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Peninsula Light – Hale Passage Crossing

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ABSTRACT: The Peninsula Light Companies' Hale Passage Crossing installed a 3,850 foot 15kV primary feeder cable to Fox Island using HDD construction methods. The alignment of the 12-inch casing and inner-duct cable bundle crossed the Puget Sound at a depth of 180 feet, beginning and ending in high end residential neighborhoods directly adjacent to Puget Sound. Launched from a shoreline neighborhood on Fox Island during the middle of the rainy season, the project required avoiding impacts to an adjacent brackish tide pool identified as a sensitive marine habitat while minimizing inconveniences to the neighbors. The glacially derived geology made the crossing challenging as highly variable soils and artesian aquifers were encountered, each posing different challenges for the contractor. The project highlights the collaborative efforts of the Owner, Engineer, and Contractor to overcome these challenges, work with the neighbors, construct the bore, and grout artesian water bearing zones that surfaced through the borehole. The fast tracked project was designed, permitted, constructed, and made operational within an 11 month period ending an emergency power condition for the resident of Fox Island a few weeks before the peak tourist season. This $ 2.5 million on-budget project was the largest capital expenditure in the 80 year history of Peninsula Light.

1. INTRODUCTION

To bore, or not to bore? That was the question faced by the Peninsula Light Company (PenLight), Gig Harbor, WA., when confronted with the replacement of an aged three-phase 600A submarine feeder cable that crosses the 3,500 foot wide Hale Passage from the Gig Harbor Peninsula to Ketner's Point on Fox Island, WA. This case study examines several challenges faced by the construction of the crossing and several of the strategies used to create a collaborative construction effort while minimizing Owner risk.

2. PROJECT SETTING

Fox Island, a residential island community approximately 3.5 miles west of the Tacoma Narrows Bridge is known for its high-end housing, picturesque views of Mount Rainier, and proximity to the Puget Sound. Within this idealistic "western Washington" setting, PenLight, a member-owned electric coop, provides electric service to approximately 30,000 customers in the Puget Sound area. The service area includes the Gig Harbor and Key Peninsula, and three islands: Fox Island, Herron Island, and Raft Island. Fox Island, the largest of the three, and Raft Island, are accessible by bridges; Herron Island is accessible only by ferry. The entire service area lies within the borders of Pierce County, WA, the second most populated county in the State of Washington.

Figure 1 – Hale Passage, Pierce County, WA.

3. PROJECT NEED

Electric power was originally supplied to Fox Island in 1930 when the island residents constructed a single-phase 7.2kV system. Once the distribution system had been installed on Fox Island, PenLight acquired the system and installed a single-phase submarine cable to serve the load. By 1950, the growth of the electric load on Fox Island prompted the installation of a two-phase 12.5kV submarine cable. To meet the continued growth of energy demand on Fox Island, a three-phase 600A submarine cable was installed in 1970 obviating the previous cable installations.

In 2008, PenLight recognized the vulnerability of the nearly forty year-old submarine cables, and initiated a replacement program. In June of that year, PenLight's Engineering Department commenced an analysis to determine water body crossing alternatives which would yield the most cost effective and least risky method to replace the aged cable. The alternatives included:

1. Replacement in kind with a cable laid on the sea floor (submarine cable),
2. Construction of an aerial crossing,
3. Open cut trenching, or
4. Utilizing horizontal directional drilling technology (HDD).

Of the four alternatives, only the submarine and HDD crossing were considered the viable means to accomplish the project. Further investigations were initiated including conducting a geotechnical investigation and detailed feasibility analyses for the two viable options.

4. FEASIBLITY ANALYSIS

To evaluate the HDD project, geotechnical investigations were performed on land near the proposed crossing alignment. Soil units encountered during the exploratory phase were sampled and tested at five foot intervals and at fasces charges from two shoreline exploratory borings. Soils were generally characterized as very stiff, overconsolidated glacial deposits of silt and clay with an intermediate layer of very dense gravelly sand. The very dense gravelly sand posed concern because the non cohesive properties and proximity to the shoreline bank contributed to a high risk of frac-out on the Peninsula side of the crossing. Though not encountered in the exploratory borings, large boulders, cobbles, and gravels were observed on the beach, indicating some potential for similar soils or rock to be encountered in the HDD alignment.

