competent rock masses, or penetrate the fabric of weak rocks. Thus, joint or fracture spacing, aperture, and infilling will all play a role in determining whether existing discontinuities in apparently-competent rock masses can allow mechanical excavation. The strength of the intact rock will also control whether fresh discontinuities can be induced during excavation activities. Therefore, while seismic data can provide reliable guidelines, RETTEW recommends that the rocks to be excavated be checked for these other geotechnical characteristics through examination of local outcrops, test pits, or boring logs.

We have enjoyed and appreciated the opportunity to have worked with you. If you have any questions, please do not hesitate to contact the undersigned.

Charles H. Rhine, MSc, PG
Senior Project Manager

Timothy D. Bechtel, PhD, PG
Senior Project Manager

Felicia Kegel Bechtel, MSc, PG
Director of Geophysics

Enclosures
Figure 1: Topographic Basemap
Figure 2: Data Coverage Map and Geologic Setting
Figure 3: Seismic Refraction Survey Results
Figure 4: Seismic MASW Survey Results
Figure 5: Geophysical Results Summary
Appendix A: Geophysical Survey Parameters
Appendix B: Introduction to Seismic Refraction
Appendix C: Caterpillar Ripping Charts

References

Berg, T.M., Edmunds, W.E., Geyer, A.R., and others, 1980, Geologic Map of Pennsylvania, PA Geological Survey, 4th series.

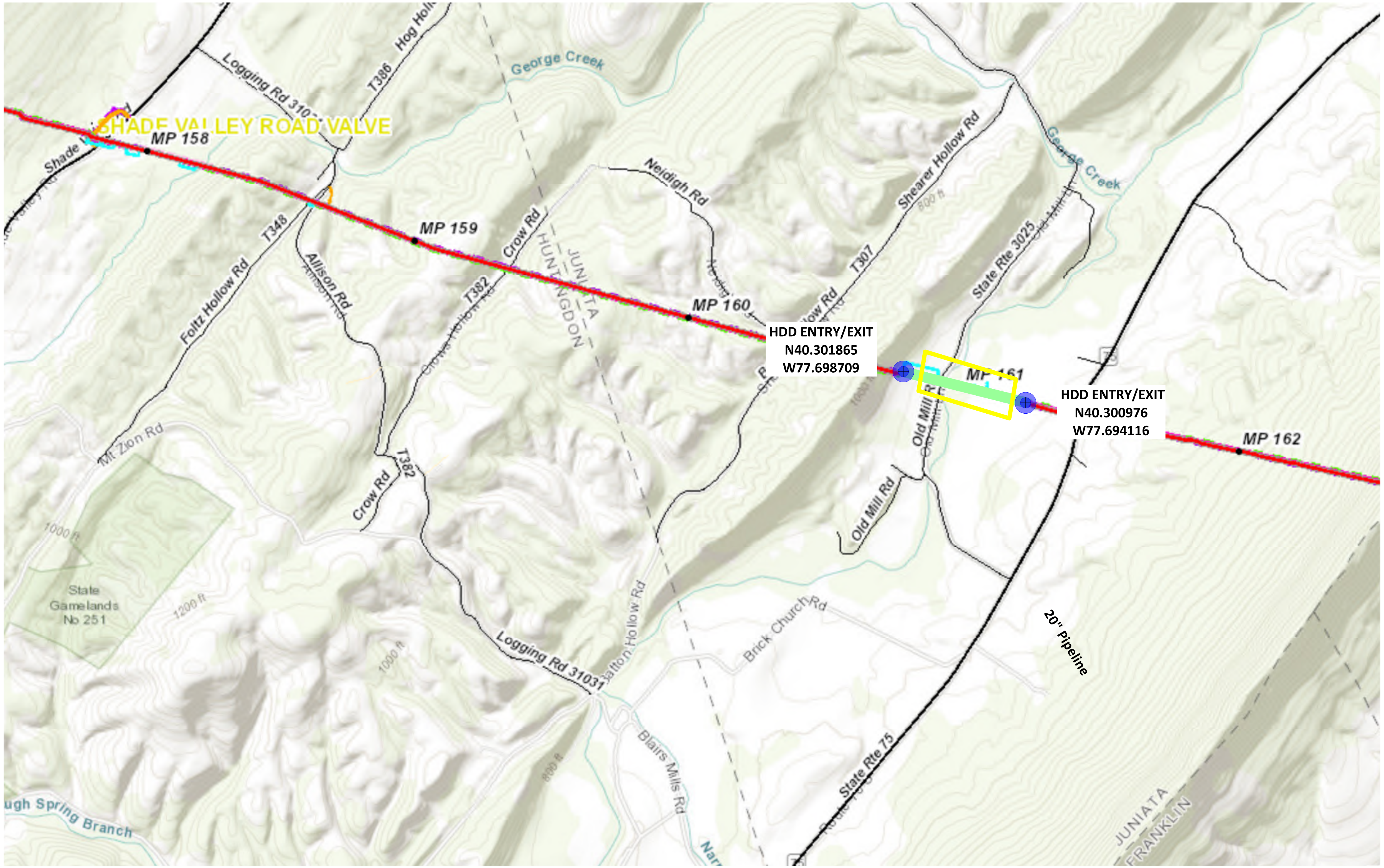
Carmichael, R. S. (1989), Physical Properties of Rocks and Minerals, CRC Press.

Caterpillar Tractor Company (1995), The Applicator, Caterpillar Tractor Company Marketing Division.

Kirsten, HAD (1982). A classification system for excavating in natural materials. Civil Engineering (Siviele Ingenieurswese), 24(7), 293-308.

PA Department of Conservation and Natural Resources Geology Interactive Map, (http://www.gis.dcnr.state.pa.us.html), 2019.

ENCLOSURES



Geophysical Survey Legend

- Proposed 20" HDD Alignment
- Geophysical Survey Area
- HDD Entry/Exit Point

Scale (ft)
0 1000 2000 3000 4000

Notes:

Basemap from Google Earth Pro, extracted 07/2019.

SURVEY DATE: 06/25/2019
RETTEW No.: 096302008
REVIEWED BY: CHR
DRAWN BY: JS
DATE: 07/22/2019
SCALE: 1" = 2000'
FIGURE NO. 1 of 6

RETTEW ENVIROSCAN

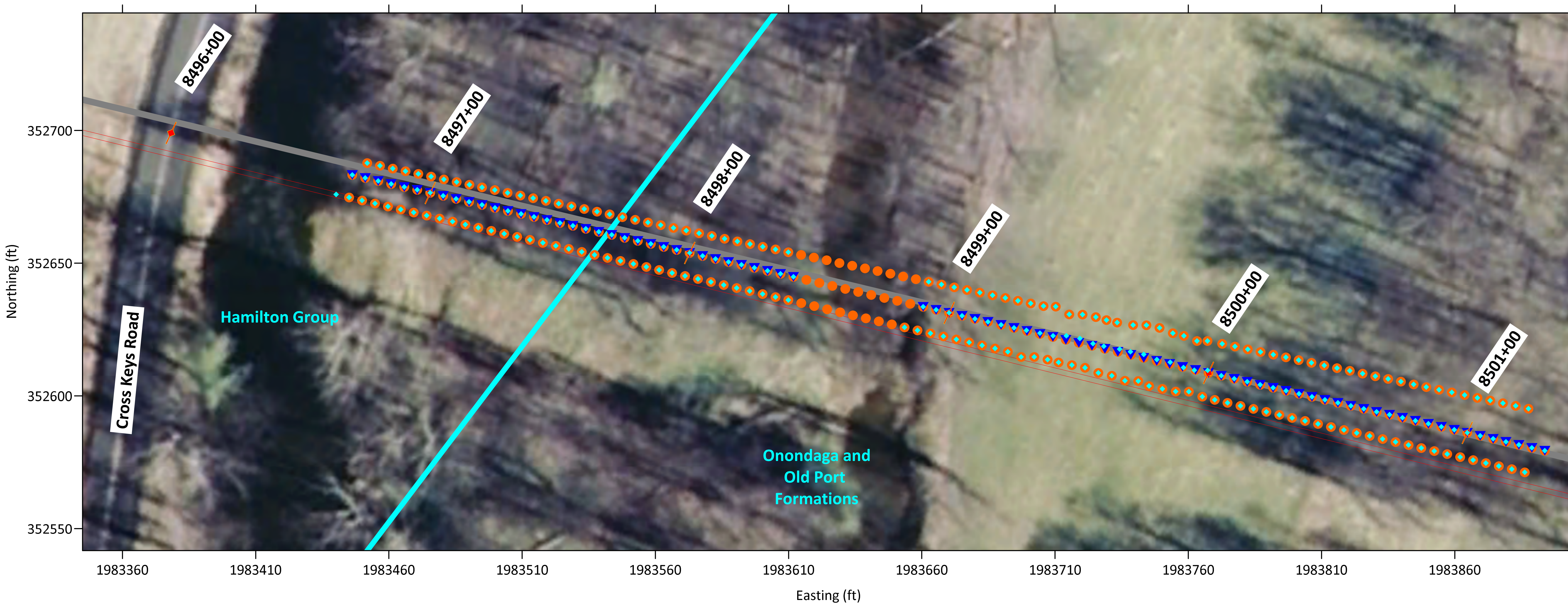
RETTEW Field Services, Inc.
3020 Columbia Avenue, Lancaster, PA 17603
Phone 1-800-738-8395

