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717-854-2641

Project: BGE Russett to Tipton

Location: Fort Meade, MD

Project Details:

Aaron Enterprises, Inc. was contracted to install 23,000 LF of 30” diameter HDPE conduit bundles for 230kV electric lines by HDD. The crossings were installed as three separate parallel installations ranging from 1,100 LF to 2,600 LF. Several environmentally sensitive features with a fixed inadvertent return (IR’s) disturbance area were crossed. AEI employed a comprehensive instrumentation program that successfully reduced the risk and impact of IR’s while drilling. See attached paper presented at the ASCE Pipelines 2017 Conference below for more details.

Final Product: (5) 10”, (1) 4” HDPE Bundle

Geology: Hard sticky clay, 50 plus blow counts

Project Profile

Horizontal Directional Drilling

Completion Date

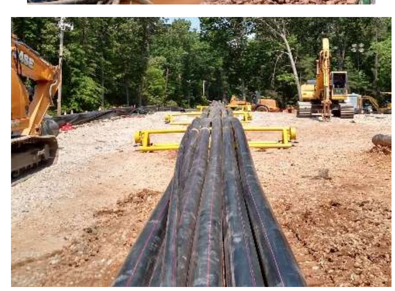
February 2018

Installation Methods:

Horizontal Directional Drilling
Pipe Ramming
Soil Stabilization
Grouting

Markets Served:

Electric



Owner:	Engineer:	Contractor:
Baltimore Gas & Electric	Brierley Associates/Black & Veatch	Argo Systems, LLC

For More Information:

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Reference Job # 1531146

Use of Downhole Instrumentation to Reduce Risk of Inadvertent Return ("Frac-Out")

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Abstract

For a large-scale, multi-phase cable installation located in central Maryland, HDD has been used to install new duct bundles to reduce surface disturbance associated with open-cut construction. Complex geologic conditions and excessive downhole pressures have caused significant fracouts (inadvertent returns) during previous project phases, resulting in excessive cleanup costs and permitting delays. To reduce this risk, the project team has implemented a comprehensive instrumentation program for 15 new HDD bores. This includes instrumenting the pilot rods, and reamers. The instrumentation allows the project team to monitor rate of penetration, pump rates, tool torque, and downhole pressures during all aspects of drilling, including pilot hole development, reaming, and duct bundle pullback. Data collected is provided in real-time to all team members using wireless links for immediate evaluation. The instrumentation, coupled with a site-specific drill fluid design, has allowed immediate response to elevated annular pressures, significantly reducing the incidence rate of fracouts. The data collected also allows evaluation of the contractor's activities, from the standpoint of drilling efficiency.

This paper provides a summary of the HDD installations, the instrumentation used, and the benefits and lessons-learned from real-time downhole data acquisition.

PROJECT BACKGROUND

Baltimore Gas and Electric recently completed installation of a new underground 230kV electric cable distribution system in south-central Maryland. The cable alignment passes through numerous upland wetlands, and crosses the Little Pawtuxtent River, which is a tributary to Chesapeake Bay. The Patuxent River was designated as a scenic river by the Maryland General Assembly, and is targeted for protection by the Maryland Department of the Environment (MDE). To minimize environmental disturbance, and to meet MDE permit requirements, five (5) separate sections of the cable alignment were designated for trenchless construction during project planning.

TRENCHLESS DESIGN

The five designated trenchless sections ranged in plan length from about 1,100 to 2,600 feet. The ampacity requirements of the proposed cables required that each trenchless section include three (3) separate and parallel installations. Each installation would require a duct bundle approximately 24 inches in total diameter. Based on these criteria, horizontal directional drilling (HDD) was identified as the preferred trenchless installation method for the project during planning stages.

A series of sampled test borings was completed to support design of the HDD installations. Each boring was drilled to a depth of 60 to 75 feet below grade, and sampled with split spoons at 5-ft vertical intervals. The samples retrieved from the test borings revealed a complex stratigraphy of interbedded gravel, sand silt and clay, which were interpreted to represent Coastal Plain deposits of the Pawtuxent Formation. These geologic materials range dramatically on density, from very soft to hard, and contain occasional cemented horizons.

