



**Wilmington Harbor, North Carolina
Navigation Improvement Project**

**Integrated
Section 203 Study
&
Environmental Report**

Appendix B

Geotechnical

February 2020

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Wilmington Harbor Deepening Survey

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Wilmington Harbor Deepening 2017 Survey
Wilmington, North Carolina

29 January 2018
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Wilmington Harbor Deepening 2017 Survey Wilmington, North Carolina

This report describes the data acquisition, processing and results from a hydrographic and seismic reflection survey conducted from April through June 2017 along the inner and outer channels of the Cape Fear channel in Wilmington, North Carolina. Data collected during the 2017 survey were integrated with historical information and used to characterize site conditions as summarized in this report. The objective of this study is to provide an evaluation of materials that may be encountered during future navigation improvements conducted to deepen, widen, and/or alter the channel alignments.

The 2017 survey included collecting bathymetric and seismic data along sections of the Cape Fear River in Wilmington Harbor from the Anchorage Basin in the north to Baldhead Shoal Reach 3 in the south. The survey also encompassed an outer channel that extends south from the mouth of the Cape Fear River. The 2017 seismic reflection data was integrated with existing geotechnical borings and wash probes conducted by others and mapping performed by others to provide a characterization of subsurface conditions and interpreted elevation of the top of rock strata. This report also provides an assessment of the potential beneficial use of materials that may be dredged as part of deepening or widening of the channels. This report provides a description of the data collection, data processing, and characterization of the subsurface conditions based on our interpretation of the integrated seismic reflection and geotechnical data.

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1. INTRODUCTION

1.1 Purpose and Scope

Studies have recently been conducted to evaluate potential navigation channel improvements of the Wilmington Harbor located near Wilmington, North Carolina. We understand that current dredging activities maintain the channel to at least an elevation (El.) of -42 feet (referenced to mean lower low water [MLLW]) with an overdredge allowance of 2 feet from Anchorage Basin to Lower Swash and El. -44 feet (MLLW) with an overdredge allowance of 2 feet from Battery Island to Baldhead Shoal Reach 3. Future navigation channel improvements may include deepening, widening, and/or realigning the existing navigation channel.

Geotechnical borings and wash probes conducted by others in the Wilmington Harbor channel since 1987 are inferred to have encountered unconsolidated deposits and indurated material (e.g. limestone) within the study area. Those historical data indicate that future channel deepening and/or channel alignment dredging activities may encounter the indurated strata. The indurated materials encountered by the borings are inferred to be of varying strength based on the reported standard penetration test blow counts and unconfined compressive strength (UCS) tests and some rock intervals may be difficult to dredge.

The purpose of this study is to collect bathymetric and seismic reflection data and integrate it with available geotechnical data to develop a characterization of the materials that may be encountered during deepening, widening, and/or channel alignment modifications. Our study is particularly focused on (1) characterizing the location of the formation materials (e.g. limestone) and other potentially dense/strong materials within the area of the future dredging envelope and (2) identifying opportunities for beneficial use of future dredge materials. The latter represents an opportunity to offset future dredging costs and provide beneficial use of dredged materials via creating underwater habitat areas, use of dredge materials for land reclamation or beach nourishment projects, or other potential beneficial use.

The 2017 bathymetric and seismic reflection survey encompasses the portions of the navigation channel from the Anchorage Basin in the northern end of the channel to the southern end of the outer harbor which is approximately 16 nautical miles offshore. The survey area and surveyed vessel tracklines are presented on Figure 1 and Chart 1, respectively. The survey utilized two different seismic survey techniques to map the sub-bottom. A high frequency (2 to 16 kHz) Chirp seismic reflection survey was conducted in the inner harbor to interpret shallow sub-bottom stratigraphic conditions in the upper 5 to 15 feet of river bottom. The second seismic reflection survey utilized a lower frequency (0.5 to 12 kHz) Chirp seismic system for mapping deeper stratigraphic conditions. We also collected multibeam echosounder data to measure the water depths along the channel flanks (outside the navigation channel) to complement the recent United States Army Corps of Engineers (USACE) survey data collected within the navigation channel from 2014 through 2017.

The seismic data were processed and integrated with the available geotechnical data to support the interpretation and characterization of the subsurface site conditions. This report provides a description of the field survey, data processing, interpretation, and summary of the study.

2. FIELD SURVEY AND DATA PROCESSING

2.1 Survey Overview

Subsurface stratigraphic mapping (e.g. interpretation of limestone strata elevation) utilized two seismic reflection systems; a high frequency Chirp system to image the upper 5 to 15 feet and a lower frequency Chirp system to penetrate deeper within the outer channel.

Two vessels were utilized to conduct the survey. The survey vessel *M/V Schilpad* was used to conduct the inner channel survey and a the vessel *R/V Seahawk* was used to conduct the outer channel survey. Survey operations were conducted from April 25 through June 19, 2017. Data processing, analyses, and report preparation followed the demobilization from the site.

The Schilpad is a 22-foot long, shallow draft survey vessel that is ideal for river surveys and was the vessel used for the inner harbor survey. The Seahawk is a 33-foot long survey vessel that was used for the outer channel survey. Vessel schematics and equipment offsets are shown in Figures 2a and 2b. The vessel tracklines are shown on Chart 1. The vessel tracklines represent the common reference point (CRP) for each vessel. Both systems (low and high frequency Chirp) were run at different times and in different areas depending the suitability of the system for the river-bottom conditions and water depth.

Eighty-three Chirp lines were collected in the inner channel from Anchorage Basin to Baldhead-Caswell for a total cumulative length of approximately 95 nautical miles. Primary Chirp survey lines were conducted on either side of the channel with tie lines occurring approximately every 3,000 feet. Twenty-One Chirp lines were collected in the outer channel from Baldhead-Caswell to Baldhead Shoal (Reach 3) for a total cumulative length of approximately 36 nautical miles. Primary Chirp survey lines were conducted on either side of the channel in a similar fashion in which the inner channel was conducted. Extending approximately 8 nautical miles to the southwest from the end of Baldhead Shoal (Reach 3) twenty-three Chirp lines were collected totalling approximately 60 nautical miles. Six primary Chirp survey lines were conducted approximately 150 feet apart with tie lines occurring roughly perpendicular to the primary survey lines approximately every 6,500 feet.

A multibeam echosounder survey was conducted simultaneously with the seismic survey to provide accurate water depths. An R2 Sonic 2024 with electronic beam steerable capability was used to collect bathymetric data that provided bottom coverage on the edges of the channel boundaries to complement the survey data collected by the USACE from 2014 to 2017.

2.2 Positioning and Navigation

A wide-area Differential Global Positioning System (DGPS) was used to position the survey vessel. DGPS is a satellite-based positioning system operated by the U.S. Department of Defence. A "wide-area" application operates with correction values applied to a standalone GPS receiver from base stations located over large distances. DGPS corrections were supplied to the system using the STARFIX II network, a nationwide differential network operated by Fugro. STARFIX II broadcasts differential corrections via a communications satellite downlink to field receivers. DGPS signals provided the field navigation information

to sub-meter accuracy. Post-processing of the positioning data utilized data recorded from United States Army Corps of Engineers (USACE) base stations. This post-processing improved the horizontal positioning of the common reference point (CRP) on the vessel to be resolved to within about 1 inch.

Equipment offsets and laybacks from the CRP were measured during mobilization using a steel tape and level. Measurements were recorded to the tenth of an inch.

Vessel motions were recorded using an Applanix POS MV to control vessel motion and attitude. The POS MV delivers full 6-degree-of-freedom position and orientation solutions for marine survey vessels and outputs all motion variables at high rate: position, velocity, heave, roll, pitch, true heading, acceleration vectors, and angular rate vectors. The system combines GPS/DGPS with rugged high-quality inertial sensors. The system measures true heading together with roll and pitch to 0.02 degree accuracy under dynamic conditions including hard turns and rapid acceleration and deceleration with heave accuracy of 5 cm in real time. The POS MV system consisted of two GPS antennas mounted atop the Schilpad and Seahawk, a processor, and an Inertial Measurement Unit (IMU) was mounted above the multibeam transducers. Data were fed from the processor to Hypack via Ethernet at 25 hertz. Delayed heave and position data, used for the post-processing of data, were logged at 50 hertz.

2.3 Chirp Sub-bottom Profiler

2.3.1 Data Acquisition

EdgeTech 3200-series Sub-bottom Profiler (Chirp) systems were utilized to obtain shallow seismic reflection data of the sediment layers immediately beneath the seafloor in both the inner and outer channel. These shallow data provide information on the spatial distribution and thickness of shallow sediments. The Chirp signal penetrated to the consolidated layers over approximately 65 percent of the survey area. In areas where the Chirp data did not reach the consolidated strata and image it, we relied on geotechnical exploration data to interpret the top of rock and deeper strata.

The EdgeTech 3200 systems used include the SB-216S Towfish and SB-0512i Towfish, the Model 3200 topside processor, and EdgeTech's Discover acquisition software. The SB-216S towfish was deployed and towed from the port side stern of the Schilpad for data collection in the inner channel (Anchorage Basin to Baldhead-Caswell). The system was triggered at a 8-Hz pulse rate with a swept frequency range between 2 to 16 kHz over 20 milliseconds (ms). The SB-0512i towfish was deployed and towed from the port side stern of the Seahawk for data collection in the outer channel and had a frequency range between 500 Hz to 12 kHz over 20 milliseconds (ms). All navigation information and sub-bottom data were time tagged and logged to a hard drive.

2.3.2 Data Processing

Chirp sub-bottom data processing included checking and de-spiking all navigation points using Starfix.Proc, an application for automated (batch) processing of navigation data. After the data are cleaned, verification was made that the corrected navigation files were referenced from the towed position (where the sub-bottom was towed from the vessel). The corrected navigation data were then inserted into a raw JSF file

(Edgetech's Proprietary format) using Starfix.Gplot. The JSF files were replayed through the Discover software for TVG, swell filtering, and direct arrival removal. Following the data filtering, the JSF files were then converted to SEG-Y format and loaded into Kingdom Suite for interpretation. Representative Chirp data examples are provided on Figures 8, 9, and 10.

2.4 Bathymetric Data

Bathymetric data were collected during the seismic survey using an R2 Sonic 2024 multibeam echosounder. Two survey tracklines were collected on either side of the navigation channel on the inner harbor and offshore through the Baldhead Shoal Reach 3 channel segment. The intent of these lines is to augment the USACE bathymetric data available from within the navigation channel. In general, the 2017 survey bathymetric data agree reasonably well with the channel condition survey data. Offshore of Baldhead Shoal Reach 3 segment, 6 primary survey lines spaced approximately 145 feet (45 meters) apart were collected within the channel and were complemented by tie lines spaced approximately 6,560 feet (2,000 meters) apart. The multibeam data provide full coverage of the offshore channel surveyed area. Vertical control of the multibeam data were provided using a Post-Processing Kinematic (PPK) method. The bathymetric data are referenced to mean lower low water (MLLW) datum and are presented in plan-view panels shown on Charts 2 through 8.

2.5 Geotechnical Explorations

From 1987 to 2013, various parties conducted over 400 geotechnical explorations at the locations shown on Charts 2 through 6 and Figures 3 and 4. The exploration data were input into the seismic work station and GIS database that were used to support interpretation and create subsurface profiles. Geotechnical information and data input into the GIS database include:

- Exploration location coordinates, water depth, and exploration depth
- Lithologic classification of soil and rock as described on the available logs,
- Interpreted top of rock (if encountered),
- Unconfined compressive strength laboratory test results,
- Grain size test results, and
- Fines content.

It should be noted that channel deepening has occurred after some of the explorations have been conducted. Therefore, explorations presented on cross sections in this report may appear to be higher than the current channel bottom. Table 2.1 lists a summary of the explorations used to characterize site conditions and prepare the report.

Table 2.1: Historical Explorations Utilized in the Current Study

Exploration Type	No. Explorations	Typical Exploration Depth (Feet)	Year Performed
Boring	12	20	1989
	30	10	1990
	22	10	1992
	74	25	1993
	32	20	1994
Washprobe	68	5	1990
	26	20	1992
	117	10	1993
	22	25	1994
Vibracore	20	20	2012
	6	20	2013

2.6 Top of Rock Data

Data recently acquired to supplement our original assessment of the top of rock was composed of both point and contour data throughout the channel. The density of the data varied along the length of the channel and was mainly confined to the channel center. Figure 3b displays the location and extent of this data. Although limited background information was provided, the data included approximately 4,000 points of interpreted top of rock throughout the inner and outer channel, that was derived from both historical geotechnical explorations and geophysical surveys. Some of the previous mapping of the top of rock presented in this study and extracted from this data may appear higher than the current channel bottom. Areas where this occurs it is assumed that the top of rock is at the current channel bottom which is defined by the most recent hydrographic survey.

3. GEOLOGIC SETTING

3.1 Regional Geology

The project area is located in the Atlantic Coastal Plain Physiographic Province and is part of the Outer Coastal Plain of the Carolinas. This coastal plain province is characterized by subdued relief and a general seaward slope (USACE, 1994). The Cape Fear River valley, in which the Wilmington Harbor Project is located, lies along the Cape Fear arch, a large deep seated tectonic feature which influences the local geomorphology and sedimentation patterns (Figure 3-1) (Soller, 1988). Sediments in this area were deposited during transgressive-regressive cycles produced by glacioeustatic sea level fluctuations, which ideally include a relatively thin marine unit deposited during interglacial periods as the ocean transgressed and thicker overlying deposits as the ocean regressed. During interglacial periods, sequences of marine and strandline sediments were deposited on the now-emerged Coastal Plain. During glacial maximums, low sea level caused a regression of strandlines, entrenchment of streams, and the erosion and dissection of the Coastal Plain deposits (USACE, 1996). The Cape Fear River is steadily migrating to the southwest over time due to the influence of the Cape Fear arch, and is depositing considerable fluvial sediments as it drains the Piedmont and erodes Coastal Plain marine terraces (Soller, 1988).

3.2 Site Geology

Beneath the alluvial overburden that is present throughout much of the channel, older formations that range in age from Cretaceous to Pleistocene are encountered along the Wilmington Harbor Channel. The stratigraphic units described in the historical subsurface explorations, include (from oldest to youngest) the Peedee, Olive Sand, Turritellid Limestone, Castle Hayne (Units A and B), Trent, and Waccamaw (Figure 3-2) (USACE, 1996). The Turritellid Limestone in the port has been interpreted to overlie the Peedee formation and Rocky Point member and underlie the Castle Haynes formation, where present. The Turritellid Limestone is interpreted to be Paleocene to Eocene in age and may actually be a part of one of the overlying or underlying formations.

From the northern Federal Project limit (25 Foot Project) to the northern end of Upper Big Island, the Peedee Formation is the uppermost rock unit encountered (Charts 2 and 3). From Upper Big Island through Lower Big Island, Castle Hayne Units A and B appear to be the uppermost rock units encountered, with a few explorations indicating the Peedee Formation (Chart 3). Keg Island through Snows Marsh the Peedee Formation is assumed to be the uppermost rock unit, except for a small area at the transition between the Upper and Lower Lilliput channel reaches which appears to be Castle Hayne Unit A (Charts 3 through 6). From Lower Swash to Baldhead Reach 1 it is interpreted that the Castle Hayne Formation is the uppermost rock unit (Chart 6). From Baldhead Shoal Reach 1 to the end of Baldhead Reach 2, it is interpreted that the Turritellid Limestone is the uppermost rock (Charts 6 and 7). In Baldhead Reach 3 The Castle Hayne is assumed to be the uppermost rock unit (Chart 7).

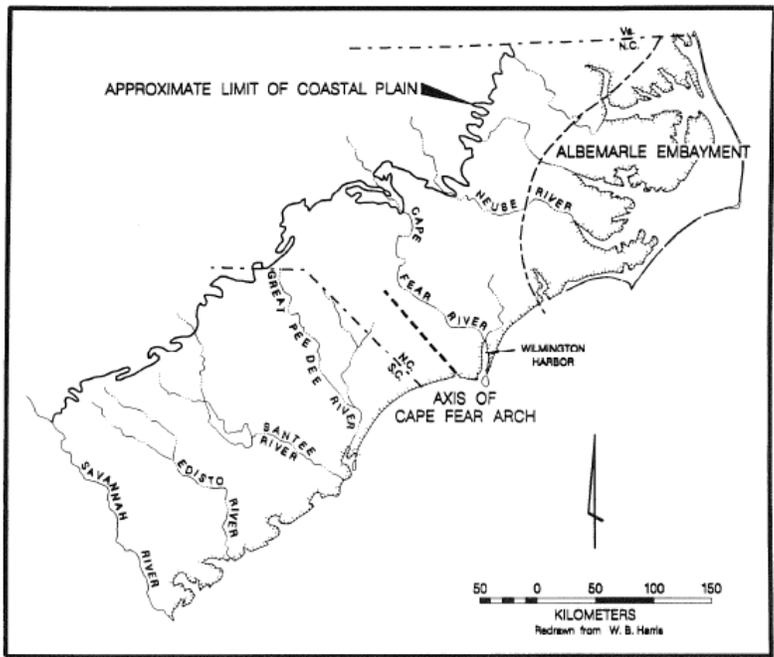


Figure 3.1: Stratigraphic Units Encountered in the Subsurface, Wilmington Harbor (USACE, 1996)

AGE		UNIT	LITHOLOGY	
PLEISTOCENE		WACCAMAW FORMATION	PHOSPHATIC, QUARTZ-RICH, CALCAREOUS SAND	
OLIGOCENE		TRENT FORMATION	CALCAREOUS, PHOSPHATIC, QUARTZ SAND	
EOCENE	UPPER			
	MIDDLE	CASTLE HAYNE LIMESTONE	UNIT B	MEGAFOSSILIFEROUS, BIOTURBATED MUDSTONE TO WACKESTONE AND BRYOZOAN PACKSTONE
			UNIT A	CROSS-BEDDED, BRYOZOAN GRAINSTONE AND PHOSPHATE-PEBBLE CONGLOMERATE
PALEOCENE OR LOWER EOCENE		TURRITELLID LIMESTONE	SANDY, MOLLUSCAN-MOLD, WACKESTONE-PACKSTONE	
PALEOCENE		OLIVE SAND	OLIVE-GREEN, CALCAREOUS, GLAUCONITIC, FINE GRAINED, QUARTZ SAND	
CRETACEOUS	UPPER	PEEBEE FORMATION	ROCKY POINT MEMBER	CALCAREOUS, QUARTZ ARENITE AND MOLLUSCAN-MOLD GRAINSTONE
				VERY FINE TO FINE, CALCAREOUS, MUDDY, QUARTZ SAND

Figure 3.2: Stratigraphic Units Encountered in the Subsurface, Wilmington Harbor (USACE, 1996)

4. SUBSURFACE CONDITIONS

Longitudinal cross sections were performed along the entire length of the Wilmington Harbor Channel, beginning at the 25 Foot Project reach in the north to Baldhead Shoal Reach 3 in the south (Charts 2 through 7). A total of three cross sections were created along this length, one along the channel centerline and one on either side of the channel. The cross sections located on either side of channel were positioned at the toe of the slope which roughly correlated to the channel boundaries. An inferred top of slope elevation is also given on channel boundary cross section to provide a three-dimensional illustration of the channel flanks. This configuration of cross sections allows for a more robust incorporation of historical explorations to be used, as well as an ability to gain a better understanding of the type of material that could be encountered if the channel were to be widened or deepened in certain areas.

To interpret and categorize the type of material which could be encountered, grain size curves and data plots showing fines content and unconfined compressive strength (UCS) versus elevation were created for channel reaches which contained historical data (Figures 4, 5, and 6). Transverse cross sections were also performed approximately every 1,500 feet beginning at Anchorage Basin to the end of Baldhead Shoal Reach 3 to aid with the interpretation and characterization (Figure 7). The Chirp data acquired in 2017 for this project provided additional interpretation for the location of potential shallow rock outcrops, especially on the channel flanks, to further aid in both the inner and outer channel subsurface conditions (Figures 8, 9, and 10). The 2017 seismic data was correlated with the historical geotechnical and previous mapping to interpret which formation is likely to be encountered (if any) if deepening were to occur. A previously unmapped area 8.7 miles long, southwest of the end of Baldhead Reach 3, was surveyed and the interpreted geologic formations are shown in the profile views on Chart 8. Table 4.1 provides a summary of the interpreted subsurface conditions for each channel reach, with the material being categorized based on its potential beneficial use. The following are the basis for material separation, which are partly based on the Beneficial Use Planning Manual (2007):

- Category A = Potentially Suitable for Engineering Structural Fill or Beach Nourishment; Fines content typically less than 10% and low calcium carbonate content.
- Category B = Potentially Suitable for Non-Engineered Fill; Fines content typically between 10 and 20%; may include thin lenses of fine-grained deposits.
- Category C = Potentially Suitable for Low-Quality Fills (e.g. habitat restoration and development, offshore berms, parks and recreation, etc.); Fines content 20 to 25%.
- Category D = Disposal Area (Upland or Offshore)

Table 4.1: Summary of Subsurface Conditions

This summary table has been removed and is superseded by Table 3.1 in the February 25, 2019 report.

5. SEISMIC DATA LIMITATIONS AND CAPABILITIES

The quality and amount of information obtained with a seismic data set depends on a number of factors including the equipment, acquisition parameters, processing, available tangible data to provide control to interpretation, and the environment.

Equipment can play a significant role in the success of a project. The seismic data used to interpret conditions within the dredge envelope were derived from two EdgeTech 3200 series Chirp systems (SB-216S and SB-512I). The SB-512i Chirp system, with its lower frequency range (0.5 to 12 Hz), was in general able to penetrate deeper than the SB-216S system (2 to 16 Hz). The Chirp seismic data quality is judged to be fair to good and correlated good to very good to the geotechnical data. In general, the Chirp data achieved signal penetration of about 5 to 20 feet for the SB-216S system and 20 to 40 feet for the SB-512I system. The EdgeTech 3200 series Chirp systems are considered to be capable of imaging layers 1 foot or more in thickness. The vertical accuracy of the Chirp system is generally considered to be approximately +/- 2 feet. However, constraining the interpretation of shallowest reflectors to the multibeam-derived water bottom may improve the accuracy beyond +/- 2 feet.

The composition of the soil or rock also plays a part in how well seismic energy can image the subsurface. The presence of a reflector or horizon in the seismic data indicates an impedance contrast (a difference in the velocity that sound can travel through the material) between the material above and below the reflector. If the material above and below a geologic contact are of the same P-wave velocity, a reflector may not be seen in the data and that geologic boundary between materials would be called acoustically transparent. Therefore, correlating soil changes in historical borings with seismic horizons is not always possible. In addition, the presence of a high-amplitude impedance contrast may absorb the bulk of the energy from the seismic source which prevents energy from passing through and imaging deeper reflectors.

In this survey, we estimate that the seismic data imaged what we interpret to be the top of rock along approximately 65 percent of the surveyed length of Wilmington Harbor. The best results are from the Lower Midnight channel reach southward. The data north of the Lower Midnight reach was often obscured by the seafloor multiple and the top of rock could not be seen in the data.

For this survey, the historical geotechnical borings were loaded into a seismic workstation and integrated with the seismic data. This integration of the historical data aided with the correlation of horizons with geologic formations and changes in soil type described on the boring logs. The changes in soil type on the boring logs generally matched well with the elevation of the seismic horizons. The character of horizons H15, H25, and H30 are typically flat or gently dipping surfaces which we interpret to be the tops of the Castle Haynes Limestone Unit B, Unit A, and the Turritellid Limestone respectively (Figures 8 through 10). Above the H15, H25, and H30 reflectors, we interpret there to be mostly sandy unconsolidated material with some paleochannels that contain fine-grained material (silt and clay). Line type and symbology used to depict interpretation of subsurface conditions on Figures 8 through 10 reflect various confidence levels. Dashed lines indicate where a seismic reflector was observed, dotted lines indicate where interpretation of a seismic reflector was uncertain, and question marks indicate areas of additional uncertainty.

6. SUMMARY

The objective of the study is to characterize subsurface materials that may be encountered during future deepening, widening and/or realignment of the navigation channel using data recently acquired in 2017 and integrated with historical data. This report provides a summary of subsurface conditions interpreted from historical geotechnical data, top of rock mapping performed by others, and multibeam and sub-bottom profiler data collected during the 2017 survey.

A survey was conducted during the summer of 2017 that included collecting multibeam bathymetry and Chirp sub-bottom profiler data along two parallel lines along the outer limits of the inner harbor navigation channel. A channel-wide survey using the multibeam and Chirp sub-bottom profiler was also performed along the outer reaches of the offshore approach channel. Tie lines were collected at regularly spaced intervals using both survey systems.

Geotechnical data reviewed in this study include 170 borings, 233 washprobes, and 26 vibracores conducted between 1986 to 2013. However, data from borings conducted in 1998 were not available to us for use in this study. Borings used in this study include soil sampling, rock coring, and laboratory test information. Washprobes were conducted by others to infer top of rock based on refusal depths and the washprobes did not include sampling of soil and rock materials. The various data were loaded onto a seismic interpretation work station and interpreted. Interpretations, geotechnical data, and bathymetric data were assimilated into a GIS database where mapping, modelling of the top of rock, and graphics (e.g. cross sections, maps, and graphs) were developed using ESRI's GIS software.

One of the primary objectives of the study was to map the top of rock and confirm mapping of top of rock performed previously by others. We provide the following information related to the use of "top of rock" and "top of formation" in this study. "Rock" implies that the materials have undergone lithification (deposits have been subjected to pressure, heat, and/or cementation and lithified as a rock) and exhibit physical properties (e.g. strength) of a rock. "Formation", as adopted herein, refers to materials that have been assigned to a geologic formation and been given a formation name (e.g. Castle Hayne formation). Formation materials may exhibit properties similar to a rock or soil (e.g. dense to very dense sand or hard clay). In this study, we have interpreted seismic horizons (or reflectors) and interpreted their association with formations. In the inner harbor, the interpreted seismic horizons generally correlate well with rock intervals described on exploration logs and top of rock mapping presented by others. However, in the offshore channel reaches there appear to be differences between top of rock mapping by others and the seismic horizons presented in this study. Section 6.ii. (below) provides a discussion of the differences.

We compare the top of rock surface as interpreted by previous investigators with the top of rock interpreted based on the 2017 survey data. In general, areas where the 2017 survey data are co-located with the previous mapping by others, the interpreted elevation agree reasonably well and were within approximately 5 feet of each other. We note that after we issued a draft report, we received top of rock mapping information by others that included coverage in new areas. We note that in those new areas located in the inner harbor the top of rock in the two datasets were generally in good agreement and were within about 5 feet of each other. Section 6.ii provides a discussion of where the two sets of interpretation differ.

In general, from the 25 Foot Project channel reach through the Upper Lilliput any type of deepening from the current channel bottom is likely to encounter rock. In addition, based on the average UCS data, deepening in the Fourth East Jetty, Lower Brunswick, and Keg Island reaches may require blasting (UCS > 4,300 psi) to remove the encountered rock. From Lower Lilliput through Horseshoe Shoal, deepening of the channel is not likely to encounter rock. From Snows Marsh to approximately the end of Smith Island Channel, it is likely to encounter rock (interpreted to be Castle Hayne Unit B) if any deepening were to occur, although due to a lack of strength data it is uncertain if blasting will be required to excavate the material. Baldhead Reach 2 appears to be overlying a relatively large paleochannel and any deepening is not likely to encounter rock. Deepening between Baldhead Reach 2 and Baldhead Reach 3 is interpreted to likely encounter Castle Hayne Unit B materials.

As part of the deliverable, a digital elevation model that represents the interpreted top of rock was prepared. The modelled top of rock incorporates results from interpretation of the 2017 survey data and previous mapping by others. The modelled surface generally adopts mapping by others with the exception the three notable areas.

- i. Areas where the interpreted top of rock surface extends above the current channel bottom, as defined by either the most recent channel condition assessment surveys or the 2017 hydrographic survey, we inferred that subsequent channel dredging activities had already encountered this top of rock surface and the current top of rock is now at the channel bottom surface or just below a thin sediment cover. This lowering of the top of rock surface to the current channel bottom, where applicable, is reflected in our digital surface which accompanied this report.
- ii. The areas of Snows Marsh channel to Baldhead Shoal Reach 3, mapped three seismic horizons (H15, H25, and H30) from the 2017 survey data which appear to potentially stratigraphically correlate to the Castle Hayne Unit A/B and the Turrillid Limestone (Figure 10). The seismic stratigraphic character also suggests the reflectors may correlate to weak rock or possibly dense soils. Horizons H15 and H25 are generally shallower than the interpreted top of rock previously done by others (Figure 10). In those areas, the interpretation by others generally correlate with the 2017 deepest interpreted horizon (H30) which may represent the top of the Turrillid Limestone. Examining our data in this region (Figure 10) there are two high-amplitude reflectors interpreted above (or shallower than) horizon H30 and are separated by seismically acoustic transparent areas (Figure 10). High-amplitude reflectors are generated at interfaces between materials with strong seismic impedance contrasts. Impedance is the product of the material's density multiplied by the seismic compressional wave velocity (V_p).

Washprobes conducted in this area shown in Figure 10 indicate that probes terminated or met refusal at depths that correlate with Horizon H15 (3 washprobes between distance offsets 4600 to 6600) and Horizon H25 (2 washprobes between distance offsets 8000 and 9000). Refusal of the washprobes and the high-amplitude character of the seismic horizons suggest that horizons H15 and H25 may represent the top of a formation unit (e.g. Castle Haynes units) that is rock. However, we note that some washprobes appear to have penetrated below horizons H15 and H25 and refused at depths that correspond to Horizon H30. Those observations may indicate that the material directly below Horizons 15 and H15 may exhibit properties similar to dense or hard soils instead of rock. However, the

washprobes do not recover physical samples that can be observed and tested and the physical properties of the materials between Horizons H15 and H30 are uncertain. Therefore, when creating the digital top of rock modelled data, we have conservatively assumed the shallowest seismic horizons (e.g. H15) in this area represent the top of rock. If future dredging will encroach below Horizons H15 and H25 in this area, we recommend that appropriate geotechnical explorations should be conducted to assess the physical properties of those materials and assess the dredging feasibility or methods.

- iii. In order to support high-level assessments of where widening and re-alignments of channels may encounter rock, we extrapolated the top of interpretation approximately 300 feet beyond the extent of the existing data. The extrapolation is adopted the continuation of the geologic or topographic trends in the data. The extrapolation data area provided to the project team to aid in supporting high level assessments. The extrapolated data are not suitable for design or detailed dredging cost estimates. Future engineering analyses and dredging cost estimates should acquire appropriate survey and geotechnical data to determine the presence, elevation, thickness, and physical properties of rock in the extrapolated zones or areas without data coverage to determine implications to future dredging or construction activities.

This study also evaluated potential opportunities for beneficial use of future dredge materials. Several areas were identified as containing material that potentially be used for fill or beach nourishment projects. Interpretation of geotechnical and geophysical data suggest that channel flanks in Keg Island through Lower Lilliput and Horseshoe Shoal reaches likely contain material low fines content and may be desirable for use as fills. Lower Midnight, Reaves Point, Lower Swash reaches and north of the Anchorage Basin reach appear to have materials with a low fines content and may be desirable for repurposing as Category A and B materials (refer to Section 4). The other channel reaches appear to contain material with high fines content or substantial interbeds of fines (clay and silt) and do not appear to desirable for fills and beach nourishment projects and are considered to be Category C and/or D materials (refer to Section 4).

7. REFERENCES

Soller, David R., (1988) Geology and Tectonic History of the Lower Cape Fear River Valley, Southeastern North Carolina, USGS Professional Paper 1466A, Denver, CO.

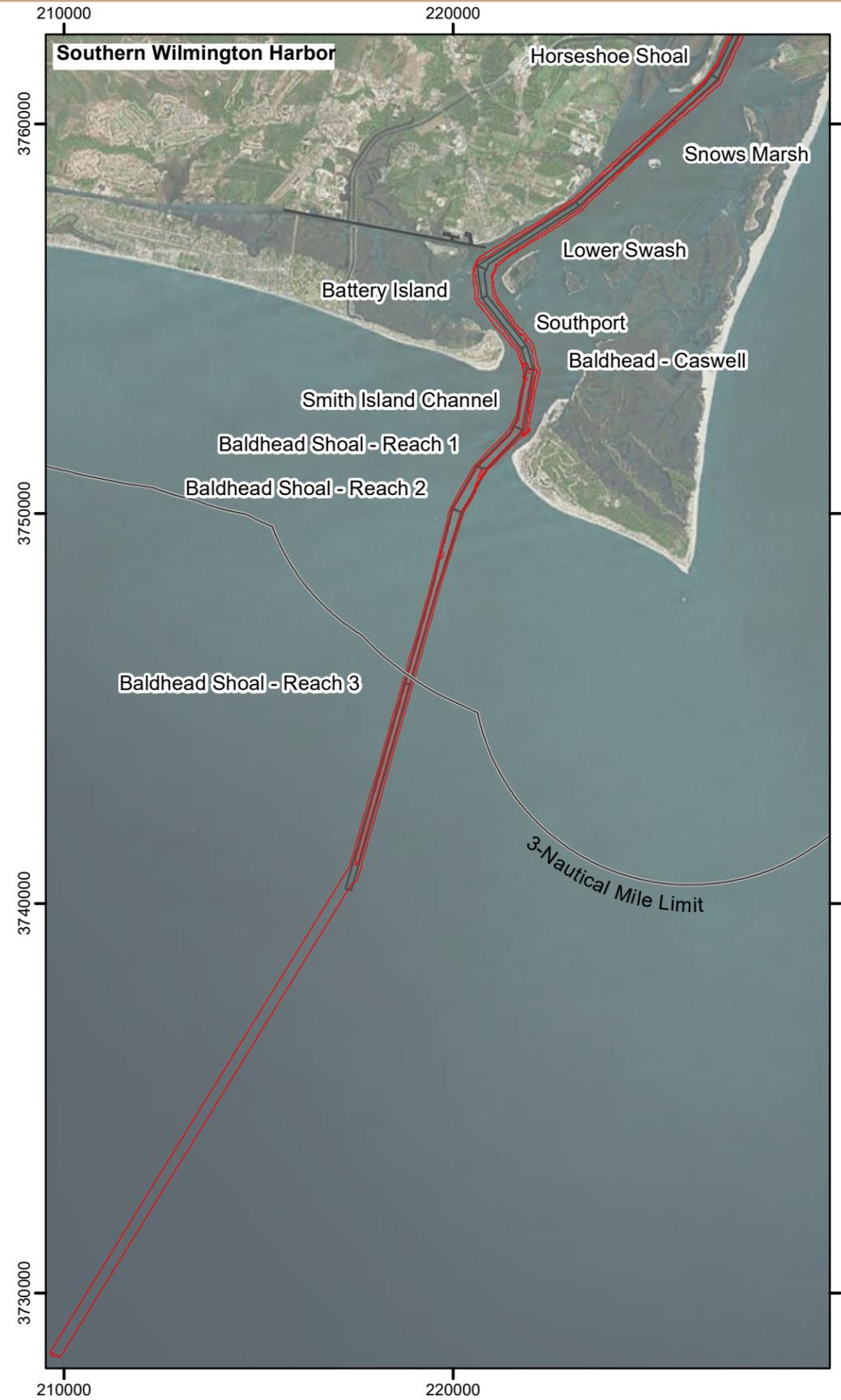
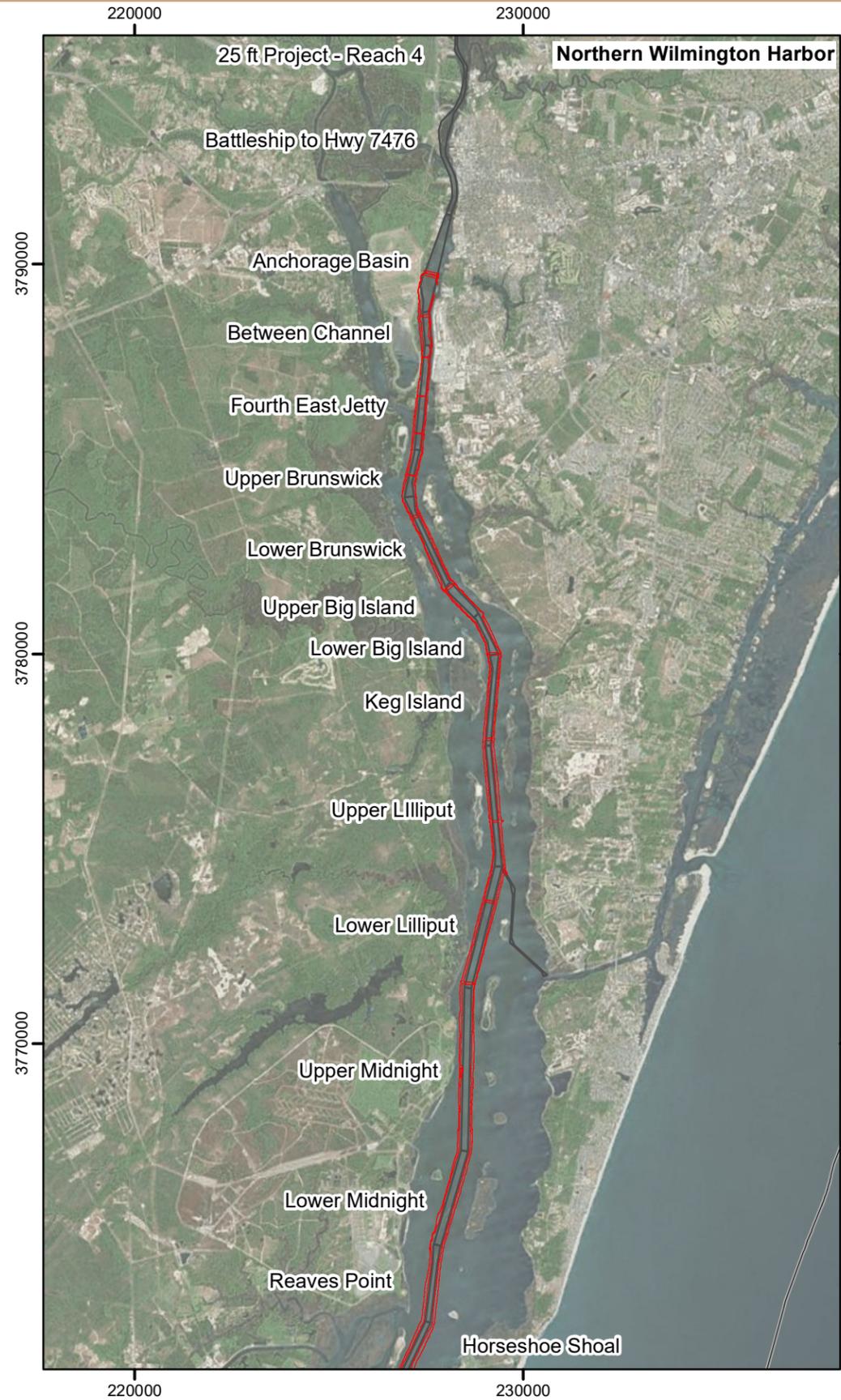
United States Army Corps of Engineers (USACE) (1996) Final Feasibility Report And Environmental Impact Statement On Improvement Of Navigation, Cape Fear – Northeast Cape Fear Rivers Comprehensive Study, Wilmington, North Carolina, June 1996.

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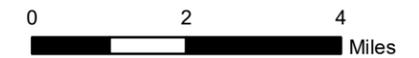
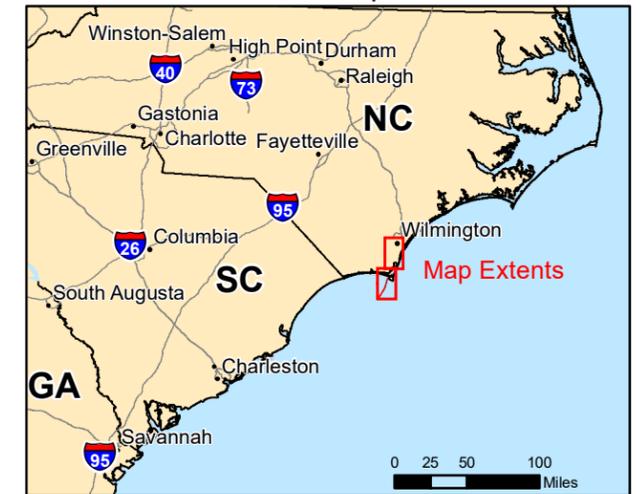
FIGURES



Legend

-  USACE Channel Reach Boundary
-  Fugro Survey Boundary (May and July 2017)
-  3-Nautical Mile Limit

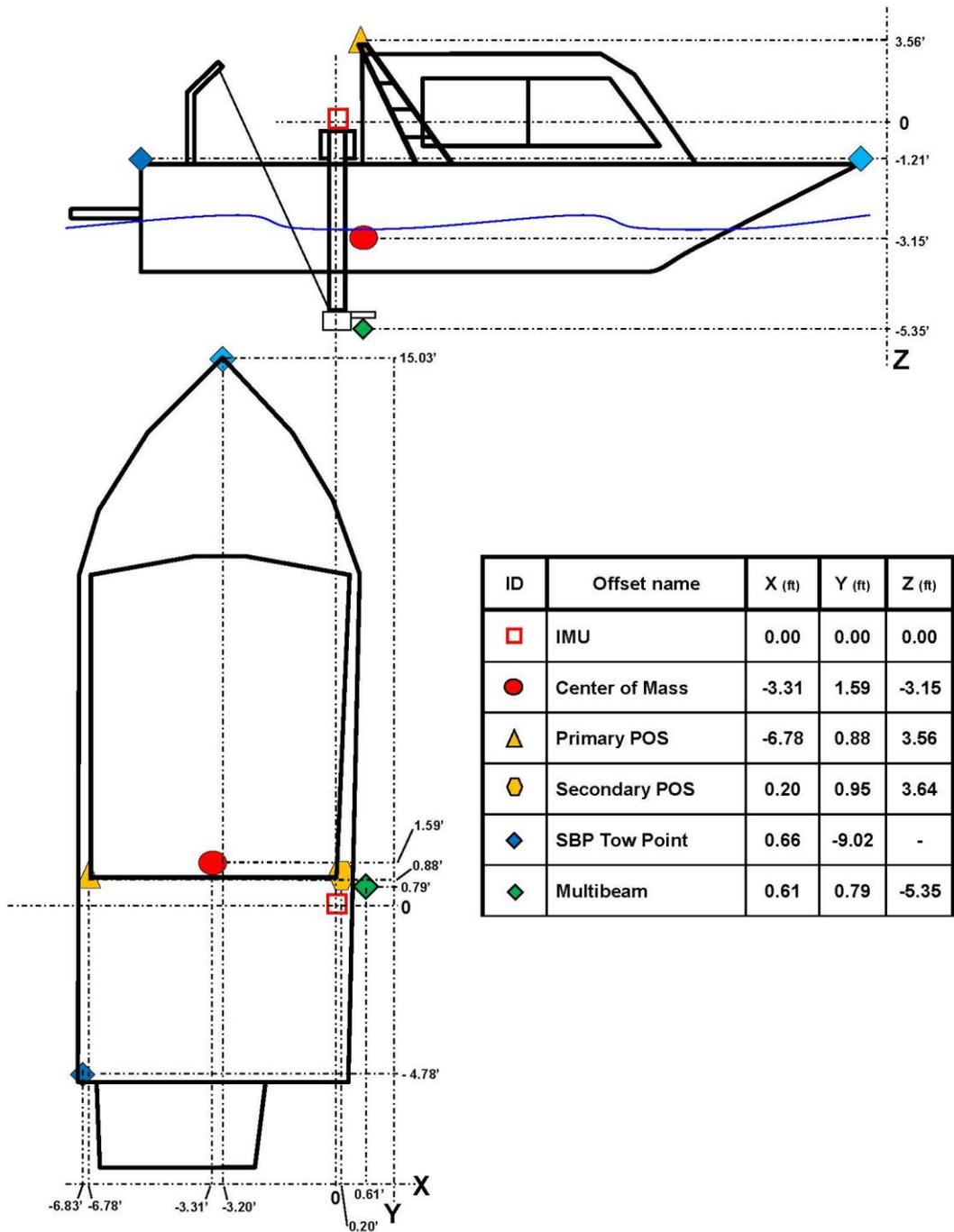
Site Map



Coordinate Grid: UTM 18N, NAD83, Meters

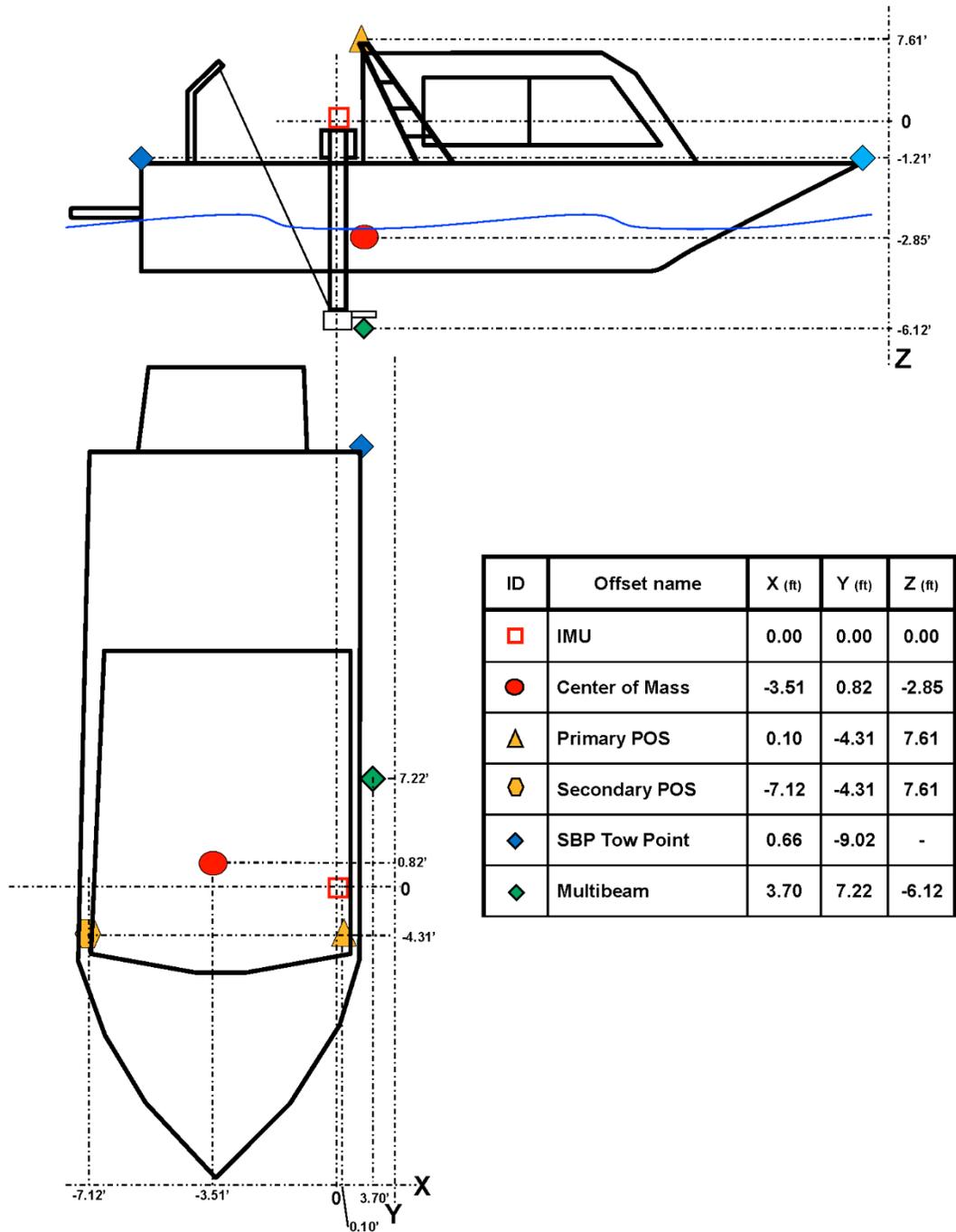
SURVEY AREA
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 1



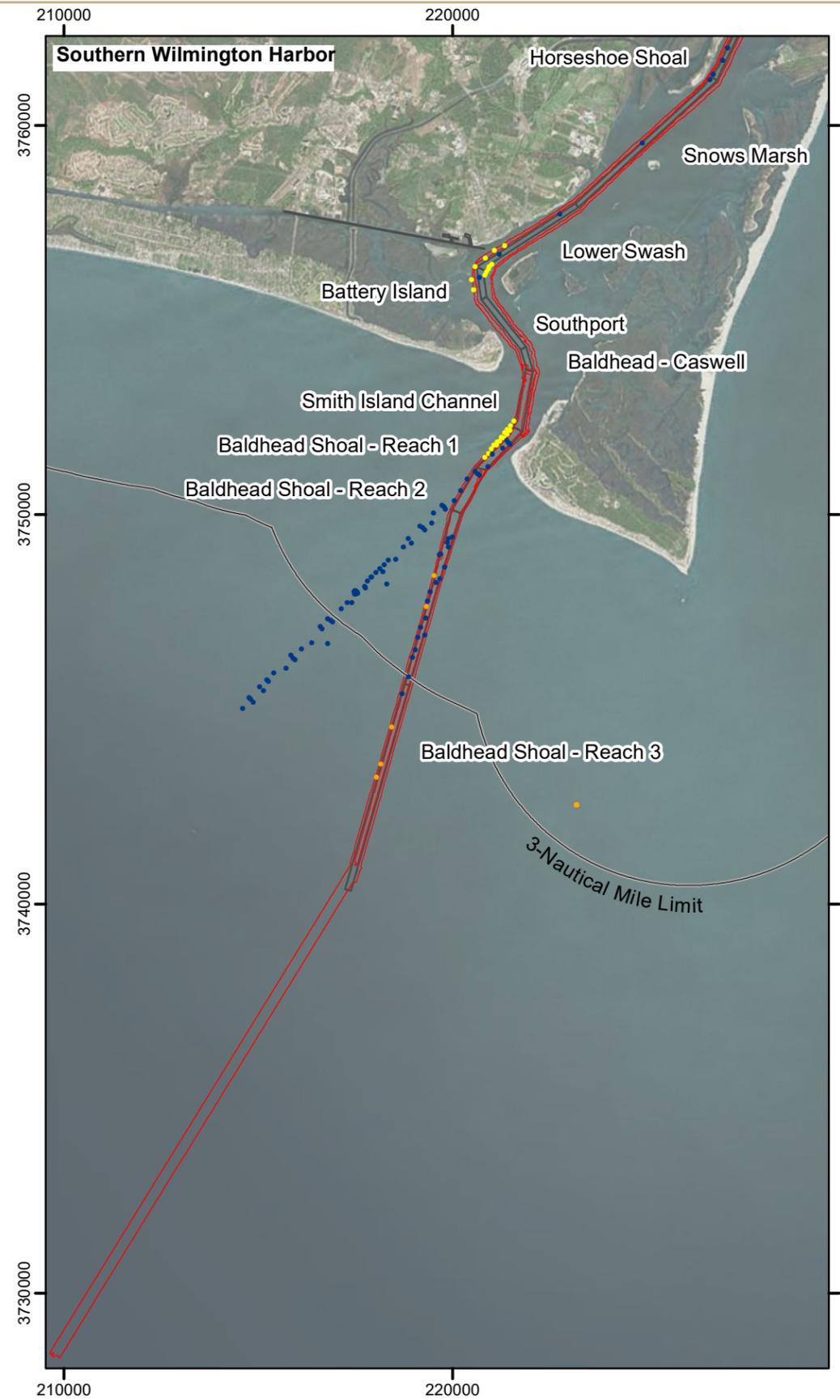
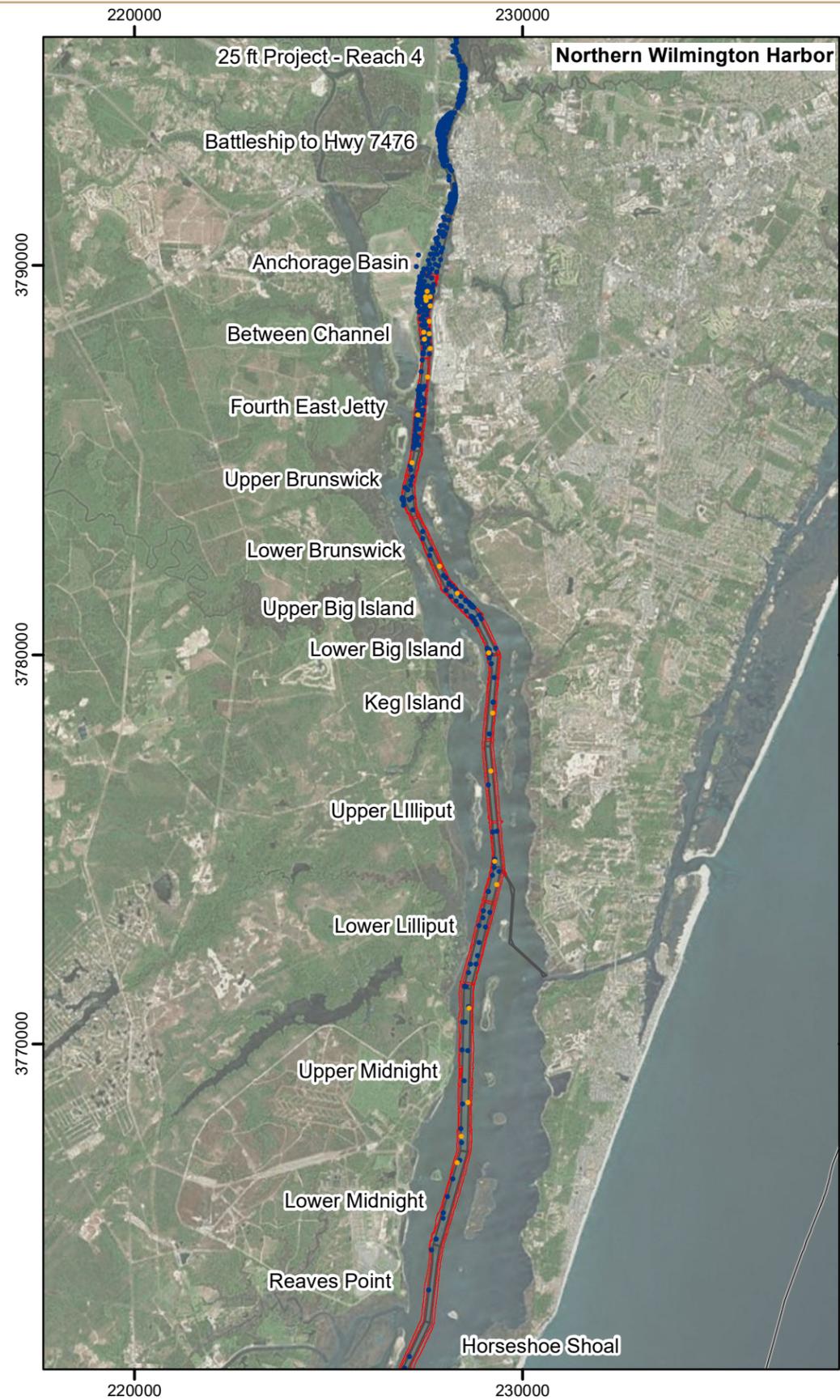
VESSEL OFFSET DIAGRAM FOR THE M/V SCHILPAD
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 2a



VESSEL OFFSET DIAGRAM FOR THE SEAHAWK
 Wilmington Harbor Deepening Study
 Wilmington, North Carolina

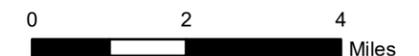
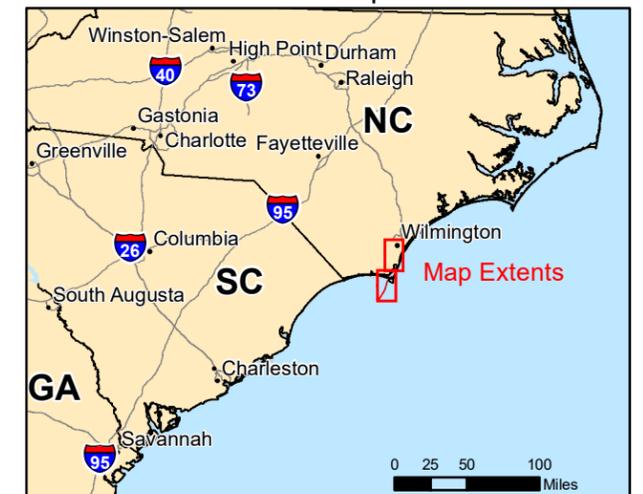
FIGURE 2b



Legend

-  USACE Channel Reach Boundary
-  Fugro Survey Boundary (May and July 2017)
-  3-Nautical Mile Limit
-  Existing Boring data used in this study
-  Existing Vibracores data used in this study
-  Existing grab samples used in this study

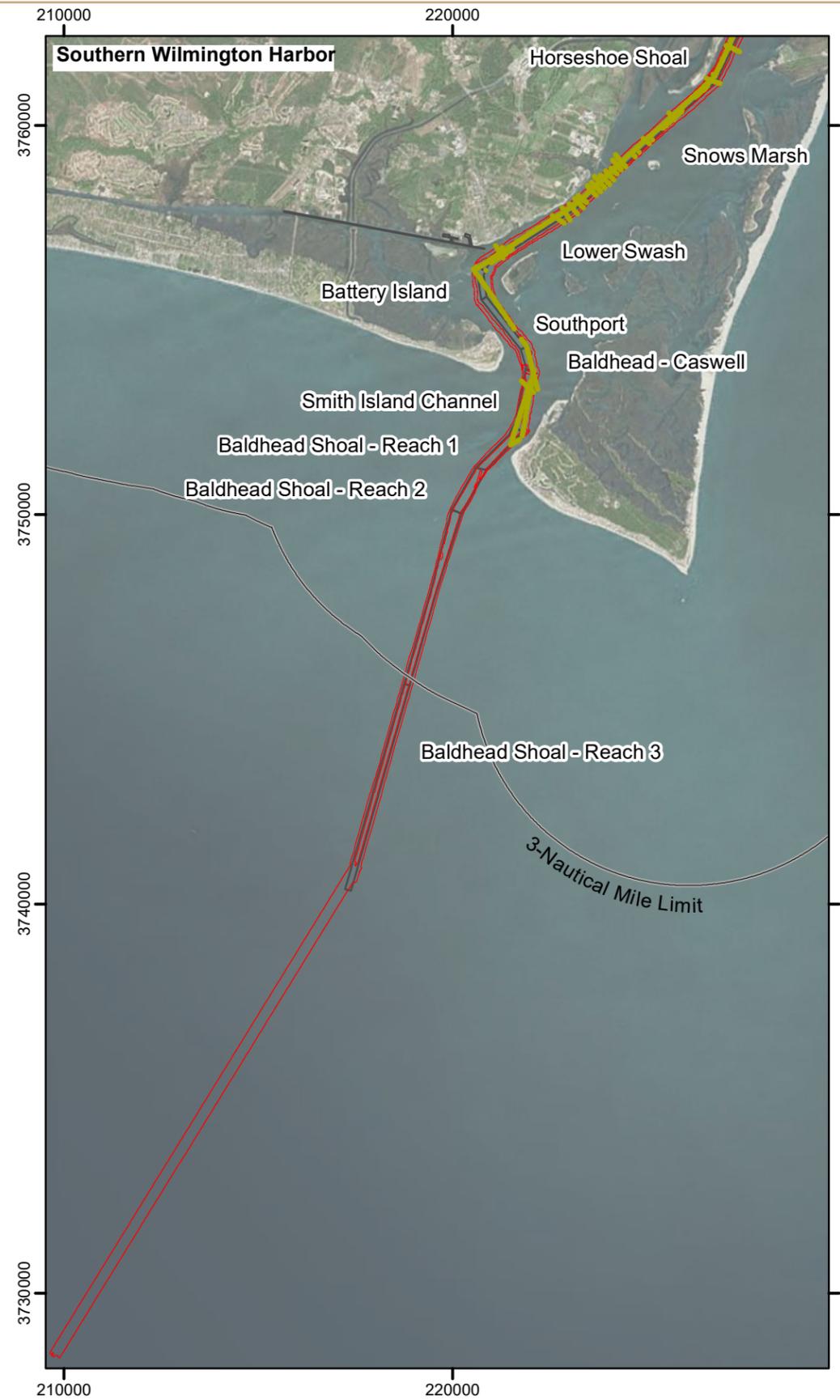
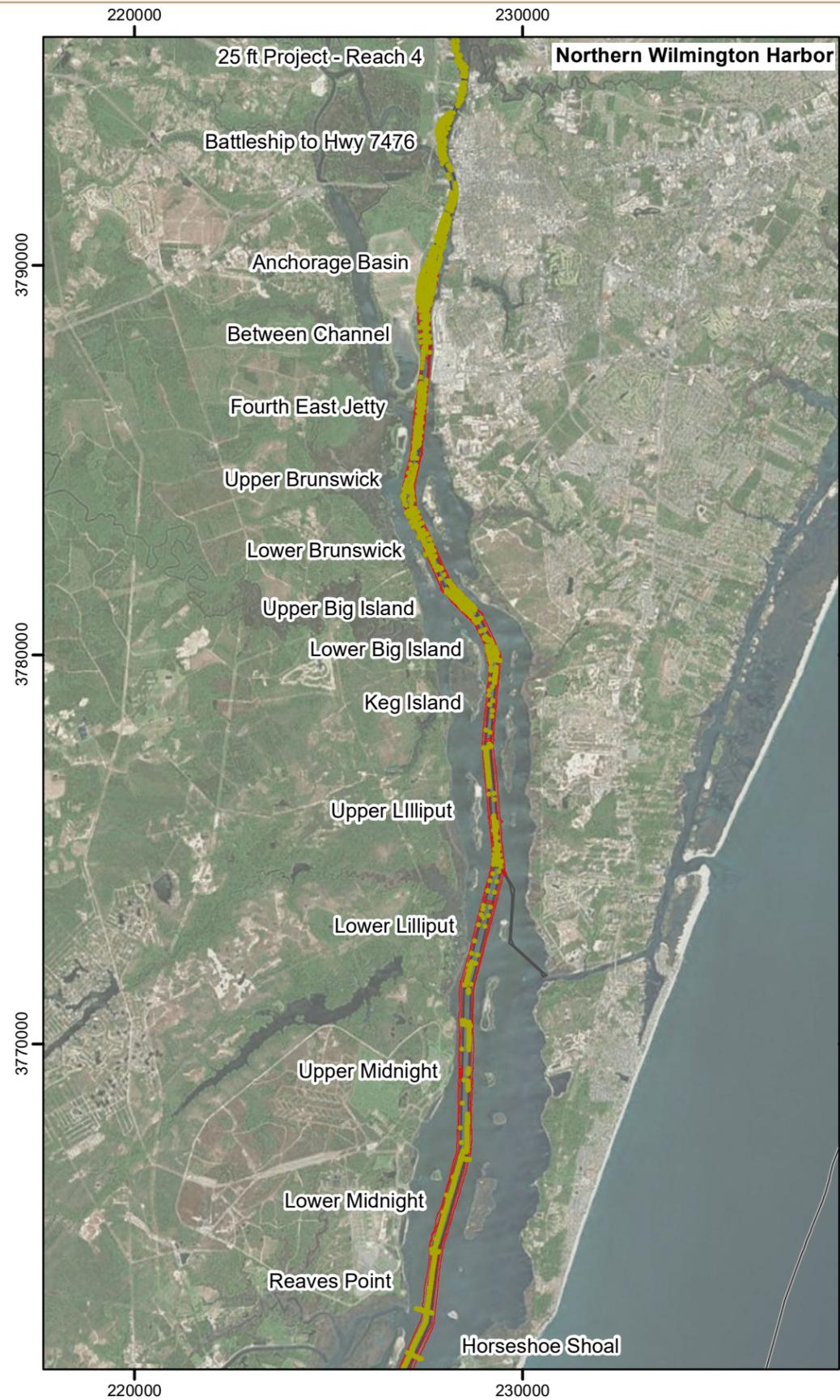
Site Map



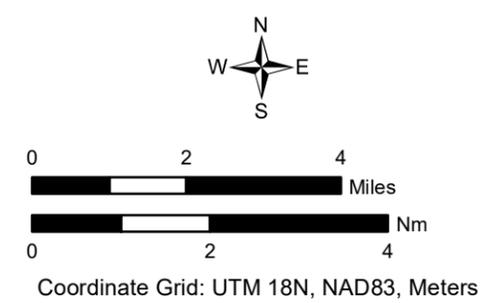
Coordinate Grid: UTM 18N, NAD83, Meters

EXPLORATION LOCATIONS
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 3a



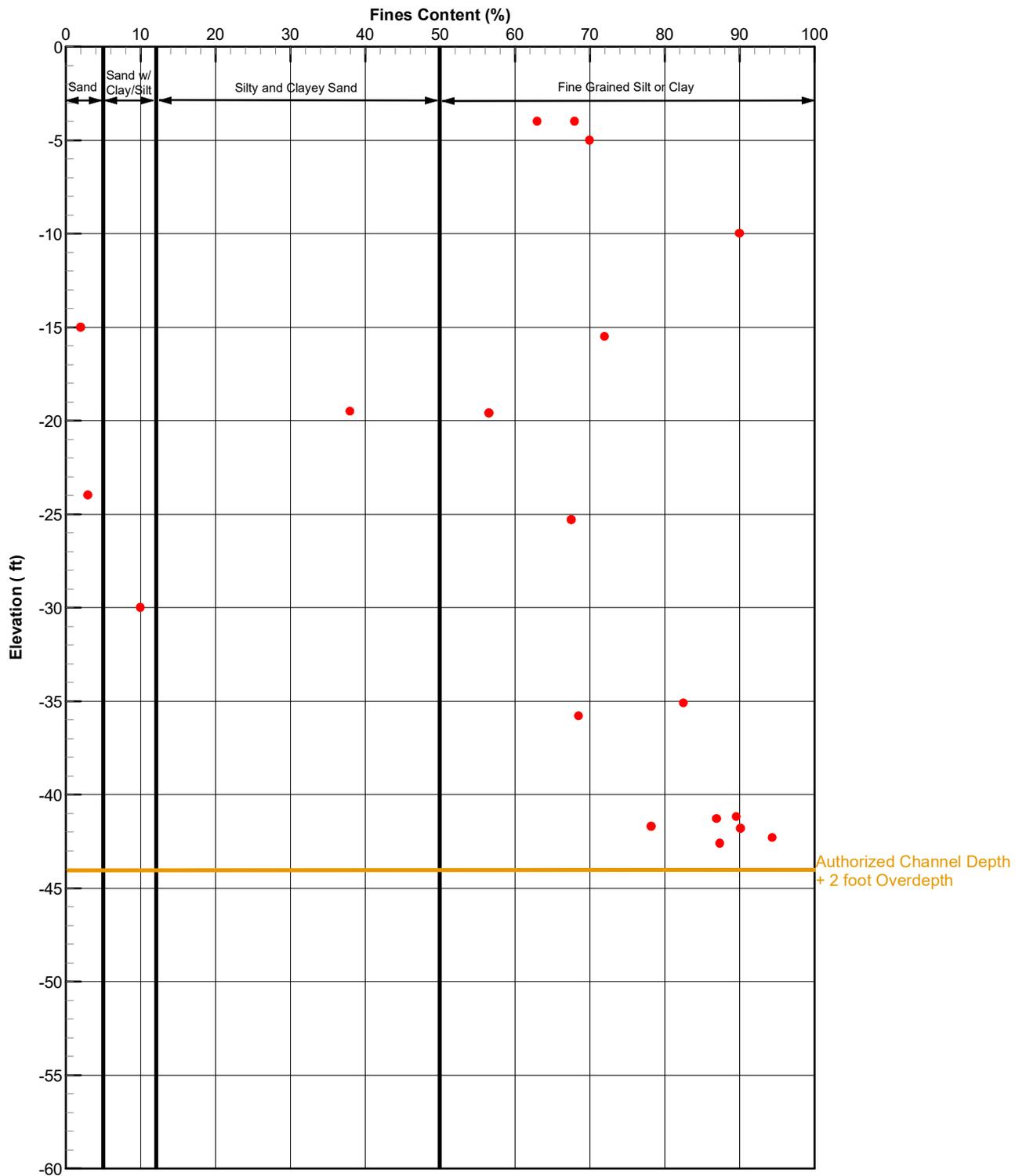
- Legend**
-  USACE Channel Reach Boundary
 -  Fugro Survey Boundary (May and July 2017)
 -  3-Nautical Mile Limit
 -  Existing top of rock data point used in this study



USACE TOP OF ROCK DATA LOCATION
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3b

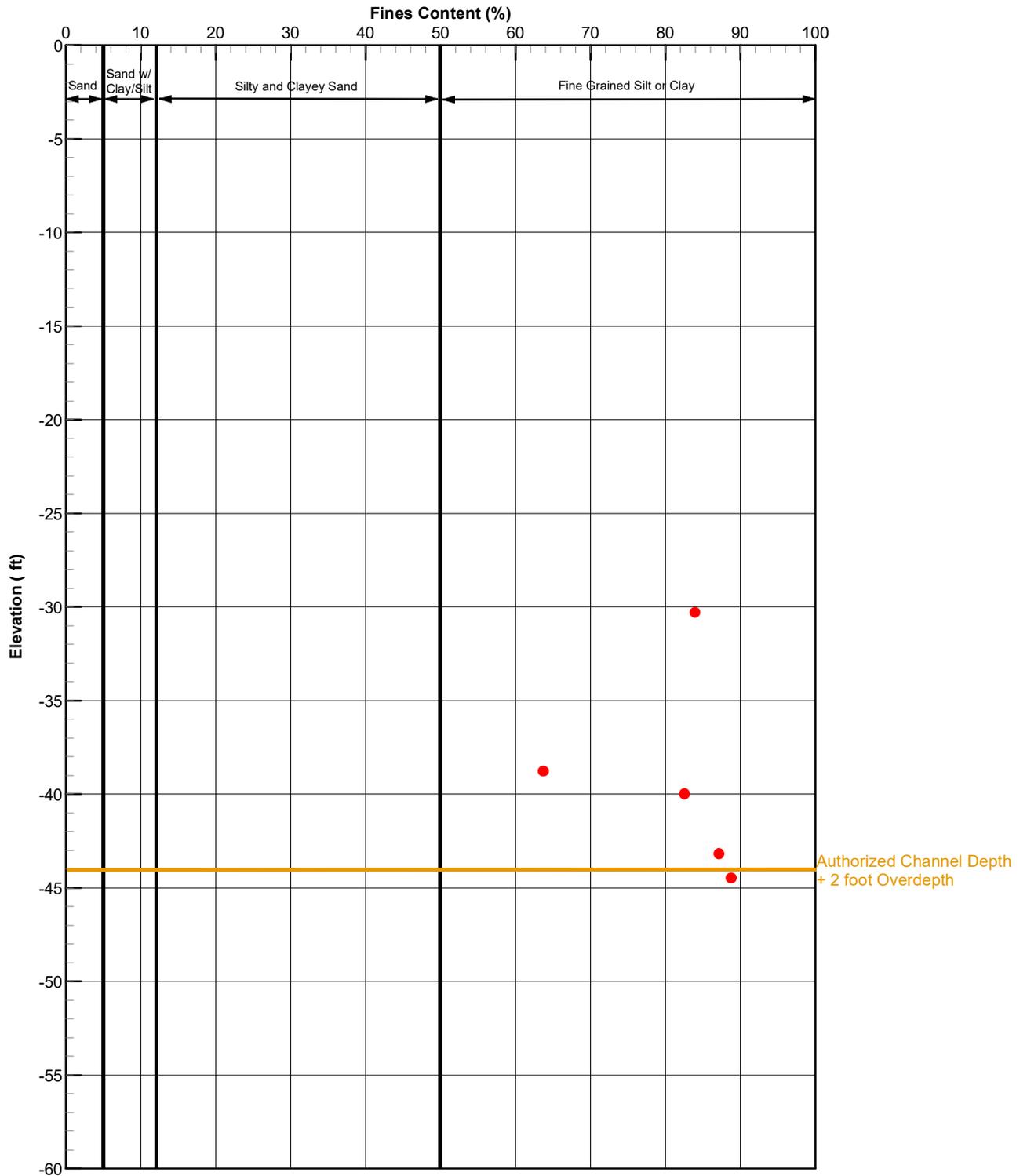
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Anchorage Basin
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-1