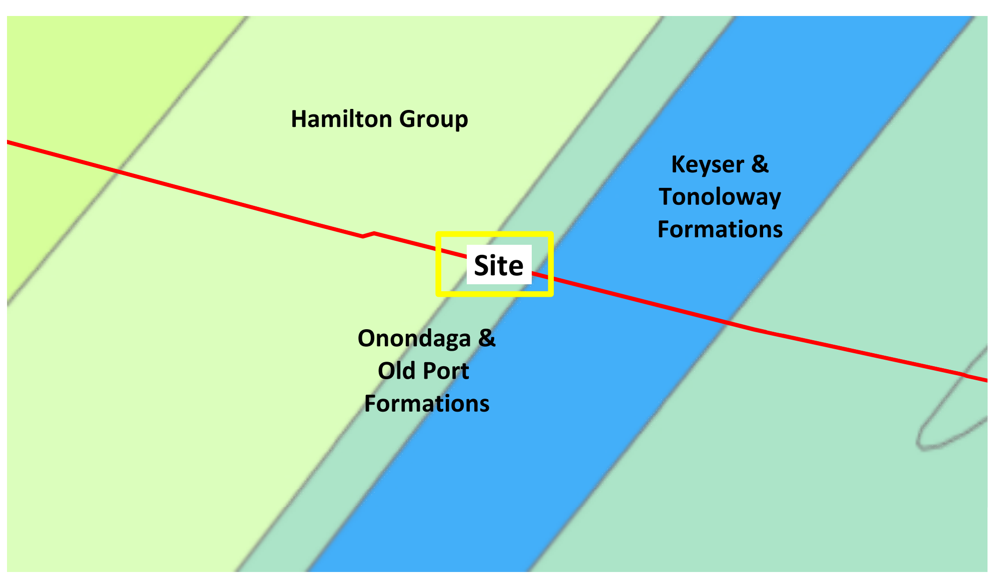
Figure 1: Topographic Basemap

Old Mill Road
S2-0156
PA-JU-004.000-WS

JUNIATA COUNTY, PA

LACK TOWNSHIP





Geologic Setting

Geophysical Survey Legend

- Electrical Resistivity Station
- Microgravity Survey Station
- Seismic Geophone Location
- Mapped Geologic Contact
- 20" Product Line with Station Number
- 11256+00 16" Product Line

Scale (ft)
0 20 40 60 80

Notes:

Basemap from Google Earth Pro, extracted 07/2019.

Survey profiles/stations from DGPS survey by RETTEW.

Geologic information from DCNR WMS Server, extracted 06/2019.

SURVEY DATE:	06/25/2019
RETTEW No.:	096302008
REVIEWED BY:	CHR
DRAWN BY:	JS
DATE:	07/23/2019
SCALE:	1" = 40'
FIGURE NO.	2 of 6

RETTEW ENVIROSCAN

RETTEW Field Services, Inc.
3020 Columbia Avenue, Lancaster, PA 17603
Phone 1-800-738-8395

Figure 2: Data Coverage Map and Geologic Setting

Old Mill Road
S2-0156
PA-JU-004.000-WS

JUNIATA COUNTY, PA

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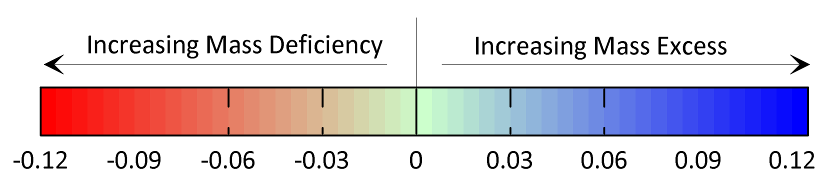
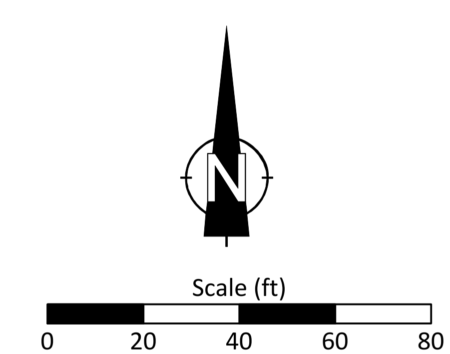
Residual Microgravity (mgals)



Geophysical Survey Legend

- Micrograviy Survey Station
- Mapped Geologic Contact
- 20" Product Line with Station Number
- 11256+00 16" Product Line



Notes:

Basemap from Google Earth Pro, extracted 07/2019.

Microgravity data from Scintrex CG-5 gravimeter, with Bouguer correction.

SURVEY DATE:	06/25/2019
RETTEW No.:	096302008
REVIEWED BY:	CHR
DRAWN BY:	JS
DATE:	07/22/2019
SCALE:	1" = 40'
FIGURE NO.	3 of 6

RETTEW ENVIROSCAN

RETTEW Field Services, Inc.
3020 Columbia Avenue, Lancaster, PA 17603
Phone 1-800-738-8395