Previous cable installations completed in this vicinity by HDD have experienced significant inadvertent surface returns (IR). In many cases, mud motors and elevated pump rates are required to penetrate the hard clay layers, but the interbedded soft soils provide limited confinement for the annular pressures which may be developed. Significant, recurring IR's have been observed during pilot hole drilling, as well as borehole enlargement by reaming. In many cases, the frequency and magnitude of these IR's has not been significantly reduced by use of Loss Control Materials (drill fluid additives intended to stop fluid loss).

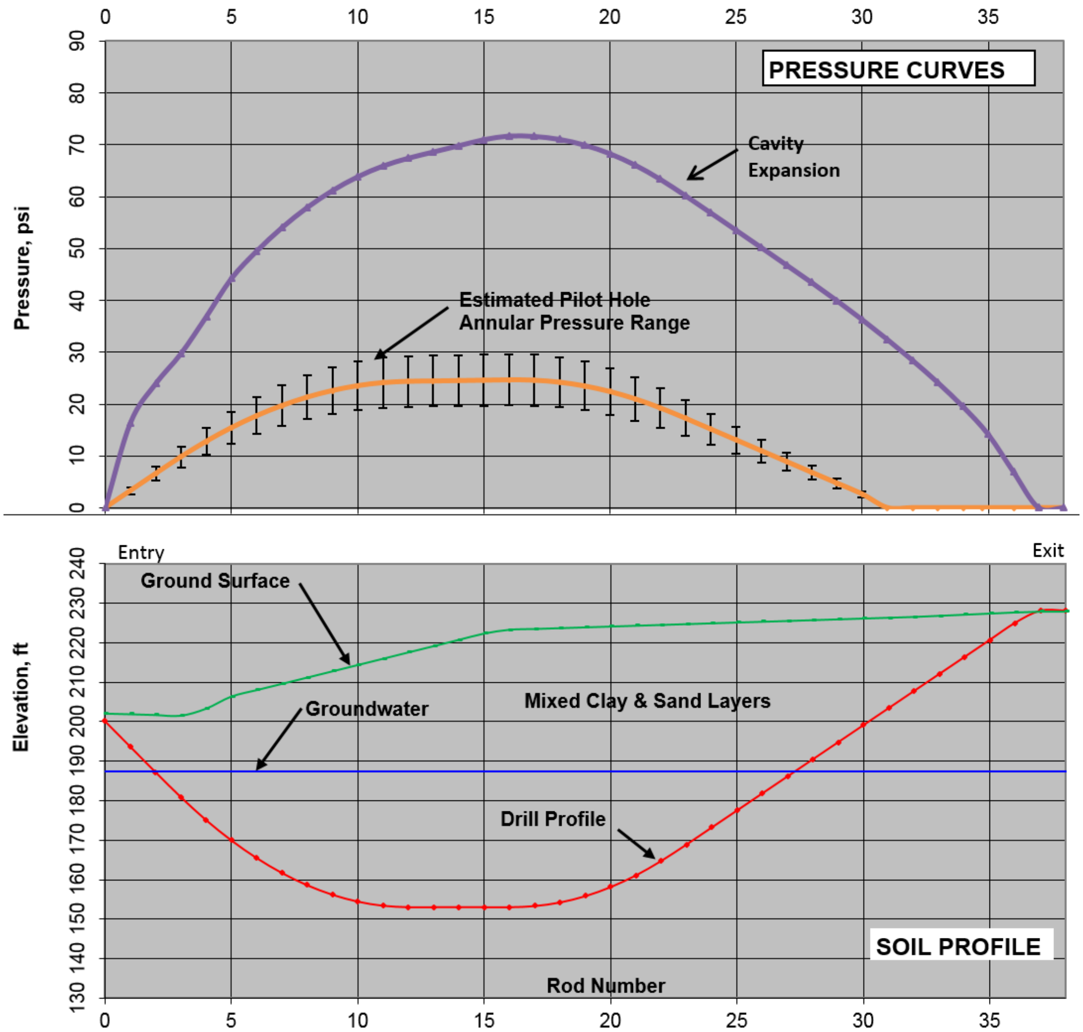

Figure 1: Top Graph - Example comparison between the anticipated range of downhole annular pressures required to complete the borehole (orange), to the anticipated confining capability of the surrounding soils (purple). Bottom Graph – Drill profile relative to existing ground surface.

