Horizontal Directional Drilling and Jet Plow: A Comparison of Cable Burial Installation Options for a 115-kV Electric Transmission Line in Little Bay

Seacoast Reliability Project

Horizontal Directional Drilling and Jet Plow: A Comparison of Cable Burial Installation Options for a 115-kV Electric Transmission Line in Little Bay

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Table of Contents

List of Tables

List of Figures

Executive Summary

In April 2016, Eversource filed with the New Hampshire Site Evaluation Committee ("SEC") for approval to construct and operate the Seacoast Reliability Project —a new 115 kilovolt (kV) transmission line connecting the Madbury and Portsmouth substations ("SRP" or the "Project"). SRP is designed to improve the reliability of electric service in the Seacoast area of New Hampshire, specifically benefitting the region where the Project is located. SRP will be approximately 12.9 miles long and will include a combination of overhead, underground and underwater components. It will travel within or along existing electric utility corridors within portions of the towns of Madbury, Durham and Newington and the City of Portsmouth, and includes a submarine cable crossing from Durham to Newington under Little Bay ("Bay").

The Company conducted a detailed analysis of potential routes that the Project could traverse to connect the Madbury and Portsmouth substations. A detailed routing analysis concluded that, on balance, the proposed route for the Project, resulted in the least environmental impacts, had fewer constructability challenges and was least cost.

The methodology chosen by Eversource to install the submarine cables in Little Bay, known as "jet plow", was chosen following careful consideration of other potential methods. When compared with other available options, the jet plow method was proposed because it meets the Project's reliability objectives, was the most technically feasible option, its environmental impacts are primarily temporary in nature and it was the least cost option. The New Hampshire Department of Environmental Services recommended approval of the installation of the submarine cable using the jet plow methodology in February 2018. DES also recommended that additional information be provided regarding the feasibility of utilizing an alternative installation methodology described as Horizontal Directional Drill ("HDD"). The SEC has since requested Eversource perform a more detailed review of the alternative HDD installation methodology.

This supplemental analysis reviews and compares all components associated with the proposed jet plow installation and alternative HDD installation methods for both a full and shore landing HDD, including, engineering, construction, environmental effects, real estate requirements schedule and cost.

In summary, while avoiding some of the temporary environmental effects associated with the jet plow installation method, either HDD installation creates intrusive and widespread construction impacts to residents and businesses in both the towns of Durham and Newington. HDD requires use of much more land on either side of the Bay and for a significantly longer duration, resulting in substantial noise and visual impacts. HDD also introduces the additional risk of an Inadvertent Return (i.e., a release) of drilling fluids during drilling operations.

If HDD were used to install the cable under Little Bay, it would be one of the longest HDD installations in the country to date and would significantly increase the construction schedule. Depending on field conditions and the option chosen, installation would take from 10 to 28 months, significantly longer than the 3 months to install using a jet plow. As a result, the HDD installation options are also exponentially higher in cost.

The analysis supports and reinforces the prior conclusion that the jet plow installation method provides a better-balanced option for the SRP submarine cable installation enabling a reliable solution that employs a combination of avoidance, minimization and mitigation measures to ensure the sustainability of environmental resources. Furthermore, it protects the interests of the abutters, electric transmission customers and the public at large by enabling the Project to be constructed in a much shorter timeframe at a considerably lower cost.

1 Introduction

1.1 Project Background

Public Service Company of New Hampshire d/b/a Eversource Energy ("Eversource") is pursuing a Certificate of Site and Facility ("Certificate") from the New Hampshire Site Evaluation Committee ("SEC") to construct and operate the Seacoast Reliability Project—a new 115 kilovolt (kV) transmission line between the Madbury and Portsmouth substations ("SRP" or the "Project"). SRP will be approximately 12.9 miles long and include a combination of overhead ("OH"), underground ("UG") and underwater components. The route for the new transmission line traverses through the towns of Madbury, Durham and Newington and the City of Portsmouth (Figure 1). The route includes an approximate 0.9-mile underwater crossing within a charted cable area of Upper Little Bay ("Little Bay"), a portion of the Great Bay Estuary system (Figure 2).

SRP is required to address electric system reliability concerns in the New Hampshire Seacoast Region as previously identified by the Independent System Operator of the New England electric system ("ISO-NE"). Eversource, working with ISO-NE, assessed the New Hampshire and Vermont portion of the New England transmission system to determine whether the existing electrical infrastructure is sufficient to reliably deliver electricity under a wide range of system operating conditions and evaluated alternative solutions to address the identified deficiencies. These studies concluded that, among other projects to address system needs in the New Hampshire Seacoast Region, additional transmission capacity is needed to support the reliable delivery of electric power to meet the Region's current and future forecasted demand for electricity. SRP is the preferred solution to meet this need.

A detailed analysis was performed to identify the best route for a transmission line to traverse to connect the Madbury and Portsmouth substations. On balance, the proposed route for the Project, including the crossing of Little Bay, resulted in the least environmental impacts, fewer constructability challenges and was the least cost. A number of alternatives were considered for crossing Little Bay. Installing a submarine cable buried in the bay floor was deemed the preferred solution. The preferred method to install the cable was to use a "jet plow."

1.2 New Hampshire Department of Environmental Services

On February 28, 2018, the New Hampshire Department of Environmental Services recommended approval of the installation of the submarine cable using jet plow installation methodology and issued its permit conditions for the Project. Project. In addition to that approval, the DES provided a recommendation, that was adopted by the SEC, that Eversource "*provide a more detailed evaluation (with supporting information) that compares the feasibility as well as surface water and other potential impacts of the currently proposed jet plow method (including diver hand jetting) to the following two potential alternatives using the Horizontal Directional Drilling (HDD) method for installing cable across Little Bay:*

1. *Crossing of Little Bay using HDD within the existing cable corridor, and;*

2. *Using HDD within the existing corridor but only in the areas where hand-jetting is currently proposed*".

The DES further recommended the Company address topics associated with the design, construction and potential impacts, which are identified below:

- *"The evaluation should be based on information provided by contractors experienced with these methods of cable installation;*
- *The applicant should consult with and obtain details from the New Hampshire; Department of Transportation (NHDOT) regarding an HDD installation of a pipe; across Little Bay (Piscataqua River) in the vicinity of the Little Bay Bridge...*
- *For HDD installation the evaluation should also:*
    - o *Identify ways to reduce the size of the on-shore set-up areas, including, but not limited to, on-site butt-fusing of plastic pipe sections;*
    - o *Explain why a bore hole smaller than the 40 inch bore hole reported in the Application cannot be used for three 6-inch diameter cables;*
    - o *Provide information regarding subsurface conditions, the potential for frac-out, ways to minimize the potential for frac-out in surface waters and measures to minimize the effects of frac-out on surface waters should it occur;*
    - o *Provide information regarding disposal of material from the bore hole including the total volume and how it would be disposed;*
    - o *Explain why HDD cannot be conducted during normal work hours, instead of continuously (i.e., 24 hours per day) as reported in its application.*
- *Address potential surface water quality impacts that include, but are not limited to, impacts on existing and designated uses, the potential discharge of any pollutants and their anticipated fate and transport, whether water quality is expected to change and, if so, the estimated degree of change in water quality, and potential impacts on any high value resources.*
- *Address other factors that may impact feasibility such as impacts on local residents, time to complete installation, size of setup area, etc.*
- *If cost is the reason given for determining an alternative is not feasible, a detailed cost estimate should be provided from at least two companies experienced with jet plowing and two companies experienced with HDD.*
- *The evaluation should include the Applicant's final recommendation for installing cable across Little Bay."*

1.3 Technical Requirements

To design and construct with both jet plow and HDD, several components must be taken into consideration. The cable design must have an ampacity rating that allows the projected maximum current to flow between the substations under a variety of electrical demand and infrastructure (generators and transmission line in or out of service) scenarios. The installation of the cable must be conducted in a manner that protects the integrity of the cable. The cable should be buried at a consistent depth, avoiding twisting and excessive bending. The surface conditions and geology of the installation path must be analyzed to determine the density of soils and or bedrock for both subsurface and surface conditions to insure cable integrity per the cable manufacturer's installation requirements. Finally, appropriate work area requirements must be assessed to determine whether an installation methodology is feasible.

1.4 Purpose of Document

The purpose of this document is to address the DES recommendations and the SEC request to provide further analysis supporting Eversource's decision to use jet plow installation technology for installing the transmission line across Little Bay and to provide a detailed comparison of HDD technology with the proposed jet plow installation method.

These installation options are discussed in detail below.

2 Jet Plow and HDD Installation Methodologies

This section provides a general overview of the jet plow and HDD technologies.

2.1 Jet Plow

2.1.1 Design

The jet plow is laid on the seafloor and towed from a surface barge ("cable lay barge"; example provided at Appendix E to the Substitute Pre-Filed Direct and Amended Testimony of William F. Wall, dated March 29, 2017). The sizes of the barge and tender needed for jet plowing are relatively small and can accommodate the shallow waters and limited access to Little Bay. The main mechanical components of the jet plow are two skids which allow the sled to slide across the bottom, and an articulated blade which rotates down into the seafloor. The blade is fitted with water injectors along its leading edge that liquefy the sediment immediately ahead of the blade greatly reducing the force required to pull the plow forward. The cable is strung through the plow blade from the barge, and as the plow moves forward, the cable runs through the blade and is embedded at a pre-determined depth in the sediment.

2.1.2 Typical Uses

Jet plowing (also referred to as hydro jetting) is a common technique for installing transmission cables requiring burial in unconsolidated sediments. Typical areas are usually shallow waters (<150 feet) where active recreational or commercial boat and fishing activity result in the need for burial for human safety and to protect the cable from damage by anchors or fishing gear. Regional examples of its use include installation of a transmission line between New York and Vermont under Lake Champlain, which has similar surface sediments as Little Bay. This installation, comprised of four Lake Champlain cable crossings, was installed in 2018.

Jet plowing was also used to install a 25-mile section of the Neptune project, a transmission line located between New Jersey and Long Island, New York within the Raritan River/Raritan Bay. Jet plowing is a frequently used technology in the Hudson River/ New York harbor area, and was utilized for two transmission cables installed between New York and New Jersey across the Hudson River and New York Harbor, respectively. Eversource operating companies have used jet plowing to install marine projects, including the NSTAR Falmouth-Martha's Vineyard- hybrid transmission/communication cable in Massachusetts and the Long Island Replacement Cable Project, which passes adjacent to oyster reefs in Connecticut and New York. In addition, Eversource is proposing a 2.7-mile transmission line from South Boston, MA through Boston Harbor to Deer Island, utilizing jet plow and shore landing HDD installation methods.

2.1.3 Benefits

The benefits of utilizing a jet plow for submarine cable installations are rooted in its simple, yet robust, design. The jet plow blade, itself, is designed to minimize bottom disturbance to the least possible footprint necessary to bury the cable beneath the seafloor. Its overall weight is distributed over wide, long skid plates designed to allow the plow body to slide easily over the sea-floor leaving minimal depressions as it passes along the cable installation route. The volume of water being pumped through nozzles at the leading edge of the plow blade can be adjusted by the operator at the surface to allow for the minimization of surface sediment being suspended within the water column, thus minimizing the impacts of turbidity in the work area. Should any mechanical issue occur with the jet plow while in operation, the jet plow itself can be recovered to the lay barge, repaired, and redeployed without issue.

The most prevalent benefit of utilizing jet-plow technology on submarine cable installations is the speed at which the jet-plow performs simultaneous cable lay and burial operations. Jet plow is the most efficient way to install a buried submarine cable. Jet plow installations typically span a few days versus months or years compared to HDD installation. Due to the speed at which a jet plow can operate, the installation timeframe allows for the rapid settlement of suspended sediments in affected area, and abutting residents and the recreational and fisheries communities to resume their normal activities as quickly as possible.

Finally, the cable system utilizing a jet plow installation, has been designed to allow for the quick and efficient location of a submarine cable fault for immediate repair should a cable break ever occur. The 30-foot separation of each phase line will not only allow for the safe passage of the jet plow with each subsequent installation run following the last, but will allow for future fault location and cable repair operations without having to disturb either of the other phase lines. All fault location and repair operations could be quickly performed with a repair barge and dive team operating and the damaged section of cable could then be easily replaced with a new cable section spliced into the existing phase line.

2.1.4 Challenges

The challenges associated with jet plow burial are minimal. The main concerns are underwater obstacles such as boulders or commercial shipping debris such as wire ropes, neither of which are anticipated to exist based on the marine route survey data already collected for the work area. In the event that a boulder or debris is encountered, the jet plow operations are suspended until the obstruction can be removed or circumvented.

2.1.5 Impacts

Impacts from jet plowing are typically temporary and relatively minor. The pressurized water jets on the leading edge of the plow facilitate installing the cable in a small footprint, but also result in some of the sediments going into temporary suspension in the water column. These suspended sediments settle back on to the bay floor over time. The settlement rate is dependent on particle sizes and currents. Large particles such as sands settle out of suspension rapidly and generally close to the jet plow site. Smaller particles such as silts and clays can be carried farther by currents.

The environmental issues evaluated when assessing impacts from sediment suspension can include the following:

Water Quality—sediment particles may become suspended in the water column resulting in turbidity, which can block sunlight penetration. Many states, including New Hampshire, have water quality standards that include turbidity thresholds. The NH Water Quality Standards state that turbidity in Class B waters, such as Little Bay, shall not exceed 10 National Turbidity Units (NTU) over background (Env-Wq 1700.11). The available turbidity data in the Great Bay estuary is highly variable and dependent on location, ranging from less than one to 200 NTUs, with more typical readings below 20 NTU. Typical readings in the Oyster River tributary are higher, but generally less than 50 NTU.

- Sediment Quality—if pollutants such as mercury or polychlorindated biphenlys (PCBs), or biological contaminants such as viruses or bacteria, are present in the sediments, they can be released to the water column during jet plowing. Contaminants associated with sediment particles are likely to remain in solid form rather than being dissolved or dissociated.
- Mobile organisms—mobile animals such as fish, lobsters, and crabs can generally avoid or tolerate a temporary sediment disturbance and suspended sediment plume as is associated with jet plowing. Demersal species for which Essential Fish Habitat (EFH) has been designated in the Great Bay Estuary system that could be affected include: Atlantic cod, Atlantic halibut, red hake, white hake, windowpane flounder, winter flounder, yellowtail flounder, and pollock (semi-demersal). See SEC Application, dated April 12, 2016, Appendix 34 (Natural Resource Impact Assessment) and Appendix 38 (Essential Fish Habitat Assessment)).
- Sessile organisms—smaller animals such as invertebrates living in the sediments within or immediately adjacent to the jet plow path could be buried by sediment deposition. If the deposition is deep enough, the animals may not survive the burial. Larger animals, such as softshell or razor clams, can burrow up to the surface. Other organisms that reside on the substrate surface, such as oysters, mussels or anemones, can tolerate the temporary suspended sediments either by halting filtering until the plume has passed, or ingesting and expelling the excess sediments. The tidal flats in Little Bay support a population of shellfish of interest to harvesters, including softshell clams and razor clams, as well as ecologically important species such as various clams of the *Macoma* species (see Natural Resource Impact Assessment, SEC Application, Appendix 34, dated April 12, 2016 and Revised Natural Resource Impact Assessment, Document 5, SEC Supplemental Information, filed

September 19, 2017). Infaunal[1] animals that are anticipated to occur in the footprint of the cable trenches will be impacted by the jet plow and hand jetting activities.

- Wetlands—temporary impacts to intertidal and subtidal wetlands can occur as a result of the jet plow installation. The impacts are temporary and the habitats typically fully recover due to the natural processes upon completion of the Project.

2.2 Horizontal Directional Drilling (HDD)

2.2.1 Design

HDD is a trenchless method of installing underground utilities within a pipe along a pre-designed bore path using a surface-launched drilling rig. The process initially involves drilling a small diameter "pilot" hole to establish an accurate bore path, then gradually enlarging the hole through a series of reaming passes. Once the hole is fully prepared, the product casing or pipe(s) is attached to the drilling rods and pulled into place. The depth and trajectory of the HDD needs to be carefully designed to account for subsurface conditions and the bending tolerances of the drill rods and the product pipe.

All stages of the HDD drilling process involve pumping a bentonite (naturally occurring volcanic clay) based drilling fluid into the borehole. The drilling fluid maintains borehole stability, removes cuttings and cools the drilling tools.

For SRP, both a full and shore landing HDD have been reviewed and are discussed. A full HDD includes a bore path under the entirety of Little Bay. A shore landing HDD involves a combination of HDD and jet plow installation with HDD confined to near-shore areas on either side of Little Bay.

2.2.2 Typical Uses

HDD is a common alternative to open-cut cable installation to reduce surface disturbance in environmental sensitive areas (i.e., protected cultural and natural resource areas) and avoid of other existing infrastructure (i.e., roadways, railroads and utilities) and when deep burial depths are required (for example, under federal navigation channels). HDD is frequently used for the installation of small diameter pipes and cables, typically less than 36 inches. Common HDD lengths range from about 500 to 3,500 feet, although longer installations are technically viable using larger equipment. Installations in either soil or bedrock are possible, provided the appropriate drilling tools are utilized.

[1] Benthic animals that live in the substrate of a body of water, especially in a soft sea bottom are referred to as Infauna. Infauna may construct tubes or burrows and are commonly found in intertidal and subtidal waters. Clams, tubeworms, and burrowing crabs are infaunal animals.

Utilities and other entities frequently employ HDD as an installation method. Eversource has utilized HDD for crossing under highways and other land-based features and for crossing under water bodies, such as the Housatonic River in Connecticut.

Given the length and subsurface conditions of the Little Bay crossing, there are limited comparable projects to reference. Similar projects of significant HDD length include a 345kV Public Service Enterprise Group (PSEG) Newark Bay Crossing for the Bergen-Linden Corridor (BLC Project) project as well as a 230 kV Florida Power &Light River Crossing in Port St. Lucie, Florida. An HDD crossing constructed in the same geographic area as the Project is a Unitil Project. In 2013, Unitil conducted an HDD installation of a natural gas transmission beneath the mouth of Little Bay in the vicinity of the Little Bay Bridge. Due to reconstruction of the Little Bay Bridge, the existing Unitil gas line, which was located on the bridge, needed to be relocated across the channel between Dover and Newington. The Unitil project utilized HDD for approximately 2,500 feet in length with a borehole diameter of 15 inches to accommodate a 10-inch diameter gas transmission line. The HDD borehole depth was 30 feet below the bottom of the Piscataqua River. The installation of the HDD was approximately 4-5 months to construct with an additional two months for restoration. Unlike SRP, the Unitil project did not require a continuous casing to span the entire borehole length or the necessary staging and assembly requirements.

2.2.3 Benefits

Benefits of an HDD are to facilitate installation of linear facilities where trenching or alternative trenchless methods (such as "jack and bore") are not technically feasible.

2.2.4 Challenges

Challenges and risks associated with both the full and shore landing HDD variations are bulleted below:

- Work spaces are typically required for the entire duration of construction.
- Release of drilling fluid to the ground surface, which is referred to as an Inadvertent Return (IR). This may occur when the downhole drill fluid pressure exceeds the confining capability of the surrounding soil or bedrock. Drilling fluid and drilling fluid additives are chemically inert, biodegradable, and non-toxic. However, the occurrence of a IR typically requires cleanup, and may result in borehole instability (e.g., collapse, squeezing). In certain marine environments, the presence of a clay plume resulting from a IR may present a risk to sedentary organisms such as shellfish.
- Excessive tool wear, reduced production rates resulting from rock abrasivity, compressive strength.
- Excessive drill rod stress.
- Inability to maintain design HDD geometry during drilling. The parallel bore paths will require compound curves with broad minimum radii in bedrock, which will be challenging and time consuming to achieve.
- Excessive casing installation forces; casing stuck or compromised during pullback.

- Risk of compromised thermal grout installation within casing annulus.
- Impacts of magnetic anomalies on steering accuracy.
- Encountering obstructions in soil (abandoned piles, utilities, etc.).

Risks specific to the Full HDD include:

- Full steel casing length will require many pieces of equipment and planning to accommodate pullback.
- Large casing and cut laydown area required for long periods of time.

Risks specific to the Shore Landing HDD include:

- Higher risk of IRs, as the bores will exit in Little Bay.
- Risk of barge anchor instability.

Should a cable fault ever occur within the HDD, the entire phase line would need to be pulled out of the casing and replaced. A spare conduit is included in the duct bundle design, which may enable the installation a new cable without the need to remove the failed cable. The same installation operation required to initially install the cable would need to be re-staged at both sides of the Bay. The damaged cable section (6000+ feet for full HDD) would then need to be de-terminated from the shore-based manholes and replaced with all of the same construction equipment, terminating personnel and construction crews required for the initial installation operations.

2.2.5 Impacts

Environmental impacts from HDD are typically temporary and minor. Similar to jet plowing, some of the HDD activities result in some sediments going into suspension in the water column. Activities likely to generate suspended sediments include movement of the barge and drilling associated with deep geotechnical borings, and drilling activities at the entry/exit points. The suspended sediments settle back on to the bay floor over time and the settlement rate is dependent on particle sizes and currents. Large particles such as sands settle out of suspension rapidly and generally close to the jet plow site. Smaller particles such as silts and clays can be carried farther by water currents. IR, while not a frequent occurrence, can have significant effects on the environment if enough bentonite-laden drilling fluid escapes to impact the filtration capacity of adjacent immobile organisms (i.e. shellfish). Clean-up from an IR can also result in mortality to bottom-dwelling organisms and loss of surface sediments. Remediation of an IR can be more complex if the release is spread out over a wider area, rather than suspended in the water column.

The environmental issues evaluated when assessing impacts from sediment suspension from HDD activities can include the following:

- Water Quality—sediment particles may become suspended in the water column resulting in turbidity, which can block sunlight penetration. Many states, including NH, have water quality standards that include turbidity thresholds.

