RETTEW

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December 9, 2020
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Mr. Robert Burke
Energy Transfer
1300 Main Street
Houston, TX 77002

RE: Geophysical Survey
Sunoco Pipeline, LP Pipeline Project
Horizontal Directional Drill S3-0360 Biddle Drive
Uwchlan Township, Chester County, Pennsylvania
RETTEW Project No. 096303002

Dear Mr. Burke:

RETTEW Associates, Inc. completed a multi-technique geophysical survey at the S3-0360 Biddle Drive horizontal directional drill (HDD) site. The purpose of the survey was to detect and delineate fractures, soft zones, or subsurface voids that could potentially contribute to possible earth features at the site or could act as preferred pathways for water flow prior to the proposed 20-inch HDD Drill. A coincident survey was completed on the east or downstream end of the HDD in January of 2020 following drilling of the 16-inch HDD. The results of this survey were presented in a report dated February 27, 2020. The following report, figures, and attachments describe the methods and results of the investigation.

EXECUTIVE SUMMARY

The multi-technique geophysical survey of the west end was completed on November 17, 2020 and the east end on October 19, 2020. 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 high- and low-density zones. The low-density zones may indicate deeper rock, possibly resulting from deeper weathering along fractures. Three gravity low areas that were previously identified in the February 2020 report on the downstream (east) end of the HDD again appear in this survey.
- Seismic refraction and multi-spectral analysis of surface waves (MASW) profiles confirmed the presence of an undulating bedrock surface likely due to deeper weathering along suspected fracture zones, but no apparent extremely-low-velocity zones of the type associated with voids or incipient earth features.
- Electrical resistivity imaging (ERI) on the downstream (east) end of the HDD identified a relatively conductive surface layer over a discontinuous mildly resistive layer, with the low-resistivity discontinuities possibly confirming the presence of fracture zones. The lowest resistivities were recorded in the shallow subsurface adjacent to Shoen Road and are presumed to represent saturated (and therefore electrically conductive) soils associated with ongoing groundwater seepage in this area. Site conditions prevented completion of an ERI survey on the upstream end.

Results from the geophysical techniques are consistent with each other, and with the geology as mapped by the PA Geological Survey; all suggesting that the local bedrock is fractured. Subsurface low resistivities adjacent to Shoen Road are consistent with possible water flowing along the HDD path and emerging into the soil to enhance a natural pre-HDD seep north of Shoen Road. This seep discharged turbid water in August 2020, and a containment and diversion system was installed to capture any future turbid discharge, and has since been removed. A subsidence feature that appeared at the eastern end of the gravity low on the south side of Shoen Road was excavated and inspected during installation of this system. The rock exposed in this excavation was non-karst. A boring from 2017 (OW-1 – see location on the map in **Appendix C**) did encounter karstified dolomitic bedrock, suggesting that the contact between karst and non-karst may not be as mapped by the PA Geologic Survey, but the karst does not extend to the HDD entry/exit or anywhere along the path. One of the gravity lows (encompassing the subsidence feature) was probed with two geotechnical borings (360A and 360B in **Appendix C**) and did not encounter karst; only surficial loose soils. The two persistent gravity lows that have not been investigated are recommended for further geotechnical investigation and monitoring.

SITE DESCRIPTION

The Biddle Drive HDD site is located between Devon Drive and Shoen Road in Uwchlan, Chester County, Pennsylvania (see **Figure 1**). A geophysical survey was conducted over accessible areas of the HDD exit/entry locations (**Figure 2**). The actual exit/entry areas were inaccessible due to wooden and plastic matting in the east, and inaccessible to ERI surveying in the west.