For each of the crossing locations, the estimated confining capabilities of the subsurface conditions were modeled using information obtained from the test borings, and the criteria recommended by the HDD Consortium. The anticipated range in downhole annular drill fluid pressure was also developed for comparison. An example annular pressure comparison is shown in Figure 1.

In each case, a pressure comparison model similar to that shown in Figure 1 was used to develop a borehole geometry intended to reduce the risk of drill fluid loss. The ultimate depths of the bore designs ranged from about 65 to 75 feet below existing surface grade. A center-to-center bore spacing of 20 feet was employed to ampacity requirements, and to maintain right-of-way constraints.

The design team elected to require a wireline tracking system, to ensure the Contractor would be capable of maintaining the design bore geometries. This requirement was included in the project specifications. In addition, the Contractor was required to provide downhole annular pressure monitoring during pilot hole drilling for each HDD bore, to ensure that the threshold confining pressures established during the design not be exceeded.

A requirement for a third-party drill fluid specialist ("mud engineer") was also specified. The mud engineer would be responsible for designing, testing, and modifying the drill fluid during construction.

The project was bid in 2015, and awarded to Argo Systems LLC (Argo). Argo elected to utilize Aaron Enterprises Inc. (Aarons) to complete the HDD installations.

INSTRUMENTATION SYSTEM

Historically, downhole pressure monitoring has been completed using a wireline connection to a pressure sonde located behind the drill bit. This employs a wireline located in the center of the hollow drill rods, which is also connected to the steering tool. The annular pressure developed in the hole annulus are recorded manually by the steering hand. The disadvantage of this is that it only allows annular pressure monitoring of the pilot hole process. In addition, the data is only available to the steering hand, whose primary purpose is monitoring the pilot hole orientation, not the annular pressure. Consequently, monitoring of the annular pressure often becomes secondary to steering. In addition, it may not be possible for the Owner's site representatives to easily view the annular pressures in real time, and comparison to the established limits can be difficult.

Aarons proposed a comprehensive instrumentation system to facilitate monitoring and report of annular pressures developed during construction. The system selected consisted of the Inrock Crossview System, which is capable of monitoring and recording various data in real time, and conveying this data to the desired recipients be means of a wireless remote. Aaron's proposed to use this system to facilitate data transfer, and allow direct input from the design team during drilling, in the event elevated borehole pressures were observed.

For this project, the instrumentation system was configured to provide following data related to drill fluid management:

- Borehole annular pressure monitoring during pilot hole drilling;
- Borehole annular pressure monitoring during reaming and product pullback;
- Drill fluid pump volume;
- Drill fluid pump pressure;
- Drill fluid pump strokes and total strokes;
- Drill fluid pit volume (drill fluid); and
- Drill fluid pit volume totals

In addition to these data, the instrumentation system for this project was also configured to measure the following data:

- Bit location (using Paratrack steering System)
- Force on Bit (FOB);
- Rate of Penetration (ROP);
- Thrust Force;
- Pull Force;
- Rotary Torque;
- Spindle Rotation Per Minute & Count; and
- Bit/Reamer Cone Revolutions.

Each of the recipients designated for data access was provided with a software application whereby the data could be viewed by desktop computer, or cell phone.

CONSTRUCTION

HDD construction for the project began during the early spring of 2015. Aaron's utilized two drill rigs to complete the installations, an American Augers DD-220 and 440. Both of these rigs were equipped with the instrumentation system, as described above. In each case, a mud motor was utilized for the pilot bore to provide penetration in the full suite of subsurface materials present. The pump rates required to operate the mud motor ranged from about 300 to 400 gallons per minute.

In most cases the holes were reamed to a diameter of 36 inches, usually through a combination of push and pull reaming. It was found that PDC reamers were more effective than rollercone and fly cutter reamers, which had a tendency to clog and "ball up" due to the clayey soils.