- Sediment Quality—if pollutants such as mercury or PCBs, or biological contaminants such as viruses or bacteria are present in the sediments, they can be released to the water column during an IR or when remediating an IR. Contaminants associated with sediment particles are likely to remain in solid form rather than being dissolved or dissociated.
- Mobile organisms—mobile animals such as fish, lobsters, and crabs can generally avoid or tolerate a temporary sediment disturbance and suspended sediment or bentonite plume associated with a full or shore landing HDD. Other wildlife impacts can also occur from HDD and are associated with the workspace needed for the conduit and casing assembly. The temporary road and work pads required will displace some animals, but will primarily serve as a barrier for animals attempting to cross active work zones.
- Sessile organisms—smaller animals such as invertebrates living in the sediments in the could be buried by drilling fluid deposition during an IR. As the deposition consists of very fine clay particles, the animals may not survive the burial. Larger animals such as softshell or razor clams can burrow up to the surface. Other organisms that reside on the substrate surface, such as oysters, mussels or anemones, can tolerate the temporary suspended particles either by halting filtering until the plume has passed, or ingesting and expelling the excess sediment.
- Wetlands—impacts to freshwater wetlands can occur as a result of work pads and temporary roads constructed within the staging areas and work spaces needed for the land-based construction for HDD. The staging areas are typically less than an acre in size, but are intensively used for the duration of the project. The workspaces required for pipe casings and conduit typically equal the length of the HDD, but are narrower and have a little more flexibility to minimize impacts to streams and surface waters. The impacts HDD are temporary – though of longer duration - and are fully restored upon completion of the project.

3 Project Specific Submarine Cable Installation Methodologies

The following sections provide project specific details of design and impacts associated with both the jet plow and HDD installation methodologies as specifically related to SRP.

3.1 Jet Plow

The jet plow design and general installation process summarized above is described in detail in several sections of the SEC application (Application Section 301.03, Section (g)(9)(a)(11)); the pre-filed testimony of Troy Godfrey, pages 4-7, now adopted by William Wall; the pre-filed testimony of James Jiottis, pages 18-20, now adopted by Kenneth Bowes. Impacts to water quality and organisms are summarized in the application (Application Section 301.07, Sections (b) and (c)); the pre-filed testimony of Ann Pembroke, pages 2-9; and the Natural Resource Impact Report (Appendix 34, Section 5.0). A summary of the SRP design, process and impacts is provided below. See Figure 3 for a depiction of the route and general concept.

3.1.1 Design and Installation

For SRP, three cables are proposed to be installed across Little Bay, each with 42 inches of cover in the intertidal and shallow subtidal zones and 5 feet in the deeper channel. The installation plan calls for laying the submarine cables from reels in three parallel runs from shore-to-shore utilizing the jet plow technology. Each of the cables will be laid in a single, shallow, open cut landing trench in the upper intertidal zone. The open cut trench will be created using a common tracked excavator positioned on temporary matting. Moving out into Little Bay, the space between the cables will expand to approximately 30 feet apart for the majority of the crossing until approaching the opposite shore where the cables will converge into a common trench. A 30-foot separation between the cables installations is required in the area where the jet plow will be utilized, as this is the minimum safe working distance of the plow from each previously installed cable. Wherever a 42-inch burial cannot be achieved with the jet plow, articulated concrete mattresses will be installed over the top of the submarine cables for protection against damage from outside forces such as anchors or fishing gear. A description of articulated concrete mattresses is provided in Appendix A[2] Initial investigations have indicated that shallow ledge may prevent full 42-inch burial, primarily in the nearshore zone.

Cable installation will begin on the west shore during a high slack tide to allow sufficient water depth for the jet plow and barge to operate. The jet plow will be set as close to the shoreline as possible to minimize the distance between the open-cut trench and the termini of the jet plow launch section. The western and eastern ends will require divers using hand jets to complete cable burial.

The cable lay barge, typically 180-feet by 54-feet, will be fitted with a four-point anchor winch system, and may also include a centrally placed pulling anchor. All anchors will be controlled by anchor winches on the barge. This will allow guided movement of the barge across Little Bay by controlling the anchor wires. The cable lay barge will be supported by a dedicated support tug boat, a separate crew boat to ferry personnel to and from the cable lay barge, and several small work skiffs. The jet plow will be controlled from the cable lay barge utilizing a proven software program that allows for the accurate real-time measurement of cable positioning during the installation, and transmits other operational data, such as residual cable tension, and burial depth.

Cable landfall operations will include the use of a large winch on the shore. The winch will be used to haul the cable end onto the shore at the beginning and the end of each run. Following each jet plow run, the cable lay barge will be towed back to the staging port located in Newington to load the next reel of cable.

The remaining sections of cable between the open-cut trench at each shoreline and the end of the jet plow operation will be buried by divers using a hose ('hand jetting process'). Prior to the start of hand jetting operations, a turbidity curtain will be deployed around the work area on both shores, to the extent feasible.[3] The deployed turbidity curtain will create a barrier to minimize suspended

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[2] Appendix A was provided to the parties on December 9, 2016 in response to Data Request CFP 1-033.

[3] Stronger currents preclude deployment of turbidity curtains near the east shore in the deeper section of Little Bay.

particulates migrating from the vicinity of the work area. Due to the tidal fluctuation and the need for sufficient water depth, hand jetting in shallow water can only occur for approximately 4 hours per day.

It is anticipated that each cable jet plow run will take between 7 to 13 hours to complete. Hand jetting will take up to 30 days to bury all cable sections, and trenching is expected to be 1 to 2 days.

Prior to the jet plow run, sections of existing decommissioned underwater transmission cables will be removed along with clearing of surface debris (i.e., fishing gear, anchors, trash) via a pre-lay grapnel run from the cable routes. The details of the cable and debris removal are depicted in the Eversource Seacoast Reliability Project Existing Cable Removal Plan submitted to the SEC on June 30, 2017.

3.1.2 Construction Equipment Deliveries & Access

Typical on-shore construction equipment will consist of an excavator and general construction vehicles and require a staging/laydown area.

Most of the construction activities will be occurring on/in the water. The barge will be loaded with necessary equipment before leaving the dock in Newington. On cable pulling days, a crew and winch will be positioned on each shore. A small boat is sent to the shore with the cable to begin cable pulling. The barge, tug boat and small work boats will be visible off shore.

3.1.3 Potential Environmental Effects

The jet plow installation will result in some temporary environmental effects. The Natural Resource Impact Assessment study (SEC Application dated April 12, 2016, Appendix 34, as amended by Appendix 34(a) submitted to the SEC on March 29, 2017) identified the potential for impacts to water quality, sediment and marine organisms present in Little Bay and concluded that these impacts would be expected to be minor and temporary in nature. Pursuant to the DES final recommendation, Eversource is working with DES to develop monitoring criteria that will confirm conditions during and after the cable installation, and identify appropriate mitigation for any unexpected exceedances in accordance with the final Wetlands Permit and associated 401 Water Quality Certificate for the Project. These effects are briefly summarized below.

Water Quality

The jet plowing and hand jetting operations will result in the suspension of some sediment in the water column. These operations were modeled to estimate the concentration and extent of turbidity generated by each activity in a range of hydrodynamic conditions (tide ranges, jet plow speed, wind). The modeled results indicate the suspended sediment plume is temporary, limited to when the installation activities occur, and completely dissipated within 1 to 2 hours after the operations stop (see the most recent sediment dispersion model results in Document 1 of the SEC Supplemental Information, filed June 30, 2017, and Document 1 of the SEC Supplemental Information filed September 19, 2017). The dispersion of the suspended sediment plume is influenced by the currents. Times of weaker currents have a smaller overall footprint. Because natural turbidity levels are highly variable in Great Bay, the organisms in the Project area are expected to tolerate the brief levels of elevated turbidity that will be generated during the cable installation.

Using average tide data for Little Bay, the jet plow model calculated the areas that would be exposed to an excess (i.e., above ambient conditions) concentration. Excess concentration is defined as of 10 milligrams per liter (mg/L)[4] or greater as time passed after the operations stops. The model demonstrated that approximately 91.2 acres would be exposed to excess concentrations for up to one hour past cessation of the jet plow activity. This drops dramatically to approximately 0.2 acre at 2 hours past cessation of the jet plow activity. After 3 hours of the jet plow activity, no areas were affected by excess concentrations. The modeled case deposition thickness patterns indicate that deposition immediately over the cable lay area will be less than 0.5 inches, and found that deposition over 1 millimeter (0.04 inches) encompassed approximately 22.6 acres after jet plowing the three cable runs.

The current schedule for the cable installation utilizing the jet plow technology plans for a 5 to 7-day interval between cable installations. The analysis of water column suspended sediment concentration duration shows that the excess concentration will drop to zero within approximately 1 hour following cessation of jet plow operations (See Section 3.4 in Document 1 of the SEC Supplemental Information, filed June 30, 2017). Sediments redeposited after each jet plow run may be subject to resuspension on subsequent tides. Modeling of the potential impacts of the tides indicates that resuspension produces much lower levels of suspended sediments over a limited area. The modeling further demonstrate that the impacts of the tides will not be apparent within 3 days of each jet plow pass. Thus, there will be no cumulative increases in suspended sediment concentrations because of these installations.

The hand jetting operations will take place intermittently over a longer span of time (4 hours a day between 9-18 days for each shoreline area) as compared to the jet plow operations. The intermittent installation is due to operational constraints limited by water depth and currents. The sediment concentrations resulting from hand jetting are intermittent and dissipate quickly due to the relatively low amount of sediment, particularly in areas located within areas where the silt curtain will be deployed. The hand jetting activity results in concentration plumes local to the immediate areas of the work and diminish shortly after activity ceases. Concentrations diminished to zero after 20 minutes. As such, there no anticipate impacts to water quality from hand jetting operations.

Sediment Quality

Eversource conducted sediment testing to address the potential for increased exposure risk resulting from the dispersal of the possible sediment-born contaminants in the Great Bay System. The results demonstrated sediments were generally somewhat coarser than initially modeled, meaning the sediment would settle quickly during cable installation using jet plow and hand jetting. Coupled with

[4] 10 – 20 mg/L are naturally occurring suspended sediment levels observed in the Little Bay during the fall and studies summarized by Wilber and Clarke (2001; 2010)

the high quality of the sediments in terms of low contaminants, this consistency indicates that impacts to Little Bay resources, as a result, of cable installation will be minimal.

In September 2016, sediment testing occurred in twelve locations along the cable route (see Sediment Characterization Report, December 1, 2016). Sediments were sampled to a depth of 96-inches, where possible, using a vibratory sampler. At several locations, the presence of stiff, naturally occurring clay several feet below the substrate surface prevented penetration to the planned sampling depth. When cores penetrated greater than 48-inches, the upper 48-inches of sediments was separated from the lower section and the two portions were analyzed separately. In shallow portions of the route where cable burial is planned at 42-inches, 48-inch deep cores were collected, homogenized, and analyzed for chemical constituents.

All samples were analyzed for typical dredge material analytes: grain size, total organic carbon (TOC), a suite of eight metals, specific polycyclic aromatic hydrocarbon (PAH), and PCB, as well as total petroleum hydrocarbons (TPH), dioxins/furans, and perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). Results of the Project site-specific survey were compared to existing data on sediment contaminants in Little Bay and to available screening criteria (such as National Oceanic and Atmospheric Administration's (NOAA) Screening Quick Reference or SQuiRT tables) that were developed based on biological responses to exposure.

Results of the Project's survey were consistent with the US EPA National Coastal Condition Assessment (NCCA)[5] dataa and were all below levels of environmental concern, with the exception of arsenic. Arsenic was slightly higher than the lowest screening level value (NCCA Effects Range Low, meaning that there is a low, but possible, likelihood of a biological effect), but within the range of concentrations observed in Little Bay under the NCCA program. The NCCA program also included bioassay testing and determined that exposure to surface sediments from Little Bay resulted in no significant difference in mortality as compared to reference sediments.

TPH, PFOA, and PFOS results all fell below detection limits in every Project sample. Dioxins/furans occurred in most samples but at very low levels, and never exceeded the screening criteria. In the context of ecological risk, the analysis concluded that there is no potential for ecological effects from constituents of potential concern in the sediments that will be disturbed during cable installation.

Additional sediment testing was conducted in May 2017 (see Document 2 of the SEC Supplemental Information, filed June 30, 2017). Specifically, the sediment was tested for pesticides, nitrogen, arsenic and grain size for comparison with the cores taken in 2016. The sampling was performed in the same twelve locations and with the same equipment as 2016. Vibratory cores were collected to the same depth (48-inches) in the shallows as in 2016, and 72-inches in the channel (modified from 96-inches because the burial depth in the channel has been reduced from 96-inches to 48-inches.

[5] Grain size, TOC, metal, PAH, and PCB concentrations had all been studied in Little Bay during the US EPA National Coastal Condition Assessment (NCCA) program in the year 2010.

Only the upper 24-inches of sediments were analyzed for chemical and physical data, to more accurately represent the fraction of sediments most likely to be suspended during jet plowing.

The pesticide results were below detection limits, indicating no environmental concern. The contribution of nitrogen from sediment to the water column during construction will not affect the long-term compliance with nutrient criteria for the Great Bay system. There was no evidence for substantial segregation of contaminants in the sediment column, indicating that the original conclusions from the prior analysis remain valid. That is, the jet plow process would not result in water quality criteria violations for contaminants during the cable installation.

Sessile Organisms

Shellfish

Three aquaculture facilities in upper Little Bay are located close enough to the planned crossing to be potentially exposed to the sediment plume. Joe King Oyster Cooperative and Fat Dog Shellfish Company are located on the western side of Little Bay just south of Durham Point. For a period of up to about four hours, the plume will flow towards these locations. Water quality modeling predicted that excess suspended concentrations in the plume near, and potentially overlapping, these oyster farms will be about 10-20 mg/L. These concentrations are well within naturally occurring suspended sediment levels observed in the Little Bay and oysters are able to withstand exposure to even more elevated levels of suspended sediments. For example, oysters exposed to suspended sediment concentrations of 710 mg/L for 20 days exhibited no effect although exposure to suspended sediment concentrations of 1,000 mg/L for two days could elicit a reduced pumping or feeding rate.[6] Given that the potential duration of exposure of the farmed oysters in Little Bay to much lower suspended sediment concentrations is expected to be limited to a few hours, no impacts to these farms are anticipated.

Bay Point Oyster Company, located on the eastern side of the Bay partially within and extending north of the charted cable area, is approximately 400 feet from where a portion of the cable will require burial by divers and where it is infeasible to use silt curtains. Temporary plumes emanating from the installation may reach this farm during the hand jetting, however the excess suspended sediment concentrations in the portion of the plume nearing this facility are expected to be < 10 mg/L, which is the lowest modeled concentration and within the natural variability of Great Bay. As described above, this increase in suspended sediments is much lower than levels found in the literature to elicit either sublethal (reduced feeding) or acute (mortality) effects in oysters, therefore no impacts to oysters at the Bay Point Oyster Company are expected.

Trenching will subject individual shellfish adjacent to the trenches to burial. Softshell, razor and *Macoma* clams are capable of active burrowing so it is likely they will be able to burrow out of the excess sediments.

Shellfish under the concrete mattresses utilized in the upper intertidal zones on both sides of the cable crossing where rocks or bedrock may occur beneath the sediment surface, will likely be killed by

[6] See footnote 3

placement of the mattresses. However, it is likely that the mattress will also provide suitable substrate for macroalgae and other shellfish species such as oysters, mussels and barnacles.

Mobile Organisms

Benthic Infauna

Benthic infauna along each cable route will be displaced into the water column and adjacent substrate by the jet plow (see Natural Resource Impact Assessment, SEC Application, Appendix 34, dated April 12, 2016 and Revised Natural Resource Impact Assessment, Document 5, SEC Supplemental Information, filed September 19, 2017). This impact will be limited to the immediate area surrounding each jet plow path. Displaced individuals may experience some mortality. At least some of the infaunal species observed in the Project area are active burrowers and will survive re-deposition of suspended sediments. Some of the abundant species are small-bodied embedded surface-deposit feeders and may not survive burial. Infaunal organisms occurring in the upper intertidal zone would be impacted by placement of articulated concrete mattresses used to protect cables where the required burial depth cannot be achieved. It is likely that the artificial substrate would ultimately be colonized by macroalgae and macrofauna typically found on hard substrate in this depth zone.

The Project's baseline survey indicated that the benthic community along the route is similar to the community in nearby sediments and elsewhere in Little Bay. As the adjacent resources will be a source of recruitment to repopulate the disturbed area, it is expected that the benthic infaunal community will recover in terms of abundance, and possibly species richness, by the end of the following reproductive period. Infaunal species observed in the Project footprint are also abundant in nearby habitats. These adjacent populations will be a source for recruitment. Therefore, there would be no permanent impact to the benthic community.

Lobsters and Horseshoe Crabs

American lobsters and horseshoe crabs are large benthic organisms likely to occur along the submarine cable route. Population estimates are not available for Little Bay and the cable area does not contain unique habitat for lobsters or horseshoe crabs. Because lobsters often burrow into the substrate during the day, those along the cable route would be impacted by the jet plowing. Although lobsters adjacent to the trenches would be subject to deposition, this is unlikely to have a deleterious effect because this species is an active burrower and will be able to extricate themselves from any redeposited sediments (see Natural Resource Impact Assessment, SEC Application, Appendix 34, dated April 12, 2016 and Revised Natural Resource Impact Assessment, Document 5, SEC Supplemental Information, filed September 19, 2017). In addition, the area potentially affected by jet plow passage and subsequent deposition of sediments is small relative to the available habitat.

Horseshoe crabs likely feed on the tidal flats along the Little Bay shorelines. Individuals located along the path of the jet plow would be impacted by the jet plowing. Those adjacent to the jet plow installation would be subject to deposition. It is expected the deposition result in a minor and temporary impact for two primary reasons: (1) this species is capable of active burrowing in soft sediments, such as along the cable route, and would be able to extricate themselves from the unconsolidated sediments; and (2) the area potentially affected by jet plow passage and subsequent deposition of sediments is small relative to the available habitat.

All available data demonstrates that while the cable area likely provides habitat for lobsters and horseshoe crabs, suitable habitat conditions for these species are widely available in the estuary. Thus, the proportion of suitable habitat within the Great Bay Estuary affected by the cable installation is minimal and, therefore, the number of American lobsters and horseshoe crabs potentially affected is also limited.

Fish

Impacts to fish will be temporary and include alteration of benthic habitat, exposure to increased levels of suspended sediments, and mortality of early life stages entrained in the jet plow's water system. Available habitat for bottom-feeding (demersal) species will be temporarily disturbed and altered, slightly reducing the area available for use.

Highest concentrations of suspended sediments will be close to the seafloor adjacent to the trench being plowed. This could be a deterrent for some fishes, particularly mid-column (pelagic) species, and cause them to avoid the densest part of the plume. Pelagic species for which EFH has been designated in Great Bay include pollock (semi-demersal), Atlantic mackerel, and bluefish. The Little Bay crossing area may also provide nursery or staging habitat for diadromous[7] species, including American eel, alewife, American shad, rainbow smelt, and sea lamprey. Given that duration of the highest densities in the plume are limited to about an hour per cable and the plume will never encompass more than about 10% of the width of Little Bay, it is not expected that these species would be impacted by exposure beyond a possible temporary, minor degradation of habitat.

Early life stages of several species of fish could be vulnerable to being drawn into the water intake (entrainment) during jet plow operation, and are likely to be in the water column during cable installation. These include Atlantic cod, Atlantic mackerel, white hake, windowpane flounder, and yellowtail flounder. A very small volume of water will be needed to operate the plow relative to the volume in Little Bay (0.17% of the high tide volume to 0.27% of the low tide volume). Given this relatively small volume and the naturally high mortality rates of early life stages of fishes, it is unlikely that entrainment will have a significant effect on these populations.

Wetlands

The jet plow installation will result in permanent wetland impacts of up to 8,681 square feet (0.2 acres) in tidal waters due to the need for concrete mattresses where design burial depths cannot be achieved due to shallow bedrock. Temporary impacts from the jet plow installation include 268,531 square feet (6.2 acres) in tidal waters and 1,456 square feet (0.03 acre) to fringing salt marsh resulting from the placement of timber mats to allow construction equipment to cross the marsh to reach work areas and from the burial of cables beneath the marsh. (See Revised Natural Resource Impact Assessment, Document 5, SEC Supplemental Information, filed September 19, 2017). The temporary impacts to tidal waters are expected to recover naturally and will be monitored to track recovery. The latter effort will require salvage of the existing peat where feasible, and replacement of

[7]Diadromous is a general category describing fish that spend portions of their life cycles partially in fresh water and partially in salt water. These represent both anadromous and catadromous fish. Anadromous fishes spend most of their adult lives at sea, but return to fresh water to spawn.

the peat and salt marsh restoration after the cable burial is completed. (See Salt Marsh Protection and Restoration Plan, Document 5, SEC Supplemental Information, filed June 30, 2017).

3.1.4 Impacts to the General Public

Impacts to recreation within the Bay and to shoreline residences will be temporary and minimal. Construction of the Project will mostly occur from the in the open water on Little Bay, therefore, the Project will coordinate with the US Coast Guard, municipal harbor masters, NH Marine Patrol and other appropriate organizations to issue alerts for construction traffic and timing of activities that will affect the public's use of Little Bay. Most construction activities will be limited in scale and will generally not affect boat usage on Little Bay. It is expected that the barge and jet plow may partially obstruct the channel for a period of hours on three separate days during cable burial.

Impacts to residents will include engine and generator noise from the barge and other support vessels. Noise from construction equipment for the days of cable pulling on the east and west sides of the Bay will be audible. The nearshore trenching will be performed by equipment mobilized on both shores for the on-shore portion of the transmission construction.

3.1.5 Schedule

The installation of the cable via jet plow would span over 3 months, primarily between September to November. The timing of the installation was proposed to avoid sensitive fish spawning and migration periods in the spring, and to minimize impacts to recreational boaters in the summer. Because the cable installation cannot occur during freezing temperatures, the Project requested a waiver from the fisheries time-of-year restriction (Env-WT 304.11(b)), which typically limits "dredging" in tidal waters from November 15 to March 15. DES recommended granting the waiver in the final permit conditions, dated February 28, 2018.