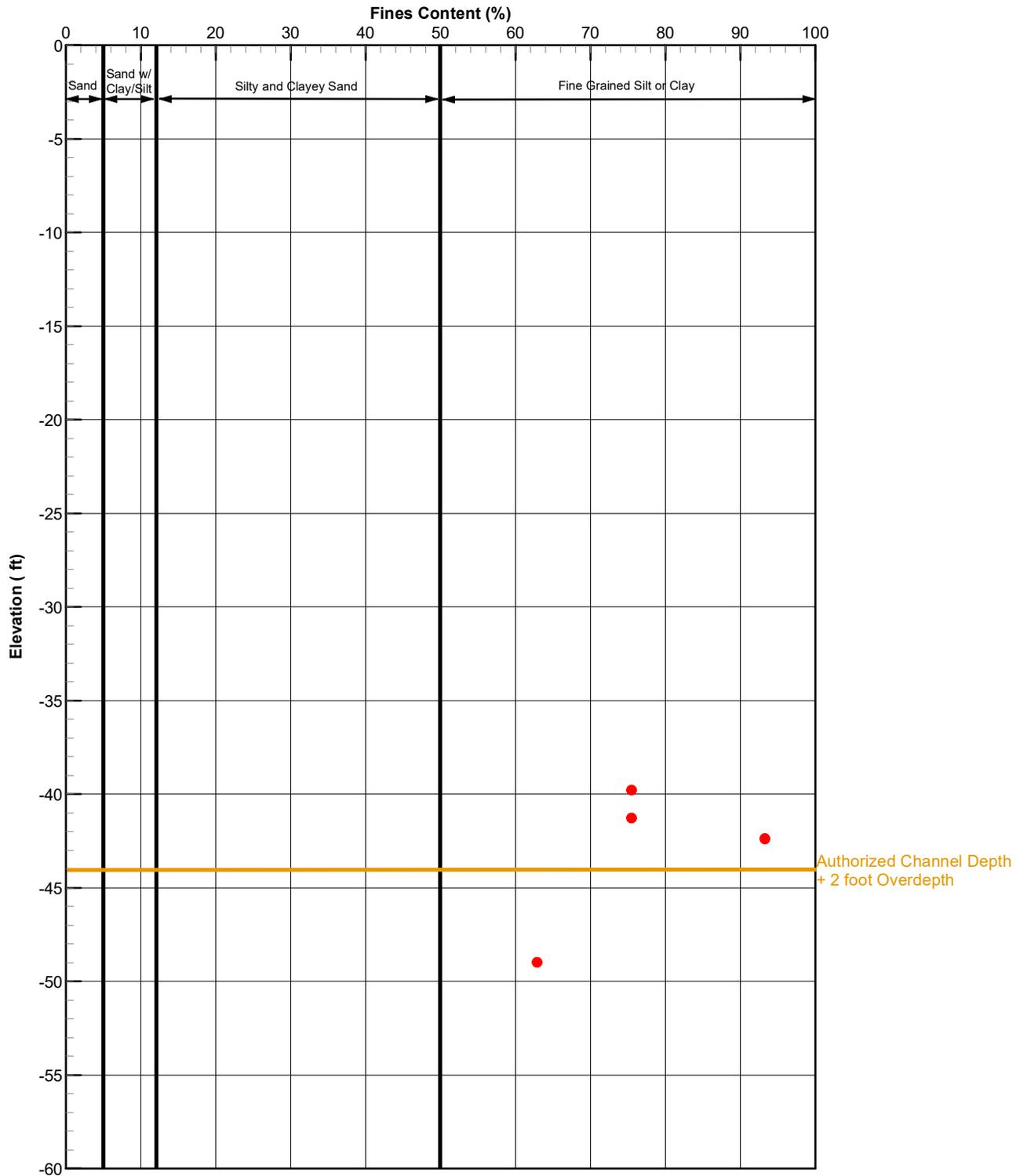
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Between Channel
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-2

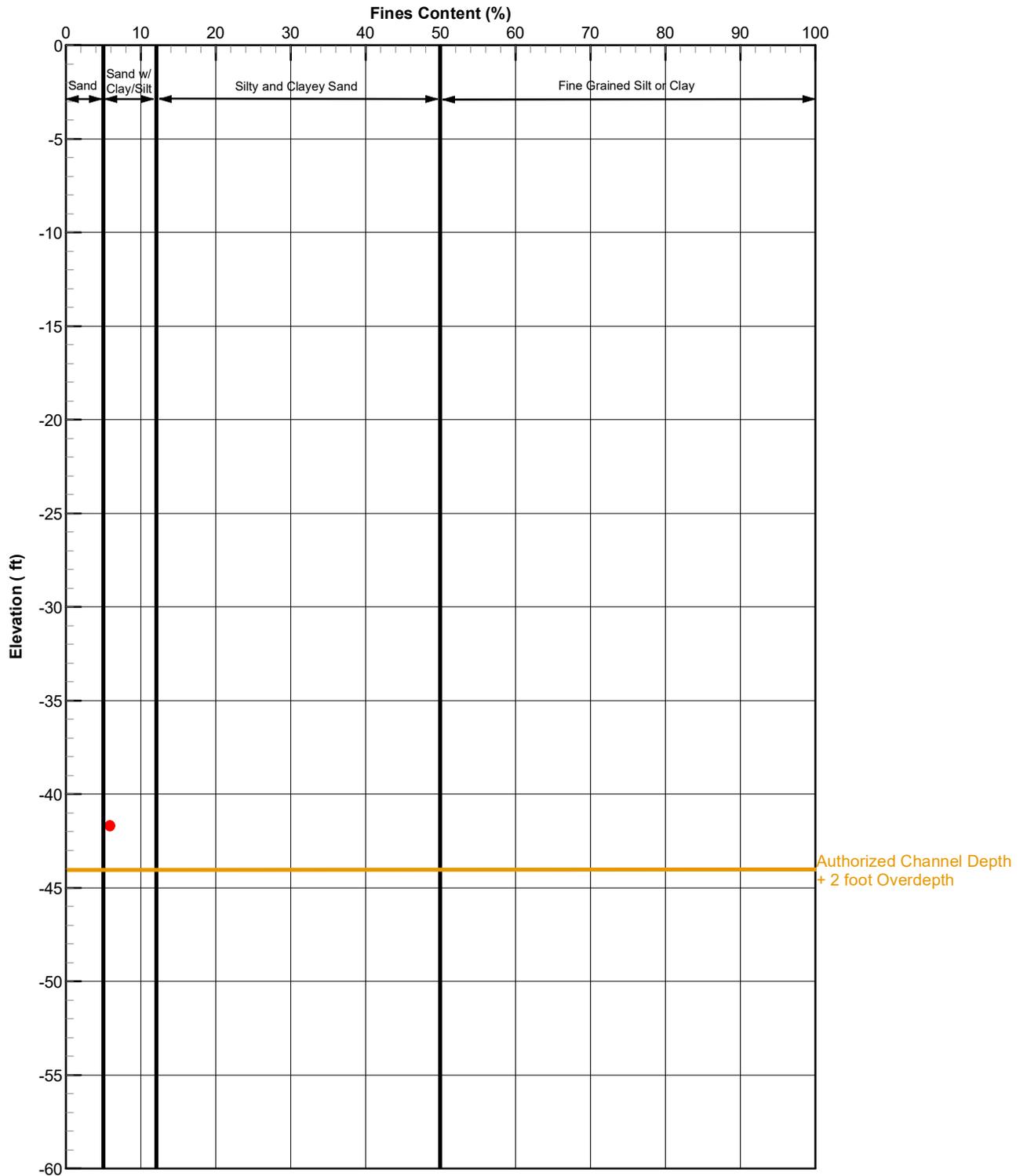
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Fourth East Jetty
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-3

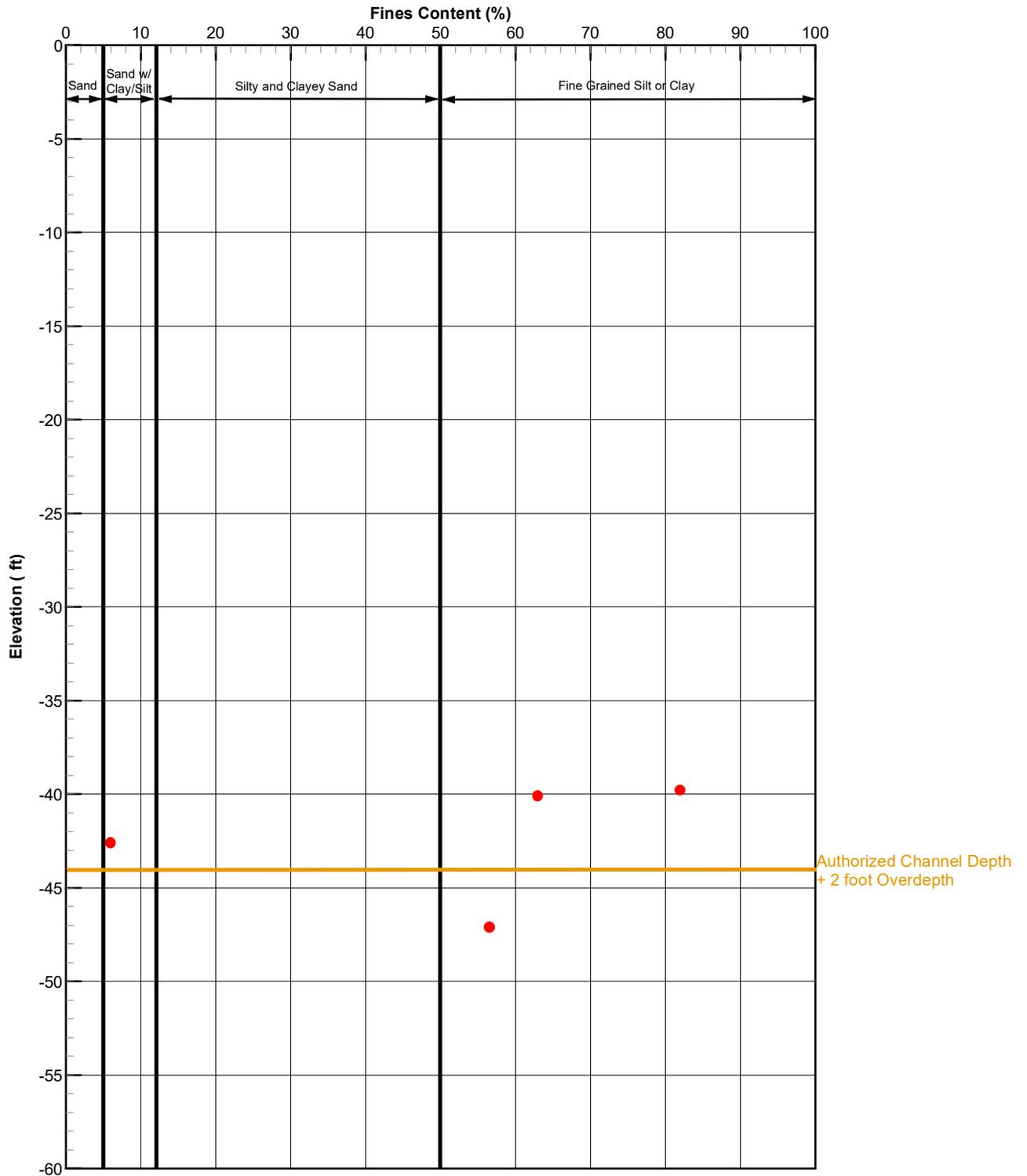
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Upper Brunswick
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-4

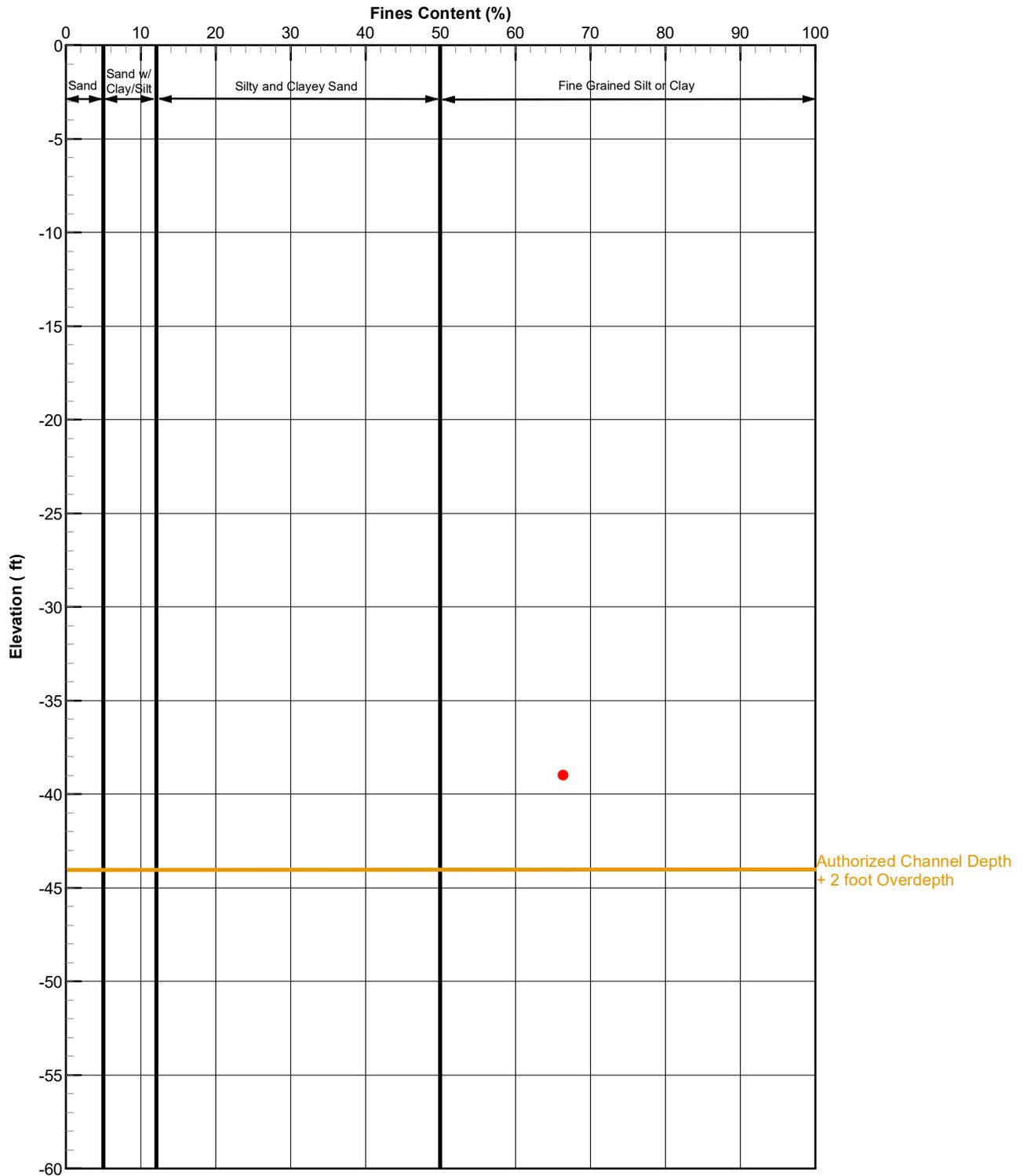
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Lower Brunswick
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-5

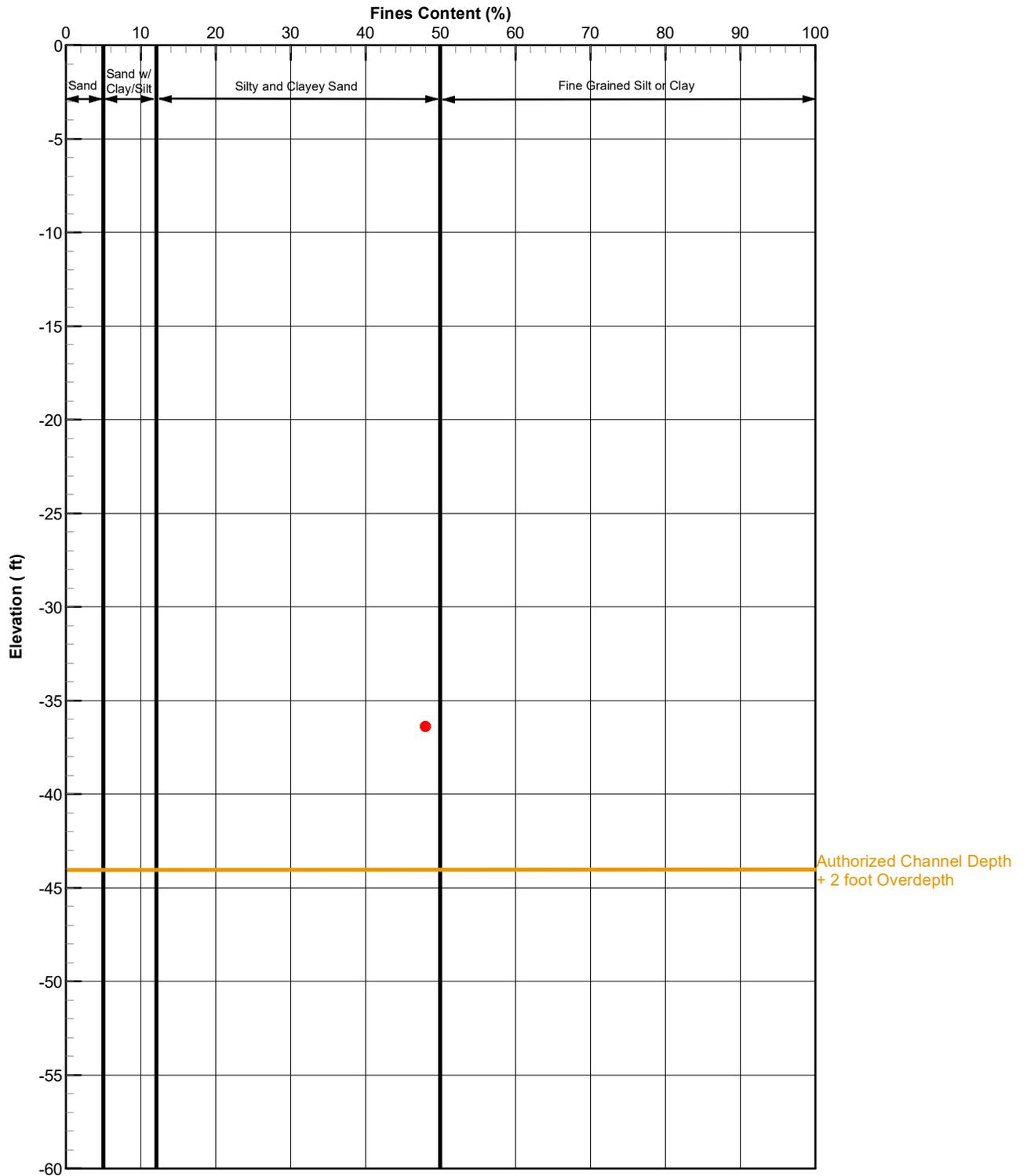
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Upper Big Island
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-6

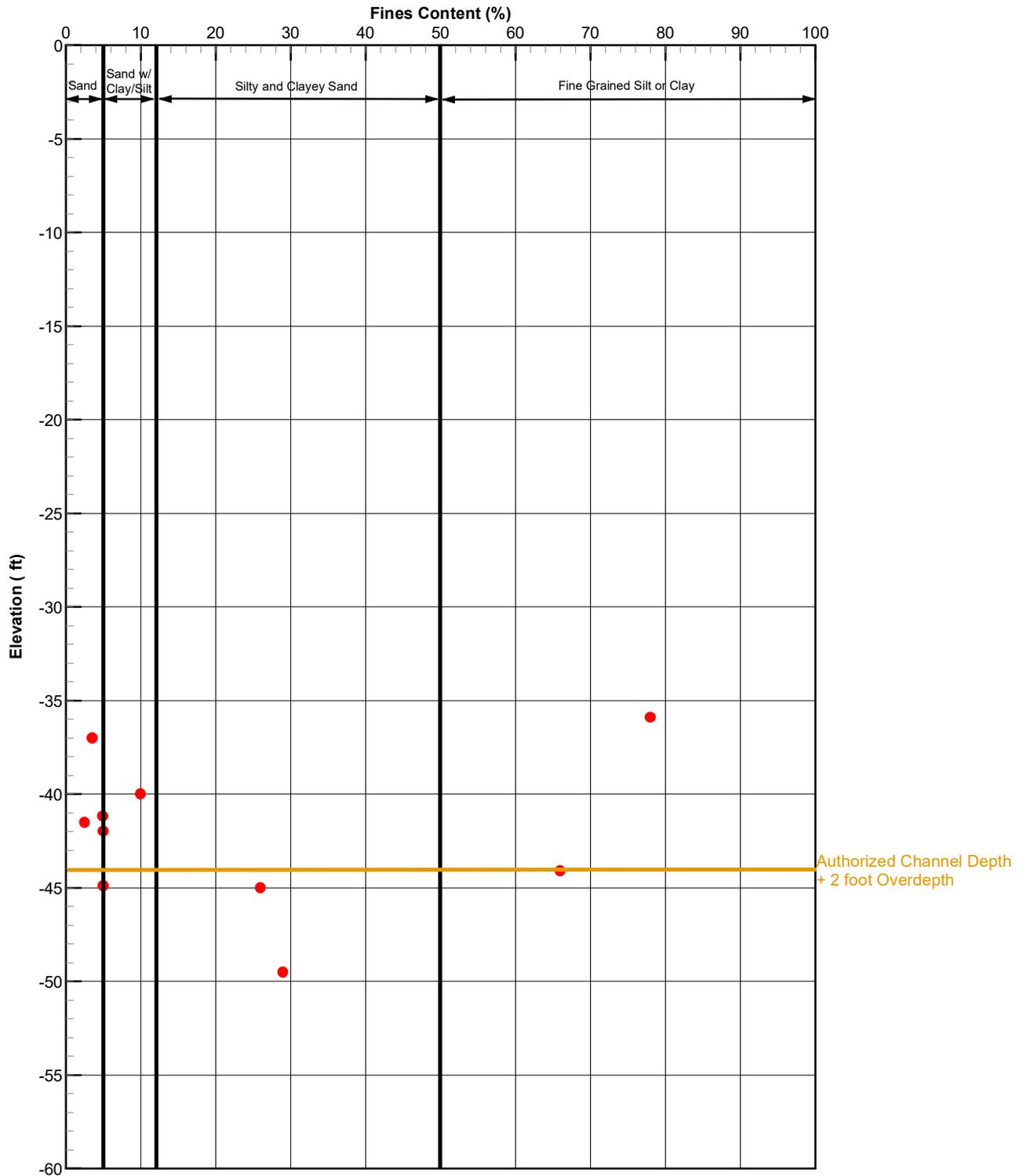
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Lower Big Island
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-7

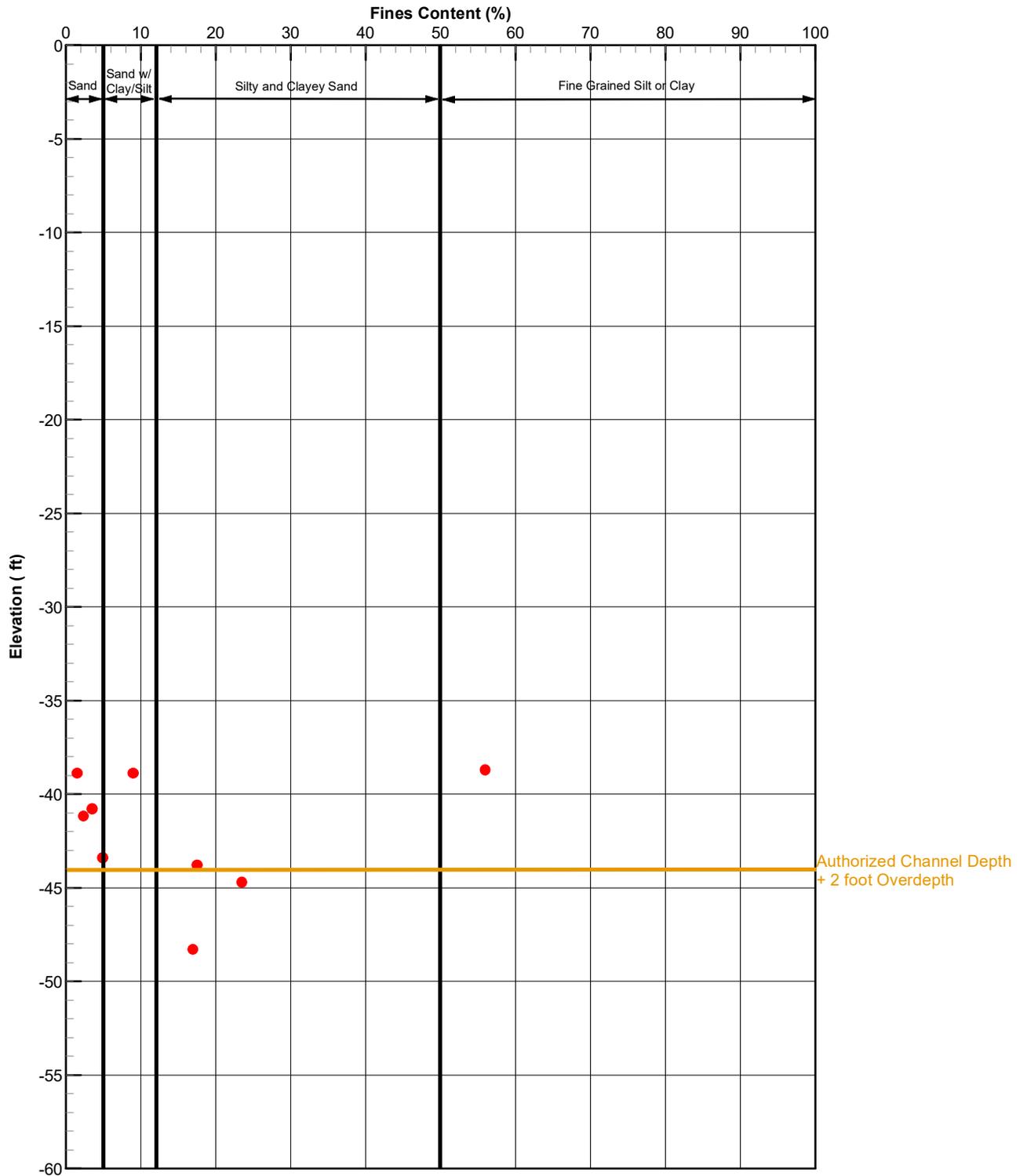
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Keg Island
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-8

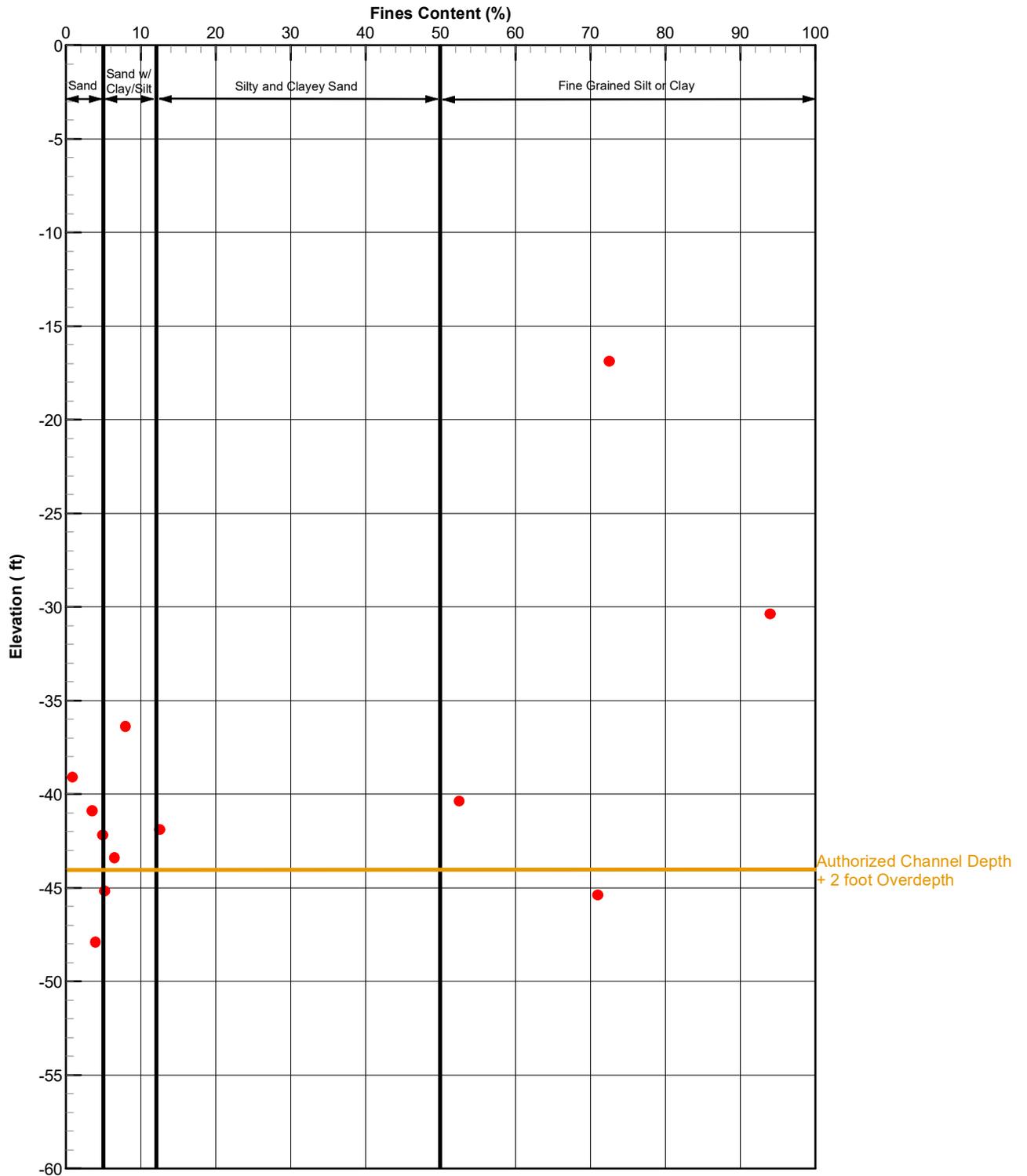
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Upper Lilliput
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-9

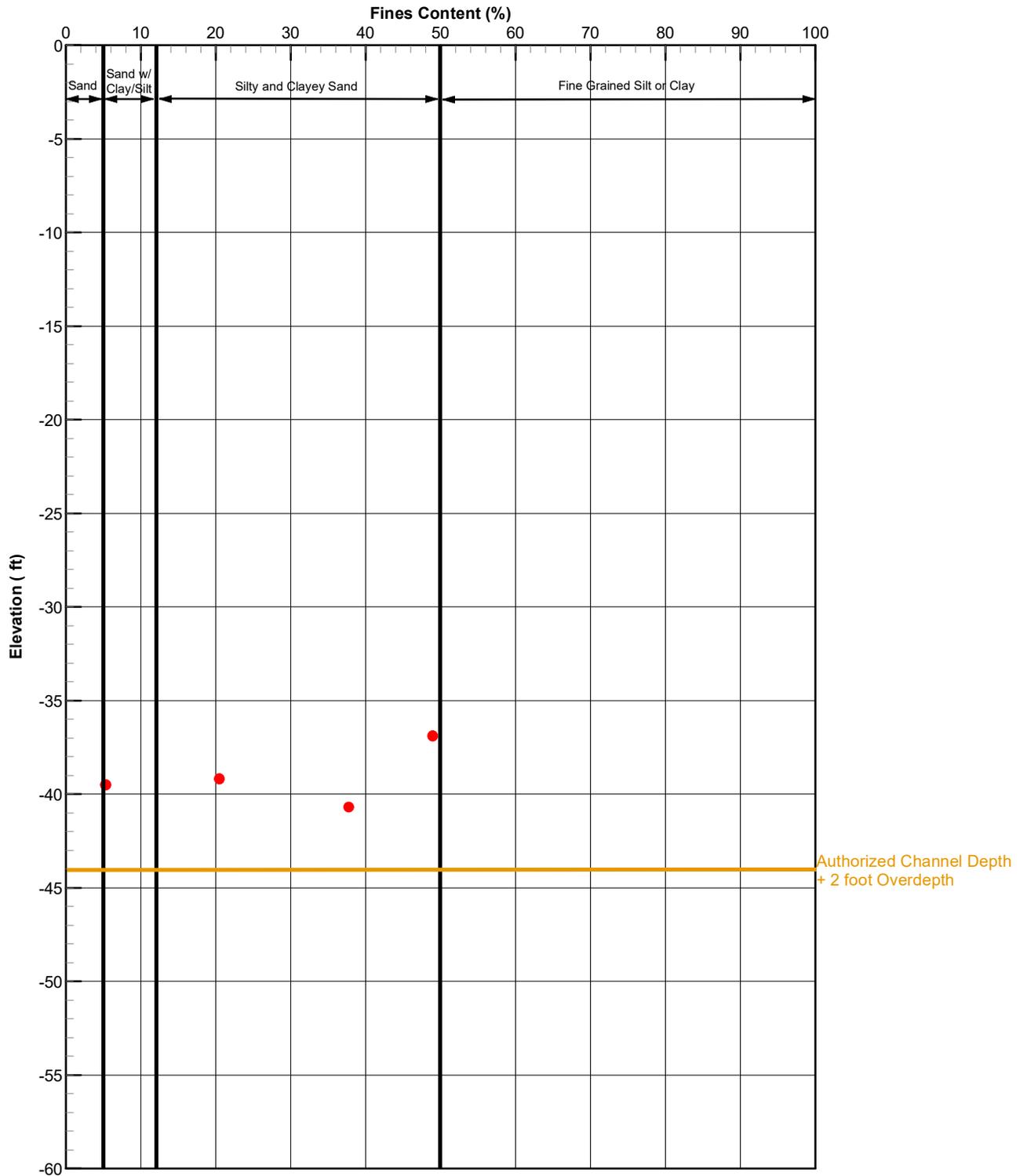
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Lower Lilliput
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-10

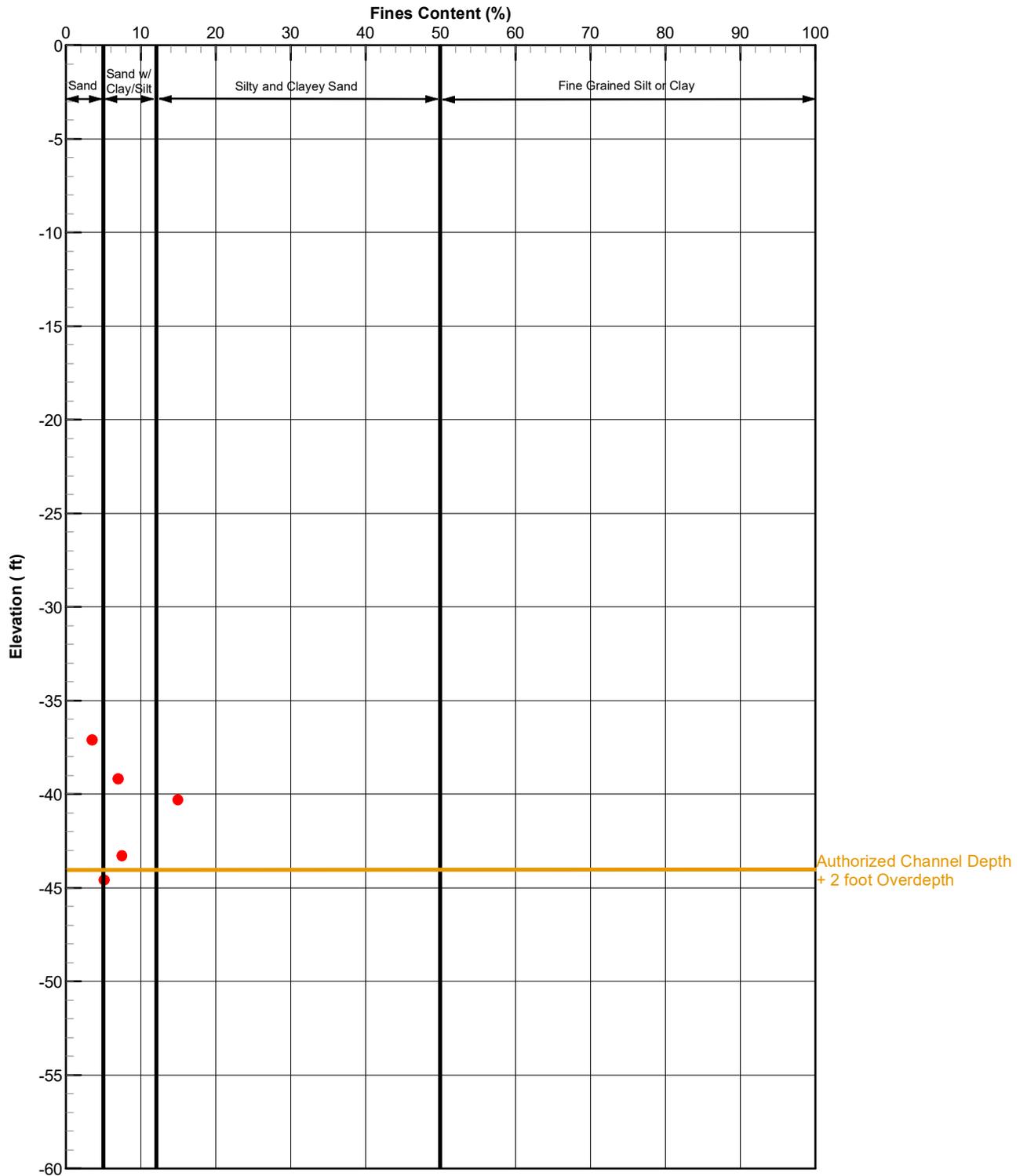
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Upper Midnight
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-11

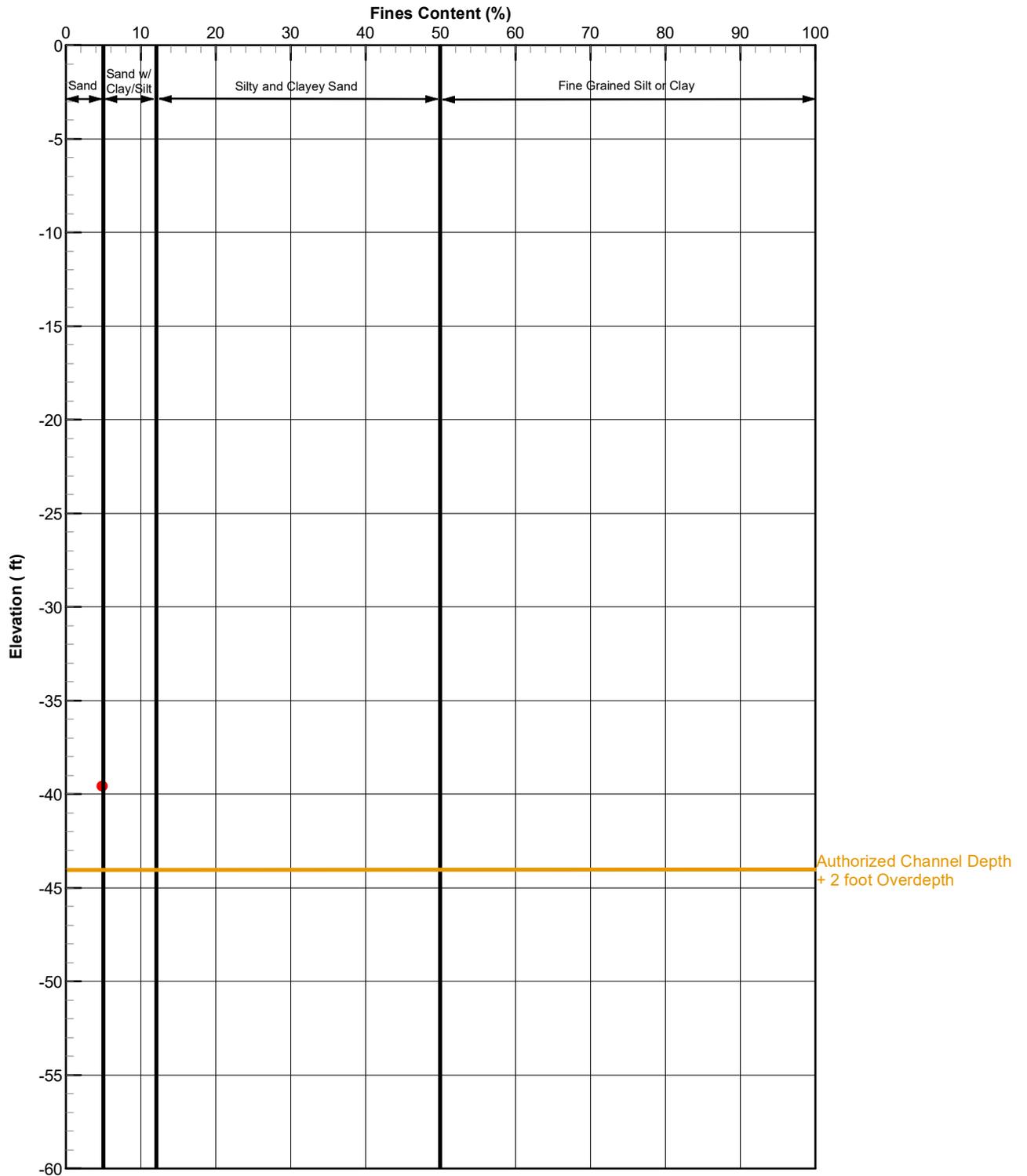
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Lower Midnight
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-12

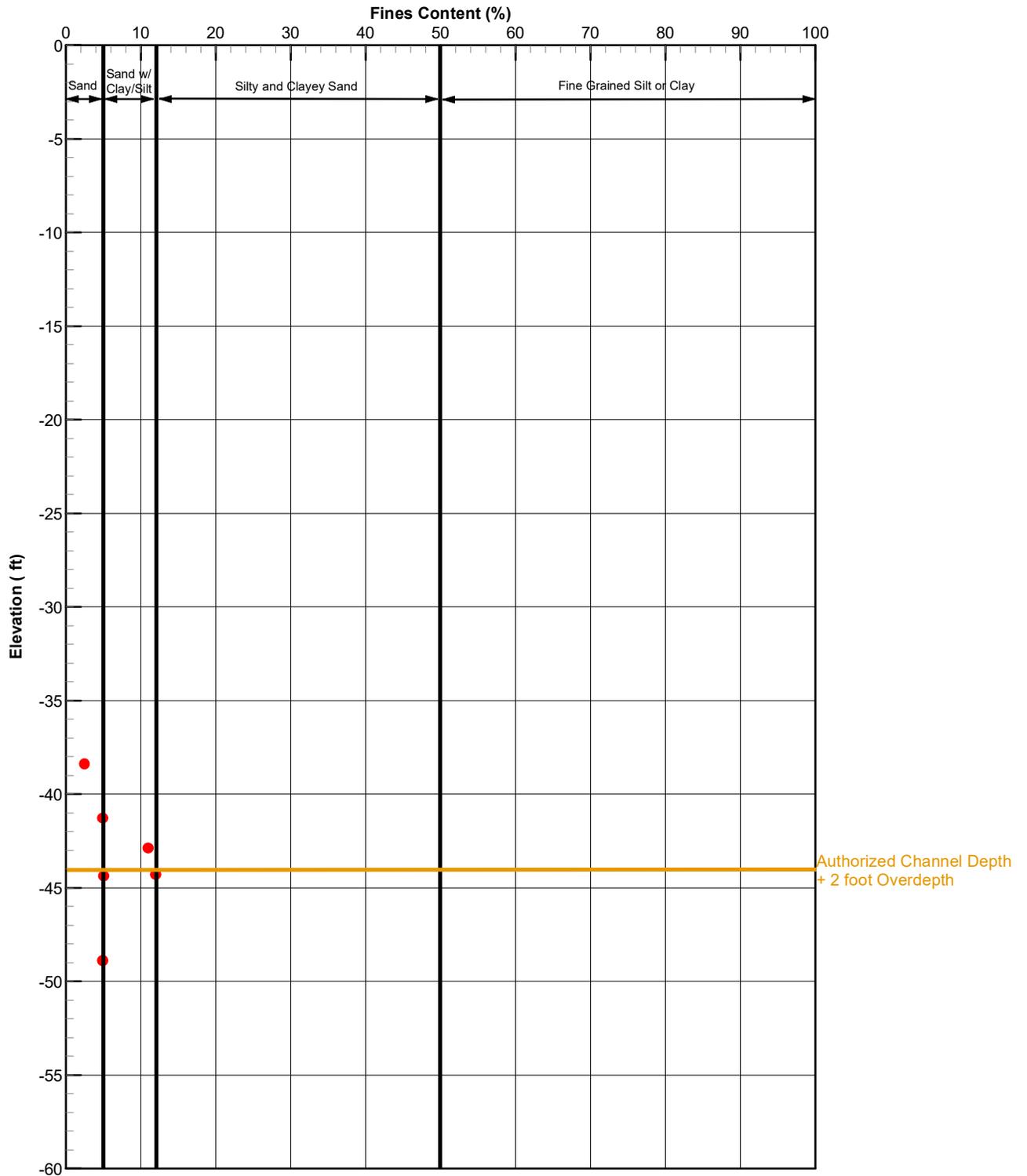
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Reaves Point
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-13

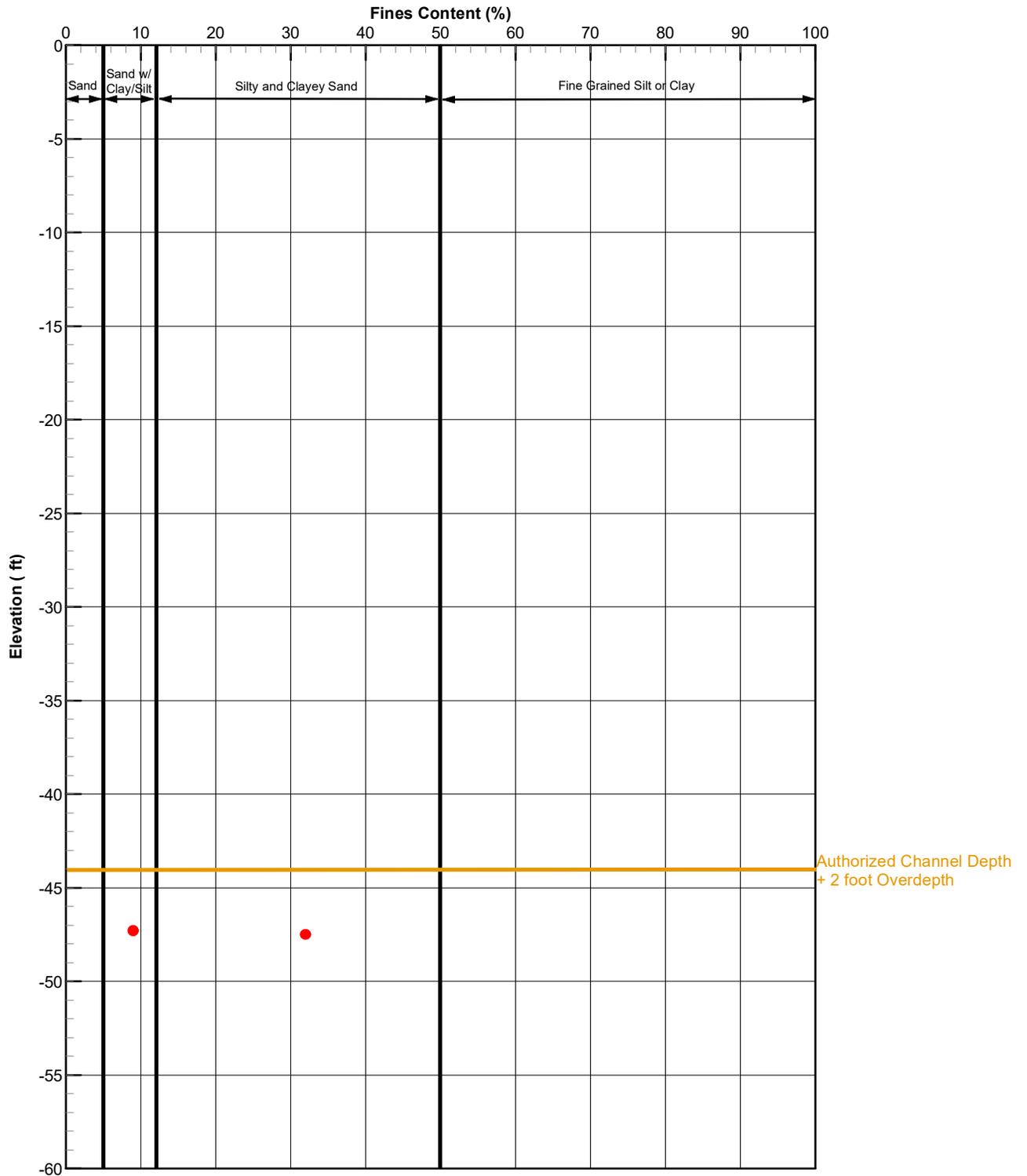
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Horseshoe Shoal
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-14

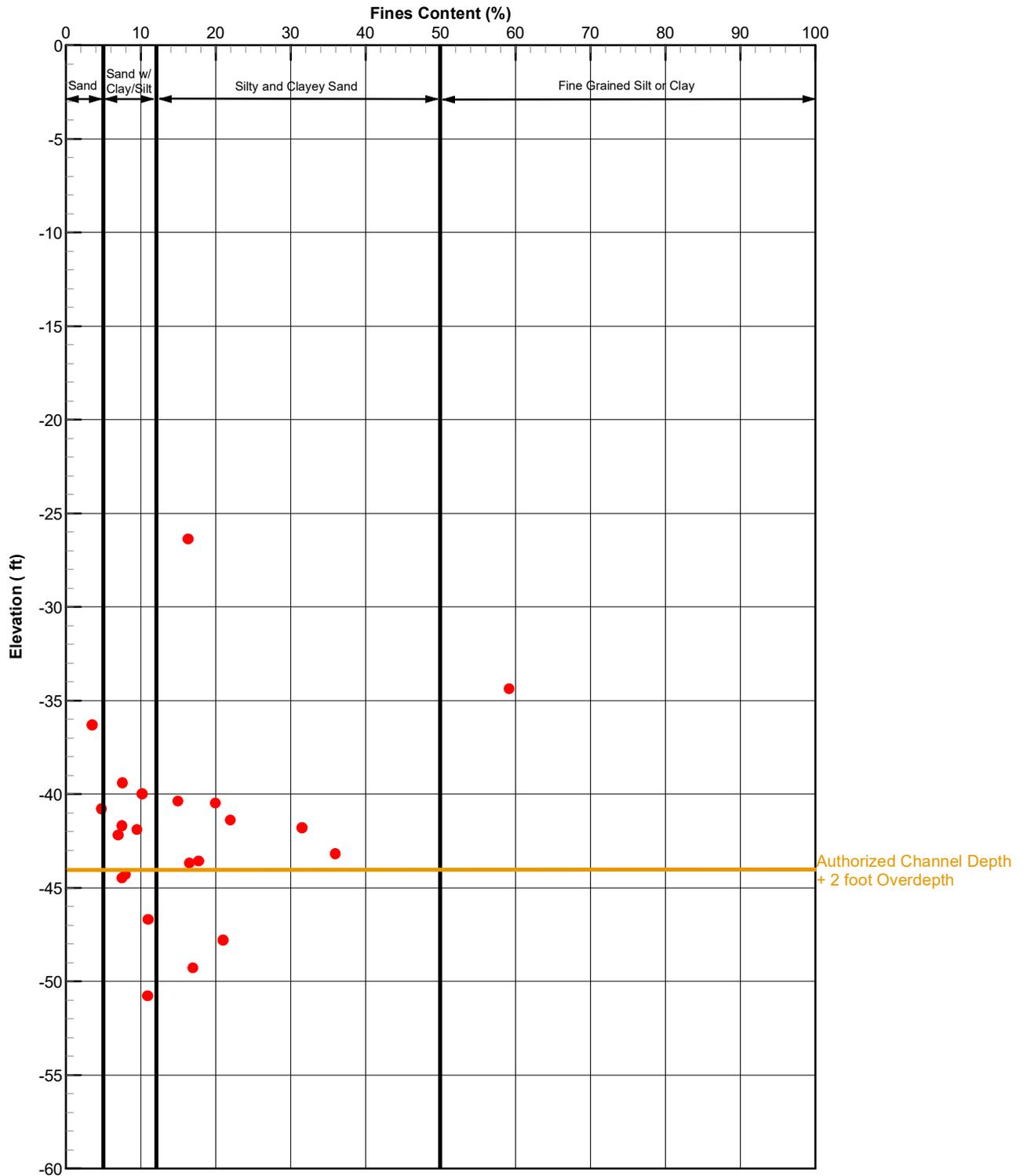
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Snows Marsh
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-15

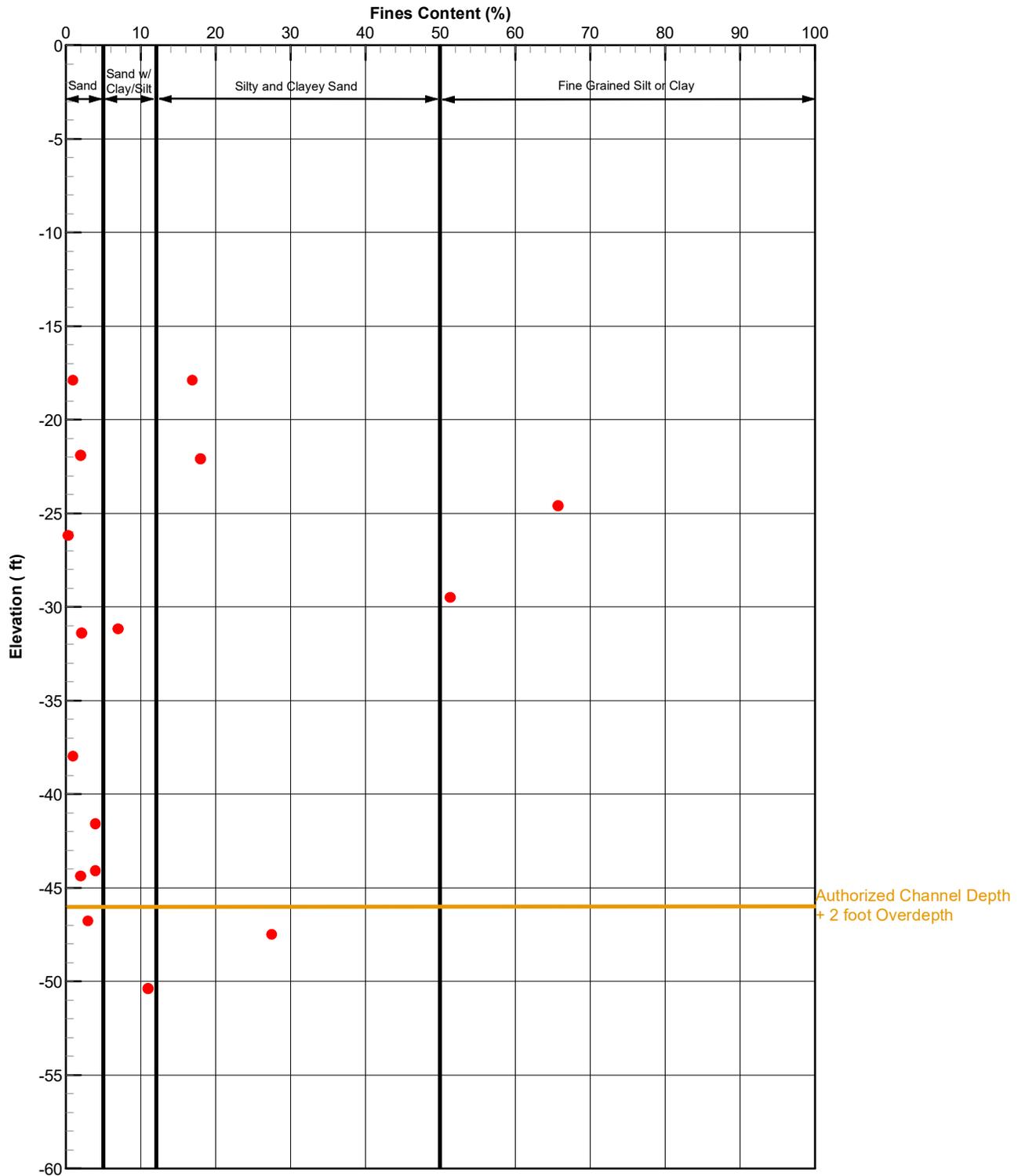
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Lower Swash
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-16

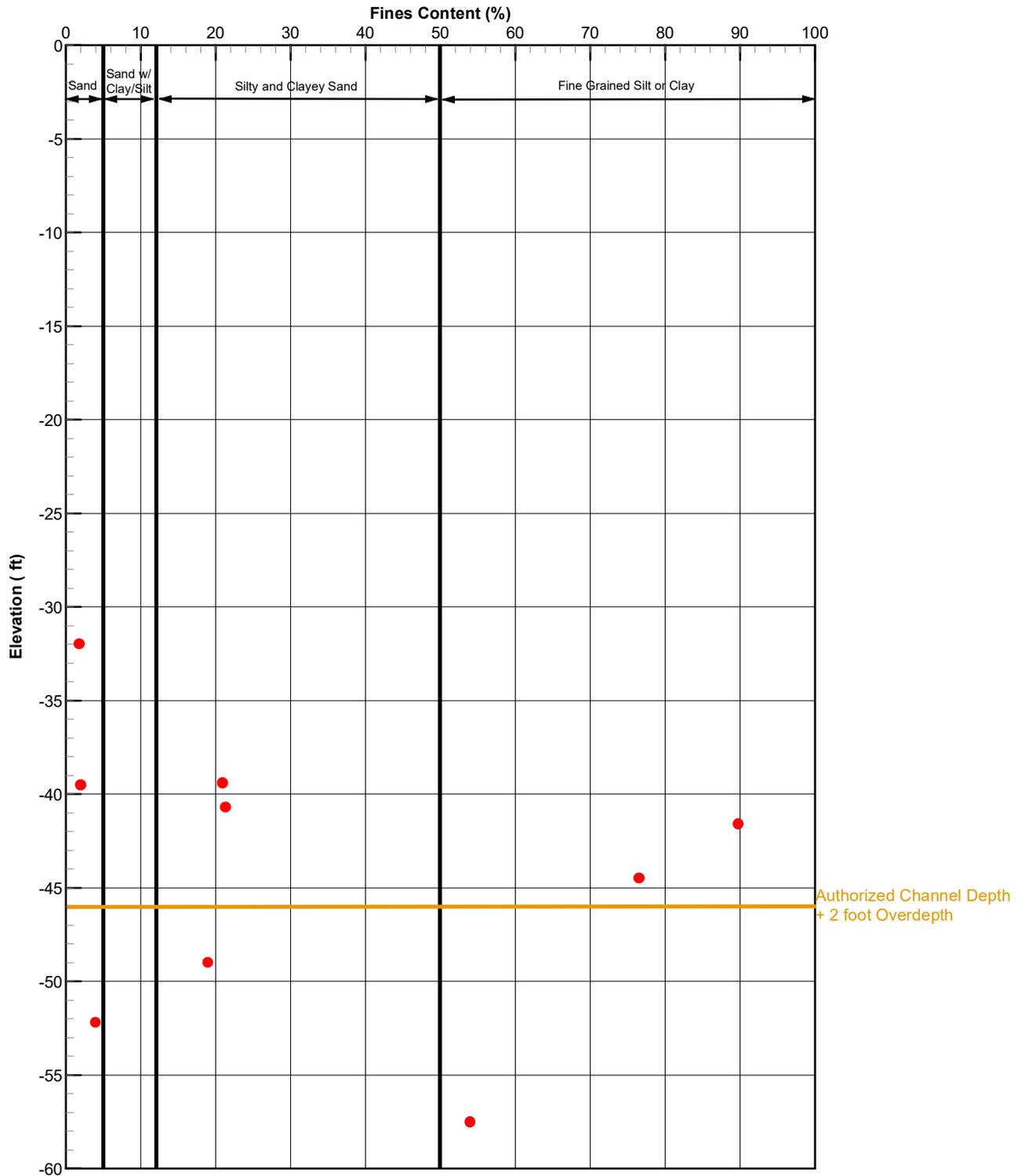
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Battery Island
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-17

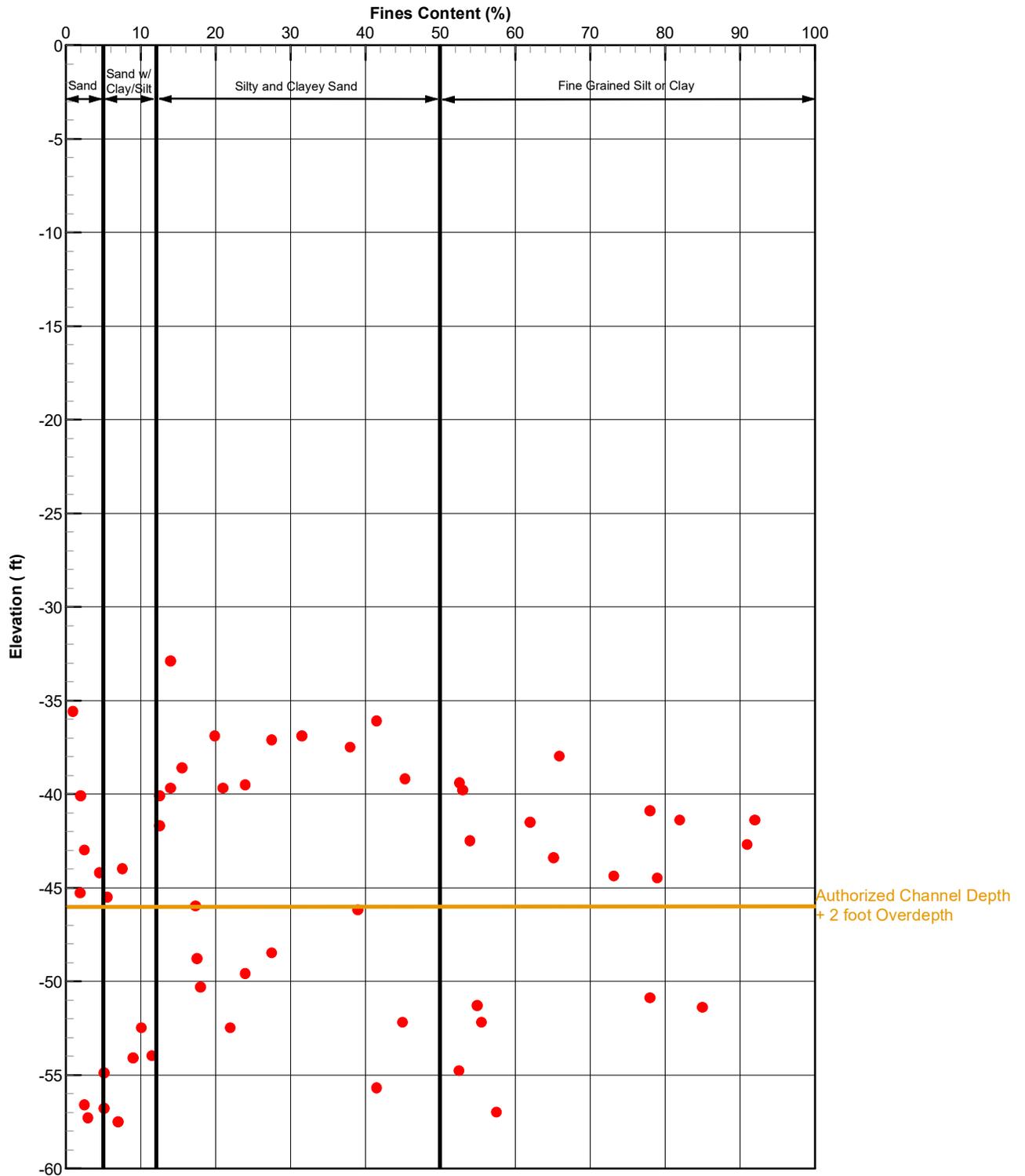
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Smith Island
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-18

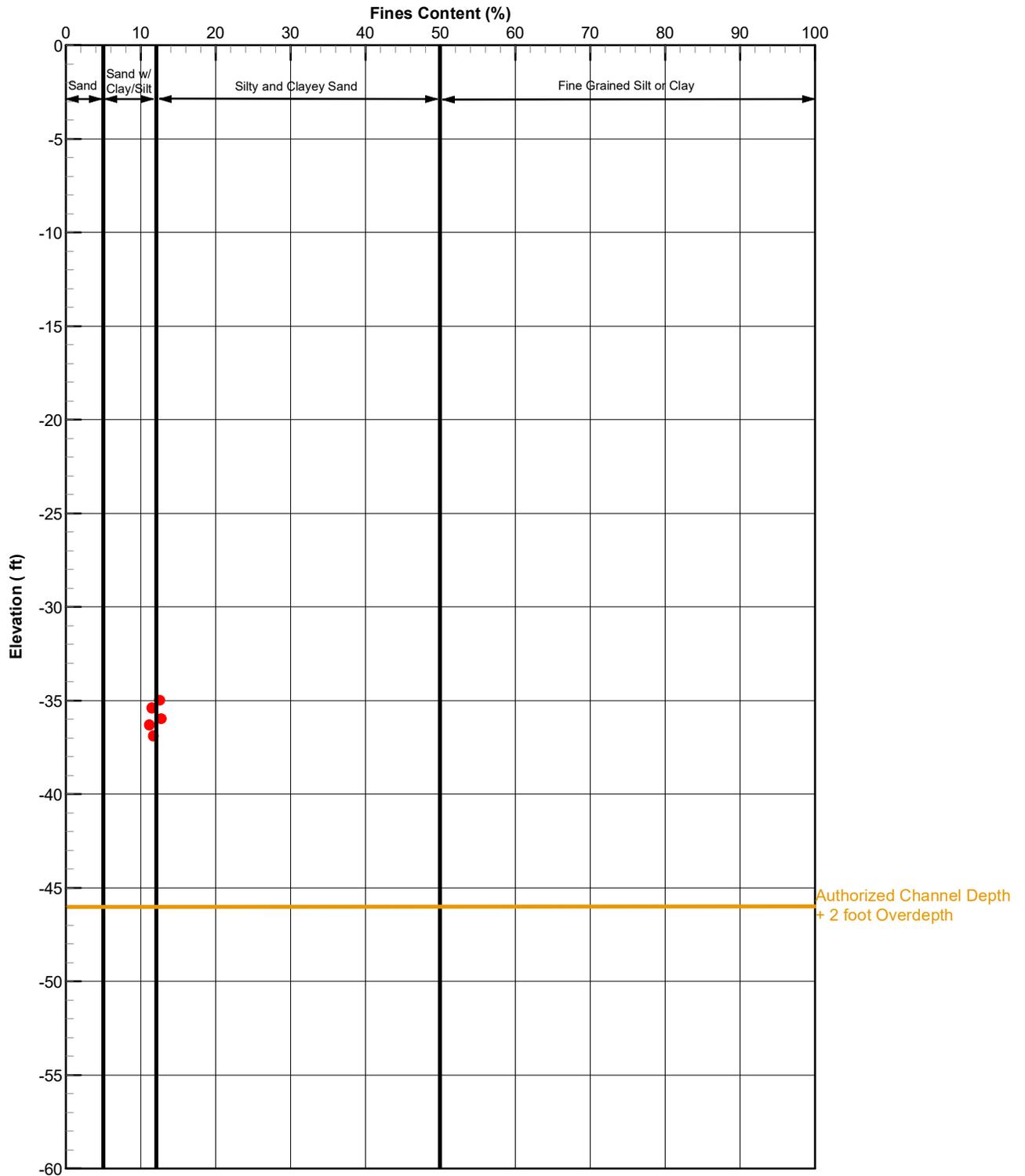
SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT



FINES CONTENT
Baldhead Shoal
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-19

SUPERSEDED BY FIGURES 4-1 through 4-6
IN THE FEBRUARY 25, 2019 REPORT

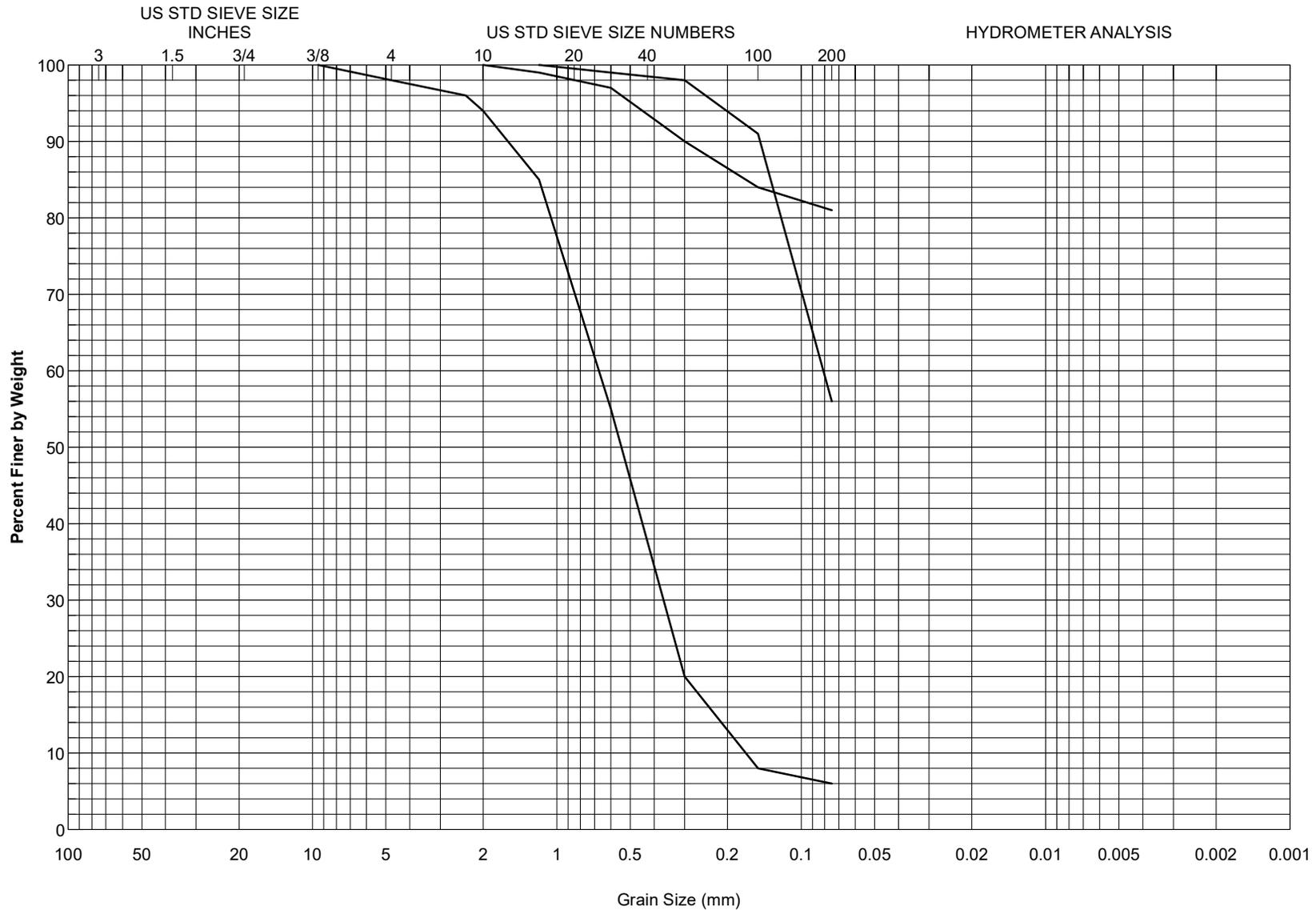


FINES CONTENT
Outer Channel Approach
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 4-20