Figure 3: Residual Microgravity Results

Old Mill Road
S2-0156
PA-JU-004.000-WS

JUNIATA COUNTY, PA

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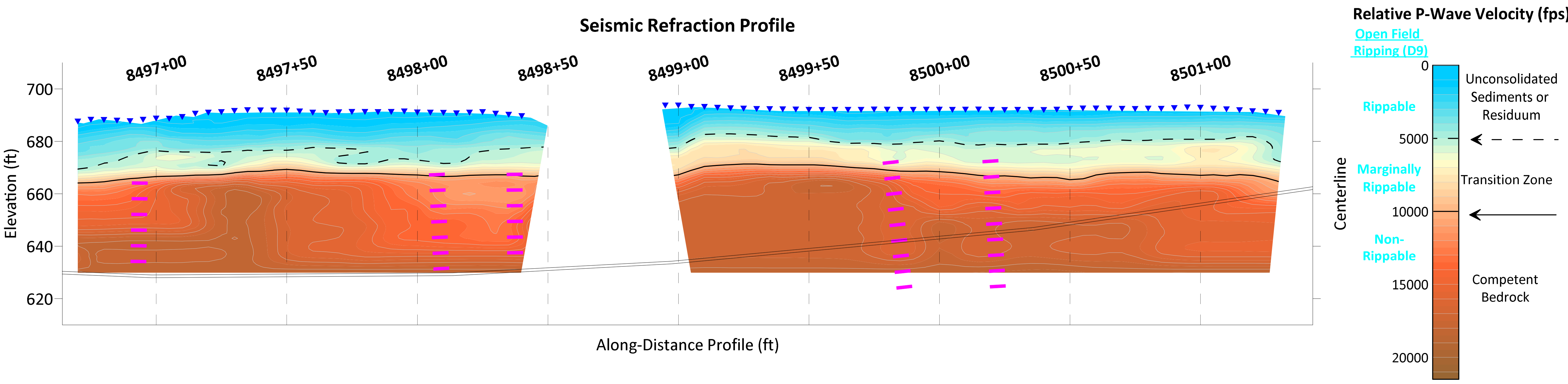
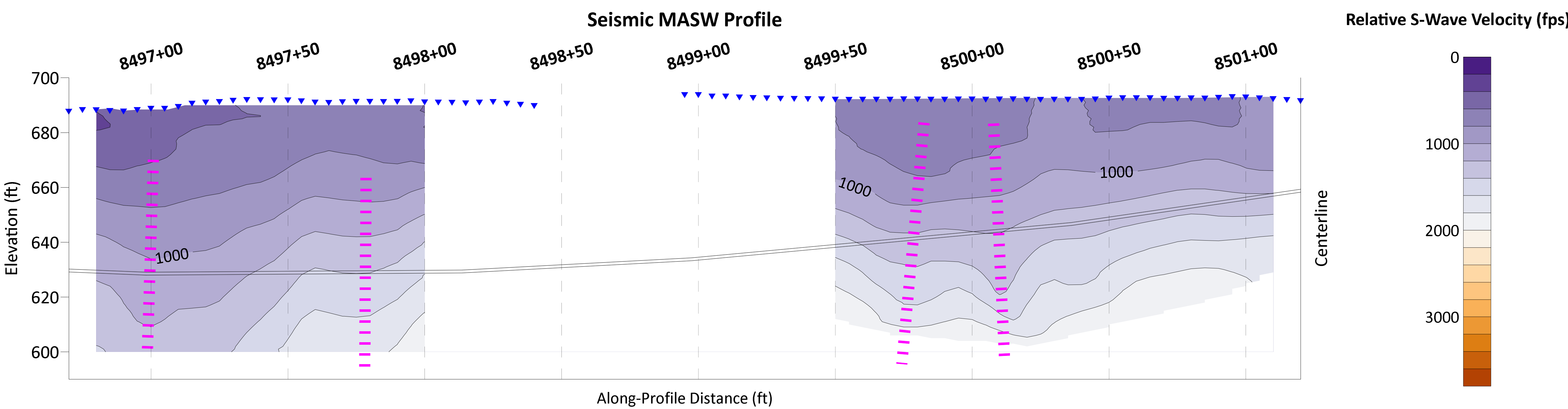
Seismic Refraction Profile



Seismic MASW Profile



Geophysical Survey Legend

- Seismic Geophone Location
- Possible Fracture Zone
- 20" HDD
- 8501+00 Station Number

Notes:

Seismic data from Geometrics 24-channel Geode with 4.0 Hz geophones.

Relative seismic velocity models from SeisImager (by Oyo Corporation) tomographic and ReMi inversions.

SURVEY DATE:	06/25/2019
RETTEW No.:	096302008
REVIEWED BY:	CHR
DRAWN BY:	JS
DATE:	07/22/2019
SCALE:	1" = 40'
FIGURE NO.	4 of 6

RETTEW ENVIROSCAN

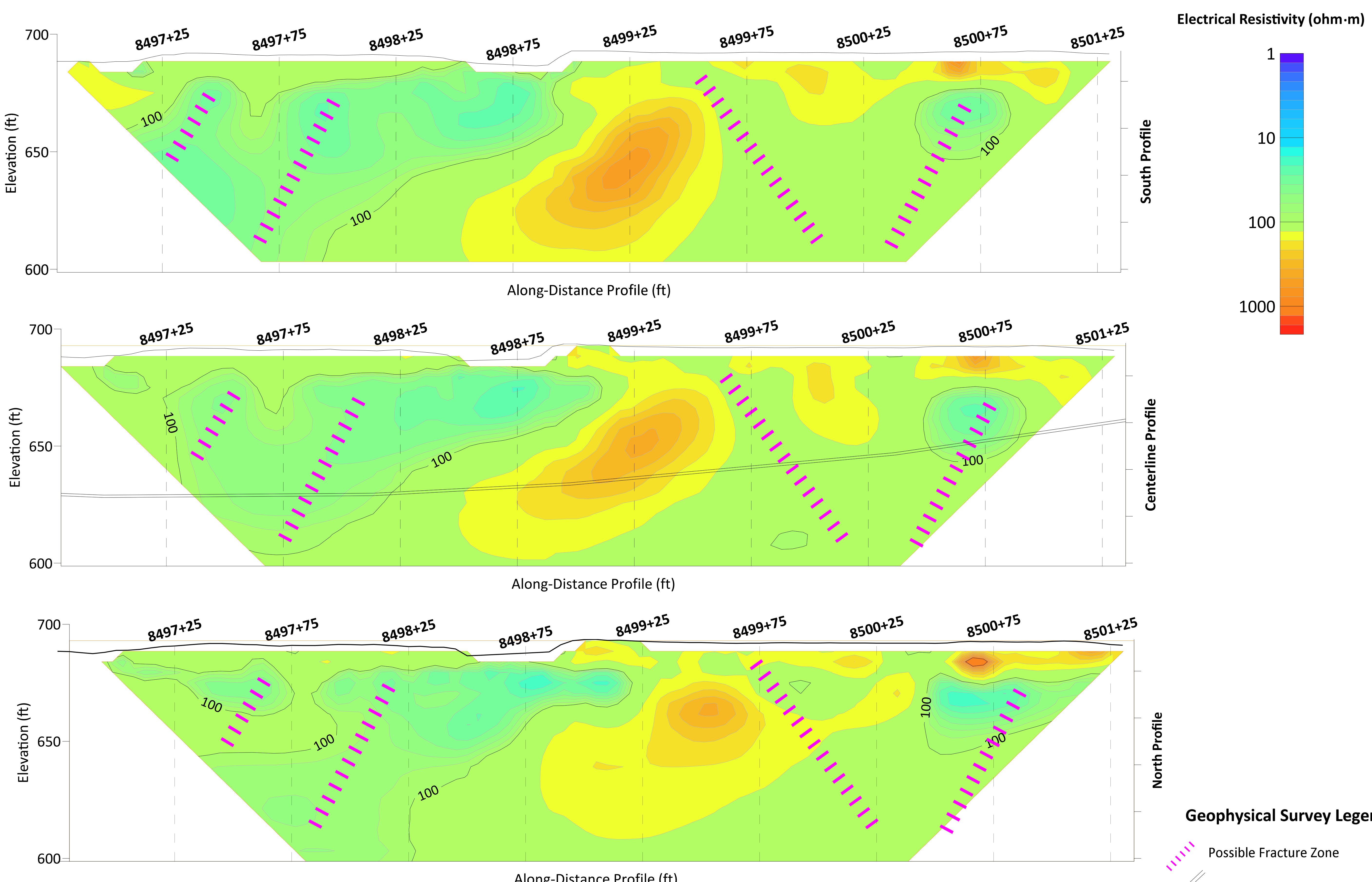
RETTEW Field Services, Inc.
3020 Columbia Avenue, Lancaster, PA 17603
Phone 1-800-738-8395

Figure 4: Seismic Survey Results

Old Mill Road
S2-0156
PA-JU-004.000-WS

JUNIATA COUNTY, PA

LACK TOWNSHIP



Geophysical Survey Legend

- Possible Fracture Zone
- 20" HDD
- 8501+30 Station Number

Notes:

Resistivity data from AGI Super Sting R-8, 93 channels, 5-ft electrode spacing.

Resistivity models from EarthImager 2D (by AGI Corporation) inversions.

SURVEY DATE: 06/25/2019
RETTEW No.: 096302008
REVIEWED BY: CHR
DRAWN BY: JS
DATE: 07/22/2019
SCALE: 1" = 40'
FIGURE NO. 5 of 6

RETTEW | ENVIROSCAN

RETTEW Field Services, Inc.
3020 Columbia Avenue, Lancaster, PA 17603
Phone 1-800-738-8395

Figure 5: Electrical Resistivity Survey Results

Old Mill Road
S2-0156
PA-JU-004.000-WS

JUNIATA COUNTY, PA

LACK TOWNSHIP

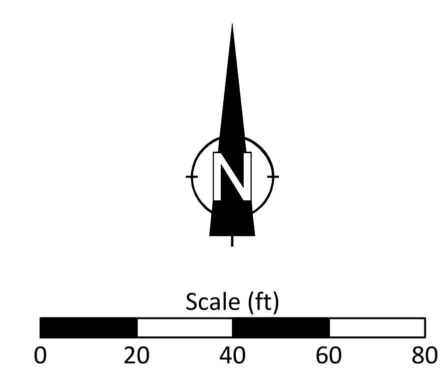
Geophysical Survey Legend

- Mapped Geologic Contact
- 20" Product Line with
- 16" HDD & Station Number (11627+00)
- *Possible Fracture Zone Detected By:*
  - Electrical Imaging
  - Seismic MASW
  - Seismic Refraction
  - Microgravity

Notes:

Basemap from Google Earth Pro, extracted 07/2019.