3.1.6 Cost

The Seacoast Reliability Project cost for the currently submitted project utilizing the jet plow method to cross Little Bay is $84M (-/+ 25%).[8] This estimate includes the substation terminal ends at Madbury and Portsmouth Substations as well as the 115kV line.

3.2 HDD Option

3.2.1 Design and Installation

Eversource assessed, with the assistance of several experienced engineers and contractors, the feasibility of utilizing HDD for trenchless cable installation below Little Bay by analyzing cable design and installation requirements, concept-level HDD geometries specific to the site surface constraints and subsurface conditions, and cable installation methodologies.

[8] Applicant's Amendment to the Application, March 29, 2017, at page 13.

Eversource evaluated two HDD design variations for crossing Little Bay, full HDD and shore landing HDD.

- **Full HDD Installation,** which is a complete HDD across Little Bay between Newington and Durham depicted in Figure 4 (Full HDD). It involves two parallel HDD bores installed approximately 20 feet apart. Each bore would include a polyethylene thermoplastic, typically High-density polyethylene ("HDPE"), duct bundle placed in a 36-in diameter steel casing. The duct bundle would include spacers located at 5-ft intervals. The annulus between the casing and conduit would be filled with a thermal grout, intended to aid in heat dissipation during cable operation.
- **Shore Landing HDD Installation,** which would also involve two HDDs at the Little Bay shore landings (Newington and Durham), located approximately 20 feet apart, to locations in the Bay where jet plowing can commence. The shore landing HDD installations would allow the project to reduce the total amount of hand jetting (though not eliminate it entirely) required to install the submarine cable. (*See* Figure 5 depicting Shore Landing HDD). Each bore would include an HDPE duct bundle with spacers located at 5-ft intervals. Each duct bundle would be placed in a 36-in HDPE casing.

3.2.2 Engineering Cable Design

The installation of cables underground requires engineering analysis to ensure the required electrical current is maintained. Items such as cable depth and the materials surrounding the cables impact efficiency of power transfer and may require forms of remediation. The two engineering cable design configurations for crossing Little Bay for both the Full HDD and Shore Landing HDD options are further described below.

For each installation option, two cable designs configurations were reviewed. The first, Design A, is one cable per phase, for a total of three conductors. Design B is two cables per phase for a total of six phase conductors. Both designs were evaluated for both the ampacity[9] considerations and open sheath voltages for the cable to determine how many cables and bores would be required to meet the electrical loading requirements of the Project.

Design A: Single HDD borehole (3 power cables installed in a single bundle)

An engineering review of the design options was completed to address the ampacity requirements and to incorporate data collected during a comprehensive review of projects of similar scope. Details of this review are included in the report titled, "Public Service of New Hampshire 115kV Circuit F107 Transmission Line – Little Bay Crossing Ampacity Report," dated April 4, 2018 (Appendix B).

It was determined the length of HDD required for this Project is too long for an HDPE casing due to mechanical and installation limitations of the material. It is unlikely that the

[9] Ampacity is defined as the maximum amount of electric current a conductor or device can carry before sustaining immediate or progressive deterioration.

HDPE casing could withstand the anticipated installation force and friction associated with the long length of the casing, causing the HDPE to pull apart or buckle and collapse. Eversource determined that a steel casing would be required to successfully complete the current length of the HDD installation. However, the steel casing results in a conservative estimate of a 20% ampacity de-rating due to heating caused by eddy current[10] and hysteresis[11] losses generated in the steel. This derating has been determined by finite element computer modeling as well as lessons learned from the BLC Project. Simply stated, as electricity travels through the cables, the casing reduces the amount of power that reaches the final destination as a result of the generated heat casued by the circulating discussed above. The shore landing HDD designs are much shorter in length and can use the HDPE casing. Given a thermoplastic casing does not result in the same ampacity de-rating as a steel casing does, the ampacity de-rating is not applicable for the shore landing HDD calculations.

When designing an underground transmission installation, reliability and safety of the system is the most important consideration. The reliability of underground cables is improved with the use of surge protection, which comes in many forms including the sheath that is around the transmission cable and varies for different operating scenarios (i.e., steady state conditions, fault-duty conditions, lightning). As part of the updated engineering design, Eversource calculated open sheath voltages[12] on the cables for various surge protection or 'bonding schemes'. Limiting the open sheath voltage on the cables is critical to the reliability of the cable as excessive voltages can lead to premature degradation and failure of the cable. Different bonding schemes have effects on the allowable ampacity of the circuit as well as the open sheath voltage performance so both criteria need to be reviewed to determine reliable system performance.

As a result of the analysis, Eversource determined that 3 cables in a single bundle cannot provide the required ampacity without exceeding the open sheath voltage requirements for the Project; therefore the 3-cable bundle design was not further considered for either the full and shore landing HDD options. *See* Appendix B (Ampacity Report for the complete assessment).

Design B: Two HDD boreholes (6 power cables and 2 fiber optic cables installed in two separate bundles). Based on the analysis outlined in the Ampacity Report, it has been determined that it is technically feasible to construct the desired cable system to meet all ampacity and open sheath voltage requirements utilizing either the full or shore landing HDD options. For full HDD, two cables per phase (a total of six cables) each constructed with 5000 kcmil copper coated conductors would be required. This is based on a

[10] Eddy current are defined as a localized electric current induced in a conductor by a varying magnetic field.

[11] The energy lost as heat, which is known as the hysteresis loss, in reversing the magnetization of the material is proportional to the area of the hysteresis loop.

[12] Open sheath voltages are voltages induced in the sheath of an underground cable from an AC circuit.

combination of required ampacity and open sheath voltage limits. For shore landing HDD, two cables per phase (a total of six cables) would also be required. This requirement is based on ampacity and open sheath voltage requirements for the project. The two-cable per phase system provides additional capacity to meet the project requirements which cannot be achieved by a single cable per phase outline in Design A. *See* Appendix B (Ampacity Report for the complete assessment).

The requirement for two cables per phase (6 power cables total) adds additional engineering complexity to the design and installation. See Figure 6 for cross-sections of the cables proposed for full and shore landing HDD. Each duct bundle includes conduits for 3 cables and a spare conduit to replace a cable should one fail in the future. For full HDD, two manholes will be required on both sides of Little Bay to transition from the HDD installation to the terrestrial duct bank system. The cables installed in the HDD bores will be pulled into the manholes (3 cables per manhole). The cables will then be spliced to underground cables in an underground duct bank system from the manhole to the riser structure.

For shore landing HDD, two manholes will be required on the Newington and Durham side of Little Bay to transition from the HDD installation to the terrestrial duct bank system. The cables will then be spliced to underground cables in an underground duct bank system from the manhole to the riser structure. At the riser structures, all six conductors will be brought up the pole and connected to the overhead line. A riser structure with six cables will be approximately 10-20 feet taller (80-90feet total) and larger in diameter and have more supporting equipment than one supporting 3 underground cables.

3.2.3 Installation Design and Construction Constraints

The following sections provide the design and construction constraints shared by both full and shore landing HDD.

Subsurface Conditions

An evaluation of the suitability of HDD for cable installation below Little Bay considered the subsurface conditions, which can present challenges to the installation, increase risk of an IR and increase cost. The subsurface conditions in the vicinity of the Little Bay crossing were assessed through review of existing land-based test borings and geophysical survey data, and evaluation of readily available geologic literature. It is anticipated the following geologic units, listed in order from ground (or marine bottom) to below surface:

- Fill: manmade materials placed during previous site grading along both margins of Little Bay, consisting of sand and silty sand.
- Estuarine Deposits: Located along and below Little Bay, resulting from geologic recent estuarine deposition. Likely consisting of silt and sand with organics.
- Stratified Glacial Deposits: silt, sand and gravel deposited in lakes and streams associated with the Pleistocene glacial advance and retreat.
- Glacial Till: silty sand and gravel with cobbles and boulders, deposited beneath the advancing and retreating glacial.

- Bedrock: mapped as the Kittery and Elliot Formations, metasedimentary lithologies such as phyllite and quartzite. The bedrock in this area may exhibit unconfined compressive strengths in excess of 30,000 pounds per square inch ("psi"). These materials are also considered abrasive and may result in excessive tool wear during HDD drilling and reaming. The rock strength and abrasivity has the potential to increase the duration of the HDD installation and result in additional equipment failure.

A preliminary geologic profile is shown on Figures 4 and 5. Additional sample test borings would be required to facilitate final HDD design for the Little Bay crossing.

Inadvertent Drill Fluid Return Analysis

Utilizing the results of the geophysical survey, a preliminary annular pressure analysis ("frac out analysis") has been completed for the full HDD and the shore landing HDD variation to evaluate the risk of IR during pilot hole drilling. It is generally assumed that the risk of IR is greater during pilot hole drilling than reaming, given that the drill fluid may only flow toward the HDD entry (communication to the HDD exit has not yet been established). For each borehole geometry, the anticipated range of downhole drill fluid pressures (static and dynamic) has been calculated and are shown on Figures 7, 8 and 9. The static pressure is a function of the density of the drill fluid at a specific location and depth below the drill entry elevation. The dynamic pressure is the pressure required to move the drill fluid (and cuttings) up the borehole annulus, and is a function of pump rates, hole geometry, fluid density, fluid velocity and fluid rheology.

The annular pressure analyses compare the drill fluid pressures to the estimated confining capabilities of the surrounding geologic materials. For a full HDD, the majority of the bore paths are located in bedrock. For the shore landing HDD variation, the bore paths are located in both bedrock and soil.

The potential for an IR may be considered greatest at locations where the anticipated range of downhole drill fluid pressures are close to or exceed the estimated confining capabilities of the surrounding materials. The results of the preliminary annular pressure analyses (Figures 7, 8 and 9) suggest the following:

- For the full HDD, the risk of IR is greatest in the middle of Little Bay, where the depth of bedrock cover over the bores is limited.
- For the shore landing HDD, the risk of IR is greatest near the HDD exits, where the bores transition from bedrock to soil, and the depth of the bores decrease.

  The risk of IR associated with the shore landing HDD Option is greater than the risk associated with the Full HDD Option due to the exit holes occurring within Little Bay.

The annular pressure analysis is considered a tool to identify areas of potential risk. It is not considered an exact predictor of the location or degree of an IR. The annular pressure analysis is not an accurate predictor of borehole leakage, where drill fluid leaks to the adjacent materials through existing porosity or fractures.

HDD Geometry

A preliminary plan and profile geometry for the HDD installations is shown on Figures 4 and 5, and are based on the following criteria:

- available work space;
- the bending capability of the drill tools;
- the bending capacity of the product casing and casing handling requirements;
- the anticipated subsurface conditions, and the ability of the subsurface conditions to contain the drill fluids;
- typical HDD entry and exit angles; and
- thermal constraints associated with cable operation.

3.2.4 HDD Design Summary

The Full and Shore Landing HDD operations are summarized as follows:

Full HDD Installation

A full HDD would involve crossing the entirety of Little Bay. The entry area for a full HDD installation would be in the Town of Newington, to the south of the existing Eversource easement in the middle of Gundalow Landing (Figure 10), approximately 600 feet from the edge of Little Bay. Preliminary evaluation suggests that it will not be possible to place the HDD entry location within the existing Eversource easement due to the limited bending capabilities of the steel casing.

The exit pit for a full HDD installation would be on the western shore in the Town of Durham, within the existing Eversource easement (Figure 11), approximately 500 feet from the edge of Little bay. It should be noted that the limited bending capability of the steel casing will require that the bore paths will be located to the south of the Eversource easement near the shore, as shown on Figure 11.

A full HDD installation would follow an approximately 6,000-ft long bore path, with a minimum depth of 70 feet below the bottom of the bay. It could be completed with a single drill rig, or two separate rigs positioned on either side of Little Bay drilling to a predetermined point below Little Bay (by intersect method).

The preliminary geometry for the full HDD option is shown on Figure 4. In this case the minimum curvature radius of the bores will be controlled by the 36-in steel casing. For the purpose of this study, a minimum bending radius of 3,600-feet has been assumed for the casing, consistent with industry practice. To accommodate the existing Eversource easement configurations, multiple compound curves will be required. Although technically feasible, a parallel bore path configuration of this length and geometry will be technically challenging to construct. Partial location of the full HDD option alignment outside of the existing Durham and Newington easement limits will be required. As shown on Figure 4, the full HDD option bore paths will be placed almost entirely in bedrock.

Currently, Eversource has determined that the casing and duct for a full HDD installation would be pulled from west to east (from Durham to Newington) requiring that the casing and duct be assembled in Durham (see Work Space, below).

An HDD entry area located east of Little Bay Rd. was also considered for the full HDD installation to address the anticipated impacts to residential abutters. Relocation of the entry pit would require an approximately 7,400-ft long bore path, which is uncommonly long. While this length is technically achievable, it would add significant risk and complexity to the installation, given the geometry of two parallel bore paths, the diameter of the boreholes and the subsurface conditions present. Increasing the bore length would also significantly impact the cost and schedule of the project.

Shore Landing HDD Installation

A shore landing HDD variation would involve the use of HDD to install the casing and duct below the eastern and western nearshore areas of Little Bay, and then connecting the two HDD segments with a jet plow installation across the center of Little Bay. A barge or pile-supported platform will be located in Little Bay, adjacent to the HDD exits. The barge would support a smaller drill rig, which would assist with the reaming process. The exit point locations would be controlled by water depth. Based on existing site conditions, it is anticipated that the eastern (Newington) HDD shore landing would be approximately 2,693-feet in plan length, and the western (Durham) HDD shore landing would approximately 2,730 feet in length. Each HDD shore landing would be drilled to a depth of at least 65 feet below bottom of the Bay. In this case, a jet plow installation, as well as hand jetting, would be required to connect the HDD shore landings would be about 1,950 feet in plan length.

The preliminary geometries for the HDD shore landing options are shown on Figure 5. In this case, the minimum curvature radius of the bores will be controlled by the HDD drill rod steel. A radius of 2,000 feet has been assumed. As shown on the preliminary geologic profile on Figure 5, the HDD shore landings installations would encounter fill, stratified glacial deposits, glacial till and bedrock.

3.2.5 HDD Staging Area Requirements

Staging areas for the HDD drill rig, and supporting equipment would need to be established at each point of entry/exit.

Full HDD Installation

A full installation would require one or more large HDD rigs. The staging areas for a full HDD drilling operation will require a minimum work/staging area of 100x300 feet (30,000 square feet) on each side of Little Bay, as depicted on Figures 10 and 11. The staging area would contain the drill pits and equipment needed to support the drilling operation, including the drill rig, control cab, generator, drill pipe rack, mud pump, drill fluid recycling unit, slurry holding pit, office and crew space and parking (Figure 12). The size of the staging area is dependent upon developing an appropriate workflow between various construction activities, as shown by examples from other large HDD projects on Figure 13). Reducing the size of the staging area may reduce workflow efficiency and increase risk to safety of the crews during construction.

A full HDD installation would require a drill fluid containment barge to be staged in close proximity to the HDD operations to provide rapid response to an IR within Little Bay.

The full HDD installation requires both steel casings and HDPE duct bundles. The entire length of casings would need to be preassembled in advance of the pullback, to reduce delays and the risk of the casing becoming stuck in the borehole. The HDPE duct bundle also needs to be completely fused and prepped prior to installation in the casing. Consequently, a laydown length equivalent to the length of the HDD would be required (approximately 6,000 feet long). To accommodate two casings and two duct bundles, a laydown width of at least 65 feet would be needed. The existing ROW corridor on the Durham side of Little Bay is proposed to be used for this purpose. The duct/casing would need to cross at least one private driveway, as well as Durham Point Road. The approximately limits of the laydown area for a full HDD installation are shown on Figure 11. Road and driveway crossings would be accomplished by shallow excavations, covered by steel plates. For the SRP crossing, it may be assumed that the laydown area will be occupied by materials and equipment for the full duration of HDD construction (approximately 28 months).

<u>Shore Landing HDD Installations</u>

The Shore landing HDD installations would require a large drill rig on each shore of the Little Bay. The work space dimensions required are assumed to be the same as those described for the Full HDD installation (above), and are shown on Figure 12).

For the shore landing HDD installations, a barge or pile supported work platform will be required in Little Bay at each HDD exit. The barge would support a smaller drill rig, which will assist with rod handling and the reaming process. The barge/platform will also be required to assist with casing and duct pullback. Drill fluid flowing to the HDD exit would be collected by a steel conductor casing, or a gravity cell (steel container). The approximate footprint of the barge/platform for each shore landing installation is shown in Figure 5. In addition, a crew boat to transport work personnel will be required. Fuller developed road infrastructure may be required to accommodate construction equipment.

The installations of the shore landing HDD will require duct assembly area in Newington (2,630 feet long) and in Durham (2,730 feet long) as shown in Figures 14 and 15. A laydown area at least 65 feet wide, with a length equivalent to the full length of the installation, would also be required for each installation. On the Newington side, the casing and duct laydown area would extend eastward from Little Bay Road. On the Durham side the casing and duct laydown area would extend across Durham Point Road.

3.2.6 Borehole Drilling

The HDD process begins by drilling a small diameter (approximately 10 inches) pilot hole along a predesigned trajectory. During drilling, the location of the drill head is tracked using a downhole survey tool, connected to the ground surface by a wireline located within the drill rods. For the full HDD installation, the pilot hole may be established using a single drill rig, or two drill rigs drilling to a predetermined intersect point below Little Bay (intersect method).

For the shore landings, the pilot hole would be advanced by a land based drill rig to a barge or pile supported work platform located in Little Bay. The drilling fluid flowing to the exit would be contained in a steel conductor casing, or gravity cell.

Once the pilot hole is completed, it will be enlarged by a series of pull or push reams, depending on the subsurface conditions encountered. The additional diameter is achieved with each backstream pass and is dependent on the subsurface conditions. For the Project, it is anticipated that three to four reaming passes would be required. A final reamed borehole diameter of approximately 48 to 52 inches is anticipated for both the full and HDD shore landing installations to accommodate the 36-in casing (steel or HDPE). Consistent with industry practice, the final borehole diameter would be at least equal to the outer diameter of the casing, plus 12 inches. The additional space is required to more readily facilitate pulling of the casing through the borehole by reducing friction.

During all stages of drilling and reaming, a bentonite-based drilling fluid is pumped down the center of the drill rods into the borehole. The drill fluid transports the cuttings out of the borehole (between annulus between drill rods and edge of borehole), cools and lubricates the drill tools. Once the drill fluid exits the hole, it is pumped through a recycling system, and reused.

3.2.7 Casing/Duct/Cable Installation

Full HDD Installation Option

As previously stated, a 36-in steel casing and HDPE duct are both required for the full HDD installation. Once the borehole is prepared, a pulling head would be welded to the casing and connected to the drill rods. The casing would then be slowly pulled into the borehole. The casing would be fully welded prior to commencing pullback operations. Once the casing is installed, the duct would be pulled into the casing. Following installation of the duct, the internal annulus (space) between the duct and steel casing would be filled with a grout designed to facilitate heat transfer during cable operation.

Once the full HDD installation is completed, the cable would be pulled through the duct and secured to its respective transition points at each shore.

Shore Landing HDD Option

A 36-in HDPE casing is required for the HDD shore landing installations. The casing would be fused to a pulling head, and connected to the drill rods. The casing would be water ballasted, and pulled into the borehole from water to land. Once the casing is installed, the duct would be pulled into the casing. Following installation of the duct, the internal annulus (space) between the duct and HDPE casing would be filled with a grout designed to facilitate heat transfer during cable operation.

Once the shore landing HDD installations are completed, the cable would be pulled into one conduit from the water and secured to its transition point to a land-based cable (manhole on the east and west shore). Waterside, the cable would then be buried via jet plow under Little Bay (same burial depths and specifications as currently proposed for the jet plow installation). It would then be fed into that conduit until it was secured to its transition point to land cable on the opposite shore. Hand jetting would be required at the junctures of HDD and jet plow. This process would be repeated for each of the 6 cables.

3.2.8 Thermal Grout

Both full and shore landing HDD options will require installation of a thermal grout between the casings and cable duct. The purpose of the grout is to aid in heat dissipation during cable operation. The grout will be installed by means of tremie tubes once the casing and duct are in place, by pumping from the east and west ends of the HDD. This will require at least four (4), 2 to 3-inch diameter HDPE tremie tubes be installed with the duct bundle, and will remain in place following grouting.

Preliminary estimates suggest that approximately 62,000 cubic feet of thermal grout will be required for the full HDD option, and 36,500 cubic feet will be required for the shore landing HDD option.

3.2.9 HDD Drill Spoils Management

The HDD process requires management of drilling spoils. Drilling spoils consist of earth material from the borehole and the bentonite slurry used in the drilling process.

Typically, the drilling fluid and cuttings are circulated through a filtration system and dewatering system which separates solids and recirculates water for reuse in the drilling operation.

Given the large volume of drilling spoils that would be generated, they would be disposed of offsite at a landfill or other permitted receiving facility. Drilling water would also need to be transported offsite to an acceptable receiving facility, such as a waste water treatment facility.

Prior to disposal, dry spoils and drilling water would need to be chemically analyzed to confirm that they meet disposal acceptance criteria. In addition to general disposal criteria, spoils generated from drilling operations east of Little Bay may also require assessment for the class of contaminants known as perfluoronated compounds (PFCs) which are contaminants of concern in Newington, associated for the former Pease Air Force Base.

The volume of spoils generated is dependent on a number of factors including the borehole volume and the amount of bentonite slurry used. Assuming the full (6,000 ft.) HDD option was employed, the bentonite slurry was two times the borehole volume, Eversource conservatively estimates that 127 tanker trucks (9,000-gallon capacity) would be required to dispose of water and 136 conventional truckloads (25 cubic yard capacity) would be required for solids disposal.

3.2.10 Construction Equipment Deliveries & Access

The HDD process will require large, heavy drill rigs and support equipment (e.g., recyclers) which will be transported to and from the site(s) by road. A traffic plan would need to be developed, which would consider maximum vehicle widths and equipment loads, particularly where secondary road and bridge use is required. The shared driveway to the Durham site would require substantial clearing and upgrading. A standard 40' long trailer would require additional maneuvering for both unloading and turn-around operations.