The pressure sonde during pilot hole drilling was typically 41 feet behind the bit. During reaming, the sonde was typically 61 feet behind the reamer. In some instances, elevated pressures reported by the sonde were attributed to blockage of the ports by clay (requiring rod retraction and cleaning)

The drill fluid specialist selected by Aaron was On-site Drilling Solutions, Inc. (On-site), who were responsible for development of the drill fluid design. On-site was also effective in providing recommendations related to penetration rate, to optimize cuttings carrying capacity of the drill fluid, and to reduce annular pressures.

DRILL FLUID PRESSURE MONITORING AND MANAGEMENT

The instrumentation system allowed direct monitoring of the annular pressure in real time, and comparison to other pertinent data, which often included changes in pump rate, rate of penetration, and pit volumes (which provided a means of tracking uphole fluid returns. This amount of data, which was generated during all stages of drilling (not just during the pilot), allowed a much clearer understanding of the ground behavior, and allowed the driller to respond in real time to variable ground conditions, and elevated annular pressures. It also allowed all necessary parties to observe the data in real time, which facilitated communication during drilling.

Periodic elevated annular pressures above the anticipated range were observed in most of the bores. By closely monitoring the data collected during the initial pilot hole and reaming passes, it was determined that many of the pressure spikes were generally related to the presence of soft clay layers, which had a tendency to squeeze into the hole, decreasing the annulus for drill fluid flow. This scenario was often signaled by a steadily increasing annular pressure, which in some cases (although not all) was accompanied by increase in corresponding rotary torque of the drill string. These pressure spikes were typically addressed by completing a partial swab pass, typically within 3 to 4 drill rods of the face of the borehole, which reestablished the desired annulus, and compacted the adjacent soils. This process is shown graphically in Figure 2, which shows occurrences of annular pressure spikes during the initial portion of a pilot hole (red dots), and the corresponding pressures (green dots) following a partial hole swab.

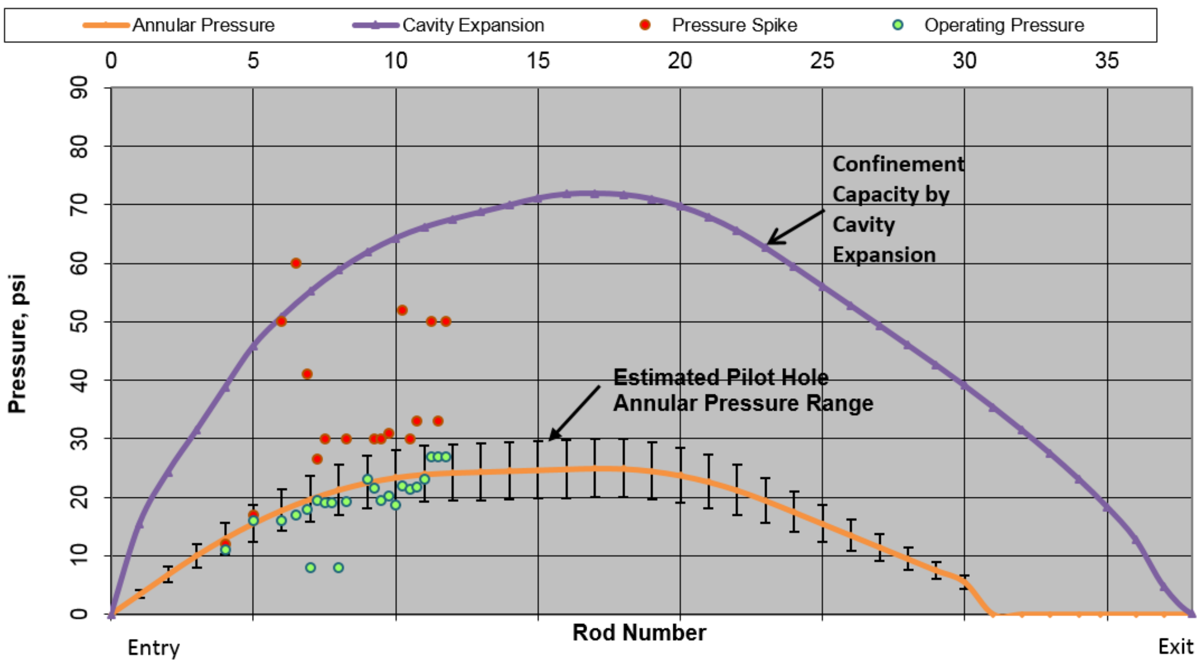

Figure 2: Elevated pressure spikes (red dots) and corresponding pressures following partial swab. Data collected during initial portion of pilot hole drilling, single bore.