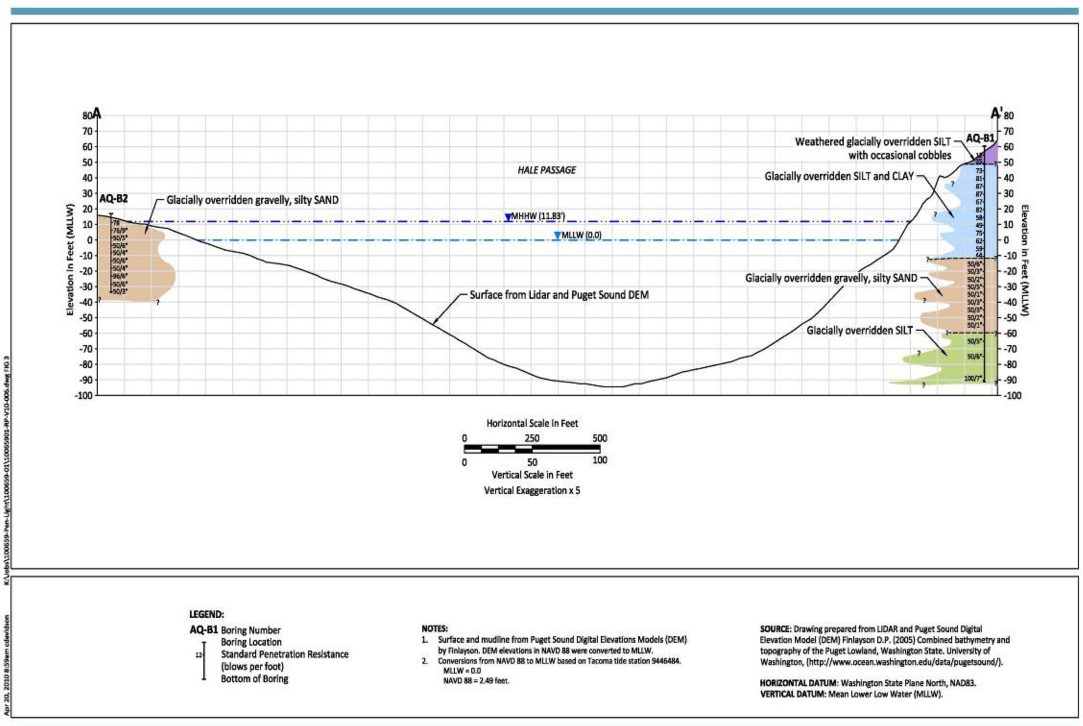

Figure 2 – Summary of exploratory borings.

A cost comparison was prepared resulting in the submarine crossing having a construction cost approximately 20-percent to 40-percent less than the anticipated cost of an HDD crossing. However, permitting for the submarine cable was estimated to take two years and could require additional costs to mitigate for shellfish and eel grass beds impacted by the trenched landings. An additional 20 percent contingency was added to the estimate for the submarine crossing to account for the uncertainty associated with environmental compliance. In the final cost analysis, the HDD option was anticipated to cost approximately 20 percent more, but could be permitted and ready for construction within one year. The HDD crossing also had several constraints that would need to be mitigated to reduce the risk of the project to acceptable levels including:

- project proximity and risk of fluid release into Puget Sound (approximately 200 feet from the entry);
- uncertain bathymetric features;
- lack of geologic data for the off shore segment of the crossing; and
- the presence of non cohesive soils (gravels) on the peninsula side of the Passage.

Benefits of the HDD crossing included achieving PenLight's goal to promote and advocate sustainable designs and useful infrastructure long into the future. PenLight also recognized that after a submarine cable's useful life span of twenty to thirty years, a similar investment would have to be made to replace the cable. In contrast, by using HDD to install a casing with inner-ducts, only the cable would need to be replaced should it fail, or if it is desired to increase capacity.