3.2.11 Land Rights Requirements for HDD

The need to acquire land rights for HDD installation and construction could add significant cost, greater impact to private property and delay to the Project siting process and schedule.

Full HDD Option

Eversource does not presently own or control the land rights required for cable installation utilizing a full HDD.

On the Newington side of Little Bay, Eversource is constrained by a 100-foot wide easement through properties in Gundalow Landing. Similar constraints exist with respect to Eversource's existing easements for overhead lines running easterly of Little Bay Road, including the "Flynn Pit" parcel owned by the Town of Newington. None of these existing easements allow for underground lines or the type or scope of construction work needed for the installation of HDD across Little Bay. While Eversource has negotiated option agreements to acquire underground rights with certain existing landowners in Newington, these options are only for the installation of the SRP line in an underground configuration within Eversource's existing right of way, and do not provide expressly for any rights to use those lands to install or construct HDD across Little Bay. Due to the limited bending capability of the steel casing, the HDD borepath geometries and staging area on the Newington would need to occupy private property beyond Eversource's existing 100-foot wide easement.

On the Durham side of Little Bay, Eversource owns in fee the parcel of land situated on the shoreline, but is again constrained by owning only a 100-foot wide easement for overhead lines inland of that parcel. The staging area needed for casing handling on the Durham side would have to extend well beyond the Eversource parcel, and would need to use private lands for which no rights exist other than the existing Eversource overhead easement. The HDD staging area on this property would, similar to the Newington side of the Bay, need to be considerably larger than just the width of the existing Eversource easement. Furthermore, the property in this location is subject to an existing conservation easement held by The Nature Conservancy, which presents further restrictions on any use of that property beyond those allowed under Eversource's existing easement. As with the Newington side, the HDD bore paths in Durham would need to be located outside of the Eversource easement, specifically between the exit pit and the shoreline of Little Bay.

Eversource would be required to obtain the necessary private property land rights in Durham and Newington to install and construct the Project using HDD technology and construction methods. As the duration of the HDD is substantial, it is uncertain whether, and under what terms or conditions, such temporary land rights could be acquired by Eversource.

The PUC water crossing license order for Little Bay was obtained assuming jet plow installation and not for full HDD or a shore landing HDD installation. A change to an HDD installation across the Bay would require a new PUC water crossing license application or a request to amend the license.

Land Rights Requirements for Shore Landing HDD

Eversource does not presently own or control the land rights required for installation for a shore landing HDD. The land requirements are similar to that for a full HDD installation.

3.2.12 Environmental Impacts

Environmental impacts from HDD to Little Bay primarily relate to the potential for IR during drilling and temporary wetland impacts at the subtidal HDD exit points and the freshwater wetlands within the casing and conduit laydown areas. Other sources of environmental impacts include the geotechnical borings, and the marine support required for the HDD Shore Landings. The potential impacts include:

Sediment and Water Quality

HDD activities likely to generate suspended sediments in the water column include the barge and drilling associated with deep geotechnical borings and the in-water work at the exit points of the HDD in Little Bay. A full HDD installation will likely require approximately 7 geotechnical borings to be drilled in the Bay to characterize the sediments and rock to a depth of approximately 20 feet below the planned borehole depth (total depth up to 90 feet below the bay bottom). The shore landing HDD option would likely require 4 borings in Little Bay, due to the shorter drill path. Each test bore is expected to take approximately 3 days to complete, for a total of 21 days. Environmental impacts from this operation include sediment disturbance and direct impacts to organisms from the spuds used to hold the barge stationary, and minor turbidity from the drilling process itself. Should HDD be required, Eversource would work with DES to acquire the appropriate permits for the geotechnical investigations, if necessary.

Environmental impacts specific to the HDD shore landings are associated with the four exit points proposed in Little Bay. The impacts are associated with the barge, and conductor casings proposed to be placed at each exit point to control the drill and drilling fluid when the drill reaches the surface. The barges and conductor casings will cause physical disturbance to the floor of Little Bay, resulting in minor turbidity and the mortality of bottom-dwelling organisms within the footprints of the barge spuds and conductor casings. These impacts are expected to be relatively minor and temporary, with recovery expected by the next growing season.

The long shallow intertidal/subtidal shelf on the west side of Little Bay requires that the HDD extend approximately 2,700 feet, exiting in the channel. HDD from the east side would extend to the channel, leaving approximately 2,000 feet to be connected via jet plow. The shore landing HDD would require six passes of the jet plow as each cable would have to be installed separately. Compared to the jet plow only alternative therefore, the shore landing HDD jet plow segment would impact approximately 3.7 acres of subtidal substrate, and would result in more but shorter periods of increased suspended sediments.

Inadvertent Drill Fluid Returns

As noted previously, a bentonite-based drill fluid is pumped into the HDD bore during all drilling and reaming activity. The drilling fluid removes cuttings, stabilizes the borehole, lubricates and cools the drill tools. The drilling fluid exerts a pressure on the surrounding materials (soil, bedrock), which is a function of the static weight of the drill fluid, and the dynamic pressure required to push it out of the borehole. One potential adverse impact of HDD is an IR of drill fluid to the ground surface or bay bottom). This condition occurs when the annular drill fluid pressure within the borehole exceeds the confining capability of the surrounding geologic materials (soil or bedrock).

For either a full or shore landing installation, an HDD design would be developed to minimize the risk of an IR by targeting geologic materials (where possible) with in-situ strengths capable of withstanding the anticipated drill fluid pressures. In addition, the Contractor would be required to monitor and control downhole drill fluid pressures during drilling.

Despite design and construction controls, IR's occur regularly in the HDD industry. Typically, an IR occurrence requires that the contractor stop drilling, repair the borehole (through swabbing or plugging the release point), or if necessary redirecting the borehole around the release point, and containing and removing the drill fluid released to the surface.

For land-based portions of the HDD, an IR could be contained using hay bales and shallow surface excavations, and removed by hand tools and vacuum trucks. This remediation activity may result in additional surface disturbance, including impacts to vegetation.

Depending on depth and location, an IR within Little Bay could be contained by silt booms and a gravity cell. This operation would require a dedicated standby vessel to be anchored over the IR area; a gravity-cell containment system to be placed over the IR location with a barge mounted crane; and a diver-operated vacuum operation to be conducted until all bentonite is transferred up to frac-tanks on the barge.

In the event of an IR within Little Bay, the bentonite clay based drilling fluid would likely sink to the bottom of Little Bay and has the potential to smother macroinvertebrates in the sediments. A large release could result in injury or death to larger non-mobile organisms such as shellfish and oysters. Experience suggests that more mobile species such as fish, lobsters and horseshoe crabs could avoid the bentonite plume.

The material safety data sheet ('MSDS') for bentonite clay indicates that there are potential acute human health risks from ingestion (undefined), inhalation (irritant) or eye contact (irritant). The MSDS indicates that there is no information available on ecotoxicity.

The clean-up required for an IR is also potentially environmentally damaging. In general, agencies ask the installer to confine the plume with a gravity cell and to suction up any detectable bentonite in the water column or settled on the bottom. The gravity cell results in a bottom disturbance within the footprint of the gravity cell, and a loss of substrate as the surface sediments are suctioned up. This results in the mortality of organisms within those surface sediments, including benthic macroinvertebrates and shellfish. Similarly, suctioning of the bottom sediments to recover the bentonite not contained by the gravity cell results in sediment loss and mortality of benthic organisms. It is expected that most fish and larger mobile crabs and lobsters could avoid the suction. The eggs and larval stages of fish and shellfish, plankton and other floating organisms would be entrained (vacuumed up) during the suction process. The magnitude of entrainment would be dependent on the size of the IR and the degree of clean-up required.

HDD impacts to Little Bay would be relatively minor and temporary with recovery expected by the next growing season. The exception would be a large IR, in which excessive amounts of bentonite are released into the water column and are carried by tides to adversely affect eelgrass, natural shellfish beds, the newly established oyster reefs off Adam's Point, and/or oyster aquaculture sites.

Mobile and Sessile Organisms

Vibrations associated with shore landing HDD construction within Little Bay will result from vibratory hammers used to drive conductor casings at the exit holes. Data are not available to estimate the radial distance between the sound source and NOAA's thresholds for effects on fishes (150 dB for behavioral modifications; 183-187 cSEL [cumulative sound exposure level] for potential injury, depending on the size of the fish) but work done by MacGillivray (2018)[13] studying conductor casing installation with a hydraulic hammer in deep water provides some insight. Based on MacGillivray's findings, it is likely that noise levels would exceed the behavioral threshold at an undetermined distance from the source, resulting in fish avoidance of the work area. Data from MacGillivray are not appropriate to evaluate the likelihood that the SRP installation would reach the injury threshold because the sound characteristics differ substantially between hydraulic (concussive) and vibratory (nonconcussive) hammers.

Wildlife

For full HDD, the work corridor is estimated to be 65 feet wide, and would be on timber mats in wetlands. The environmental monitors would sweep the areas to remove wildlife such as small mammals, snakes and turtles prior to establishing the workspace, but disturbance and some mortality would likely occur during the 28 months of construction due to smaller animals attempting to cross the workspace and either getting caught in equipment or crushed by traffic. Larger animals, birds and bats would temporarily lose some habitat, but would be better able to avoid injury or mortality.

For shore landing HDD, the work corridor is estimated to be 65 feet wide, and would be on timber mats in wetlands. The environmental monitors would sweep the areas to remove wildlife such as snakes and turtles prior to establishing the workspace, but disturbance and some mortality would likely occur during the 10 months of construction due to smaller animals attempting to cross the workspace and either getting caught in equipment or crushed by traffic. Larger animals, birds and bats would temporarily lose some habitat, but would be better able to avoid injury or mortality.

In Newington, the pipe laydown area for the shore landing HDD would extend over the vernal pool in the Flynn Pit. A crane or other supporting structure would be used to avoid direct impacts to the vernal pool.

Wetlands

Temporary impacts from a complete HDD installation are expected to be approximately 2.7 acres of freshwater wetland and one stream. These impacts are anticipated due to land-based equipment and set-up requirements in Durham. In Newington, the workspace is sited in uplands only and does not include a pipe laydown area, therefore, no wetland impacts due to the full HDD are anticipated in Newington.

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[13] MacGillivray, A. 2018. Underwater noise from pile driving of conductor casing at a deep-water oil platform. Journal of the Acoustical Society of America 143, p 450. https://doi.org/10.1121/1.5021554

The work space required for HDD shore landings is similar to that for full HDD, and includes a 30,000-square foot drilling site on each side of the bay. Temporary impacts to approximately 2.9 acres of freshwater wetland (1.0 acres in Newington and 1.9 acres in Durham) are anticipated due to land-based equipment and set-up requirements in each town.

Wetlands in the work space would be protected with timber mats and erosion controls, but given the length of time anticipated for the HDD work (28 months), the vegetation underneath the mats is not expected to survive. Upon completion of the work and the removal of equipment, the impacted wetland areas would be stabilized and re-established with soil enhancement and plantings.

3.2.13 Impacts to Public

Potential impacts to the public include extended workspace occupancy with attendant, noise, vibrations and construction traffic impacting adjacent residential properties.

The primary impact to the public will be the prolonged disturbance from drilling activities at the staging areas, as depicted in Figures 12 and 13. Contractors will occupy both staging areas for the entire duration of HDD construction, which is estimated to be 10 months for shore landing HDD and 28 months for full HDD. The majority the construction activities would occur 6 days a week for 12 hours per day, except for critical stages of the drilling operation that would require 24-hour work. The HDD work will also require lighting and power at the work areas at both ends of the bore. For all HDD operations, a barge or work platform and a support vessel will be required in Little Bay for the duration of construction.

Additional marine vessels (jackup barge, crew boat) would also be required for completion of geotechnical borings needed to support project design. The current anticipated duration of the marine test boring program is approximately 33 days.

Noise associated with the HDD operations would result from initial site clearing and grading activity and later from the installation of the steel casings, operation of the HDD drill and hydraulic power units for the drill motor, electric pumps used for circulating the drilling fluid, diesel site generators and additional diesel powered light plants and from conventional construction noise sources such as, large vehicle back-up alarms, front-end loader or back-hoes (required to load drill pipe sections into the drill rig) and cranes to handle casing pipe string.

Most larger HDD drills and support equipment typically produce a sustained noise level between 95 and 105 dB(A). It should be noted, however, that the noise levels can be reduced by use of equipment mufflers and temporary noise barriers (i.e. sound walls), laced around the limits of the construction zone. The noise reduction would be quantified by instrumentation placed at adjacent receptors (e.g., residential structures).

3.2.14 Construction Traffic

HDD operations will cause additional roadway traffic in both Durham and Newington, resulting from equipment delivery/removal, material delivery (casing, conduit, etc.), spoils removal, and work force transportation. This additional traffic will be active at least 6 days per week.

The size and weight of the land-based HDD construction equipment and the cable spools are substantial. Delivery and removal of these items will require development of a project-specific transportation plan, which must consider roadway loading limits, bridge weight restrictions, equipment height limitations, and truck turning radii.

For example, for the full HDD installation, it is estimated that at least 45 separate truck deliveries will be required to provide the steel casing and HDPE conduit required.

3.2.15 Schedule

The installation of the full HDD is projected to span approximately 28 months, which includes the following:

- Land based test borings would be completed by a truck-mounted drill rig, and would take approximately two (2) days each for a total of 12 days. Test borings taken within Little Bay would require a barge-mounted drilling rig mounted on spuds capable of sampling to 20 feet below the proposed HDD depth of up to 70 feet. Each barge-mounted test boring would take approximately three (3) days for a total of 33 days.
- 2 months HDD mobilization, demobilization, and moving between boreholes
- 1.5 month total pilot hole drilling
- 23.5 months reaming and borehole conditioning.
- 1-month casing pullback, duct pullback, thermal grout installation

The installation of the shore landing HDDs is projected to span approximately 10 months, but this timeframe assumes the two shore landings are completed concurrently. This schedule assumes the following for each shore landing location:

- 2 months mobilization, demobilization, and moving between boreholes
- 1-month pilot hole drilling
- 7 months reaming and borehole conditioning
- 1-month casing pullback, duct pullback, thermal grout installation

For planning purposes, the entry and exit work space, including the casing/duct laydown area will be occupied for the full duration of construction.

For both installations, the HDD contractor would work 12-hour days, although critical stages of HDD construction (i.e. pipe pullback, equipment failures or clean-up activities for an IR of drilling fluids, etc.) would require 24-hour operations.

3.2.16 Cost

Full HDD

The approximate conceptual cost estimate (-25%/+50%) of the Project, when incorporating the full HDD option, is expected to be $216 million, $132 million more than for the Project using full jet plow installation. The estimate includes mobilization, drilling and reaming, the duct material, steel casing, thermal grout, and the cable.

Shore Landing HDD

The approximate conceptual cost estimate (-25%/+50%) of the Project with the two shore landing HDD installations (including the additional cost for the jet plow installation between the two-shore landing) is expected to be $184 million, $100 million more than for the Project using full jet plow installation. The estimate includes mobilization, drilling and reaming, and the duct material, as well as the marine support equipment.

4 Comparison of Jet Plow and HDD Cable Installation Methods

A Summary of the Jet Plow and HDD Cable Installation methods can be found at Table 1.

4.1 Jet Plow Summary

- Jet plow technology is a common and frequently utilized method for cable installation in marine environments.
- The jet plow installation in Little Bay would result in temporary impacts to wetlands and limited permanent impacts from the placement of concrete mattresses.
- Though the jet plow operations would result in the suspension of sediments, impacts would be temporary and limited and not anticipated to impact area commercial shell fisheries.
- Impacts to land use would be confined to staging in nearshore areas and no additional rights would be required.
- The duration of the jet plow installation is approximately 3 months.
- The cost of the Project, including jet plow, is $84 million (+25%/-25%).

4.2 Full/Shore Landing HDD Summary

- HDD is a common and frequently utilized method for linear installations under water bodies or to avoid obstructions, such as railroads or highways.
- A full HDD for SRP would be approaching the limit of the recorded distance for such installations and the geometry of the HDD is challenging.
- The shore landing HDD would result in temporary impacts to subtidal wetlands.

- The termini of the HDD and jet plow associate with the shore landing HDD would result in the suspension of sediments. Impacts would be temporary and limited and not anticipated to impact area commercial shell fisheries.
- HDDs carry a risk of IRs where drilling fluid would be released into the Bay or inshore areas. Exit points within Little Bay for the shore Landing HDD increase the risk of IR's.
- Impacts to land use would be substantial and of long duration.
- Additional land use rights would be required.
- Certain activities would require the work to be required during a 24-hour operation
- The duration of the HDD installations ranges from 10-months for shore landing HDD and 28 months for a full HDD.
- The cost of the Project including full HDD installation is $216 million (-25%/+50%). The cost of the Project including the shore landing installation is $184 million (-25%/+50%).

5 Conclusion

While both installation methods are technically feasible, the full and shore landing HDDs' technical and logistical challenges, associated potential impacts to the environment, substantial impacts to land use, longer installation time and significantly higher cost support the Project's selection of the jet plow as the preferred method for the cable installation across Little Bay.

Tables and Figures

Table 1. SRP comparison of jet plow, HDD cable installation and surface lay options to cross Little Bay.

Specifics	Jet Plow	Full HDD	Shore Landing HDD/ Jet Plow
Design	Three individual cable placements, spaced 30 feet apart, buried to depth of 3.5 to 5 feet for the width of Little Bay, 4,900 feet.	Six cables in two 48 to 52-inch bore holes 6,000+ feet in length up to 75 feet below the deepest part of the channel.	Six cables in two 48 to 52-inch HDD bore holes on each shore of bay; buried individually by jet plow in middle of Little Bay, 5 feet deep; hand jet at the HDD/jet plow junctions.
Design Components	Jet plow 4,270 feet; Hand jet 880 feet; Trenching 200 feet.	HDD 6,000+ feet	HDD 5,460 feet; Jet plow 2,000 feet; Hand jet 60 feet
Subsurface Conditions	Shallow bedrock at shores may prevent burial to full 3.5 feet. If burial depth cannot be achieved, concrete mattresses will be used for protection.	Length and diameter of bore hole, combined with hard bedrock and present challenges for drilling.	Hard bedrock and exiting into soil within Little Bay challenges for HDD drilling; none anticipated for jet plow.
Equipment Delivery	Cable reels and installation equipment shipped in by barge; shallow trenching on shore to connect to overhead.	Shipped by truck to staging areas; 70-ton drill rig and all supporting equipment to staging areas in Newington and Durham; cable reels, steel casing, and conduit to Durham.	Shipped by truck to staging areas; 70-ton drill rig and all supporting equipment to staging areas in Newington and Durham; cable reels, HDPE casing and conduit delivered by truck.
Cable Lay Approach	Primarily from barge, except for in shore and upland areas	Cables staged in Durham and pulled from Newington	Cable and conduit pulled from water to shore
Staging	Subtidal and tidal flats by jet plow on barge, hand jet near shore from barge, and terrestrial excavation from land.	Land-based in Newington and Durham: 100 x300 feet drilling and pulling area with drill rig, pipes, slurry pit, generator, and support equipment.	Land-based in Newington and Durham: 100 x 300 feet drilling and pulling area with drill rig, pipes, slurry pit, generator, and support equipment. Water-based cable pull and jet plow from barge.
Duration	Approximately 3 months: Jet plow 3 weeks; hand jet 30 days; upland trenching 5 days; concrete mattresses 1 week.	Approximately 28 months.	HDD 10 months; jet plow 3 weeks; hand jet 30 days.
Preliminary Work	1 week each for remove existing distribution cables from the installation pathway; pre-lay grapnel run to clear surface debris.	3-4 weeks of geotechnical exploration for planning the HDD.	3-4 weeks of geotechnical exploration for planning the HDD requires relocation of distribution cables from the installation pathway; pre-lay grapnel run to clear surface debris
Permanent impacts	Approximately 0.2 acres of concrete mattresses in nearshore areas.	None.	None; possible concrete mattress if 42" burial not achieved
Impacts			
1. Suspended Solids	Suspended solids are projected to be present (10 mg/l) for less than 6 hours in Little Bay.	Potential inadvertent return of bentonite drilling fluid.	Potential inadvertent return of bentonite drilling fluid during HDD. Suspended solids are projected to be present (10 mg/l) for less than 6 hours in Little Bay for jet plow. Hand-jetting area reduced. Silt curtains are not feasible due to high currents.
2. Shellfish	Minimal impacts anticipated, as shellfish can adapt to temporary deposition.	Potential inadvertent return occurs, a heavy bentonite deposit could smother shellfish.	If an inadvertent return occurs, a heavy bentonite deposit could smother shellfish. Minimal impacts from jet plowing.
3. Aquaculture	No impact anticipated as oysters can tolerate short periods of elevated TSS.	None anticipated.	None anticipated by HDD or jet plow.
4. Fish	None anticipated, as fish are expected to avoid short duration sediment plumes.	If an inadvertent return occurs, a heavy bentonite deposit would smother fish eggs on bottom. Effect would vary by species and time of year.	If inadvertent return occurs, a heavy bentonite deposit would smother fish eggs on bottom. Effect would vary by species and time of year. Fish will avoid short-duration plumes from jet plowing. In-water vibratory hammers for HDD conductor casing may cause temporary avoidance by fish.
5. Benthic community	Minimal impact from direct jet plow footprint and sediment redeposition to macroinvertebrates. Expected to recolonize by next reproductive season.	If inadvertent return occurs, a heavy bentonite deposit would smother macroinvertebrates. Effect would vary by species and time of year.	If inadvertent return occurs during HDD, a heavy bentonite deposit would smother macroinvertebrates. Effect would vary by species and time of year. Local impact from direct jet plow footprint and sediment redeposition to macroinvertebrates.
6. Wetlands	6.2 ac temporary impacts to tidal habitats areas and fringing salt marsh. Potential for 0.2 ac permanent impacts from concrete mattresses.	12.7 ac temporary impacts to freshwater wetland resources at the staging area on west side of the Bay.	3.7 ac temporary impacts to esturarine subtidal areas; 1.6 ac temporary impacts to freshwater wetland resources at the staging areas and casing laydown areas. No concrete mattresses expected.