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY	
Coarse	Fine	Coarse	Medium	Fine		



GRAIN SIZE CURVES

Lower Brunswick

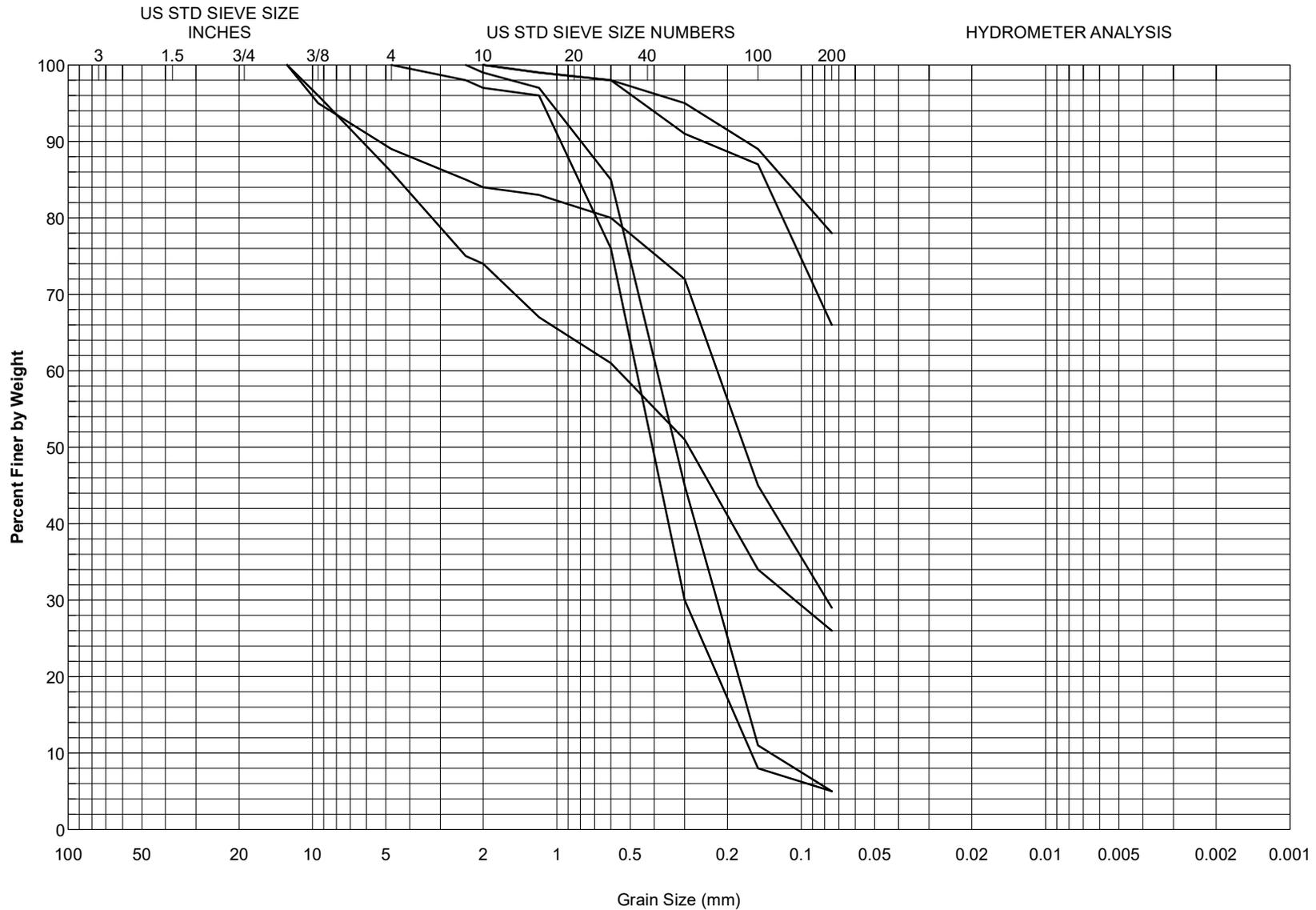
Wilmington Harbor Deepening Survey

Wilmington, North Carolina

FIGURE 5-1

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY	
Coarse	Fine	Coarse	Medium	Fine		



GRAIN SIZE CURVES

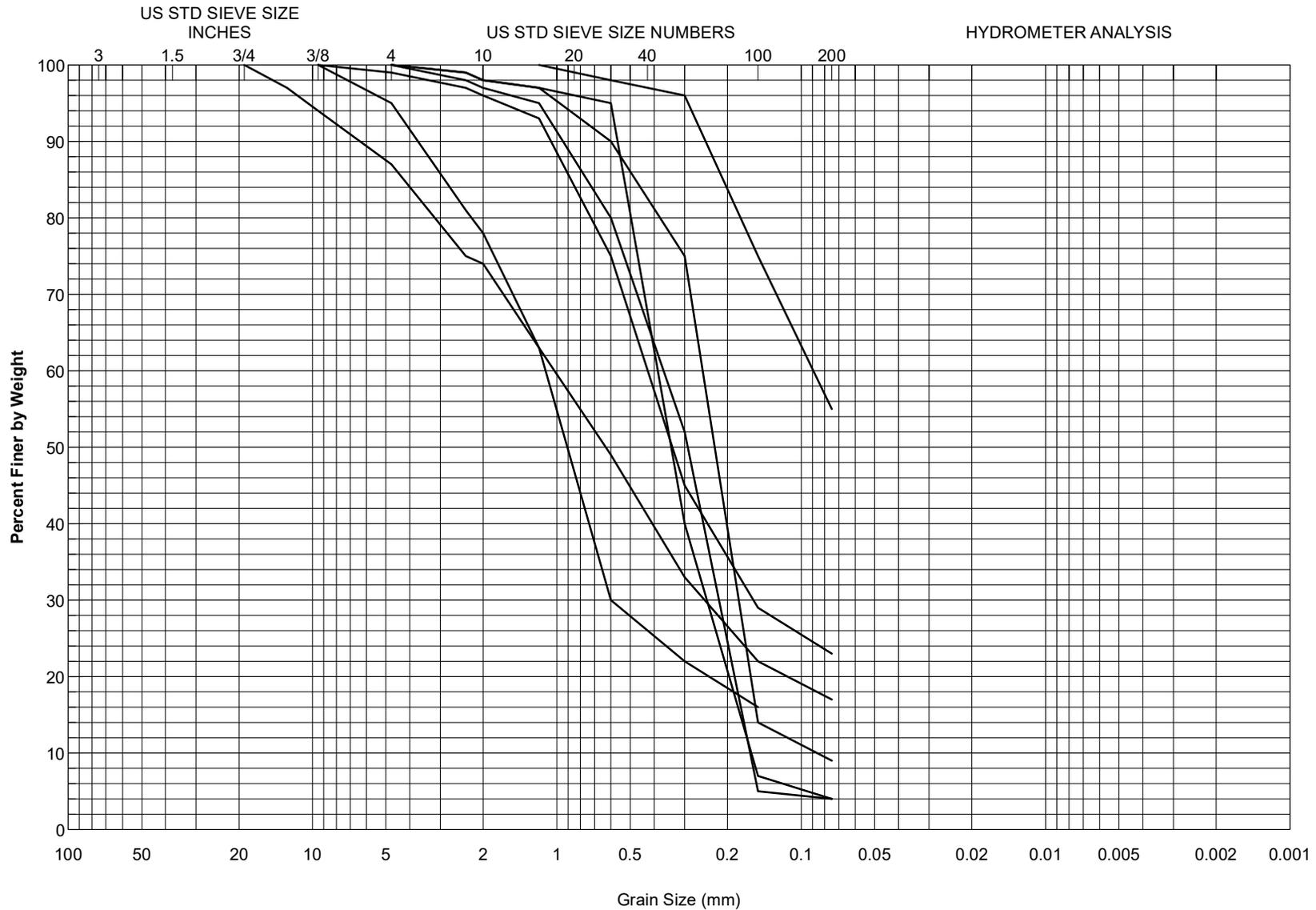
Keg Island

Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 5-2

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



GRAIN SIZE CURVES

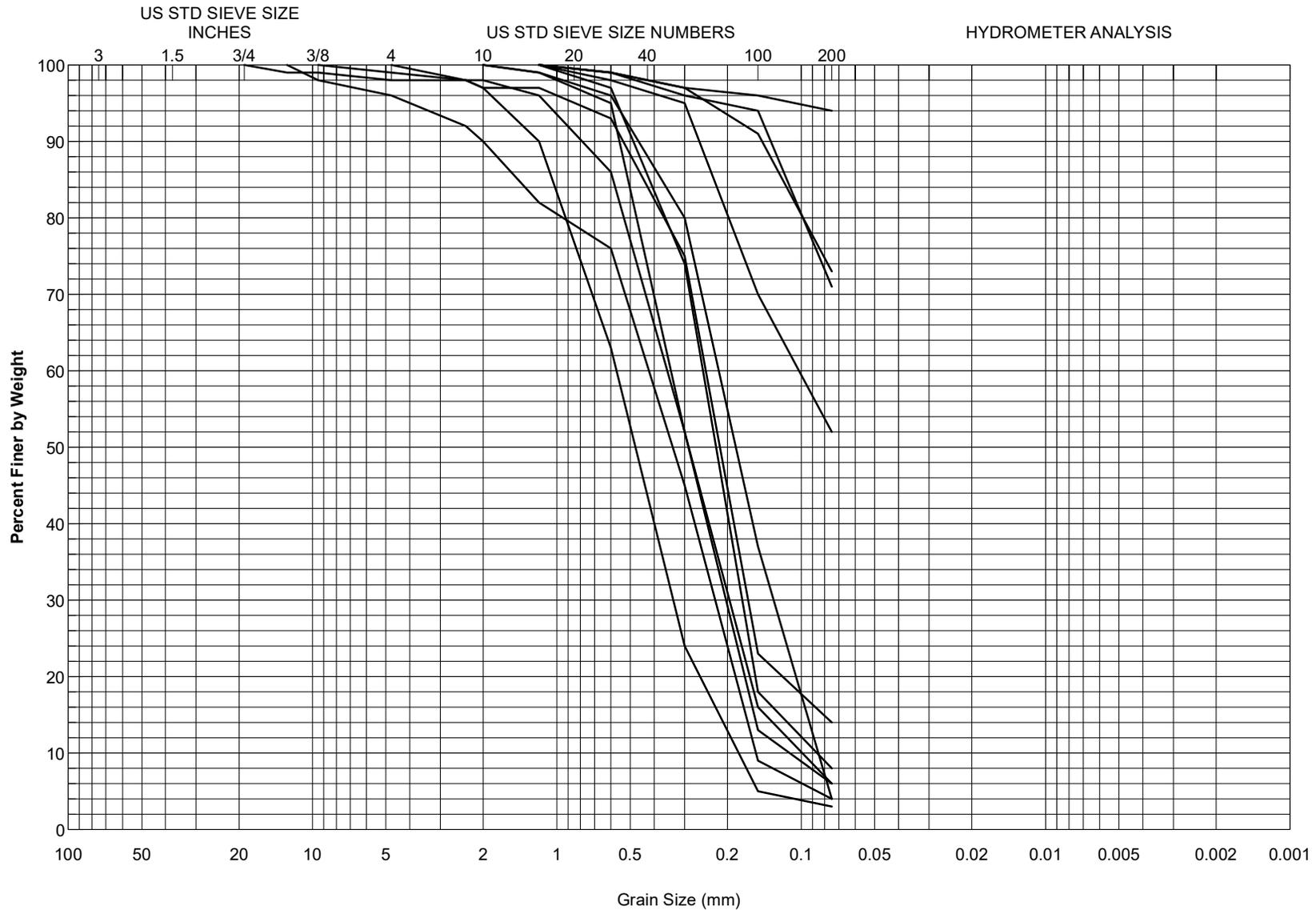
Upper Lilliput

Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 5-3

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY				
Coarse	Fine	Coarse	Medium	Fine					



GRAIN SIZE CURVES

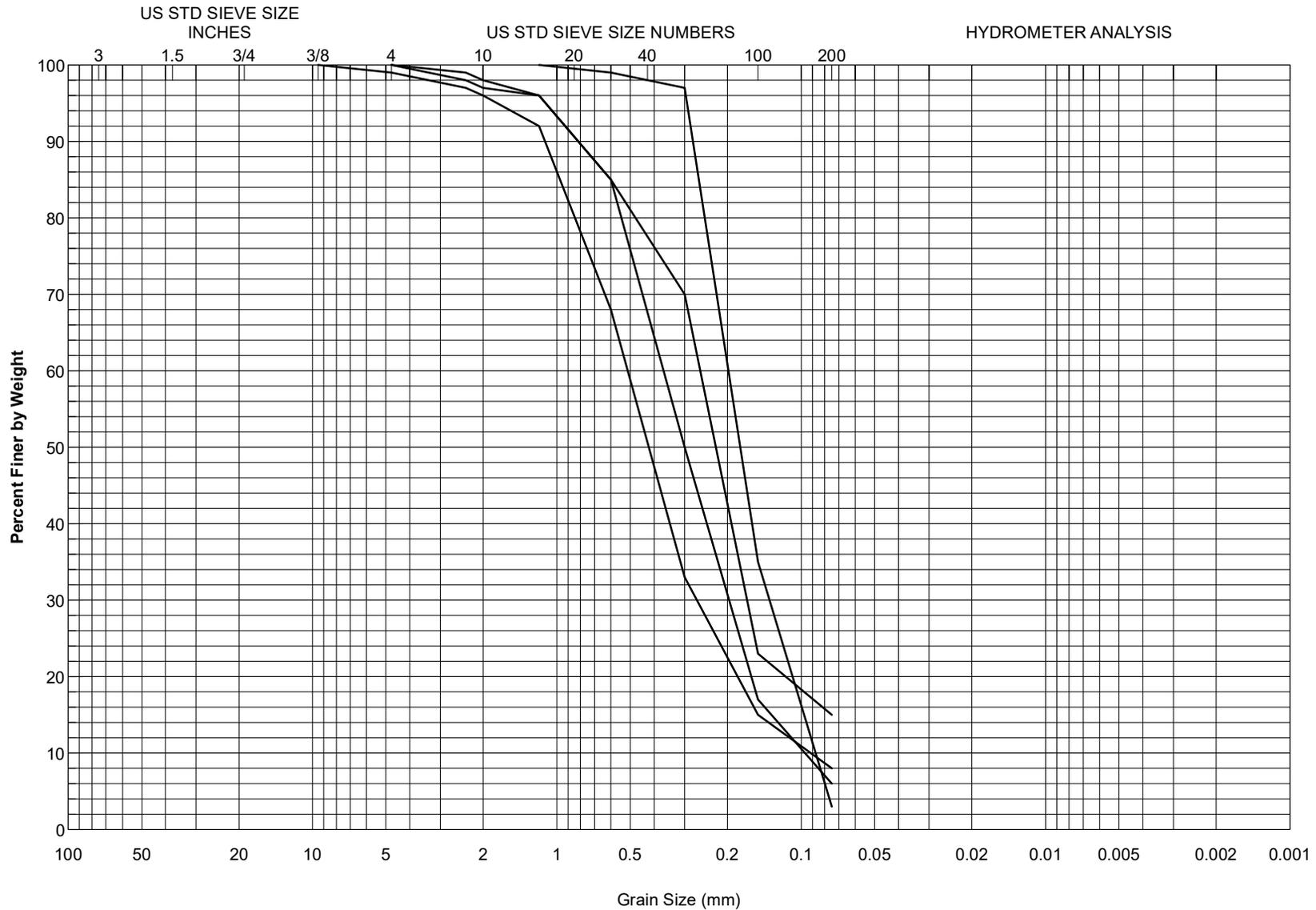
Lower Lilliput

Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 5-4

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY	
Coarse	Fine	Coarse	Medium	Fine		



GRAIN SIZE CURVES

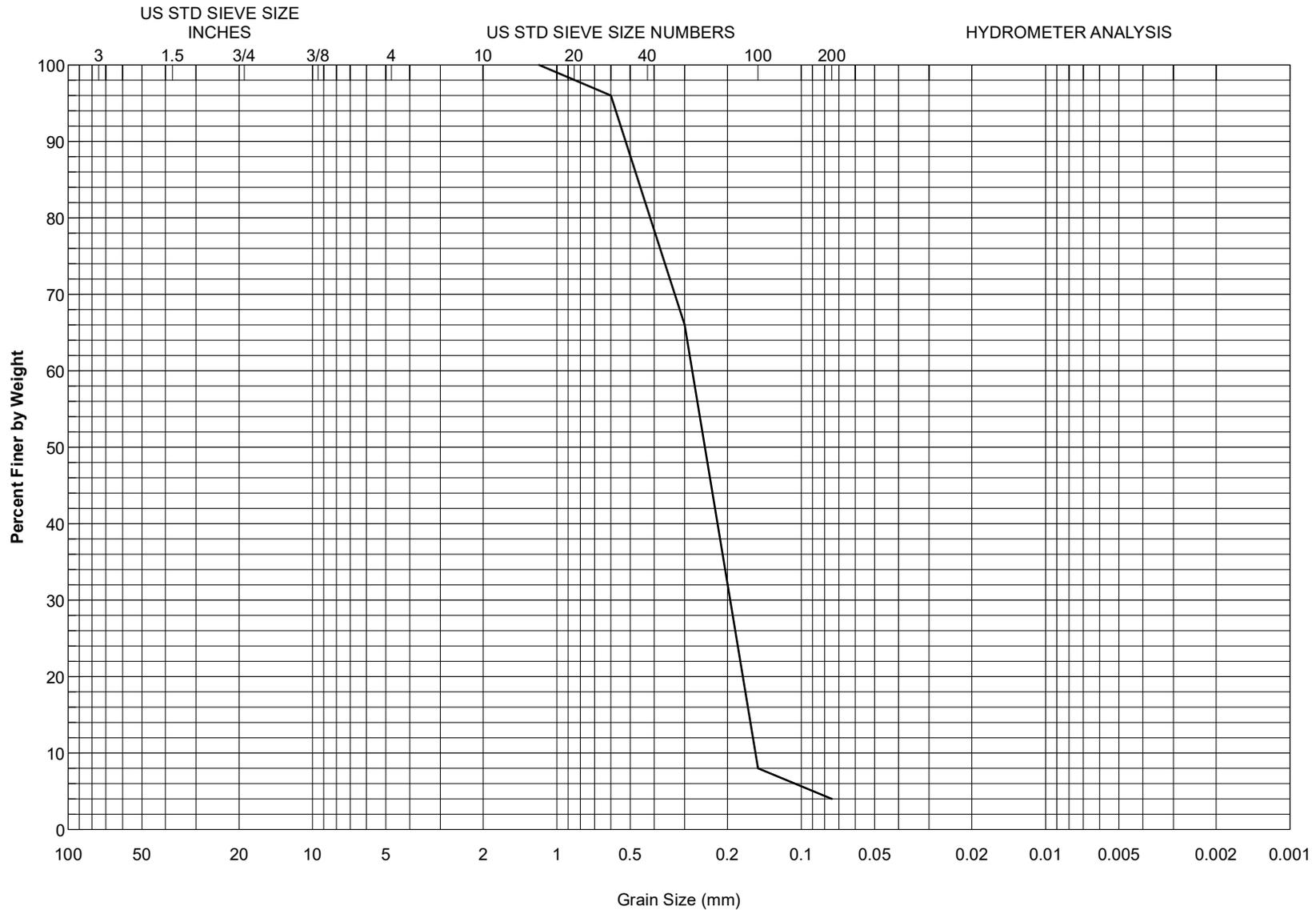
Lower Midnight

Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 5-5

SUPERSEDED BY FIGURES 5-1 through 5-17 IN THE FEBRUARY 25, 2019 REPORT

GRAVEL		SAND			SILT OR CLAY				
Coarse	Fine	Coarse	Medium	Fine					



GRAIN SIZE CURVES

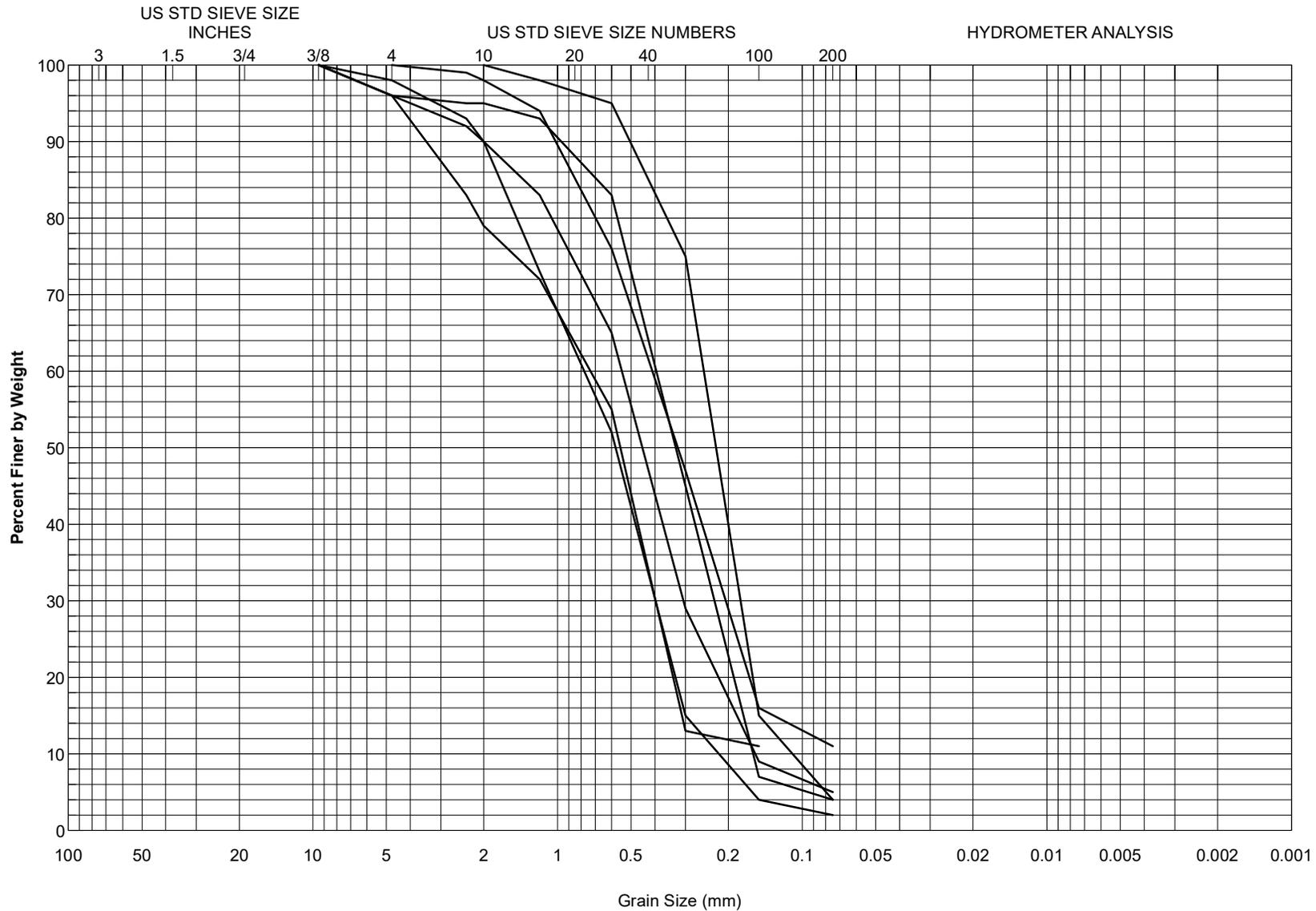
Reaves Point

Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 5-6

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	

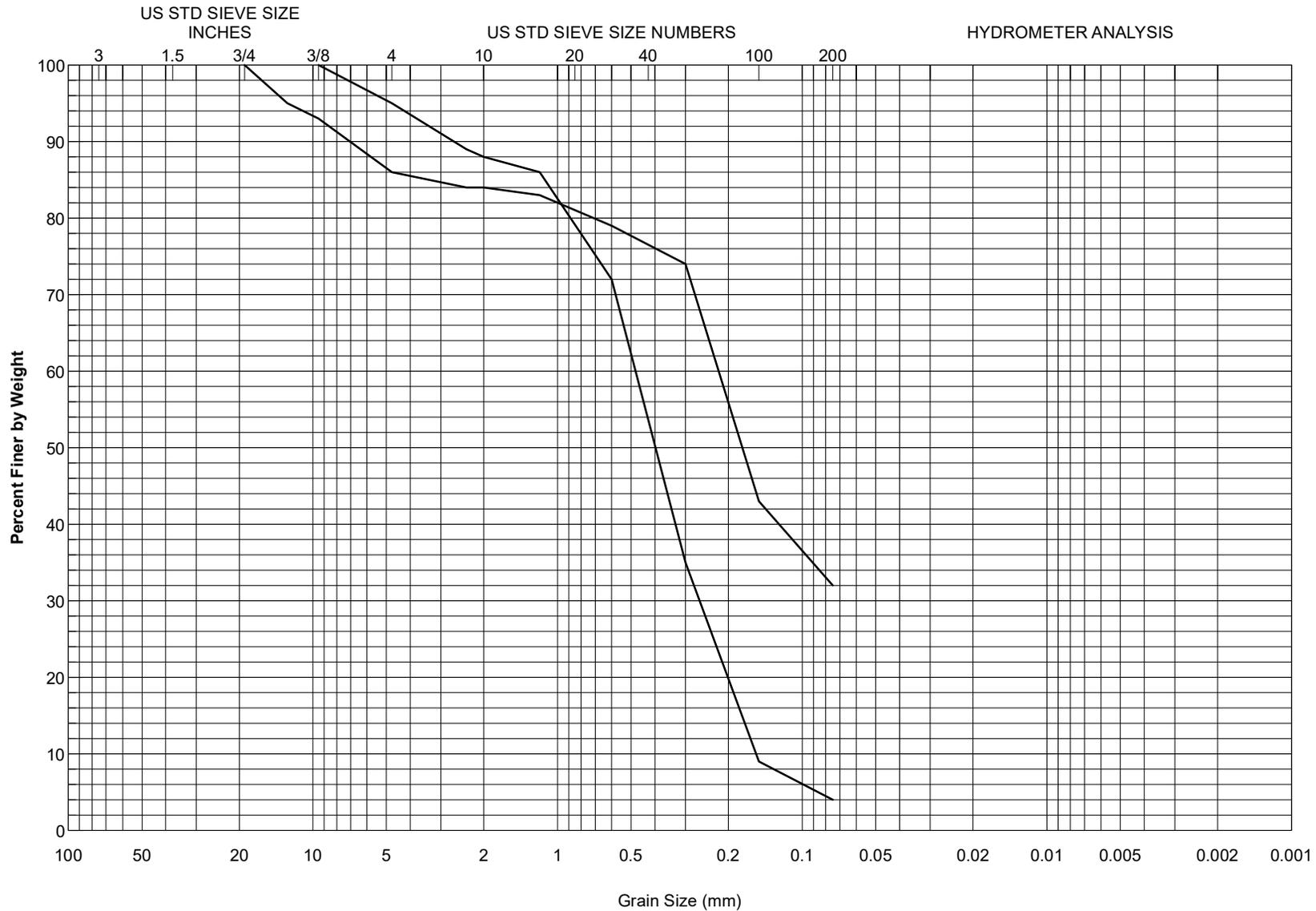


GRAIN SIZE CURVES
Horseshoe Shoal
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 5-7

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY				
Coarse	Fine	Coarse	Medium	Fine					

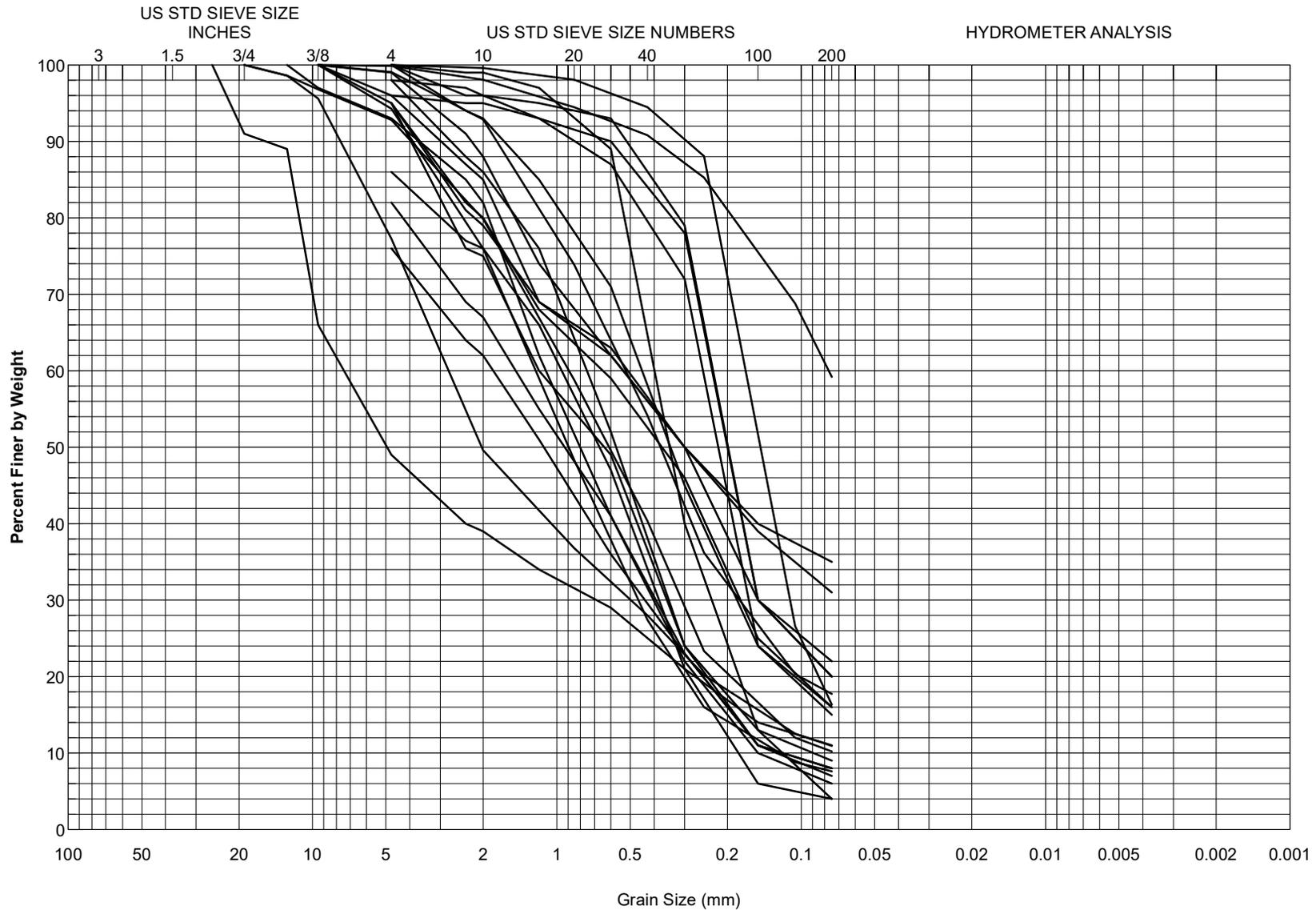


GRAIN SIZE CURVES
 Snows Marsh
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 5-8

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY	
Coarse	Fine	Coarse	Medium	Fine		



GRAIN SIZE CURVES

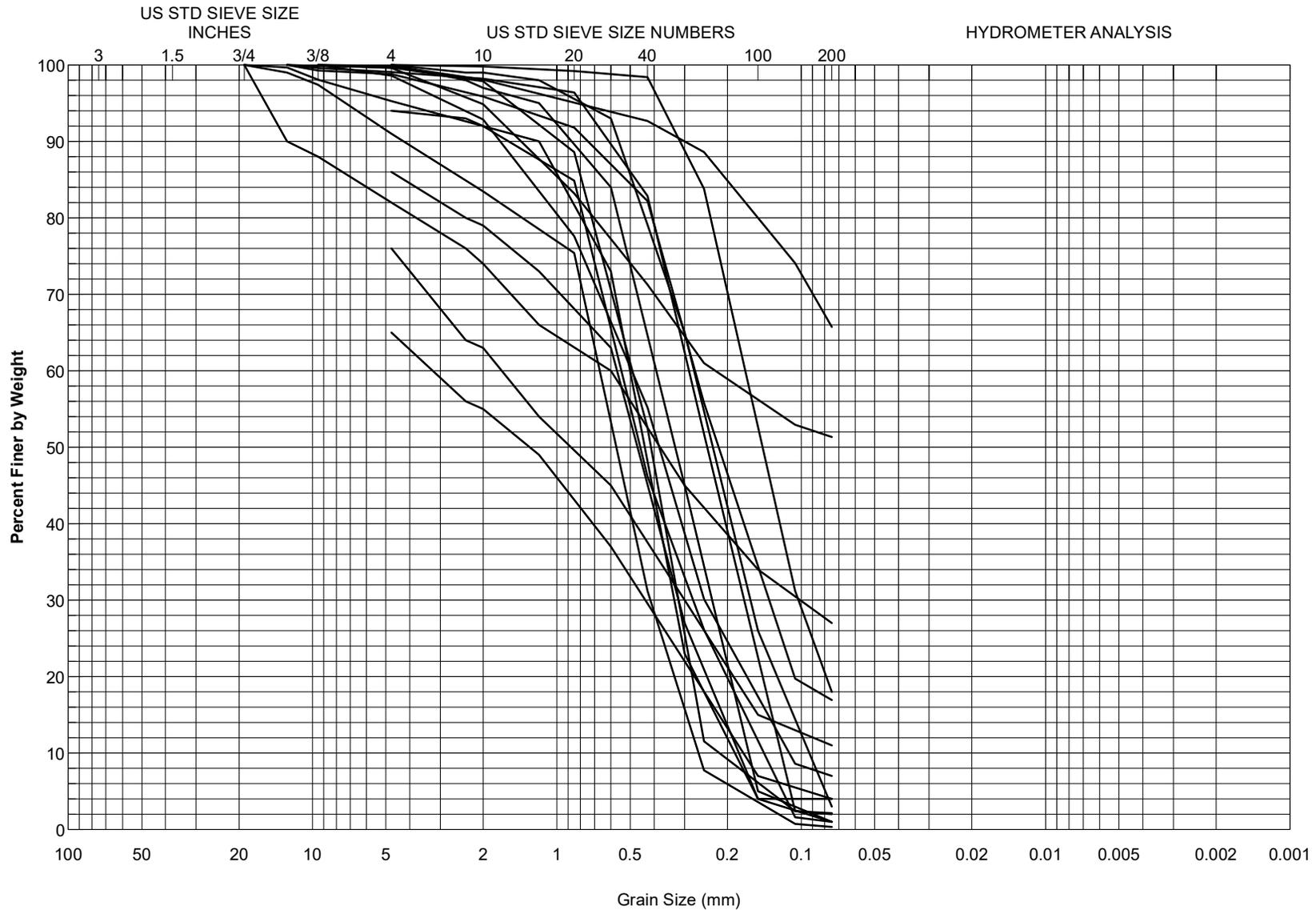
Lower Swash

Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 5-9

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



GRAIN SIZE CURVES

Battery Island

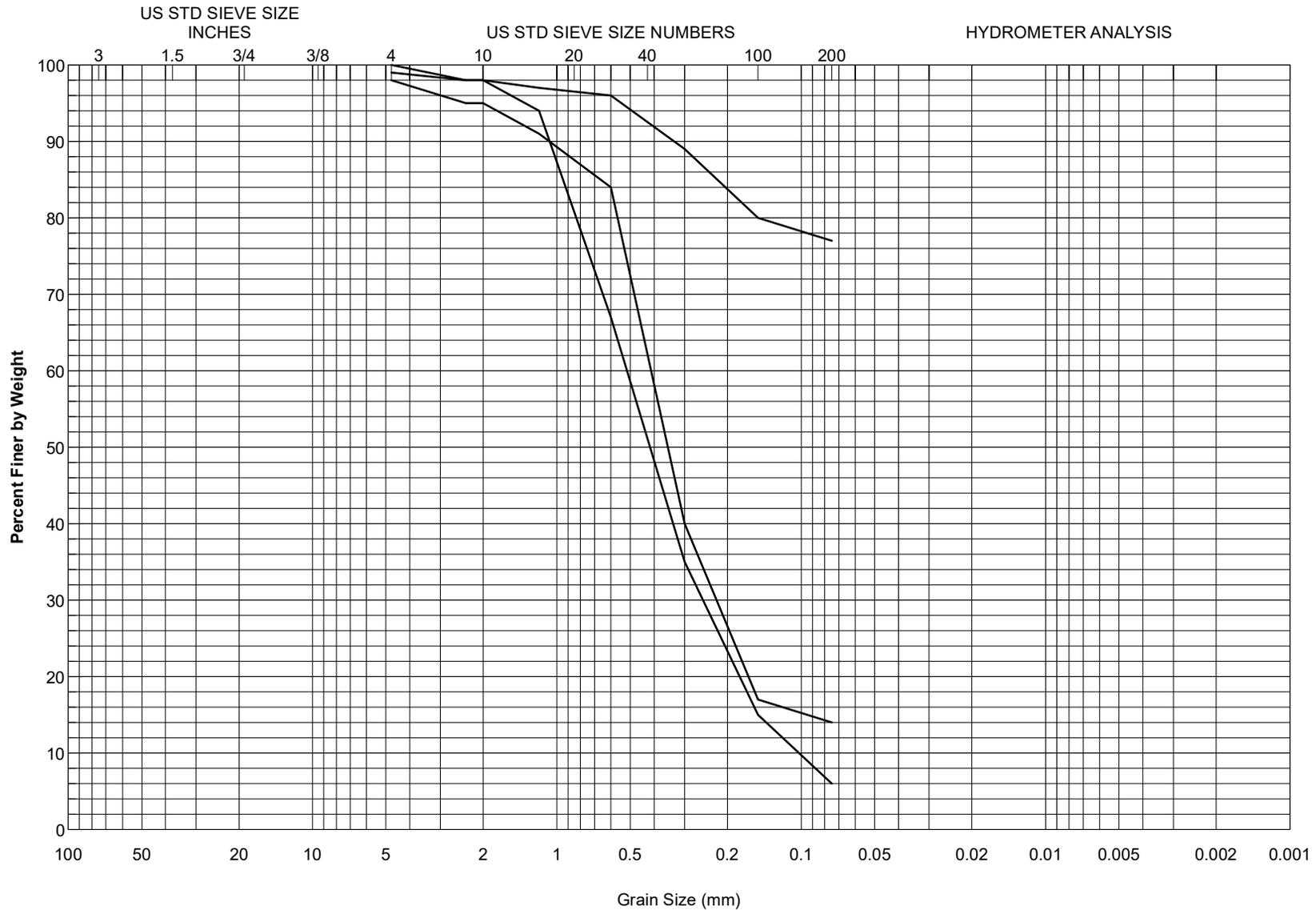
Wilmington Harbor Deepening Survey

Wilmington, North Carolina

FIGURE 5-10

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY				
Coarse	Fine	Coarse	Medium	Fine					



GRAIN SIZE CURVES
Baldhead Shoal
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 5-11

SUPERSEDED BY FIGURES 5-1 through 5-17 IN THE FEBRUARY 25, 2019 REPORT

GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	

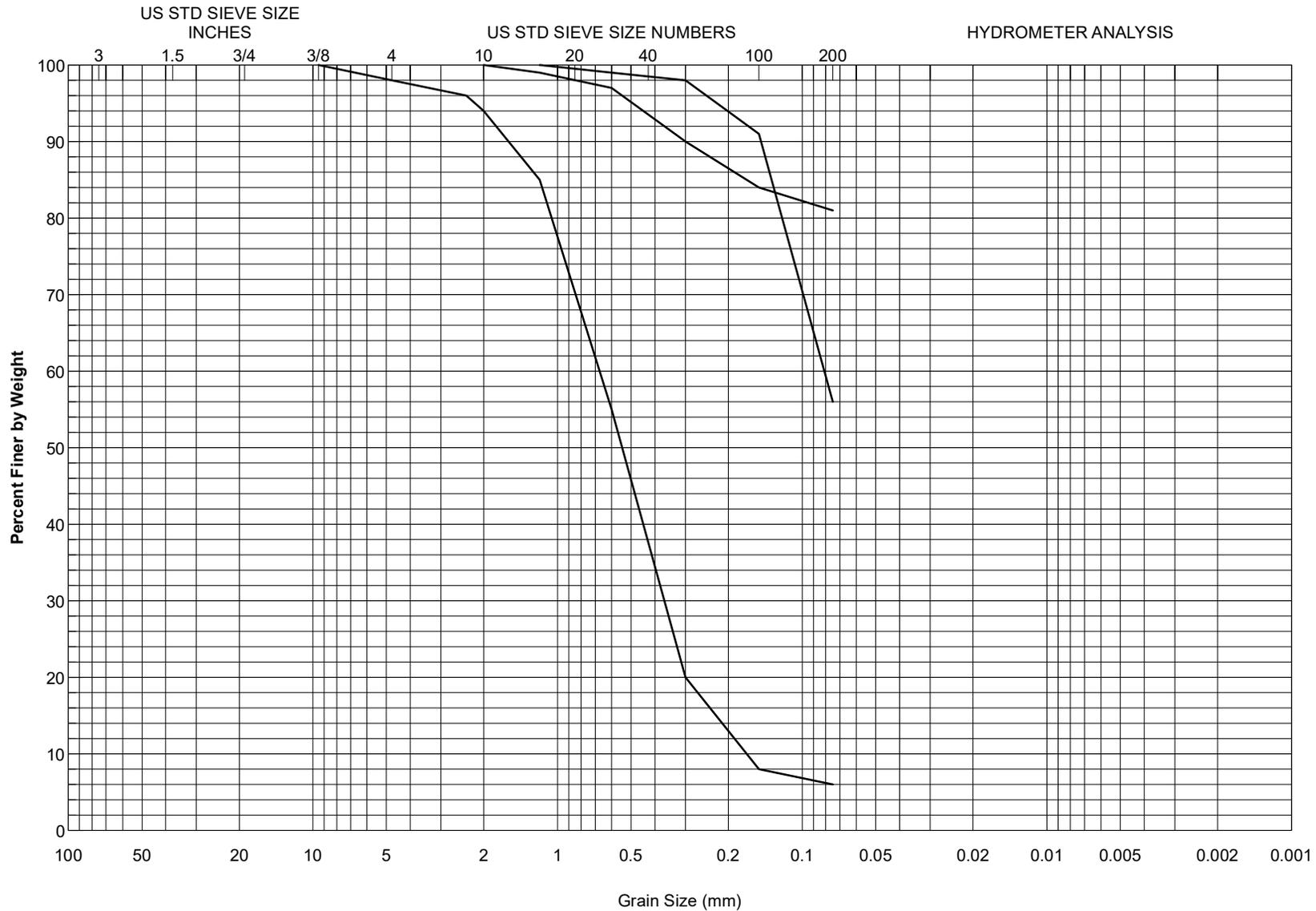
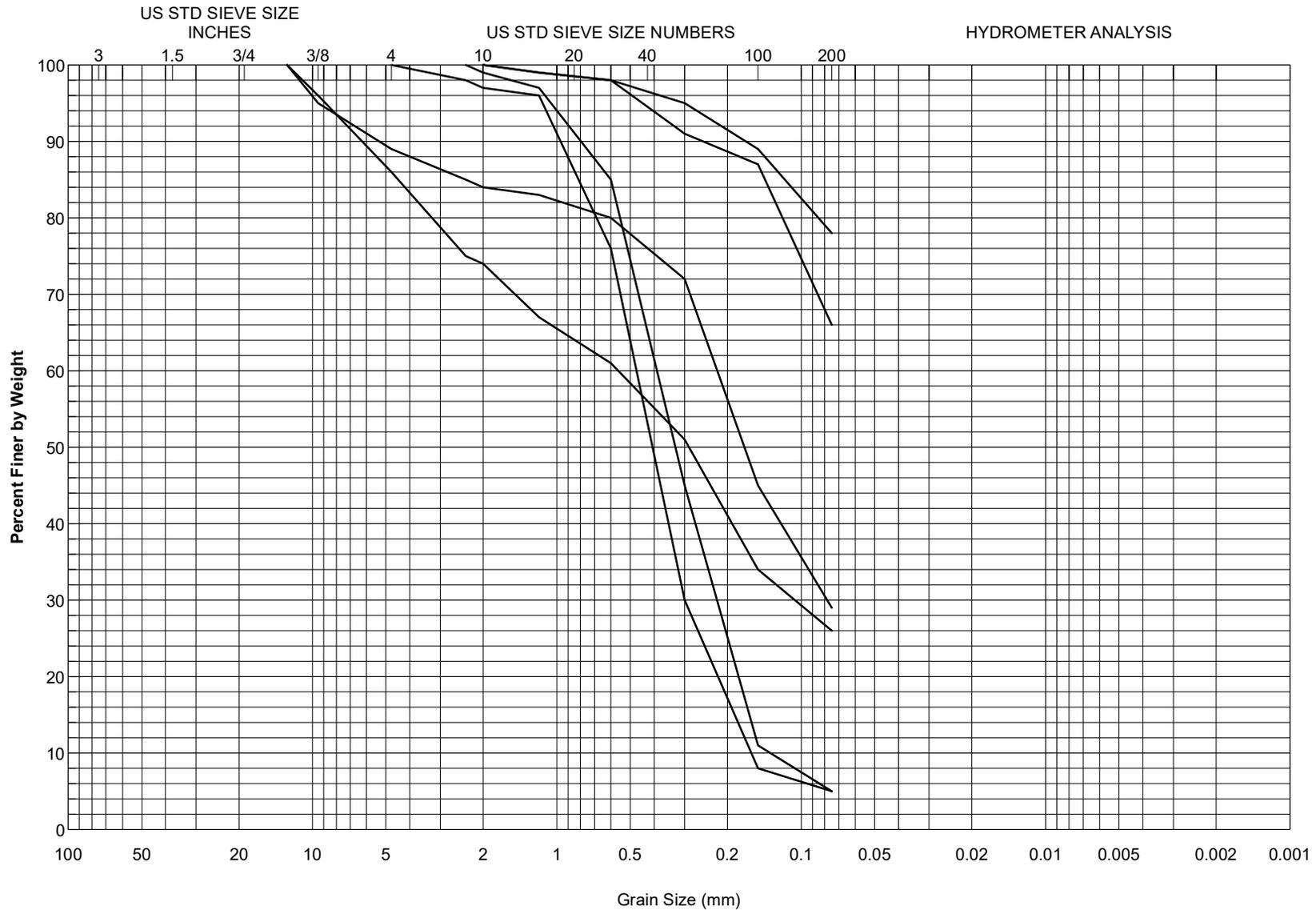


FIGURE 5-1

GRAIN SIZE CURVES
Lower Brunswick
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY	
Coarse	Fine	Coarse	Medium	Fine		



GRAIN SIZE CURVES

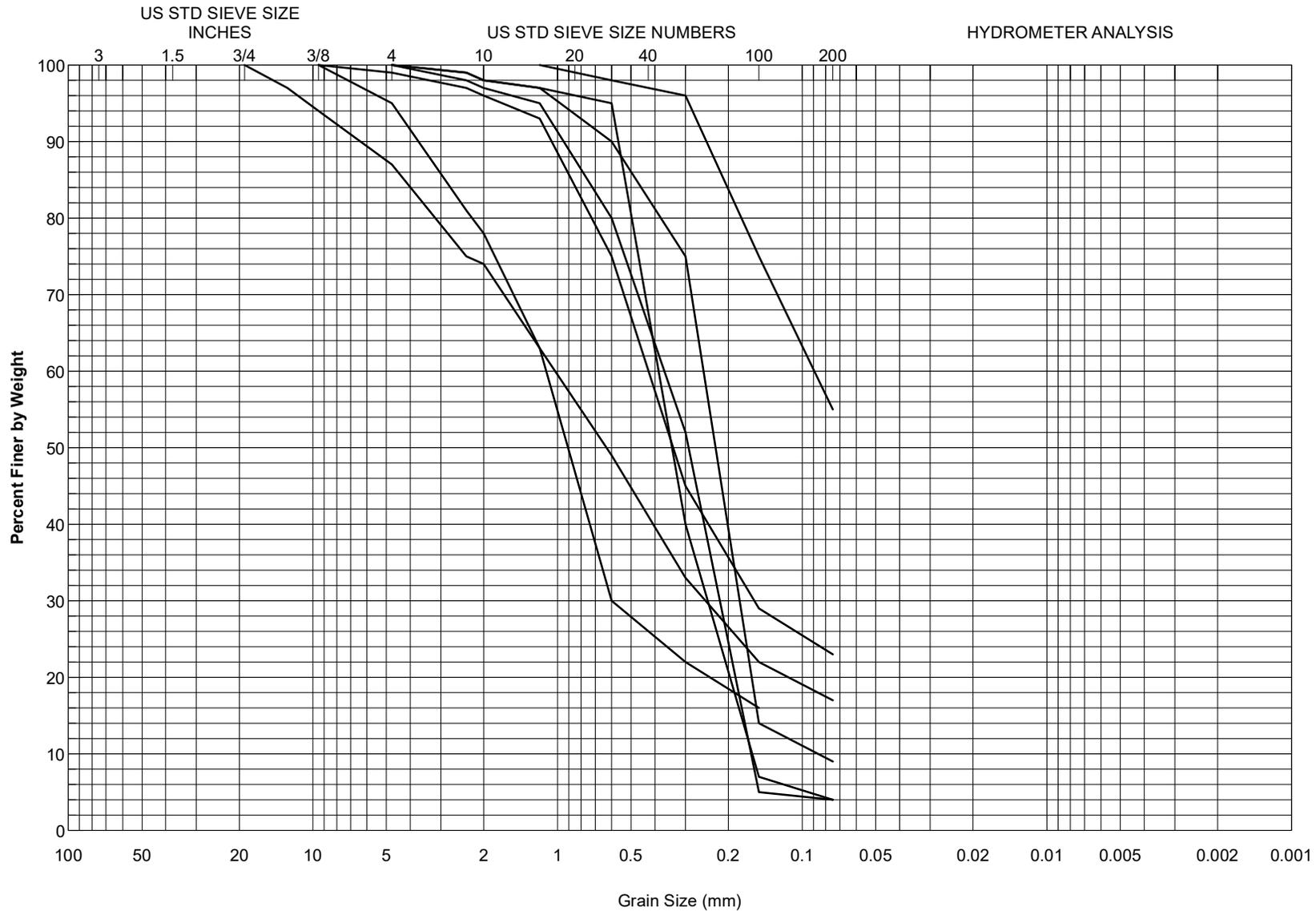
Keg Island

Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 5-2

SUPERSEDED BY FIGURES 5-1 through 5-17 IN THE FEBRUARY 25, 2019 REPORT

GRAVEL		SAND			SILT OR CLAY	
Coarse	Fine	Coarse	Medium	Fine		



GRAIN SIZE CURVES

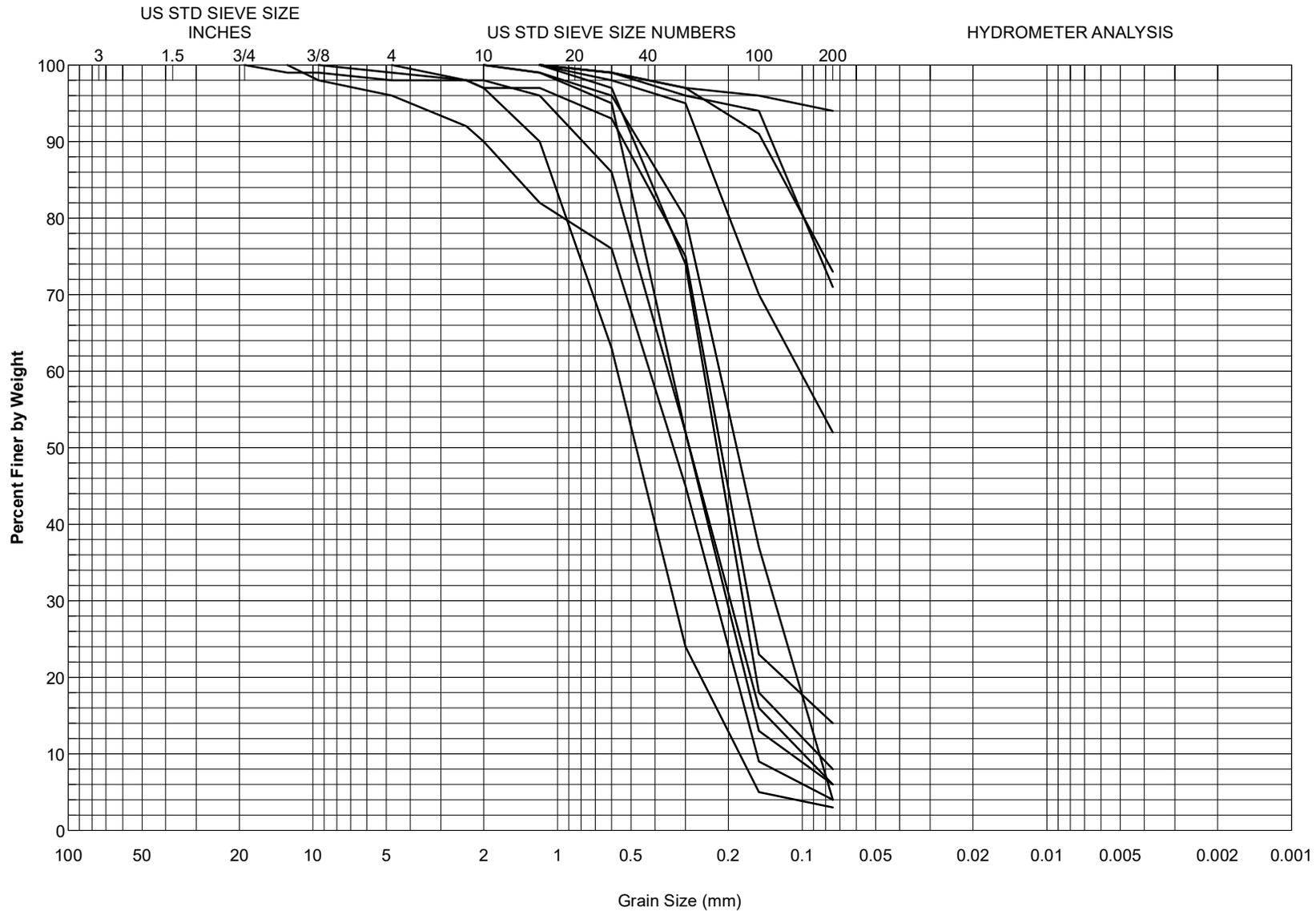
Upper Lilliput

Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 5-3

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



GRAIN SIZE CURVES

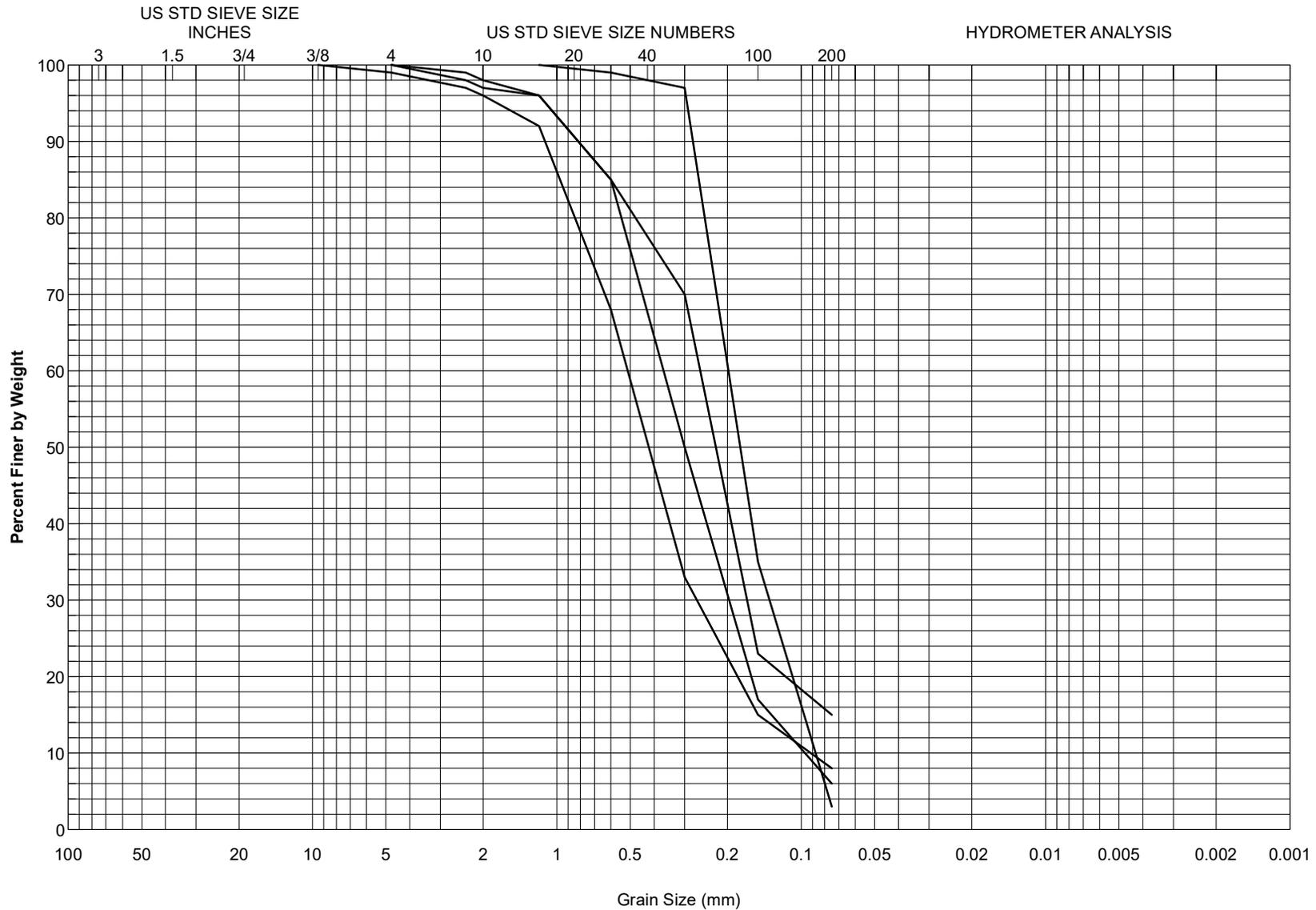
Lower Lilliput

Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 5-4

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY	
Coarse	Fine	Coarse	Medium	Fine		

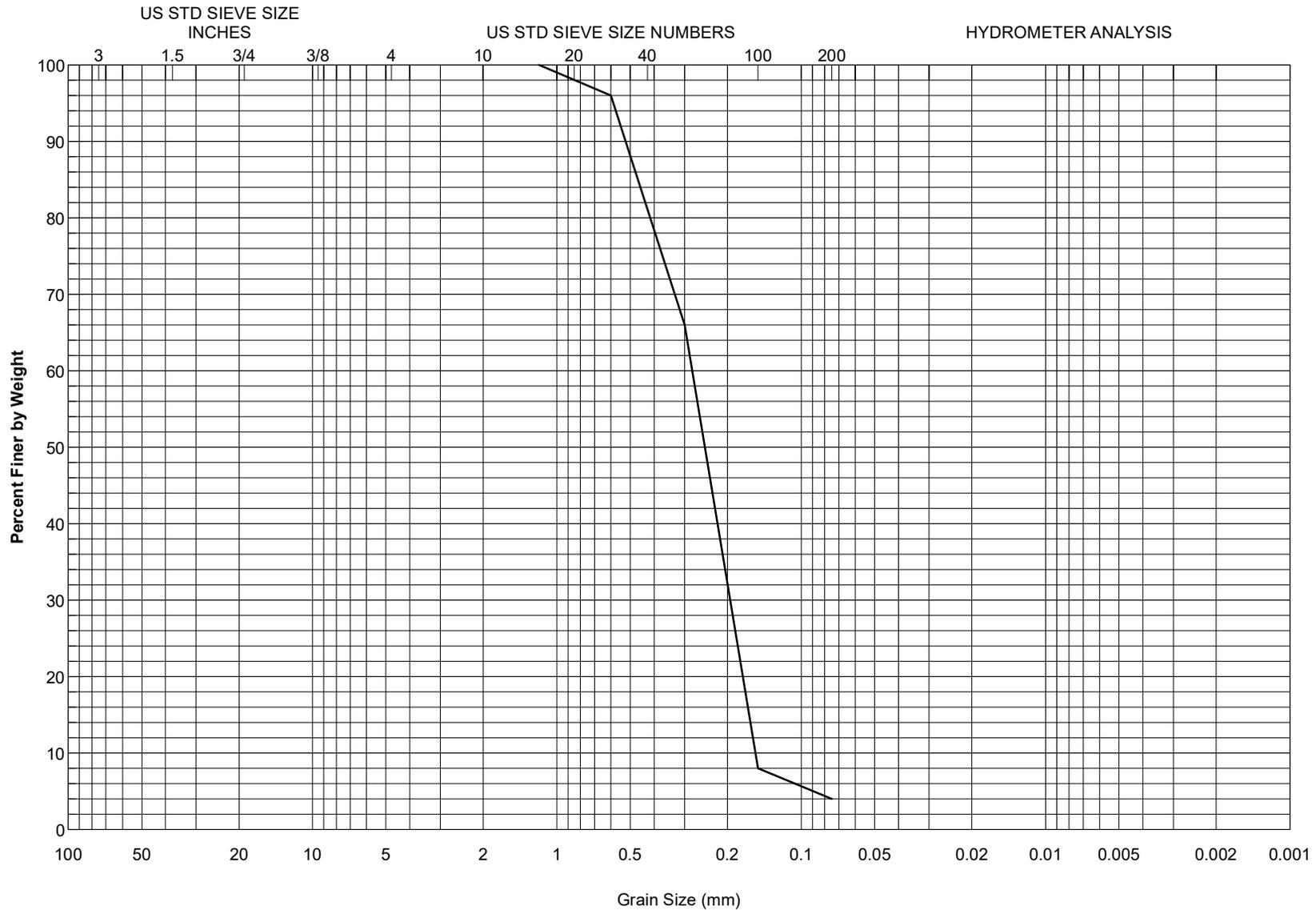


GRAIN SIZE CURVES
Lower Midnight
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 5-5

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY				
Coarse	Fine	Coarse	Medium	Fine					



GRAIN SIZE CURVES

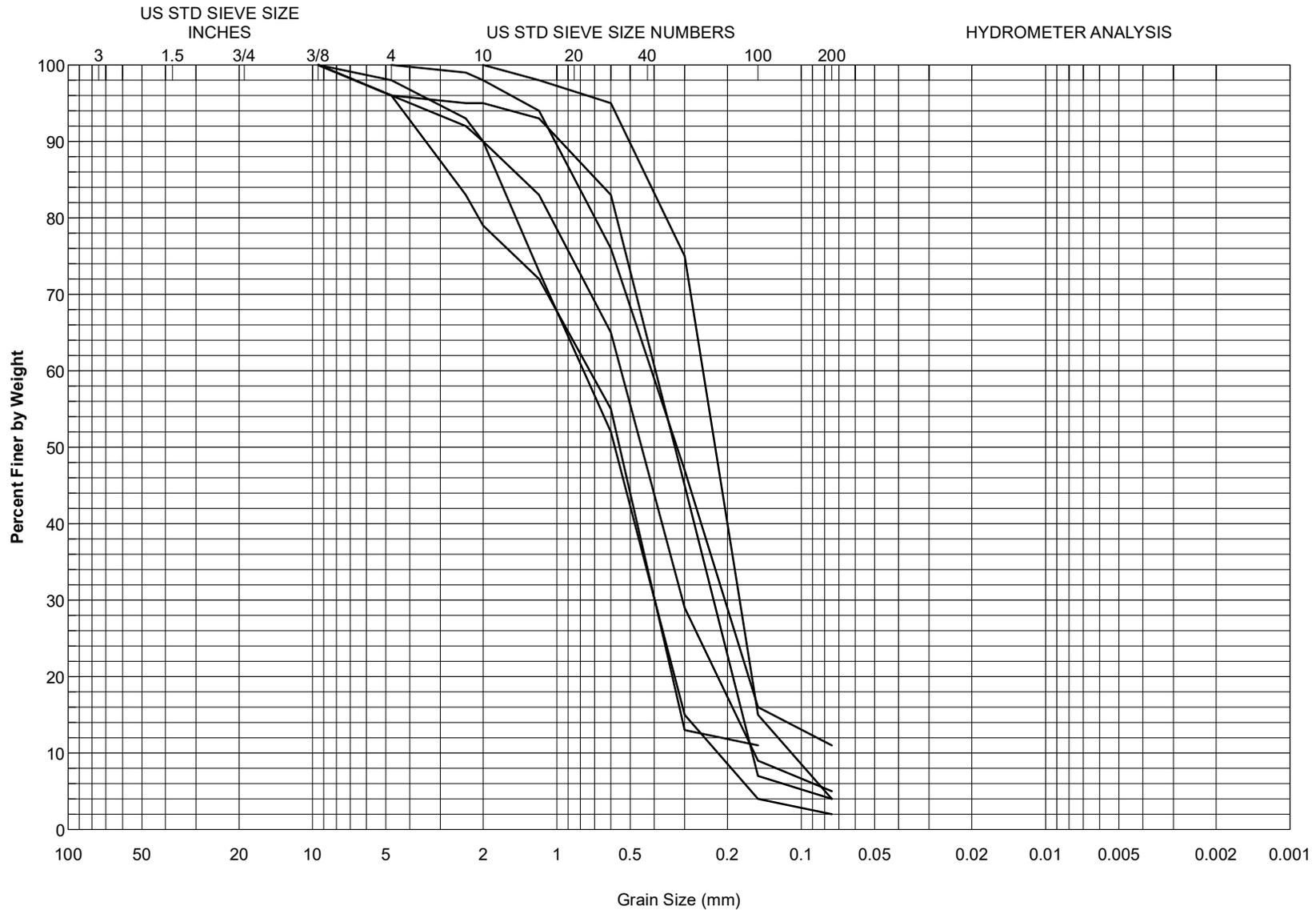
Reaves Point

Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 5-6

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY	
Coarse	Fine	Coarse	Medium	Fine		



GRAIN SIZE CURVES

Horseshoe Shoal

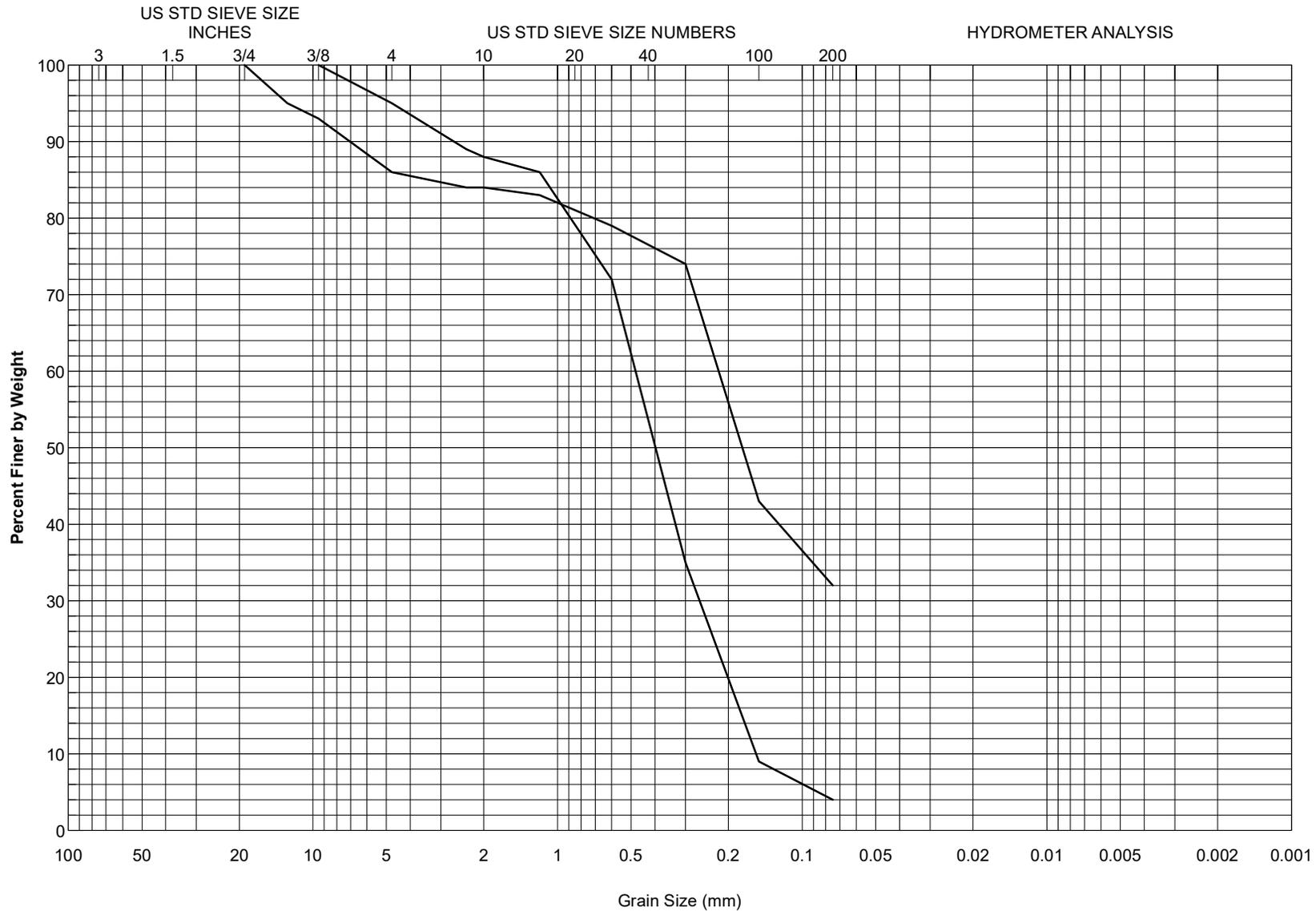
Wilmington Harbor Deepening Survey

Wilmington, North Carolina

FIGURE 5-7

SUPERSEDED BY FIGURES 5-1 through 5-17 IN THE FEBRUARY 25, 2019 REPORT

GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	

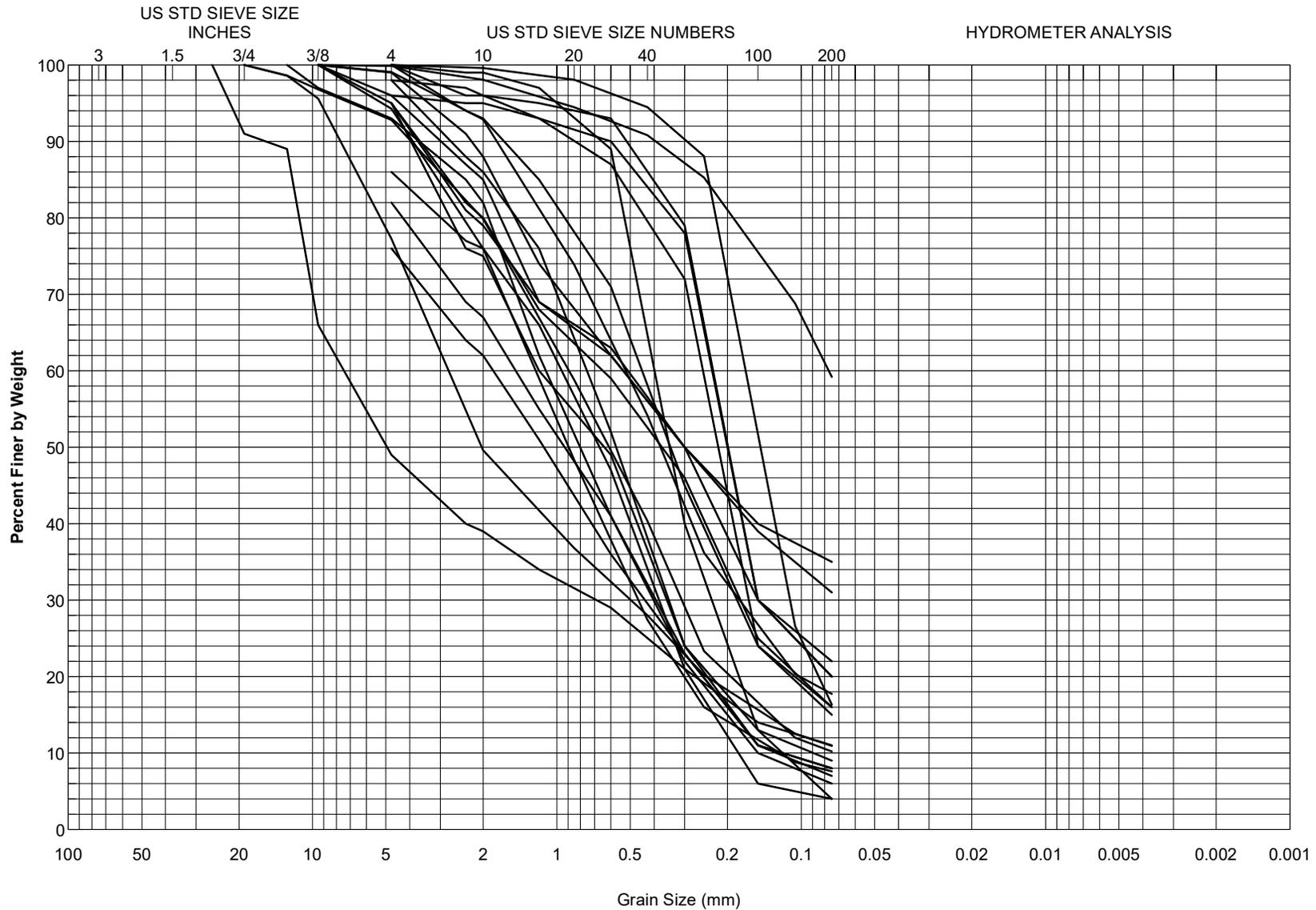


GRAIN SIZE CURVES
 Snows Marsh
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 5-8