In the final analysis, reduced impacts to the Puget Sound, the surrounding environment, and a more favorable permitting window were considered major benefits of the HDD crossing. The sea floor "submarine" installation had unknown permitting and mitigation requirements for impacts to eel grass and shell fish beds.

With an HDD crossing identified as the preferred project, it was recommended that PenLight initiate offshore geotechnical investigations from a barge and/or conduct exploratory horizontal borings using a small diameter HDD drill rig to probe each side of the crossing.

5. CABLE SYSTEM FAILURE

On July 10, 2010, consideration for more project planning came to an abrupt end when the existing submarine cable to Fox Island suffered a failure. Due to the temperate weather, a secondary feeder circuit mounted on the bridge was able to carry the entire load of Fox Island, however, it was predicted that a single feeder to the island would be incapable of meeting winter heat loads. Investigations into the cause and location of the failure did not yield definitive results from which to affect a repair, but it was determined that only one of the four conductors had failed, allowing the cable to be reconfigured with the failed conductor serving as the feeder's neutral. The crossing was reenergized and allowed to continue to serve part of the Fox Island load. Because of the suspected frailty of the cable and the approaching winter heating season, an expeditious replacement of the failed cable was considered tantamount. The PenLight Board of Directors declared the situation an emergency, implemented conservation measures for Fox Island, and directed that the design and permitting of the HDD crossing proceed immediately. A shorter overall project schedule, reduced permitting requirements, and sustainability provided the overriding arguments for breaking from the 80 year tradition of supplying Fox Island power via a submarine crossing.

6. DESIGN PHASE

In August of 2010, PenLight initiated the design of the HDD crossing of Hale Passage. Condensing the project schedule, reducing potential for cost overruns, and minimizing construction risk were primary goals for the design team; while protection of Puget Sound, obtaining permits, and minimizing impacts to the project neighbors were PenLight's metrics for achieving a successful project. The shortened time frame added risk to the project by preventing PenLight from conducting in-water exploratory borings. Plans for mitigating the uncertainty associated with the site geology were discussed and worked into the project bid as discussed below. Bathymetry for the crossing was acquired from an Owner supplied boat equipped with GPS and depth finding equipment. By the end of October, the design of the Hale Passage crossing was complete. The crossing extended 3,850 feet including upland direct buried conduit facilities.

PROJECT CONFIGURATION

The project was configured to utilize the more rural area on the Gig Harbor Peninsula for the layout and assembly of the 12-inch casing, conduits, and cable reels while the drill rig and related HDD equipment would operate from Fox Island. This configuration would place the exit approximately 60 feet above the entry elevation and require having all fluids, cuttings, and heavy construction equipment located adjacent to the front yards of the Fox Island residents and 200 feet away from a sensitive Puget Sound tide pool. Additional area was included in the project area to allow for a drill rig set up on the peninsula side, if an intercept was determined to be necessary.

Figure 3 – HDD Exit on peninsula side

Figure 4 – HDD Entrance on Fox Island side

The Fox Island launch site was designed to reduce neighborhood inconveniences. All stationary engines and motors were required to be contained in a sound dampening enclosure and access to private property was required to be maintained at all times. Added protection was determined necessary at the entry site because the alignment crossed directly under a large Douglas Fir, a property owner's driveway access and garage, and the existing 200 foot reconfigured Fox Island feeder circuit. A conductor casing was incorporated into the design to provide the site necessary protections.

The site design included designating the locations for materials handling equipment, spoil stock piles, equipment and material staging areas, and fluid storage tanks. The resulting linear setup extended along one side of two adjacent blocks. Local residents and commerce were allowed to come and go without major disruptions to their daily lives.