7. Visual	A barge, tugboat and 2 workboats for jet plow and hand jet operations for up to 2 months in the fall.	Staging areas in Durham & Newington will be construction work areas for approximately 28 months with heavy equipment, supplies and lights for night work; 20-feet tall screens around staging area will partially mitigate light; barge and support vessels stationed on water during entire HDD operation in event of inadvertent release.	Staging areas in Durham & Newington will be construction work areas for approximately 10 months with heavy equipment, supplies and lights for night work; barge and support vessel stationed on water in event of inadvertent return; barge and 2 workboats for jet plow and hand jet operations.
8. Noise Effects on Humans	Engine and generator noise from barge and support boats during jet plowing and hand jetting up to 2 months in fall; on-shore trenching with an excavator.	Elevated noise from drills and generators will occur during drilling operations (28 months) and pneumatic hammer work (1-2 weeks). 20-foot tall sound barriers will be erected to reduce sound levels	Elevated noise from drills and generators will occur during drilling operations (10 months) and pneumatic hammer work (1-2 weeks. 20-foot tall sound barriers will be erected to reduce sound levels; engine and generator noise from barge and support boats during jet plowing and hand jetting.
9. Traffic	Delivery of construction equipment and crews.	Oversized trucks and trailers will travel secondary roads in Durham and Newington, including 70-ton drill rigs and 50-ton cable reels; daily traffic for work crews and tankers to remove drilling fluids and storm water management.	For HDD, oversized trucks and trailers will travel secondary roads in Durham and Newington, including 70-ton drill rigs, and daily traffic for work crews and tankers to remove drilling fluids and storm water management. For jet plow and hand jet, no local land-based traffic anticipated.
Land Rights	Obtained.	Requires new land rights for 11 properties in Durham, and 2 properties in Newington.	Requires new land rights for 5 properties in Durham, and 10 properties in Newington.
Project Cost	$84 million (+/-25%)	$216 million (-25% /+50%)	$184 million (-25% /+50%)

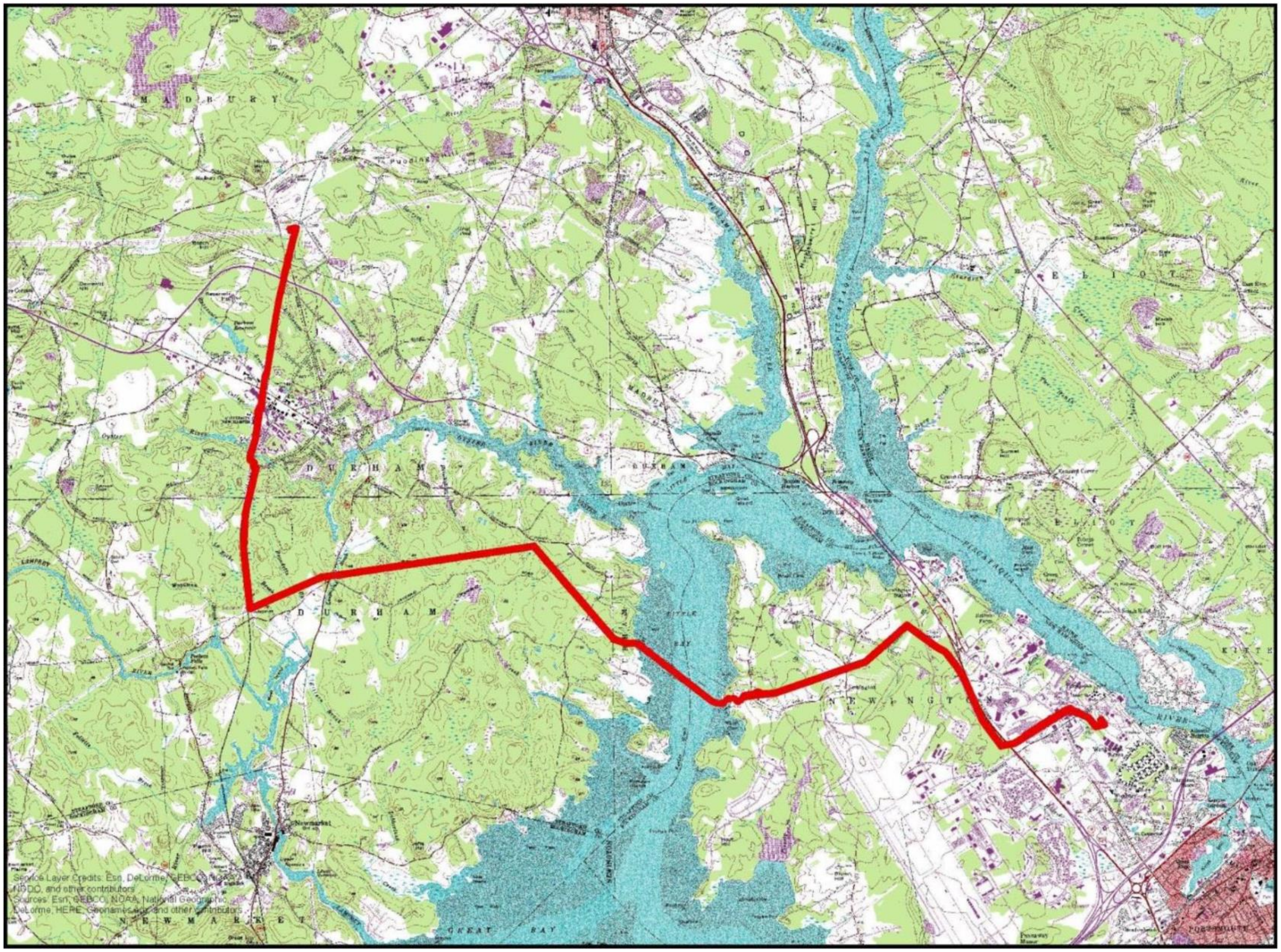


Figure 1. Seacoast Reliability Project Route.

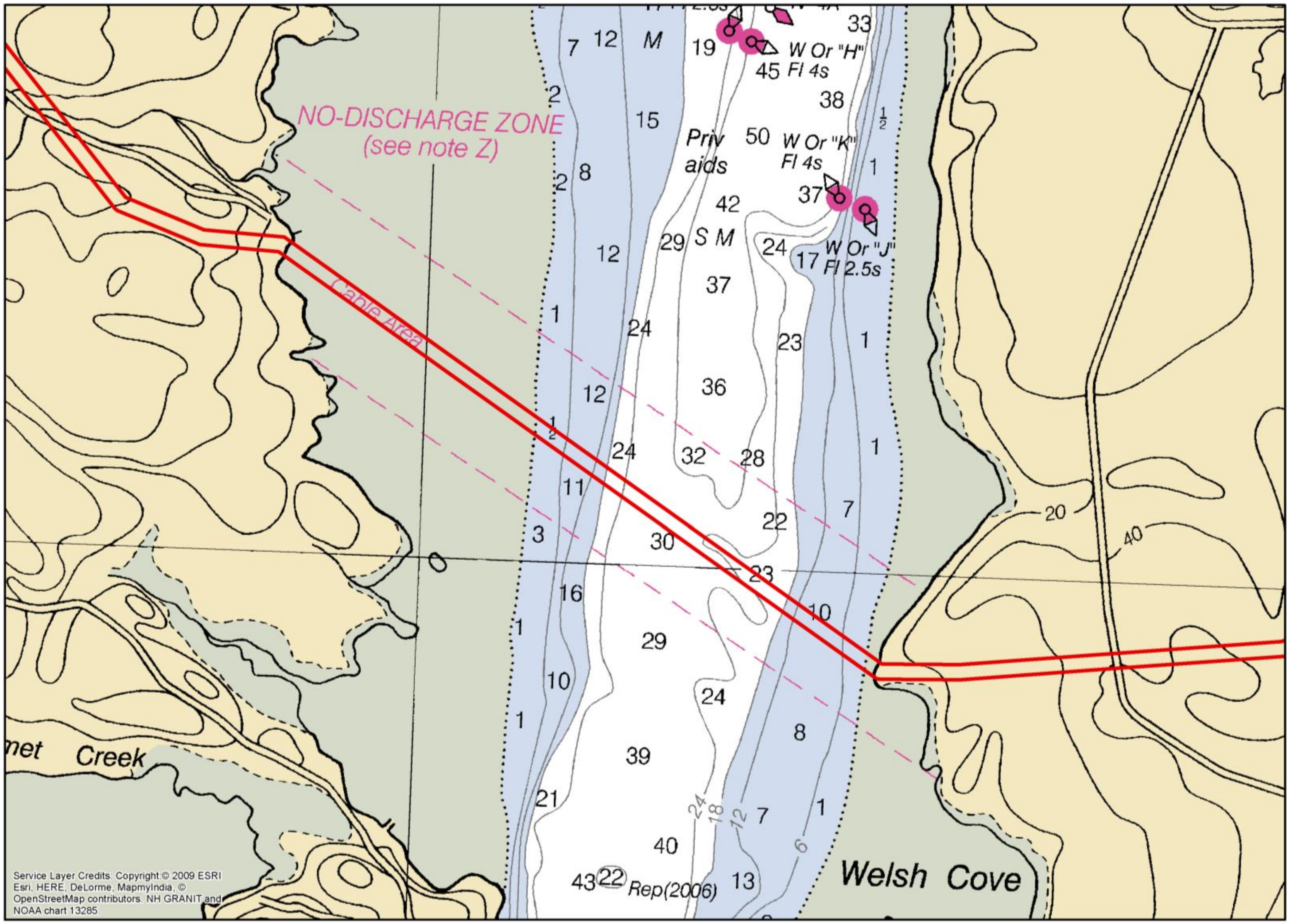


Figure 2. NOAA Charted Cable Crossing Depicting the Approximate SRP Route.

Figure 3. Jet Plow Concept Plan.

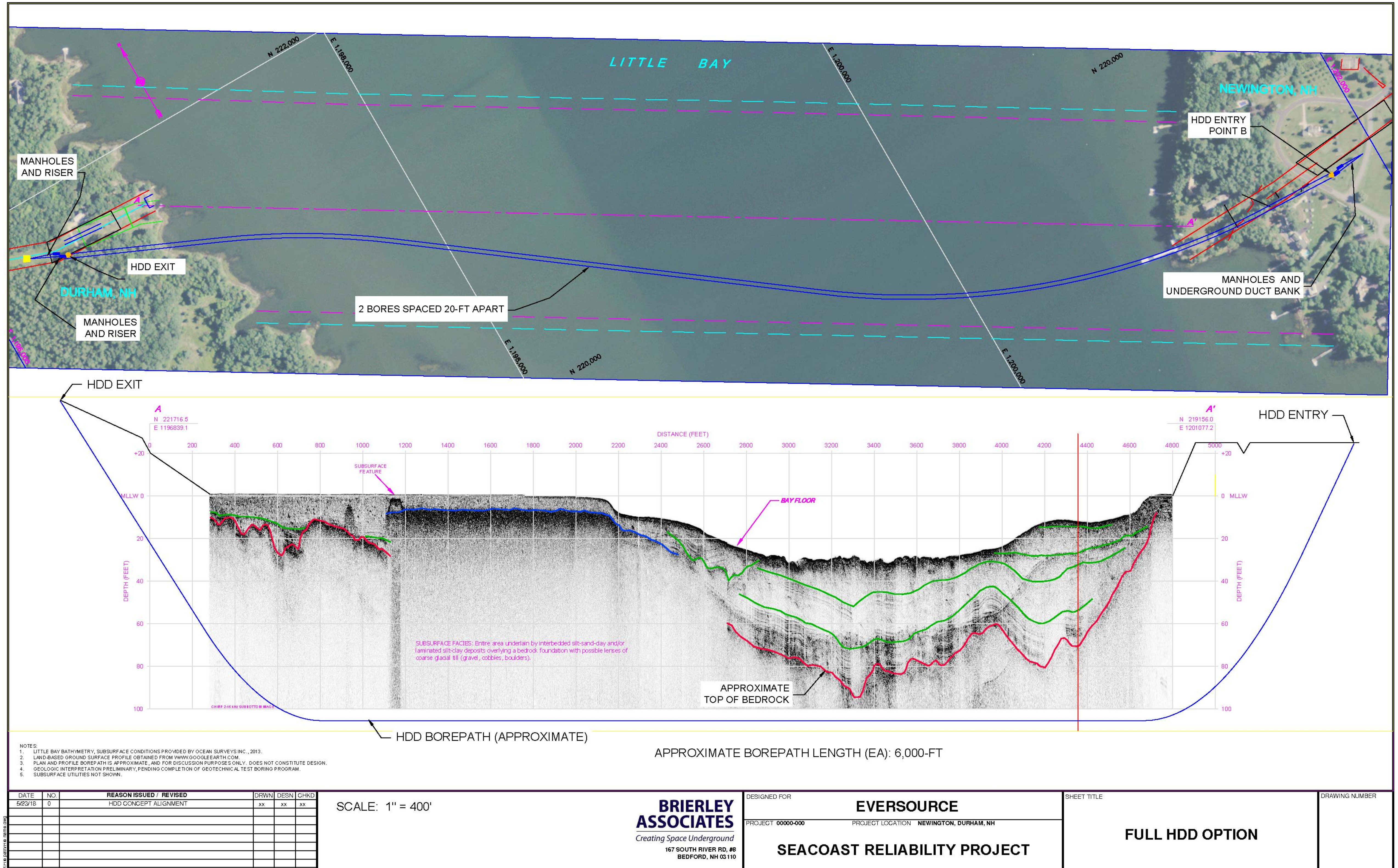


Figure 4. **Full HDD Option.**

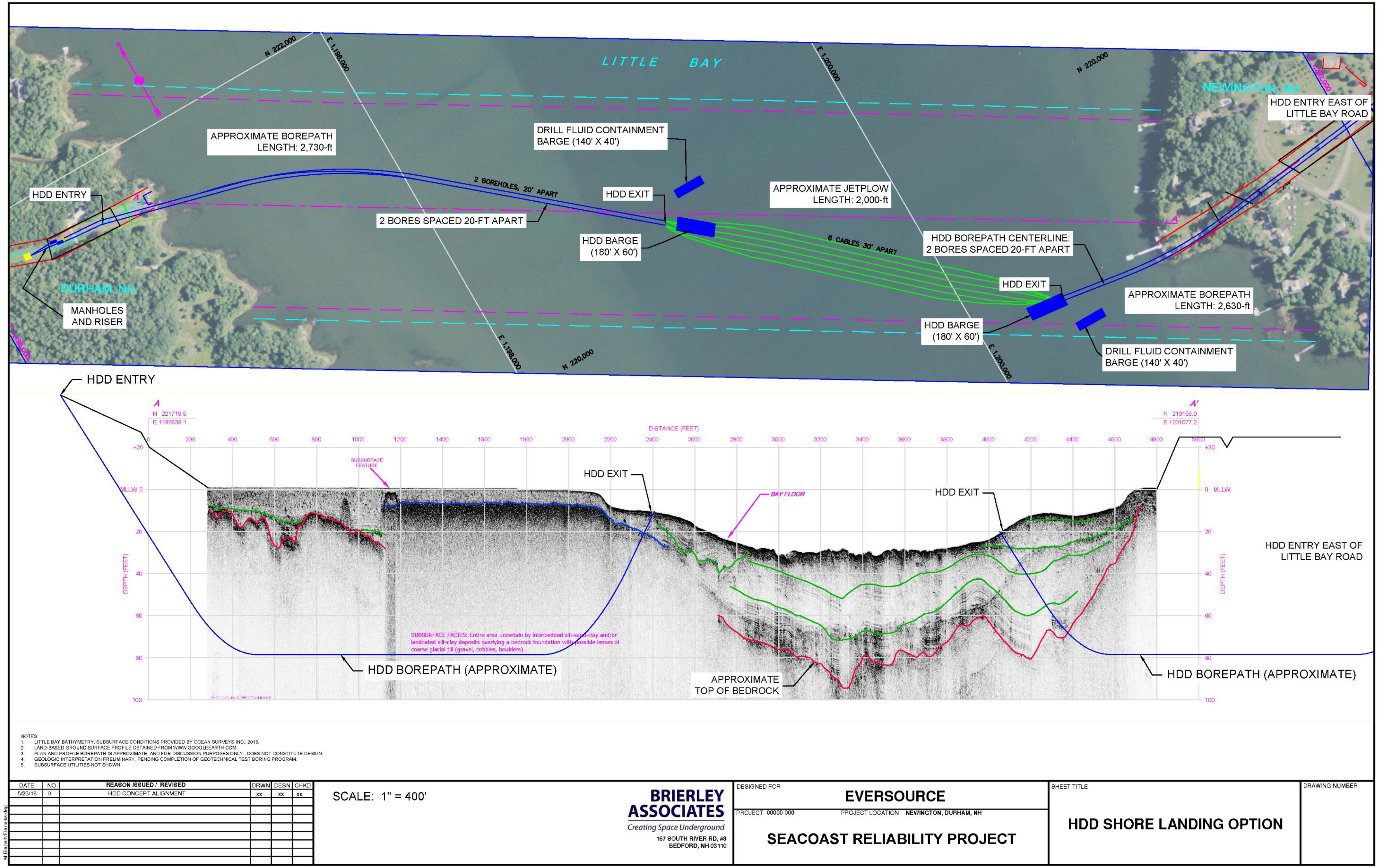


Figure 5. HDD Shore Landing Option.

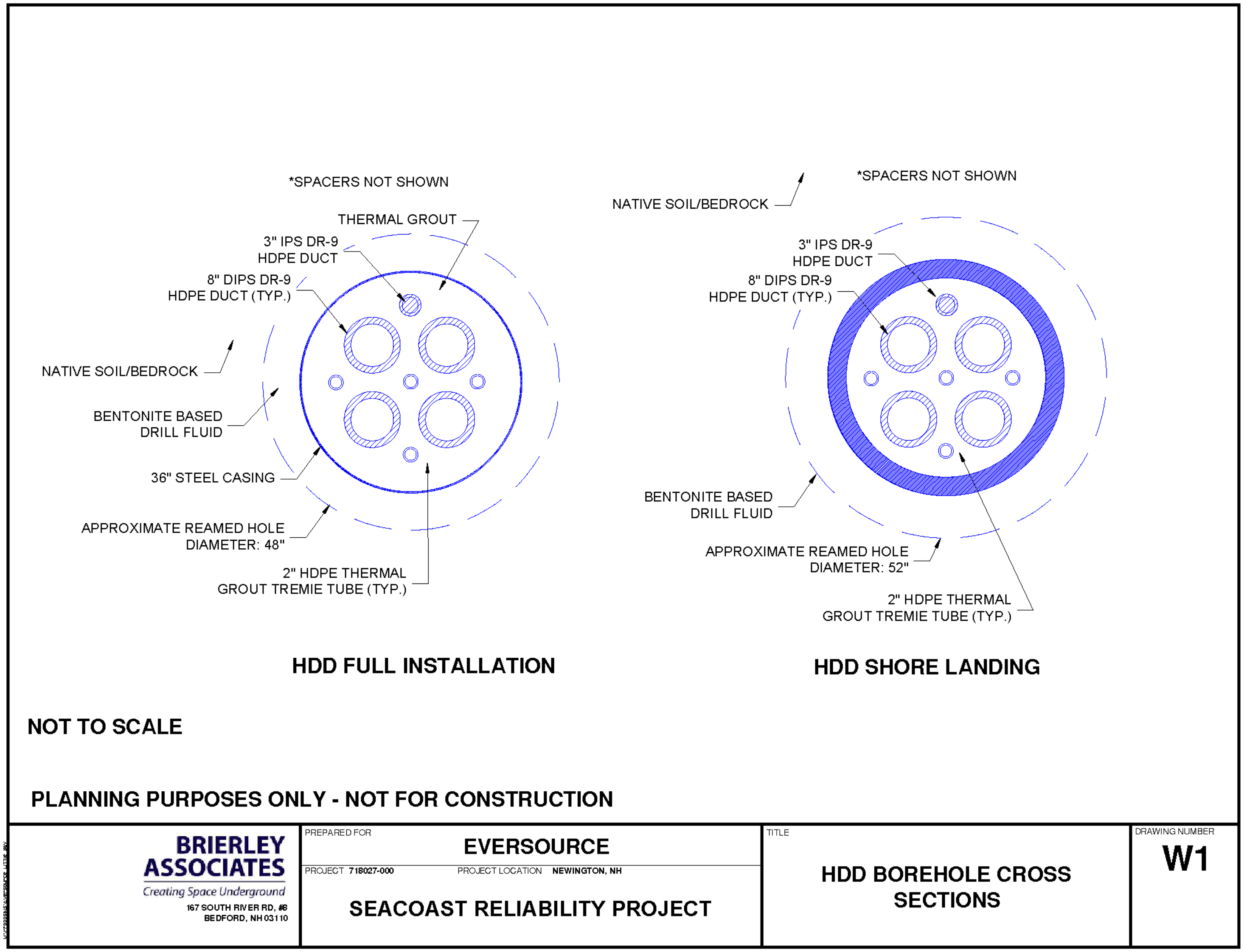
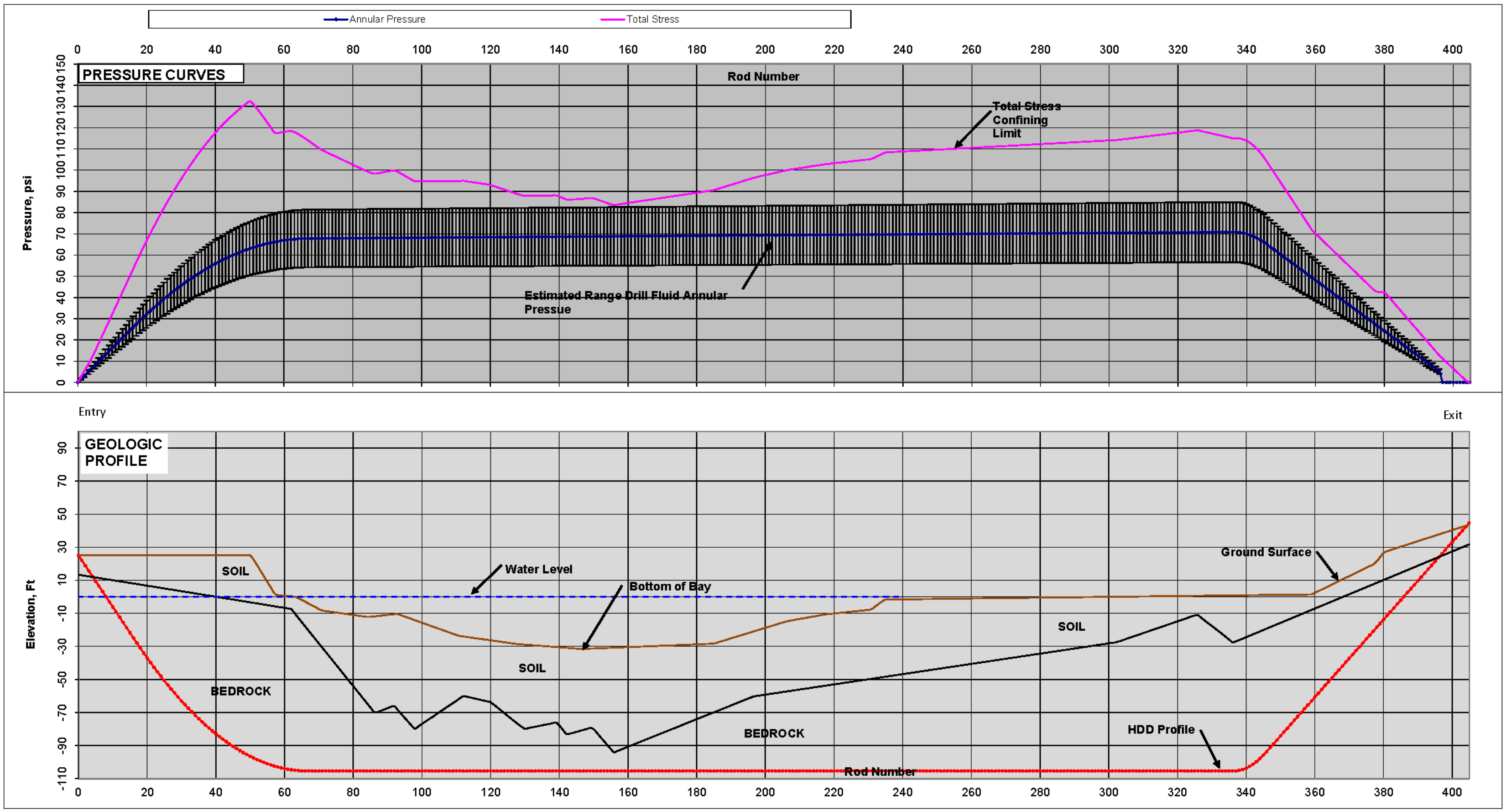


Figure 6. **HDD Borehole Cross-Sections.**



Notes:
1. Geology is interpreted from project data
2. Rod length: 31 feet
3. The error bars are at 20 %
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report, Properties are interpreted from field and laboratory data as presented in Table 3.