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY	
Coarse	Fine	Coarse	Medium	Fine		



GRAIN SIZE CURVES

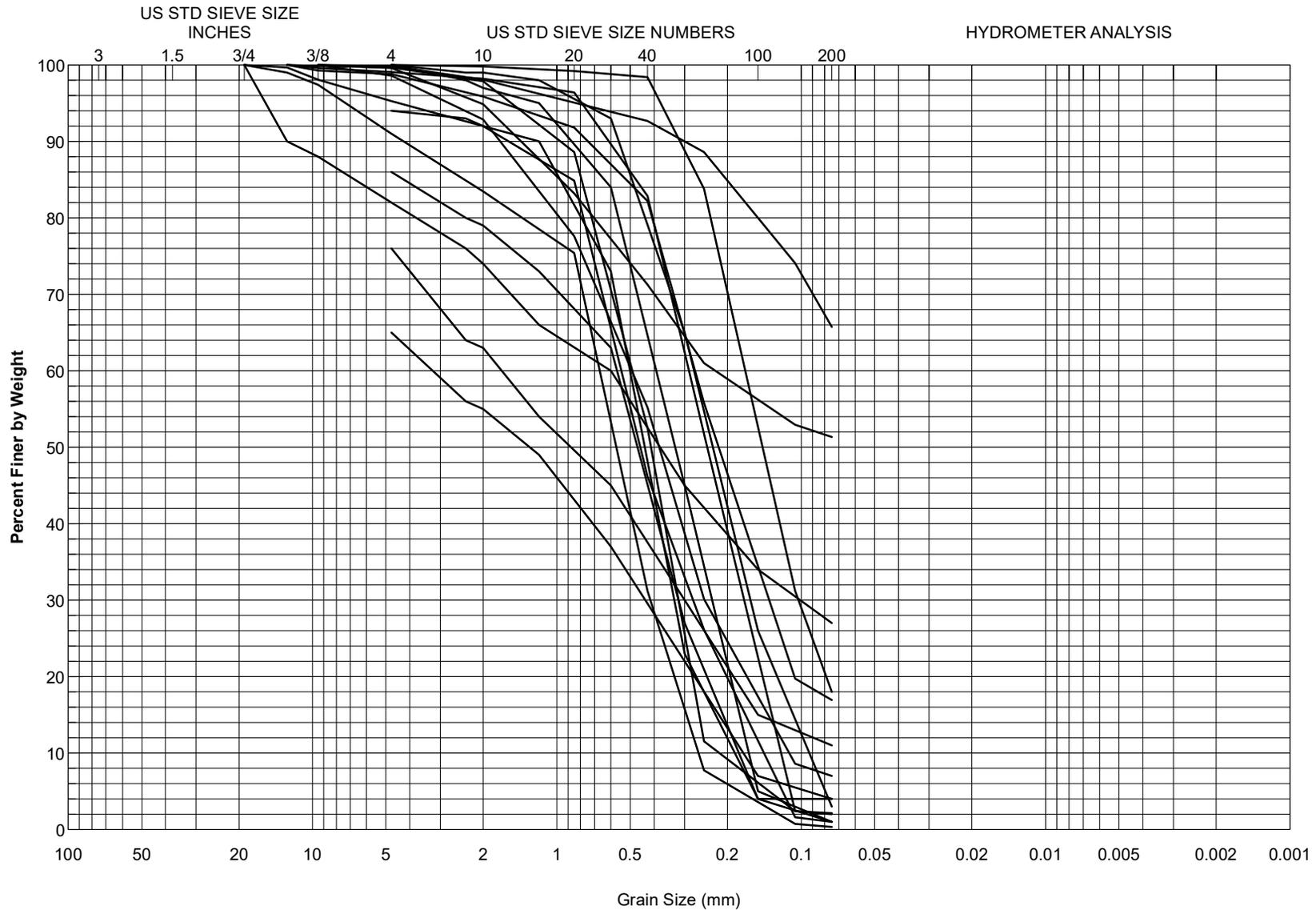
Lower Swash

Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 5-9

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



GRAIN SIZE CURVES

Battery Island

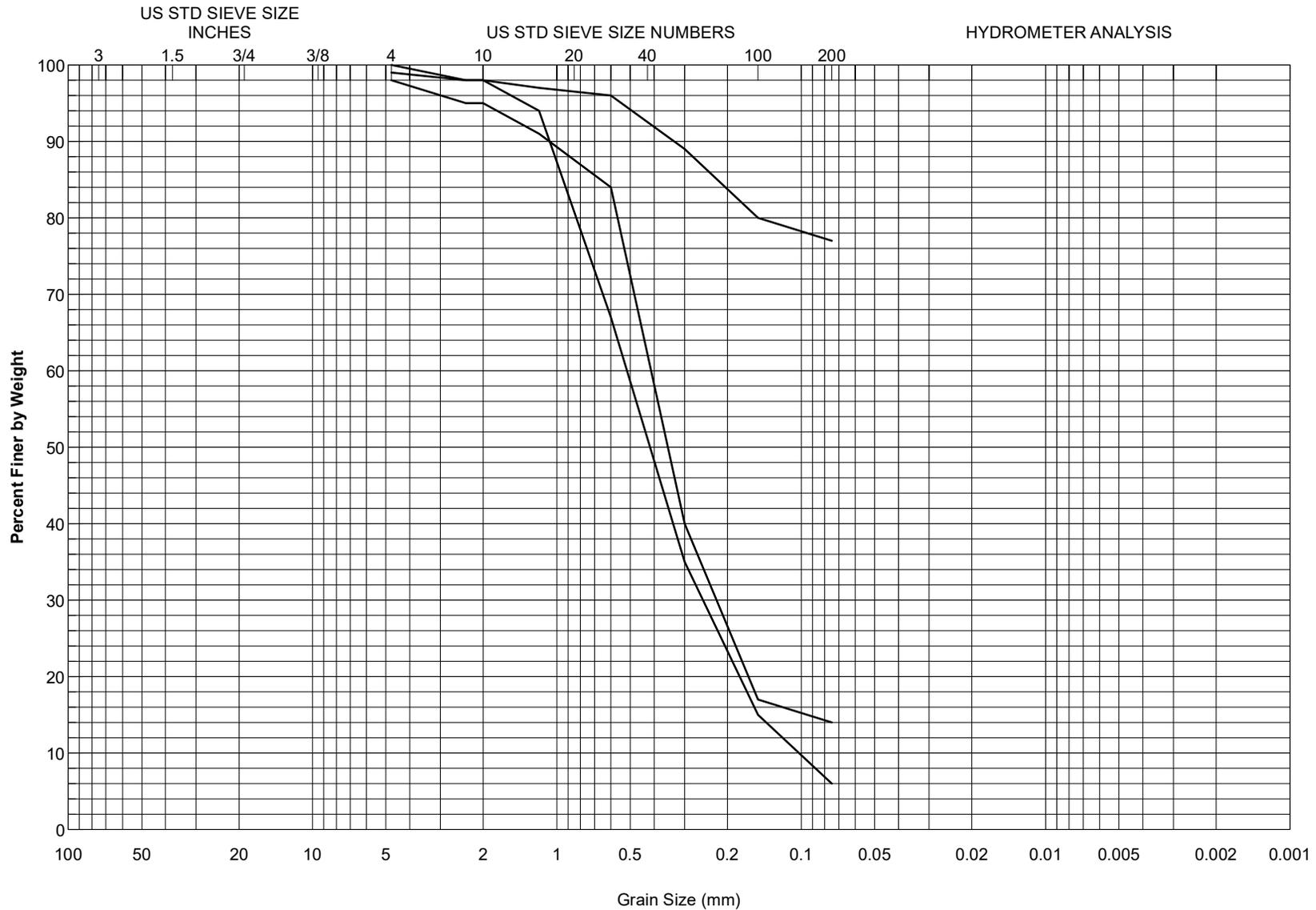
Wilmington Harbor Deepening Survey

Wilmington, North Carolina

FIGURE 5-10

**SUPERSEDED BY FIGURES 5-1 through 5-17
IN THE FEBRUARY 25, 2019 REPORT**

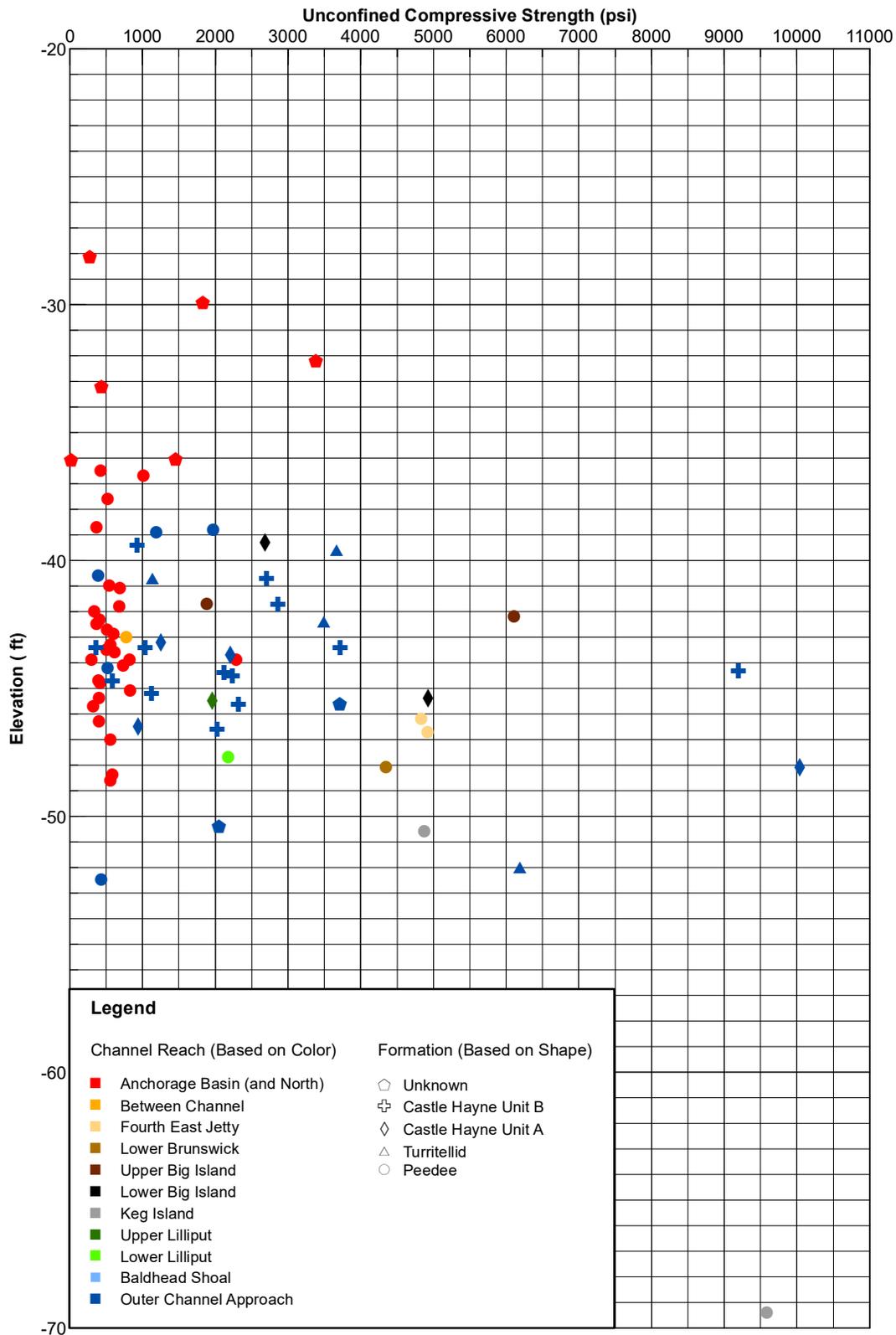
GRAVEL		SAND			SILT OR CLAY				
Coarse	Fine	Coarse	Medium	Fine					



GRAIN SIZE CURVES
Baldhead Shoal
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 5-11

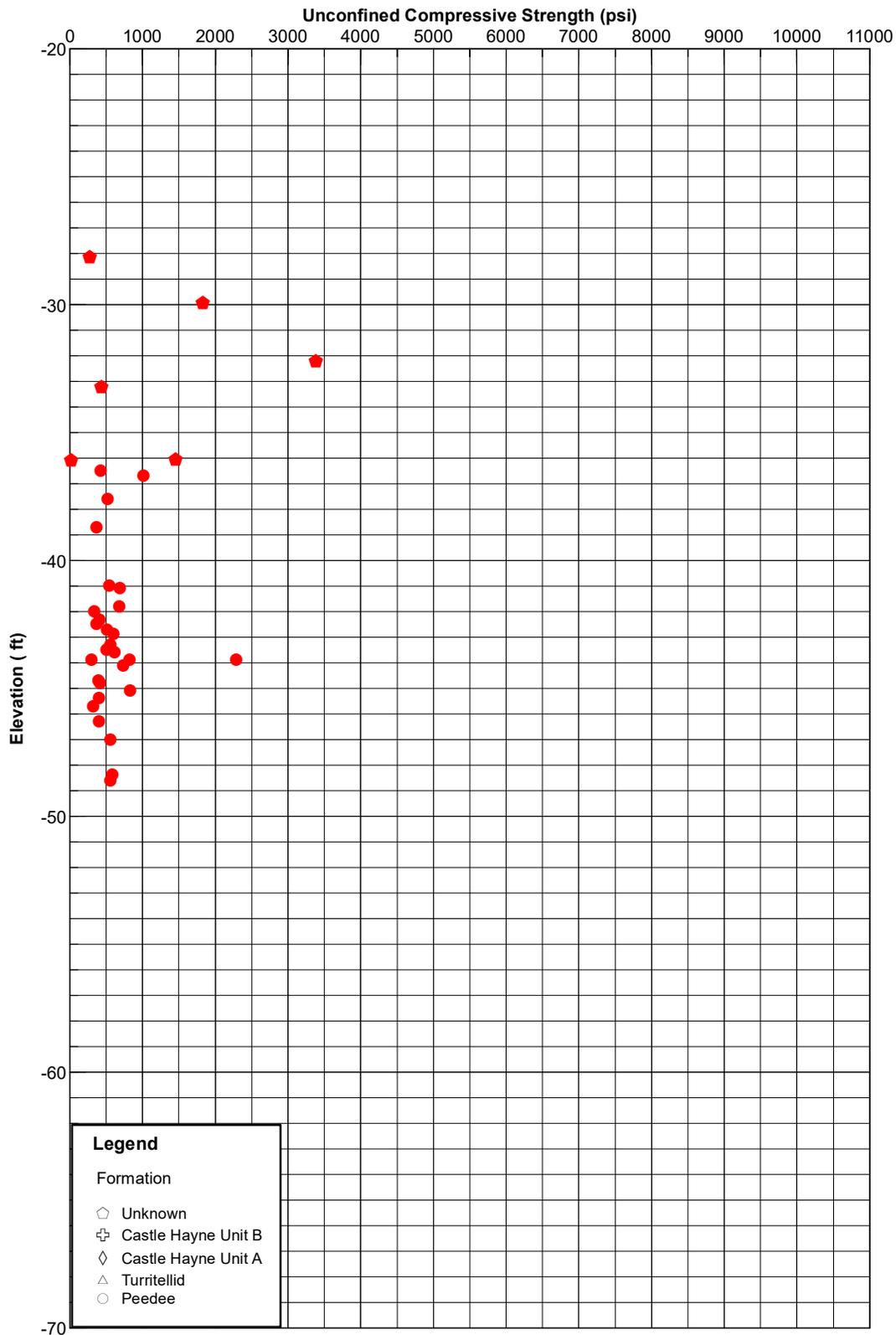
**SUPERSEDED BY FIGURES 6-1 through 6-15
IN THE FEBRUARY 25, 2019 REPORT**



UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION

Wilmington Harbor Deepening Survey
Wilmington North Carolina

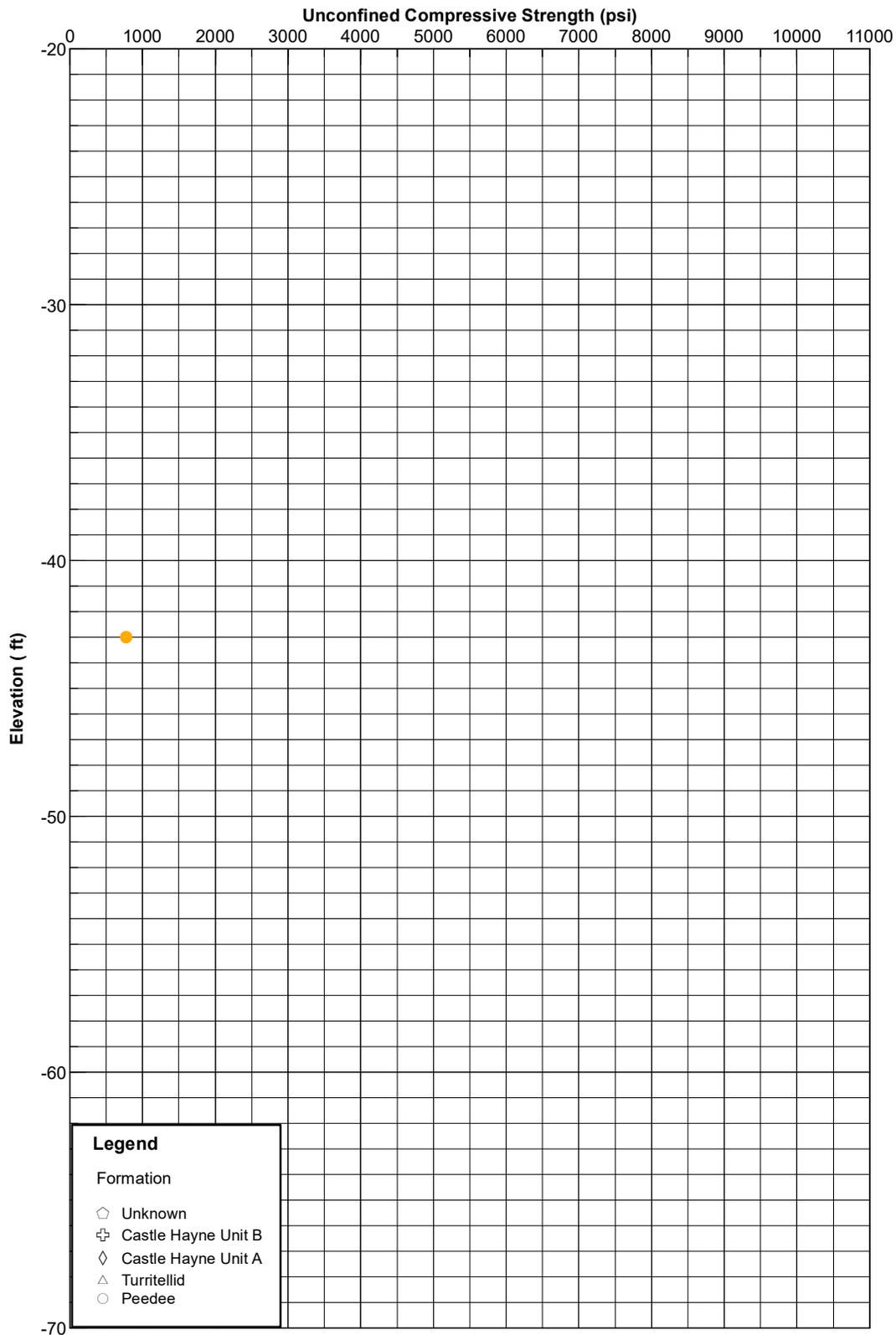
SUPERSEDED BY FIGURES 6-1 through 6-15
IN THE FEBRUARY 25, 2019 REPORT



UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
Anchorage Basin (and North)
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 6-2

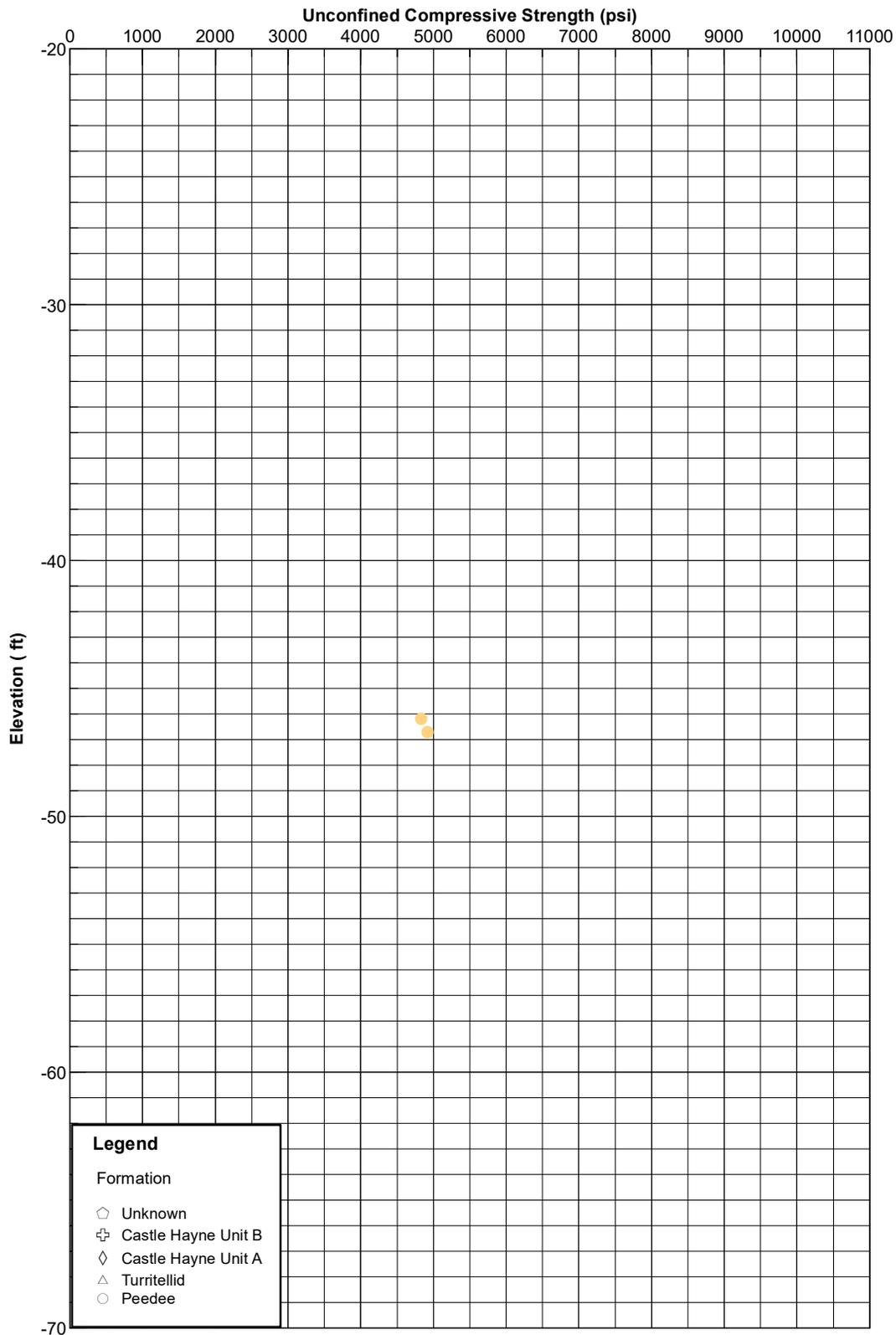
SUPERSEDED BY FIGURES 6-1 through 6-15
IN THE FEBRUARY 25, 2019 REPORT



UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
Between Channel
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 6-3

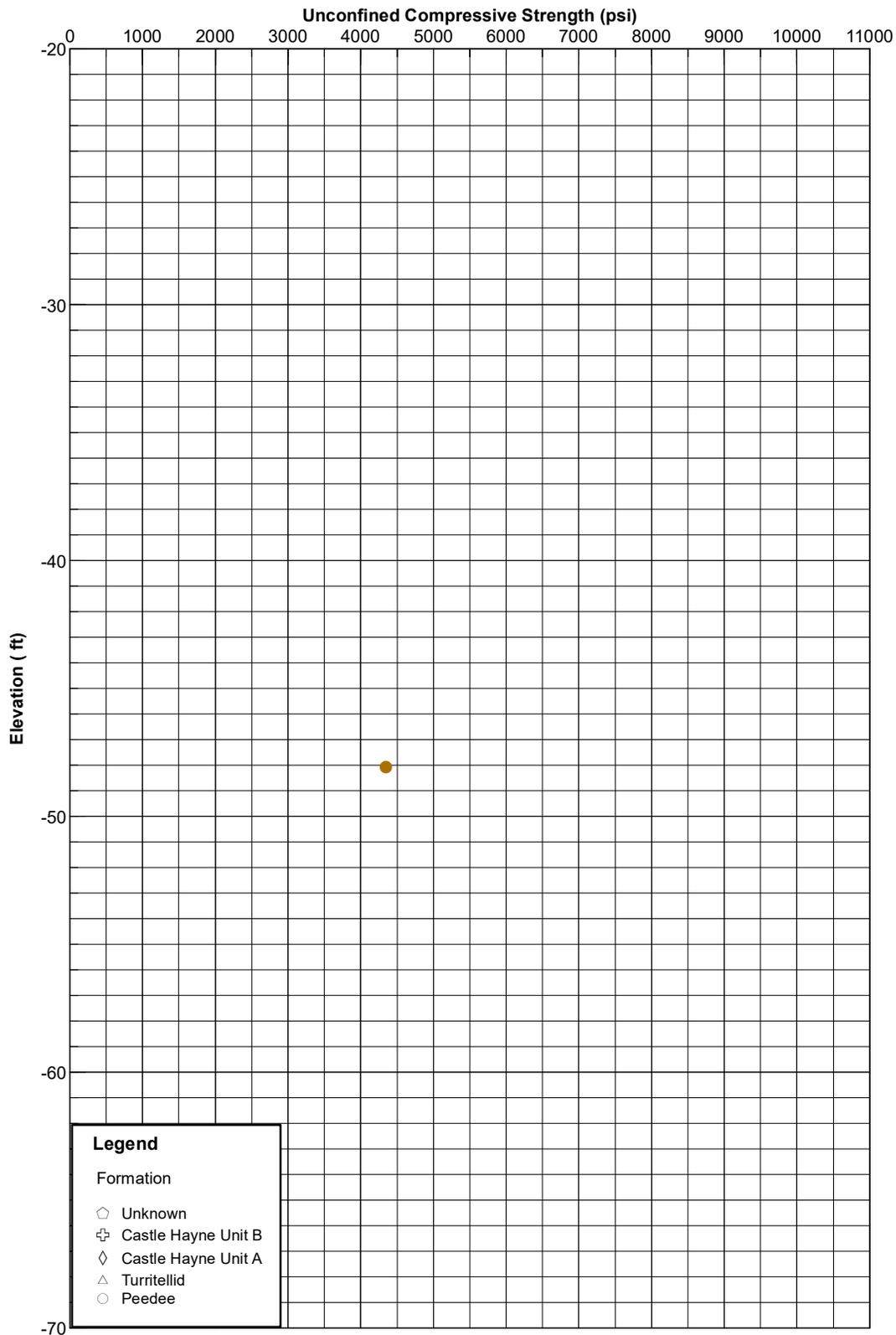
SUPERSEDED BY FIGURES 6-1 through 6-15
IN THE FEBRUARY 25, 2019 REPORT



UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
Fourth East Jetty
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 6-4

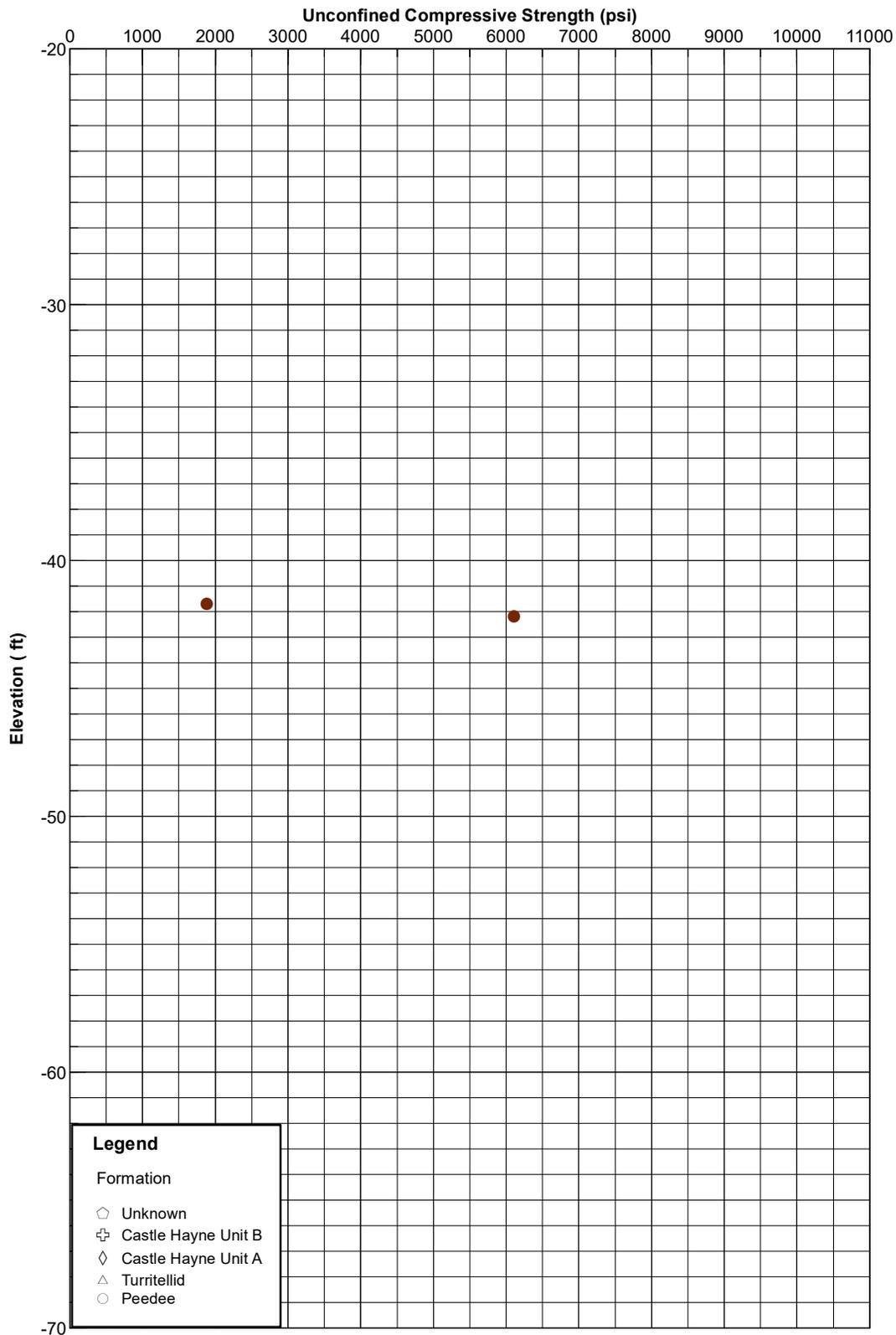
**SUPERSEDED BY FIGURES 6-1 through 6-15
IN THE FEBRUARY 25, 2019 REPORT**



UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
Lower Brunswick
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 6-5

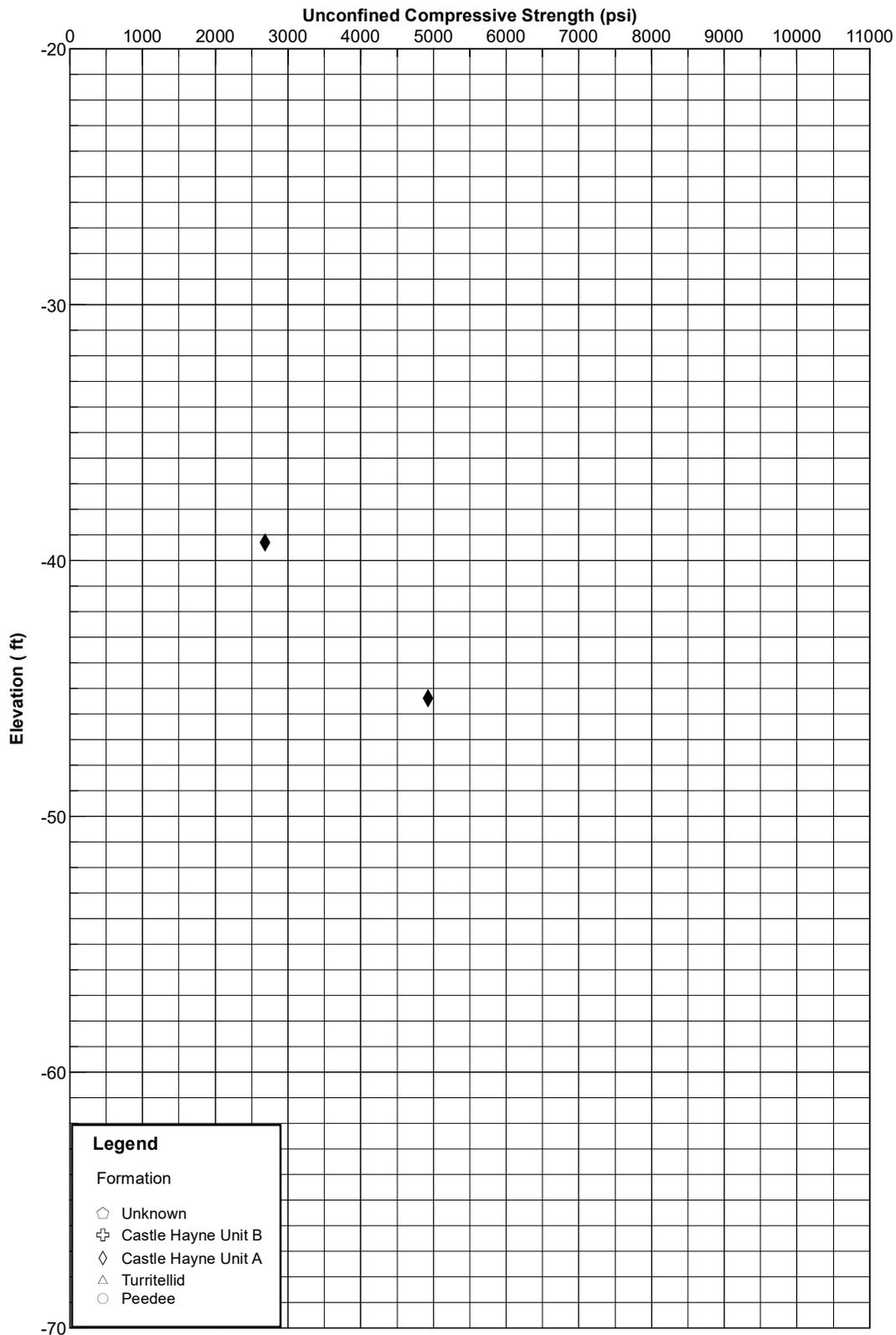
SUPERSEDED BY FIGURES 6-1 through 6-15
IN THE FEBRUARY 25, 2019 REPORT



UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
Upper Big Island
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 6-6

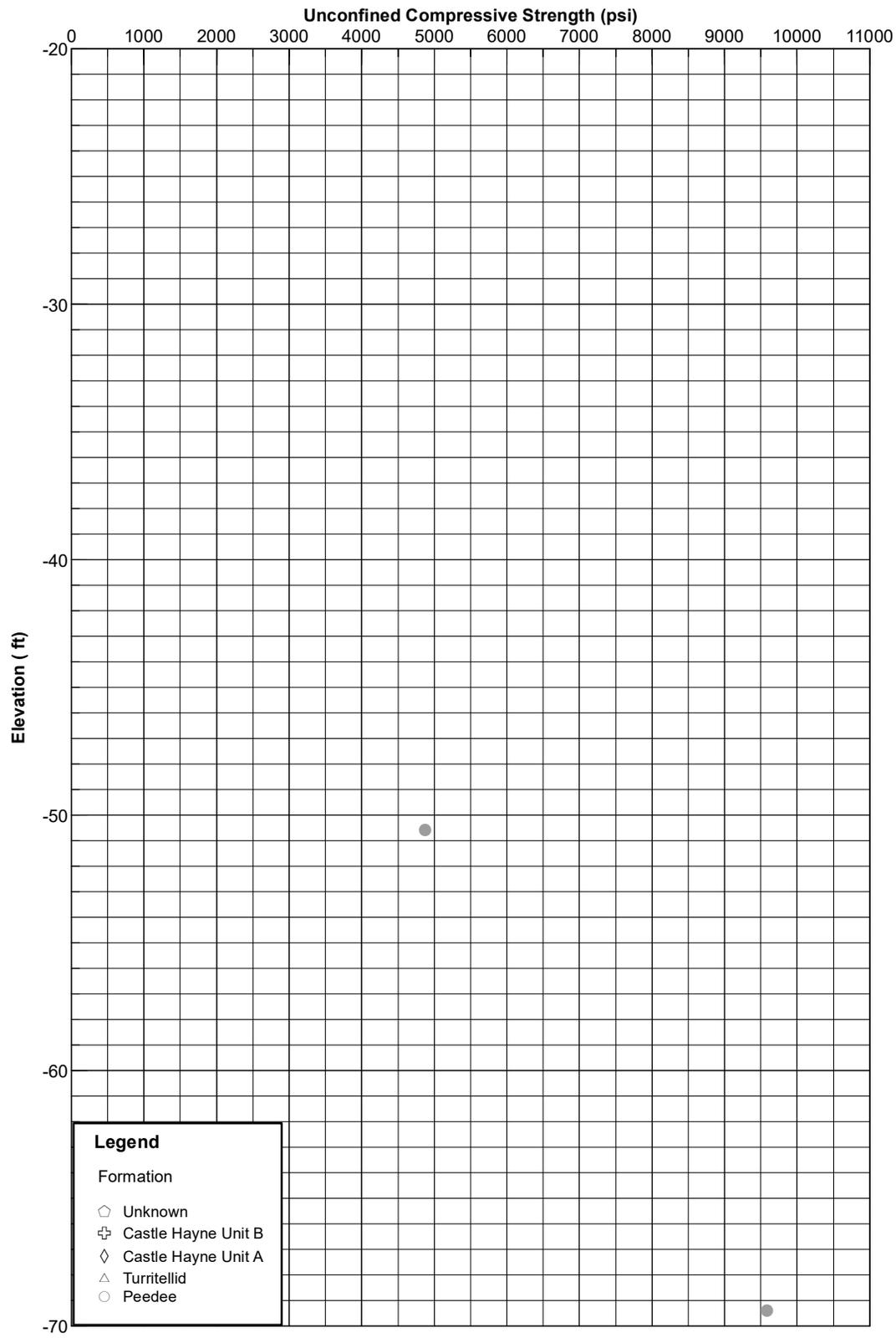
SUPERSEDED BY FIGURES 6-1 through 6-15
IN THE FEBRUARY 25, 2019 REPORT



UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
Lower Big Island
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 6-7

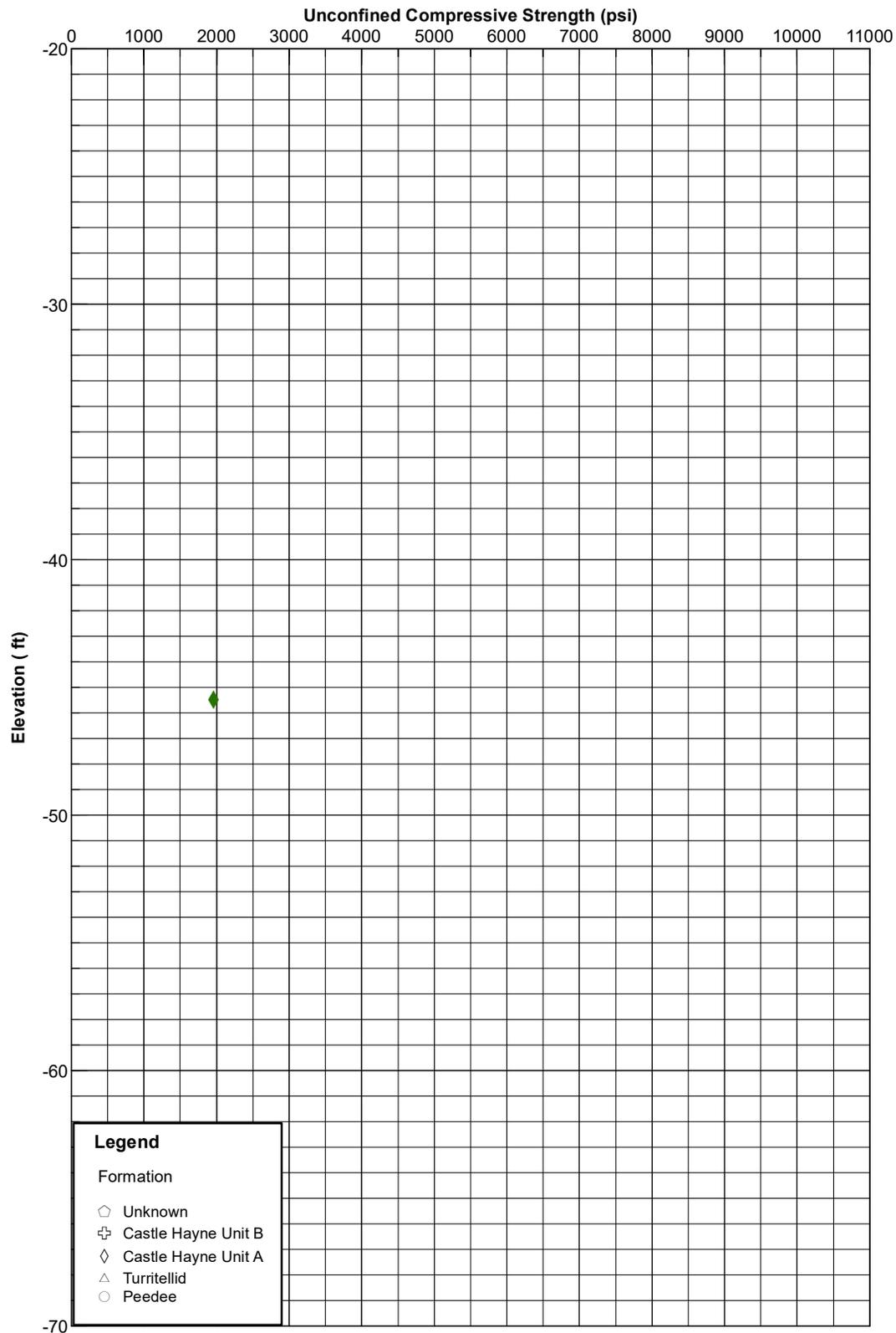
SUPERSEDED BY FIGURES 6-1 through 6-15
IN THE FEBRUARY 25, 2019 REPORT



UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
Keg Island
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 6-8

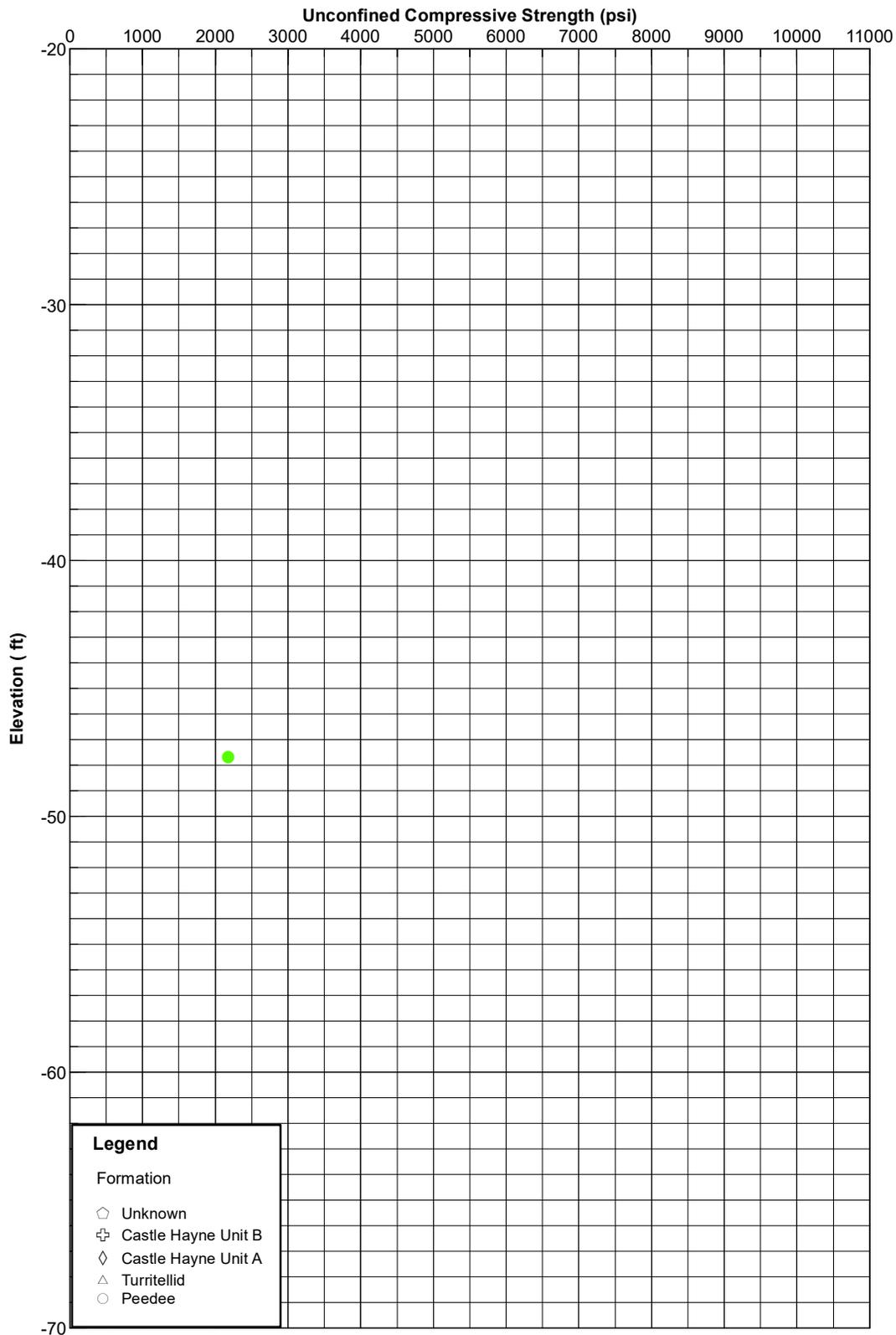
**SUPERSEDED BY FIGURES 6-1 through 6-15
IN THE FEBRUARY 25, 2019 REPORT**



UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
Upper Lilliput
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

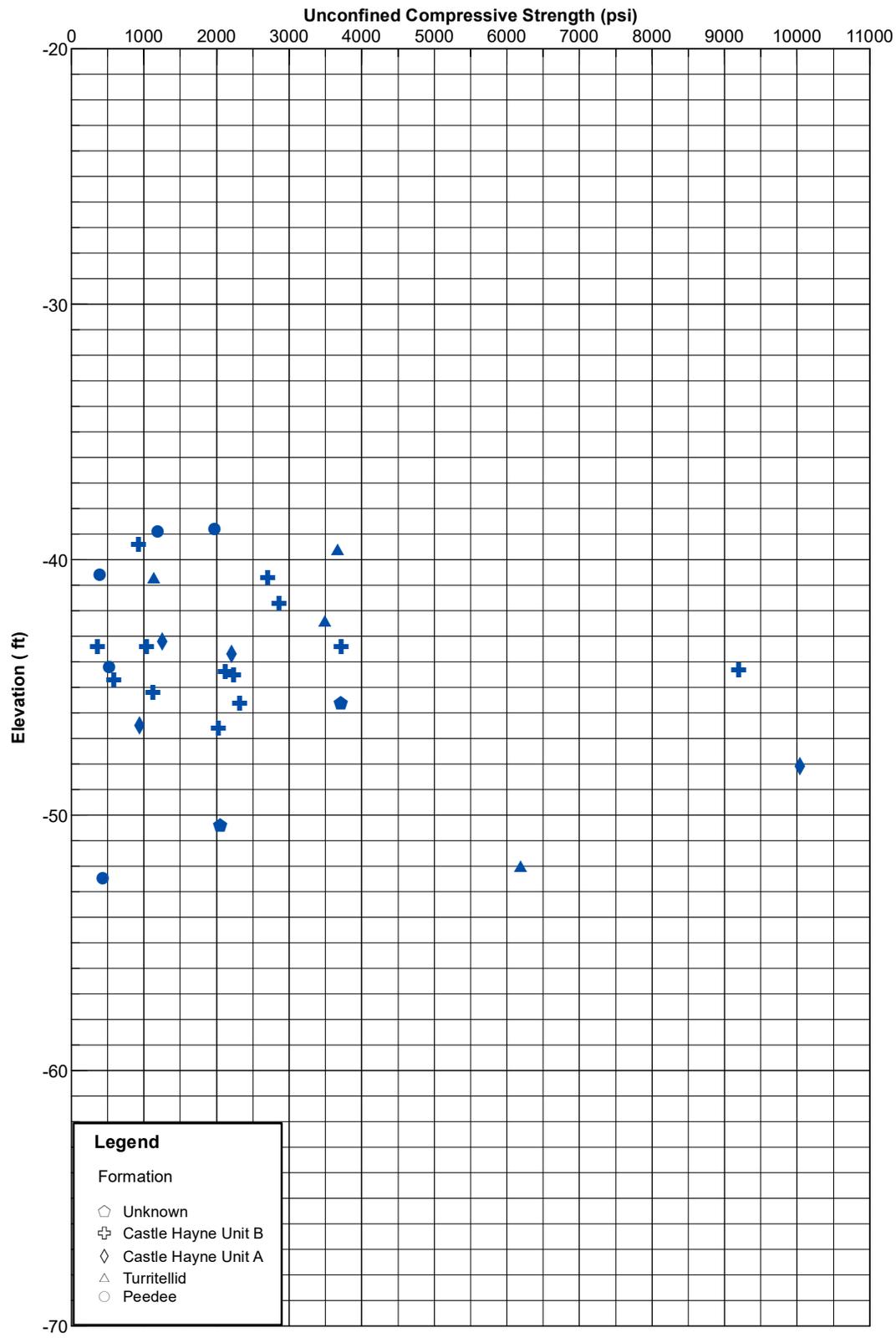
FIGURE 6-9

**SUPERSEDED BY FIGURES 6-1 through 6-15
IN THE FEBRUARY 25, 2019 REPORT**



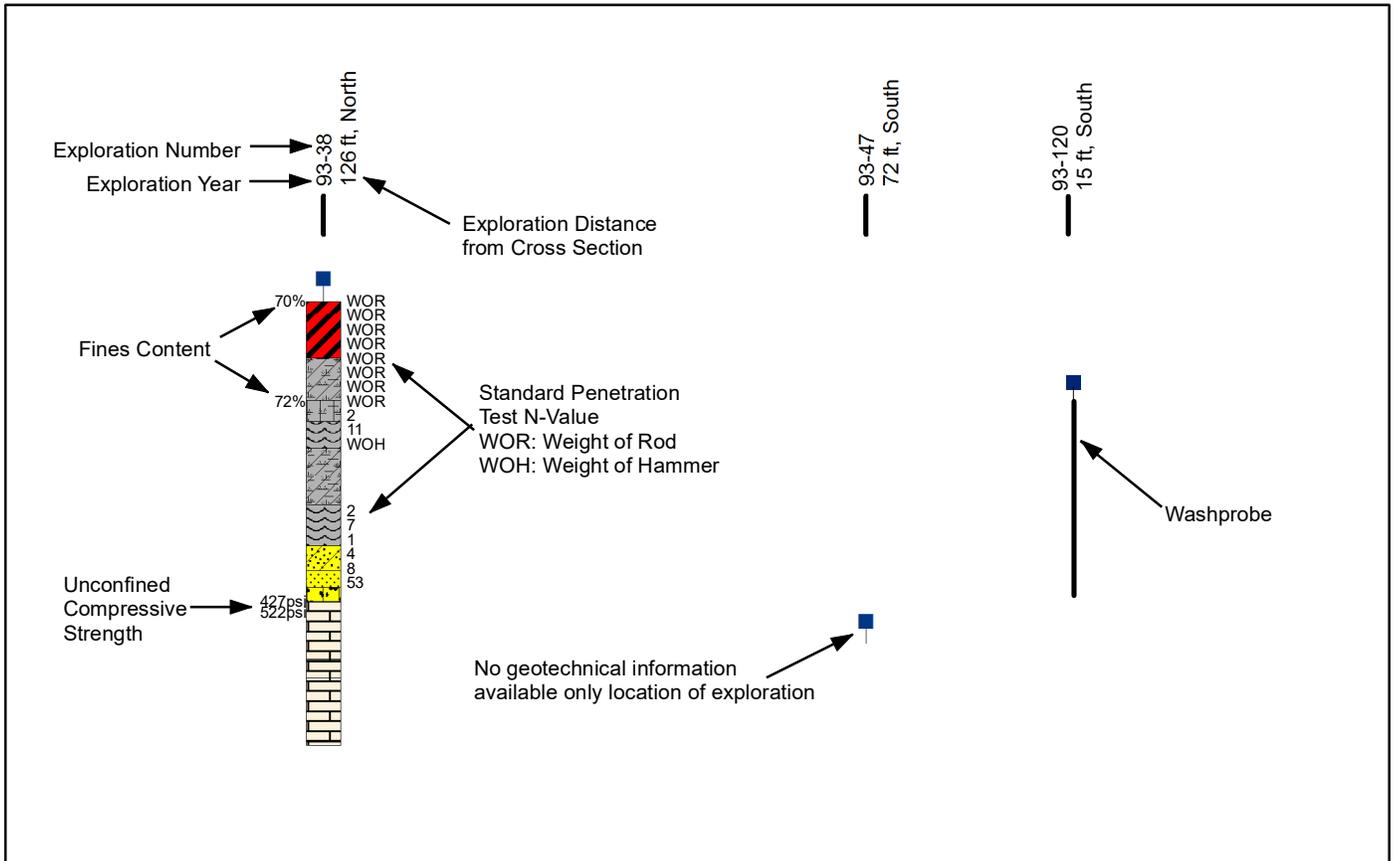
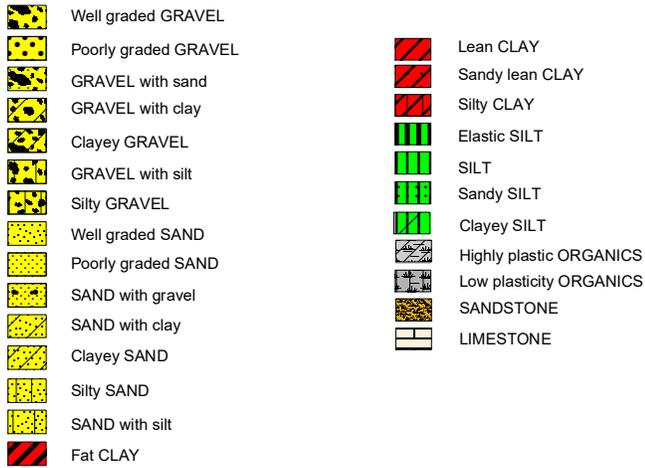
UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
Lower Lilliput
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

SUPERSEDED BY FIGURES 6-1 through 6-15
IN THE FEBRUARY 25, 2019 REPORT



UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
Outer Channel Approach
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

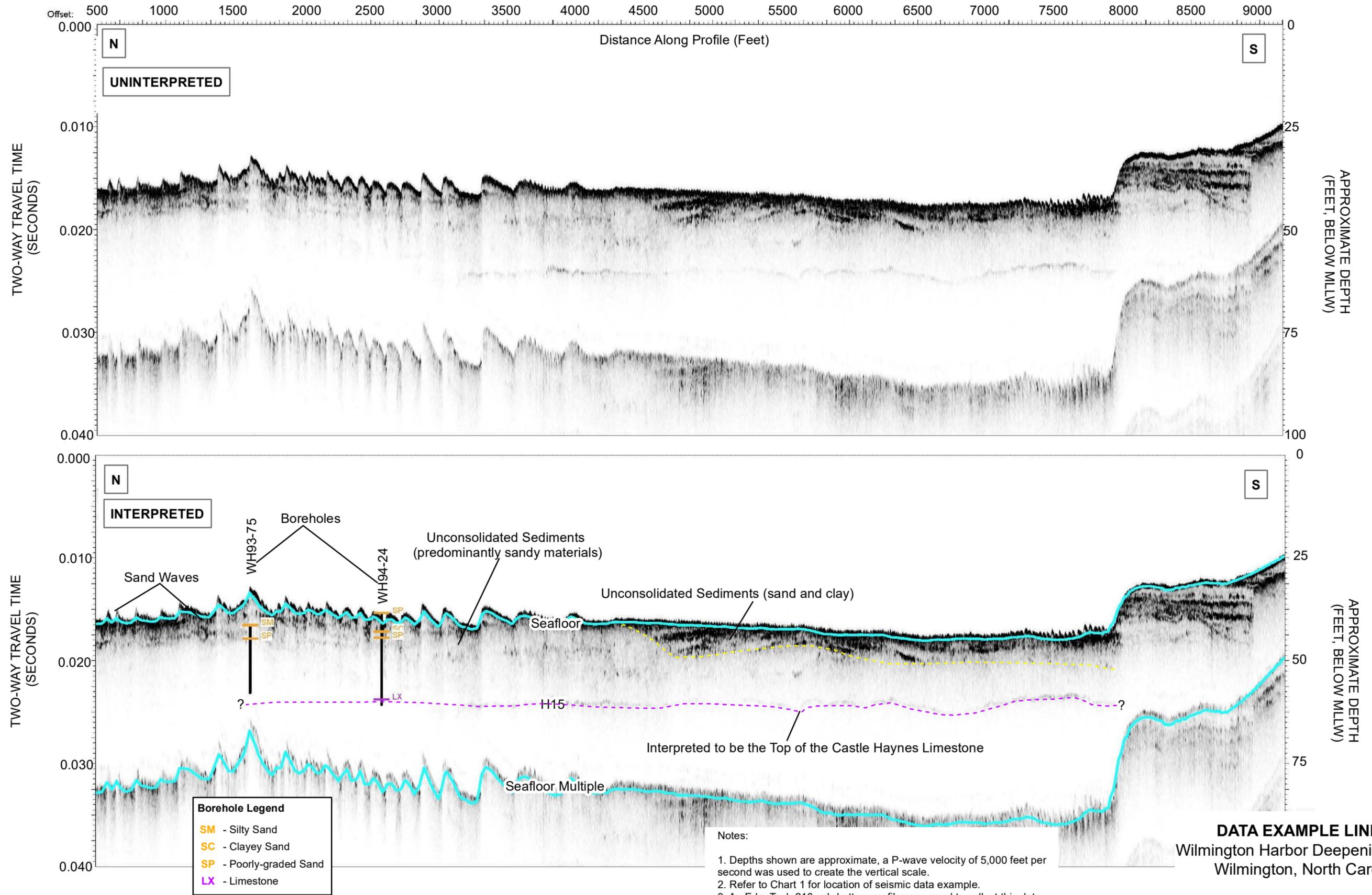
SOIL TYPES



**KEY TO CHARTS OF SUBSURFACE
CROSS SECTIONS**
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

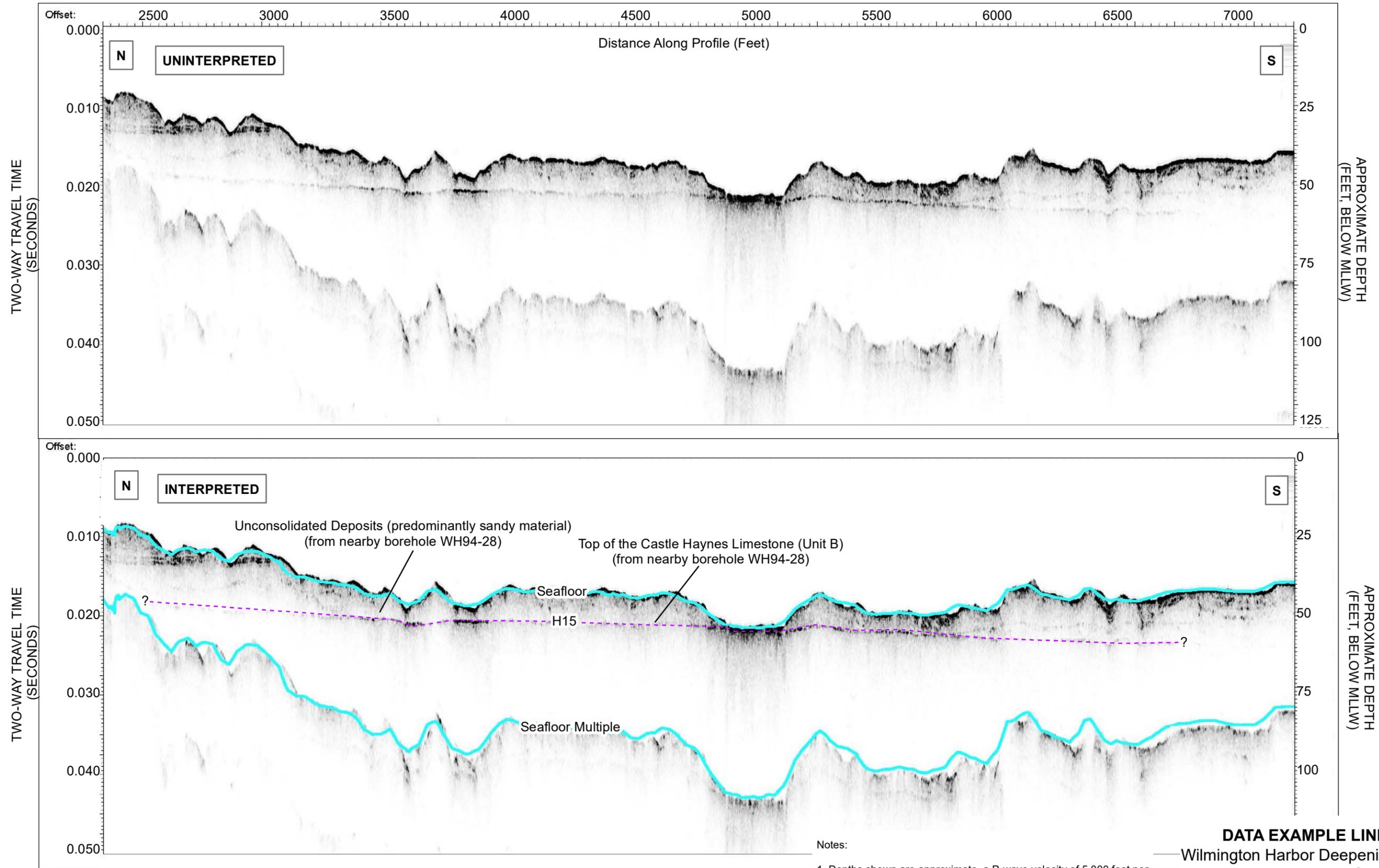
Figure 7 has been removed from this report since it is superseded by Figures 3-3 through 3-58 and Charts 2 through 8 in the February 25, 2019 report.

**SUPERSEDED BY FIGURES 7 - 10
IN THE FEBRUARY 25, 2019**



DATA EXAMPLE LINE 56
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

SUPERSEDED BY FIGURES 7 - 10
IN THE FEBRUARY 25, 2019

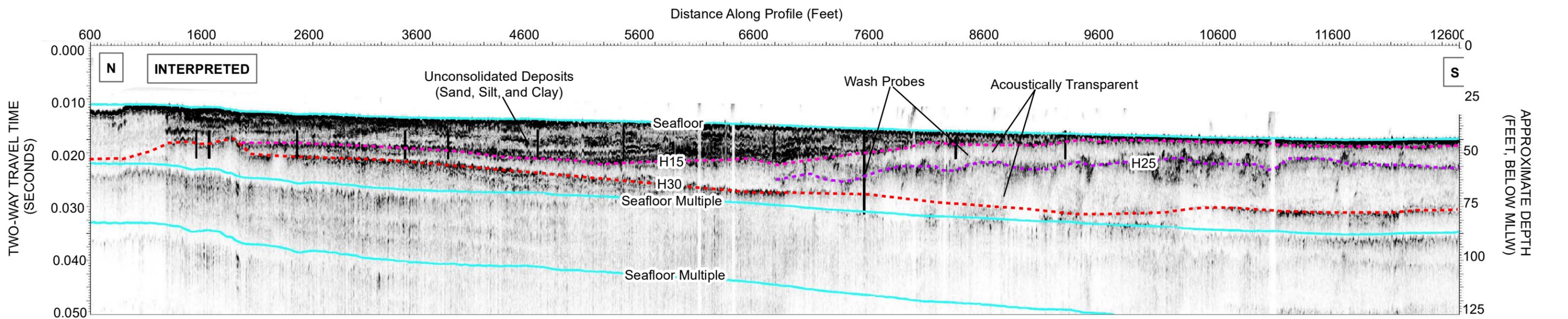
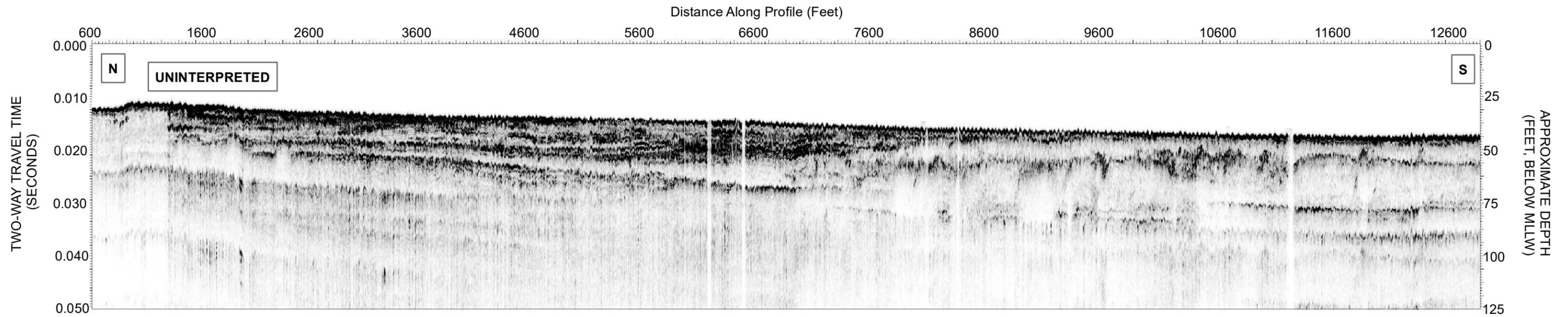


- Notes:
1. Depths shown are approximate, a P-wave velocity of 5,000 feet per second was used to create the vertical scale.
 2. Refer to Chart 1 for location of seismic data example.
 3. An EdgeTech 216 sub-bottom profiler was used to collect this data.