Geologic information from DCNR WMS Server, extracted 06/2019.



SURVEY DATE:	06/25/2019
RETTEW No.:	096302008
REVIEWED BY:	CHR
DRAWN BY:	JS
DATE:	07/22/2019
SCALE:	1" = 40'
FIGURE NO.	6 of 6

RETTEW ENVIROSCAN
RETTEW Field Services, Inc.
3020 Columbia Avenue, Lancaster, PA 17603
Phone 1-800-738-8395

Figure 6: Geophysical Survey Results Summary

Old Mill Road
S2-0156
PA-JU-004.000-WS

JUNIATA COUNTY, PA

LACK TOWNSHIP

APPENDIX A

Geophysical Survey Parameters

Geophysical Survey Parameters -- Old Mill Road

	Spacing[1] (feet)	Shot Interval[2] (feet)	Offset[3] (feet)	Spread Length[4] (feet)	Array Type[5]	Effective Depth[6] (feet)	Lateral Resolution[6] (feet)	Vertical Resolution[6] (percent)	System
Seismic Refraction	5	40	20	460		92	5	15	**Geometrics Geode**
Seismic MASW	5	5	20	460		153	5	25	**Geometrics Geode**
ERI	5		20	560	dipole-dipole	151	15	variable	**AGI Sting R-8**
MicroGravity	5		20			size-depth trade-off	depends on depth	depends on depth	**Scintrex CG-5**

[1] geophone, electrode, or station

[2] Seis (27-lb slidehammer source)

[3] distance between parallel profiles

[4] ERI or Seis

[5] ERI

[6] rule-of-thumb only (most depend on site-specific soil properties, sampling interval, depth, and target dimensions)

APPENDIX B

Introduction to Seismic Refraction

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INTRODUCTION TO SEISMIC REFRACTION

BY TIMOTHY D. BECHTEL, PHD, PG

ENERGY

Mechanical elastic (seismic) waves generated by a hammer blow, weight drop, or explosion.

SENSITIVITY

Sensitive to elastic properties or moduli – generally strongly correlated with density.

BASIC EQUIPMENT

Recording Seismograph (generally 24 or more channels); Geophones (one for each channel); Geophone cable; Hammer or weight plus strike plate or explosives; Trigger switch.

COMMON APPLICATIONS

Determination of the depth and dip of soil horizons and bedrock surfaces. Recent processing advances allow some detection and delineation of discrete targets.

PRINCIPLES

In a uniform isotropic earth, the shock wave from a blow or explosion at the surface travels outward and downward in a hemispherical wave front like a three-dimensional ripple from a pebble in a still pond. At any point on the wave front, a straight line from the shock source to the wave front depicts the path of the seismic wave and is called a ray path (see **Figure SR-1**). In reality, there are several independent shock waves; the fast-moving primary, compressional or P wave front; the slower moving secondary, shear or S wave (both of which form hemispherical wavefronts); and several disk-like wave fronts that travel only along the surface of the earth (called surface waves or ground roll). For the purposes of most seismic refraction surveys, only the fastest moving wave front — the P wave — is considered. S-wave refraction is used in selected circumstances where complete determination of elastic moduli is desired – particularly when it may be desirable to eliminate the effects of water saturation.

In a layered earth, the hemispherical P shock wave defined by the radially distributed P ray paths are deflected according to the laws of optics (Snell’s Law) at interfaces between materials with differing seismic velocities (i.e. densities or elastic properties). Figure SR-2 depicts the deflection of ray paths due to an increase in P velocity at a bedding plane. The type of deflection that a ray path will undergo is dependent upon the angle at which it strikes the interface, and falls into one of four categories:

Some direct rays (green in **Figures SR-2** and **SR-3**) travel parallel to the ground surface at the seismic velocity of the upper layer, do not strike the underlying interface, and consequently are not deflected.

Reflected rays (purple in **Figures SR-2** and **SR-3**) arise where direct rays strike the interface, and a portion of the energy is reflected symmetrically back towards the surface.

The portion of the energy of the incident direct wave that is not reflected upward is refracted or bent as it crosses the interface – making refracted waves in the lower layer (red in **Figures SR-2** and **SR-3**).

At a precise angle called the critical angle, the incident ray is refracted directly along the interface, and travels at the higher seismic velocity of the lower layer (see Critically Refracted Wave in **Figure SR-3**). As this critically refracted or head wave races along beneath the interface, it generates a secondary elastic disturbance that travels back to the surface along ray paths that define a wave front analogous to the bow wake of a ship. These returning rays again travel at the slower velocity of the upper layer.

To perform a refraction survey, a linear array of ground motion sensors or geophones is spaced out from the seismic source or shot point, forming a geophone spread. Each geophone is connected to a separate channel in a seismograph which records a wiggle trace representing the ground motion resulting from the passage of the various seismic rays.

As depicted in the time-distance (T-X) curve in Figure SR-4, the layered earth structure can be determined by analyzing the seismographic wiggle traces. At distances close to the seismic source, the first wiggle or ground motion (the first arrival after the shot) is due to passage of the direct wave travelling at the velocity of the upper layer. Reflected waves arrive later since they have by definition traveled a greater distance at the same velocity (additional later wiggles are caused by passage of the more slowly travelling S and surface waves). Beyond a distance dictated by the critical angle, the first arrival of seismic energy represents the head wave of the critically refracted ray. These refracted rays also by definition travel a greater distance than the direct wave. However, along part of their path, they have traveled at the higher velocity of the underlying more consolidated layer. At greater distances from the shot point, where the path length in the higher velocity layer becomes significant, the head wave arrivals actually race past the direct wave and become the first arrival (see labeled crossover in **Figure SR-4**). By extension, it can be shown that if a third layer with even greater velocity lies at greater depth, the head wave from this layer will become the first arrival at a sufficient distance from the shot point.

In conventional seismic refraction, only the first P wave arrivals can be reliably selected on a wiggle trace record. The later reflected P wave arrivals are generally obscured by the slower-travelling S and surface waves, and the very slow air blast or sound wave from the shot. To interpret a seismic refraction record, the first arrival travel times are measured for each wiggle trace and plotted at the appropriate point on a time-distance (T-X) curve (see Figure SR-4). In a plane-layered earth, these first arrivals define a series of line segments, each representing a discrete layer. The seismic velocity of each layer is simply the reciprocal of the slope of the associated line segment. The thickness of each layer can be calculated from the distances where the line segments intersect. The mathematics for these calculations are easily derived, and can be found in any introductory geophysics text.

True geologic strata are rarely perfectly horizontal. The effect of a dipping interface on a travel time curve cannot be recognized using a single shot point. Calculations based on a T-X curve from a single shot point should always be considered as producing apparent depths to interfaces and apparent seismic velocities for all but the uppermost layer. To determine the true depths and dips of interfaces and the true seismic velocities, it is necessary to reverse the seismic line; that is, move the shot point to a location at or beyond the farthest geophone in the spread, and repeat the shot. The calculation of true depths, dips and velocities from reversed seismic lines is also readily performed.

CAPABILITIES

Conventional seismic refraction can yield accurate measurements of depths and attitudes of soil horizons, groundwater tables, and other relatively distinct and planar strata. Modern computer analysis of multi-fold seismic refraction data (i.e. with many and overlapping shot points) can provide delineation of undulating or even irregular (as opposed to simply planar) interfaces. The latest generation of computer processing techniques require very high-fold data, but in favorable conditions, are capable of resolving even discrete targets such as foundation elements, tunnels or cavities, and can resolve gradational boundaries as well as distinct interfaces. The seismic P-wave velocities of materials are generally an indication of relative density or compaction. S-wave refraction data (collected using specialized geophones, shock sources and field procedures) can provide S-wave velocities that bear a well-constrained empirical relationship to standard penetration test (SPT) N values and therefore bearing capacity. For surveys where matching P- and S-wave velocities are determined, the dynamic elastic moduli of subsurface materials can be calculated (including Poisson’s Ration, Young’s or Bulk Modulus, and Shear Modulus or Rigidity).

