UNDERSTANDING GEOLOGICAL HISTORY FOR TRENCHLESS INSTALLATIONS:

Part 1: Effects of the Coastal Plain Barrier Islands on Long HDDs

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INTRODUCTION

On many large, engineered trenchless installations, it is imperative for the engineer to understand the geological history of the area, and determine the possible consequences and controlling effects the geology has on the proposed crossing. Deciphering the underlying geologic history (and local anomalies) drives selection of the best and most appropriate trenchless method.

Part 1 of this series looks closely at the complications associated with conducting long HDD crossings between and along the Coastal Plain Barrier Islands of the Southeastern US. An 18,000 LF installation of a 115-kV cable under Hamlin Sound SC will be reviewed in detail as a case example of the unique geological considerations associated with barrier island systems.

SELECTION OF TRENCHLESS METHODS

When undertaking new trenchless installation work, it is crucial that engineers and contractors understand how the ground may behave in response to a given trenchless method. Much of

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FOR EXPENSIVE AND LARGE-DOLLAR TRENCHLESS PROJECTS, EXTENSIVE GROUND CHARACTERIZATION IS TYPICALLY PERFORMED, BUT FOR SMALL-DOLLAR TRENCHLESS PROJECTS, ADEQUATE GROUND CHARACTERIZATION IS OFTEN OVERLOOKED.

the expected behavior is based on real-world experience and a fundamental understanding of ground behavior when a specific soil matrix is removed from the ground, or whether the ground has sufficient strength to support equipment and/or provide a good stable borehole to prevent inadvertent returns. Terms from the Tunnel-Man's Ground Classification Guide like "raveling" (slow and fast), "squeezing," and "running" (or similar terms) are used to describe the anticipated unstable ground and emphasize a potential area of concern.

For trenchless projects that are much closer to the surface, the major concerns are: weak overburden soils, weight-of-hammer (WOH) material (based on typical Standard Penetration Test (SPT) test boring data), nested cobbles, gravel with little fines, running ground, and squeezing or swelling ground that suggest unfavorable ground conditions. For expensive and large-dollar trenchless projects, extensive ground characterization is typically performed, but for small-dollar trenchless projects, adequate ground characterization is often overlooked, either due to lack of budget, a perception of low value for the upfront project cost, or from unfamiliarity and limited experience with trenchless installations and possible risks.

To many owners, a new trenchless installation project is just a line on a piece of paper. But there is much more to it. It is understanding construction risk and how to manage that risk and how the ground will behave based on a specific trenchless method. Thus, understanding regional geology and how the underlying geologic conditions were formed provides clues that inform the designer of anticipated ground behavior. For some projects, the ground changes can be hidden or unexpected, as often occurs with HDD projects drilling between the Coastal Plain barrier Islands off of the southeastern coast of the United States.

EFFECTS OF BARRIER ISLANDS ON LONG HDD

Barrier islands are long, narrow, offshore deposits of sand or other sediment that typically parallel the coast line and are built by longshore drift and onshore currents (see Figure 1). The islands are characteristically separated from the mainland by a shallow sound, bay or lagoons, (Figure 2). These shallow, ecologically-rich sounds may be one-half to several miles wide, although there are a few exceptions (such as the North Carolina Outer Banks). Coastal sand movement forms barrier island complexes when three conditions are met:

- There is a supply of sand sufficient to form islands;
- sea level is rising or generally stable; and
- there are winds and waves with sufficient energy to move the sand from offshore to onshore.

Figure 1 - Former continuous barrier island split in half due to hurricane washover and breaching action, near Ocean City, MD (from TeachOceanScience.net)

Wind-blown sand on these barrier islands form the well-known sand dunes on the lee side of the beach ridge. These sand dunes also are submerged in the shallow sounds between the islands and the mainland, and can migrate landward on top of lagoon deposits, especially in storm conditions. If not interdicted by man-made features, the barrier islands move and migrate over time, due to wave and wind action. A good example of this is Ocean City, MD. A hurricane in the 1920s broke the island in half due to storm surge and overflow of the island. The sands from the overflow are now within the sound behind the barrier island complex and can be seen moving over time as water depths change. For trenchless HDD crossings, this loose, saturated sand makes for difficult borehole stability issues.