DATA EXAMPLE LINE 70
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

FIGURE 9

SUPERSEDED BY FIGURES 7 - 10
IN THE FEBRUARY 25, 2019



Interpreted Seismic Horizons

H15 - Interpreted to be the Top of the Castle Haynes Limestone

H25 - Interpreted to be an internal reflector within the Castle Haynes Limestone (Possibly a separation between Units A and B)

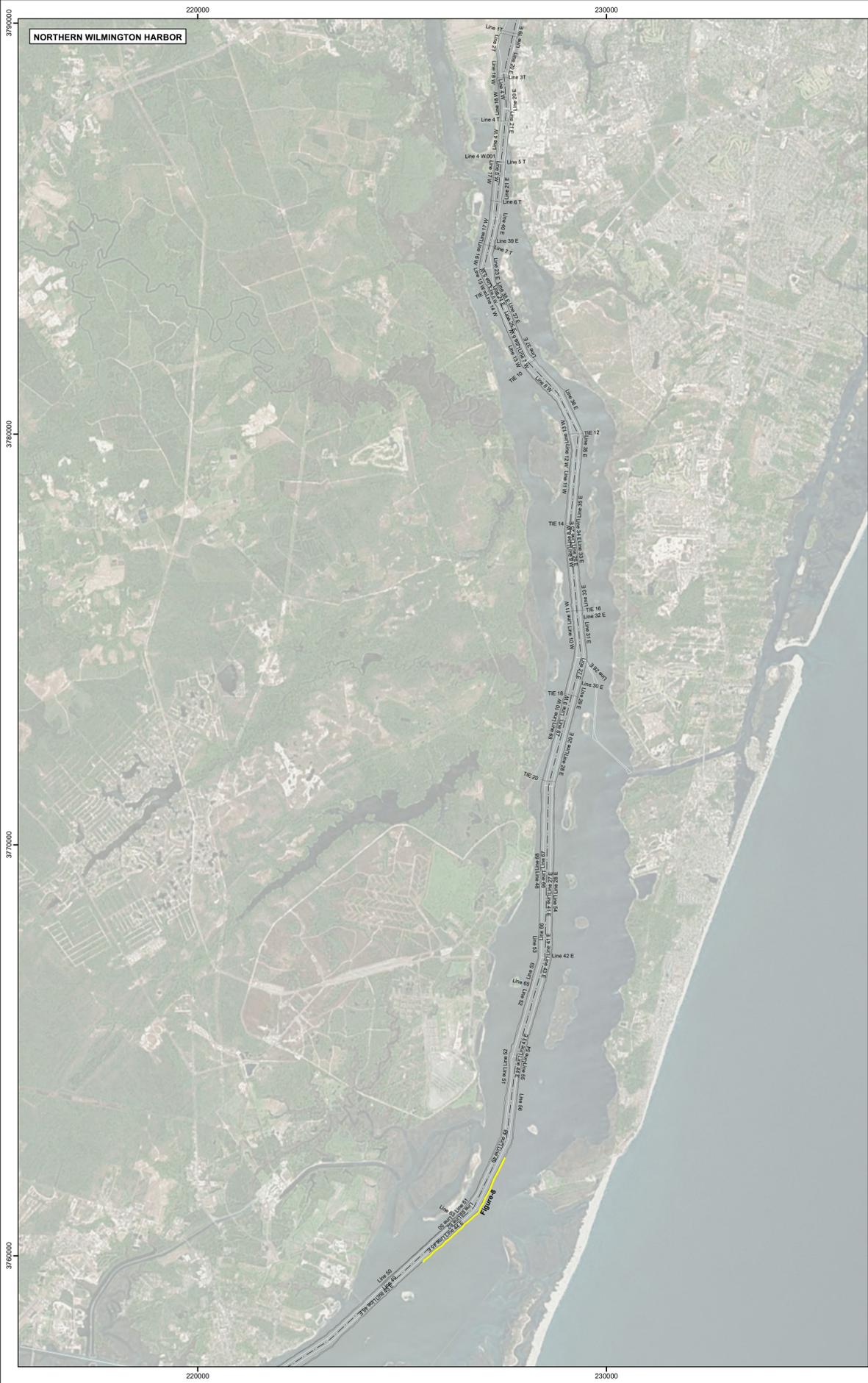
H30 - Interpreted to be the Top of the Turrillid Limestone

Notes:

1. Depths shown are approximate, a P-wave velocity of 5,000 feet per second was used to create the vertical scale.
2. Refer to Chart 1 for location of seismic data example.
3. An EdgeTech 512 sub-bottom profiler was used to collect this data.

DATA EXAMPLE LINE 02a
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

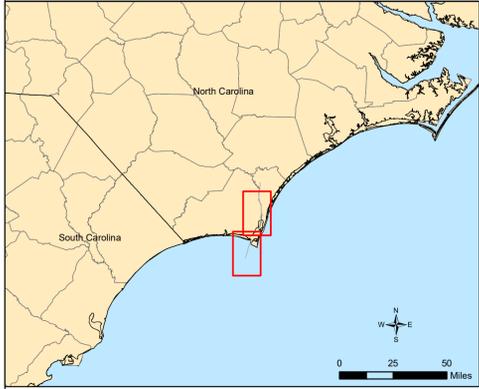
CHARTS



LEGEND

- Inner Harbor Trackline (May 2017)
- Outer Harbor Trackline (July 2017)
- Seismic Data Example Figure Location
- - - Channel Centerline
- ▭ Channel Boundaries

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SURVEY VESSEL TRACKLINES
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

HORIZONTAL SCALE

NO.	DATE:	DESCRIPTION:	DRAWN:	CHKD:	APPR:
1	Sept. 2017	Survey Post-Plot	WC	KS	KS
2					
3					

JOB NUMBER: 02.17041145 SHEET NO. 1

Charts 2 through 8 have been removed from this report since they are superseded by Charts 2 through 8 in the February 25, 2019 report.

Wilmington Harbor Deepening Update

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Wilmington Harbor Deepening Update Report
Wilmington, North Carolina

25 February 2019
Project No.: 02.18011412

Wilmington Harbor Deepening Update Report

Wilmington, North Carolina

25 February 2019 (Initial Report)
Project No.: 02.18011412

2					1 November 2019	
1					4 October 2019	
0					29 February 2019	
Issue	Document Type	Status	Prepared	Checked	Approved	Date

Our ref: 02.18011412

Report Date: 25 February 2019 (Initial Report)

Wilmington Harbor Deepening Update Report
Wilmington, North Carolina

This report presents an updated evaluation of site conditions that was presented in the January 29, 2018 report. This update has incorporated additional historical geotechnical and geophysical information (e.g. boreholes, wash probes, vibracores, top of rock mapping results from prior geophysical surveys, etc.) received after issuing the January 29, 2018 report.

Data collected during a 2017 hydrographic and geophysical survey was integrated with historical hydrographic, geotechnical, and geophysical data collected by others and used to characterize subsurface conditions in the surveyed area. This report provides a summary of data and our updated characterization of subsurface conditions beneath the channel. The objective of this study is to provide an evaluation of materials that may be encountered during future navigation improvements conducted to deepen, widen, and/or alter the channel alignments.

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-
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1. INTRODUCTION

1.1 Previous Work (2017 Survey and Characterization)

Studies have recently been conducted to support planning of modifying and deepening the Wilmington Harbor navigation channel. As part of those studies, a reconnaissance hydrographic and geophysical survey was conducted from April 25 to June 19, 2017 in Wilmington's inner harbor and outer harbor which extends approximately 16 nautical miles offshore. This survey measured water depths along the channel using a multibeam echosounder and also collected low frequency and high-frequency sub-bottom profiler data to image the shallow subsurface. The 2017 survey report evaluates the results of the survey and integrates the geophysical survey data with the existing geotechnical data to characterize the subsurface conditions along the Cape Fear river and Wilmington Harbor. Since issuance of the 2017 survey report (issued in January 2018), additional historical data have obtained and assimilated into this report. Figure 1 and Chart 1 present the extent of the 2017 survey.

1.2 Purpose and Scope

Recent studies have been conducted evaluate potential navigation channel improvements of the Wilmington Harbor located near Wilmington, North Carolina. We understand that current dredging activities maintain the channel to at least an elevation (El.) of -42 feet (referenced to mean lower low water [MLLW]) with an overdredge allowance of 2 feet from Anchorage Basin to Lower Swash and El. -44 feet (MLLW) with an overdredge allowance of 2 feet from Battery Island to Baldhead Shoal Reach 3. Future navigation channel improvements may include deepening, widening, and/or realigning the existing navigation channel.

The purpose of this study is to incorporate new geotechnical data and further identify and characterize areas of the Wilmington Harbor Channel that could be problematic for channel deepening or widening. New data includes geotechnical boring, washprobe, and vibracore logs, lab data (including unconfined compressive strength and grain size), and top of rock picks from the boring logs. Using this new data, updated top of rock elevation picks were made and updated on maps and cross sections. Unconfined compressive strength, RQD, recovery, and rock layer thickness all factor in to help determine the dredge-ability within the channel. These values were posted on maps and cross sections to provide an easy reference for the project team to identify problematic areas. Exploration locations are shown on Figure 2-1 and explorations interpreted to have encountered the top of rock are shown on Figure 2-2.

2. GEOLOGIC SETTING

2.1 Regional Geology

The project area is located in the Atlantic Coastal Plain Physiographic Province and is part of the Outer Coastal Plain of the Carolinas. This coastal plain province is characterized by subdued relief and a general seaward slope (USACE, 1994). The Cape Fear River valley, in which the Wilmington Harbor Project is located, lies along the Cape Fear arch, a large deep-seated tectonic feature which influences the local geomorphology and sedimentation patterns (Figure 2.1 in the text) (Soller, 1988). Sediments in this area were deposited during transgressive-regressive cycles produced by glacioeustatic sea level fluctuations, which ideally include a relatively thin marine unit deposited during interglacial periods as the ocean transgressed and thicker overlying deposits as the ocean regressed. During interglacial periods, sequences of marine and strandline sediments were deposited on the now-emerged Coastal Plain. During glacial maximums, low sea level caused a regression of strandlines, entrenchment of streams, and the erosion and dissection of the Coastal Plain deposits (USACE, 1996). The Cape Fear River is steadily migrating to the southwest over time due to the influence of the Cape Fear arch, and is depositing considerable fluvial sediments as it drains the Piedmont and erodes Coastal Plain marine terraces (Soller, 1988).

2.2 Site Geology

Beneath the alluvial overburden that is present throughout much of the channel, older formations that range in age from Cretaceous to Pleistocene are encountered along the Wilmington Harbor Channel. The stratigraphic units described in the historical subsurface explorations, include (from oldest to youngest) the Peedee, Olive Sand, Turritellid Limestone, Castle Hayne (Units A and B), Trent, and Waccamaw (Figure 2.2 in the text) (USACE, 1996). The Peedee formation, Turritellid Limestone, and Castle Hayne formation appear to be the most common materials reported to have been encountered by historical explorations beneath the Quaternary age deposits. The following overview of the stratigraphic units is largely based on work previously reported by the USACE (1996).

2.2.1 Peedee Formation

Historical borings that have encountered this formation in the port describe the materials as typically interbedded silty sand or clayey sand and limestone layers of Cretaceous age. The limestone thickness may vary from a few inches to several feet thick. Cementation and hardness is variable and rock strength based on uniaxial compressive strength according to classification presented by ISRM (1979; Figure 2.3 in the text) is typically very low to low strength (Figure 6a). The Peedee formation is light gray to gray. The limestone in places is fossiliferous, vuggy, and sandy. Lower Peedee sediments are conformably overlain by the Rock Point member of the Peedee formation, when not removed by erosion or absent by nondeposition. The Rocky Point member is mostly sandy limestone or limy sandstone which is occasionally fossiliferous with some pelecypod and gastropod molds.

2.2.2 Olive Sand

The Olive Sand unit was tentatively and informally identified as the Olive Sand by Zullo and Harris (1992). This unit has been reported to have been encountered in deep borings located in Baldhead Shoal Channel and not encountered elsewhere in the Wilmington Harbor by historical explorations (USACE, 1996). The

Olive Sand is mostly an unconsolidated olive-green, calcareous, glauconitic, fine-grained quartz sand (USACE, 1996). In Baldhead Shoal Channel the Olive Sand is unconformably overlain by the Turritellid Limestone and is not anticipated to be encountered during dredging.

2.2.3 Turritellid Limestone

This unit was tentatively and informally identified as the Turritellid Limestone by Zullo and Harris (1992). This informal name has been used to describe limestone in which turritelline gastropods 1) comprise at least 20 percent of the total actual or estimated biomass or at least 20 percent of the macroscopic individuals in the assemblage, and 2) are at least twice as abundant as any other macroscopic species in the assemblage (Allmon, 2007). The Turritellid Limestone in the port has been interpreted to overlie the Peedee formation and Rocky Point member and underlie the Castle Haynes formation, where present. The Turritellid Limestone is interpreted to be Paleocene to Eocene in age and may actually be a part of one of the overlying or underlying formations. The Turritellid Limestone is typically a moderately to well lithified, sandy limestone.

2.2.4 Castle Hayne, Unit A

This unit of the Castle Hayne formation was informally named Unit A by Zullo and Harris (1992). The Castle Hayne, Unit A is predominantly a gray to light gray, moderate to well indurated, fossiliferous limestone. Fossil content in places is mostly bryozoan fragments. Unit A is disconformably overlain by Unit B (USACE, 1996).

2.2.5 Castle Haynes, Unit B

This unit of the Castle Hayne formation was informally named Unit B by Zullo and Harris (1992). For simplification, all Castle Hayne carbonates above Unit A are placed in Unit B. Unit B may be crème colored, fossiliferous in places with bryozoan fragments and occasionally numerous megafossils and fossil fragments.

2.2.6 Trent Formation

This unit has been reported to have been encountered by at least one boring and was interpreted to be less than 1 foot thick (Harris and Laws, 1994). This unit is considered to be comprised of tan-brown, phosphatic, quartz sand. Due to its limited extent and thickness, this unit is not considered a be significant to future deepening activities (USACE, 1996).

2.2.7 Waccamaw Formation

This unit has been reported to have been encountered by at least one boring and was interpreted to be less than 1 foot thick (Zullo and Harris, 1994). This unit has been described as fossiliferous, phosphatic, calcareous sand. tan-brown, phosphatic, quartz sand. Due to its limited extent and thickness, this unit is not considered a be significant to future deepening activities (USACE, 1996).

2.2.8 Unconsolidated Sediments

The harbor channel bottom sediments are predominantly comprised of sand, silt and clay materials inferred to be Holocene in age. They vary in thickness and may be several to tens of feet thick in areas. In areas

where dredging has removed them and exposed the rock and formation strata on the channel bottom (e.g. Anchorage Basin reach), there may be only a thin veneer of unconsolidated sediments less than a foot thick.

2.2.9 Generalized Formations (Potential Rock Units) that Underlie Unconsolidated Sediments

From the northern Federal Project limit (25 Foot Project) to the northern end of Upper Big Island, the Peedee Formation is the uppermost rock unit encountered (Charts 2 and 3). From Upper Big Island through Lower Big Island, Castle Hayne Units A and B appear to be the uppermost rock units encountered, with a few explorations indicating the Peedee Formation (Chart 3). Keg Island through Snows Marsh the Peedee Formation is assumed to be the uppermost rock unit, except for a small area at the transition between the Upper and Lower Lilliput channel reaches which appears to be Castle Hayne Unit A (Charts 3 through 6). From Lower Swash to Baldhead Reach 1 it is interpreted that the Castle Hayne Formation is the uppermost rock unit (Chart 6). From Baldhead Shoal Reach 1 to the end of Baldhead Reach 2, it is interpreted that the Turritellid Limestone is the uppermost rock (Charts 6 and 7). In Baldhead Reach 3 The Castle Hayne is assumed to be the uppermost rock unit (Chart 7).

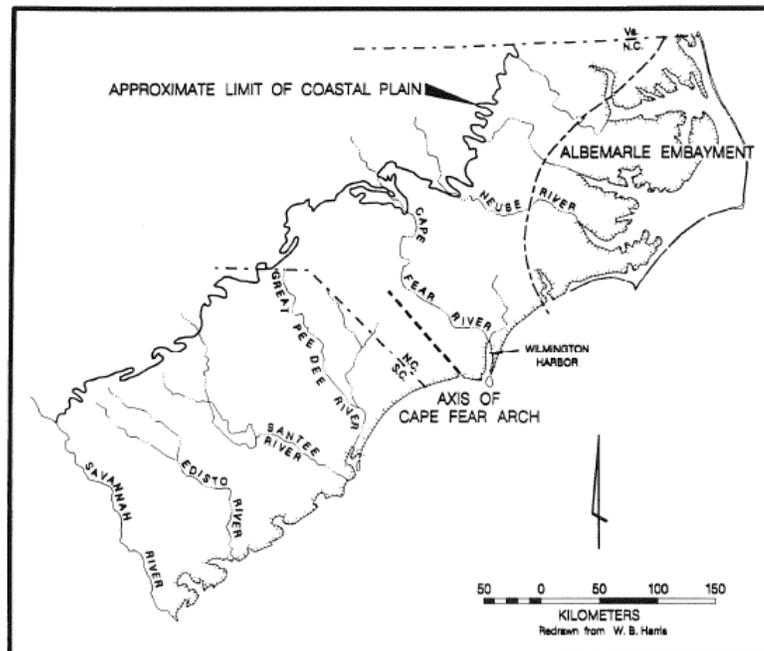


Figure 2.1: Stratigraphic Units Encountered in the Subsurface, Wilmington Harbor (USACE, 1996)

AGE	UNIT	LITHOLOGY	
PLEISTOCENE	WACCAMAW FORMATION	PHOSPHATIC, QUARTZ-RICH, CALCAREOUS SAND	
OLIGOCENE	TRENT FORMATION	CALCAREOUS, PHOSPHATIC, QUARTZ SAND	
EOCENE	UPPER		
	MIDDLE	CASTLE HAYNE LIMESTONE	UNIT B MEGAFOSSILIFEROUS, BIOTURBATED MUDSTONE TO WACKESTONE AND BRYOZOAN PACKSTONE
		UNIT A CROSS-BEDDED, BRYOZOAN GRAINSTONE AND PHOSPHATE-PEBBLE CONGLOMERATE	
PALEOCENE OR LOWER EOCENE	TURRITELLID LIMESTONE	SANDY, MOLLUSCAN-MOLD, WACKESTONE-PACKSTONE	
PALEOCENE	LOWER	OLIVE SAND OLIVE-GREEN, CALCAREOUS, GLAUCONITIC, FINE GRAINED, QUARTZ SAND	
CRETACEOUS	UPPER	PEEBEE FORMATION	ROCKY POINT MEMBER CALCAREOUS, QUARTZ ARENITE AND MOLLUSCAN-MOLD GRAINSTONE
		VERY FINE TO FINE, CALCAREOUS, MUDDY, QUARTZ SAND	

Figure 2.2: Stratigraphic Units Encountered in the Subsurface, Wilmington Harbor (USACE, 1996)

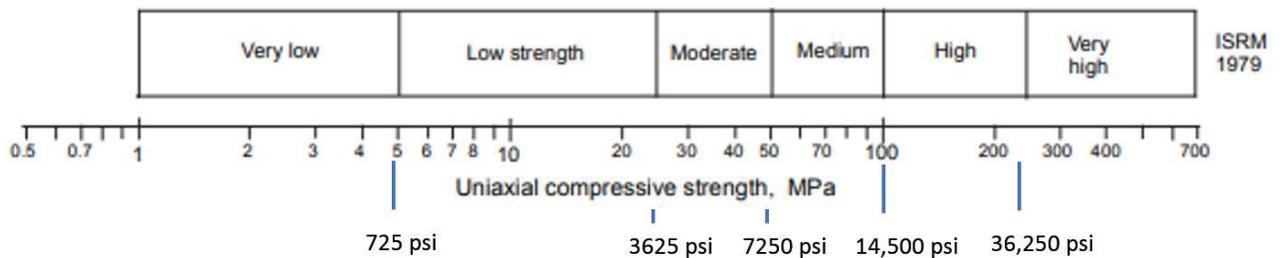


Figure 2.3: Rock Strength Classification (ISRM, 1979)

3. SUBSURFACE CONDITIONS

Longitudinal cross sections, first created for the 2017 characterization, were updated along the entire length of the Wilmington Harbor Channel, beginning at the 25 Foot Project reach in the north to Baldhead Shoal Reach 3 in the south (Charts 2 through 7). A total of three cross sections were created along this length, one along the channel centerline and one on either side of the channel. The cross sections located on either side of channel were positioned at the toe of the slope which roughly correlated to the channel boundaries. This configuration of cross sections allows for a more robust incorporation of historical explorations to be used, as well as an ability to gain a better understanding of the type of material that could be encountered if the channel were to be widened or deepened in certain areas. Interpreted top of rock elevation is presented on Figures 3-1 through 3-58.

To interpret and categorize the type of material which could be encountered, updated grain size curves and data plots showing fines content and unconfined compressive strength (UCS) versus elevation were created for channel reaches which contained historical data. The following series of figures presents the historical data;

- Figure 4-1: Plan view summary of fines content and median grain size per channel reach,
- Figures 4-2 and 4-3: Graphical presentation of fines content and median grain size per channel reach,
- Figures 5-1 through 5-17: Grain size curves per reach based on sieve analyses,
- Figures 6-1 through 6-15: Summary of compressive strength tests per channel reach.

The Chirp data acquired in 2017 provided additional interpretation for the location of potential shallow rock outcrops, especially on the channel flanks, to further aid in both the inner and outer channel subsurface conditions (Figures 7 through 10). The seismic data was correlated with the historical geotechnical and previous mapping to show which formation is likely to be encountered (if any) if deepening were to occur. A previously unmapped area 8.7 miles long, southwest of the end of Baldhead Reach 3, was surveyed in 2017 and the interpreted geologic formations are shown in the profile views on Chart 8. For more details regarding the general geology, 2017 survey and historical data sets, refer to the January 2018 report.

Table 3.2 provides a summary of subsurface conditions and is referenced in the following sections.

3.1 Previous Studies

Exploration data and information from the following studies were used to support preparation this report.

- ANAMAR Environmental Consulting, Inc. (2013) Final Report Evaluation of Dredged Material Proposed for Ocean Disposal, Maintenance of Wilmington Harbor, MPRSA Section 103 Sediment Testing and Analysis Wilmington, North Carolina, September 2013.
- International Society of Rock Mechanics (ISRM) (1979), Descriptions of Discontinuities in Rock Masses International Journal of Rock Mechanics and Mining Sciences, Vol. 15, 1979.
- Soller, David R., (1988) Geology and Tectonic History of the Lower Cape Fear River Valley, Southeastern North Carolina, USGS Professional Paper 1466A, Denver, CO.

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- United States Army Corps of Engineers (USACE) (1996) Final Feasibility Report and Environmental Impact Statement On Improvement Of Navigation, Cape Fear – Northeast Cape Fear Rivers Comprehensive Study, Wilmington, North Carolina, June 1996.
 - United States Army Corps of Engineers (USACE) (2015) Draft Integrated Feasibility Report and Environmental Assessment, Wilmington Harbor Navigation Improvements, June 2015.
 - United States Army Corps of Engineers (USACE) (2016) Final Integrated Feasibility Report and Environmental Assessment, Wilmington Harbor Navigation Improvements, June 2016.
 - United States Army Corps of Engineers (USACE) (1994) Final Interim Feasibility Report and Environmental Impact Statement On Improvement Of Navigation – Wilmington Harbor Channel Widening, Wilmington, North Carolina, March 1994.
 - Wolf Technologies, Inc. and USACE (2008) Wilmington Inner Ocean Bar. November 2008.

3.2 Interpreted Top of Rock Mapping

Additional data from geotechnical borings, vibracores, and washprobes were incorporated into the previous mapping done as part of the 2017 survey and related report issued in January 2018. Figure 2-1 presents the locations of all geotechnical data types used in the study. New borings provided interpreted top of rock elevations and descriptions of the rock/soil encountered and allowed a more detailed geologic model to be summarized. Vibracores provided little information regarding the elevation of the rock, but did provide grain size data in areas where data was previously lacking. Additional washprobe data, although not as reliable as soil or rock borings, did provide useful data for refusal or interpreted top of rock elevation. Where possible, data from washprobes were compared to nearby geotechnical borings to determine their accuracy. Figure 2-2 presents geotechnical boring and washprobe locations where interpreted top of rock elevation values were available. This data were also used to update the top of rock elevation mapping.

Updated top of rock elevation mapping incorporated 2017 data from both geotechnical investigations as well as Chirp sub-bottom profiler data collected during the 2017 survey. The 2017 data along with additional data incorporated for this current study helped fill in knowledge gaps and produce a more comprehensive mapping product. Figures 3-1 through 3-58 are a series of maps in a north to south sequence that show the interpreted top of rock elevation contours. Where available top of rock elevations from borings and washprobes were posted on the maps to show data density and 2017 Chirp survey tracklines illustrate geophysical data coverage. Reaches such as the Anchorage Basin and Baldhead Shoals have more densely spaced data points than reaches in the central portion of the Cape Fear river and thus the confidence in these areas is higher. Reaches at the extreme southern part of the study, namely Baldhead Shoal Reach 3, has very little geotechnical data, so top of rock elevation contours rely heavily on interpreted horizons from the 2017 Chirp survey. Charts 2 through 8 present the additional geotechnical data acquired for this study and the updated top of rock interpretation is also shown.

3.1: Summary of Subsurface Conditions

Channel Reach	Description	Channel Widening ¹				Channel Deepening ¹				Deepening Interval (ft)	Rock Encountered	Estimated Top of Rock Elevation (ft-MLLW)	Average Rock Strength (psi)	Current Maintained Channel Depth (ft, MLLW) ²	Current Authorized Channel Depth + Overdepth (ft, MLLW) ²	Current Approximate Water Depth (ft, MLLW)
25 ft Project	Thin layer of loose to very loose sediments caps a medium dense to dense layer of silty/gravelly sand which overlies the Peedee Formation.	A	B	C	D	A	B	C	D	0 to 5	Not Likely	-34 top -46 ³	Table 3.2	25	36	25
						A	B	C	D	5 to 10	Likely (Peedee)					
Battleship to Hwy 7476	Peedee Formation is at or near surface; where not exposed a thin layer of dense silty/gravelly sand overlies.	A	B	C	D	A	B	C	D	0 to 5	Likely (Peedee)	-40 to -53 ³	Table 3.2	32	40	35
						A	B	C	D	5 to 10	Likely (Peedee)					
Anchorage Basin	Peedee Formation is at or near surface in center of channel; where not exposed a thin layer of dense silty/gravelly sand overlies. Channel flanks contain a relatively thick layer of clay and silt.	A	B	C	D	A	B	C	D	0 to 5	Likely (Peedee)	-41 to -52 ³	Table 3.2	42	44	45
						A	B	C	D	5 to 10	Likely (Peedee)					
Between Channel	Peedee Formation is at or near surface in center of channel; where not exposed a thin layer of silt overlies. Channel flanks contain a relatively thick layer of clay and silt.	A	B	C	D	A	B	C	D	0 to 5	Likely (Peedee)	-42 to -54 ³	Table 3.2	42	44	47
						A	B	C	D	5 to 10	Likely (Peedee)					
Fourth East Jetty	Peedee Formation is at or near surface in center of channel. Channel flanks contain interbedded layers of a fine-grained material with loose to medium dense sand overlying the Peedee Formation.	A	B	C	D	A	B	C	D	0 to 5	Likely (Peedee)	-47 to -54 ³	Table 3.2	42	44	50
						A	B	C	D	5 to 10	Likely (Peedee)					
Upper Brunswick	Peedee Formation is at or near surface in center of channel. Channel flanks contain a layer of clay followed by a layer of medium dense to dense sand layer which overlies the Peedee Formation.	A	B	C	D	A	B	C	D	0 to 5	Likely (Peedee)	-47 to -57 ³	Table 3.2	42	44	49
						A	B	C	D	5 to 10	Likely (Peedee)					
Lower Brunswick	Peedee Formation is at or near surface in center of channel. Channel flanks contain a thin layer of silt followed by a medium dense to very dense sand layer which overlies the Peedee Formation.	A	B	C	D	A	B	C	D	0 to 5	Likely (Peedee)	-47 to -57 ³	Table 3.2	42	44	47
						A	B	C	D	5 to 10	Likely (Peedee)					
Upper Big Island	Castle Hayne is at or near surface in center of channel. Channel flanks contain a layer of fine-grained material followed by medium dense to very dense sand layer which overlies the Castle Hayne Formation.	A	B	C	D	A	B	C	D	0 to 5	Likely (Castle Hayne Unit B/A)	-45 to -50 ³	Table 3.2	42	44	45
						A	B	C	D	5 to 10	Likely (Castle Hayne Unit B/A)					
Lower Big Island	Castle Hayne is at or near surface in center of channel. Channel flanks contain a medium dense to dense silty/gravelly sand layer which overlies the Castle Hayne Formation.	A	B	C	D	A	B	C	D	0 to 5	Likely (Castle Hayne Unit B/A)	-47 to -52 ³	Table 3.2	42	44	46
						A	B	C	D	5 to 10	Likely (Castle Hayne Unit B/A)					
Keg Island	A medium dense to very dense silty sand of varying thickness overlies the Peedee Formation.	A	B	C	D	A	B	C	D	0 to 5	Likely (Peedee)	-47 to -67 ³	Table 3.2	42	44	47
						A	B	C	D	5 to 10	Likely (Peedee)					
Upper Lilliput	A thin layer of fine-grained material caps a medium dense to very dense silty sand of varying thickness which overlies the Peedee Formation.	A	B	C	D	A	B	C	D	0 to 5	Likely (Peedee)	-47 to -57 ³	Table 3.2	42	44	46
						A	B	C	D	5 to 10	Likely (Peedee)					
Lower Lilliput	A thin layer of fine-grained material caps a medium dense to very dense silty sand of varying thickness which overlies the Peedee Formation.	A	B	C	D	A	B	C	D	0 to 5	Localized areas (Peedee/Castle Haynes)	-47 to -62 ³	Table 3.2	42	44	46
						A	B	C	D	5 to 10						

Channel Reach	Description	Channel Widening ¹				Channel Deepening ¹				Deepening Interval (ft)	Rock Encountered	Estimated Top of Rock Elevation (ft-MLLW)	Average Rock Strength (psi)	Current Maintained Channel Depth (ft, MLLW) ²	Current Authorized Channel Depth + Overdepth (ft, MLLW) ²	Current Approximate Water Depth (ft, MLLW)
		A	B	C	D	A	B	C	D							
Upper Midnight	Fine-grained material caps a medium dense to very dense sand layer which overlies the Peedee Formation.	A	B	C	D	A	B	C	D	0 to 5	Not Likely	-56 to -65	Table 3.2	42	44	47
						A	B	C	D	5 to 10	Not Likely					
Lower Midnight	Fine-grained material caps a medium dense to very dense sand layer which overlies the Peedee Formation.	A	B	C	D	A	B	C	D	0 to 5	Not Likely	-56 to -65	Table 3.2	42	44	47
						A	B	C	D	5 to 10	Not Likely					
Reaves Point	A loose to medium dense sand layer with occasional interbedded fine-grained material overlies the Peedee Formation.	A	B	C	D	A	B	C	D	0 to 5	Not Likely	-57 to -62	Table 3.2	42	44	45
						A	B	C	D	5 to 10	Not Likely					
Horseshoe Shoal	A loose to medium dense sand layer overlies the Peedee Formation.	A	B	C	D	A	B	C	D	0 to 5	Not Likely	-58 to -66	Table 3.2	42	44	46
						A	B	C	D	5 to 10	Not Likely					
Snows Marsh	The Peedee formation is at or near surface with some areas having a thin silty fine sand overlying.	A	B	C	D	A	B	C	D	0 to 5	Likely (Peedee)	-47 to -59 ³	Table 3.2	42	44	47
						A	B	C	D	5 to 10	Likely (Peedee)					
Lower Swash	A medium dense to dense sand layer with occasional interbedded fine-grained material overlies the Castle Hayne Formation.	A	B	C	D	A	B	C	D	0 to 5	Likely (Castle Hayne Unit B)	-47 to -52 ³	Table 3.2	42	44	48
						A	B	C	D	5 to 10	Likely (Castle Hayne Unit B)					
Battery Island	Castle Hayne Formation is at or near surface, with a sand to clayey sand layer overlying the Castle Hayne on the channel flanks.	A	B	C	D	A	B	C	D	0 to 5	Likely (Castle Hayne Unit B)	-47 to -52 ³	Table 3.2	44	46	48
						A	B	C	D	5 to 10	Likely (Castle Hayne Unit B)					
Southport	A medium dense to dense sand layer with occasional interbedded fine-grained material overlies the Castle Hayne Formation.	A	B	C	D	A	B	C	D	0 to 5	Likely (Castle Hayne Unit B)	-47 to -72 ³	Table 3.2	44	46	50
						A	B	C	D	5 to 10	Likely (Castle Hayne Unit B)					
Baldhead-Caswell	A medium dense to dense sand layer with occasional interbedded fine-grained material overlies the Castle Hayne Formation.	A	B	C	D	A	B	C	D	0 to 5	Not Likely	-70 to -75	Table 3.2	44	46	48
						A	B	C	D	5 to 10	Not Likely					
Smith Island	Interbedded fine-grained and sand deposits overlie the Castle Hayne Formation.	A	B	C	D	A	B	C	D	0 to 5	Not Likely	-70 to -80	Table 3.2	44	46	50
						A	B	C	D	5 to 10	Not Likely					
Baldhead Shoal Reach 1	Interbedded fine-grained and sand deposits overlie the Castle Hayne Formation.	A	B	C	D	A	B	C	D	0 to 5	Not Likely	-65 to -72	Table 3.2	44	46	50
						A	B	C	D	5 to 10	Not Likely					
Baldhead Shoal Reach 2	A medium dense to dense sand layer with occasional interbedded fine-grained material overlies the Castle Hayne Formation.	A	B	C	D	A	B	C	D	0 to 5	Not Likely	-62 to -75	Table 3.2	44	46	50
						A	B	C	D	5 to 10	Not Likely					
Baldhead Shoal Reach 3	Castle Hayne Formation is at or near surface, with a sand to clayey sand layer overlying the Castle Hayne on the channel flanks.	A	B	C	D	A	B	C	D	0 to 5	Likely (Castle Hayne)	-46 to -58	Table 3.2	44	46	50
						A	B	C	D	5 to 10	Likely (Castle Hayne)					

- Notes: 1. Cells highlighted under the Channel Widening and Channel Deepening columns are the interpreted material category.
2. Maintained and authorized channel depths were obtained from the USACE's "Draft Integrated Feasibility Report and Environmental Assessment Wilmington Harbor Navigation Improvements" (June 2014).
3. Channel widening or excavation of the cut slope may encounter rock shallower than indicated by this range.

3.3 Rock Strength Test Data

In support of future deepening and widening of the Wilmington Harbor Channel, additional rock test data from unconfined compressive strength tests were incorporated and analyzed for this study. Based on previous dredging operations conducted in Baldhead Shoal Channel, the US Army Corps of Engineers recommends the following values when determining if rock can be dredged without blasting:

- Rock with UCS of 4,300 psi or less
- Percentage of core recovery of 47% or less
- Rock Quality Designation of 30% or less
- Thickness, approximately less than 2 to 3 feet; length, approximately less than 500 feet, and width, approximately less than 400 feet.

These values are considered approximate and should be used on a case by case basis. For example, a rock layer that has a strength of 5,000 psi, but is only 1 to 2 feet thick and has a low RQD value may still be dredged without the use of rock blasting. Fugro did not review previous records from dredging operations, thus these values were used as a screening process for identify areas that may require blasting.

With the above parameters in mind, rock strength test data from UC (unconfined compressive) strength tests were analyzed and summarized by reach (Figures 6-1 through 6-15). The compressive strength presented in this report are based on laboratory analysis of rock samples. However, results from small lab samples generally yield higher compressive strength results compared to the respective large-scale (i.e. outcrop or formation sized) rocks. Rock strengths discussed herein thus may represent conservative estimates and in-field rock strength will likely be less.

Figure 6-1 presents rock strength test results for all channel reaches. The color of the data symbols indicate the channel reach they were collected from. The shape of the symbols represent the stratigraphic unit the samples were tested from. Rock strengths from the Upper Big Island and Keg Island exceeded 10,000 psi which is classified as medium strong rock according ISRM (1979). Figure 10 presents the approximate extent of this medium strong rock zone. Strength data from rocks in the Anchorage Basin reach are some of the lowest averaging around 500 psi or less which is considered to be a very low rock strength (ISRM, 1979). The map series in Figure 3-1 through 3-58 also presents the rock strength data in map view along each channel reach. Table 3.2 provides a summary of rock strength, rock quality designation (RQD), and rock layer thicknesses based on the reviewed exploration logs. We note the most test data is shallower than El. -50 feet.

Table 3.2: Rock Summary

Channel Reach	Proposed Dredge Cut (El., MLLW, Feet)	Rock Quality Designation (RQD)			Rock Layer Thickness (ft) ^a			UCS (psi) ^c		
		Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.
Turning Basin	-52	26	0	100	4.2	0.1	20	624	257	2,286
Between Channel	-52	50	7	98	2.8	0.2	6	1,025	776	1,269
Fourth East Jetty	-52	7	0	34	0.5	0.1	2.5	4,880 ^b	4,835 ^b	4,924 ^b
Upper Brunswick	-52	11	0	24	0.4	0.1	0.9	--	--	--
Lower Brunswick	-52	13	0	34	0.6	0.2	1.2	1,666	319	4,346
Upper Big Island	-52	43	0	99	3.3	0.1	9.7	4,258	461	12,273
Lower Big Island	-52	69	10	99	2	0.4	14.4	4,077	242	7,462
Keg Island	-52	26	0	46	1.9	0.2	12.2	4,956	1,384	10,167
Upper and Lower Lilliput	-52	26	26	26	2.5	0.4	9.4	1,939	1,682	2,177
Upper Midnight, Lower Midnight, Reeves Point, Horseshoe Shoal	-52	--	--	--	3.45	1.3	5.6	--	--	--
Snow Marsh	-52	15	0	63	4.6	1.3	10	2,636	2,636	2,636
Lower Swash	-52	36	0	76	5	4	6	1,473	1,473	1,473
Battery Turn	-54	54	54	54	9	4	14.1	--	--	--
Southport, Baldhead-Caswell, Smith Island, Baldhead Shoal Reaches 1 and 2	-54	--	--	--	--	--	--	--	--	--
Baldhead Shoal Reach 3	-54	41	0	100	4.3	0.2	8.5	1,239	969	1,473

Notes:
 General Note: RQD, rock layer thickness, and UCS data are from the full boring data set and were not screened to present data only collected within the proposed dredge cut envelope. UCS data were primarily limited to shallower than El. -50 feet.
^a = Rock layers are based on layers delineated in exploration logs. In some cases, rock layers delineated on logs may comprise a thicker section of rock. For example, in the Turning basin, some explorations encountered a 15 to 20 ft section of rock comprised of several layers.
^b = only 2 test results are reported for this reach.
^c = Compressive strengths are based on laboratory analysis of rock samples. However, results from small lab samples generally yield higher compressive strength results compared to the respective large-scale (i.e. outcrop or formation sized) rocks. Rock strengths discussed herein thus may represent conservative estimates and in-field rock strength will likely be less.
 * Values highlighted in red indicate parameters that exceed thresholds for criteria used to determine if blasting is required (Section 3.3)

3.4 Beneficial Use Characterization

In addition to our assessment of the rock strength and elevation, the additional geotechnical data was evaluated for other beneficial uses. Table 3.1 provides an updated summary of the interpreted subsurface conditions for each channel reach, with the material being categorized based on its potential beneficial use. The following are the basis for material separation, which are partly based on the Beneficial Use Planning Manual (2007):

-
- Category A = Potentially Suitable for Engineering Structural Fill or Beach Nourishment; Fines content typically less than 10%, d50 of at least 0.25 mm and low calcium carbonate content.
 - Category B = Potentially Suitable for Non-Engineered Fill; Fines content typically between 10 and 20%; may include thin lenses of fine-grained deposits.
 - Category C = Potentially Suitable for Low-Quality Fills (e.g. habitat restoration and development, offshore berms, parks and recreation, etc.); Fines content 20 to 25%.
 - Category D = Disposal Area (Upland or Offshore)

Historical grain size test data (e.g. sieve analyses) were compiled and reviewed to support the evaluation of potential beneficial use for future dredge materials. Materials were evaluated for (1) future deepening and (2) widening activities. Grain size parameters evaluated include fines content (percent by weight of particles smaller than 0.075 mm diameter [passing through the No. 200 sieve], median grain size (d50) as determined from sieve analyses, and soil classifications as provided on exploration logs. Table 3.3 presents a statistical summary of the fines content and median grain size for each reach. Figures 4 and 5 provide presentations of the grain size characteristics.

- Figure 4-1: Map that shows fines content and d50 summary of each channel reach,
- Figures 4-2 through 4-6: Graphs of fines content and d50 values plotted referenced to elevation for each reach,
- Figure 5-1: Grain size curve for all data (global plot) symbolized by channel reach, and
- Figures 5-2 through 5-17: grain size curves per reach.
- Also, fines content values and soil classifications are shown on cross sections presented on Charts 2 through 8.

Table 3.1 presents a summary of subsurface conditions and the potential for beneficial use of dredged materials encountered during deepening or widening. The beneficial use assessment presented in this report represents a screening-level assessment of historical data. Although a significant quantity of data is available for this study, several notable limitations regarding the historical data exist:

- Exploration density is variable across the study area and locations with limited or no data exist,
- Explorations depths were primarily limited to above El. -50 feet; most reaches had a few explorations that extended to El. -55 or -60 feet.
- Explorations for widening evaluations were primarily located on the dredge cut slope instead of at the top of slope and may not fully characterize the full vertical profile of a bank-cut for widening areas.
- Materials of potential beneficial that may be encountered during widening were identified in this study. However, some of sandy materials may have fine-grained overburden. We have not incorporated the presence of overburden into the beneficial use evaluation. Future evaluations may need to incorporate the presence of overburden in the beneficial use evaluation. We note that sand bodies of appreciable thickness (e.g. 10 to 15 feet) may underlie overburden and multi-stage dredging may be viable for removing overburden and prior to accessing underlying sandy materials.

Table 3.3: Summary of Fines Content and Median Grain Size

Channel Reach	Fines Content Mean, Standard Deviation (%)	D50 Mean, Standard Deviation (mm)
Anchorage Basin	61 (31)	*
Between Channel	81 (9)	*
Fourth East Jetty	77 (11)	*
Upper Brunswick	6 (*)	0.32 (**)
Lower Brunswick	52 (28)	0.56(**)
Keg Island	23 (26)	0.31 (0.09)
Upper Lilliput	15 (16)	0.47 (0.25)
Lower Lilliput	28 (32)	0.30 (0.09)
Lower Midnight	8 (4)	0.29 (0.10)
Reaves Point	4(*)	0.26(**)
Horseshoe Shoal	7 (3)	0.42 (0.13)
Snows Marsh	18 (14)	0.30 (0.12)
Lower Swash	14 (11)	0.73 (0.90)
Battery Island	10 (14)	0.49 (0.24)
Southport	3 (3)	0.45 (0.22)
Baldhead – Caswell	1 (1)	0.51 (0.17)
Smith Island	7 (18)	0.27 (0.08)
Baldhead Shoal – Reach 1	21 (28)	0.38 (0.20)
Baldhead Shoal – Reach 2	9 (21)	0.22 (0.05)
Baldhead Shoal – Reach 3	19 (25)	0.20 (0.03)
Notes:		
* = insufficient number of data records; sediments were fine-grained and mechanical sieve tests were not able to determine the d50 value due to high fines content		
** = insufficient number of data records to determine standard deviation		

4. SEISMIC DATA LIMITATIONS AND CAPABILITIES

The quality and amount of information obtained with a seismic data set depends on a number of factors including the equipment, acquisition parameters, processing, available tangible data to provide control to interpretation, and the environment.

Equipment can play a significant role in the success of a project. The seismic data used to interpret conditions within the dredge envelope were derived from two EdgeTech 3200 series Chirp systems (SB-216S and SB-512I). The SB-512i Chirp system, with its lower frequency range (0.5 to 12 Hz), was in general able to penetrate deeper than the SB-216S system (2 to 16 Hz). The Chirp seismic data quality is judged to be fair to good and correlated good to very good to the geotechnical data. In general, the Chirp data achieved signal penetration of about 5 to 20 feet for the SB-216S system and 20 to 40 feet for the SB-512I system. The EdgeTech 3200 series Chirp systems are considered to be capable of imaging layers 1 foot or more in thickness. The vertical accuracy of the Chirp system is generally considered to be approximately +/- 2 feet. However, constraining the interpretation of shallowest reflectors to the multibeam-derived water bottom may improve the accuracy beyond +/- 2 feet.

The composition of the soil or rock also plays a part in how well seismic energy can image the subsurface. The presence of a reflector or horizon in the seismic data indicates an impedance contrast (a difference in the velocity that sound can travel through the material) between the material above and below the reflector. If the material above and below a geologic contact are of the same P-wave velocity, a reflector may not be seen in the data and that geologic boundary between materials would be called acoustically transparent. Therefore, correlating soil changes in historical borings with seismic horizons is not always possible. In addition, the presence of a high-amplitude impedance contrast may absorb the bulk of the energy from the seismic source which prevents energy from passing through and imaging deeper reflectors.

In this survey, we estimate that the seismic data imaged what we interpret to be the top of rock along approximately 65 percent of the surveyed length of Wilmington Harbor. The best results are from the Lower Midnight channel reach southward. The data north of the Lower Midnight reach was often obscured by the seafloor multiple and the top of rock could not be seen in the data.

For this survey, the historical geotechnical borings were loaded into a seismic workstation and integrated with the seismic data. This integration of the historical data aided with the correlation of horizons with geologic formations and changes in soil type described on the boring logs. The changes in soil type on the boring logs generally matched well with the elevation of the seismic horizons. The character of horizons H15, H25, and H30 are typically flat or gently dipping surfaces which we interpret to be the tops of the Castle Haynes Limestone Unit B, Unit A, and the Turritellid Limestone respectively (Figures 7 through 9). Above the H15, H25, and H30 reflectors, we interpret there to be mostly sandy unconsolidated material with some paleochannels that contain fine-grained material (silt and clay). Line type and symbology used to depict interpretation of subsurface conditions on Figures 8 through 10 reflect various confidence levels. Dashed lines indicate where a seismic reflector was observed, dotted lines indicate where interpretation of a seismic reflector was uncertain, and question marks indicate areas of additional uncertainty.

5. SUMMARY

The objective of the study is to characterize subsurface materials that may be encountered during future deepening, widening and/or realignment of the navigation channel using data recently acquired in 2017 and integrated with newly acquired historical geotechnical data. This report provides a summary of subsurface conditions interpreted from historical geotechnical data, top of rock mapping performed by others, and multibeam and sub-bottom profiler data collected during a 2017 survey. that the 2017 survey included collecting multibeam bathymetry and Chirp sub-bottom profiler data along two parallel lines along the outer limits of the inner harbor navigation channel. The 2017 survey also included a channel-wide survey using the multibeam and Chirp sub-bottom profiler along the outer reaches of the offshore approach channel. Tie lines were collected at regularly spaced intervals using both survey systems.

Geotechnical data reviewed in this study include 452 borings, over 1,400 washprobes, and 580 vibracores conducted between 1986 to 2013. Borings used in this study include soil sampling, rock coring, and laboratory test information. Washprobes were conducted by others to infer top of rock based on refusal depths and the washprobes did not include sampling of soil and rock materials. The various data were loaded onto a seismic interpretation work station and interpreted. Interpretations, geotechnical data, and bathymetric data were assimilated into a GIS database where mapping, modelling of the top of rock, and graphics (e.g. cross sections, maps, and graphs) were developed using ESRI's GIS software and software modules developed by Fugro.

5.1 Formation Materials (Rock)

One of the primary objectives of the study was to map the top of rock and confirm mapping of top of rock performed previously by others. We provide the following information related to the use of "top of rock" and "top of formation" in this study. "Rock" implies that the materials have undergone lithification (deposits have been subjected to pressure, heat, and/or cementation and lithified as a rock) and exhibit physical properties (e.g. strength) of a rock. "Formation", as adopted herein, refers to materials that have been assigned to a geologic formation and been given a formation name (e.g. Castle Hayne formation). Formation materials may exhibit properties similar to a rock or soil (e.g. dense to very dense sand or hard clay). In this study, we have interpreted seismic horizons (or reflectors) and interpreted their association with formations. In the inner harbor, the interpreted seismic horizons generally correlate well with rock intervals described on exploration logs and top of rock mapping presented by others.

The compressive strength presented in this report are based on laboratory analysis of rock samples. However, results from small lab samples generally yield higher compressive strength results compared to the respective large-scale (i.e. outcrop or formation sized) rocks. Rock strengths discussed herein thus may represent conservative estimates and in-field rock strength will likely be less.

The January 2018 report provided a comparison between the top of rock surface interpretation based on the 2017 survey and interpretation presented in previous studies. In general, the interpreted elevation agreed reasonably well and were within approximately 5 feet of each other where survey lines were collocated. The following section presents an updated characterization of site conditions based on the 2017

survey (report issued in January 2018) and additional historical geotechnical data received after issuance of the January 2018 report).

It is our understanding that current studies are evaluating the feasibility of various deepening scenarios that include:

- Turning Basin to Lower Swash to El. -52 feet
- Battery Turn to Baldhead Shoal Reach to El. -54 feet
- We also understand that shallow scenarios are considering deepening to El. -47 feet.

The following summary applies for the deeper scenario (El. -52/-54 feet).

5.1.1 Deepening in Turning Basin (Anchorage)

Past deepening dredging appear to have excavated into the formation materials inferred to be limestone materials from the Peedee formation. Existing channel bottom elevation in the Turning Basin (Anchorage) reach is shallower than down-reach (e.g. Between Channel, Fourth East Jetty, etc.). Therefore, deepening to El. -52 feet in the Turning Basin will likely encounter more rock than elsewhere and cuts may encounter approximately 10 to 12 feet of rock in the Turning Basin. The average UCS test results in the Turning Basin (Anchorage) data is approximately 624 psi and the maximum test result that we reviewed was 2,286 psi.

5.1.2 Between Channel, Fourth East Jetty, Upper Brunswick, and Lower Brunswick

Formation materials in these channels are described as limestone comprised of thin layers typically 2 feet or less thick. Past dredging activities appear to have encountered the formation materials. Future deepening to El. -52 feet is anticipated to encounter formation materials. Average report UCS test result is only 2,318 psi but test results as high as 4,924 psi were reported.

5.1.3 Upper Big Island, Lower Big Island and Keg Island

Future deepening is expected to encounter limestone and sandstone of the Castle Hayne and Peedee formations (Chart 3). Past dredging may have encountered formation materials and the limestone/sandstone may be at or very near the existing channel bottom. Average reported UCS for Upper Big Island, Lower Big Island, and Keg Island are approximately 4,258, 4,077, and 4,956 psi, respectively. Rock strength test results as high as 12,273 psi (Upper Big Island) and 10,167 psi (Keg Island). Other parameters such as RQD and layer thickness (Table 3.3) indicate the rock may require blasting according to the classification system described in Section 3. Figure 10 presents the approximate extent of this medium strong rock zone that may require blasting.

5.1.4 Upper Lilliput and Lower Lilliput

The top of rock elevation is interpreted to vary in these reaches. Several sections along the channel that are where rock is interpreted to be shallower than El. -52 feet and may have been previously encountered during past deepening activities. Those channel distances range from approximately 100 to 500 feet along

the channel where rock may be shallower than El. -52 feet. The rock is described as limestone and sandstone from the Peedee and Castle Haynes formations.

5.1.5 Upper Midnight, Lower Midnight, Reaves Point, Horseshoe Shoal

Top of rock is interpreted to be lower than El. -52 feet and is not anticipated to be encountered.

5.1.6 Snows Marsh

Top of rock is interpreted to be shallower than El. -52 feet along approximately 500 feet of channel in the central portion of the Snows Marsh reach (Charts 5 and 6). Exploration logs describe the materials as limestone one rock strength test result of 2,636 psi was reported for this material.

5.1.7 Lower Swash, Battery Island, and Southport

Top of rock is interpreted to reach the existing channel bottom in Lower Swash and Battery Island and may have been encountered during past dredging (Chart 6). The materials are described as limestone from the Castle Haynes formation. One UCS test result was reported at 1,473 psi for this area (Table 3.3). The top of rock is interpreted to deepen to the south from Battery Island and may transition below El. -54 feet (dredging interval) in Southport reach (Chart 6).

5.1.8 Baldhead-Caswell, Smith Island, Baldhead Shoal Reaches 1 and 2

Top of rock is interpreted to be lower than El. -54 feet and is not anticipated to be encountered.

5.1.9 Baldhead Shoal Reaches 3

Localized areas formation (rock) materials are interpreted to be present shallower than El. -54 feet. USC strength data is limited and the average strength was reported to be 1,239 psi and the highest reported test we identified was 1,473 psi.

5.2 Beneficial Use Material Summary

5.2.1 Anchorage (Turning) Basin, Between Channel, and Fourth East Jetty

Deepening of the main channel may encounter a thin amount of sand of variable thickness that overlies formation material (Peedee formation). The toe and bank-cuts are likely to encounter predominantly fine-grained deposits that overlie sandy deposits of about 3 to 8 feet in thickness that overlie formation materials (Chart 2). Materials encountered during deepening or widening this channel section are not anticipated to be desirable for construction or beach nourishment and considered to Category D.

5.2.2 Upper Brunswick, Lower Brunswick. Upper Big Island, and Lower Big Island

Deepening of the main channel in these reaches is likely to encounter thin sandy deposits with high fines contents that overlie formation material (Peedee and Castle Hayne formations). Widening may encounter interbedded sandy and fine-grained deposits (Chart 3). The sandy deposits are described as silty and clayey sand. Laboratory test data is limited and not available in much if this area. Widening and deepening dredge materials are not anticipated to be desirable for construction or beach nourishment projects.

5.2.3 Keg Island, Upper Lilliput, Lower Lilliput

Historical explorations indicate that the deepening may encounter Peedee and Castle Haynes formations that underlie pockets of sandy materials. Widening activities may encounter areas of 15 to 20 feet thick of sandy deposits and sections where fines content is less than 20 percent. Bank cuts may have a fine-grained overburden near the top of the cut (Chart 3). Historical data indicate that the fines contents may be less than 10 percent in areas and Category A/B material may be present in the lower section of the bank cut.

5.2.4 Upper and Lower Midnight

Very little laboratory test data is available for this reach. Exploration logs indicated that the deepening may be encounter sandy to clay sand and fine-grained deposits. The banks appear to be comprised of fine-grained deposits with thin lenses of sandy deposits (Chart 4). Widening and deepening dredge materials are not anticipated to be desirable for construction or beach nourishment projects.

5.2.5 Reaves Point and Horseshoe Shoal

Little geotechnical information is available for Reaves Point; however, the exploration logs describe material that is similar to Horseshoe Shoal reach. Geotechnical data from Horseshoe Shoal indicate that deepening and widening may encounter sandy deposits with fines contents of less than 18 percent. Some exploration logs described fined grained layers in the bank-cut up about 10 feet thick. Category A/B material may be present in deepening and widening cuts in these reaches.

5.2.6 Snows Marsh

Very limited geotechnical data is available for this reach. Geophysical and geotechnical data suggest that deepening may encounter formation materials (limestone) and widening maybe sandy to fine-grained deposits (Chart 5) that has been classified as Category C/D materials.

5.2.7 Lower Swash, Battery Island

Widening along these reaches may encounter good quality material with fines content less than 20 percent and in some areas less than 10 percent (Figure 4e). Deepening is likely to encounter Castle Haynes formation (limestone). Widening activities may encounter Category A/B materials but deepening is anticipated to encounter formation materials (Chart 6).

5.2.8 Battery Island, Southport, Baldhead-Caswell, Smith Island, Baldhead Shoal Reach 1, Baldhead Shoal Reach 2

Widening of these reaches may encounter sandy material with exceptionally low fines content. Battery Island average fines content is 11 percent while Southport, Baldhead-Caswell and Smith Island laboratory test mean values for fines contents are 5 percent or less. Category A/B materials are likely present in these reaches. Baldhead Shoal Reaches 1 and 2 had similar sand in the banks (fines content < 5 percent) however, exploration logs also indicate fine-grained layers may be present in the bank cut. For example, the west bank in Baldhead Shoal Reach 1 appears to be predominantly clay while the east bank appears to be predominantly sand (Chart 6). Baldhead Shoal Reach 2 appears to have sand in the bank cuts that may be 10 to 20 feet thick that overlies a silt is present between approximately El. -35 and -45 feet. We

understand that historically dredged materials in these reaches have been placed on beaches. Future disposal planning should take into consideration that these reaches may contain fine-grained layers (e.g. west bank along Baldhead Shoal Reach 2).

5.2.9 Baldhead Shoal Reach 3

Geotechnical data in this reach indicate deepening and widening may encounter alternating layers of sandy and silty deposits. A surficial layer of sandy sediments approximately 5 to 8 feet thick may be present in the channel banks (Chart 7). Deepening and widening materials in this reach have been categorized as C/D materials due to the presence of fine-grained layers (Table 3.1).

5.3 GIS Database

As part of the deliverable, we prepared a GIS Database that included a digital elevation model that represents the interpreted top of rock. The modelled top of rock incorporates results from interpretation of the 2017 data and previous mapping by others. The modelled surface generally adopts mapping by others with the exception the three notable areas.

- i. Areas where the interpreted top of rock surface goes above the current channel bottom, as defined by either the most recent organization hydrographic survey, we inferred that subsequent channel dredging activities had already encountered this top of rock surface and the current top of rock is now at the channel bottom surface or just below a thin sediment cover. This lowering of the top of rock surface to the current channel bottom, where applicable, is reflected in our digital surface which accompanied this report.
- ii. The areas of Snows Marsh channel to Baldhead Shoal Reach 3, the organization mapped several horizons (H15, H25, and H30) which appear to stratigraphically correlate to the Castle Hayne Unit A/B and the Turritellid Limestone (Figure 10). The seismic stratigraphic character also suggests the reflectors may correlate to weak rock or possibly dense soils. Horizons H15 and H25 are generally shallower than the interpreted top of rock previously done by others (Figure 10). In those areas, the interpretation by others generally correlate with the organization's deepest interpreted horizon (H30) which we infer to represent the top of the Turritellid Limestone. Examining our data in this region (Figure 10) there are two high-amplitude reflectors interpreted above (or shallower than) horizon H30 and are separated by seismically acoustic transparent areas (Figure 10). High-amplitude reflectors are generated at interfaces between materials with strong seismic impedance contrasts. Impedance is the product of the material's density multiplied by the seismic compressional wave velocity (V_p).

Washprobes conducted in this area shown in Figure 10 indicate that probes terminated or met refusal at depths that correlate with Horizon H15 (3 washprobes between distance offsets 4600 to 6600) and Horizon H25 (2 washprobes between distance offsets 8000 and 9000). Refusal of the washprobes and the high-amplitude character of the seismic horizons suggest that horizons H15 and H25 may represent the top of a formation unit (e.g. Castle Haynes units) that is rock. However, we note that some washprobes appear to have penetrated below horizons H15 and H25 and refused at depths that correspond to Horizon H30. Those observations may indicate that the material directly below Horizons 15 and H15 may exhibit properties similar to dense or hard soils instead of rock. However, the

washprobes do not recover physical samples that can be observed and tested and the physical properties of the materials between Horizons H15 and H30 are uncertain. Therefore, when creating the digital top of rock modelled data, we have conservatively assumed the shallowest seismic horizons (e.g. H15) in this area represent the top of rock. If future dredging will encroach below Horizons H15 and H25 in this area, we recommend that appropriate geotechnical explorations should be conducted to assess the physical properties of those materials and assess the dredging feasibility or methods.

- iii. In order to support high-level assessments of where widening and re-alignments of channels may encounter rock, we extrapolated the top of interpretation approximately 300 feet beyond the extent of the existing data. The extrapolation is adopted the continuation of the geologic or topographic trends in the data. The extrapolation data area provided to the project team to aid in supporting high level assessments. The extrapolated data are not suitable for design or detailed dredging cost estimates. Future engineering analyses and dredging cost estimates should acquire appropriate survey and geotechnical data to determine the presence, elevation, thickness, and physical properties of rock in the extrapolated zones or areas without data coverage to determine implications to future dredging or construction activities.

This study also evaluated potential opportunities for beneficial use of future dredge materials. Several areas were identified as containing material that potentially be used for fill or beach nourishment projects. Interpretation of geotechnical and geophysical data suggest that channel flanks in Keg Island through Lower Lilliput and Horseshoe Shoal reaches likely contain material low fines content and may be desirable for use as fills. Lower Midnight, Reaves Point, Lower Swash reaches and north of the Anchorage Basin reach appear to have materials with a low fines content and may be desirable for repurposing as Category A and B materials (refer to Section 4). The other channel reaches appear to contain material with high fines content or substantial interbeds of fines (clay and silt) and do not appear to desirable for fills and beach nourishment projects and are considered to be Category C and/or D materials (refer to Section 4).

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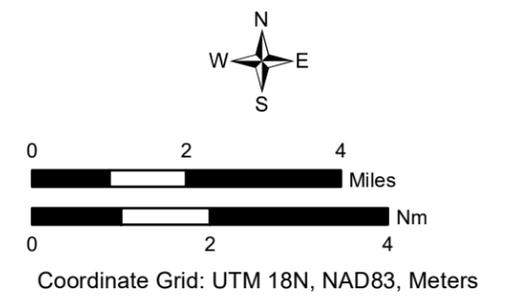
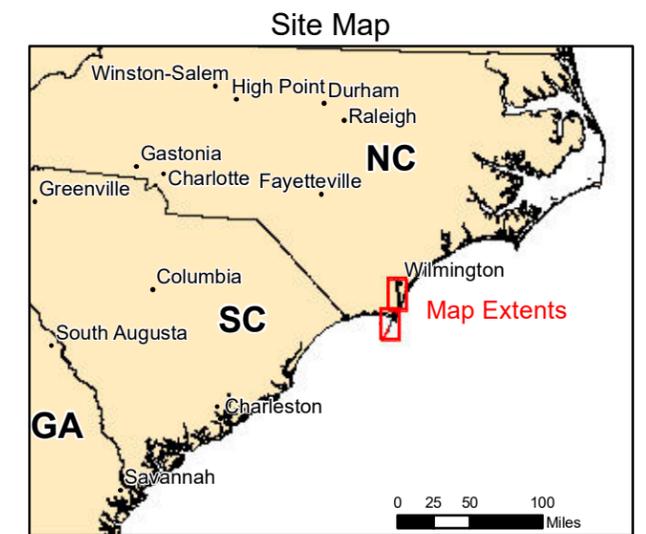
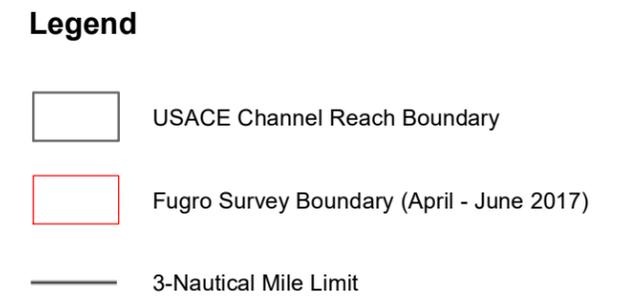
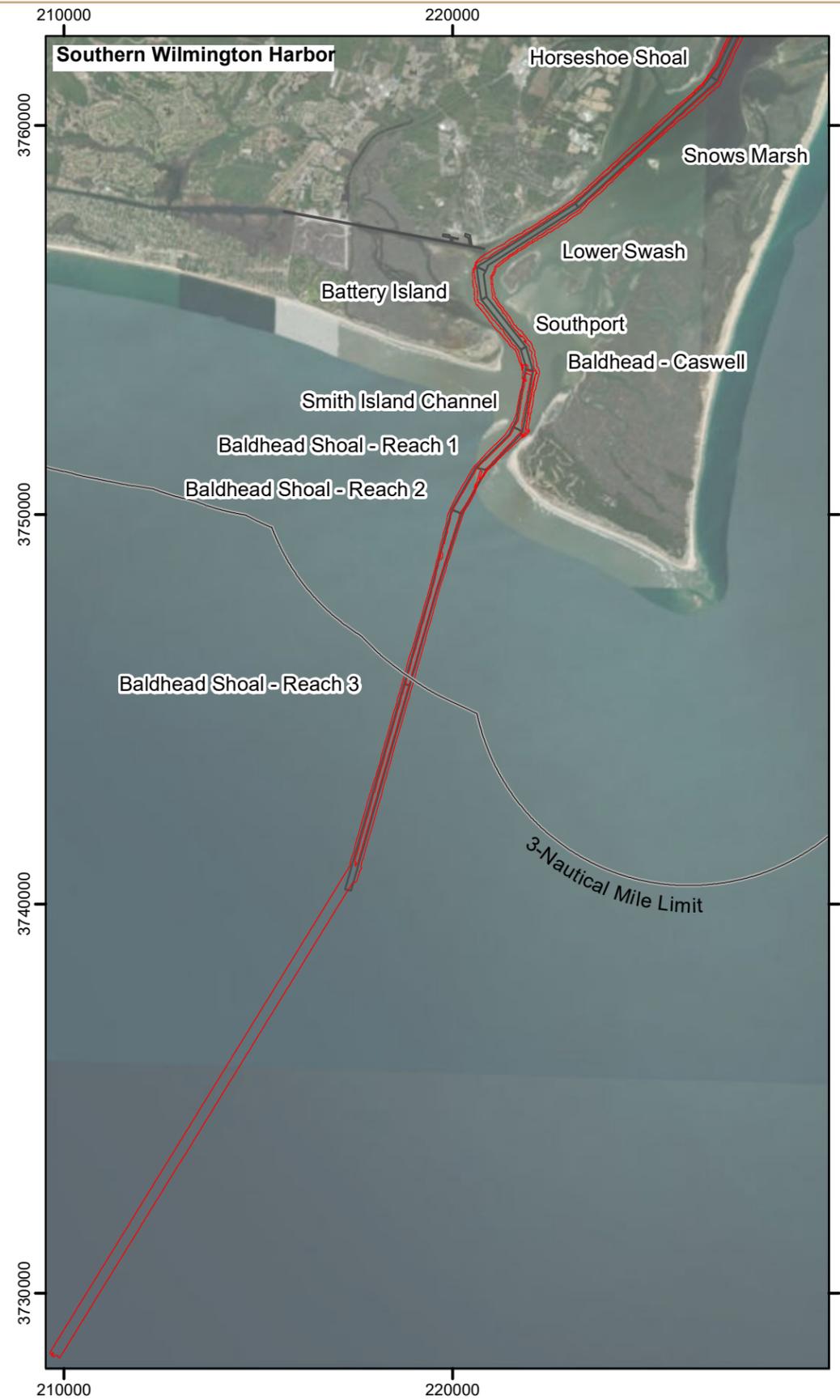
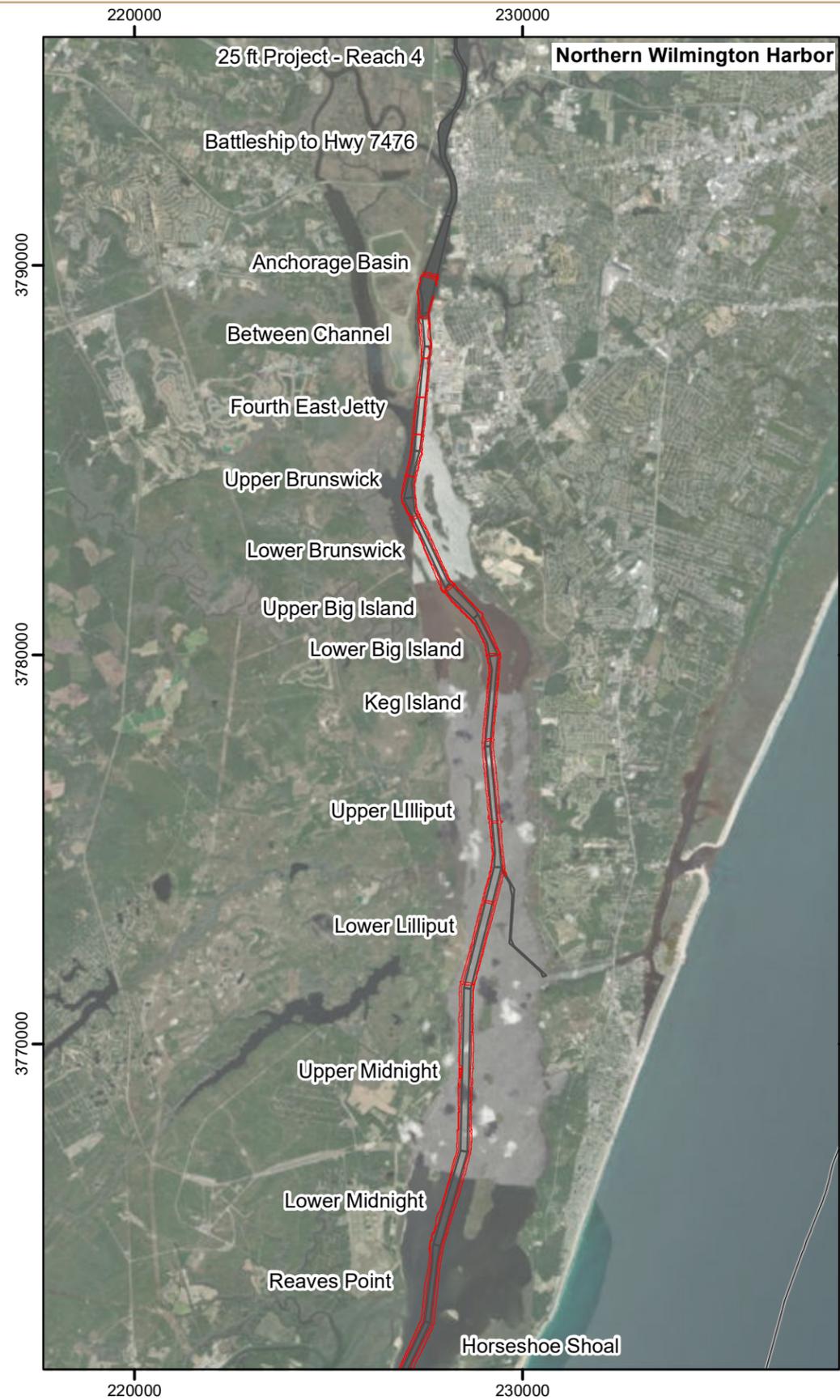
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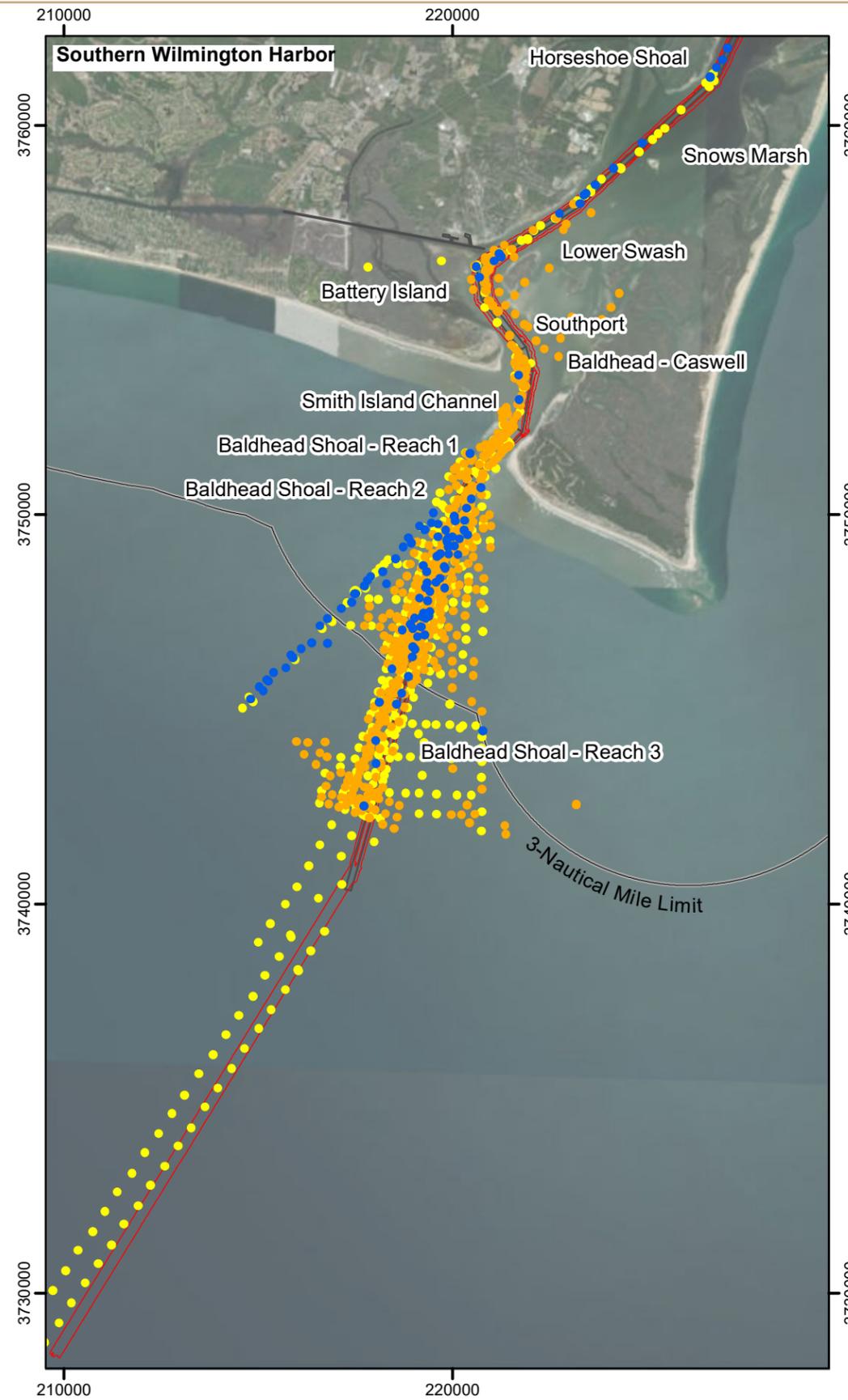
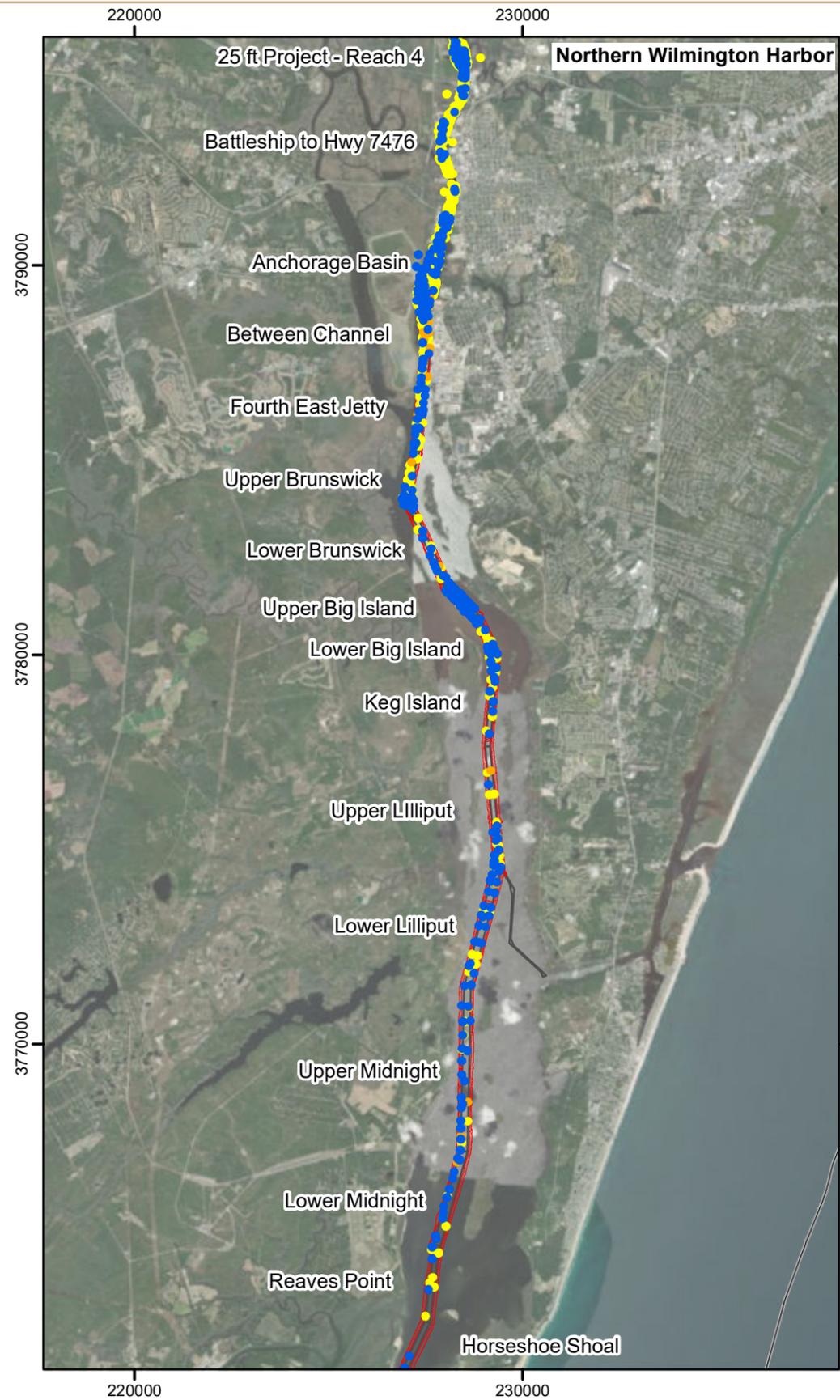
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FIGURES