A similar although more extreme condition involved development of linear clay cuttings (“ribbons”) during reaming, typically in stiffer clays. This generally occurred when using PDC-type or fly-cutter-type reamers, which had proven more effective than roller-cone reamers in the cohesive materials. This scenario was typically signaled by sudden elevated annular pressures, which were not eased by limited swabbing. In these cases, the driller was often forced to slowly pump from the bottom hole (without advancing the drill string), or completely retracting the drill tools, allowing removal of the clay ribbon blockage. An example of this process is shown in Figure 3, below.

Figure 3: Clay "ribbon" removed during reaming, through tool retraction.

It was also determined the loss of returns could be associated with duration that the elevated annular pressures we allowed to persist. In general, annular pressures within or exceeding 90% of the estimated confinement had a much greater chance in resulting in loss of returns if allowed to persist for greater than 5 to 10 minutes, than those situations where elevated pressures were addressed quickly through swabbing or tool retraction.

Use of the instrumentaion system also allowed accurate identification of locations where the ground may have been disturbed during drilling, as noted through prolonged annular pressures, coincident with lost returns. This allowed the driller to treat these potentially "damaged" areas with care during subsequent reaming passes, (e.g., through reduced pump rates) reducing the potential for additional unnecessary disturbance.

Some minor IR's were observed during initial stages of the project. In most cases these were confined to shallow portions of the bore, where the soil confining capabilities were limited. In order to reduce this potential, Argo/Aarons elected to install 48-in diameter entry conductor casings with a pneumatic pipe ram in the bores where wetlands were proximal to the entry or exit.

An added benefit of the instrumentation system utilized was that the data generated during drilling was recorded, along with a written dialogue provided by the driller. This allowed for weekly distribution in the form of summary reports, allowing for future evaluation and analysis.

SCHEDULE IMPACTS

While use of the Crossview system allowed the Contractor to better understand the ground response, and reduce the risk of IR's, this came with an associated schedule impact. This was observed in at least four (4) forms:

1. Use of the downhole system requires assembly of the wireline and maintenance of the pressure sonde during all aspects of the bore, not just the pilot process. The wireline must be physically assembled (or dissembled) when adjusting the length of the drill string. Depending on the experience of the drill crew performing this task, assembling the wireline may add between 5 and 15 minutes to each drill joint.
2. Similar to the pilot process, any malfunctions in the pressure readings noted during reaming require partial or full retraction of the drill string to fix and wireline, or check the pressure sonde.
3. The additional data takes time to process, and requires additional communication between the driller, the mud specialist, and the Owner's representatives.
4. Addressing annular pressure spikes may take time, either through modifications in advance rate, swabbing, or full tool retraction.

Ultimately, it was estimated that use of the instrumentation system added approximately 30% to the overall project schedule. The most significant schedule impact was associated with #4, as the contractor was required to address pressure spikes, relative to the established pressure limits.

Use of a similar instrumentation system for projects with with less environmental risk, and/or more favorable ground conditions would be expected to have less schedule impact.

CONCLUSIONS

Use of a comprehensive instrumentation system (Crossview system) during drill is believed to have significantly reduced the occurrence of inadvertent drill fluid returns to ground surface. The instrumentation, connected to the drill string by means of wireline, allowed the driller the ability to evaluate the ground behavior in real time, enabling modification of means and methods "on the fly".

Data collected was provided in real-time to all team members using s wireless links, which greatly improved information transfer, and communication between the Contractor, and Owner's representatives.

REFERENCES

MDE Document Entitled "Prioritizing Sites for Wetland Restoration, Mitigation, and Preservation in Maryland. May 31, 2006".

Bennett, D. R., & Ariaratnam, S. T. (2008). *Horizontal Directional Drilling Good Practices Guideline* (Third ed.). Washington DC: HDD Consortium.