The site bedrock geology consists of Cambrian-aged Chickies Formation in the west (upstream) and the Antietam and Harpers Formation in the east (downstream). Karstified dolomite of the Ledger Formation lies south of the downstream entry/exit (The Geologic Map of Pennsylvania, PA Department of Conservation and Natural Resources Geology Interactive Map, 2017 – see **Figure 2**). The Chickies Formation is described as a light-gray, hard, massive, Scolithus-bearing quartzite and quartz schist with a thin, interbedded dark slate at the top and conglomerate (Hellam Member) at the base (Berg et al., 1980). Joint and cleavage planes display a blocky pattern, are moderately well-developed, moderately abundant, widely spaced and regular, and steeply-dipping and open (Geyer and Wilshusen, 1982). The Antietam and Harpers rocks contain light-gray, buff-weathering quartzite and quartz schist, and dark-greenish gray coarse-grained phyllite and albite-mica schist. In the Harpers schist, both joint and cleavage planes display a seamy pattern, are moderately developed, highly abundant, irregularly distributed and very closely spaced; and are open and steeply- to moderately-dipping. The Antietam quartzites have fractures similar to the Chickies (Ibid.) The Geologic Map of Pennsylvania (PA Department of Conservation and Natural Resources Geology Interactive Map, 2017) shows several contacts and major fractures and faults within one mile of these survey areas, as seen in the geologic inset on **Figure 2,** upper right (Ibid). There is considerable gain in elevation going north (upstream) from the site and location of seepage (see **Figure 1**).

The geology as mapped by the PA Geological Survey (inset on **Figure 2**) may be slightly inaccurate since a boring in 2017 (OW-1) on the map in **Appendix C** reportedly penetrated karstified dolomite despite lying with the mapped Antietam and Harpers. The contact as shown in **Appendix C** has been shifted northward (with unchanged strike) to include the OW-1 location, but exclude the geotechnical borings 360A and 360B which did not encounter karst. This map also shows the location of the seep, a saw cut for a diversion trench to capture turbid seep water, and the location of a depression that developed in an anomalous area from the January 2020 geophysical survey. Excavation of the trench and this depression did not reveal a sinkhole, and confirmed non-karst geology at this location.

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. Voids below the top-of-rock are not expected in the mapped gneiss bedrock.

The residual microgravity data are shown on **Figures 3A** and **3B**. The values depict the general plan-view shallow mass distribution beneath the survey area. Relative lower values (red) represent local mass deficiencies (air- or clay-filled voids, or locally deeper, disturbed or poorly-compacted soils). Higher values (blue) represent local mass excesses (shallow bedrock or erosional remnant float blocks). Specific survey parameters are listed in **Appendix A**.

SEISMIC MASW AND REFRACTION SURVEY

Seismic 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 velocities below the top of rock that might be associated with fracture zones. The principles of seismic refraction are summarized in **Appendix B**.

The seismic survey consisted of three profiles parallel to the 16-inch alignment (see blue triangles, **Figure 2**). Color-contour velocity models of the seismic profiles for the seismic refraction and MASW are presented on **Figures 4** and **5,** respectively. 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 P-wave velocities for refraction, and shear or S-wave velocities for MASW), with increasing velocities from blue to yellow to orange to brown (seismic refraction profiles, **Figure 4**), and purple to grey to tan to brown (seismic MASW profiles, **Figure 5**). 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 into 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 the measured apparent resistivities along a profile (or profiles, in the case of 3D resistivity).

Due to site access limitations at the western entry location and on the eastern portion of the exit location (Shoen Road), a 2D resistivity survey was performed only on the eastern portion of the HDD (see orange dots, **Figure 2**). The apparent resistivity data were mathematically inverted using EarthImager 2D by AGI to provide a resistivity model of the subsurface. **Figure 6** shows three resistivity profiles. Specific ERI survey parameters are listed in **Appendix A**.

RESULTS

The microgravity data are depicted on **Figures 3A** and **3B,** as plan-view 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 data display a subtle alternating pattern of high- and low-gravity anomalies perpendicular to the pipelines. These gravity highs and lows could represent an alternating pattern of deeper and shallower rock, with the gravity lows representing deeper (and possibly less dense) soils, indicative of fracture zones. These areas would present a slightly elevated risk for potential subsurface soft zones, as well as possible pathways for water or drilling fluid migration. There are negative (low density - red) anomalies over the pipeline at 15078+25 and adjacent to the pipeline at 15057+50, and from 15078+40 to 15078+90. The low at 15078+25 correlates with a soil pile over which gravity data were collected. There are also negative (low density - red) anomalies over the pipeline at 15080+00 to 15081+00, just short of 15081+50, and on the southern edge of Shoen Road. 15081+50 may be roughly where the HDD emerges from high-velocity material (rock). These anomalies are roughly coincident with those detected in the previous (January 2020) geophysical survey.