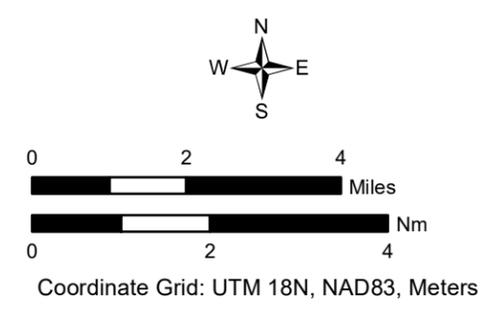
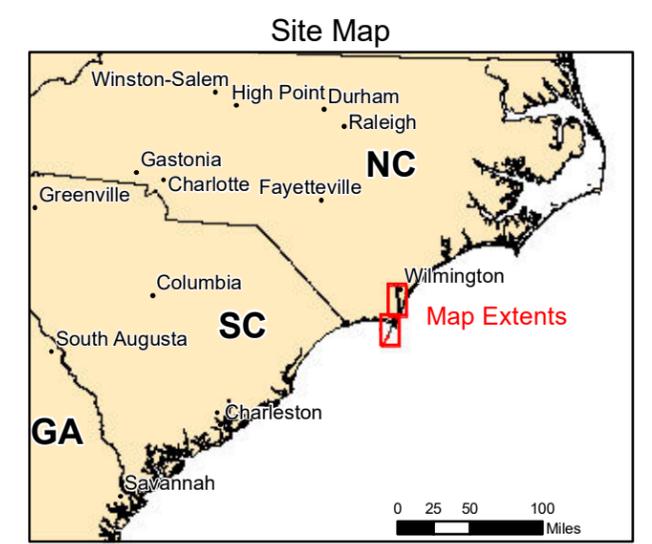


STUDY AREA
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 1

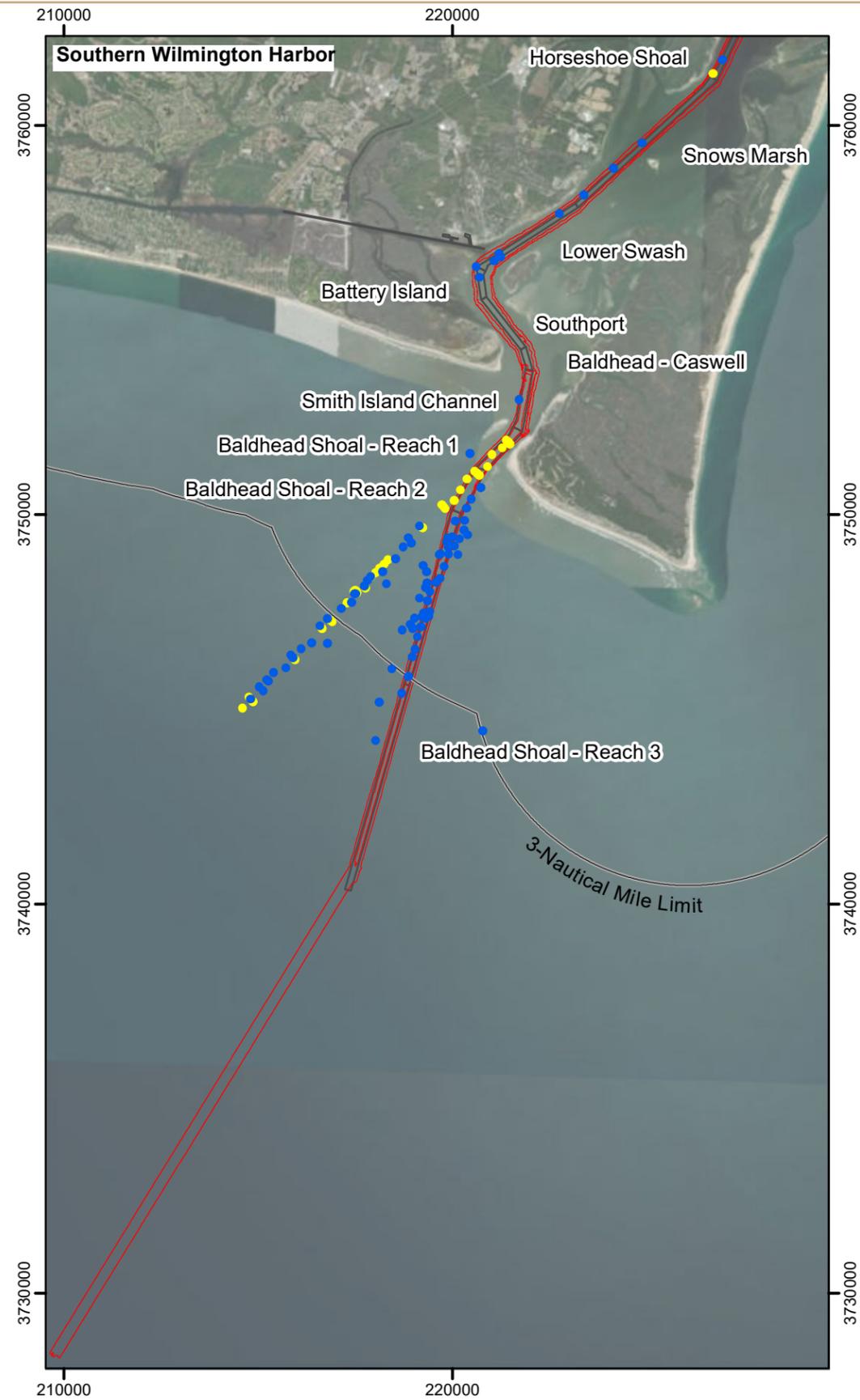
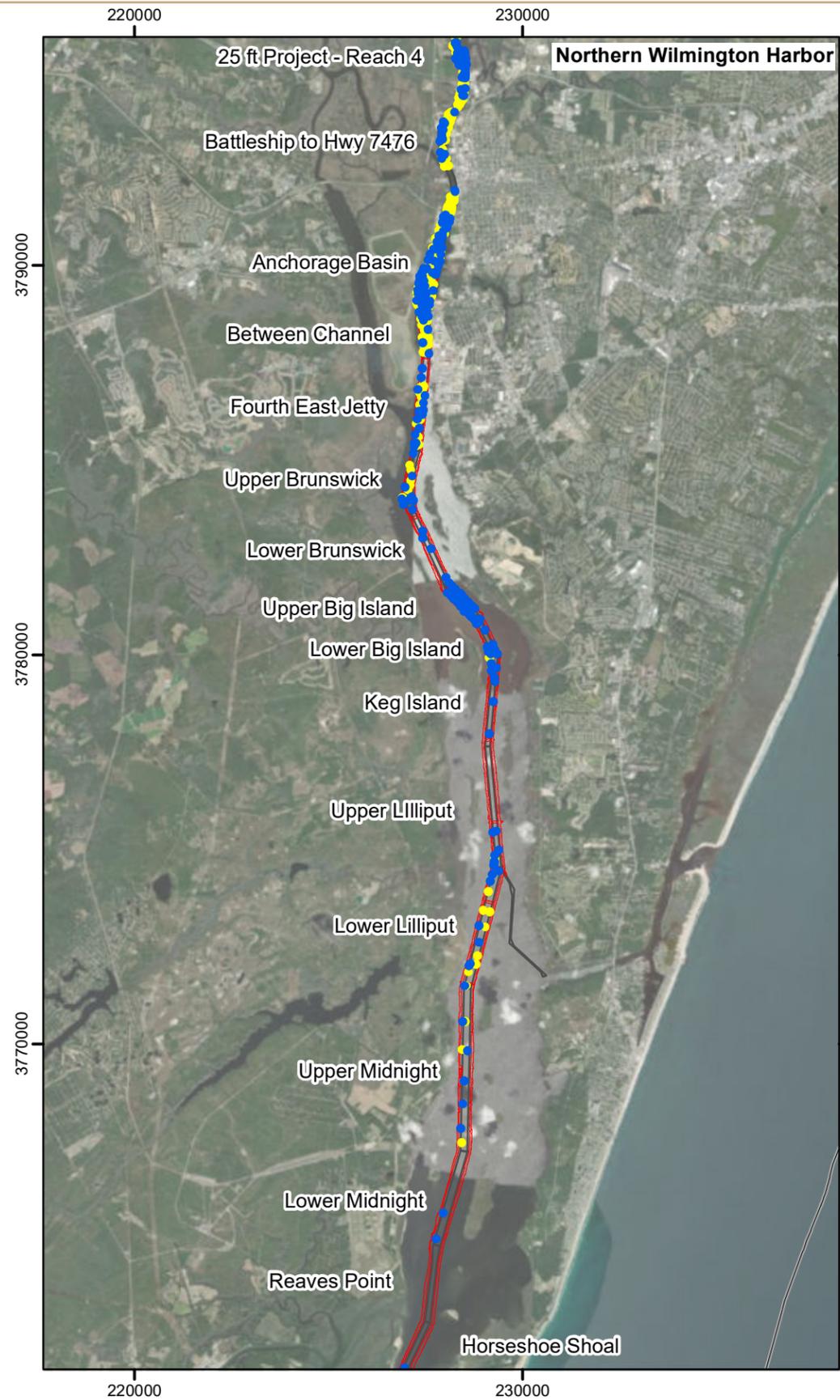


- Legend**
- USACE Channel Reach Boundary
 - Fugro Survey Boundary (April - June 2017)
 - 3-Nautical Mile Limit
 - Existing Boring data used in this study
 - Existing Vibracores data used in this study
 - Existing wash probes used in this study

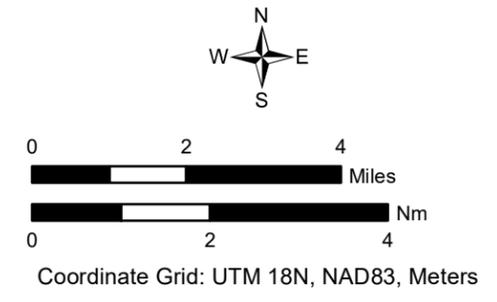
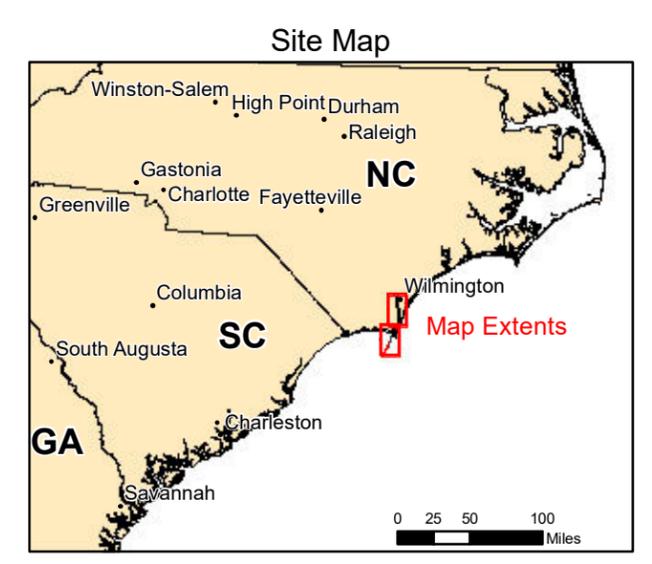


EXPLORATION LOCATIONS
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 2-1

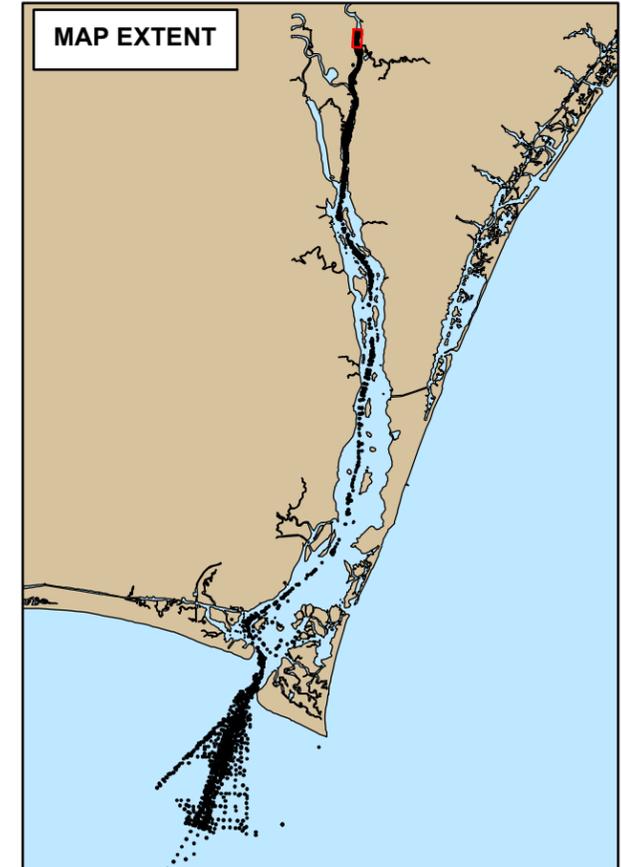
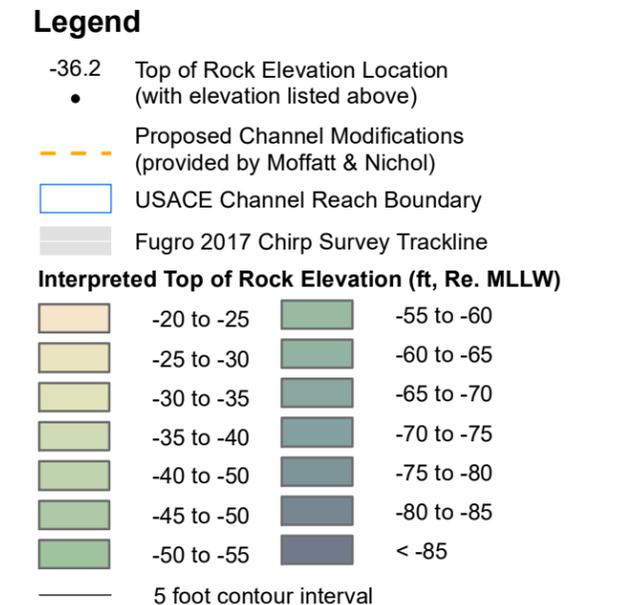
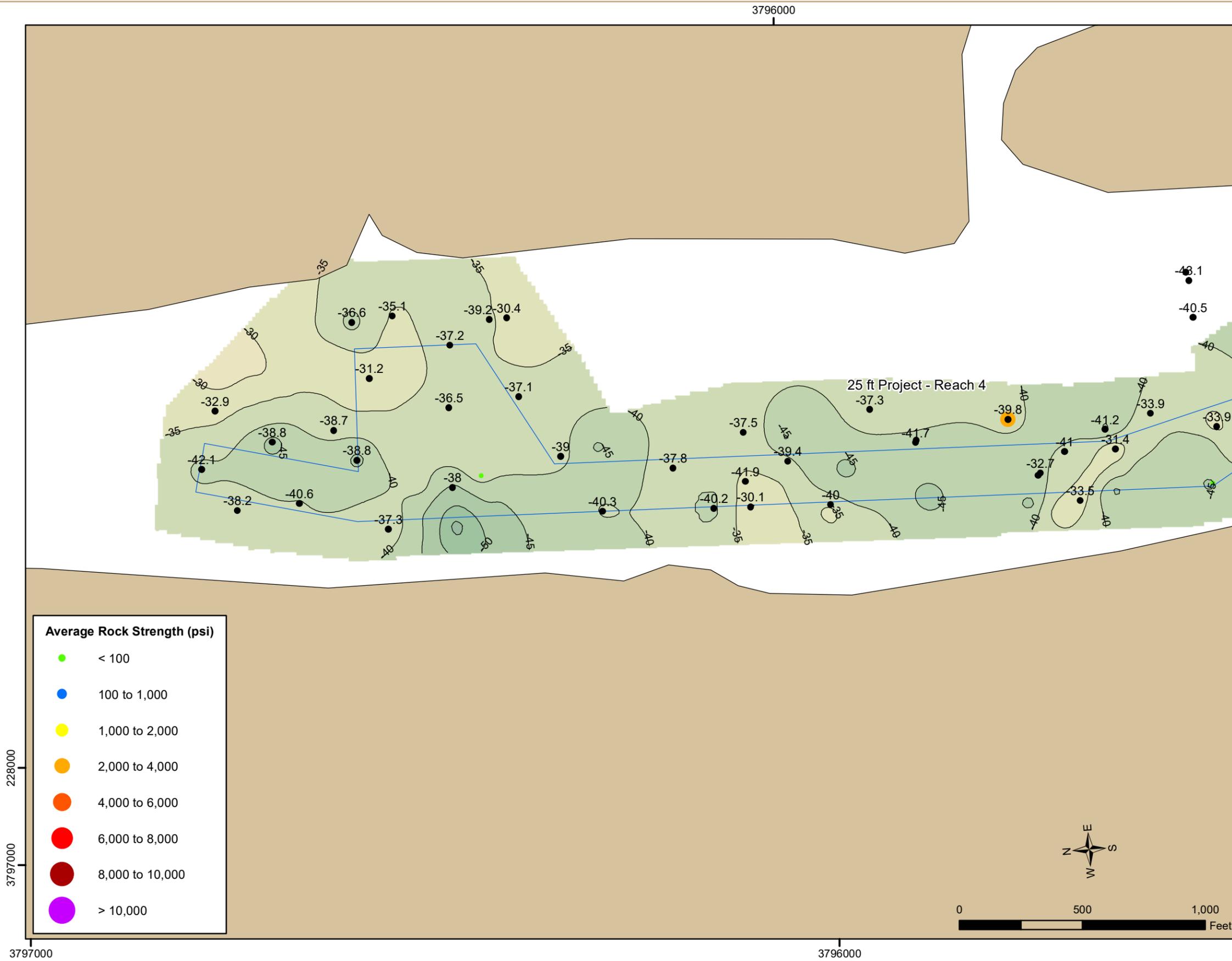


- Legend**
- USACE Channel Reach Boundary
 - Fugro Survey Boundary (April - June 2017)
 - 3-Nautical Mile Limit
 - Top of Rock Measurement (Boring)
 - Top of Rock Measurement (Wash probe)



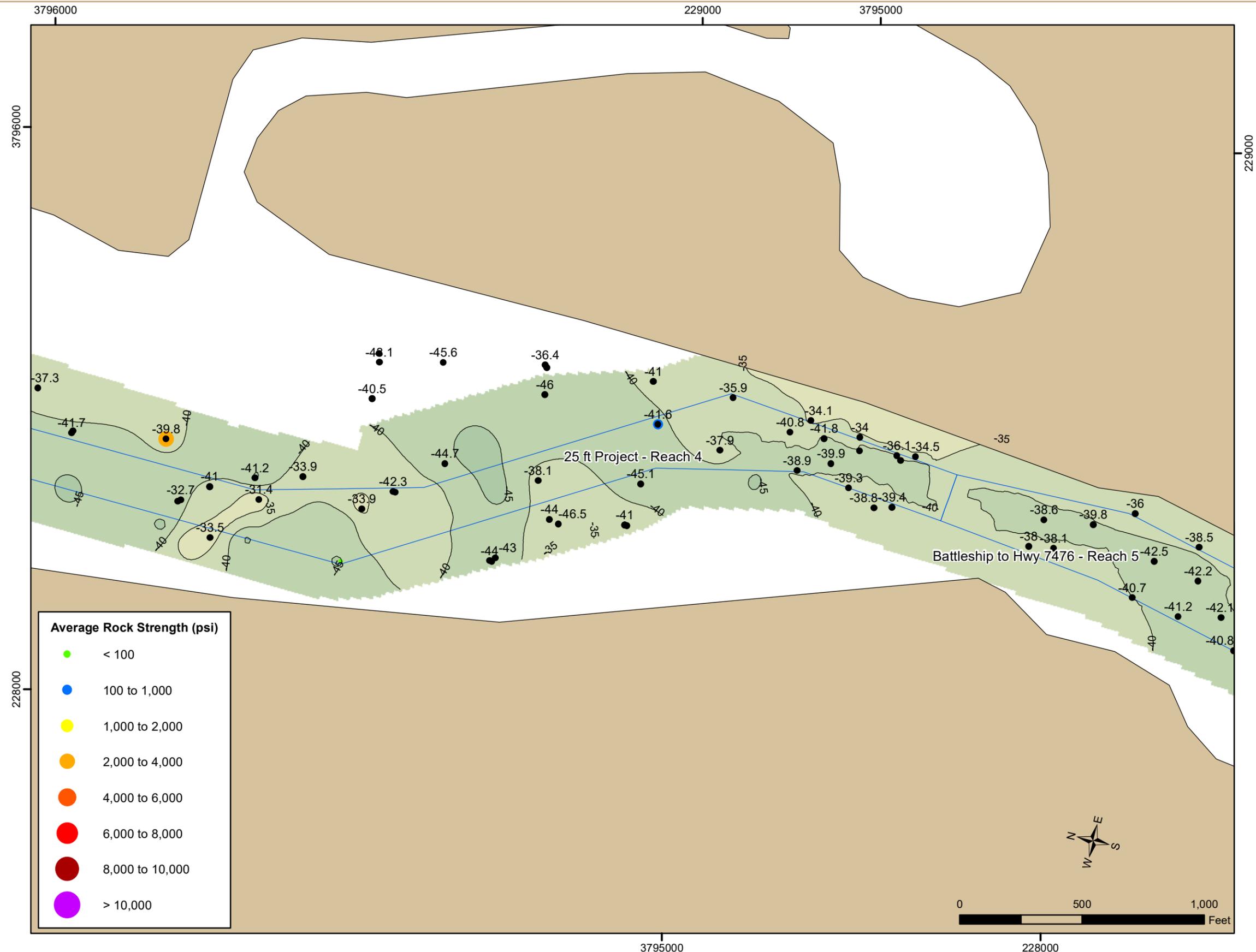
USACE TOP OF ROCK LOCATIONS
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 2-2



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-1



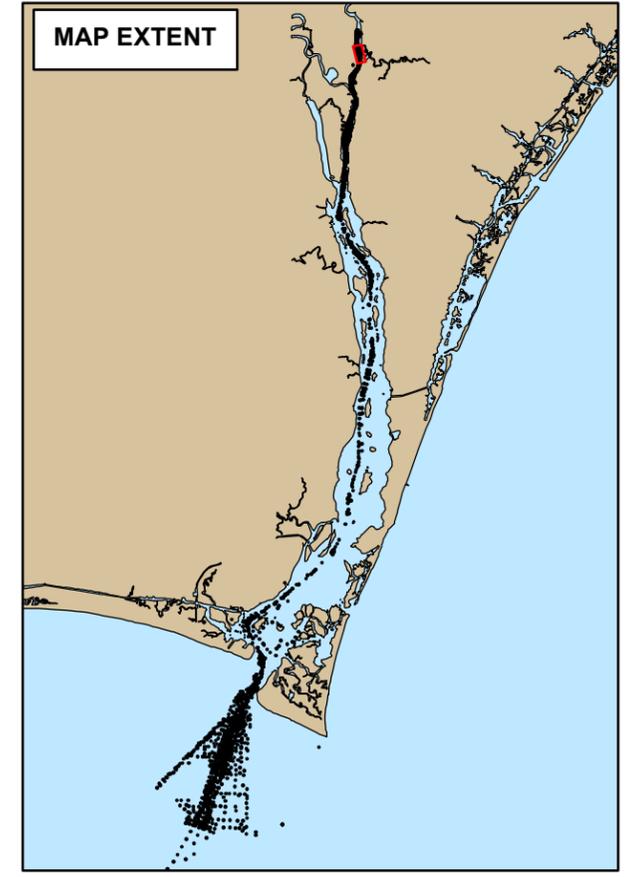
Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
- Proposed Channel Modifications (provided by Moffatt & Nichol)
- USACE Channel Reach Boundary
- Fugro 2017 Chirp Survey Trackline

Interpreted Top of Rock Elevation (ft, Re. MLLW)

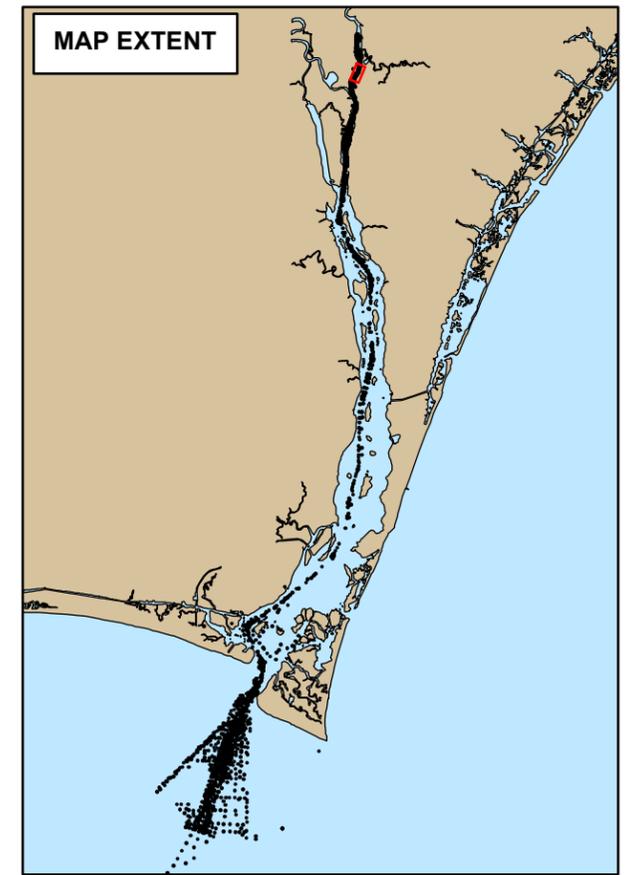
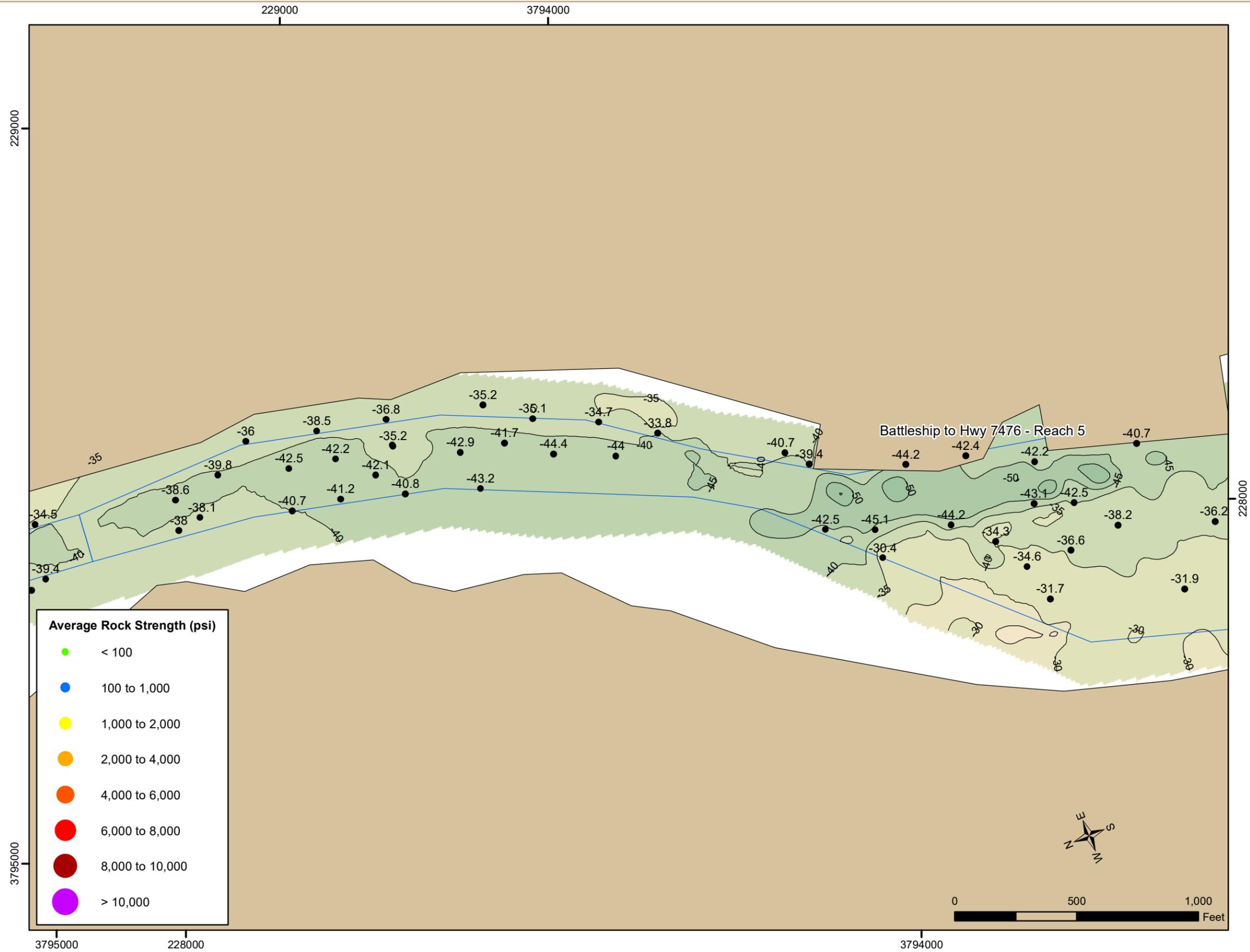
-20 to -25	-55 to -60
-25 to -30	-60 to -65
-30 to -35	-65 to -70
-35 to -40	-70 to -75
-40 to -50	-75 to -80
-45 to -50	-80 to -85
-50 to -55	< -85

5 foot contour interval



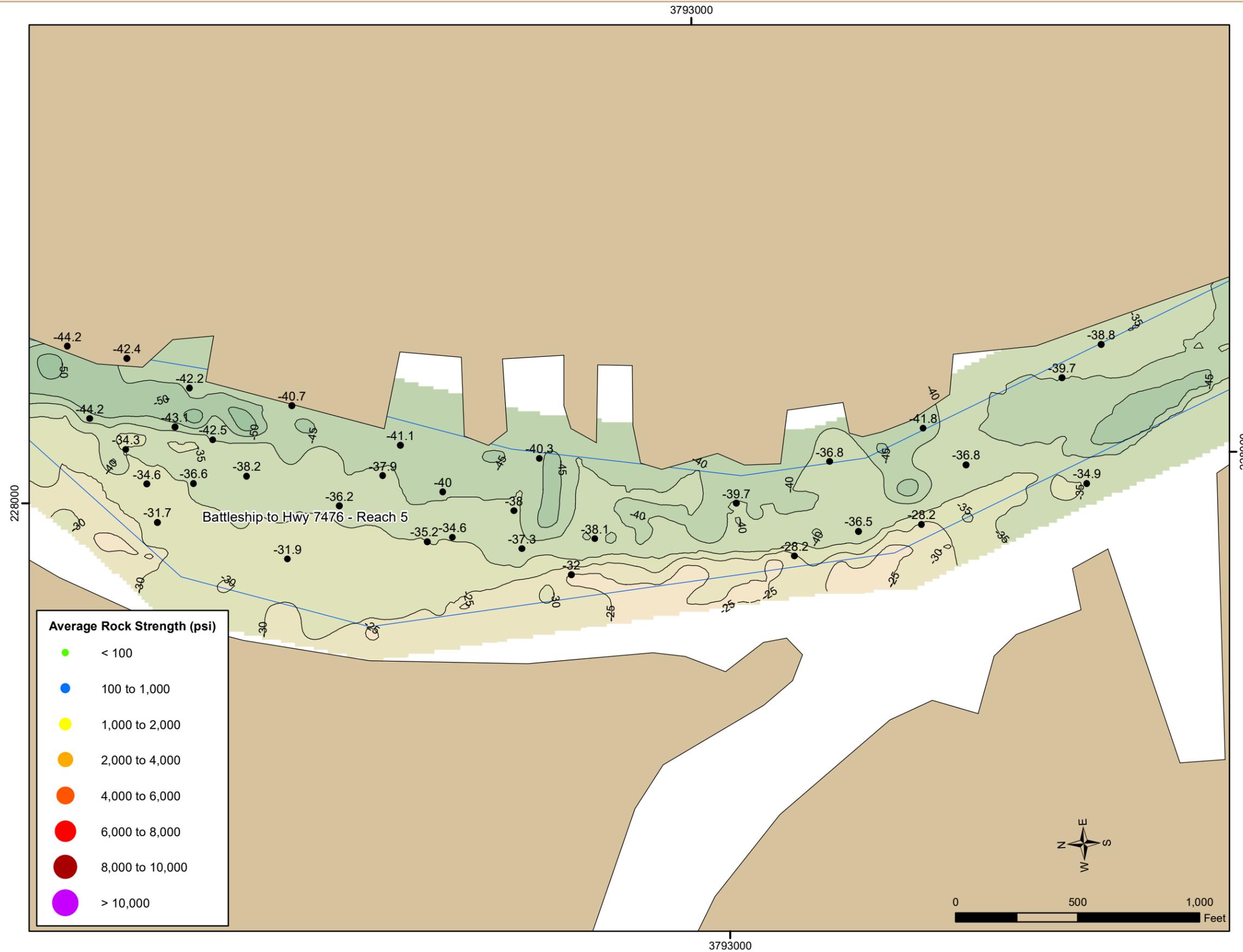
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-2



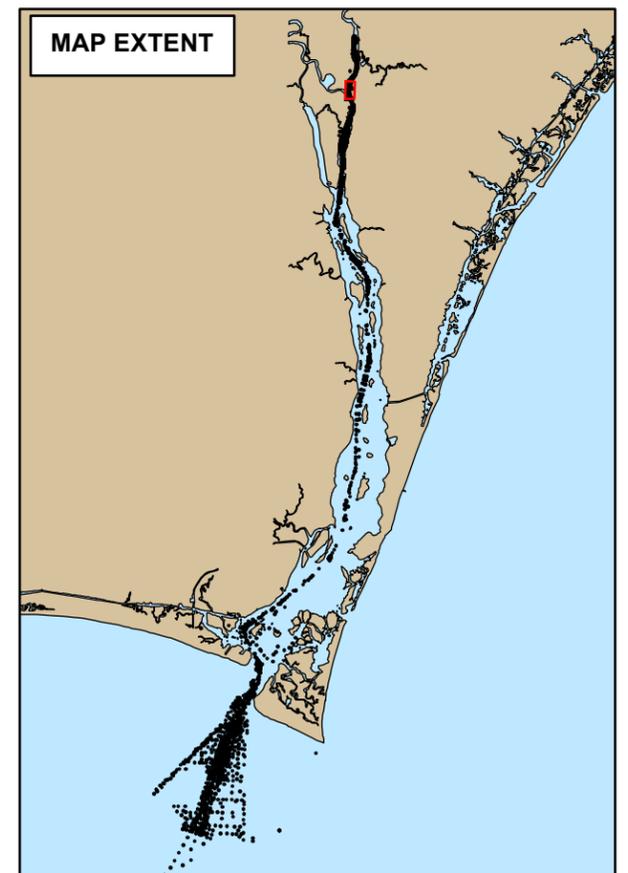
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-3



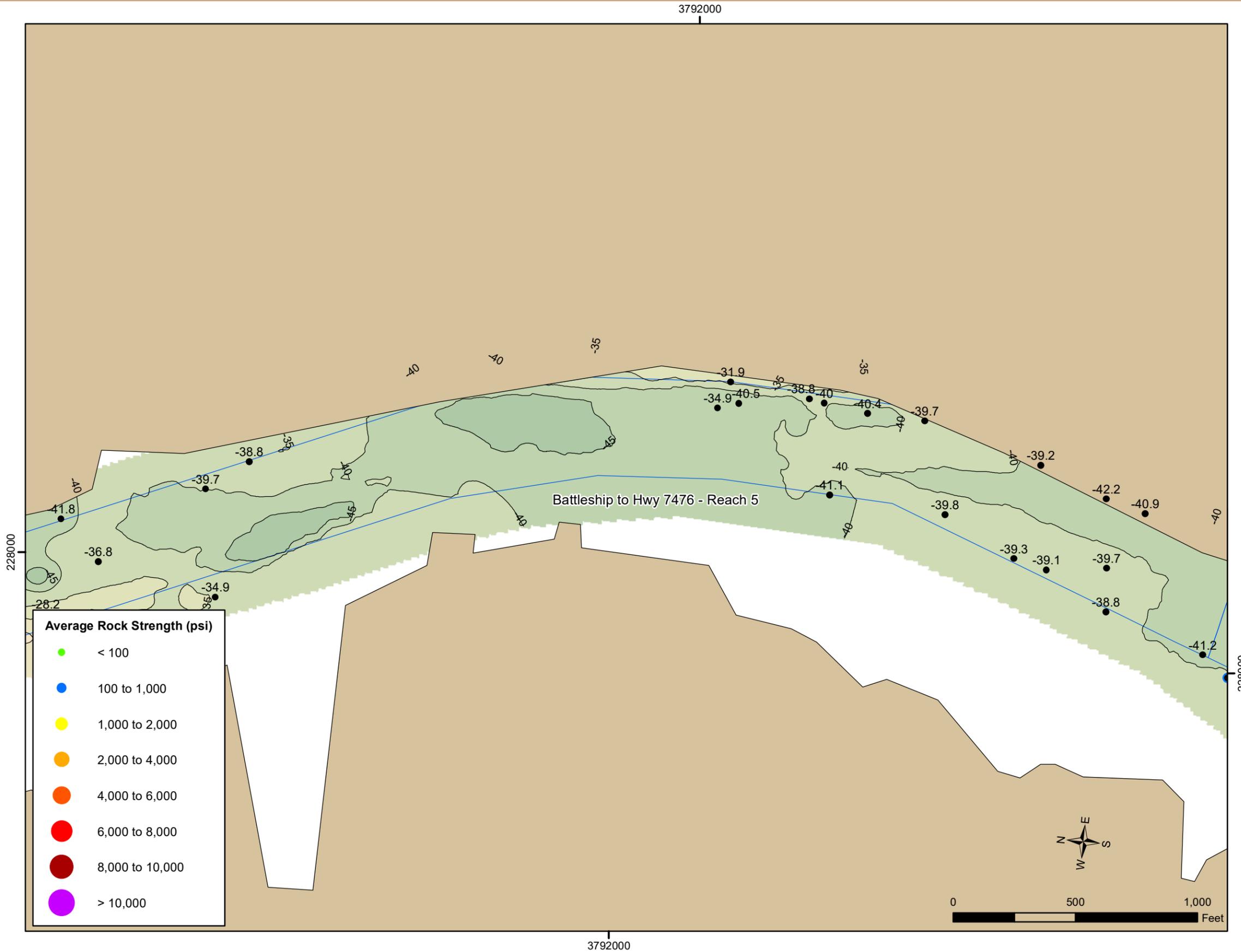
Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
 - Proposed Channel Modifications (provided by Moffatt & Nichol)
 - USACE Channel Reach Boundary
 - Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft, Re. MLLW)**
- | | |
|------------|------------|
| -20 to -25 | -55 to -60 |
| -25 to -30 | -60 to -65 |
| -30 to -35 | -65 to -70 |
| -35 to -40 | -70 to -75 |
| -40 to -50 | -75 to -80 |
| -45 to -50 | -80 to -85 |
| -50 to -55 | < -85 |
- 5 foot contour interval



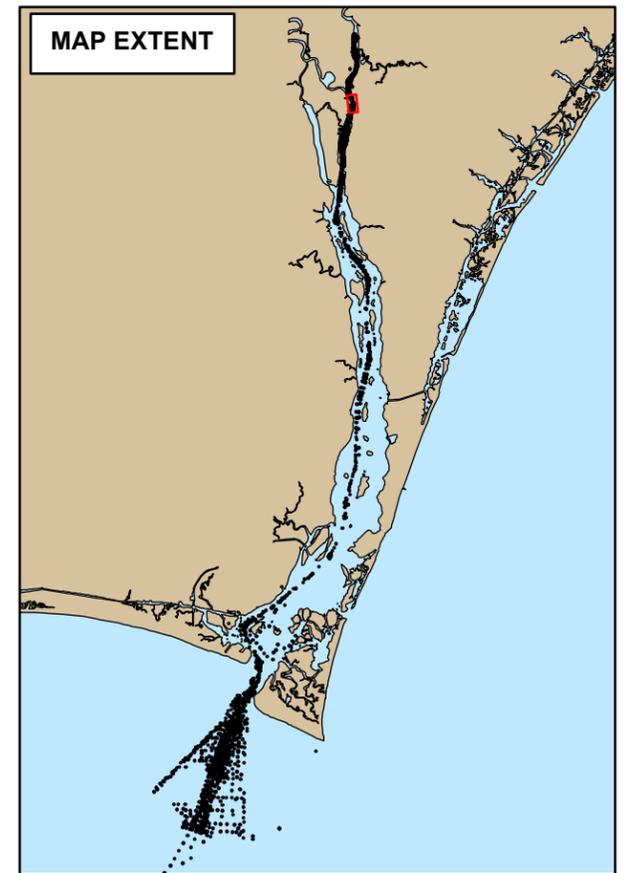
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-4



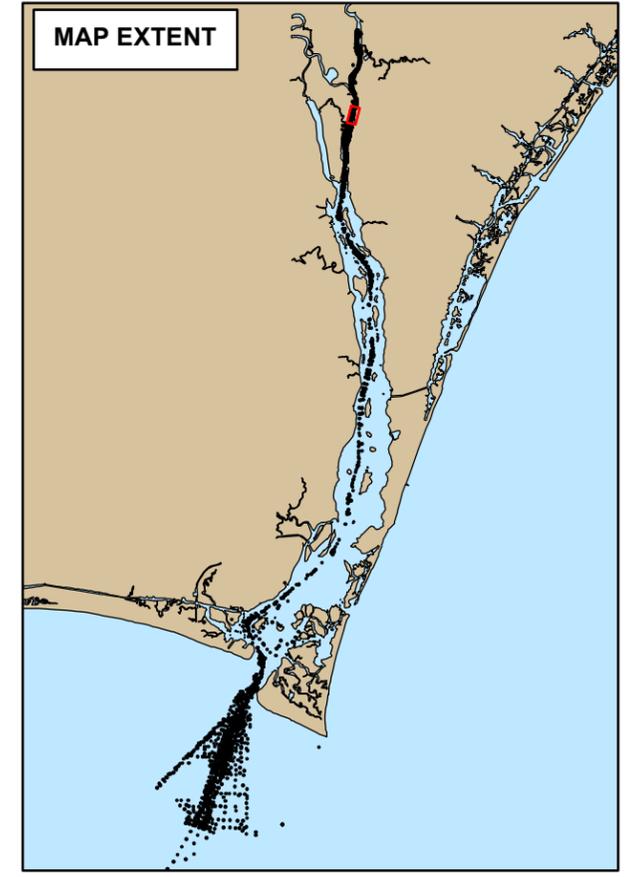
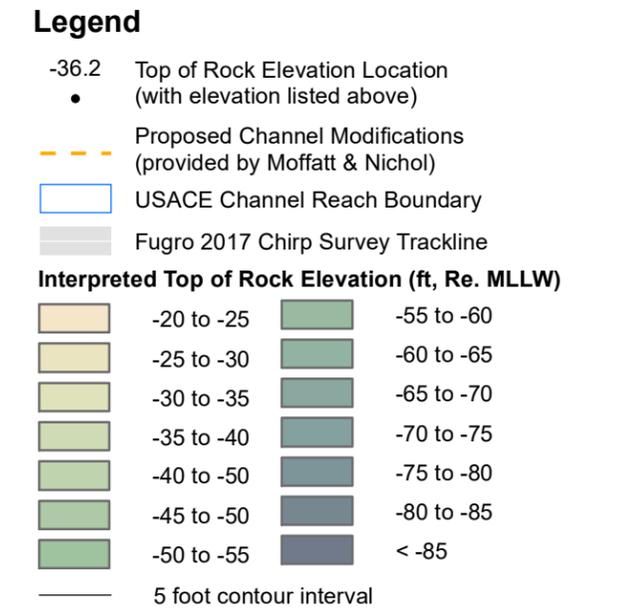
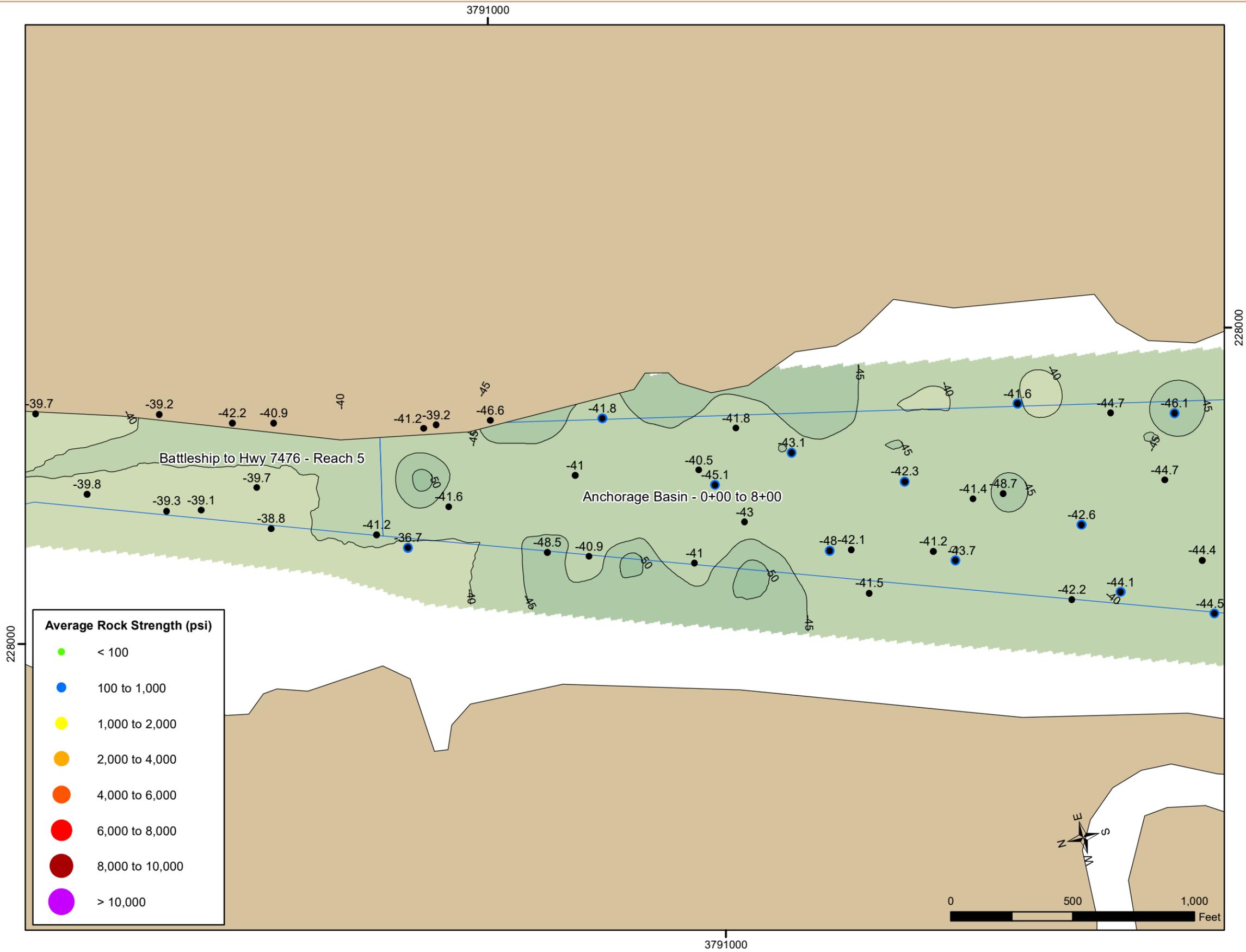
Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
 - Proposed Channel Modifications (provided by Moffatt & Nichol)
 - USACE Channel Reach Boundary
 - Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft, Re. MLLW)**
- | | |
|------------|------------|
| -20 to -25 | -55 to -60 |
| -25 to -30 | -60 to -65 |
| -30 to -35 | -65 to -70 |
| -35 to -40 | -70 to -75 |
| -40 to -50 | -75 to -80 |
| -45 to -50 | -80 to -85 |
| -50 to -55 | < -85 |
- 5 foot contour interval



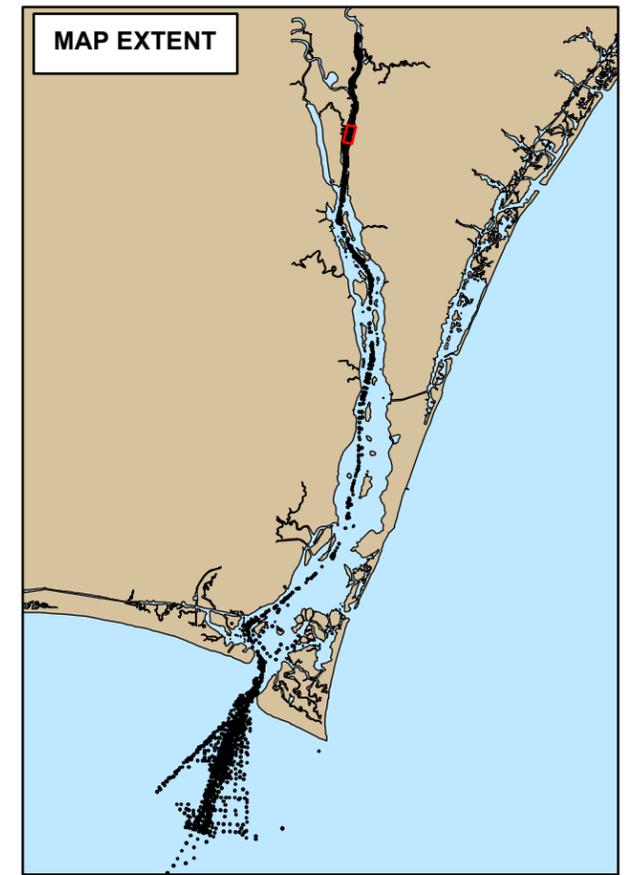
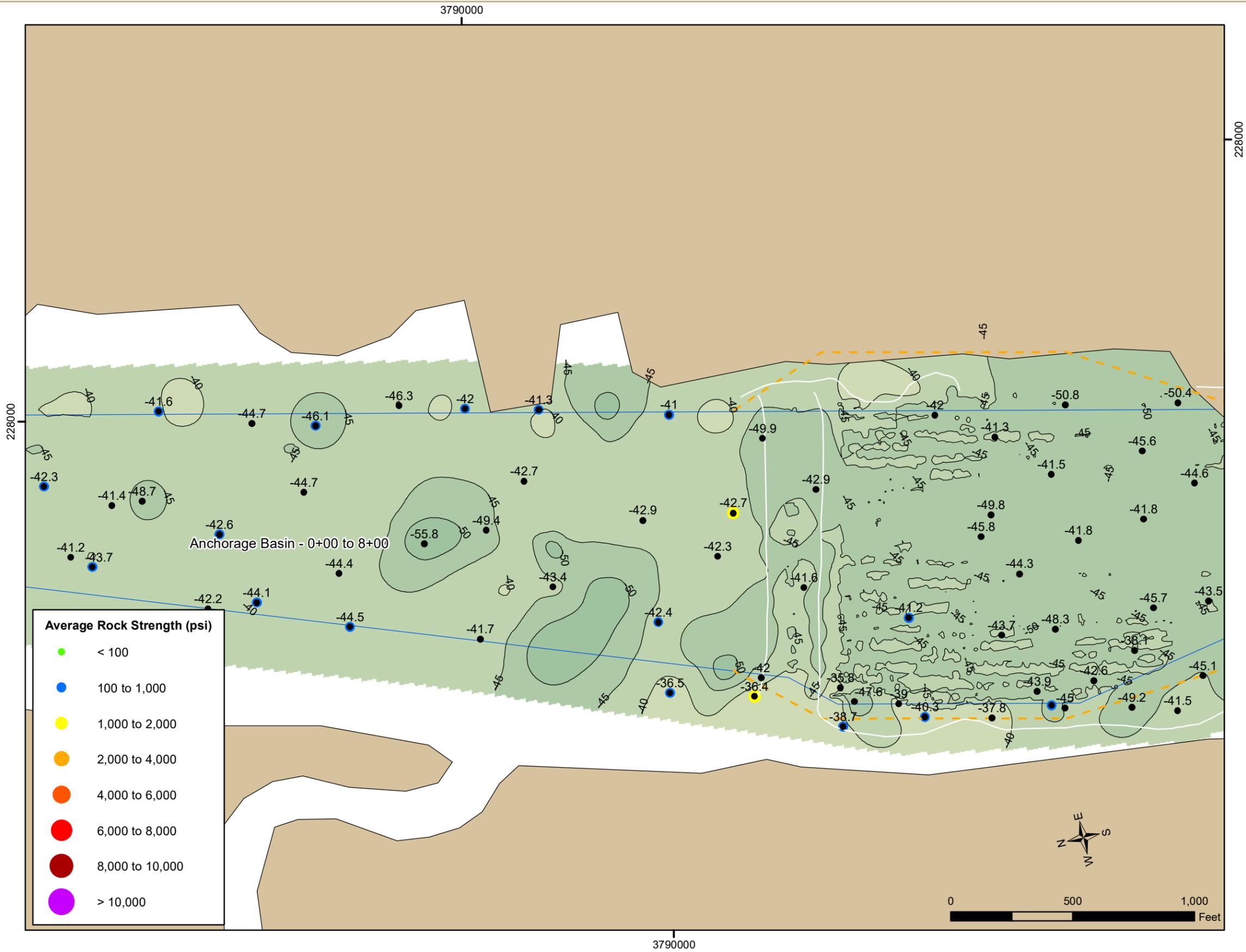
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-5



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-6



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-7

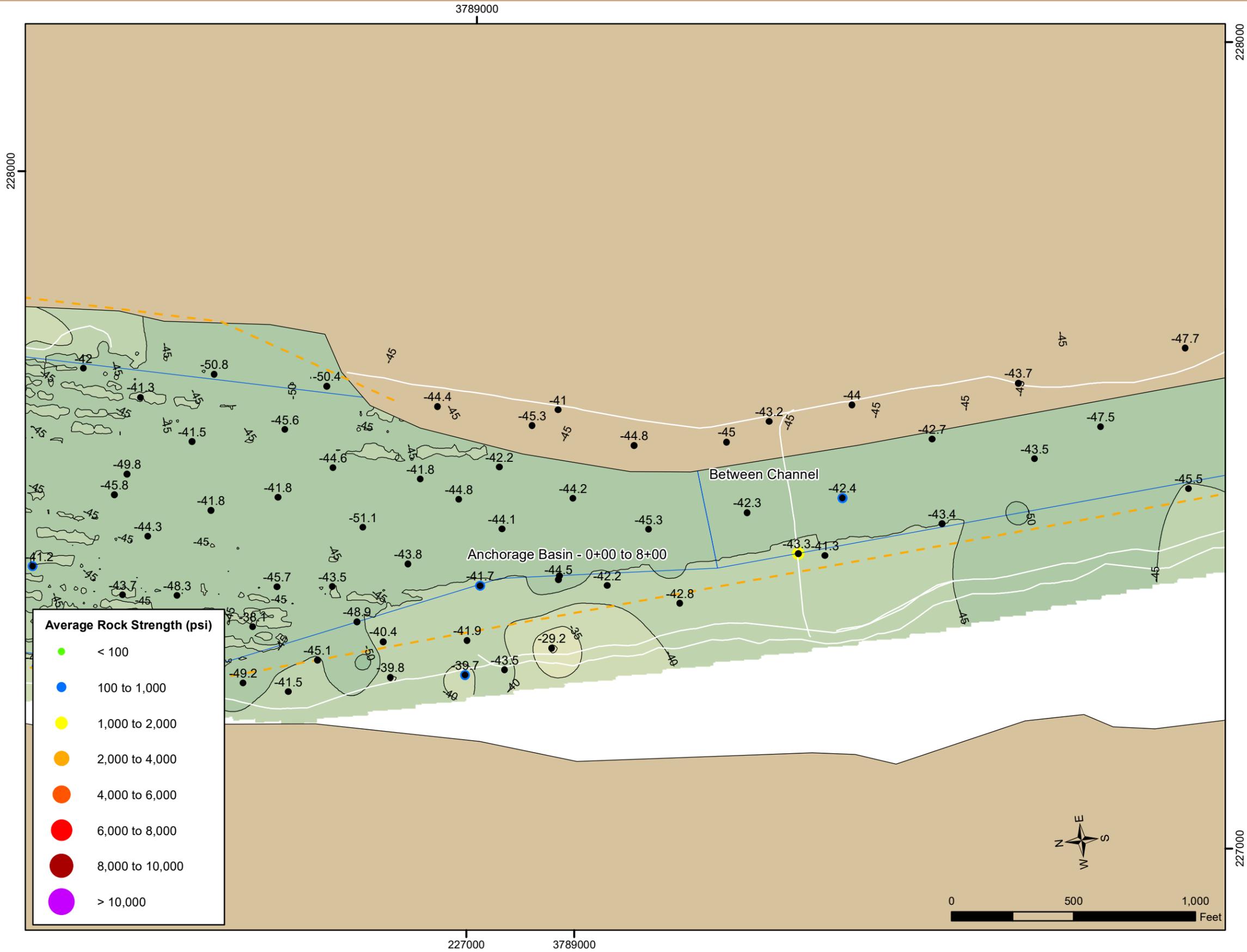
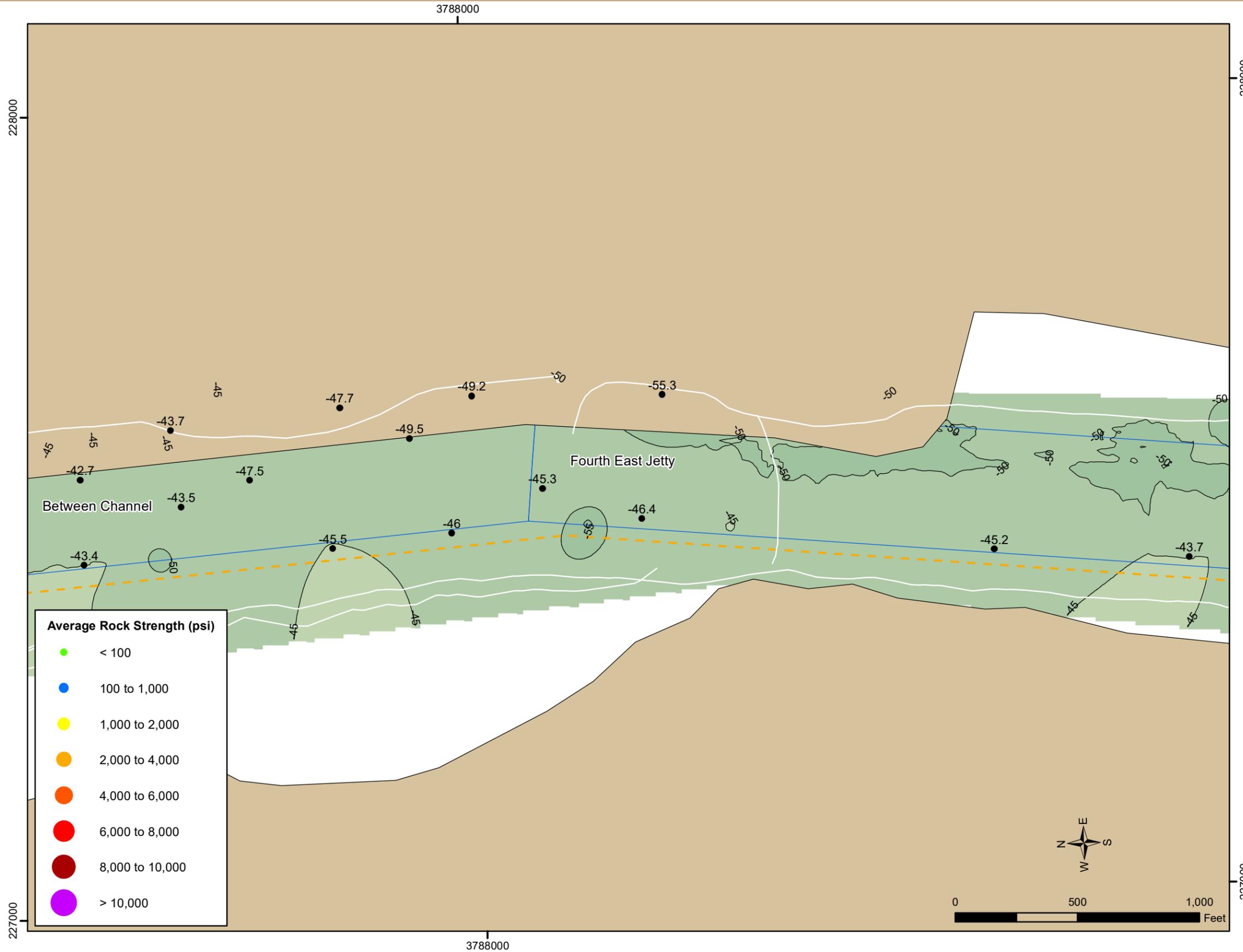
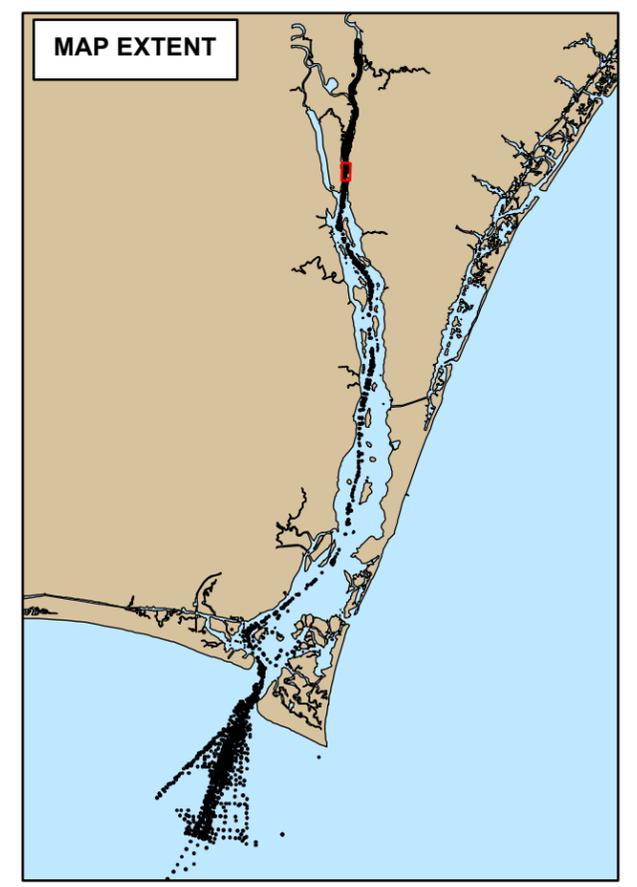


FIGURE 3-8



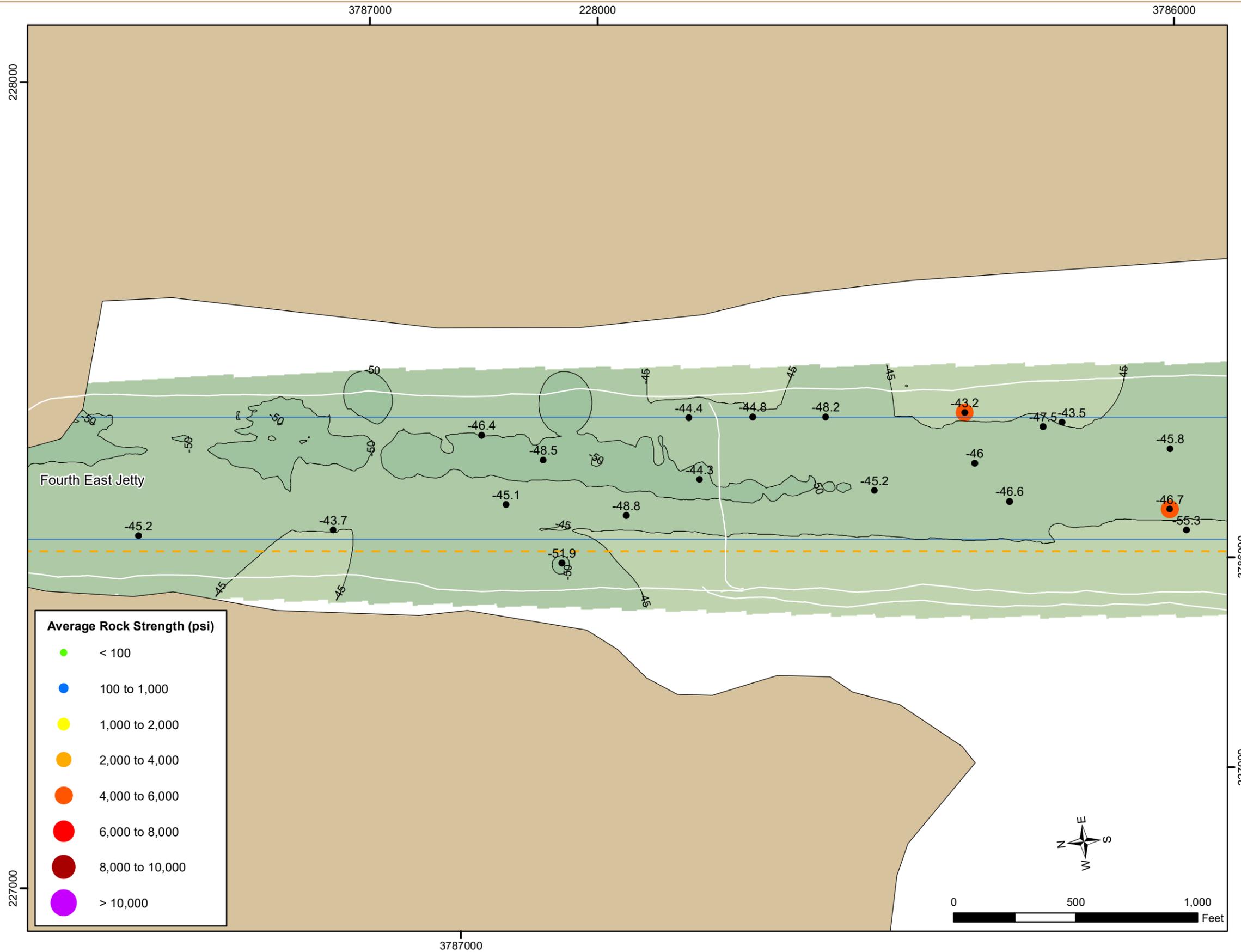
Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
 - Proposed Channel Modifications (provided by Moffatt & Nichol)
 - USACE Channel Reach Boundary
 - Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft, Re. MLLW)**
- | | |
|------------|------------|
| -20 to -25 | -55 to -60 |
| -25 to -30 | -60 to -65 |
| -30 to -35 | -65 to -70 |
| -35 to -40 | -70 to -75 |
| -40 to -50 | -75 to -80 |
| -45 to -50 | -80 to -85 |
| -50 to -55 | < -85 |
- 5 foot contour interval