STORM WATER BMPS

Recognizing that the project would occur during the upcoming winter and be subject to stringent Pierce County storm water regulations the design also incorporated local Best Management Practices (BMPs) into the site plan. Early in the design, it was determined that storm water discharged from the site had a direct pathway to a unique brackish tide pool that was identified as critical habitat for early marine life forms. Protection of this water body became the focus for the storm water BMPs. A redundant barrier separating the drilling site and the drainage system was devised that included the following:

- Spill containment was required for all stationary hydraulic equipment.
- Secondary containment was required around the mud pumps and drill rig.
- Site drainage was directed away from the construction site where waddles and gravel berms were located to allow collection of construction mud.
- The inlet to the storm water system was temporarily relocated upslope, away from the construction site.
- Geotextile linings, straw bale barriers, and rock filters were added to the site to capture, detain, and treat sediment laden runoff.
- The storm drain inlet directly above the discharge to the tide pool was isolated and a pump system designed to convey storm flows into the waste mud storage system when necessary.

EXPLORATORY PILOT BORING

Because the project timeline prevented Penlight from collecting additional geotechnical data from under the waterway, a bid provision was added to the main Contract to allow a small HDD drill rig to conduct an exploratory pilot bore. A three week exploratory drill program was allowed, which would include the contractor mobilizing onto the project site, even before final permits were cleared. The contractor was requested to probe the geology below the Hale Passage channel, achieving approximately 1,000 feet or more within the time allowed. The contractor was encouraged to address the uncertainty of the channel geology with the Owner willing to pay for the activity. It was anticipated that the Contractor would evaluate the soils near the alignment using various drilling tools and mud strategies without risking the loss of production during major construction operations.

7. BID PHASE

In November, the project was let for bid with the successful bidder for the project being The HDD Company, from Cameron Park, CA (Contractor). The contractor, who specializes in providing HDD services, submitted a bid as a general contractor with the responsibility of engaging sub-contractors to provide ancillary work such as entry and exit site preparation, conduit and vault installation, cable installation to the vaults, and site work and restoration. Purchase of the cable and the final cable termination in the vaults and tie in to the existing overhead circuits would be accomplished by PenLight crews. PenLight would purchase the cable from the Okonite Company out of Portland, Oregon.

The contract for the Fox Island Cable Crossing was awarded on December 23, 2010 for $ 1.90 million. The exploratory pilot bore bid price came in at $ 150,000. PenLight and the HDD Company, however, chose not to implement the exploratory bore, and instead chose to reserve the funds as a contingency for any difficulties attributable to the geology of the site.

8. PROJECT PERMITTING

During the design and bid phase, five local, state and national permits, and nine private, and one state occupation easements were secured over a six month period. PenLight also conducted several public information meetings to apprise the general public of the proposed construction activities and inform the residents near the entry and exit sites what to expect over the term of the project.

9. CONSTRUCTION PHASE

Construction commenced on February 14, 2011, with site preparation, sound panel assembly, BMP installation, and mobilization of the large array of equipment necessary for the project. The HDD Company mobilized their American Augers' 380,000 lb machine to accomplish the crossing. The steel pipe assembly was initiated first and included construction of the lay down area along 1,800 feet of Pierce County roadway. The assembled casing crossed seven driveways and required removal of several culverts and re-grading of ditches. The lay down site BMPs included installation of rock check dams, swale reconstruction, straw bale containment berms, and silt fencing.

Figure 5 – Lay down of 12-inch Steel Casing

The Contractor chose to install the 200 foot 24-inch conductor casing inside a short section of 36-inch casing. The secondary casing was provided by the contractor to provide additional protection from the 15KV circuit which was located one foot from the casing at its closest point. The 24-inch casing was centralized inside the 36-inch casing before being extended to its designed depth. A nine-inch pilot bore was initiated on March 12, 2011, and enlarged to eighteen-inches upon completion on April 20, 2011. During the pilot bore, the contractor utilized a Tensor steering system which provided rod depth and location data based on "Tensor Tool" technology. Annular pressure, rod penetration rates, and machine torque and thrust readings were also collected. Down hole pressure data proved extremely useful in helping the HDD Company avoid over pressurizing the borehole. Once down hole pressure increased to the predicted threshold (i.e. limit before frac-out), the contractor would trip out of the hole, adjust the return mud characteristics, swab and flush the hole, or all of the above. The exception occurred in the middle of the channel where gravels were encountered and circulation was lost causing approximately 500 feet of the alignment to be drilled without returns.