The seismic refraction data are presented as cross-sectional profiles on **Figure 4**. The data indicate a general three-layer stratigraphy consisting of a residual or sedimentary soil mantle, a weathered rock 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 25-35 feet. This is consistent with a relatively compact 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 seismic refraction results show multiple low-velocity zones indicative of possible fracture zones. The suspected fracture zones are highlighted in magenta on the seismic profiles.

The MASW seismic cross sections are presented on **Figure 5**. The MASW velocity models show lateral velocity changes within the bedrock layer across the profiles and are relatively consistent with the seismic refraction models. Low-velocity zones below the bedrock surface could indicate fractures but are not indicative of open voids.

The electrical resistivity results are shown in **Figure 6.** The electrical profiles show a general three-layer model with a relatively conductive surface layer over a discontinuous mildly resistive layer over a more conductive layer. The upper layer is relatively discontinuous, with irregularities that could represent near-surface disturbances given the site development history. The deeper conductive (blue) anomalies below the inferred top-of-rock may represent water- or clay-bearing fractures or weathered seams within bedrock. Some of the low resistivities are on the south end of the profiles and extend from roughly where the HDD may emerge from rock to the south end of the site on Shoen Road – where seepage has been observed. The anomaly amplitudes are reduced (i.e. higher resistivity) since the January 2020 survey, suggesting reduced seepage from the HDD. A low-resistivity anomaly just uphill (north) of the seep (see **Figure 7A**) may be the source of the seepage and an August 2020 IR.

CONCLUSIONS

In general, the geophysical survey results display anomalies along the alignment indicative of fractures that are possible locations for slightly-elevated subsidence and IR hazards. **Figure 7A** summarizes the anomalous areas with various colored double-arrows and hachures. Overlapping and/or adjacent arrows, and the gravity mass-deficiency anomalies (red hachures) indicate the highest risk of subsidence and possible fluid migration. **Figure 7B** is the Results Summary from the February 2020 survey for comparison. Areas A, B, and C on the February 2020 results roughly coincide with A', B', and C' from this survey (**Figure 7A**). The depression that appeared in June 2020 was on the eastern end of Anomaly C/C'. Excavation of this during installation of the seepage capture/diversion system revealed that there is no karst bedrock. A boring from 2017 (OW-1 – see location on the map in **Appendix C**) did encounter karstified dolomitic bedrock, suggesting that the contact between karst and non-karst may not be as mapped by the PA Geologic Survey, but the karst does not extend to the HDD entry/exit or anywhere along the path. Anomaly C from the February 2020 geophysical survey (**Figure 7B**) was investigated in June 2020 through geotechnical Borings 360A and 360B (see **Appendix C**). These did not encounter karst features or geology. Both encountered very loose, low blow-count material to depths of about 12 feet. The underlying material was more dense and stiff, suggesting that the anomaly source is surficial. RETTEW recommends further geotechnical investigations in the two remaining anomalies (A/A' and B/B'), as well as continued monitoring of these as further drilling is conducted. The resistivity profiles are consistent with water emerging from the HDD near where it emerges from rock and contributing to the seep slightly downhill. However, higher resistivities now than in the previous survey suggest reduced seepage.

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.

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.

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Enclosures
Figure 1: Topographic Basemap
Figure 2: Data Coverage Map and Geologic Setting
Figure 3A: Residual Microgravity Results – Upstream (West) End
Figure 3B: Residual Microgravity Results – Downstream (East) End
Figure 4: Seismic Refraction Profiles
Figure 5: Seismic MASW Survey Profiles

Figure 6: Electrical Resistivity Survey Profiles
Figure 7A: Geophysical Survey Results Summary – Fall 2020
Figure 7B: Geophysical Survey Results Summary – February 2020
Appendix A: Geophysical Survey Parameters
Appendix B: Introduction to Seismic Refraction
Appendix C: HDD and OW-1 Location Map

References

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

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