LIMITATIONS

Seismic data is collected at spaced geophones, and therefore does not provide continuous profile data. If geophones are spaced too widely, thin layers can be missed entirely.

Conventional refraction interpretations are only accurate where the velocity of strata increase with depth. Velocity inversions not only alter the data, but are particularly insidious since the presence of a low velocity zone at depth is not apparent in first arrival data. The latest generation of computer processing techniques do allow detection and delineation of laterally restricted low velocity zones (e.g. tunnels, cavities, gravel lenses, etc.).

Sharp or dramatic interface relief such as limestone pinnacles cannot always be resolved even with very tight geophone spacing. Therefore, refraction profiles of expectedly irregular interfaces should be assumed to represent somewhat smoothed versions of actual relief (see e.g. Figure **SR-5**).

Seismic records can contain noise due to heavy machinery vibrations, vehicular traffic, and sometimes even wind or distant earthquakes. Care must be taken to identify potential sources of seismic noise prior to beginning a survey.

The effective survey depth is limited to approximately 1/5 of the greatest shotpoint to geophone distance. Therefore, very deep surveys may require impractically long lines (requiring consideration of other geophysical techniques such as seismic reflection).

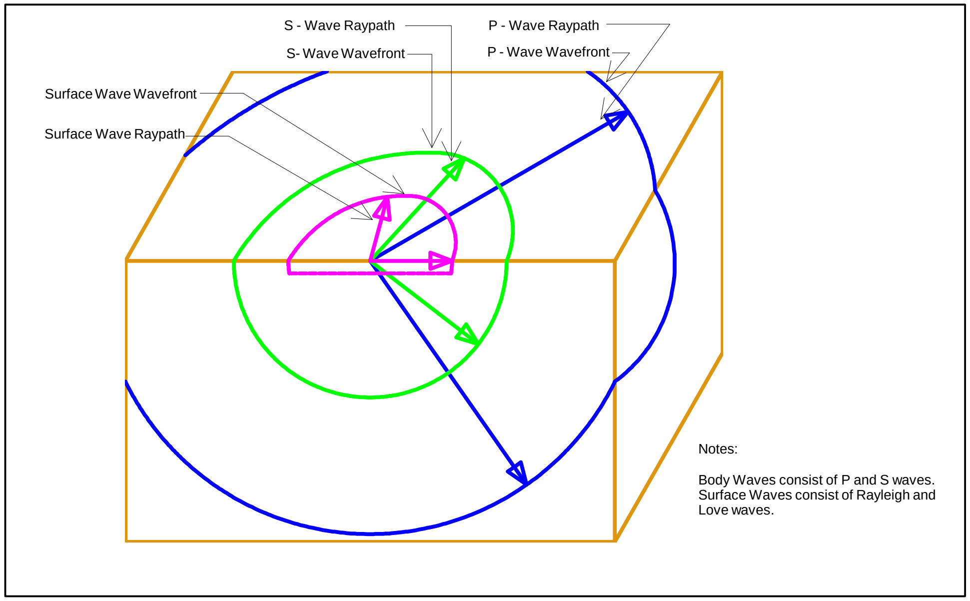


Figure SR-1 Seismic Wave Types Rev. 04/2018

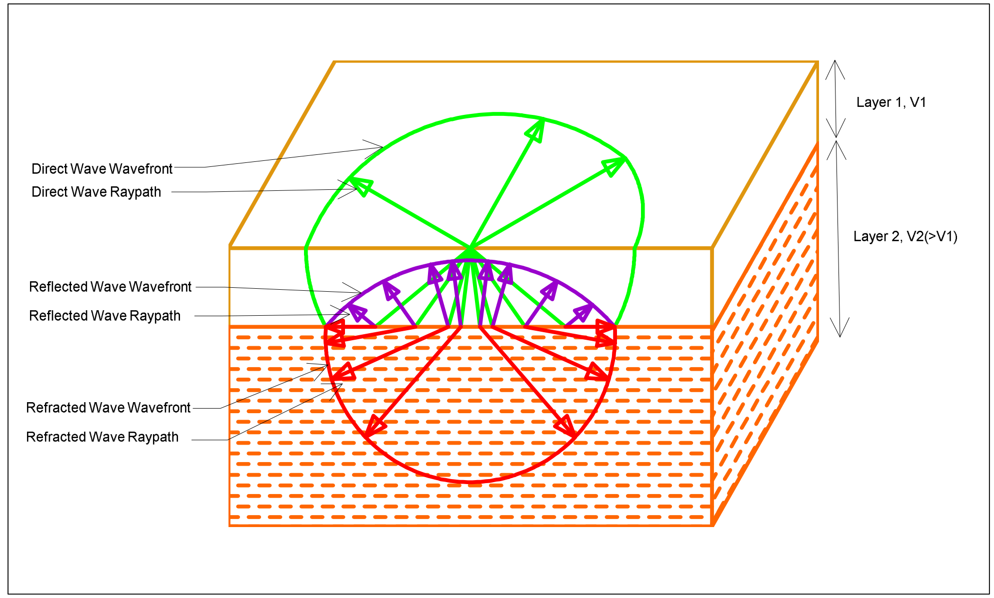


Figure SR-2 Effect of Layering on Body Wave Raypath Rev. 04/2018

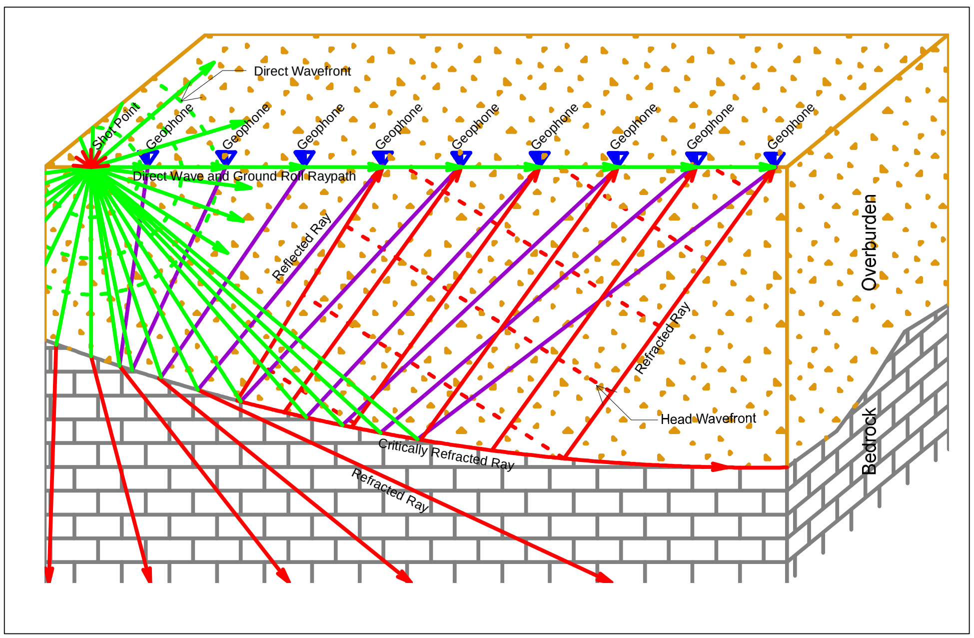


Figure SR-3 Seismic Ray Path Geometry Rev. 04/2018

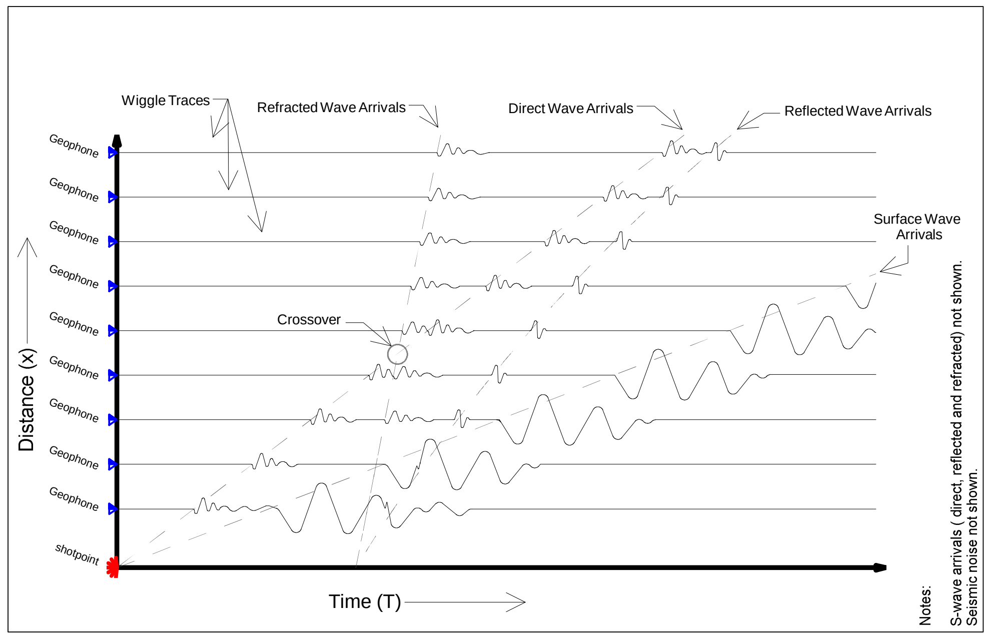


Figure SR-4 Idealized Seismic Record and T- X Graph Rev. 04/2018

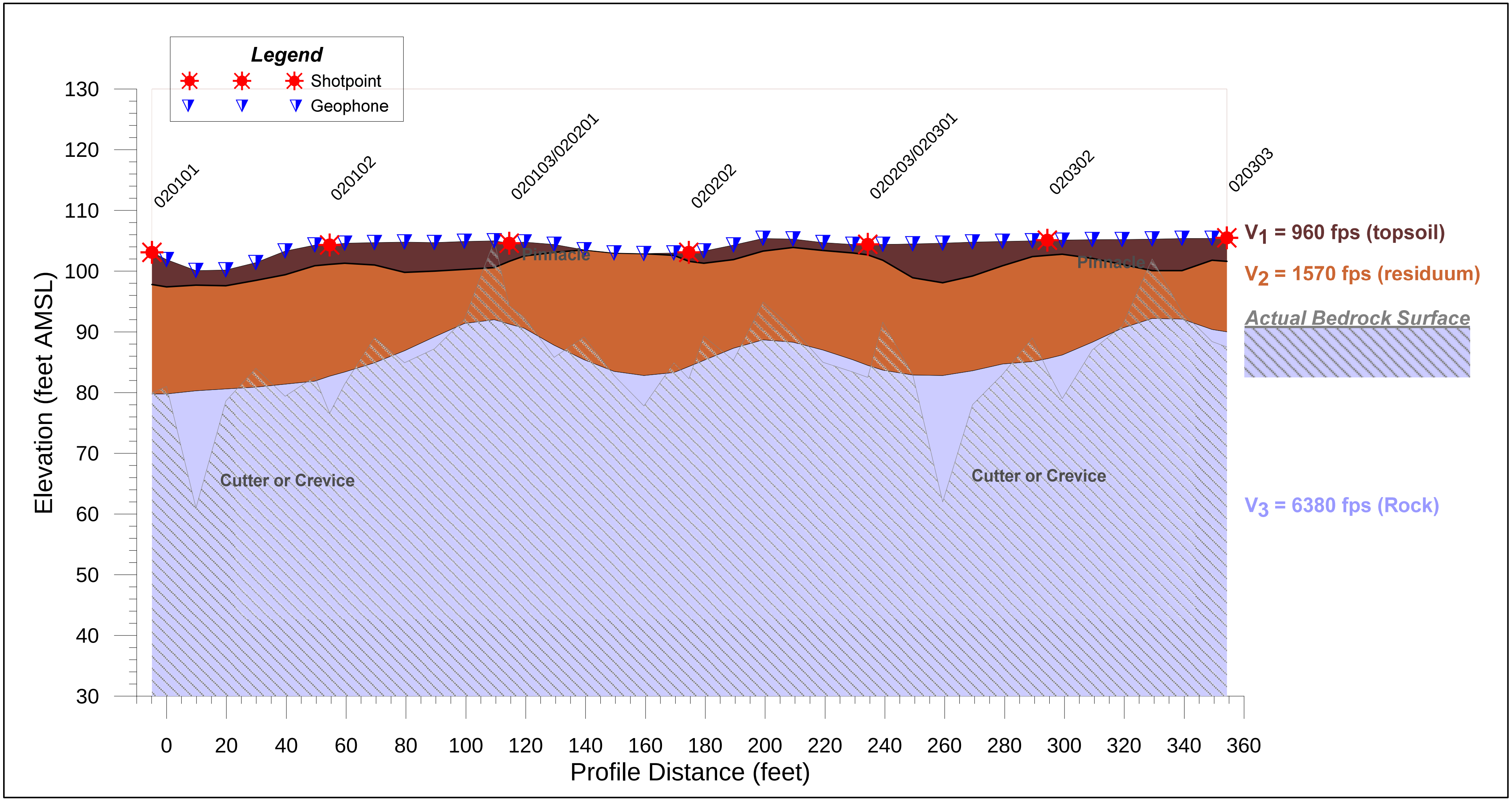
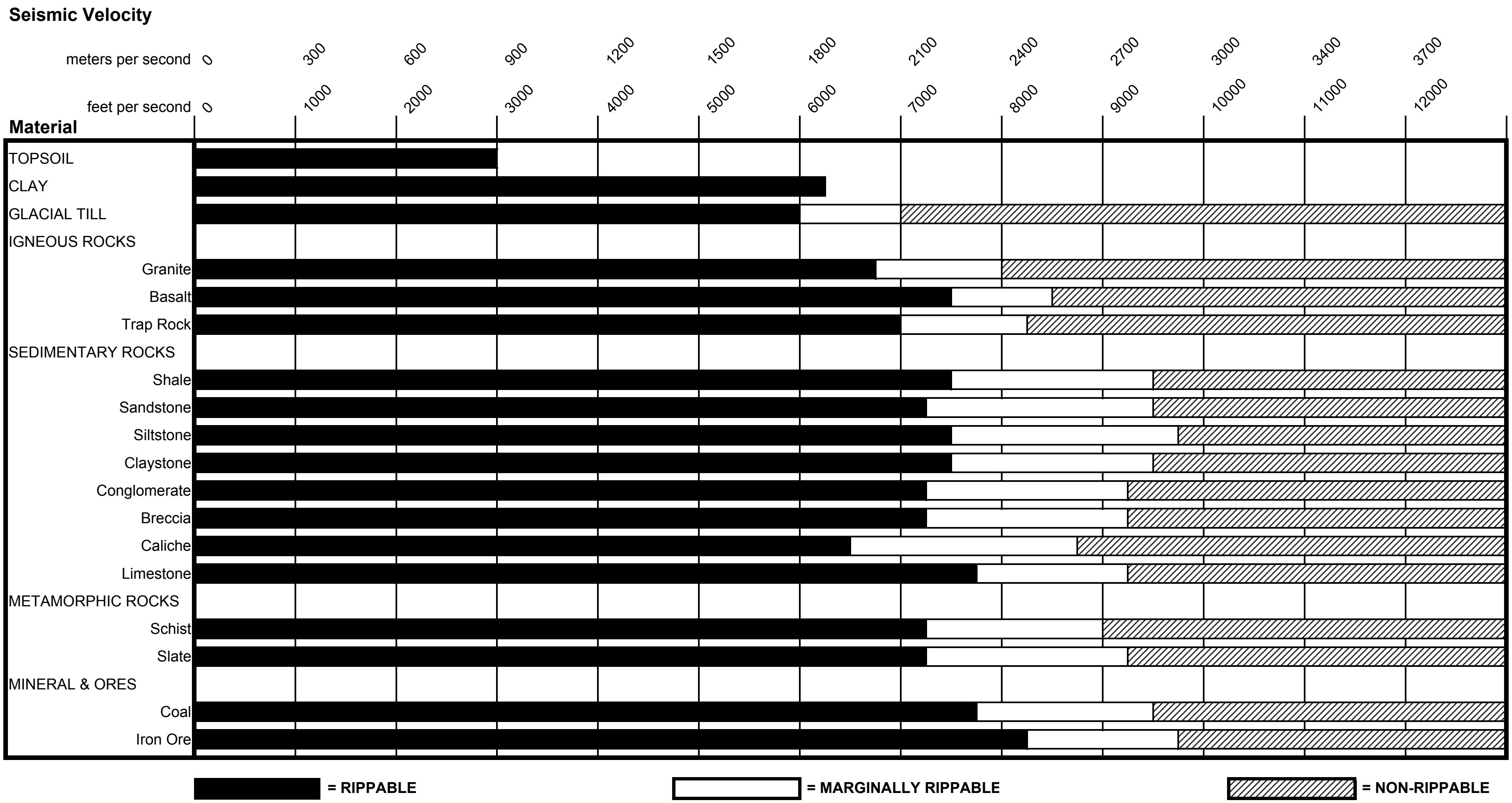