The barrier islands can also move seaward leaving submerged former sand dunes or barrier island complexes in the sounds. Successive, coast parallel barrier beaches such as those found at Hamlin Sound north of Charleston, SC are formed as the water moves offshore during periods when sea levels are dropping. Each beach ridge reflects a temporary halt in the overall retreat of the sea level, and are related to global sea level changes, rather than rising land masses.

The shallow sounds, bays, and lagoons behind the barrier island become filled with soft mud, peat, silts and sand deposits where ecologically-sensitive marshland is formed. Figure 2 below depicts the formation of this marshland ecological system. In the shallow bays and lagoons, marshlands are not only wildlife sanctuaries but also productive fishing grounds for oysters and crabs. Just inland of many of the barrier islands in the southeastern US, in the physiographic region termed the Coastal Plain, is the Intracoastal Waterway, an important maritime shipping corridor.

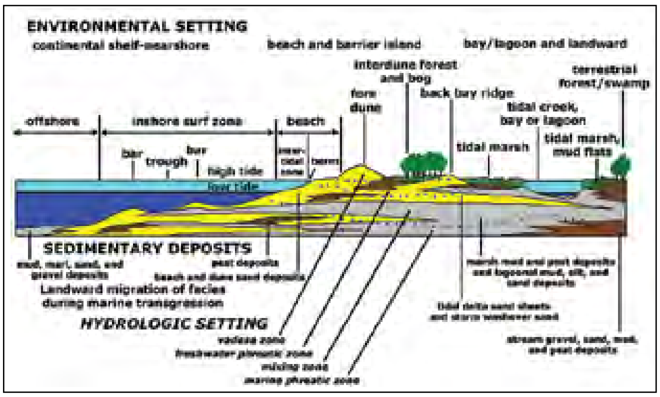

Figure 2 - The formation of Barrier Islands and inland sounds or lagoons yields complex, interfingering sedimentary relationships (from GeologyCafe.com)

Beneath the surface and within the sands there is typically a mix of fresh water near the surface; however, at deeper depths the groundwater is brackish because sea water is mixed in. Brackish water causes problems with HDD drill mud.

Barriers island systems are found all along the east coast from the New Hampshire coastline to the Texas coastline. They have increasing economic value as tourist attractions and as desirable locations to live. As a result of this increased population and the corresponding increase in electrical power demand, many energy suppliers are installing redundant underground cables between mainland sources and the barrier islands in order to maintain reliable power supply. This is done to mitigate and counter the disruptions caused when hurricanes damage and take out overhead power transmission lines. To economically and safely cross these ecologically- sensitive shallow sounds, bays, and lagoons, energy suppliers are increasingly turning to horizontal directional drilling.

CASE EXAMPLE: HAMLIN SOUND, SC:

Several years ago, South Carolina Electric & Gas (SCE&G) decided to install a 115-kV cable under Hamlin Sound between the mainland and the Isle of Palms. Although Hamlin Sound is only 12,000 feet wide at the crossing location, the actual borehole alignment required a 18,000 LF diagonal crossing. This was due to the substation location and the available workspace where barges with equipment could be placed within the environmentally-sensitive sound.

A key issue was that no drill length could exceed 7,400 LF due to the maximum length of spooled cable that could be transported to the site on a reel. This required strategically placing and building work zone platforms within the 7,400 foot maximum separation distance at locations within the shallow waters that could be accessed by barge and support boats. One of these temporary work platform is shown in Figure 3:

Figure 3 - HDD and cable splicing work platform within Hamlin Sound, SC situated in the marshland. The pipes carrying high voltage cables installed by HDD are being overboarded and buried below subsurface (Photograph courtesy of Pridmore and Varner/TD World.com)

A major area of concern requiring careful management was prevention of inadvertent drill fluid returns into the oyster beds and ecologically-sensitive marshland of the sound. Drills of this length require high downhole drill mud pressure to remove cuttings from the borehole. Geotechnical borings indicated a high potential for inadvertent returns due to the weight-of-hammer (WOH) material and loose sands, as shown on the subsurface profile in Figure 4.