During the borehole construction, an engineering geologist was on site to monitor the progress of construction; collect, analyze, and record the properties of the drilling fluid (mud analysis); sample and characterize the cuttings; monitor down hole pressure records; and prepare an interpretation of the geology along the length of the bore hole. Data collected was shared with the Contractor and Owner each morning and throughout the day as data accumulated and trends became apparent.

Geologic data was interpreted from mud samples obtained from the mud pit. A 100 ml sample was collected at each rod interval and preserved for future reference. A second sample was collected for mud properties and screening through a 40 mesh sieve for interpretation of textural characteristics. Return mud samples were identified by date, time, and rod number. Testing for each sample included:

- Viscosity
- Return mud weight
- Interpreted soil type

As data accumulated, a record of the interpreted geologic formations encountered (i.e. silty gravelly glacial outwash, clayey gravelly glacial outwash, etc.) began to emerge. The geologic interpretation, while somewhat subjective, was collected along the recorded bore path and is shown in Figure 6. During reaming, the interpretation of the cuttings became clearer as larger samples provided more material for examination.

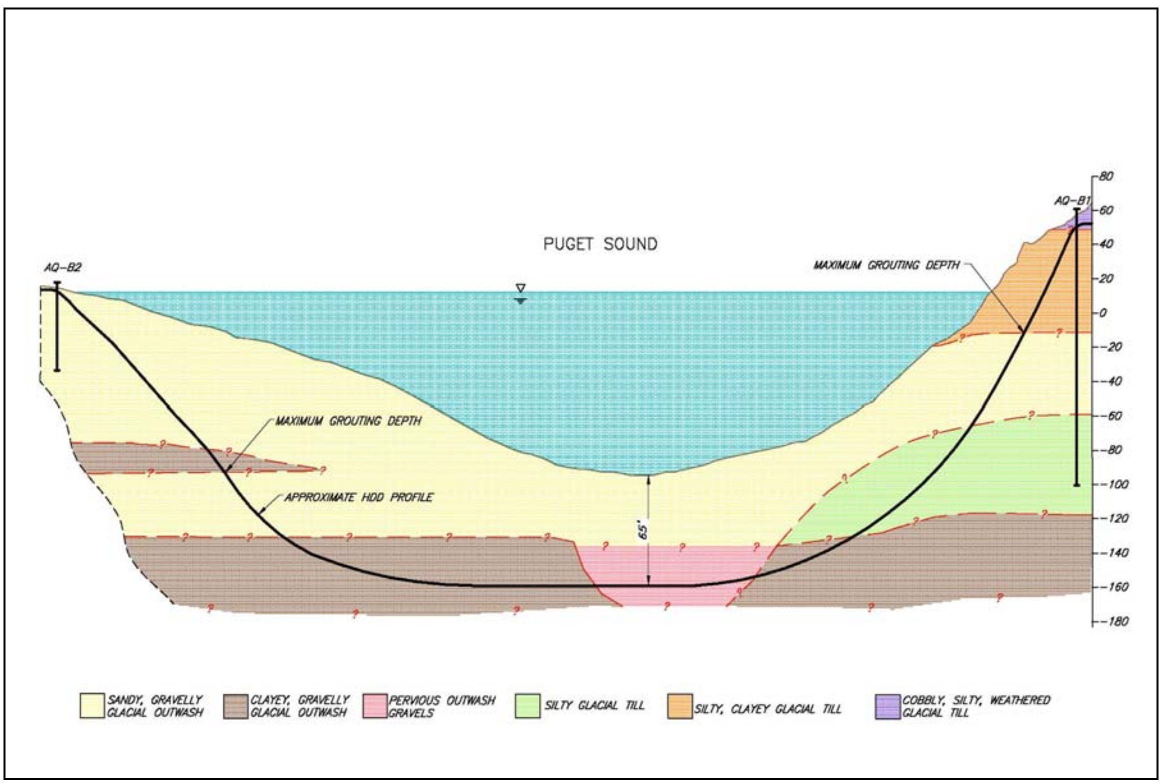

Figure 6 – Geologic Interpretation

After completion of the borehole, the 3,520 foot twelve-inch steel casing was pulled in three preassembled segments into the borehole from the peninsula to Fox Island. Once the casing was installed, a conduit bundle, consisting of five three-inch diameter and one two-inch diameter HDPE conduits was pulled into the casing. The conduit installation took place over six days.

Figure 7 – Roping in Steel Casing During Pullback

PROBLEMS ENCOUNTERED

Following the casing and conduit installation, but before the casing was plugged, groundwater began surfacing through the annulus of the borehole and exiting from around the outside of the conductor casing at a steady rate of 5 gpm. Surfacing of ground water set back the project. If allowed to continue, the constant supply of year around fresh water into the tide pool could potentially affect its habitat value and concern was raised over cross contamination of adjacent aquifers tapped by local residents. To make matters worse, the surfacing flow had entered the casing while the conduits were empty. The conduits had not been designed to withstand the hydrostatic pressure from a casing nearly full of water and, as suspected, they were later found to have collapsed.