Figure SR-5 **Example Karst Terrane Seismic Profile** **Revised 04/2018**

APPENDIX C

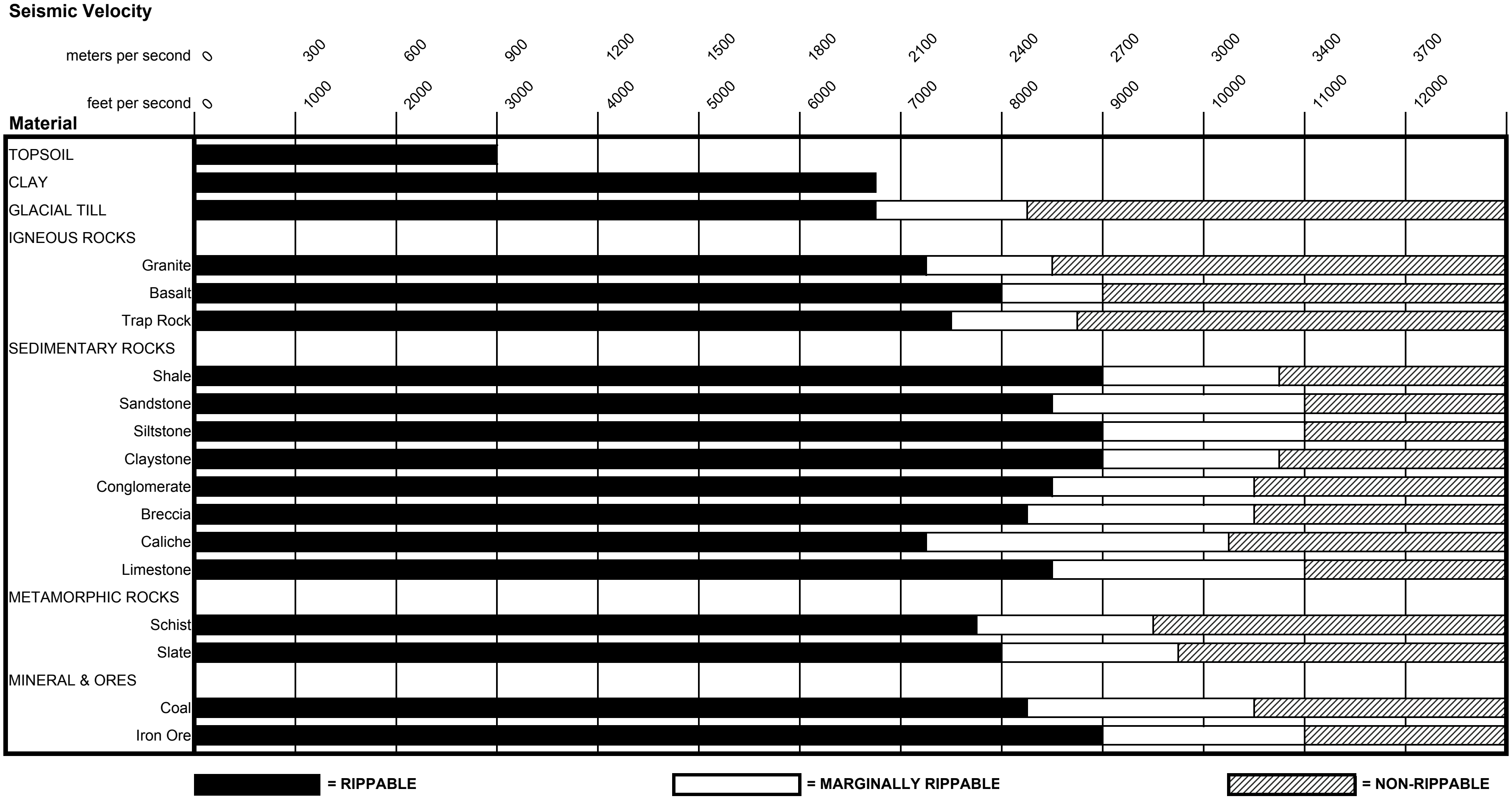
Caterpillar Ripping Charts

Ripping Chart *
D9R
Multi or Single Shank No. 9 Ripper
Estimated by Seismic P-Wave Velocities



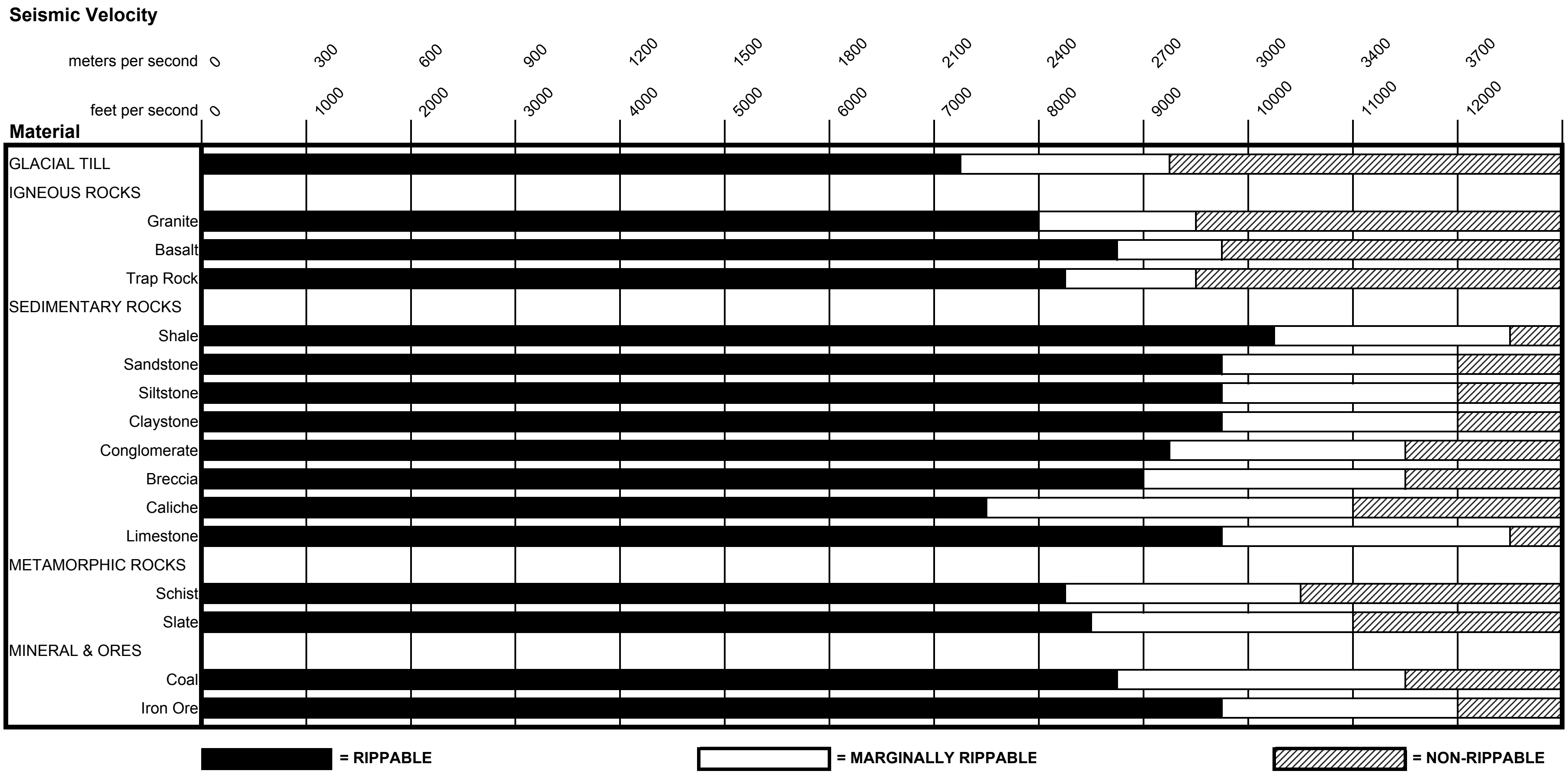
* Caterpillar Performance Handbook, Edition 26, Caterpillar, Inc., Peoria, Illinois