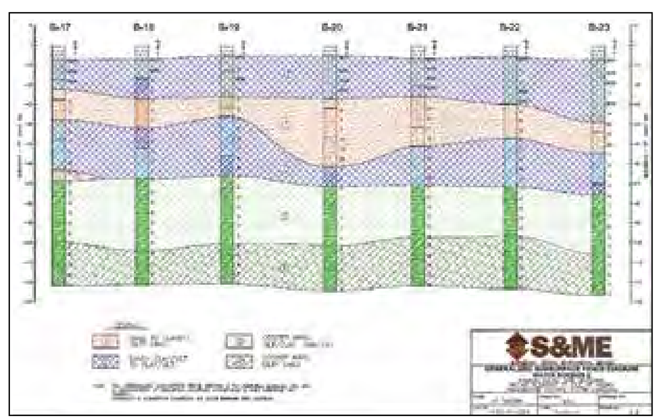

Figure 4 - Geotechnical data depicted on subsurface profile along HDD alignment below Hamlin Sound, SC (Courtesy S&ME)

As shown, the geotechnical borings indicated a geology of intermixed layers of clays, silts, peats and sand overlying a more competent deeper material known regionally as the Cooper Marl Formation. This weak overburden included 15 to 30 feet of very soft weight-of-hammer material overlying 15 to 30 feet of very loose to medium dense sands and clayey/silty sands before encountering deeper, stiff clays. The horizontal drill alignment was opportunistically designed to be in the more competent Cooper Marl formation. However, the weaker overburden led to challenges with alignment control, because the drill path had to

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exit to the surface in the middle of the sound where the geology was less able to confine the drill fluid pressures. As a mitigation measure, long steel conductor sleeves were driven from ground surface into competent ground and used in combination with the "drill-intersect" method. There were no inadvertent returns reported using these methods.

CONCLUSIONS

New trenchless installation work is not without risk. Small, low-dollar value projects combined with low exposure risk on some new installations may not necessarily warrant a detailed understanding of ground conditions, especially in areas of homogenous ground conditions not impacted by glaciers and coastal climatic actions.

However, for high-dollar-value projects, and high-risk projects, more than just a few geotechnical borings are required. Having a sound understanding of how the land mass and local geology evolved and formed provides a valuable understanding of how the ground may behave when pipe jacking, microtunneling, or selecting between a small-bore HDD versus large bore HDD. The ground can be very complex. It is not just a line on a piece of paper; understanding the geology and ground behavior when selecting a trenchless method typically leads to lower risk with an associated decrease in cost of that risk.

ABOUT THE AUTHORS:

Dennis J Doherty *is a Senior Consultant and the National Practice Leader for Trenchless Technologies at Haley & Aldrich, applying a total trenchless approach on microtunneling, HDD and other trenchless method projects for private sector energy clients. An ardent proponent of the benefits and value of trenchless methods, Dennis has a unique understanding of risk management as it relates to trenchless design, having worked on a number of innovative projects across the US. He serves on the NASTT No-Dig Show Program Committee and is an instructor for NASTT's HDD Good Practices Course. Dennis is proud to be Past-Chair of the NASTT-NE Chapter.*

Bradford A Miller *is Senior Geologist at Haley & Aldrich, whose expertise is the geologic interpretation of complex soil, rock and groundwater conditions as they influence a broad variety of geotechnical projects, including trenchless utility construction, pipelines, linear energy corridors, highway rock slopes and foundation construction. He has served as President of the New England Chapter of the Association of Engineering and Environmental Geologists (AEG).*

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