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

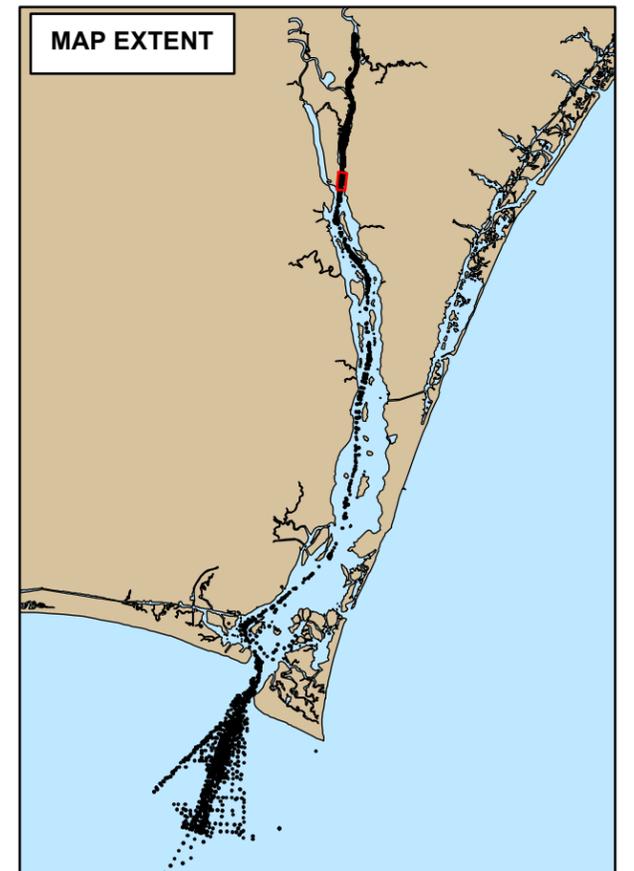
FIGURE 3-9



Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
 - Proposed Channel Modifications (provided by Moffatt & Nichol)
 - USACE Channel Reach Boundary
 - Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft, Re. MLLW)**
- | | |
|------------|------------|
| -20 to -25 | -55 to -60 |
| -25 to -30 | -60 to -65 |
| -30 to -35 | -65 to -70 |
| -35 to -40 | -70 to -75 |
| -40 to -50 | -75 to -80 |
| -45 to -50 | -80 to -85 |
| -50 to -55 | < -85 |
- 5 foot contour interval

- Average Rock Strength (psi)**
- < 100
 - 100 to 1,000
 - 1,000 to 2,000
 - 2,000 to 4,000
 - 4,000 to 6,000
 - 6,000 to 8,000
 - 8,000 to 10,000
 - > 10,000



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



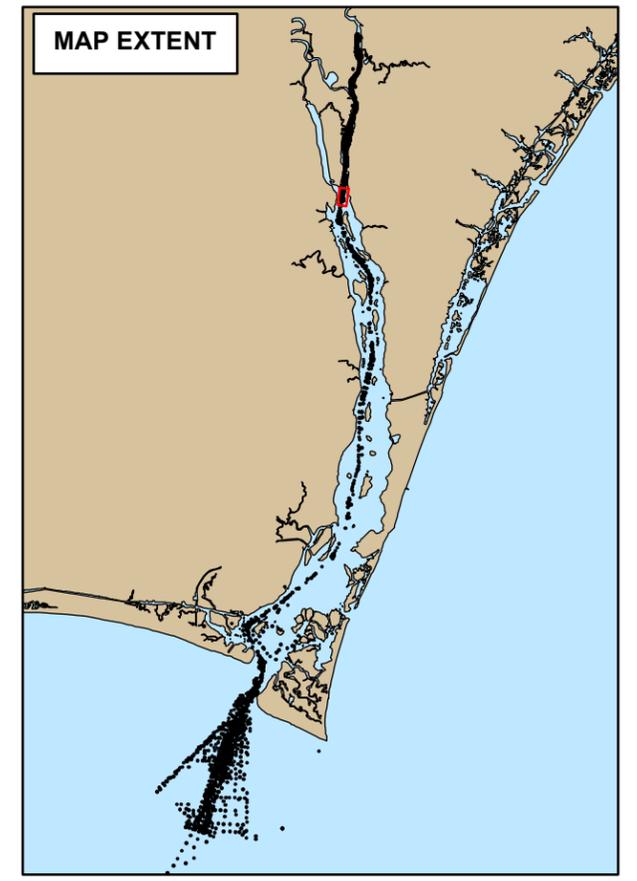
Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
- Proposed Channel Modifications (provided by Moffatt & Nichol)
- USACE Channel Reach Boundary
- Fugro 2017 Chirp Survey Trackline

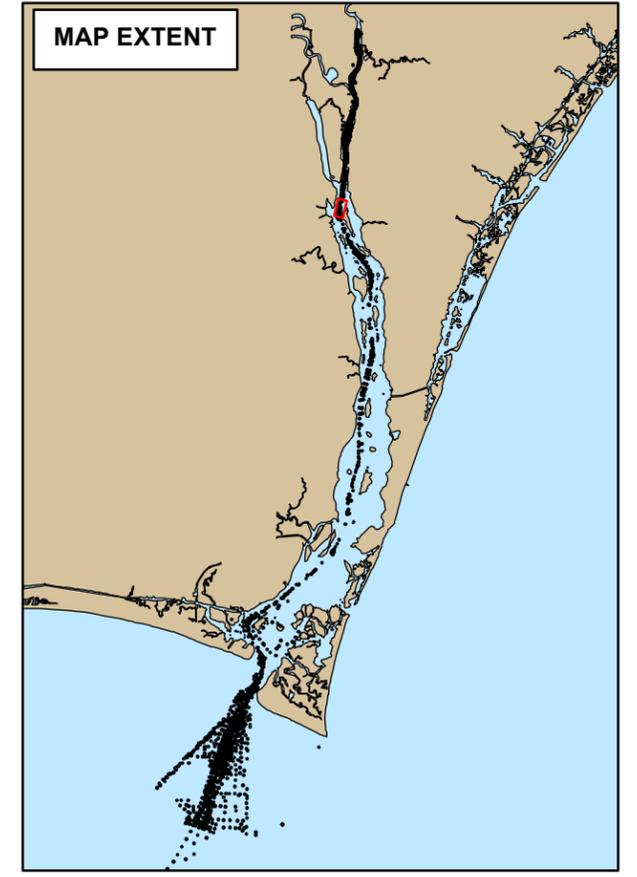
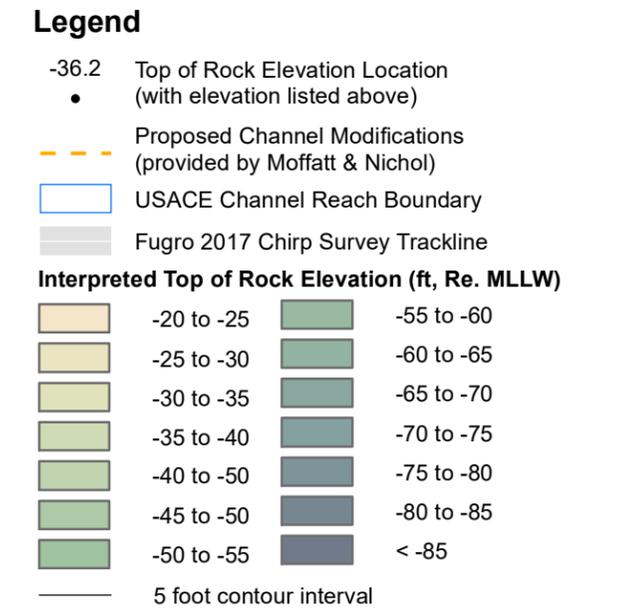
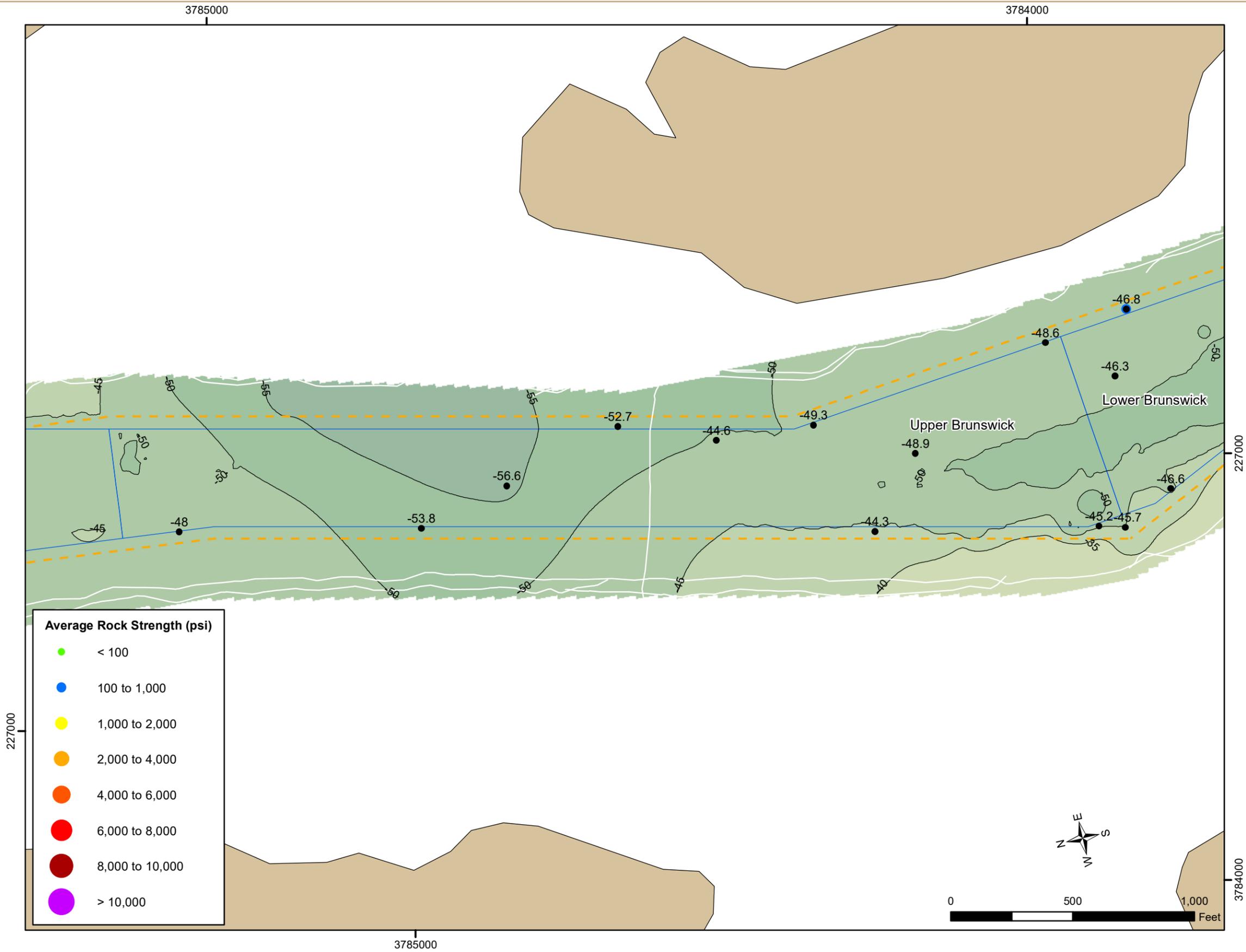
Interpreted Top of Rock Elevation (ft, Re. MLLW)

-20 to -25	-55 to -60
-25 to -30	-60 to -65
-30 to -35	-65 to -70
-35 to -40	-70 to -75
-40 to -50	-75 to -80
-45 to -50	-80 to -85
-50 to -55	< -85

5 foot contour interval

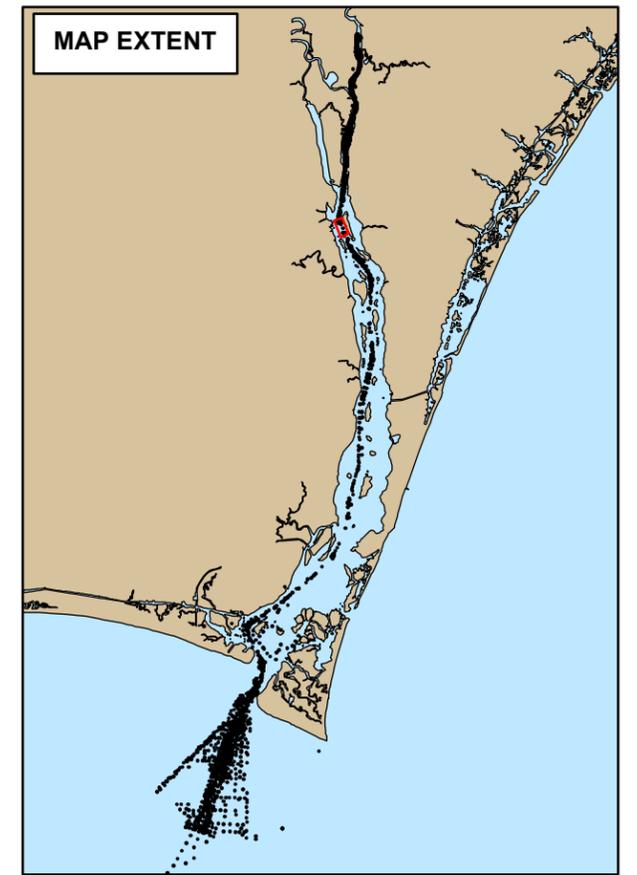
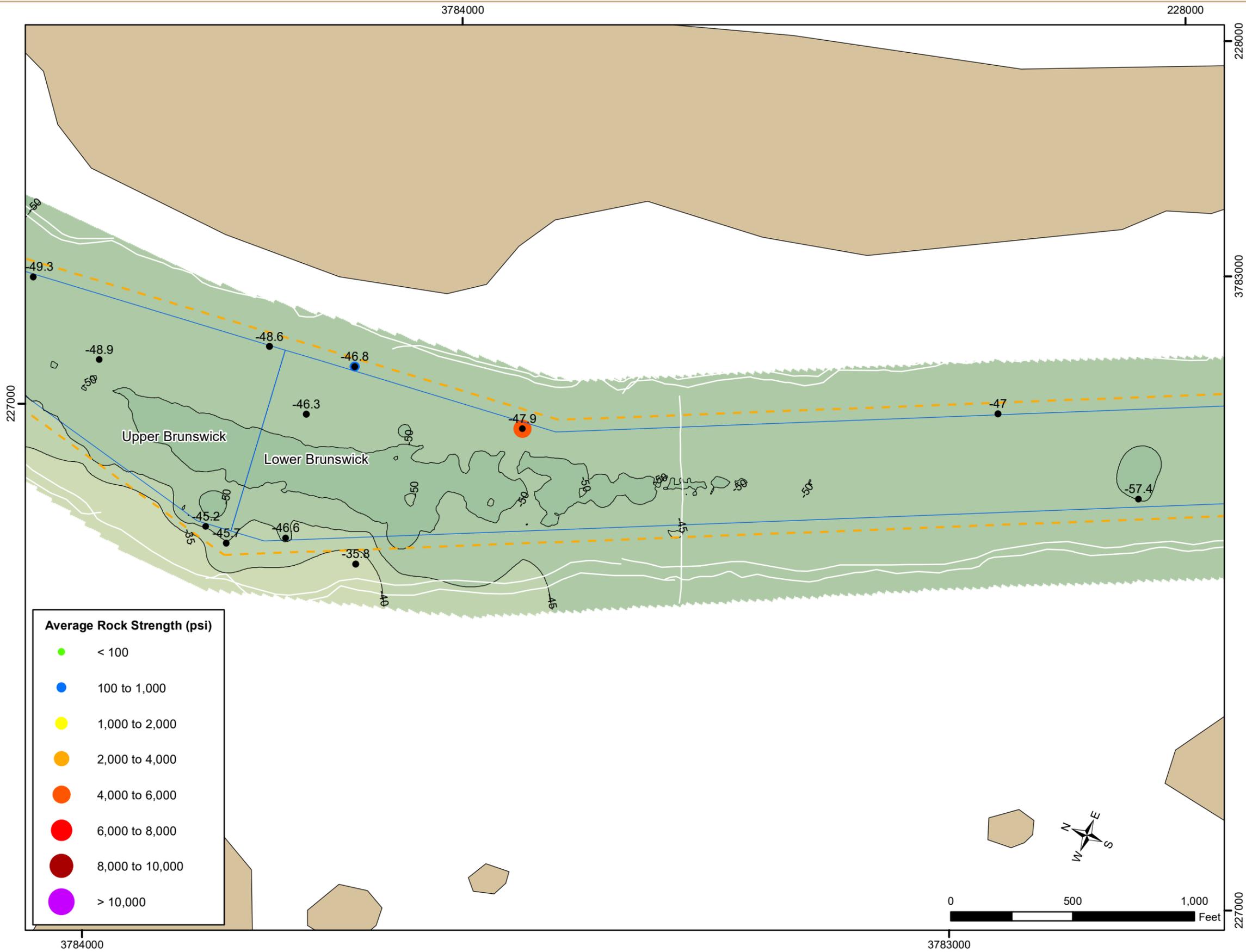


INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

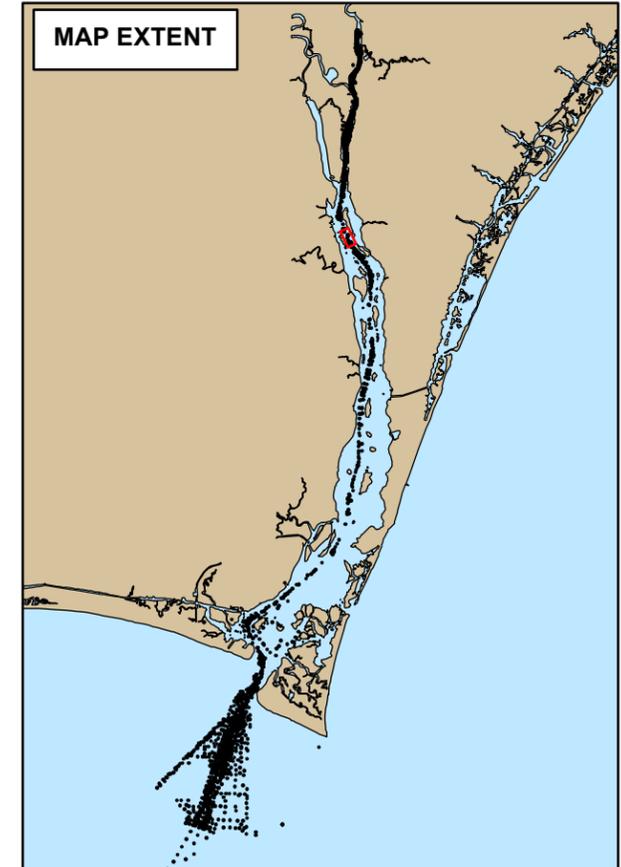
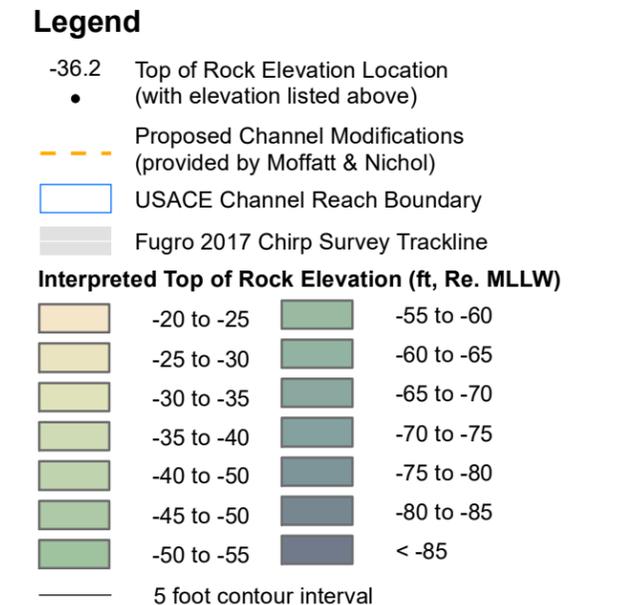
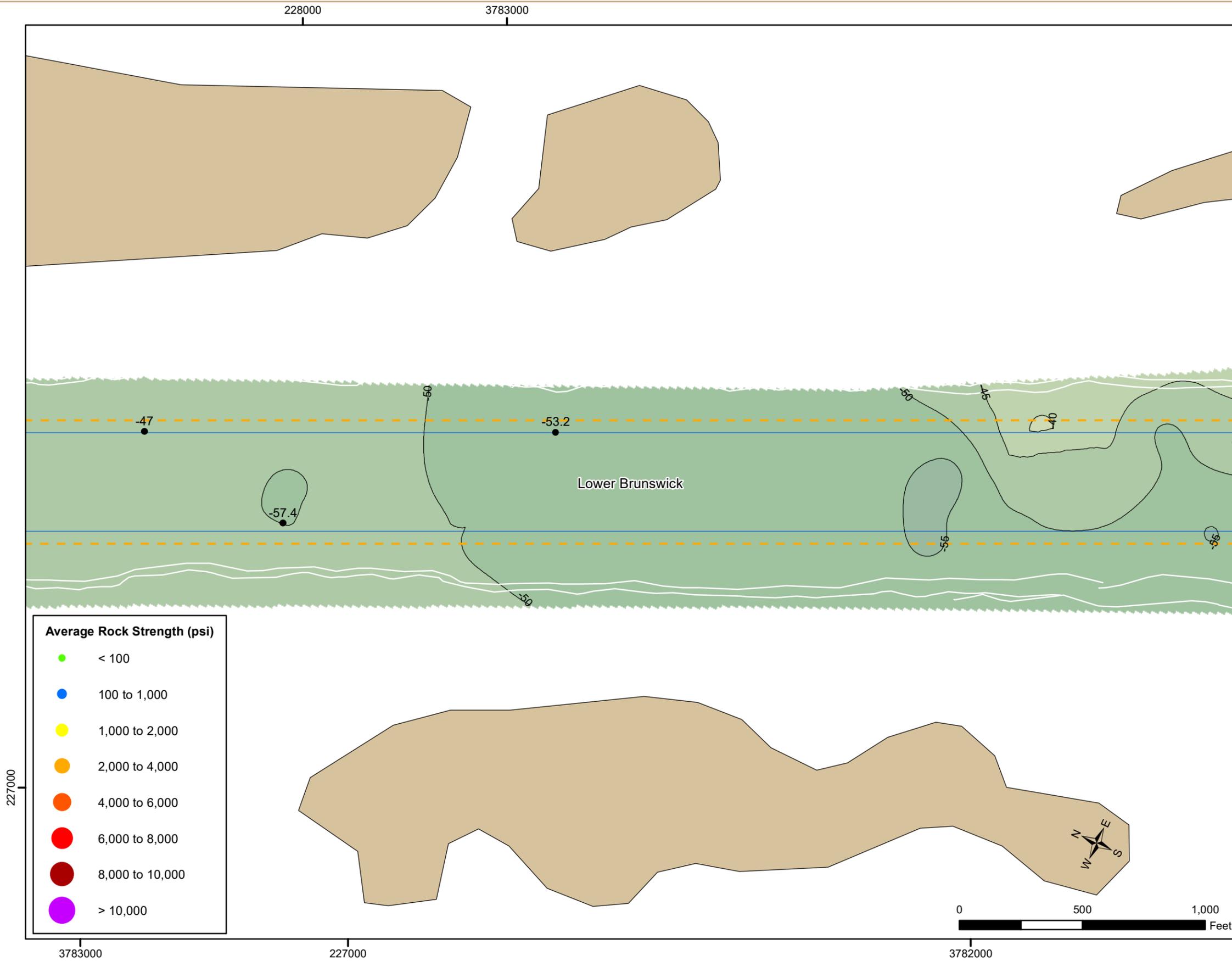


INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-12



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
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INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

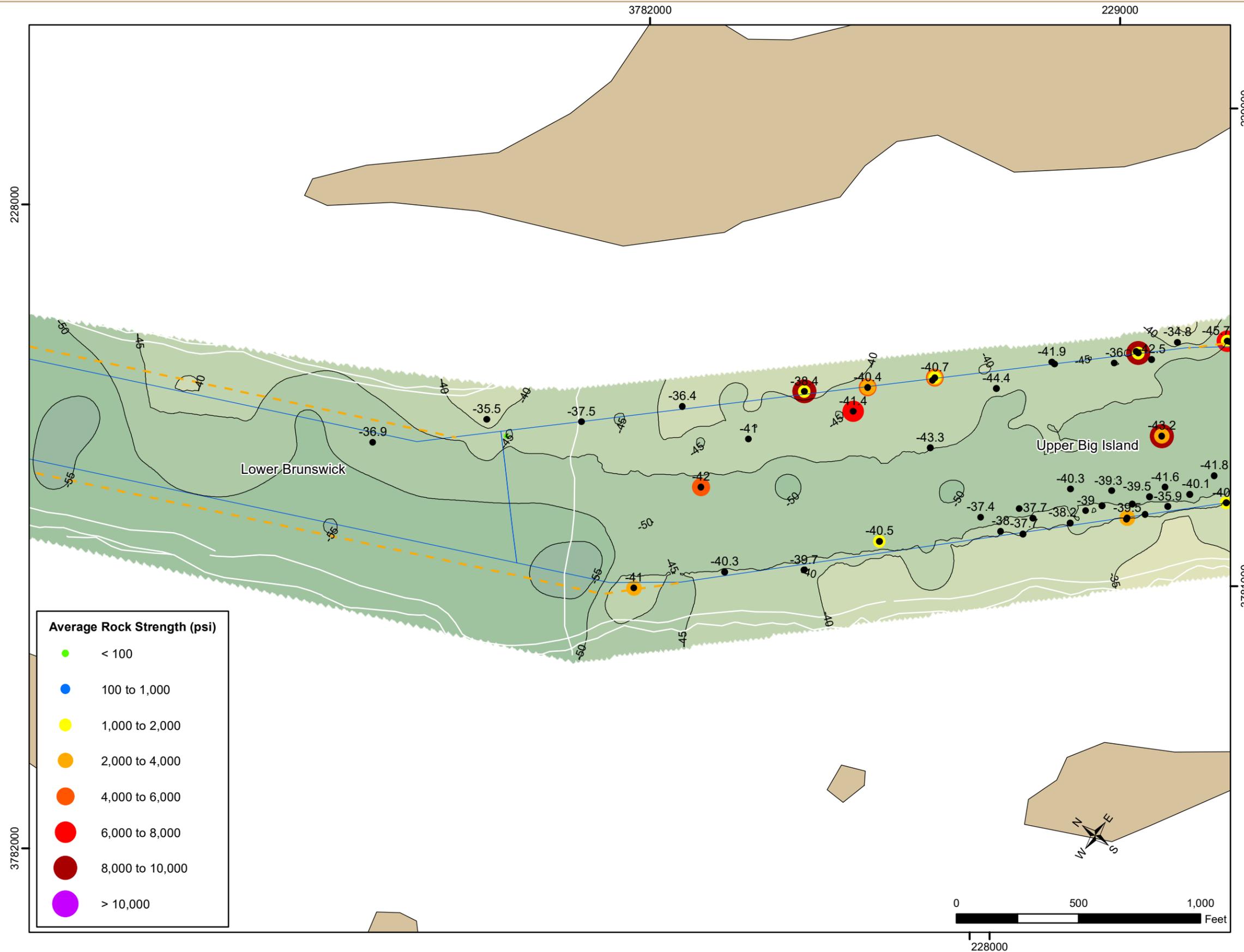
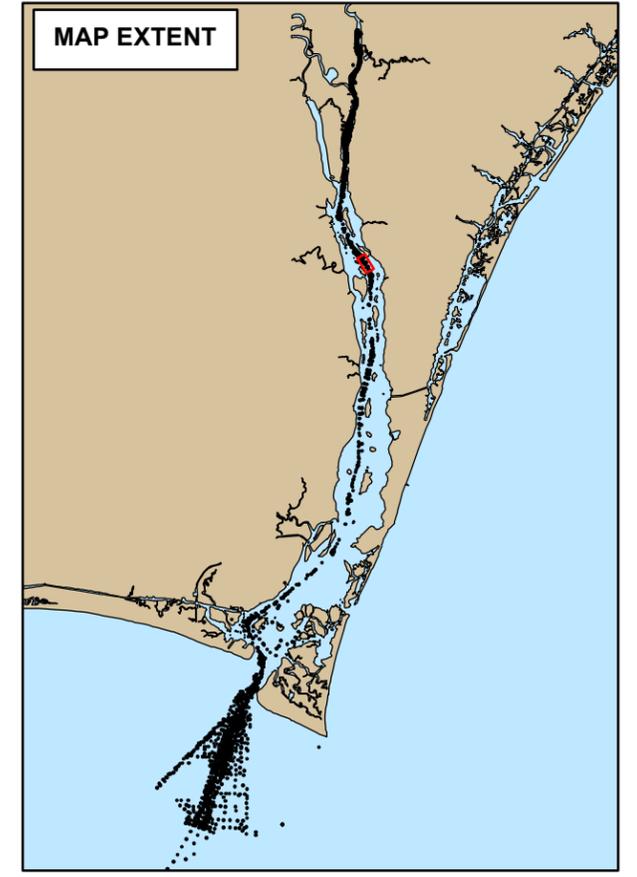
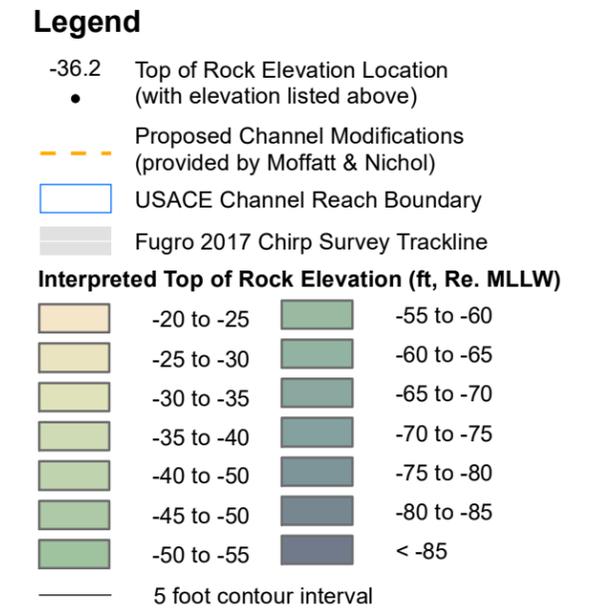
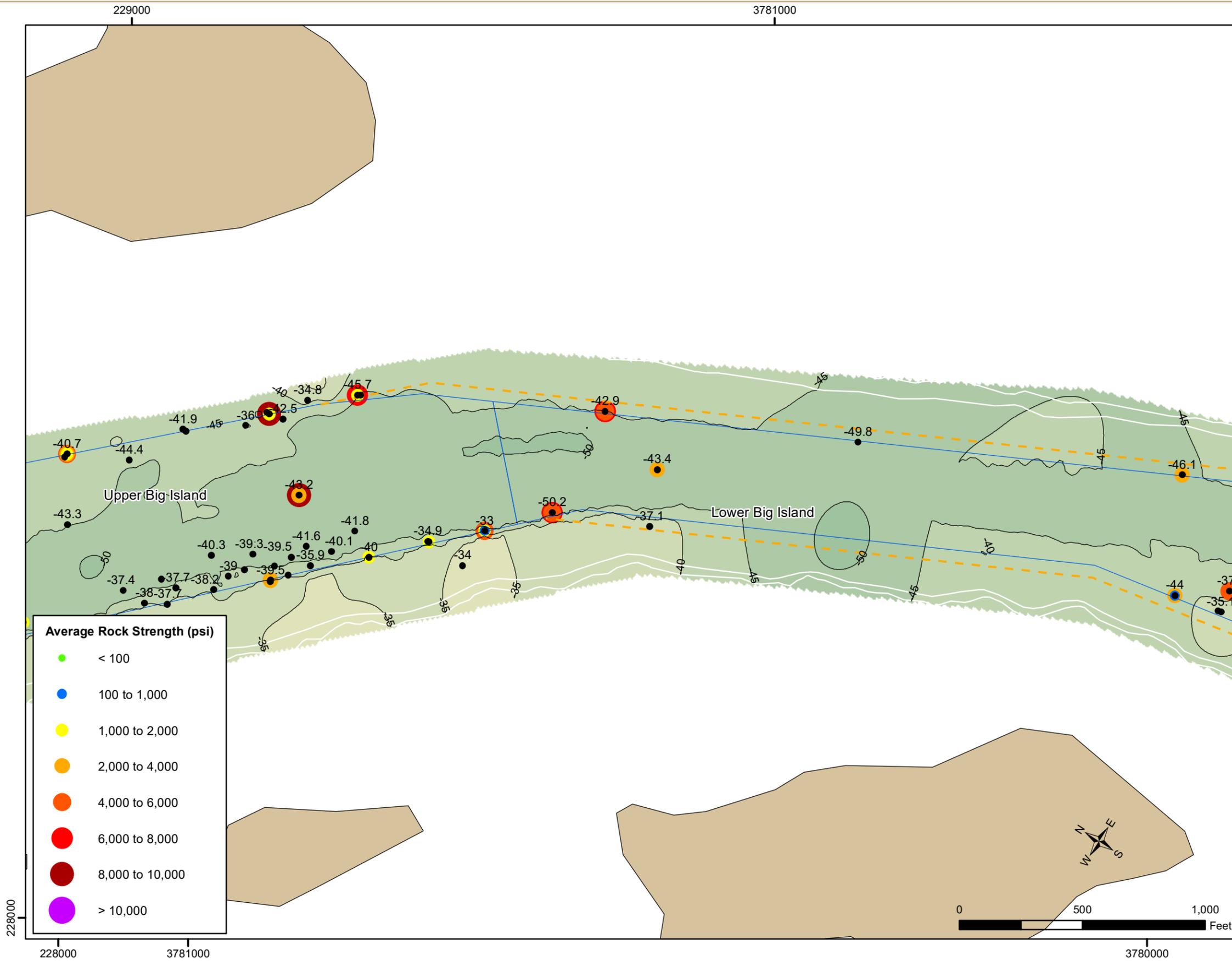
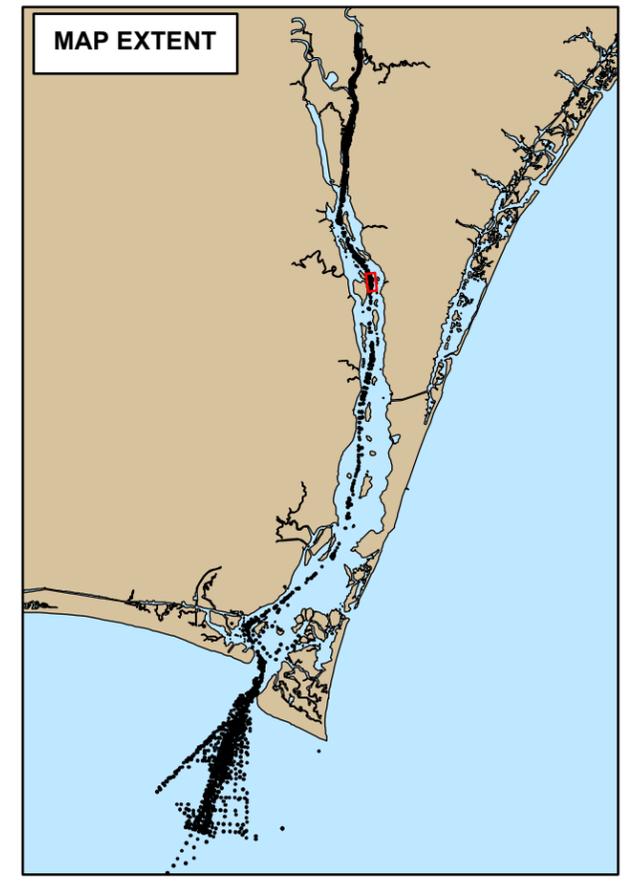
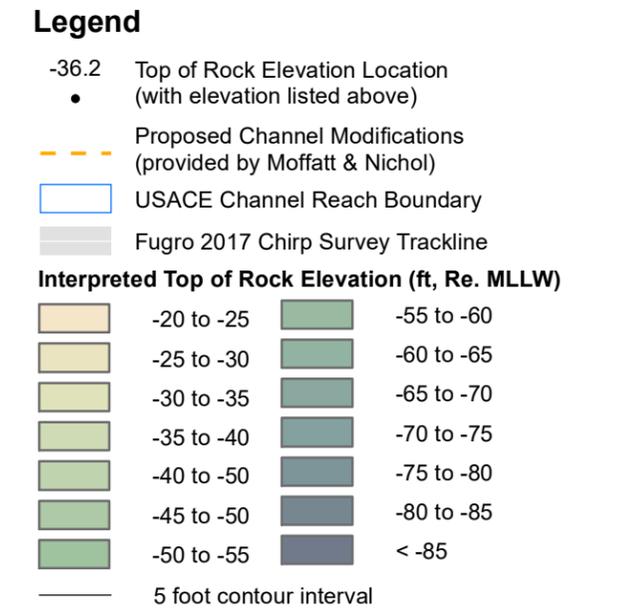
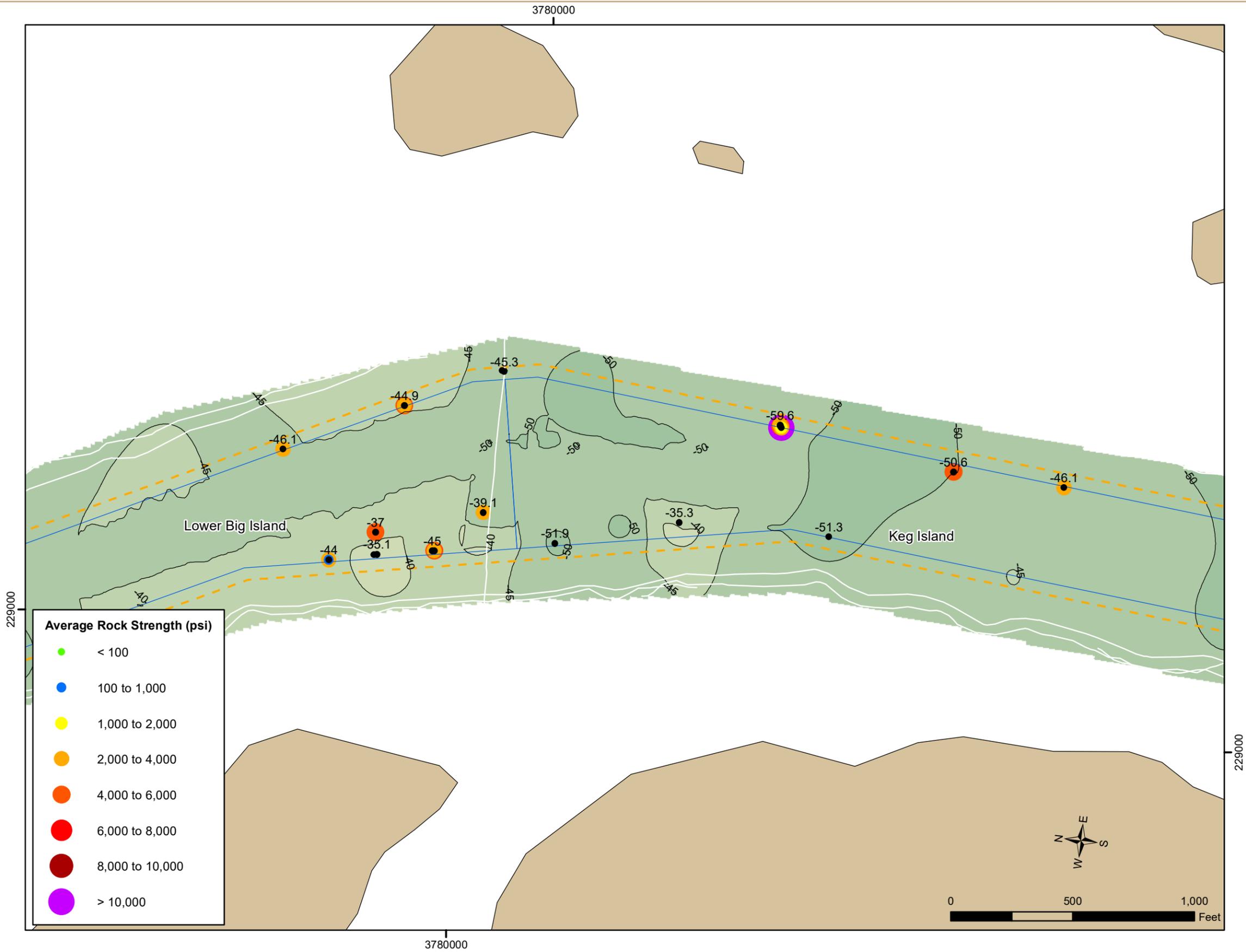


FIGURE 3-15

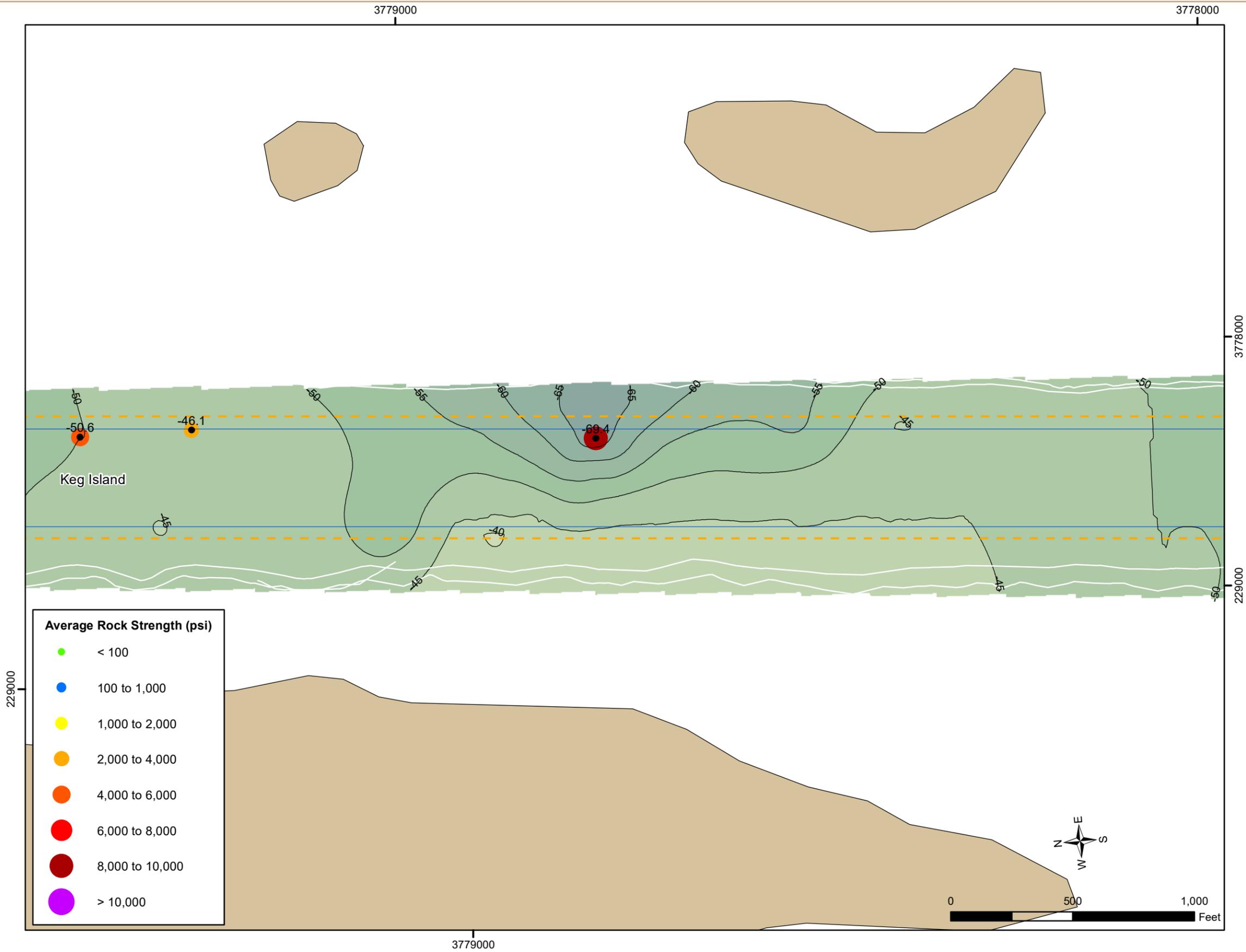


INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-16



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



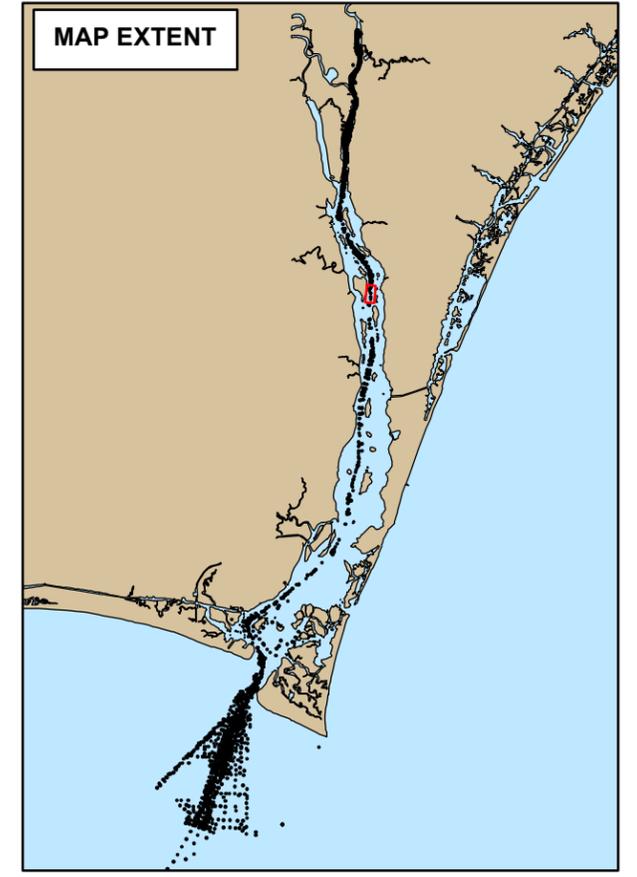
Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
- Proposed Channel Modifications (provided by Moffatt & Nichol)
- USACE Channel Reach Boundary
- Fugro 2017 Chirp Survey Trackline

Interpreted Top of Rock Elevation (ft, Re. MLLW)

-20 to -25	-55 to -60
-25 to -30	-60 to -65
-30 to -35	-65 to -70
-35 to -40	-70 to -75
-40 to -50	-75 to -80
-45 to -50	-80 to -85
-50 to -55	< -85

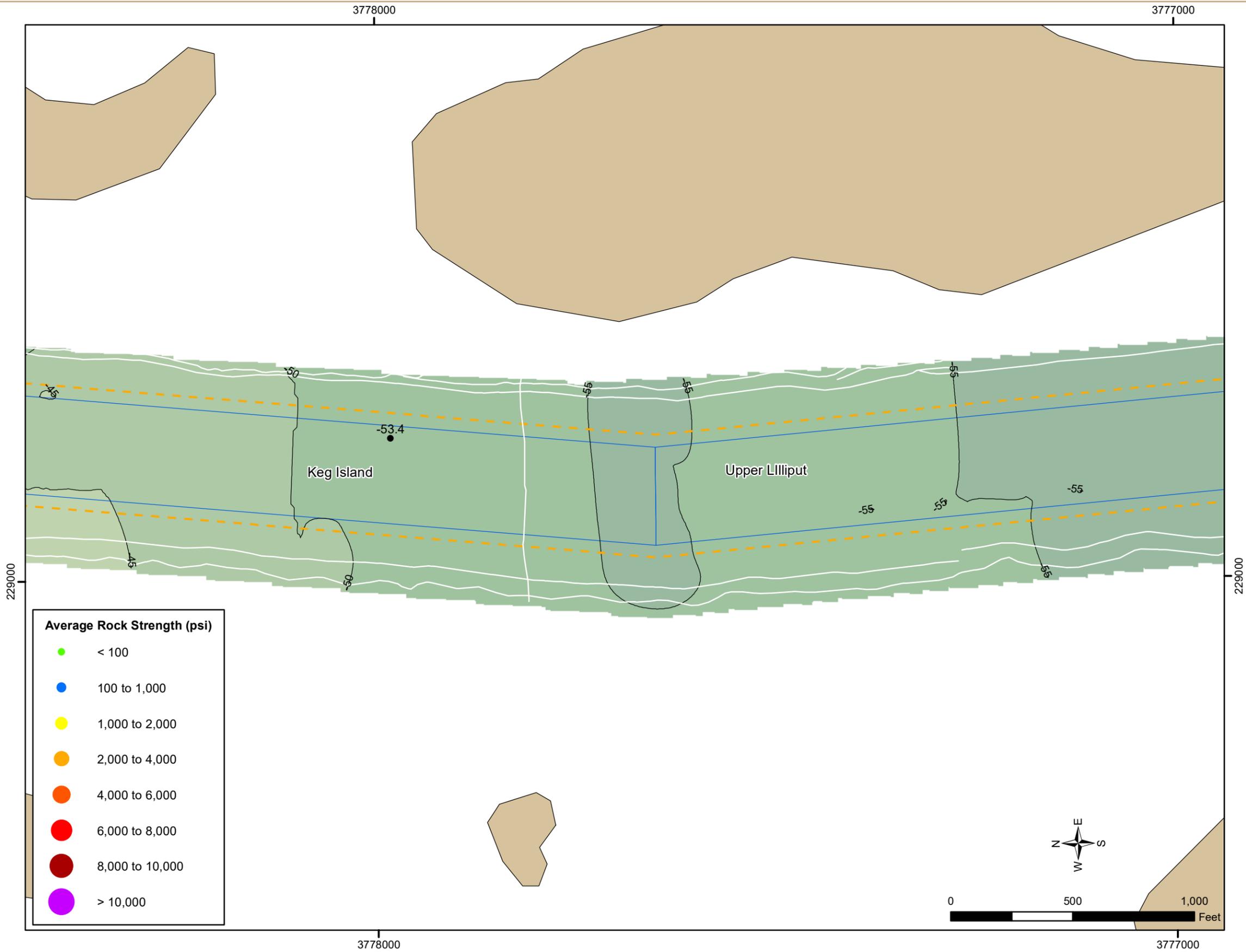
5 foot contour interval



Average Rock Strength (psi)

< 100
100 to 1,000
1,000 to 2,000
2,000 to 4,000
4,000 to 6,000
6,000 to 8,000
8,000 to 10,000
> 10,000

INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
-
- Proposed Channel Modifications (provided by Moffatt & Nichol)
- USACE Channel Reach Boundary
- Fugro 2017 Chirp Survey Trackline

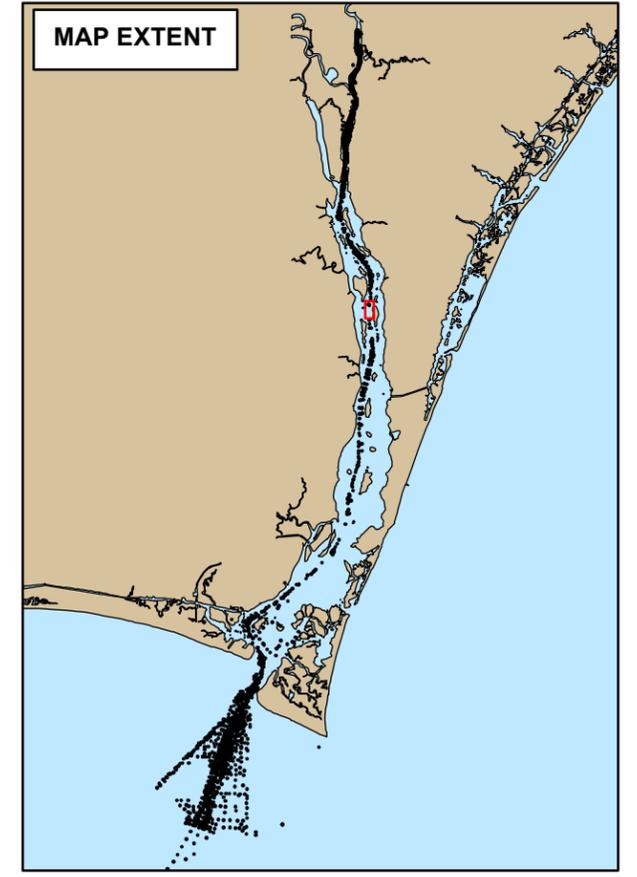
Interpreted Top of Rock Elevation (ft, Re. MLLW)

-20 to -25	-55 to -60
-25 to -30	-60 to -65
-30 to -35	-65 to -70
-35 to -40	-70 to -75
-40 to -50	-75 to -80
-45 to -50	-80 to -85
-50 to -55	< -85

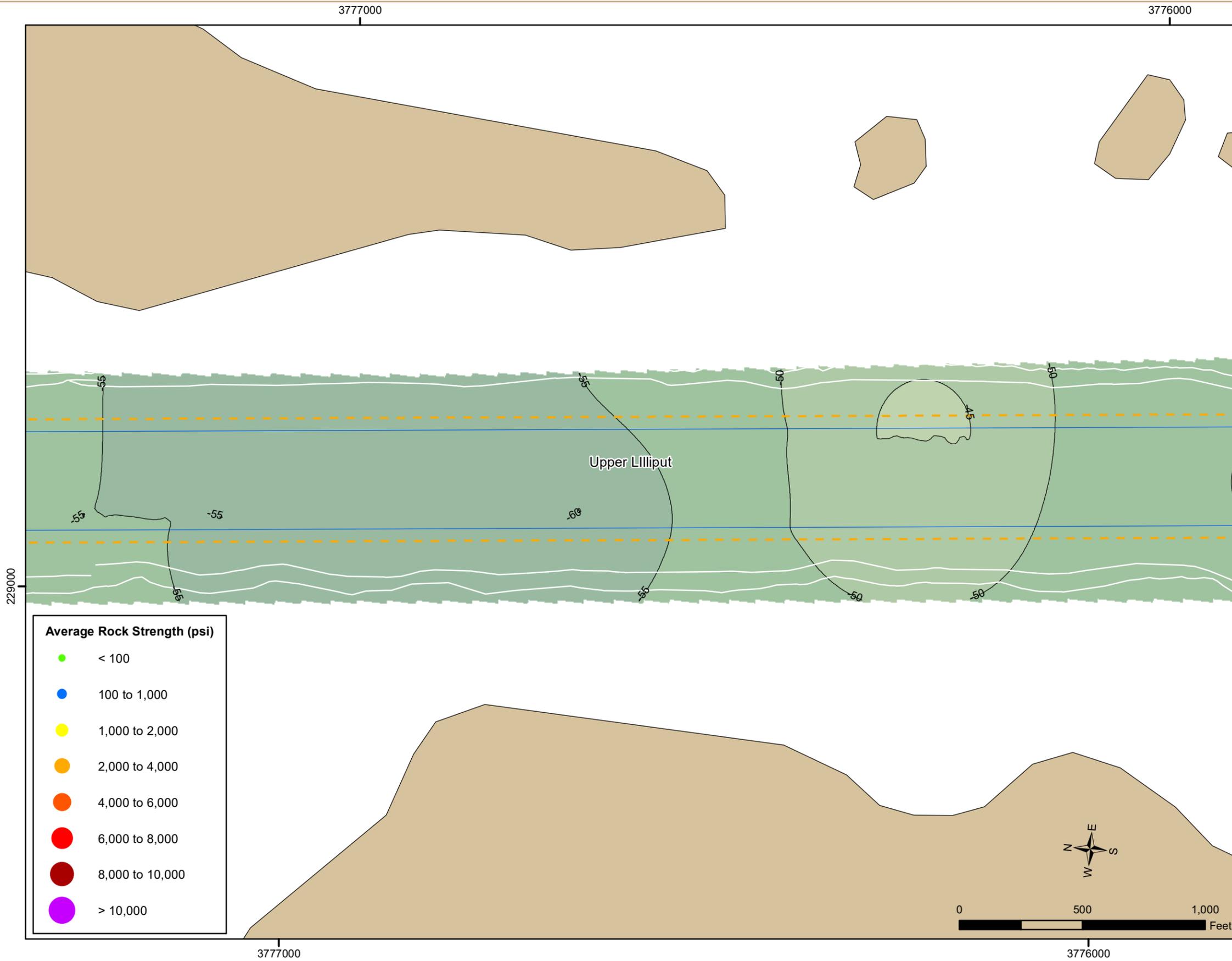
5 foot contour interval

Average Rock Strength (psi)

< 100
100 to 1,000
1,000 to 2,000
2,000 to 4,000
4,000 to 6,000
6,000 to 8,000
8,000 to 10,000
> 10,000



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



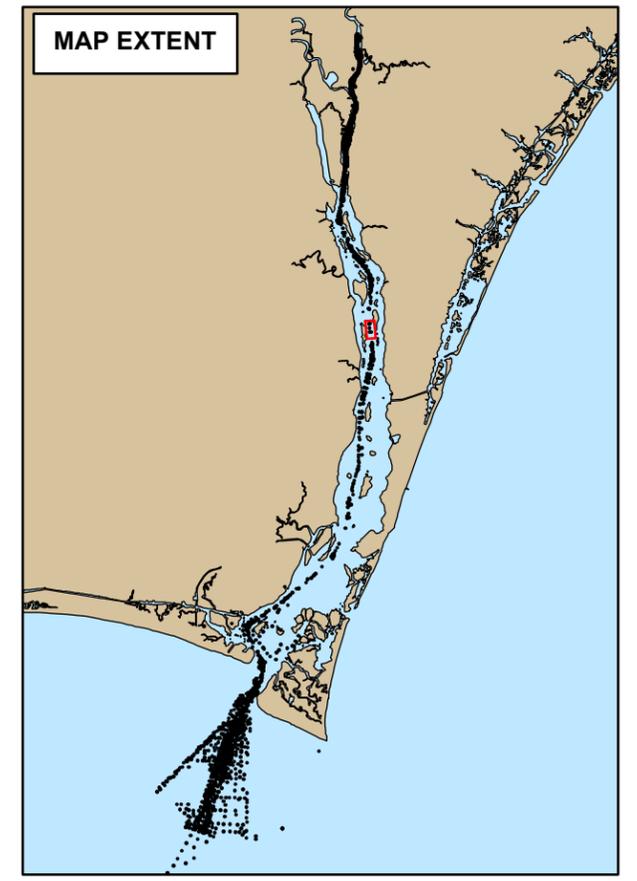
Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
- Proposed Channel Modifications (provided by Moffatt & Nichol)
- USACE Channel Reach Boundary
- Fugro 2017 Chirp Survey Trackline

Interpreted Top of Rock Elevation (ft, Re. MLLW)

-20 to -25	-55 to -60
-25 to -30	-60 to -65
-30 to -35	-65 to -70
-35 to -40	-70 to -75
-40 to -50	-75 to -80
-45 to -50	-80 to -85
-50 to -55	< -85

5 foot contour interval



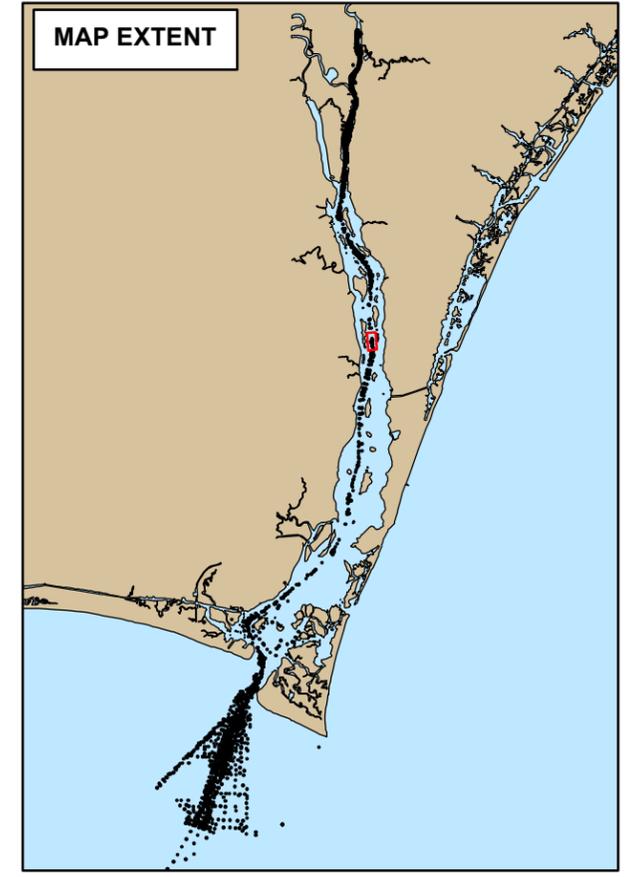
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
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FIGURE 3-20

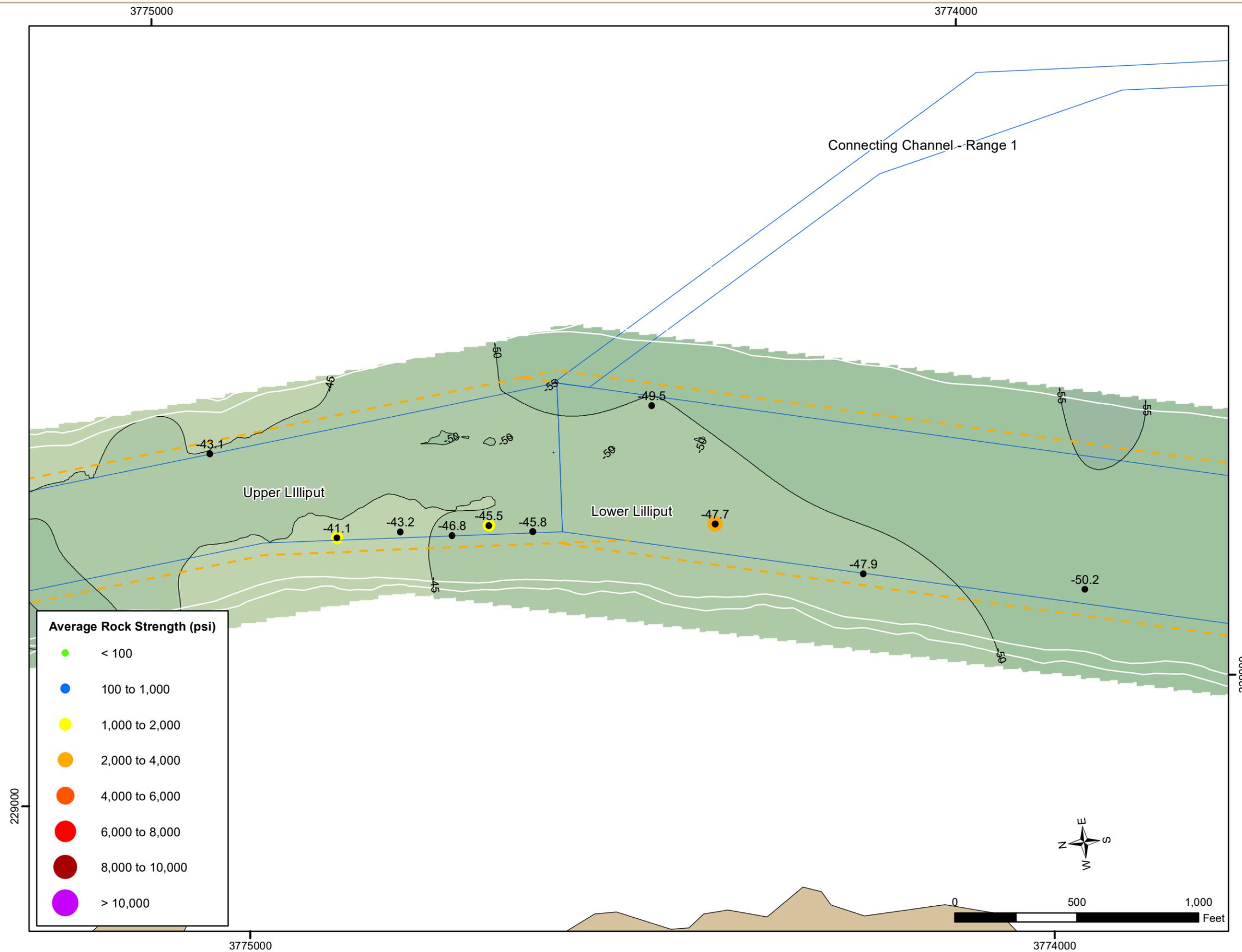


- Legend**
- 36.2 Top of Rock Elevation Location (with elevation listed above)
 -
 - Proposed Channel Modifications (provided by Moffatt & Nichol)
 - USACE Channel Reach Boundary
 - Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft, Re. MLLW)**
- | | |
|------------|------------|
| -20 to -25 | -55 to -60 |
| -25 to -30 | -60 to -65 |
| -30 to -35 | -65 to -70 |
| -35 to -40 | -70 to -75 |
| -40 to -50 | -75 to -80 |
| -45 to -50 | -80 to -85 |
| -50 to -55 | < -85 |
- 5 foot contour interval

- Average Rock Strength (psi)**
- < 100
 - 100 to 1,000
 - 1,000 to 2,000
 - 2,000 to 4,000
 - 4,000 to 6,000
 - 6,000 to 8,000
 - 8,000 to 10,000
 - > 10,000

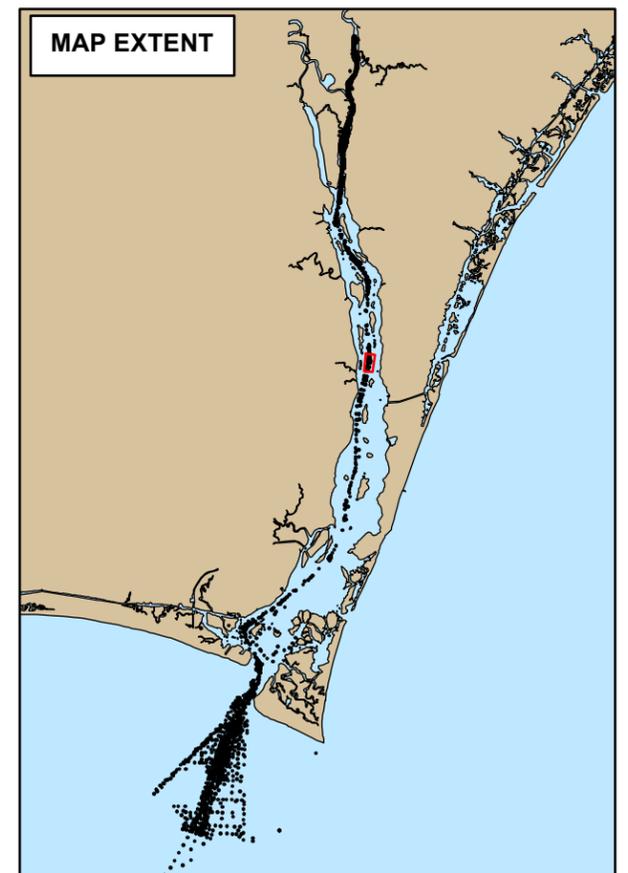


INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



Legend

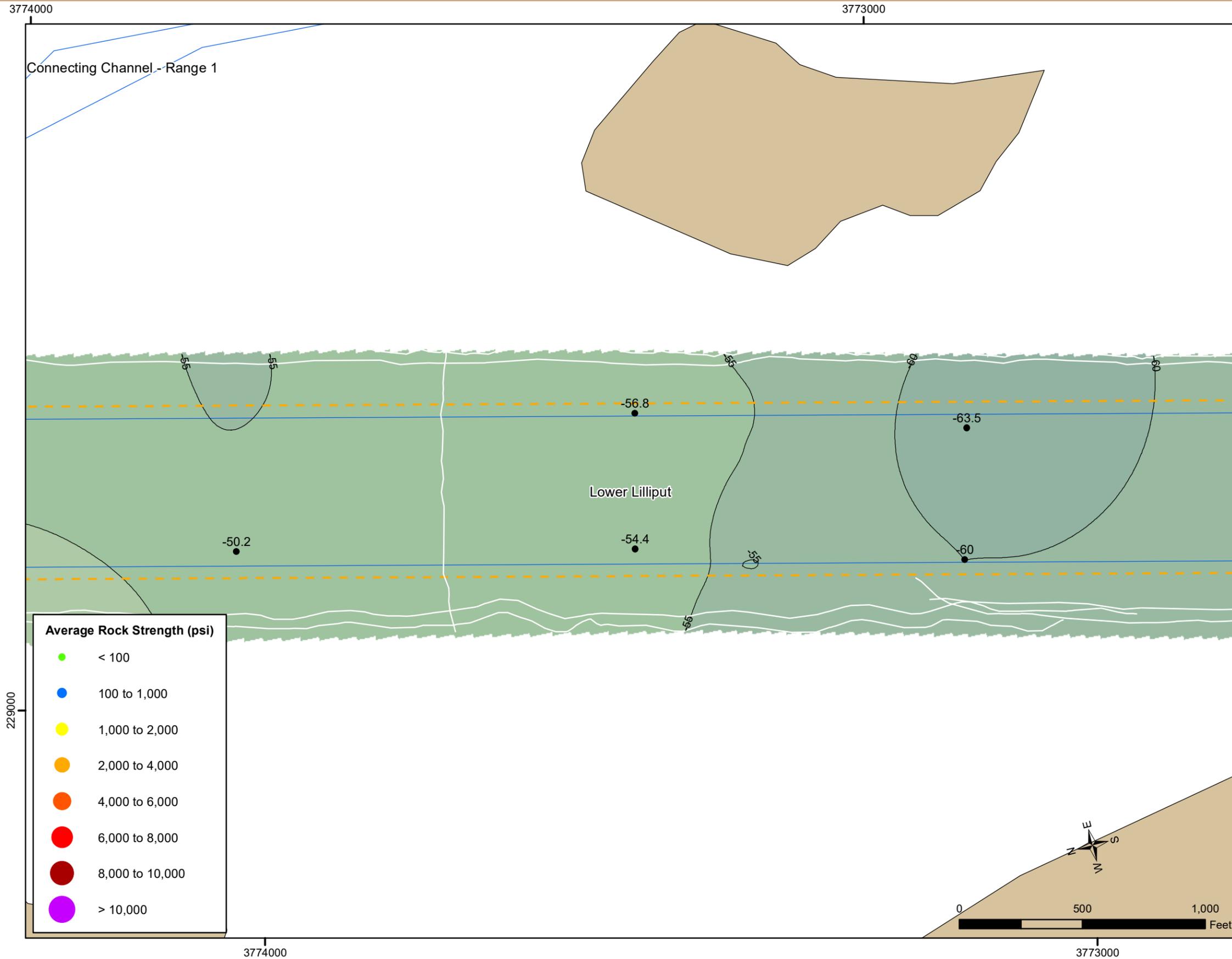
- 36.2 Top of Rock Elevation Location (with elevation listed above)
 - Proposed Channel Modifications (provided by Moffatt & Nichol)
 - USACE Channel Reach Boundary
 - Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft. Re. MLLW)**
- | | |
|------------|------------|
| -20 to -25 | -55 to -60 |
| -25 to -30 | -60 to -65 |
| -30 to -35 | -65 to -70 |
| -35 to -40 | -70 to -75 |
| -40 to -50 | -75 to -80 |
| -45 to -50 | -80 to -85 |
| -50 to -55 | < -85 |
- 5 foot contour interval