Basis of annulur pressure calculations

13.48 in	Pilot Hole Diameter
74.0 pcf	Unit Weight Drill Fluid
75 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
15	Ft per rod
20%	for APC curve

ISSUED: CONTRACTOR'S SUBMITTAL

BRIERLEY ASSOCIATES
Creating Space Underground
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603.206.5775 (O)

Seacoast Reliability Project
Little Bay Crossing
Newington, Durham NH

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
Full HDD Option

Revision 0

FIGURE 1

Figure 7. IR Risk for Full HDD Option.

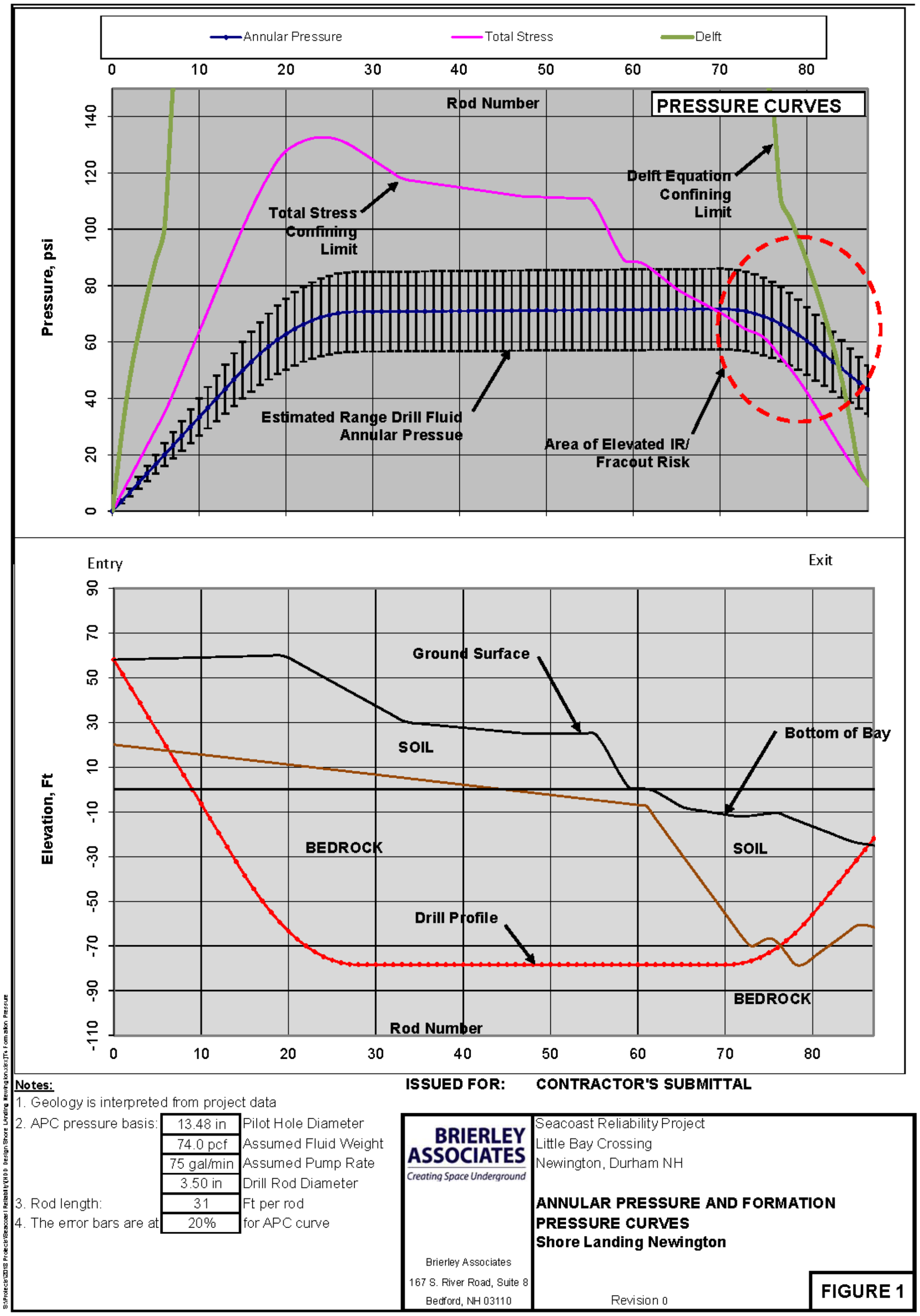
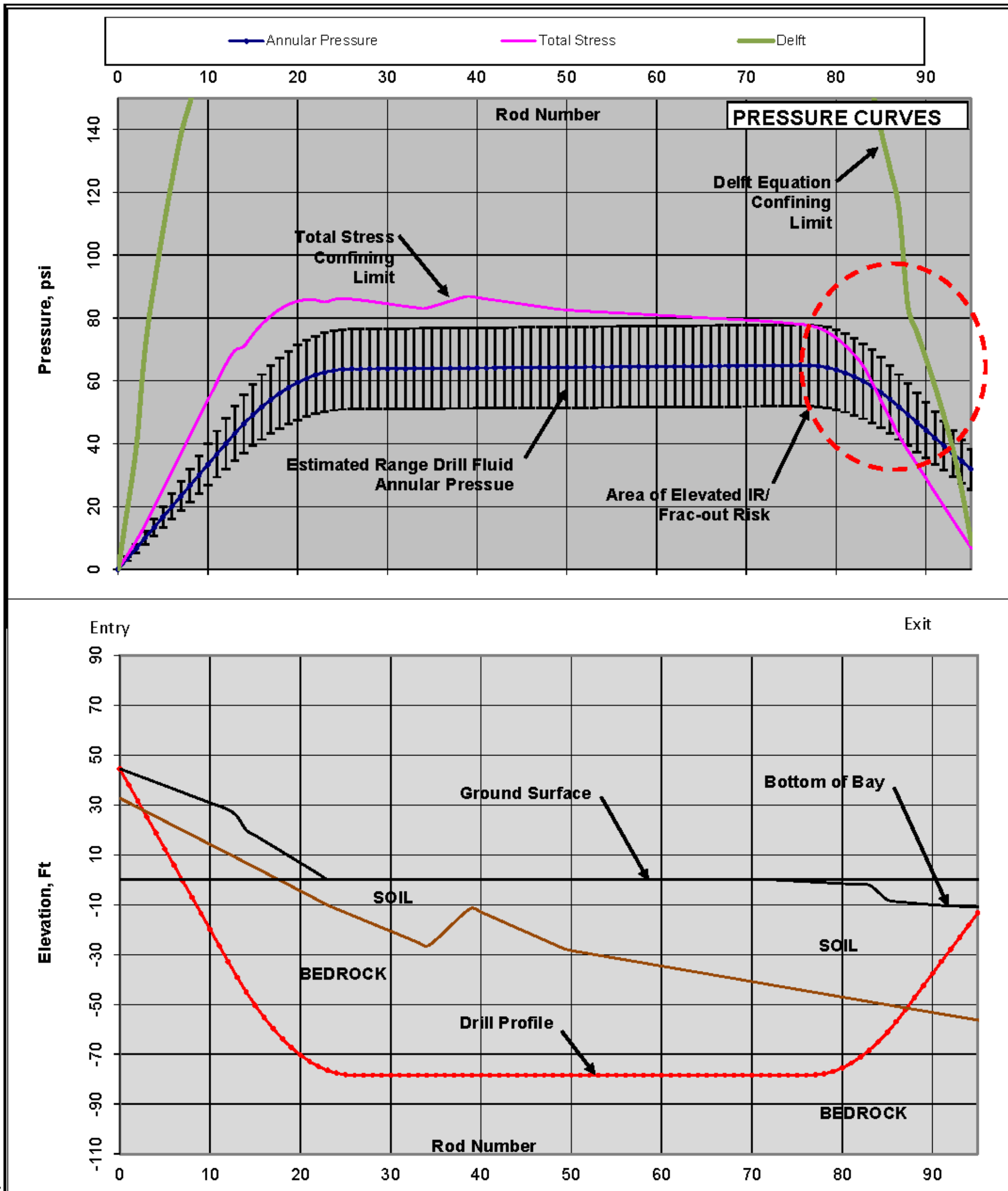


Figure 8. **IR Risk for Shore Landing HDD Option in Newington, NH.**



Notes:

1. Geology is interpreted from project data
2. APC pressure basis:

2. APC pressure basis:	13.48 in	Pilot Hole Diameter
	74.0 pcf	Assumed Fluid Weight
	75 gal/min	Assumed Pump Rate
	3.50 in	Drill Rod Diameter
3. Rod length:	31	Ft per rod
4. The error bars are at	20%	for APC curve

ISSUED FOR: CONTRACTOR'S SUBMITTAL

BRIERLEY ASSOCIATES
Creating Space Underground

Brierley Associates
167 S. River Road, Suite 8
Bedford, NH 03110

Seacoast Reliability Project
Little Bay Crossing
Newington, Durham NH

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
Shore Landing Durham

Revision 0

Figure 9. IR Risk for Shore Landing HDD Option in Durham, NH.

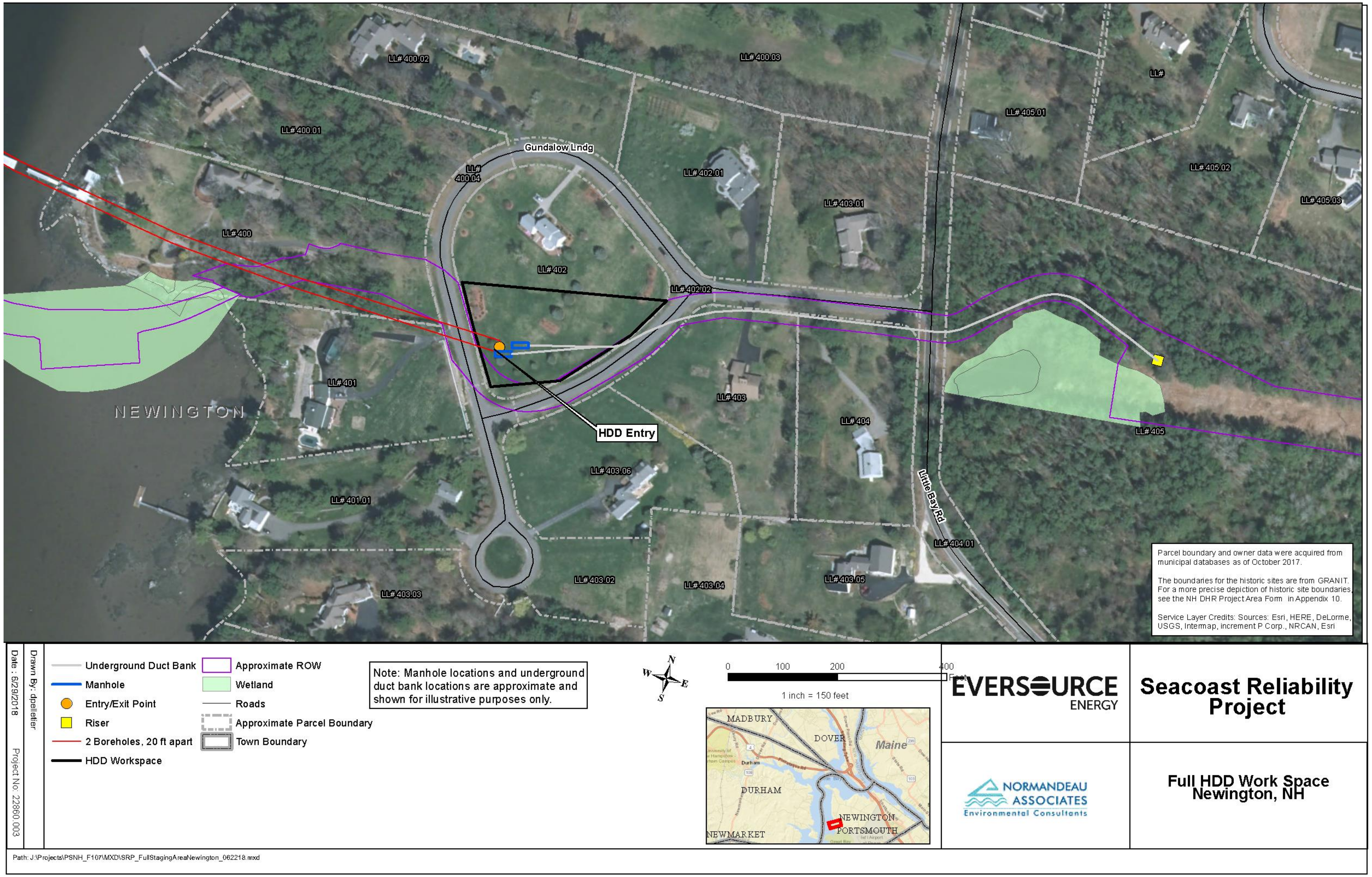


Figure 10. Full HDD Staging Area, Newington, NH.

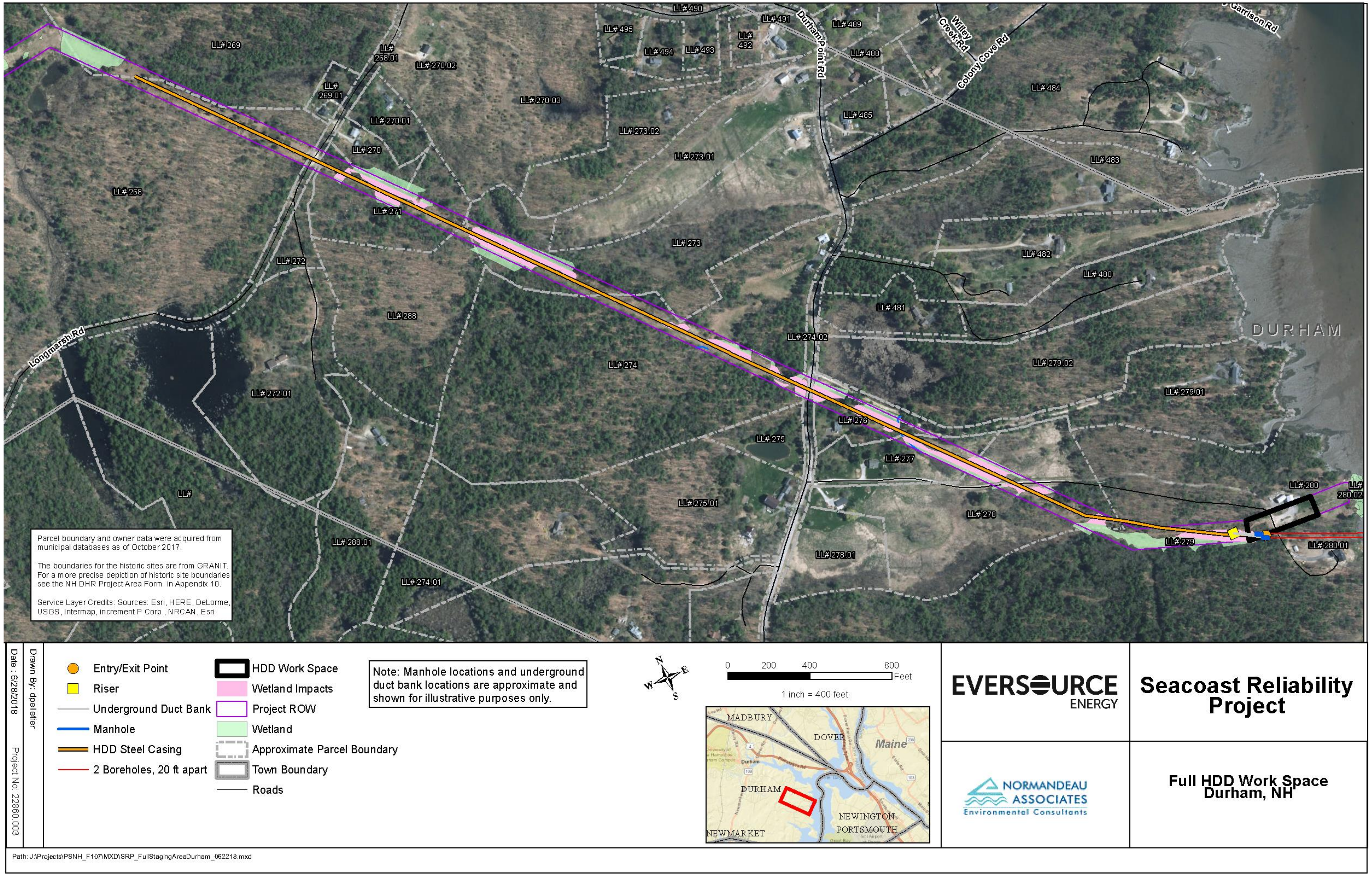


Figure 11. **Full HDD Staging Area, Durham, NH.**

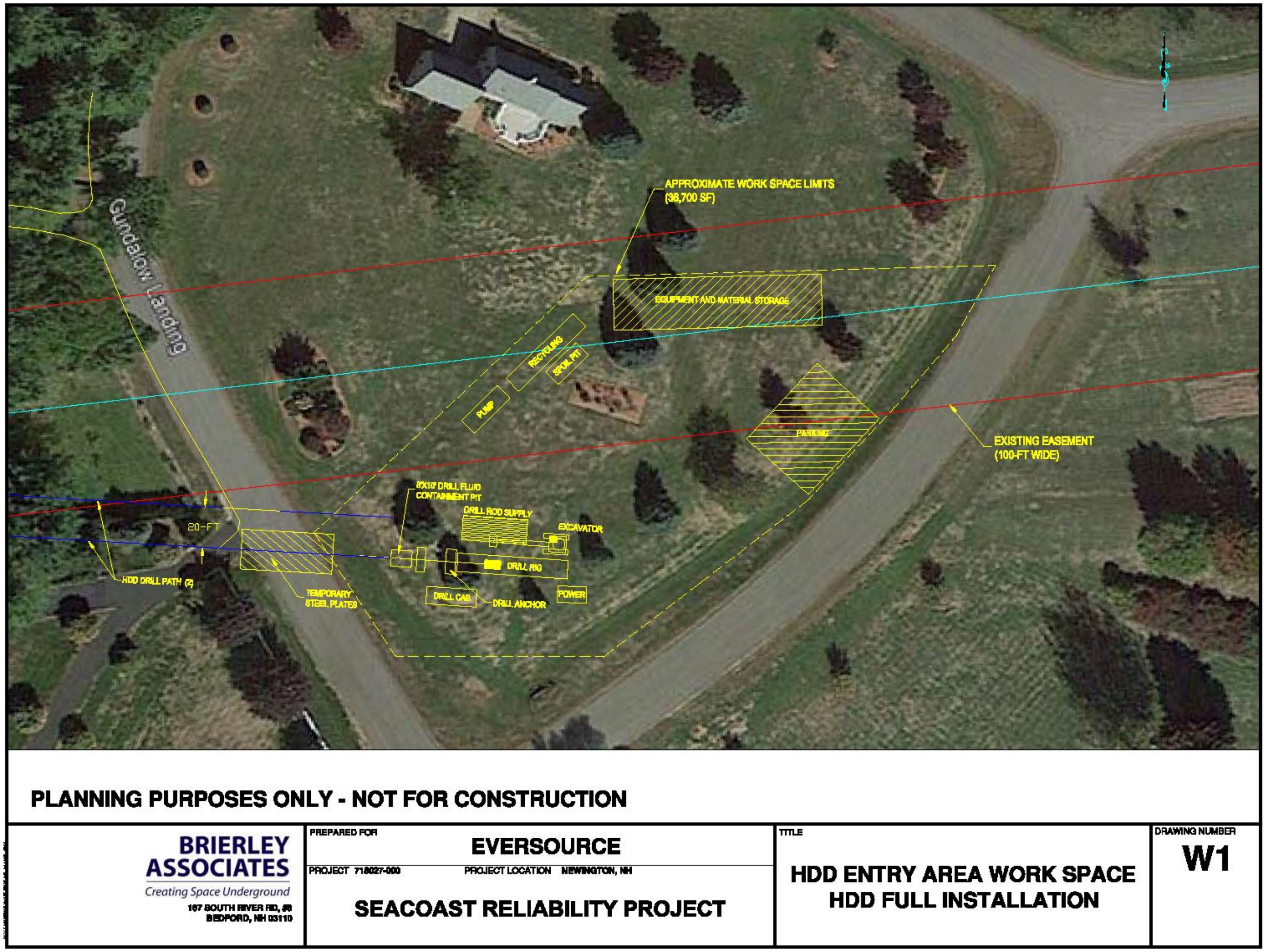


Figure 12. HDD Entry Area Work Space.