As a first priority, a contingency plan was prepared to grout the borehole and seal-off the artesian spring as soon as possible. Using the interpreted geology as a guide, the contractor, engineer, and owner identified two locations along the bore plan requiring grouting. Observation of cuttings (clayey gravelly glacial outwash), torque and mud data suggested these areas provided a confining layer for deeper sandy gravelly deposits that could not be ruled out as water bearing zones. One location was on the Fox Island side approximately 500 feet from entry. The second was on the Peninsula side at the interface with gravels encountered during the preliminary exploratory borings.

A small drill rig was mobilized on site to send down a small diameter tremie pipe using drill rod as the shuttle and tremie and the product casing as a guide. Two grouts were formulated for the operation. One grout was designed at 14.7 lbs per gallon to plug the hole and the other a heavier mud at 18.5 lbs per gallon to seal off gravelly layers. With the tremie pipe shuttled below the confining layer, the lighter grout was pumped into approximately 50 feet of the hole, presumably up from the gravelly zone and into the confining layer. The plug was allowed to set over a three day period before the heavier grout was pumped down hole. As grout was pumped into the hole, the HDD

Company extracted the rod through the confining layer to the surface. After the grouting operation, the water flow had completely stopped. A second, similar grouting operation was performed on the peninsula side to seal off another gravelly layer even though surfacing of ground water was not observed.

While the grouting operation was underway, the contractor discovered (during pigging operations) that the conduits had collapsed from the hydrostatic pressure inside the casing. Several attempts were made to reinflate the conduits and retrieve the stuck pig before success was achieved. Flooding of the conduits and pressuring them to approximately 30 psi provided the necessary re-rounding pressure.

After demobilizing the drilling and grouting equipment, the conduits were re-rounded and extended to the termination vaults in preparation for the cable installation. Installation of the cables, which consisted of three primary cables (Okonite 1100 kcmil Al Okoguard EPR 15kV) and one neutral cable (Okonite 4/0 Cu EPR 600V) was completed on June 7, 2011. Installation loads never reached more than 80 percent of the anticipated pull capacity. Penlight crews completed the tie in to the existing overhead circuit after the cables were subjected to acceptance testing. The new circuit was successfully energized on July 14, 2011, exactly one year an four days after the old cable experienced failure.

The success of this project, which came in at a total project cost of $ 2.49 million (just under PenLight's budget), is attributed to the hard work of the project team. Special consideration is warranted for the exemplary cooperation, patience, and perseverance exhibited by the neighborhood who had the unique opportunity to observe the progress of this project from their living rooms.

Figure 8 -Fox Island Cable Crossing Project Entry and Exit Locations