Ripping Chart *
D10N
Multi or Single Shank No. 10 Ripper
Estimated by Seismic P-Wave Velocities



* Caterpillar Performance Handbook, Edition 26, Caterpillar, Inc., Peoria, Illinois

Ripping Chart *
D11N
Multi or Single Shank No. 11 Ripper
Estimated by Seismic P-Wave Velocities



* Caterpillar Performance Handbook, Edition 26, Caterpillar, Inc., Peoria, Illinois

Cupp Water Sample Analytical Results Summary

Parcel ID: 6-3-5.0 (1072 Old Mill Road)
Well Location Map ID: WL-09212017-614-01

Parameter	Units	Sample Date: 9/21/2017 Sample I.D.: 09212017-614-01	Sample Date: 11/13/2017 Sample I.D.: 11132017-630-01	PA DEP Drinking Water MCL/SMCL
Coliform, fecal	col/100ml	< 1	< 1	-
E. Coli	MPN/100ml	< 1	< 1	-
Coliform, total	MPN/100ml	313	< 1	-
Dissolved Solids	mg/l	170	163	500
Suspended Solids	mg/l	ND	ND	-
Hardness (colorimetric) as CACO3	mg/l	108	98.1	-
Turbidity	NTU	0.503	0.776	-
Alkalinity	mg/l	161	148	-
pH	SU	8.11	7.78	-
Specific Conductance	umhos/cm	288	273	-
Bromide	mg/l	ND	ND	-
Chloride	mg/l	1.67	1.26	250
Sulfate	mg/l	ND	ND	250
Barium	mg/l	1.06	0.999	2
Calcium	mg/l	29.2	28.2	-
Iron	mg/l	0.109	0.117	0.3
Magnesium	mg/l	8.20	8.03	-
Manganese	mg/l	0.0358	0.0423	0.05
Potassium	mg/l	ND	ND	-
Sodium	mg/l	20.6	21.3	-
Methane	mg/l	0.538	2.17	-
Ethane	mg/l	ND	ND	-
Ethene	mg/l	ND	ND	-
Propane	mg/l	ND	ND	-
Benzene	mg/l	ND	ND	0.005
Toluene	mg/l	ND	ND	1
Ethylbenzene	mg/l	ND	ND	0.7
Total Xylenes	mg/l	ND	ND	10
Residual Bentonite	-	NA	NA	-

20-inch HDD construction dates: October 20, 2017 through April 7, 2018
16-inch HDD construction dates: Awaiting PA DEP authorization to start

Notes:
1. MCL - Maximum Primary Contaminant Level
2. SMCL - Maximum Secondary Contaminant Level
3. NA - Not Analyzed
4. ND - Not Detected
5. col/100ml - colonies per 100 milliliters
6. MPN/100ml - most probable number per 100 milliliters
7. mg/l - milligrams per liter
8. NTU - nephelometric turbidity units
9. SU - standard units
10. umhos/cm - micro ohms per centimeter

Concentrations that are bolded and highlighted exceed or are equivalent to their respective PA DEP MCL/SMCL

Shearer Water Sample Analytical Results Summary			
Parcel ID:	6-14-10 (727 Old Mill Road)		
Well Location Map ID:	WL-01312018-619-01		
Parameter	**Units**	**Sample Date: 1/31/2018** **Sample I.D.: 01312018-619-01**	**PA DEP Drinking Water MCL/SMCL**
Coliform, fecal	col/100ml	< 1	-
E. Coli	MPN/100ml	< 1	-
Coliform, total	MPN/100ml	3.10	-
Dissolved Solids	mg/l	183	500
Suspended Solids	mg/l	29.0	-
Hardness (colorimetric) as CACO3	mg/l	107	-
Turbidity	NTU	176	-
Alkalinity	mg/l	53.3	-
pH	SU	6.78	-
Specific Conductance	umhos/cm	257	-
Bromide	mg/l	ND	-
Chloride	mg/l	9.15	250
Sulfate	mg/l	53.7	250
Barium	mg/l	0.0495	2
Calcium	mg/l	30.0	-
Iron	mg/l	**21.8**	0.3
Magnesium	mg/l	5.78	-
Manganese	mg/l	**0.319**	0.05
Potassium	mg/l	1.28	-
Sodium	mg/l	6.99	-
Methane	mg/l	0.0135	-
Ethane	mg/l	ND	-
Ethene	mg/l	ND	-
Propane	mg/l	ND	-
Benzene	mg/l	ND	0.005
Toluene	mg/l	ND	1
Ethylbenzene	mg/l	ND	0.7
Total Xylenes	mg/l	ND	10
Residual Bentonite	-	ND	-

20-inch HDD construction dates: October 20, 2017 through April 7, 2018
16-inch HDD construction dates: Awaiting PA DEP authorization to start

Notes:
1. MCL - Maximum Primary Contaminant Level
2. SMCL - Maximum Secondary Contaminant Level
3. NA - Not Analyzed
4. ND - Not Detected
5. col/100ml - colonies per 100 milliliters
6. MPN/100ml - most probable number per 100 milliliters
7. mg/l - milligrams per liter
8. NTU - nephelometric turbidity units
9. SU - standard units
10. umhos/cm - micro ohms per centimeter

Concentrations that are bolded and highlighted exceed or are equivalent to their respective PA DEP MCL/SMCL

Wadel Water Sample Analytical Results Summary			
Parcel ID:	6-15-2002 (2706 Route 75 South)		
Well Location Map ID:	WL-02212019-604-01		
Parameter	**Units**	**Sample Date: 2/21/2019** **Sample I.D.: 02212019-604-01**	**PA DEP Drinking Water MCL/SMCL**
Coliform, fecal	col/100ml	< 1	-
E. Coli	MPN/100ml	< 1	-
Coliform, total	MPN/100ml	25.9	-
Dissolved Solids	mg/l	125	500
Suspended Solids	mg/l	ND	-
Hardness (colorimetric) as CACO3	mg/l	134	-
Turbidity	NTU	0.706	-
Alkalinity	mg/l	119	-
pH	SU	7.57	-
Specific Conductance	umhos/cm	238	-
Bromide	mg/l	ND	-
Chloride	mg/l	1.04	250
Sulfate	mg/l	ND	250
Barium	mg/l	0.0538	2
Calcium	mg/l	42.4	-
Iron	mg/l	ND	0.3
Magnesium	mg/l	5.85	-
Manganese	mg/l	ND	0.05
Potassium	mg/l	ND	-
Sodium	mg/l	1.57	-
Methane	mg/l	ND	-
Ethane	mg/l	ND	-
Ethene	mg/l	ND	-
Propane	mg/l	ND	-
Benzene	mg/l	ND	0.005
Toluene	mg/l	ND	1
Ethylbenzene	mg/l	ND	0.7
Total Xylenes	mg/l	ND	10
Residual Bentonite	-	NA	-

20-inch HDD construction dates: October 20, 2017 through April 7, 2018
16-inch HDD construction dates: Awaiting PA DEP authorization to start

Notes:
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2. SMCL - Maximum Secondary Contaminant Level
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