Figure 13. Examples of Large Land-based HDD Work Spaces. Note the tan inflated sound barriers in the lower image.

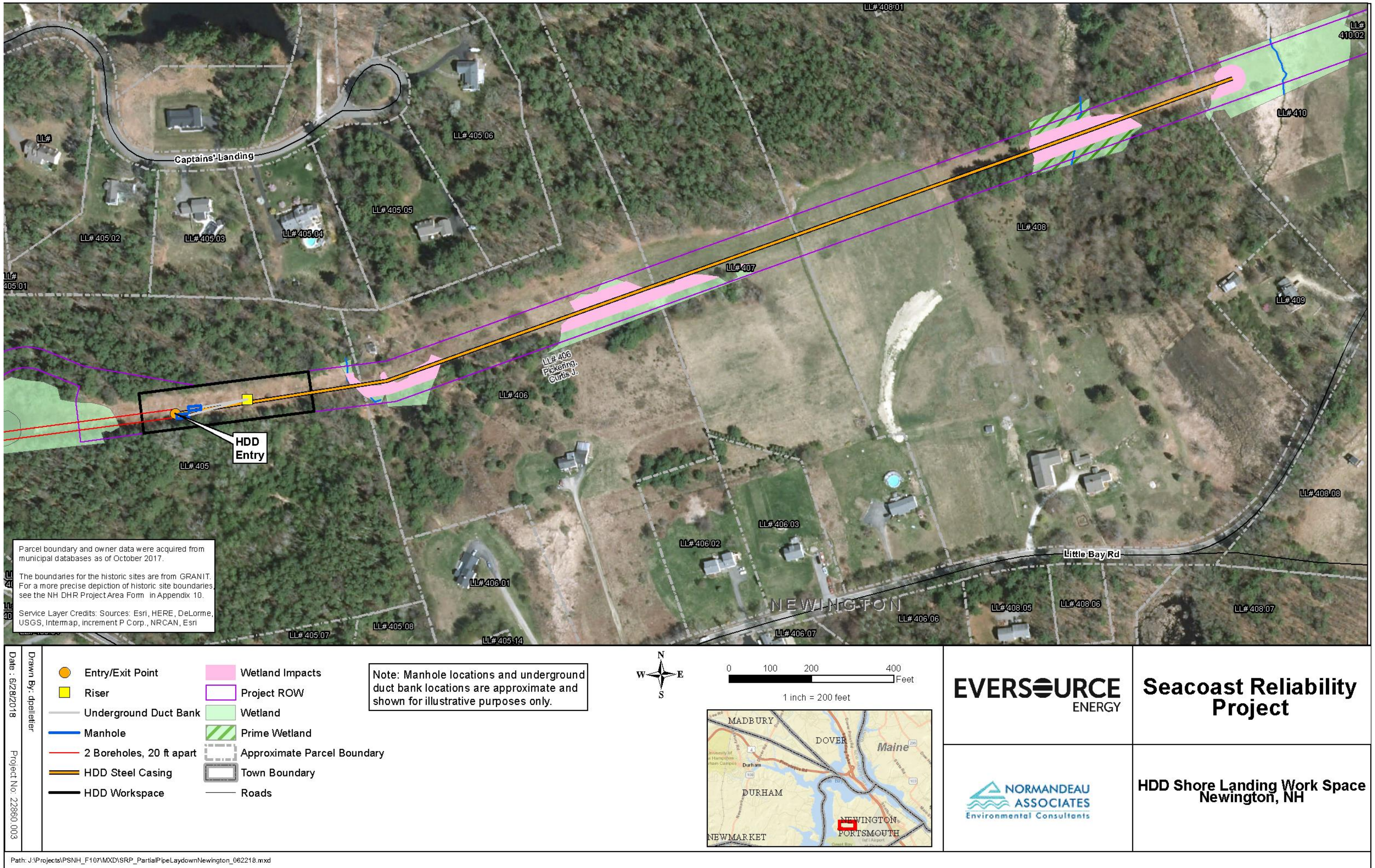


Figure 14. HDD Shore Landing Workspace and Pipe Laydown Area, Newington, NH.

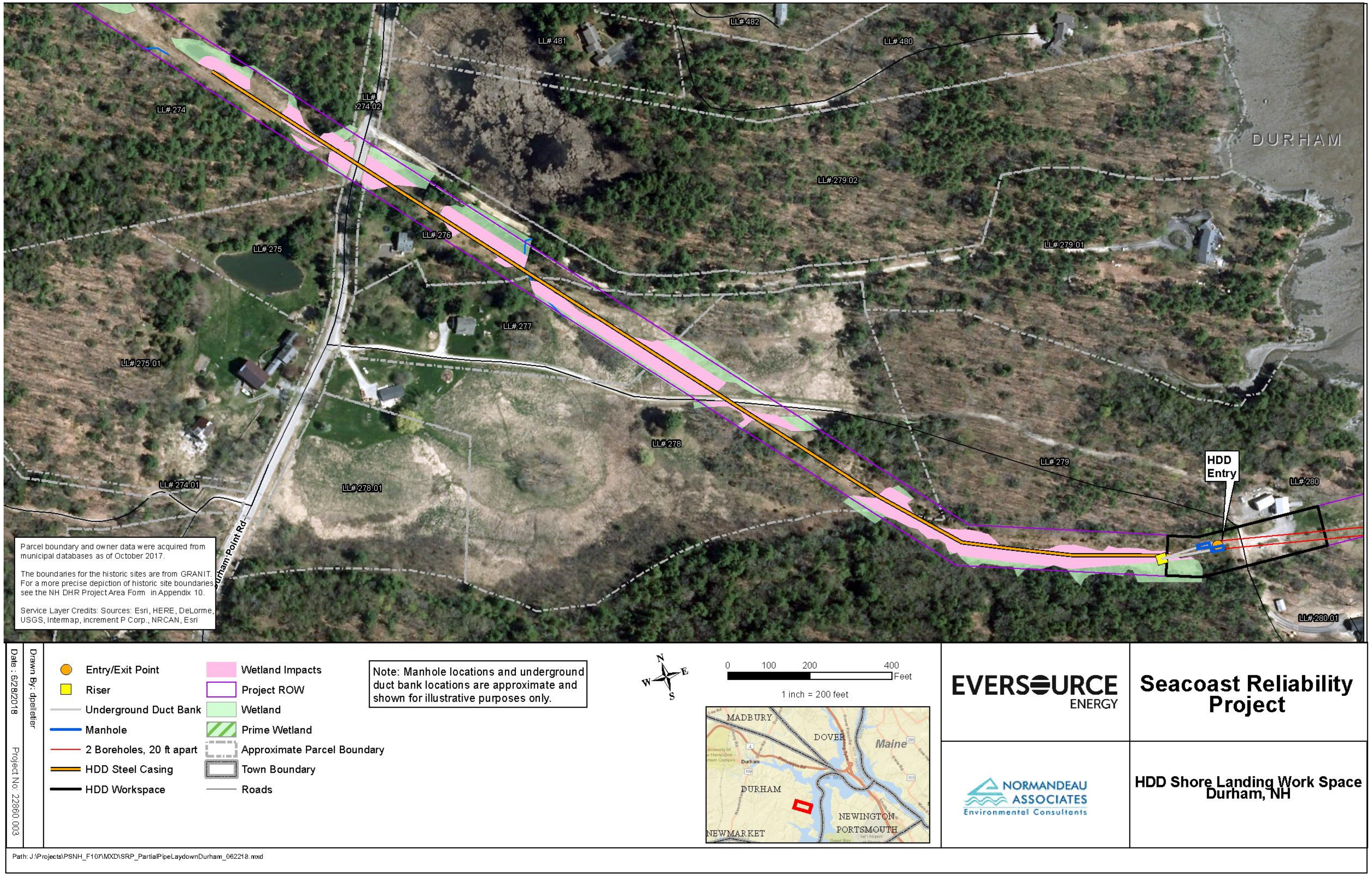


Figure 15. **HDD Shore Landing Workspace and Pipe Laydown Area, Durham, NH.**

Appendix A—Articulated Concrete Mattress Installation Descriptive

Caldwell
Marine International, LLC

Madbury Substation to Portsmouth Substation
Public Service New Hampshire F-107 Line Project

Caldwell Marine International, LLC
Permitting and Regulatory Support

Articulated Concrete Mattress Installation Descriptive

18 February, 2016

CONTENTS

1 INTRODUCTION

Caldwell Marine International (CMI) has been requested by the PSNH permitting team to provide the following descriptive / narrative information in support of the PSNH Portsmouth – Madbury F-107 Line Project. The intent of this document is to provide a descriptive regarding the purpose for use, and equipment and methodology typically employed when installing protective articulated mattresses over cables in a shallow water environment.

1.1 Articulated Concrete Mattress Installation Reasoning and Potential Installation Areas

In cases where a submarine cable has been simultaneously laid / buried with a jet plow, there may be sections of cable that did not reach full specification depth due to the incidence of resistive substrate. The most commonly incurred substrates not conducive to jet plow burial are basement / bedrock, cobbles, boulders, and very stiff clays.

In areas where shallow buried cables are particularly susceptible external aggression such as anchor strikes, fishing / trawling / dredging activity, or ice scour, it is often recommended to add additional protection over the cable in the form of articulated concrete mattresses.

The most likely areas of reduced burial in the submarine cable portions of the F-107 line crossing Little Bay are in the shallow water sections at the landing approaches.

Exposed basement / bedrock, boulders, cohesive and stiff clays have been noted in both the survey data and site visit notes at the Western Landing, and manual depth probing at this approach showed at least some sections where burial to only 12" may be reasonably achieved with the jet plow. Although trenching by excavator fitted with a rock tooth will likely create a suitably protective trench at the inter-tidal zone, permit applications should include the possibility of the need for installation of mattresses at (and seaward of) the intertidal zone should they be deemed necessary.

Rock outcrops and resistive gravels have been noted in both the survey data and site visit notes at the Eastern landing, with upturned sedimentary stone block seen exposed near the Eastern landing at the intertidal zone. Vibracoring at LB9 and LB10 locations yielded limited penetrations with notes of cohesive gray clays. Good penetrations were achieved at the LB11 location in Welsh Cove, and limited penetration in stiff clay was achieved at the LB12 location in the Easternmost section of Welsh Cove. Although trenching by excavator fitted with a rock tooth will likely create a suitably protective trench at the inter-tidal zone, permit applications should include the possibility of the need for installation of mattresses at (and seaward of) the intertidal zone should they be deemed necessary.

Based on the review of available survey, coring, and field data, it is recommended that permit applications conditionally allow for the potential installation of the following:

Western Landing Approach: Allow for the conditional installation of ~160LF of mattresses between the intertidal zone and mud flat areas. (Each mattress covers 20LF of cable x 3 cable runs totaling **24 mattresses**.)

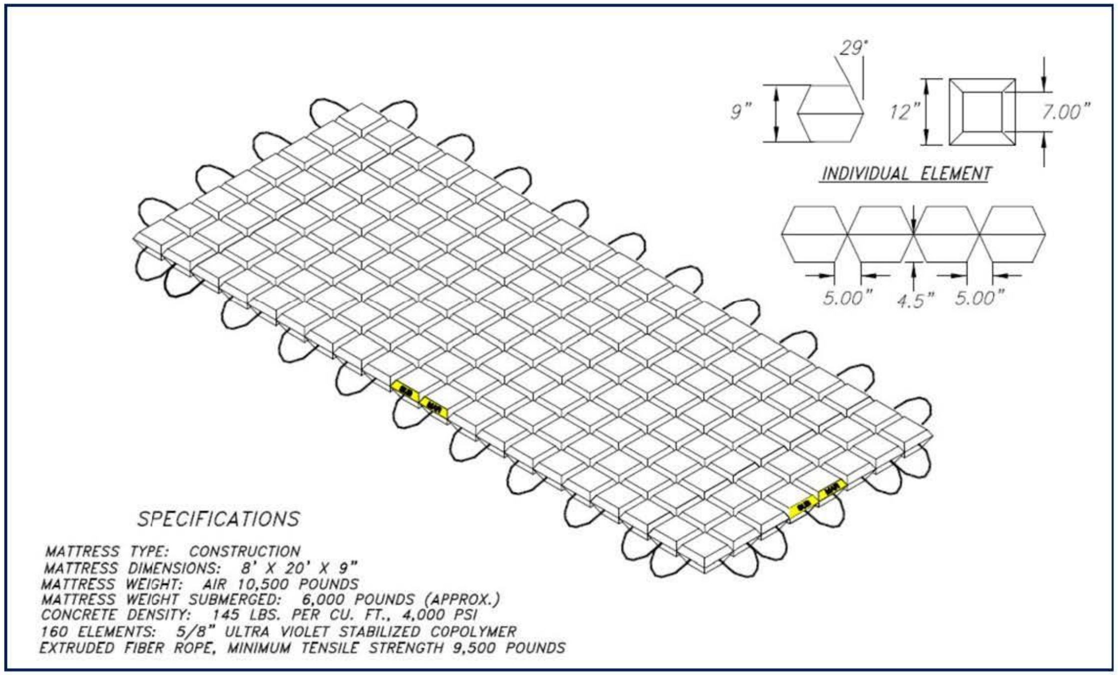
Eastern Landing Approach: Allow for the conditional installation of ~80LF of mattresses between the intertidal zone and area immediately seaward of the intertidal zone. (Each mattress covers 20LF of cable x 3 cable runs totaling **12 mattresses**.)

At either landing / approach, should mattresses be deemed unnecessary, they will not need to be installed.

Page | 4

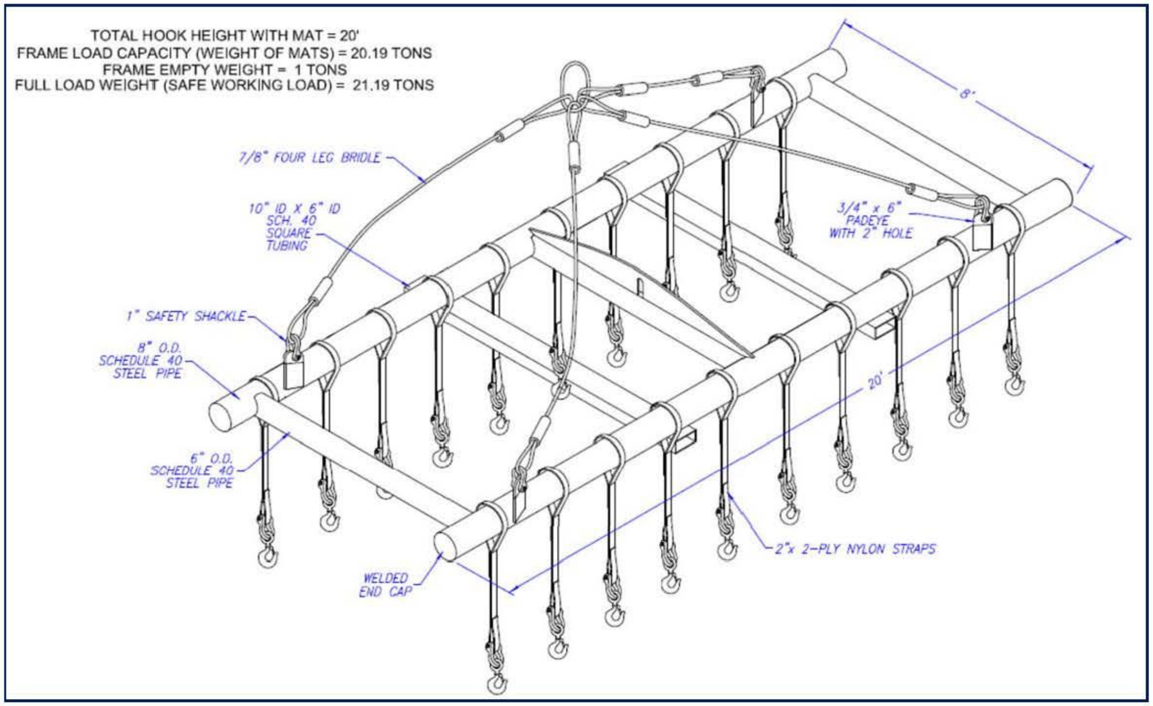
1.2 Articulated Concrete Mattress Specification

Articulated concrete mattresses are specifically designed for use in marine environments and are commonly used to provide protection from external aggression to submarine pipelines and cables. They can be laid directly on top of armored submarine cable types. A sample specification is included below.



1.3 Articulated Concrete Mattress Installation

Should articulated concrete mattresses be required, they can either be installed utilizing a land crane or long reach excavator (intertidal zone) or by crane from the installation barge in shallow water or offshore. All mattress installation will require the use of an installation bracket designed by the mattress manufacturer and manually operated by divers. Any mattresses installed would be included in the final installation drawings. A sample installation bracket specification is included below.



Appendix B—Ampacity Report

Public Service of New Hampshire

115kV Circuit F107 Transmission Line – Little Bay Crossing

Ampacity Report

May 22, 2018

Summary

Public Service of New Hampshire is reviewing the feasibility and constructability of using Horizontal Directional Drill (HDD) as an alternative to the proposed submarine crossing of Little Bay for the F107 circuit.

POWER Engineers Inc. (POWER) has been asked to verify cable sizing and requirements for HDD alternatives to the proposed crossing of Little Bay using a submarine cable installed by jet plow and hand jetting means. The alternatives were required to meet the ampacity requirements for the circuit. In addition to the ampacity analysis, POWER analyzed the open-sheath voltages that would be present in this length of crossing. Calculations were performed in accordance with applicable Eversource UTRM's.

POWER evaluated two different HDD installation options. Option 1 is a complete HDD across Little Bay, from the Durham shore landing to the Newington shore landing. Option 2 is a partial HDD at the Little Bay shore landings to locations in the bay where jet plowing can commence. The partial HDD installations would allow the project to reduce the total amount of hand jetting (though not eliminate it entirely) required to install the submarine cable. For each option investigated, two designs were reviewed. Design A is one cable per phase conductor, for a total of three conductors. Design B is two cables per phase for a total of six phase conductors. The reason for the two designs for each option was to evaluate both the ampacity considerations and also open sheath voltages for the cable system.

Based on the analysis outlined in this report it has been determined that it is technically feasible to construct the desired cable system to meet all ampacity and open sheath voltage requirements utilizing either of the options explored. For Option 1 (full HDD), two cables per phase (a total of six cables) each constructed with 5000 kcmil copper coated conductors would be required. This is based on a combination of required ampacity and open sheath voltage limits. For Option 2 (partial HDD at the shore landings), two cables per phase (a total of six cables) would also be required. This requirement is based on ampacity requirements for the project.

Public Service of New Hampshire
115kV Circuit F107 Transmission Line – Little Bay Crossing

Design Criteria

POWER evaluated two different HDD installation options: Option 1: This is a complete HDD across Little Bay, from the Durham shore landing to the Newington shore landing. Option 2: This is partial HDD at the Little Bay shore landings in Durham and Newington out to locations in the bay where the water depth and soil conditions are more conducive to operating a jet plow. The partial HDD option would still utilize the jet plow to install the cable across Little Bay (between the ends of the two HDD portions) . This option, however, would reduce the amount of hand jetting required specifically at the near shore intertidal zones. Additionally, for these two HDD methods two designs were reviewed. Design A is one cable per phase conductor, for a total of three conductors. Design B is two cables per phase for a total of six phase conductors. The report addresses conductor specifications and design criteria for each option.

Option 1: Complete Horizontal Directional Drill Across Little Bay (Design A & B)
To evaluate a potential HDD installation across Little Bay POWER assessed two (2) design options. Design A consists of conduits installed in a single 36-inch bore with a 30-inch steel casing utilizing one (1) 5000 kcmil CU coated XLPE insulation cable per phase. Design B consists of conduits installed in two (2) 36-inch bores 30-inch steel casings utilizing two (2) 5000 kcmil CU coated XLPE insulation cables per phase. The casings in Design B are separated horizontally 15-ft and vertically 5-ft. This separation reduces the risk of inadvertent construction failure during drilling operations. POWER reviewed the possibility for installing all of the conduits required for Design B in a single steel casing. This option was ultimately removed from consideration for the following reasons. First the size of the required bore to accommodate the larger steel casing would present technical challenges to the drill as well as pulling in the casing and conduit bundles. This option would also place each set of cables in close proximity which would result in an additional derating (reduction of available capacity) of the cables due to mutual heating.

A 5000 kcmil conductor represents the maximum conductor size currently available in the industry at this voltage level that could be installed on the system. Utilizing coated conductors further improves the rating of the cable. This conductor was chosen for modeling purposes only. A smaller conductor size may be achievable for the circuit. However, this will not change the conduit or bore size assumptions.

Due to the length of the crossing (approximately 6,050-ft) and through consultation with drilling contractors and industry experience, an exterior casing installed within the bore has been modeled. A steel casing has been assumed for all full horizontal directional drill designs due its superior tensile strength. Other common casing materials such as HDPE and fusible PVC (fPVC®) do not have the necessary flexibility or tensile strength required for this length of installation. The bundle of conduits required for this installation would be approximately 18-20 inches in diameter. Therefore the overall casing would be approximately 30-inches in diameter to provide adequate clearances between the individual conduits and allow for proper thermal grout filling in the remaining pipe annulus resulting in optimal ampacity results. To install this casing, a bore hole of approximately 36-42 inches would be required. A 36-inch bore hole was utilized for the ampacity model. Utilizing a larger 42-inch bore hole would have negligible impact on the overall ampacity calculations. This bore size is also in line with similar trenchless crossings completed in recent projects. In addition, the bore will accommodate the accessory conduits that are required for the circuit including communication and ground continuity conductors.

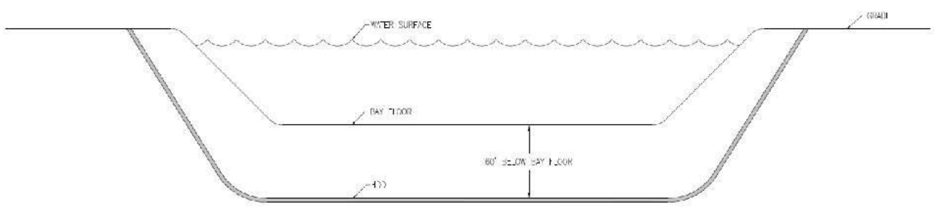
For ampacity purposes, the casings were modeled at a nominal depth of 60-ft with an engineered thermal grout injected into the annulus of the casings after the conduit bundle installation. The thermal grout optimizes the heat transfer inside the casing, providing for an optimized cable system ampacity design. This depth was chosen based on the profile of the bay crossing and a desire to maintain a minimum of twenty-feet (20′) beneath the main channel. Final depth of the casings would be determined during a detailed engineering and design process that involves further geological investigation of the subsurface conditions at these depths beneath the bay.

The use of a steel casing will introduce additional ferromagnetic heating losses to the overall system. To

Public Service of New Hampshire
115kV Circuit F107 Transmission Line – Little Bay Crossing

simulate these losses, the steady-state and emergency ampacity results were de-rated by 20%. This de-rating factor was ascertained by POWER through finite element analysis of a recently completed crossing with similar cable and conduit construction.

Figure 1 - Design A & B Conceptual Profile



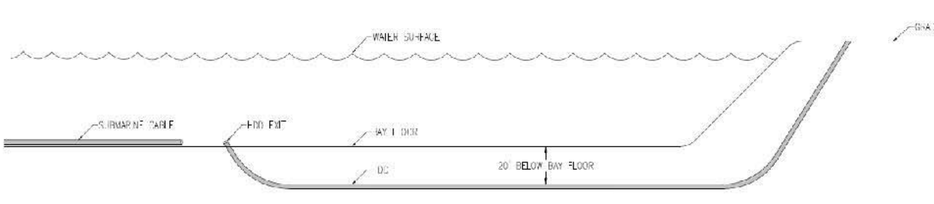
Option 2: Partial HDD – Shore Landings via Horizontal Directional Drill
An alternate design was assessed by POWER of an HDD-Submarine Cable hybrid installation. The installation would consist of two (2) shorter HDD's. One HDD would be on the eastern shore and the other HDD would be on the western shore of Little Bay. These HDDs would intersect the Submarine Cable installation at a point in deeper water and "land" the cables into the transmission corridor. The Submarine Cables would enter 36-inch bore(s) in individual conduits and exit in transition manholes on land. A single cable per phase (Design A) and two (2) cable per phase (Design B) were assessed in a multi-point bonding scheme. The cable construction and direct burial of the armored cable make it impractical to utilize special bonding techniques to improve cable system ampacity. The bores in the two (2) cables per phase model are separated horizontally 15-ft and vertically 5-ft. This separation reduces the risk of inadvertent construction failure during drilling operations.

The Submarine Cable is modeled per the existing LS cable design, specified in document LSCNS-16031-TP-A06.

Due to the reduced length of this HDD installation, a casing has not been modeled. If a casing were necessary for constructability reasons, an HDPE/Fusible PVC (fPVC®) casing could be used. These types of casing materials do not require an ampacity de-rating of the cables and therefore the presence or absence of the casing will not impact the ampacity calculations.

For ampacity purposes, the bores were modeled at a nominal depth of 20-ft with thermal grout injected into the annulus of the casings after the conduit installation. This depth was chosen based on the profile of the bay crossing and a desire to maintain a minimum of twenty-feet (20′) beneath the main channel.

Figure 2 - Partial HDD Conceptual Profile (duplicated on both landings)



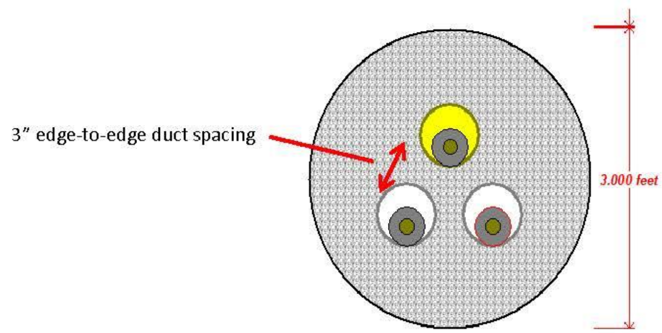
Public Service of New Hampshire
115kV Circuit F107 Transmission Line – Little Bay Crossing

The bore configurations utilized for the ampacity calculations are presented in the figures below.

Option 1: Full Horizontal Directional Drill

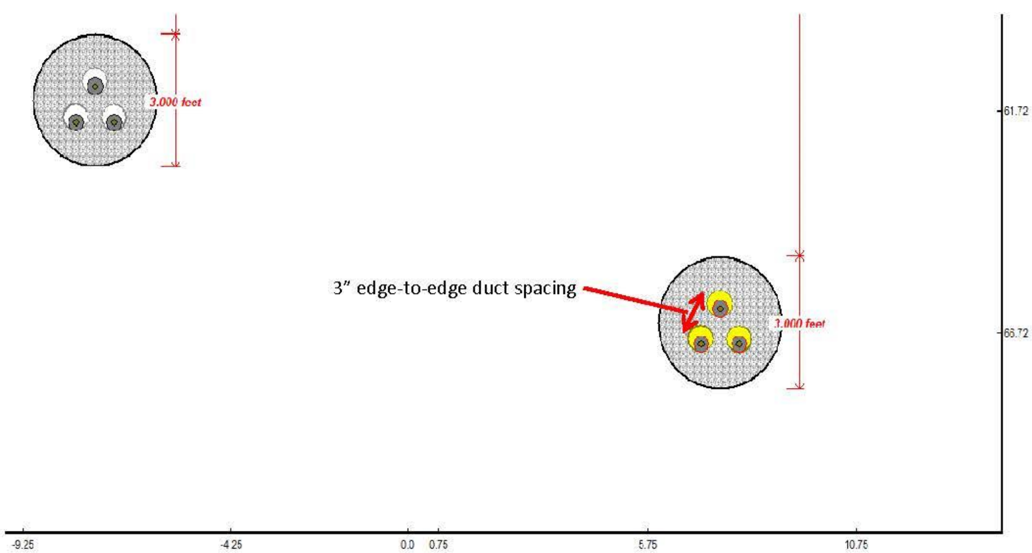
Design A – Single Cable Per Phase:

Figure 3 – Single Cable Per Phase Configuration



Design B – Two (2) Cables Per Phase:

Figure 2 – Two (2) Cables Per Phase Configuration

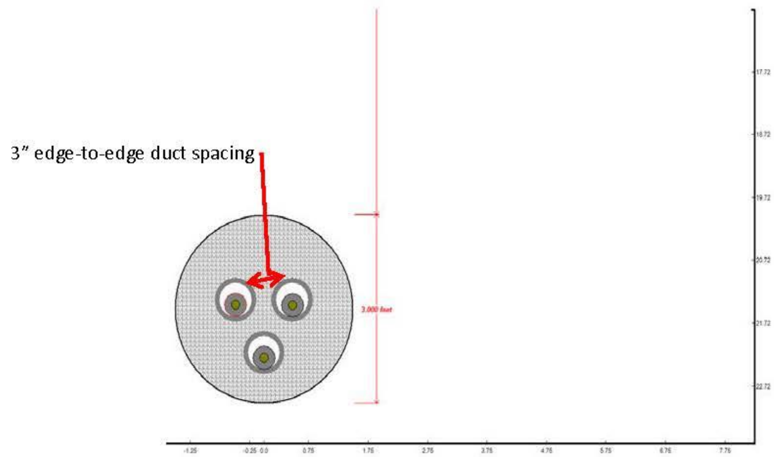


Public Service of New Hampshire
115kV Circuit F107 Transmission Line – Little Bay Crossing

Option 2: Partial Horizontal Direction Drill at Shore Landings

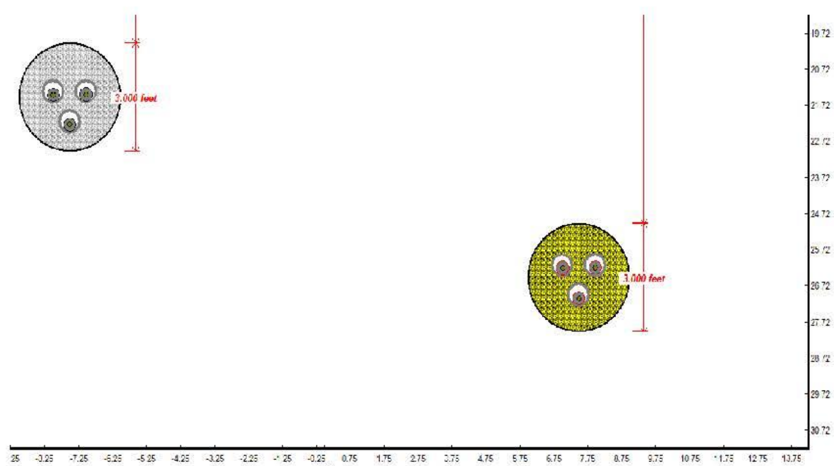
Design A – Single Cable Per Phase:

Figure 4 - Alternate Design (Single Cable per Phase)



Design B – Two (2) Cables Per Phase:

Figure 5 - Alternate Design (Two (2) Cables per Phase)



Public Service of New Hampshire
115kV Circuit F107 Transmission Line – Little Bay Crossing

Ampacity Calculations

POWER performed cable ampacity calculations using CYME International's Cable Ampacity Program (CYMCAP) 7.2 Revision 4 to model the cable systems based on the following design criteria (per UTRM 170.2)

Operating Voltage: ....123 kV

Design A & B
Conductor Size ....5000 kcmil CU coated compact segmental conductor
Insulation ....800 mils cross-linked polyethylene (XLPE)
Concentric Neutral……………………………………………...84 #12 CU
Sheath ....6mil CU laminate foil
Jacket ....150 mils High Density Polyethylene (HDPE)
Ks (skin effect)…………………………………………………0.35
Kp (proximity effect)…………………………………………...0.20

Horizontal Directional Drill Landings
Conductor Size ....1400 mm^2 CU keystone conductor
Insulation ....830 mils cross-linked polyethylene (XLPE)
Sheath ....130mil extruded lead alloy
Serving..160 mils polypropylene yarn with bitumen
Ks (skin effect)...…………………………………………………0.80
Kp (proximity effect)…………………………………………...0.80

Max Conductor Operating Temperature: ....90°C (Steady-State)
....105°C (Emergency)
Emergency Duration ....12 hours
Emergency Pre-Load Factor ....75% of Steady State
Steady-State Load Factor: 75%
Normal Rating Requirement: ....1250 Amperes (250MVA)
Emergency Rating Requirement: ....1750 Amperes (350MVA)
Soil Ambient Temperature*..10 °C
Soil Thermal Resistivity ....100 C° -cm/ Watt**
Grout Thermal Resistivity……………....................................75 C° - cm/ Watt

Transmission Power Cable Conduit..8" HDPE DR9

* Based on average ground water temperature from region
** Conservative value assumed due to unknown soil conditions at these depths

Public Service of New Hampshire
115kV Circuit F107 Transmission Line – Little Bay Crossing

Summary of Ampacity Calculations

Option 1: Full Horizontal Directional Drill between East and West Shores

Case 1 & 2 simulate one (1) 5000 kcmil CU coated XLPE cables per phase (Design A) in a single point bonding (cable sheath and shield bonded at one end only) and multi point bonding (solid bonding) configuration (cable sheath and shield bonded at both ends). **Emergency Amperage was not calculated for any case that does not meet Steady State requirements.**

Case 3 & 4 simulate two (2) 5000 kcmil CU coated XLPE cables per phase (Design B) in a single point bonding and solid bonding configuration.

Solid grounding would significantly reduce the standing voltage but increase losses in the cable due to induced current flow in the sheath and shield wires. Cables meeting ampacity requirements may still fail open sheath voltage requirements. Both components must be met for an applicable solution.

A cable system of one (1) or two (2) 5000 kcmil coated copper conductor XLPE cable per phase, single point bonded, meets the proposed ampacity requirements.

Case	Case Description	Steady State Amperage*	Steady State MVA	Emergency Amperage* (12hr)	Emergency MVA (12hr)
1	Horizontal Directional Drill 3ph 5000 kcmil CU Coated 800 mil XLPE **Single Point Bonded**	1440	307	2240	477
2	Horizontal Directional Drill 3ph 5000 kcmil CU Coated 800 mil XLPE **Multi Point Bonded (Solidly Grounded)**	630	133	N/A	N/A
3	Horizontal Directional Drill 3ph 5000 kcmil CU Coated 800 mil XLPE 2 cables per phase **Single Point Bonded**	2600	554	5028	1070
4	Horizontal Directional Drill 3ph 5000 kcmil CU Coated 800 mil XLPE 2 cables per phase **Multi Point Bonded (Solidly Grounded)**	1100	235	N/A	N/A

[red] = Does not meet ampacity requirements
* Includes 20% de-rating for steel casing

For the HDD Landings, a single submarine cable per phase solidly bonded does not meet ampacity requirements. Two (2) submarine cables per phase meets the proposed ampacity requirements.

Public Service of New Hampshire
115kV Circuit F107 Transmission Line – Little Bay Crossing

Option 2: Partial Horizontal Directional Drill at Shore Landings

Case	Case Description	Steady State Amperage	Steady State MVA	Emergency Amperage (12hr)	Emergency MVA (12hr)
5	Horizontal Directional Drill Landings 3ph 1400 mm^2 CU Submarine Cable **Multi Point Bonded (Solidly Grounded)**	983	209	N/A	N/A
6	Horizontal Directional Drill Landings 3ph 1400 mm^2 CU Submarine Cable 2 cables per phase **Multi Point Bonded (Solidly Grounded)**	1750	374	2760	587

= Does not meet ampacity requirements

Open-Sheath Voltage Calculations

A preliminary sheath voltage calculation was performed for a 5000 kcmil XLPE cable modeled in Design A & B. The calculation shows the magnitude of standing voltage in this crossing given single point bonding and a load equal to the required emergency amperage. Calculations were performed in accordance with ANSI-IEEE 575-2014, per Eversource UTRM 064.

In a multi-point bonding scheme, open-sheath voltages are nominally zero.

$$V_{Sheath} = jw * I * (2 * 10^{-7}) log_e[\frac{2 * S}{d}]$$

Design A & B – Single Point Bonding:

I = Emergency Current (rms)
Design A……………………………………………………………………………………...1750 A
Design B*...……………………………………………………………………………….....875 A
S = Axial Phase Spacing………………………………………………………………….....11 in (280 mm)
d = Geometric mean diameter of sheath……………………………………………………4.40 in (112 mm)
w = ……………………………………………………………………………………………...2*π*60hz

* Assumed balanced loading per cable (Emergency Current Rating divided by 2)

Length of Little Bay Crossing: 1,850 meters

Design Option	V_{Sheath} (V/m)	V_{Sheath} (V_{rms})
A	0.213	394
B	0.107	198

= Does not meet sheath voltage requirements

A single-circuit HDD crossing of Little Bay at a length of 1,850 meters (6,050 feet) will have a sheath voltage of approximately 400 V for Design A and 198 V for Design B given the emergency current rating. Per UTRM 064 "The maximum allowable open-end standing sheath voltage under normal operation shall not be greater than 200 volts rms with respect to local ground during normal conditions". This UTRM requirement is in line with North American industry standard. **As a result, Design B single point bonded meets these requirements while Design A single point bonded does not.**

Public Service of New Hampshire
115kV Circuit F107 Transmission Line – Little Bay Crossing

Transient Sheath Voltage Calculation

A preliminary sheath voltage calculation was performed for a transient fault from a single phase to ground in Design A & B with the power cable sheaths in a single point bonding configuration. The calculation conservatively assumes the ground continuity conductor (GCC) is carrying the entire fault current.

$$V_{Sheath(a)} = jw * I * (2 * 10^{-7})\, log_e \left[\frac{2 * S_{ag}^2}{d * r_g}\right] \text{ V/m}$$

Design A & B – Single Point Bonding Transient Conditions:

I = Fault Current (rms)……………………………………………………………………………40,000 A
S_{ag} = Axial Spacing Phase-GCC……………………………………………………11 in (280 mm)
d = Geometric mean diameter of sheath………………………………………………4.40 in (112 mm)
r_g = Geometric mean radius of GCC……………………………………………………0.75*0.50*d_g
d_g = Outer diameter of GCC……………………………………………………………18.1mm
w = ……………………………………………………………………………………………2*π*60hz

$$V_{Sheath(a)\ transient} = 16.072\ V/m$$

Length of Little Bay Crossing: 1,850 meters

$$\boldsymbol{V_{Sheath(a)\ transient} = 29.733\ kV}$$

The maximum induced sheath voltage from a phase-ground fault is approximately 29.7 kV based on a fault current of 40 kA and the bore configuration(s) presented above. Using the surge arrester catalog and TOV (Temporary Over Voltage) curve provided by LS and typical TOV curve, this installation would require a 27 kV (U_r) rated arrester, in comparison to the 21 kV (U_r) rated arrester previously specified for other portions of this circuit. This new arrester is approximately 30% larger in height and would require greater phase-phase and phase-ground clearances.

Expanding the current ~2.5-ft Link Box design to accommodate these arresters would most likely result in a Link Box that is greater in width and height than the manhole openings. This would require specialized hardware as the Link Box would need to be assembled together within the manhole.

Clarifications

Geotechnical borings to the depth of a proposed HDD have not been completed for this project. Geotechnical borings have previously been completed near the shore landings as well as shallow depths within Little Bay. Based on this data, past engineering experience with similar soils and projects, educated assumptions are used in the development of these calculations and are listed within this document. These assumptions follow good engineering practice and are not anticipated to change the conclusions of this report.

For purposes of this report the 5000 kcmil CU coated XLPE cables were used to determine the feasibity of the full and partial HDD options as well as Designs A and B. It is possible that with Design B a smaller conductor size may be achievable for the circuit. However, this will not change the conduit or bore size assumptions. The effect of smaller cables would be negligible to the total project cost for HDD installation.

Public Service of New Hampshire
115kV Circuit F107 Transmission Line – Little Bay Crossing

Conclusion

Preliminary ampacity calculations reveal that a single point bonded, one (1) or two (2) 5000 kcmil CU coated XLPE cables per phase in a Horizontal Direction Drill meets the loading requirements. A multi-point bonded (solid grounding) system does not meet the requirements.

A 20% de-rating was used in reporting the ampacity results due to the losses associated with a steel casing. This de-rating factor is supported by POWER through finite element analysis of a recently completed crossing with similar cable and conduit construction.

The proposed HDD crossing would require at least two (2) cables per phase in a single point bonded system to meet the loading requirements of the circuit. This number of cables per phase would differ from the single cable per phase required for the submarine crossing. The additional cables would increase the cost of the Little Bay crossing for both the electrical and civil components. Further complexities would arise from interfacing the two (2) cables per phase to the single cable per phase for the proposed land segments.

Design A or B, single point bonded, would also require larger surge arresters than currently specified for this circuit. This new arrester is approximately 30% larger and would require greater phase-phase and phase-ground clearances.

POWER also completed ampacity calculations associated with using HDDs to install the submarine cables on the two shores of Little Bay. For this scenario, a two (2) cable per phase multi-point bonded installation would be needed to meet the proposed ampacity requirements. This installation would require at least six (6) Submarine Cables to be installed across Little Bay, in comparison to the currently proposed three (3) cables by LS. In addition, a total of four (4) HDD bores (two on each shore) would be required with drilling staging on both landings.

A sensitivity analysis was performed by POWER with the maximum conductor size Submarine Cable available for the HDD Landings. This analysis resulted in the same conclusion; two (2) Submarine Cables are required for this installation. As with a complete HDD crossing of Little Bay, further complexities would arise from interfacing the two (2) cables per phase to the single cable per phase for the proposed land segments.

Design Option	Case	Bonding Scheme	Meets Ampacity Requirements (Y/N)	Meets Sheath Voltage Requirements (Y/N)
A - One (1) Cable per Phase -	1	Single Point	Y	N
	2	Multi Point	N	Y
B - Two (2) Cables per Phase -	3	Single Point	Y	Y
	4	Multi Point	N	Y
HDD Landings - One (1) Cable per Phase -	5	Multi Point	N	Y
HDD Landings - Two (2) Cables per Phase -	6	Multi Point	Y	Y