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

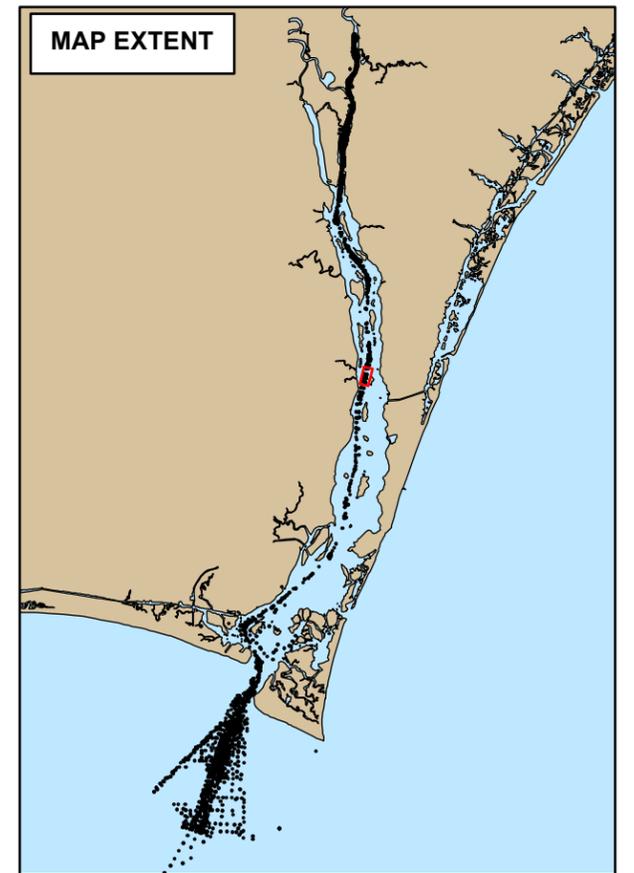
FIGURE 3-22

- Average Rock Strength (psi)**
- < 100
 - 100 to 1,000
 - 1,000 to 2,000
 - 2,000 to 4,000
 - 4,000 to 6,000
 - 6,000 to 8,000
 - 8,000 to 10,000
 - > 10,000

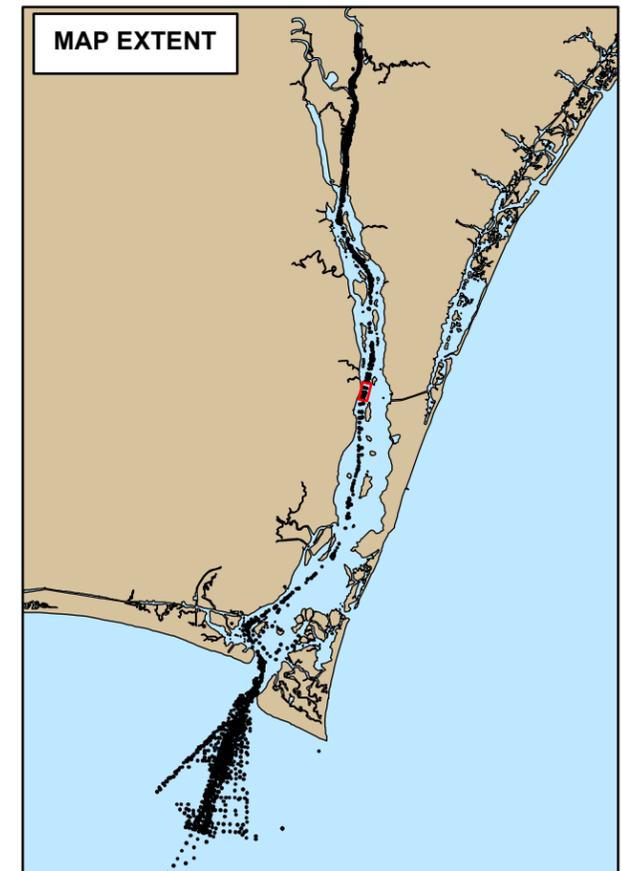
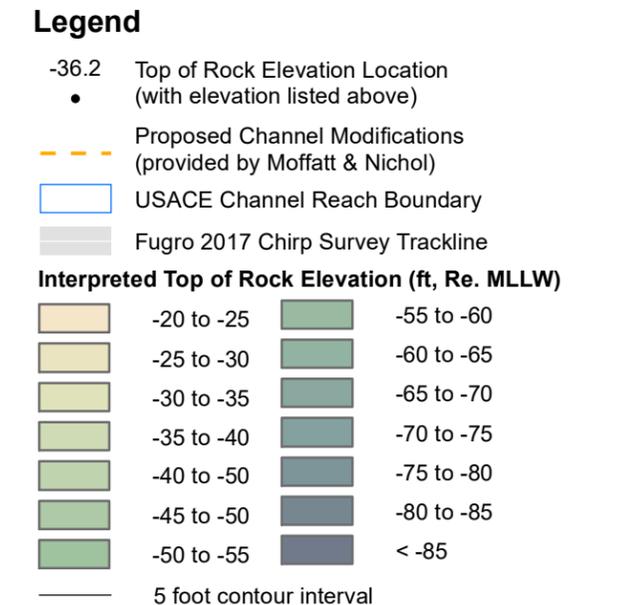
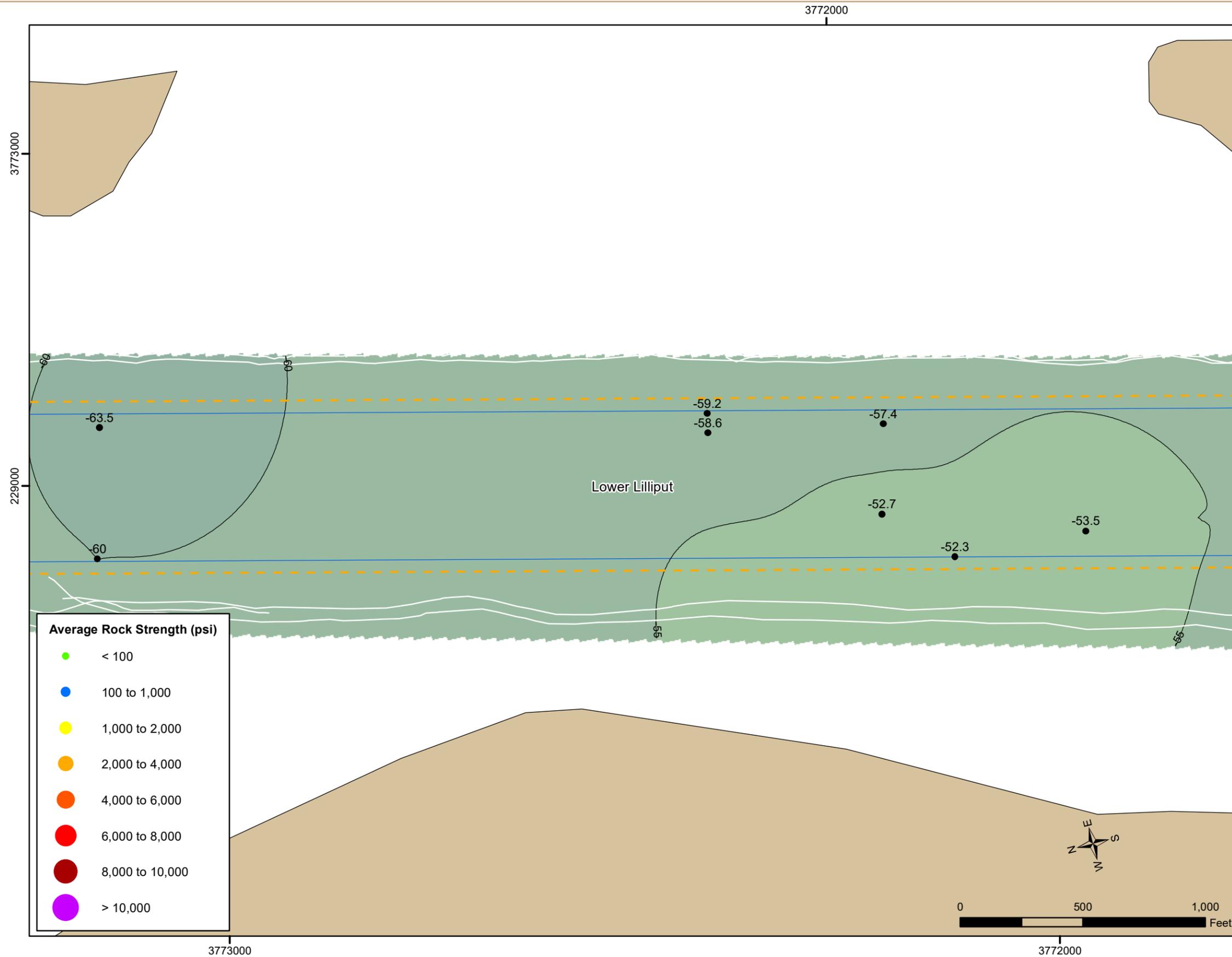


Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
 - Proposed Channel Modifications (provided by Moffatt & Nichol)
 - USACE Channel Reach Boundary
 - Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft. Re. MLLW)**
- | | |
|------------|------------|
| -20 to -25 | -55 to -60 |
| -25 to -30 | -60 to -65 |
| -30 to -35 | -65 to -70 |
| -35 to -40 | -70 to -75 |
| -40 to -50 | -75 to -80 |
| -45 to -50 | -80 to -85 |
| -50 to -55 | < -85 |
- 5 foot contour interval

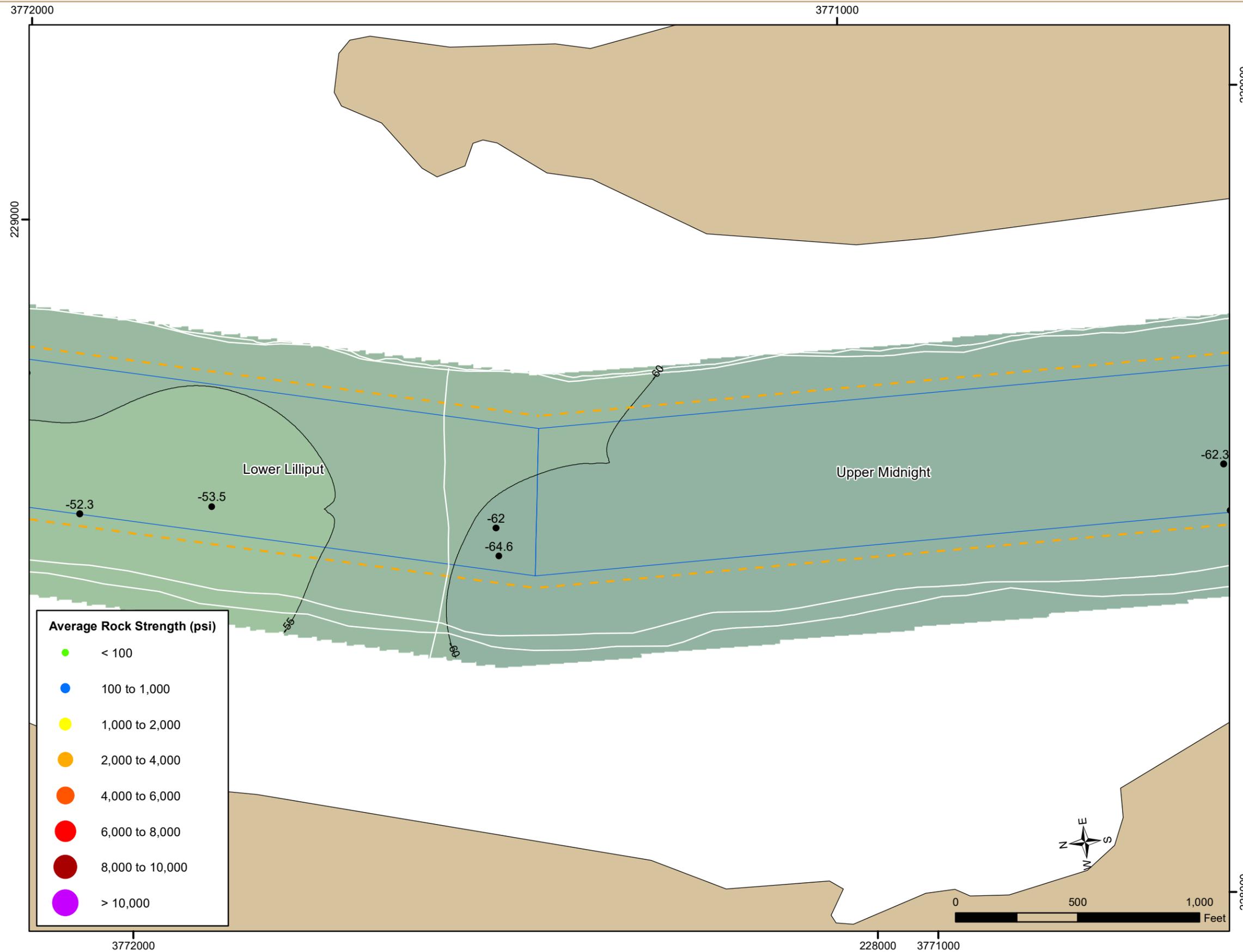


INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



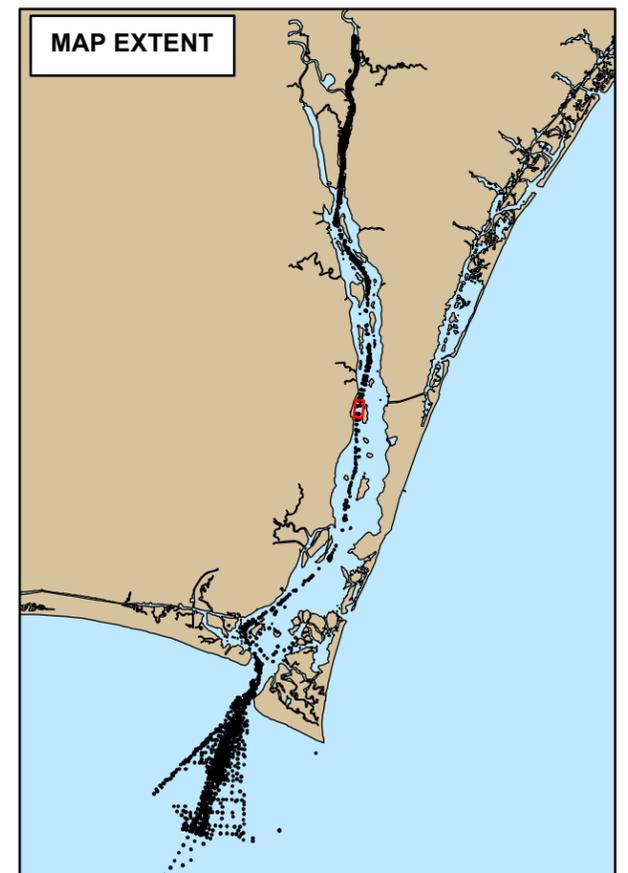
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-24

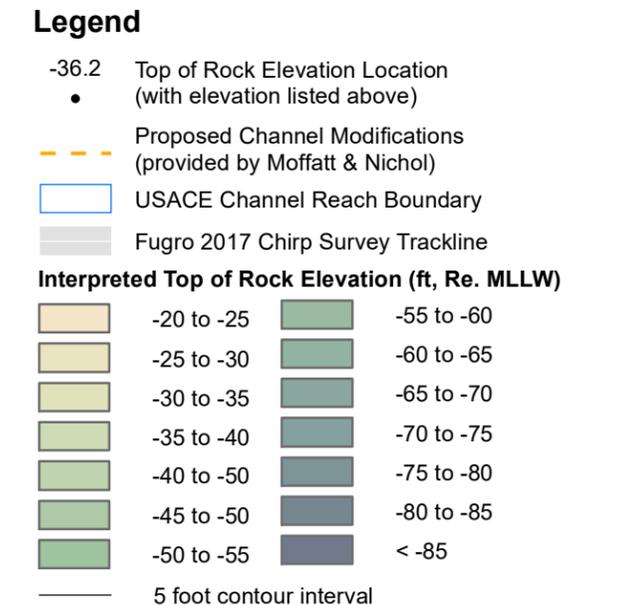
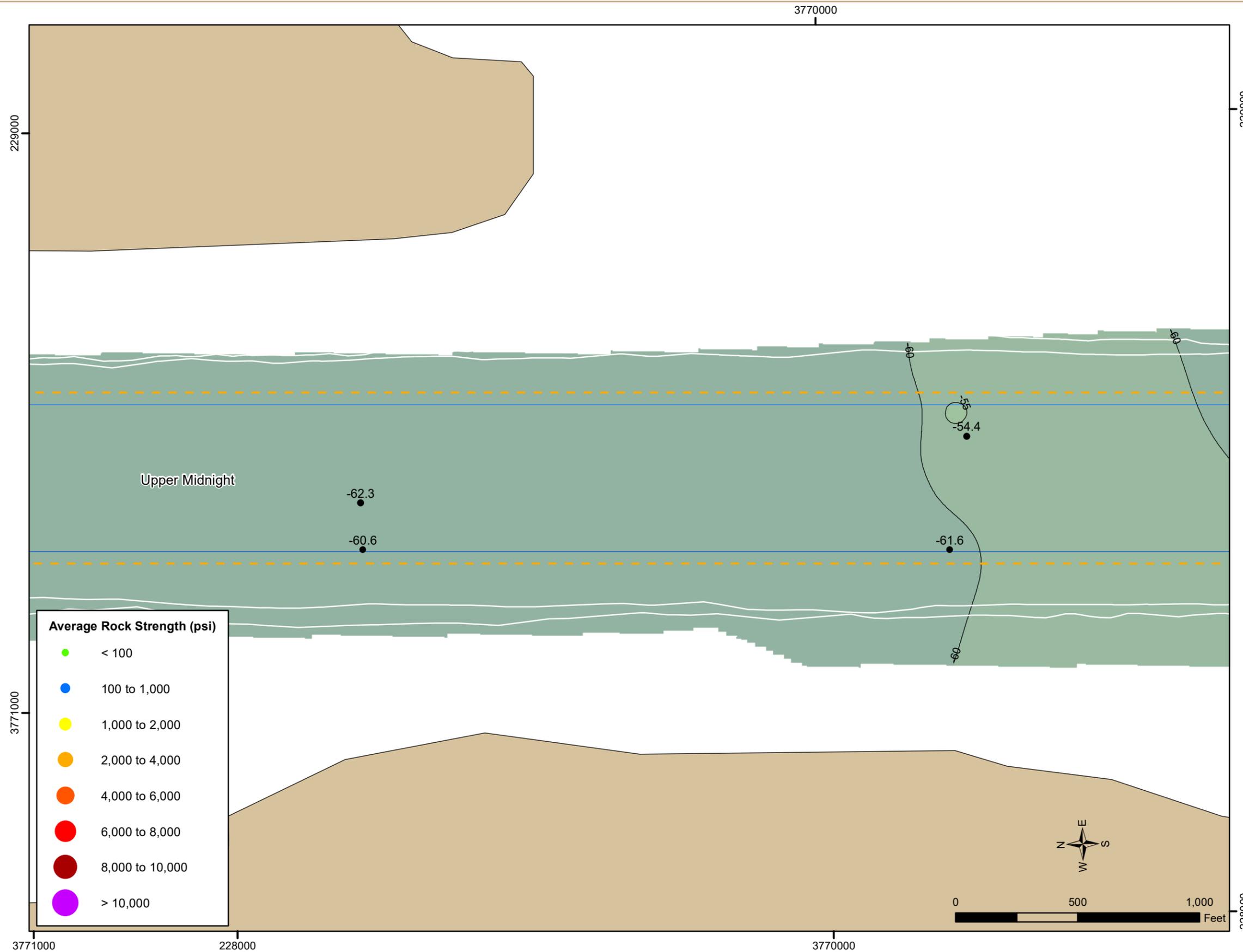


Legend

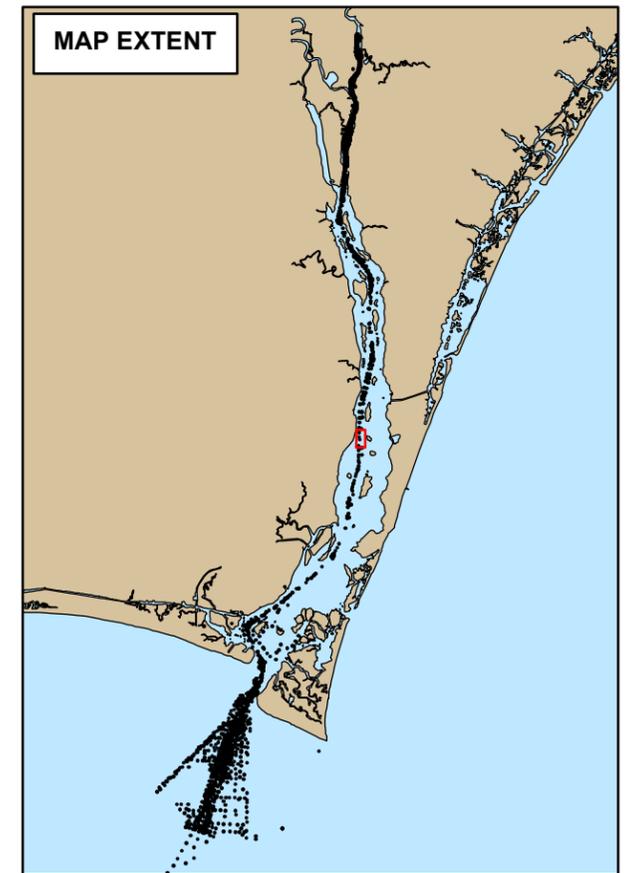
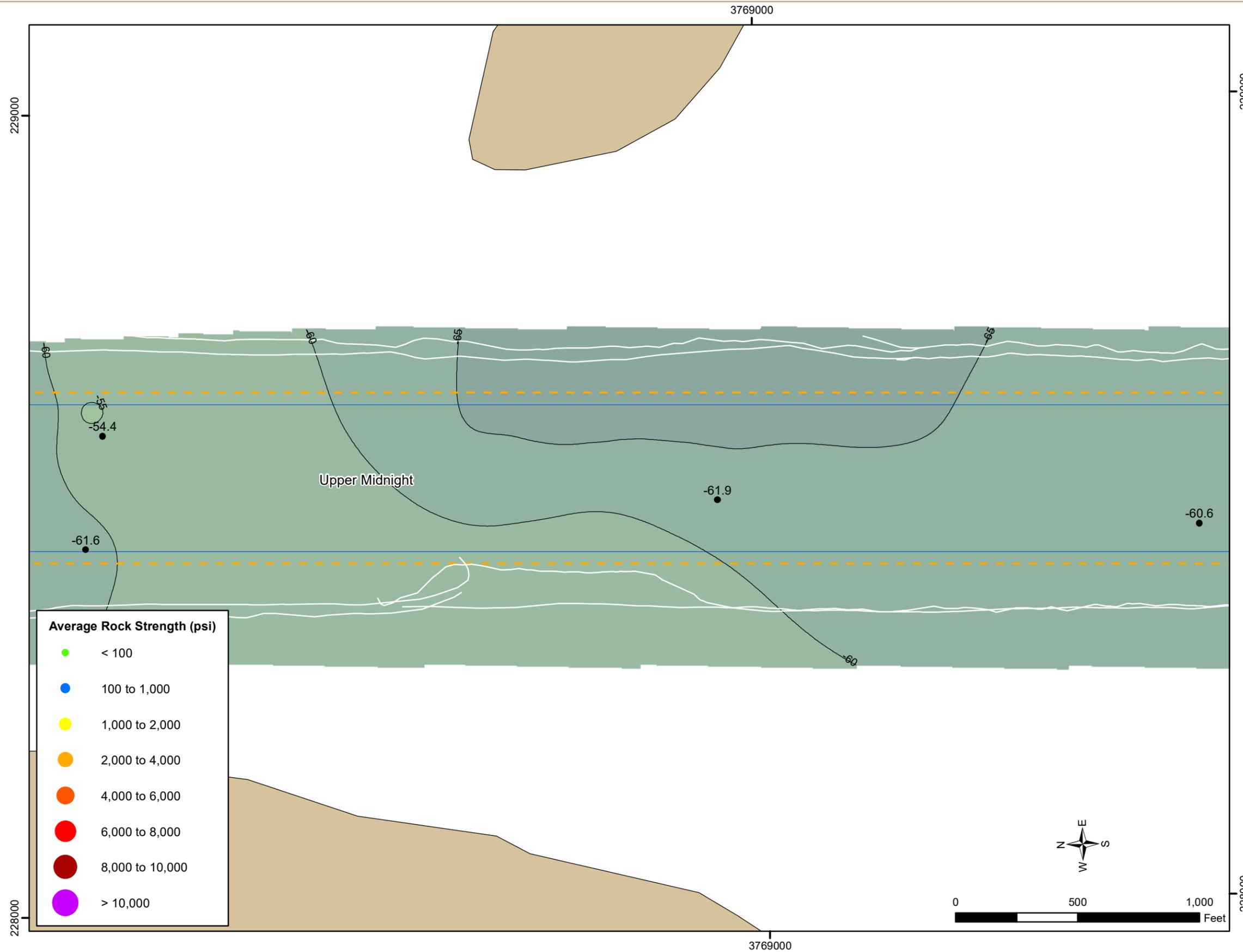
- 36.2 Top of Rock Elevation Location (with elevation listed above)
-
- - - Proposed Channel Modifications (provided by Moffatt & Nichol)
- USACE Channel Reach Boundary
- ▬ Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft. Re. MLLW)**
- -20 to -25
- -25 to -30
- -30 to -35
- -35 to -40
- -40 to -50
- -45 to -50
- -50 to -55
- -55 to -60
- -60 to -65
- -65 to -70
- -70 to -75
- -75 to -80
- -80 to -85
- < -85
- 5 foot contour interval



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

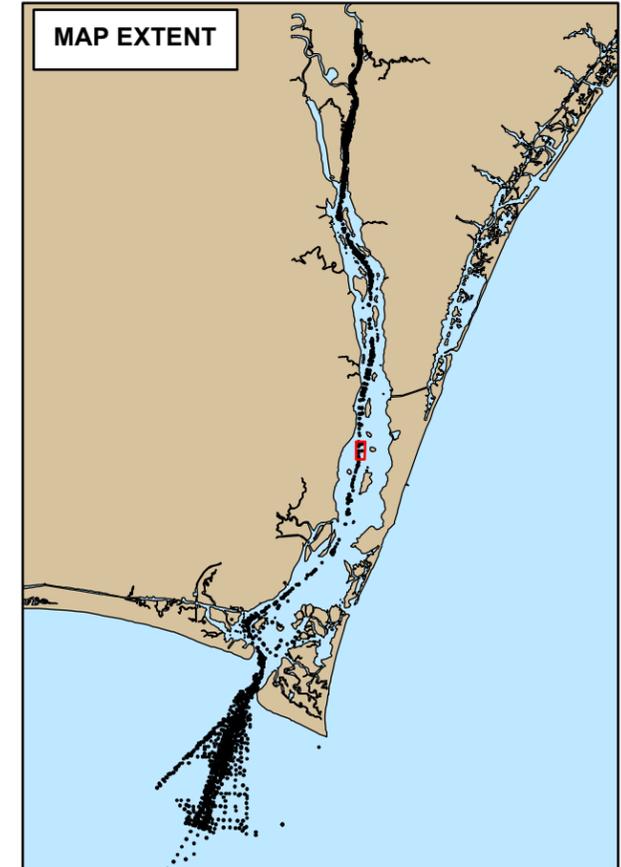
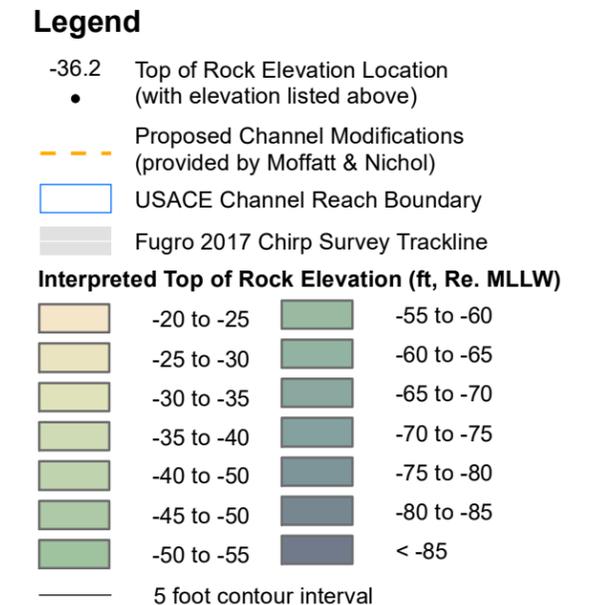
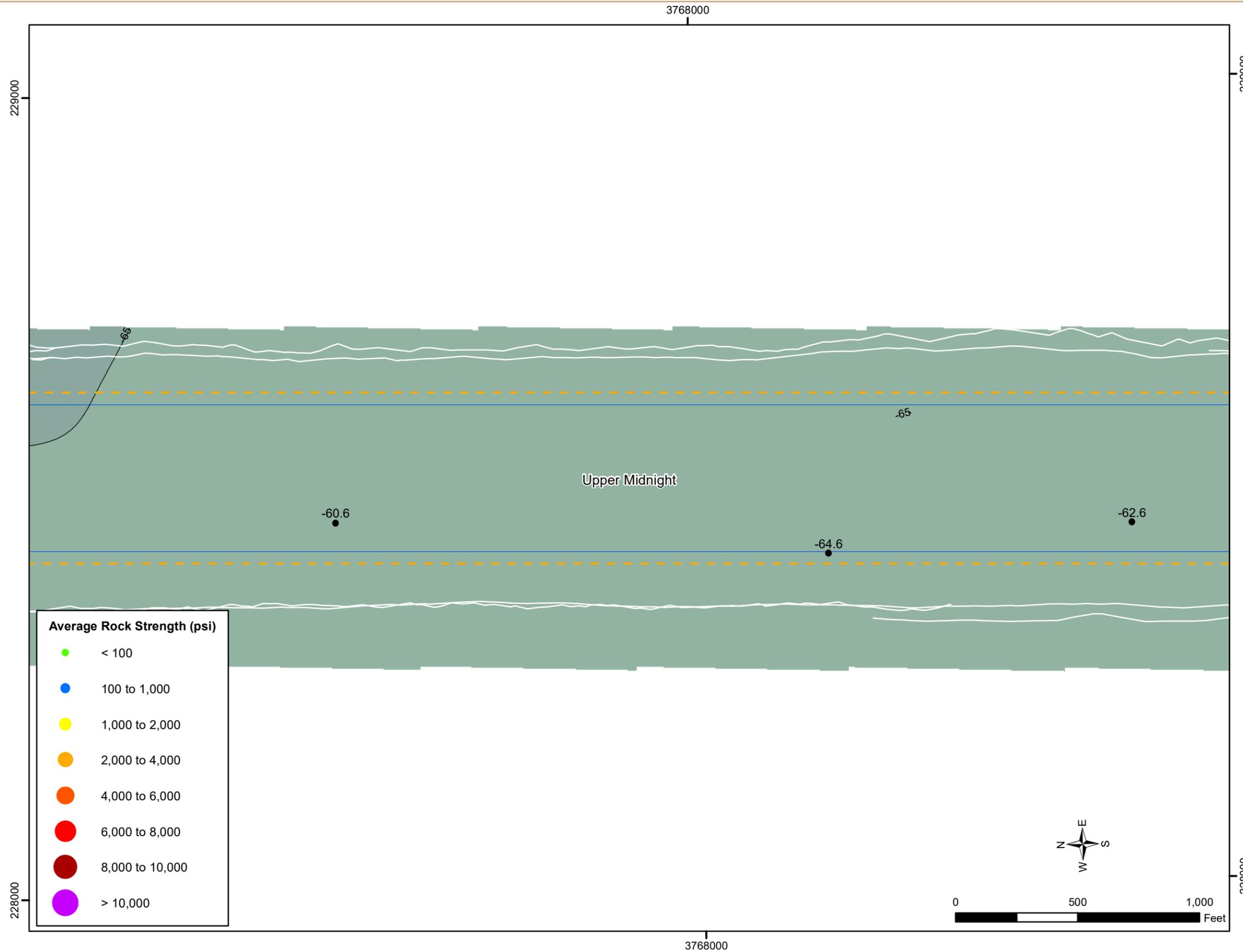


INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



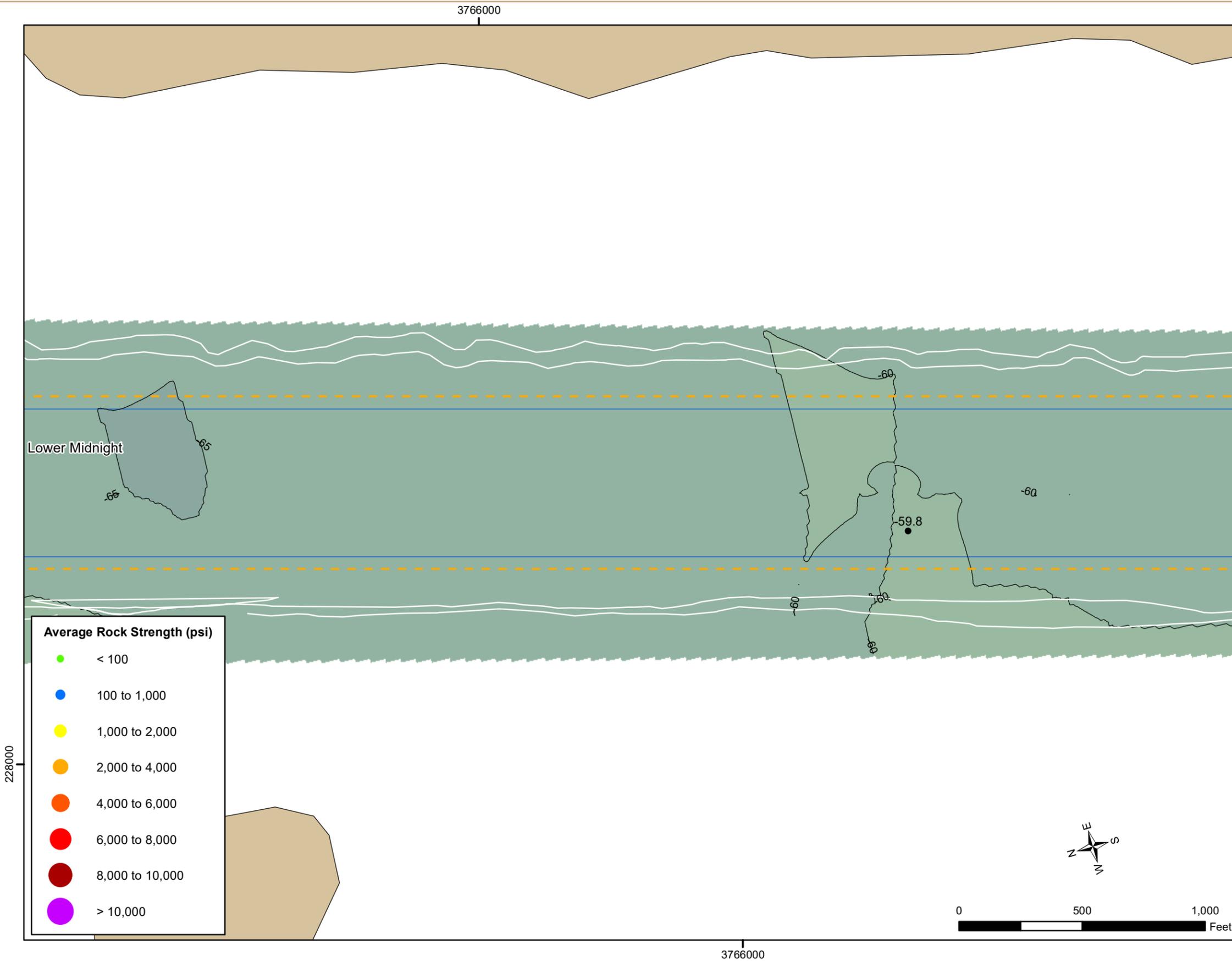
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-27



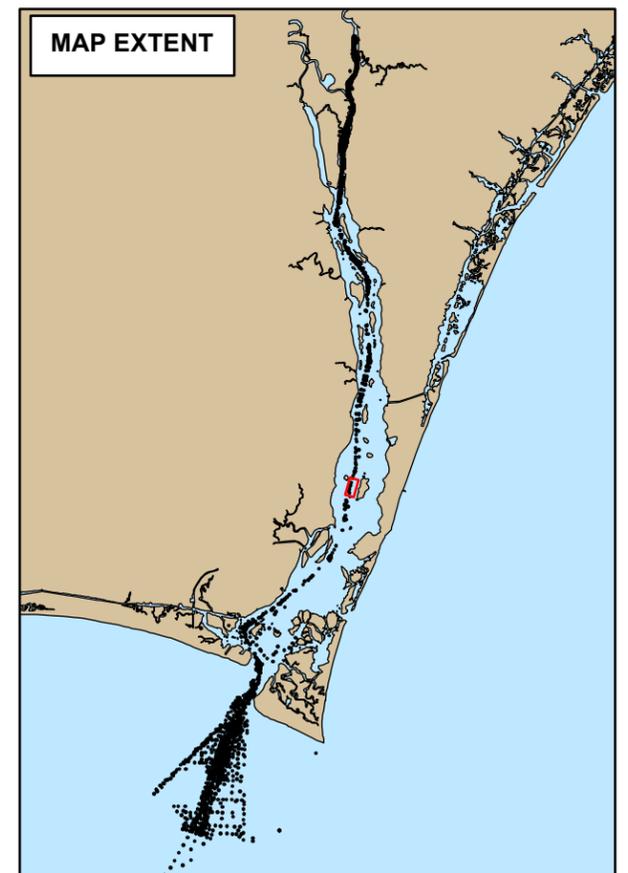
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-28



Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
 - Proposed Channel Modifications (provided by Moffatt & Nichol)
 - USACE Channel Reach Boundary
 - Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft, Re. MLLW)**
- | | |
|------------|------------|
| -20 to -25 | -55 to -60 |
| -25 to -30 | -60 to -65 |
| -30 to -35 | -65 to -70 |
| -35 to -40 | -70 to -75 |
| -40 to -50 | -75 to -80 |
| -45 to -50 | -80 to -85 |
| -50 to -55 | < -85 |
- 5 foot contour interval



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-30

3763000

228000

3762000

228000

3762000

227000

227000

3763000

Legend

-36.2 Top of Rock Elevation Location (with elevation listed above)

Proposed Channel Modifications (provided by Moffatt & Nichol)

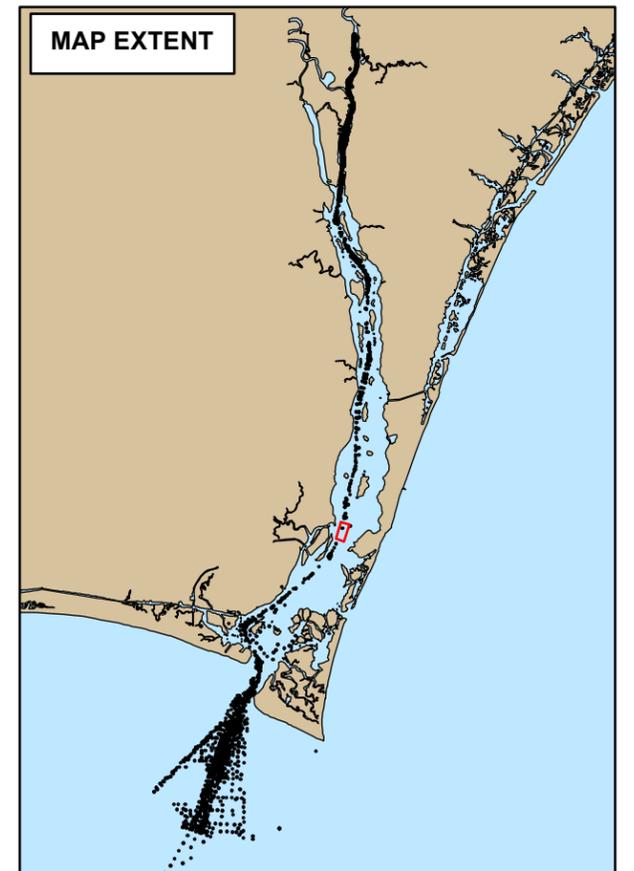
USACE Channel Reach Boundary

Fugro 2017 Chirp Survey Trackline

Interpreted Top of Rock Elevation (ft, Re. MLLW)

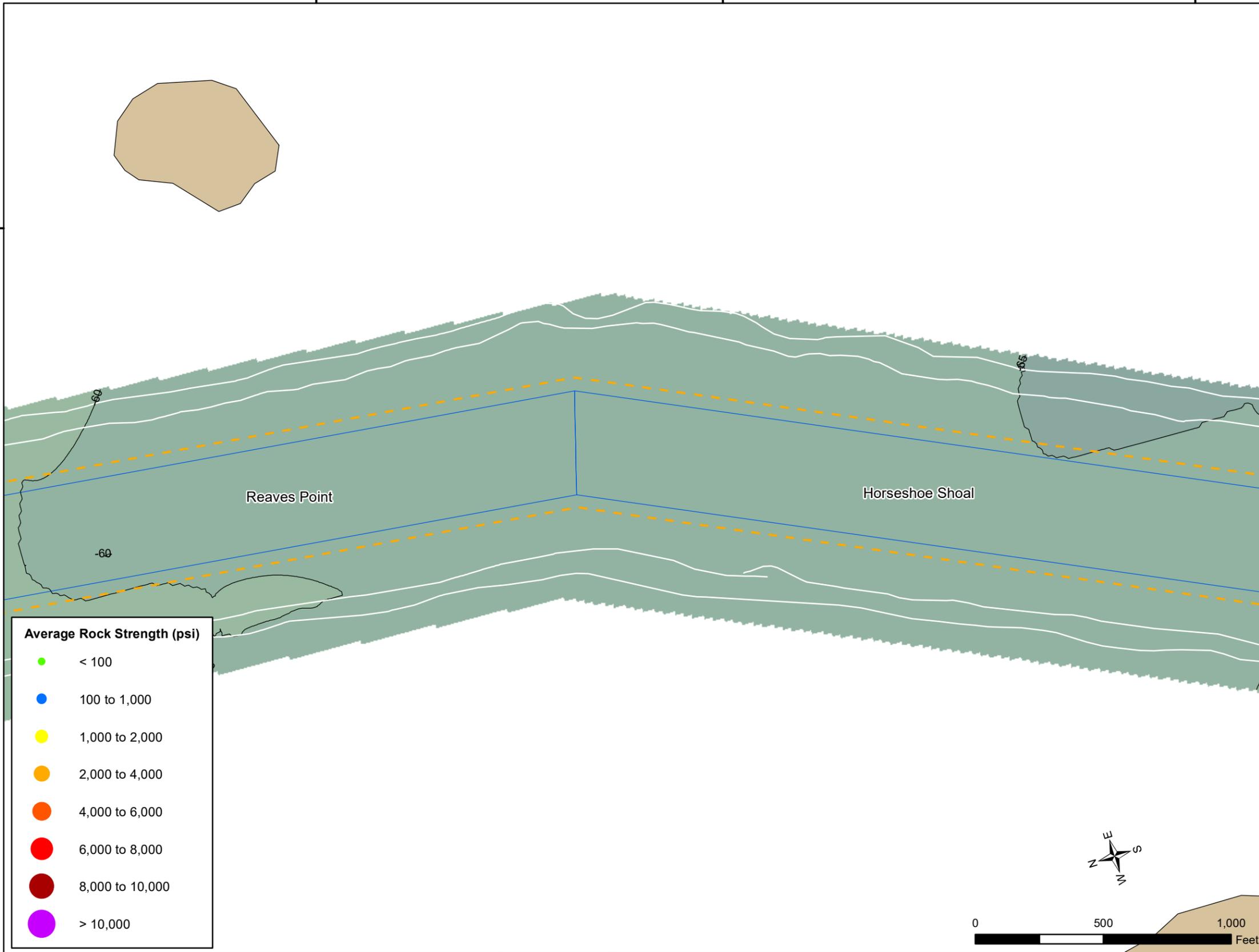
-20 to -25	-55 to -60
-25 to -30	-60 to -65
-30 to -35	-65 to -70
-35 to -40	-70 to -75
-40 to -50	-75 to -80
-45 to -50	-80 to -85
-50 to -55	< -85

5 foot contour interval



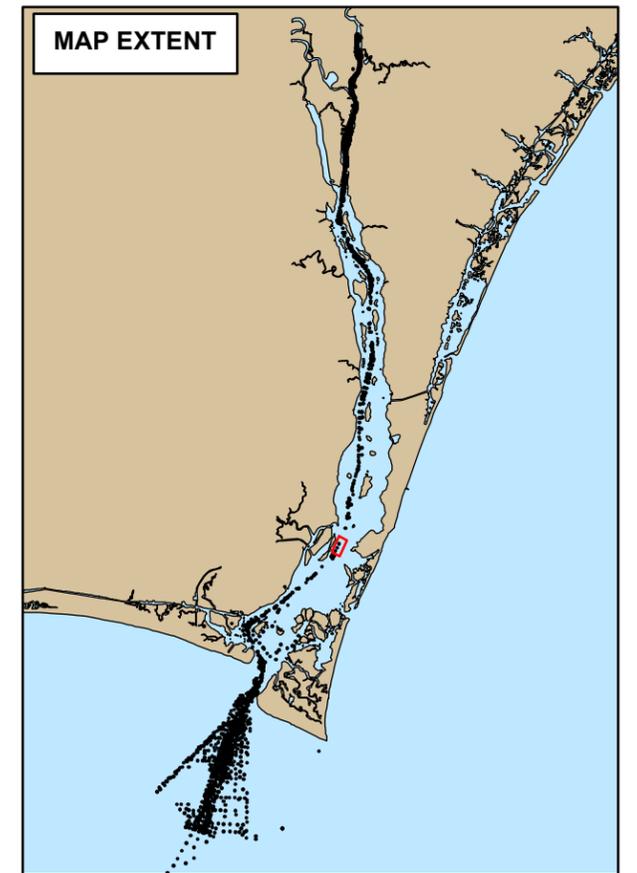
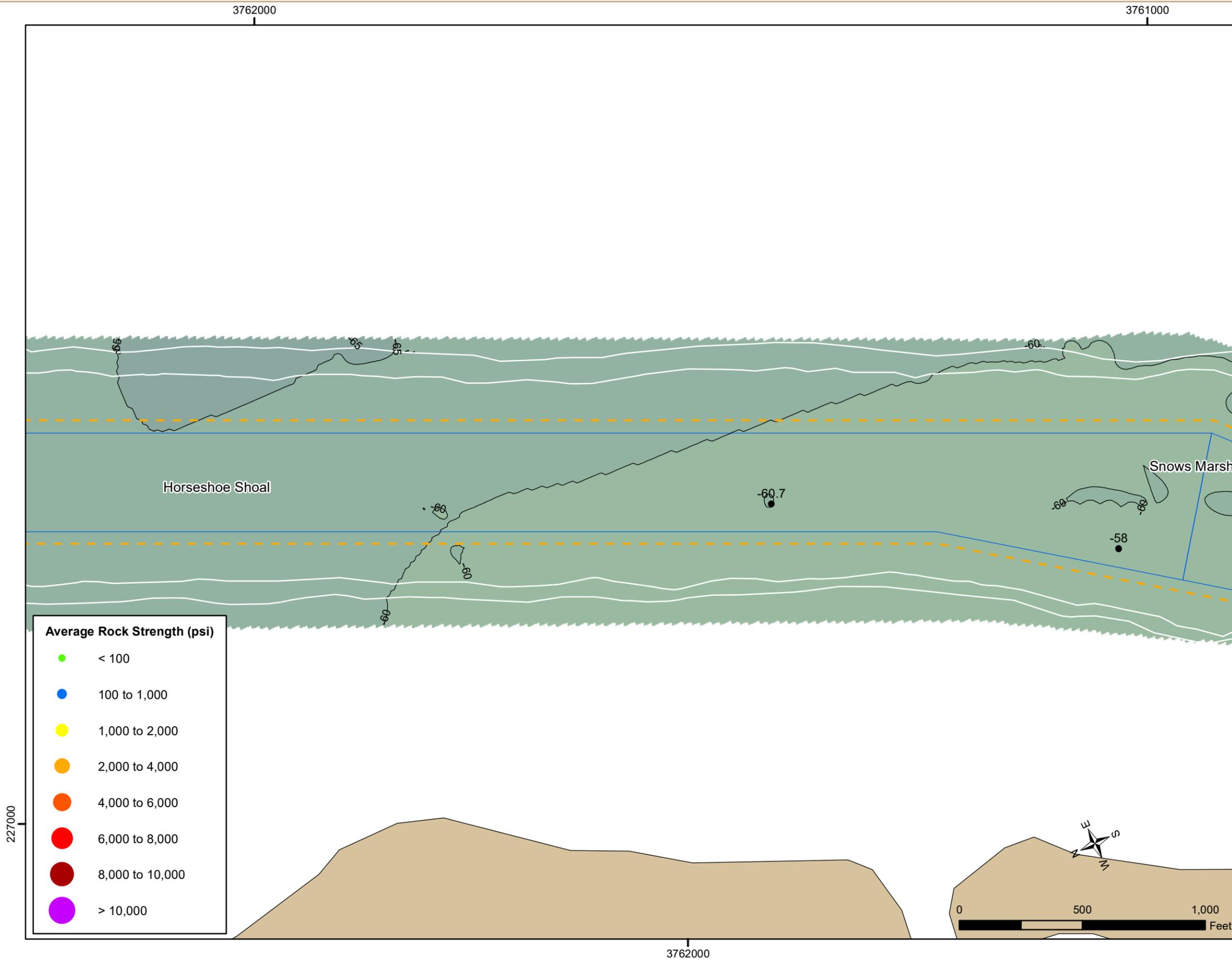
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-33



Average Rock Strength (psi)

< 100
100 to 1,000
1,000 to 2,000
2,000 to 4,000
4,000 to 6,000
6,000 to 8,000
8,000 to 10,000
> 10,000



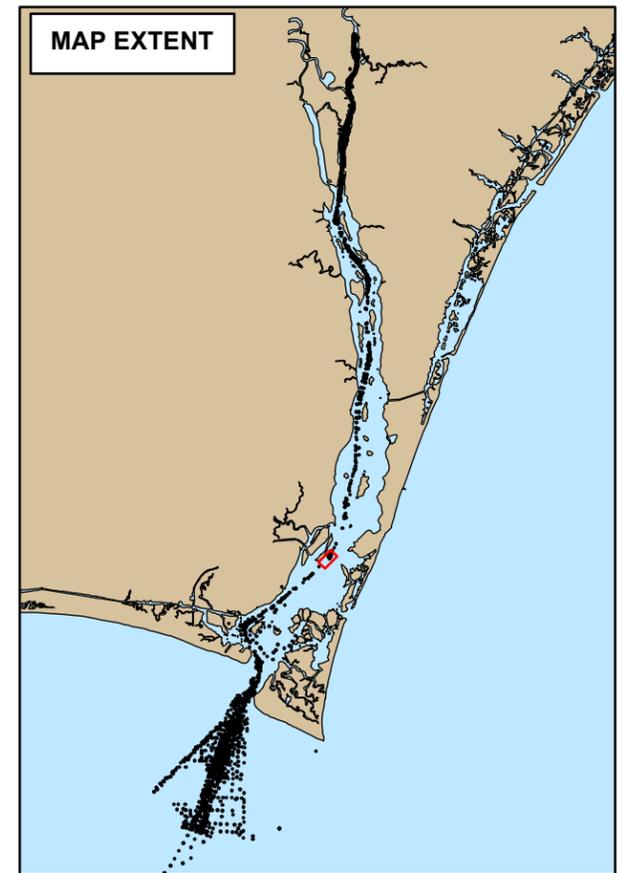
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-34



Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
 - Proposed Channel Modifications (provided by Moffatt & Nichol)
 - USACE Channel Reach Boundary
 - Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft, Re. MLLW)**
- | | |
|------------|------------|
| -20 to -25 | -55 to -60 |
| -25 to -30 | -60 to -65 |
| -30 to -35 | -65 to -70 |
| -35 to -40 | -70 to -75 |
| -40 to -50 | -75 to -80 |
| -45 to -50 | -80 to -85 |
| -50 to -55 | < -85 |
- 5 foot contour interval



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-35

3760000

226000

Legend

-36.2 Top of Rock Elevation Location (with elevation listed above)

Proposed Channel Modifications (provided by Moffatt & Nichol)

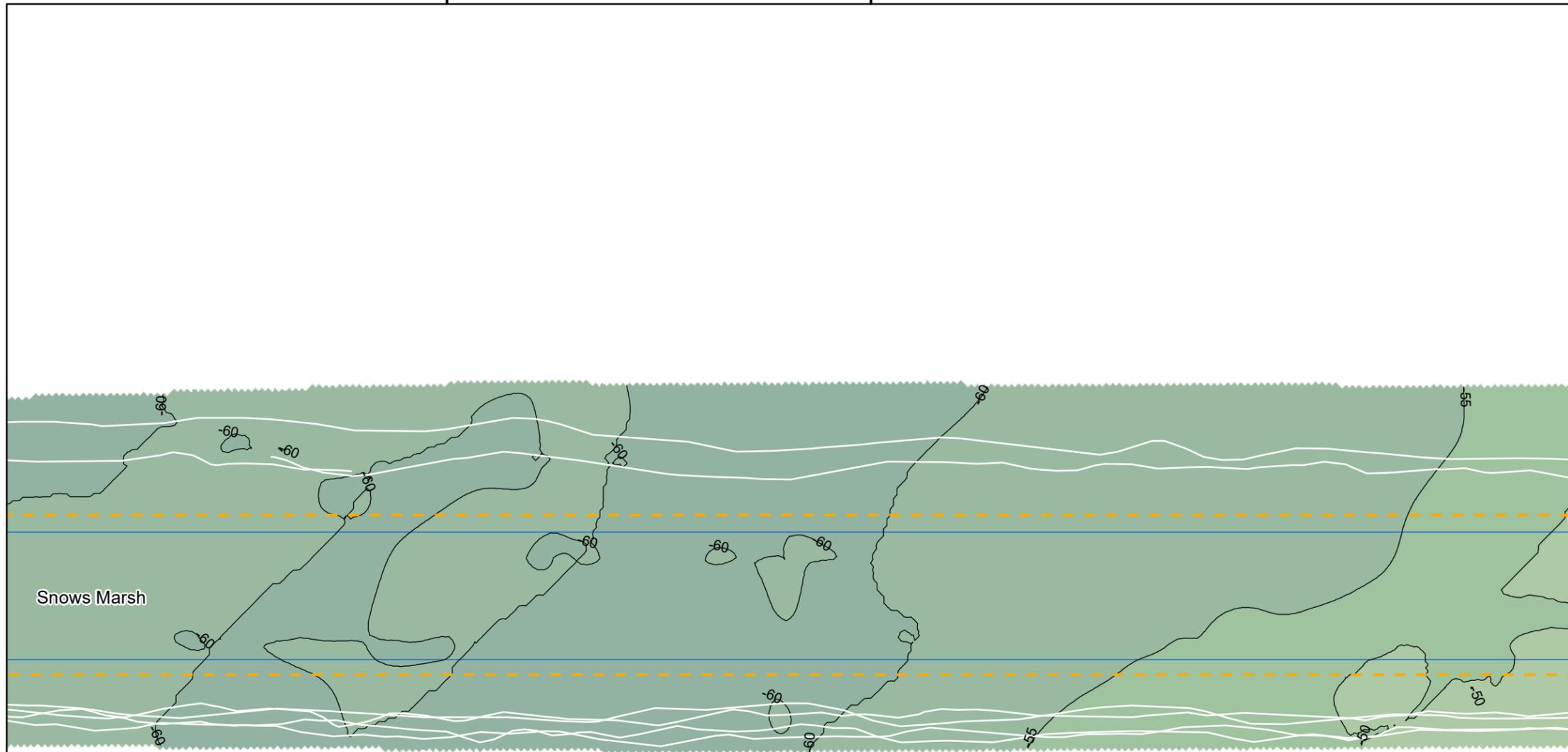
USACE Channel Reach Boundary

Fugro 2017 Chirp Survey Trackline

Interpreted Top of Rock Elevation (ft, Re. MLLW)

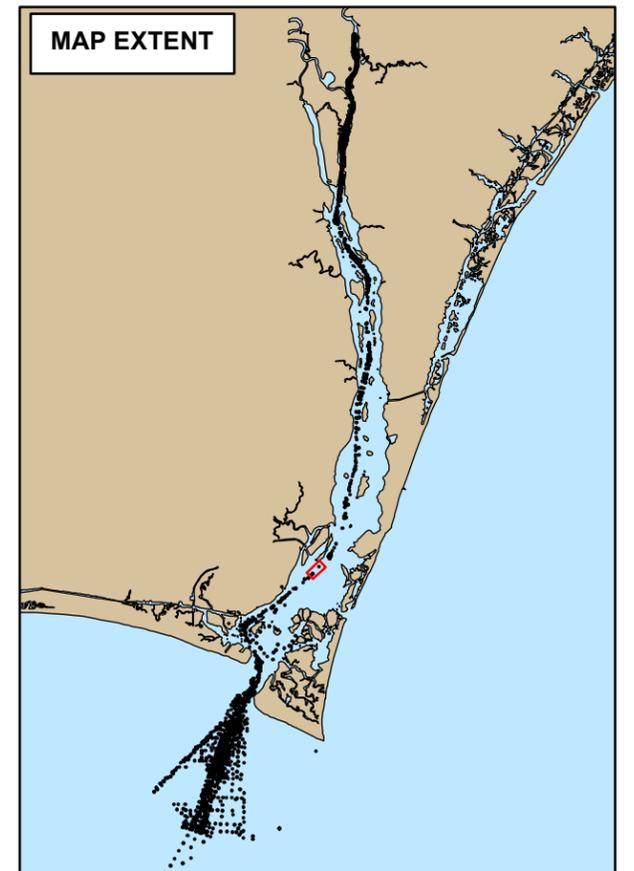
-20 to -25	-55 to -60
-25 to -30	-60 to -65
-30 to -35	-65 to -70
-35 to -40	-70 to -75
-40 to -50	-75 to -80
-45 to -50	-80 to -85
-50 to -55	< -85

5 foot contour interval



Average Rock Strength (psi)

< 100
100 to 1,000
1,000 to 2,000
2,000 to 4,000
4,000 to 6,000
6,000 to 8,000
8,000 to 10,000
> 10,000



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-36

3761000

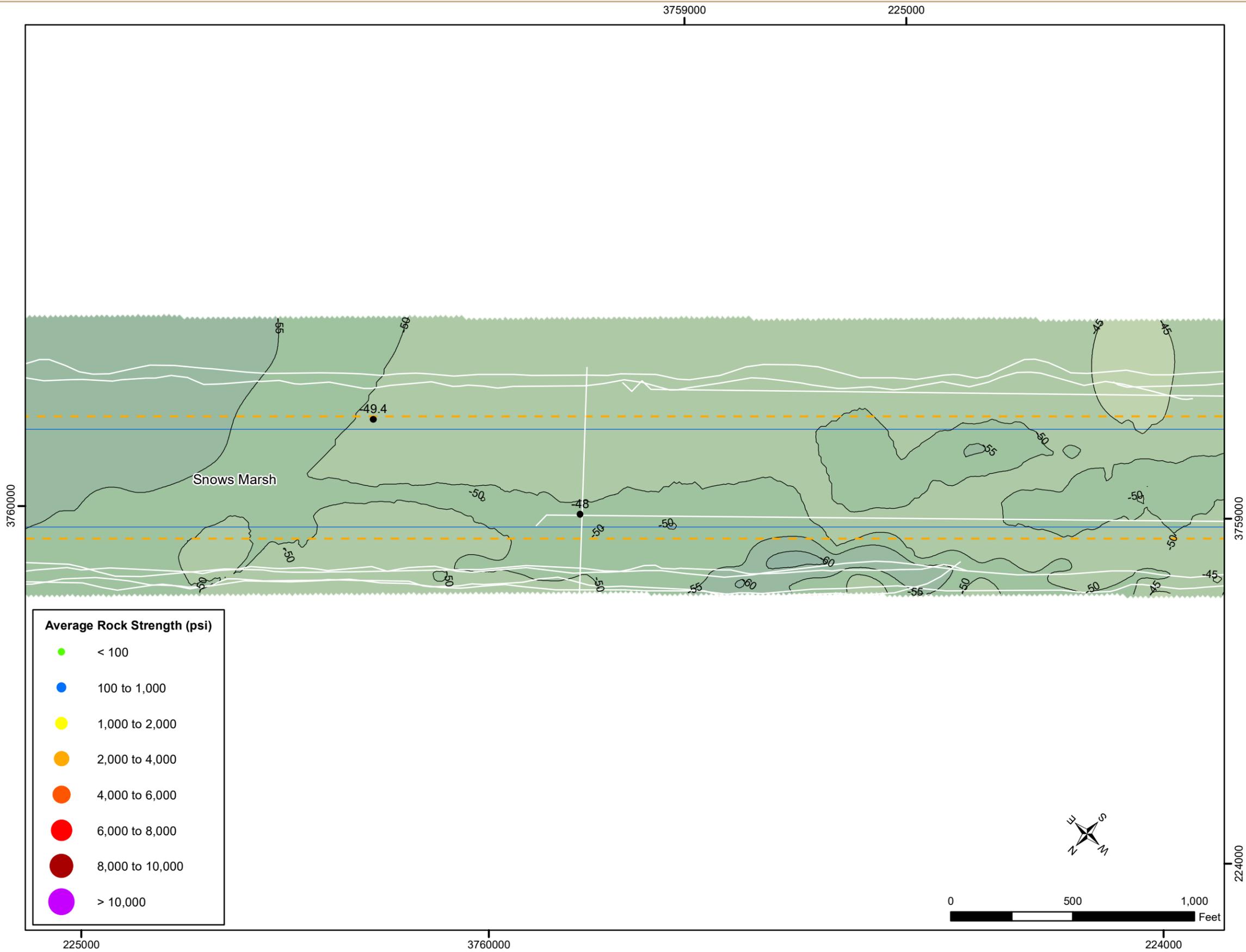
3761000

225000

225000

3760000

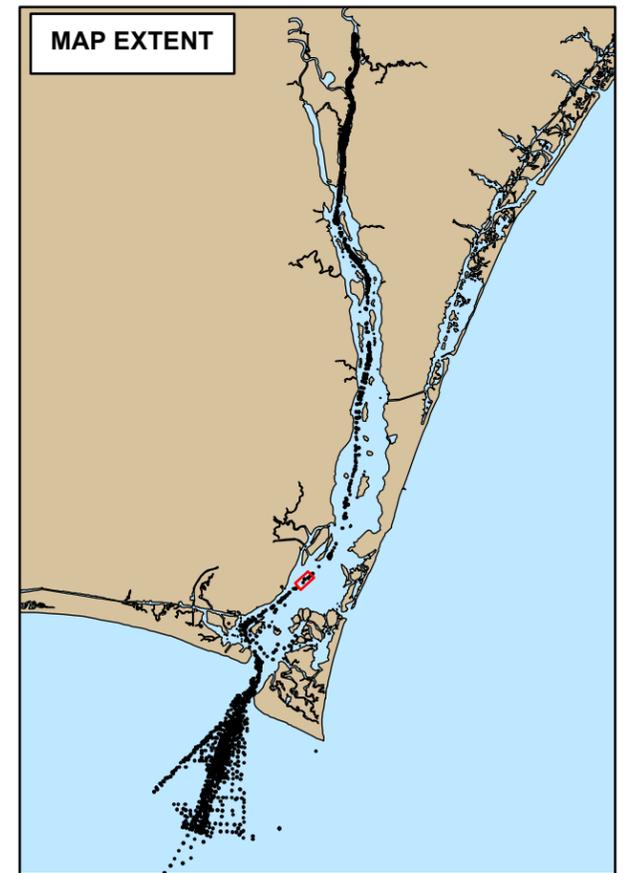




Legend

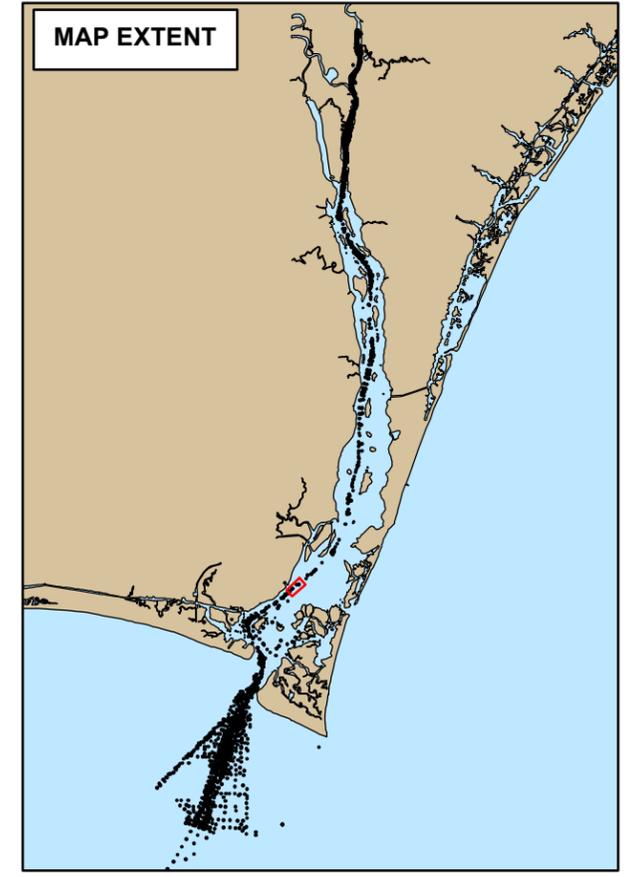
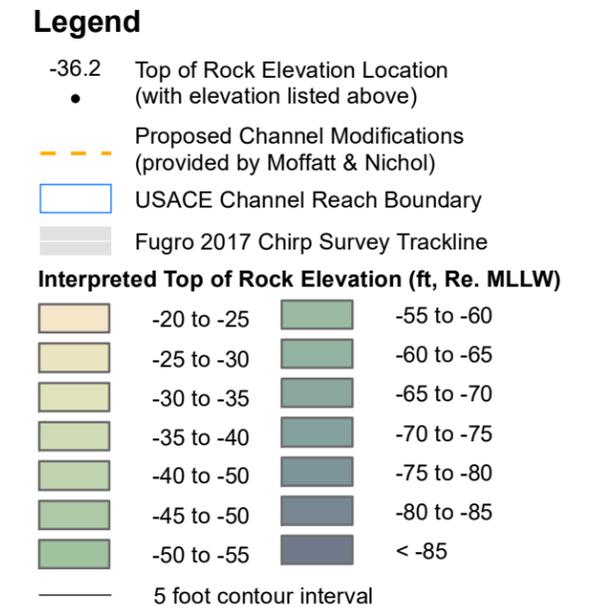
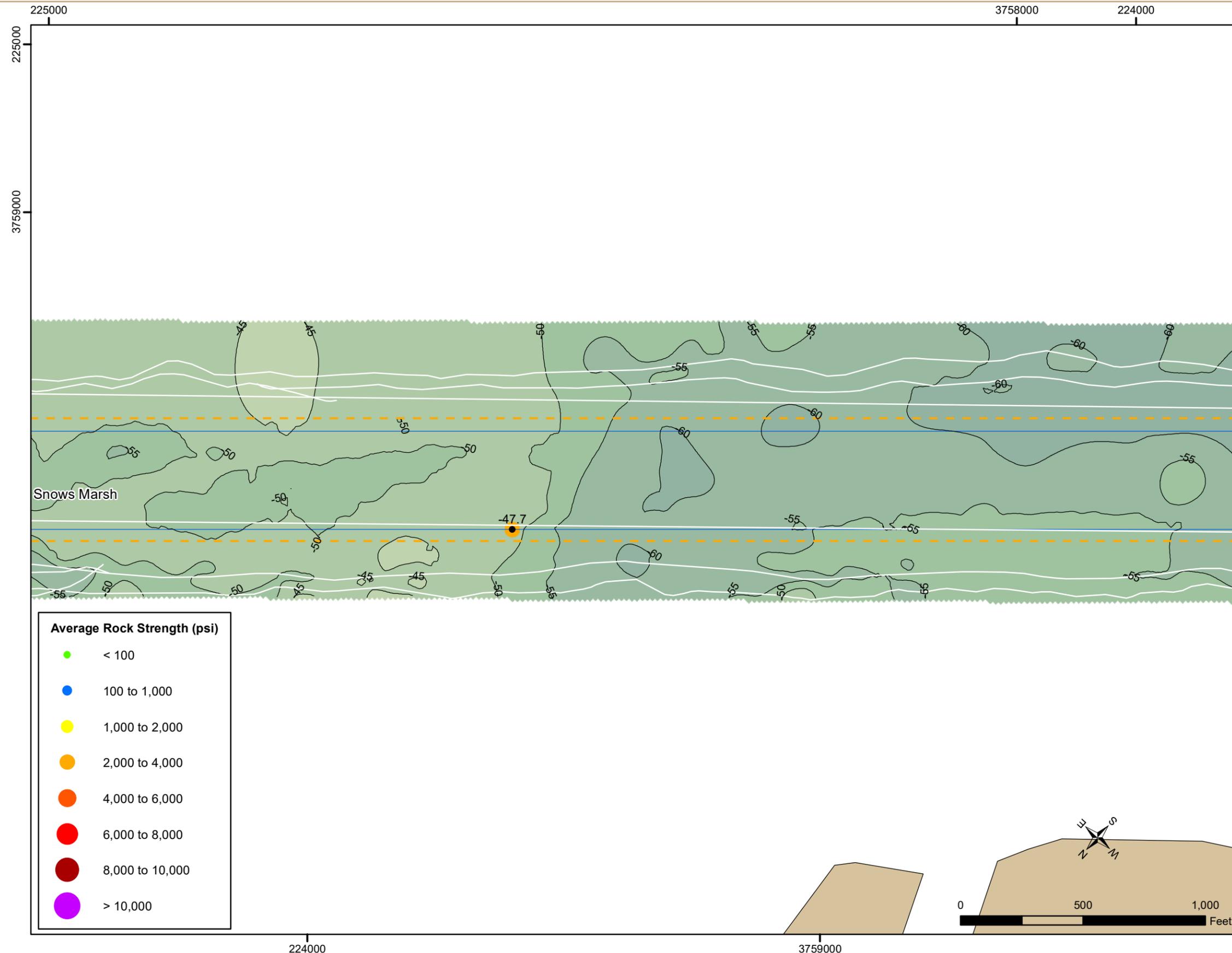
- 36.2 Top of Rock Elevation Location (with elevation listed above)
 - Proposed Channel Modifications (provided by Moffatt & Nichol)
 - USACE Channel Reach Boundary
 - Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft, Re. MLLW)**
- | | |
|------------|------------|
| -20 to -25 | -55 to -60 |
| -25 to -30 | -60 to -65 |
| -30 to -35 | -65 to -70 |
| -35 to -40 | -70 to -75 |
| -40 to -50 | -75 to -80 |
| -45 to -50 | -80 to -85 |
| -50 to -55 | < -85 |
- 5 foot contour interval

- Average Rock Strength (psi)**
- < 100
 - 100 to 1,000
 - 1,000 to 2,000
 - 2,000 to 4,000
 - 4,000 to 6,000
 - 6,000 to 8,000
 - 8,000 to 10,000
 - > 10,000

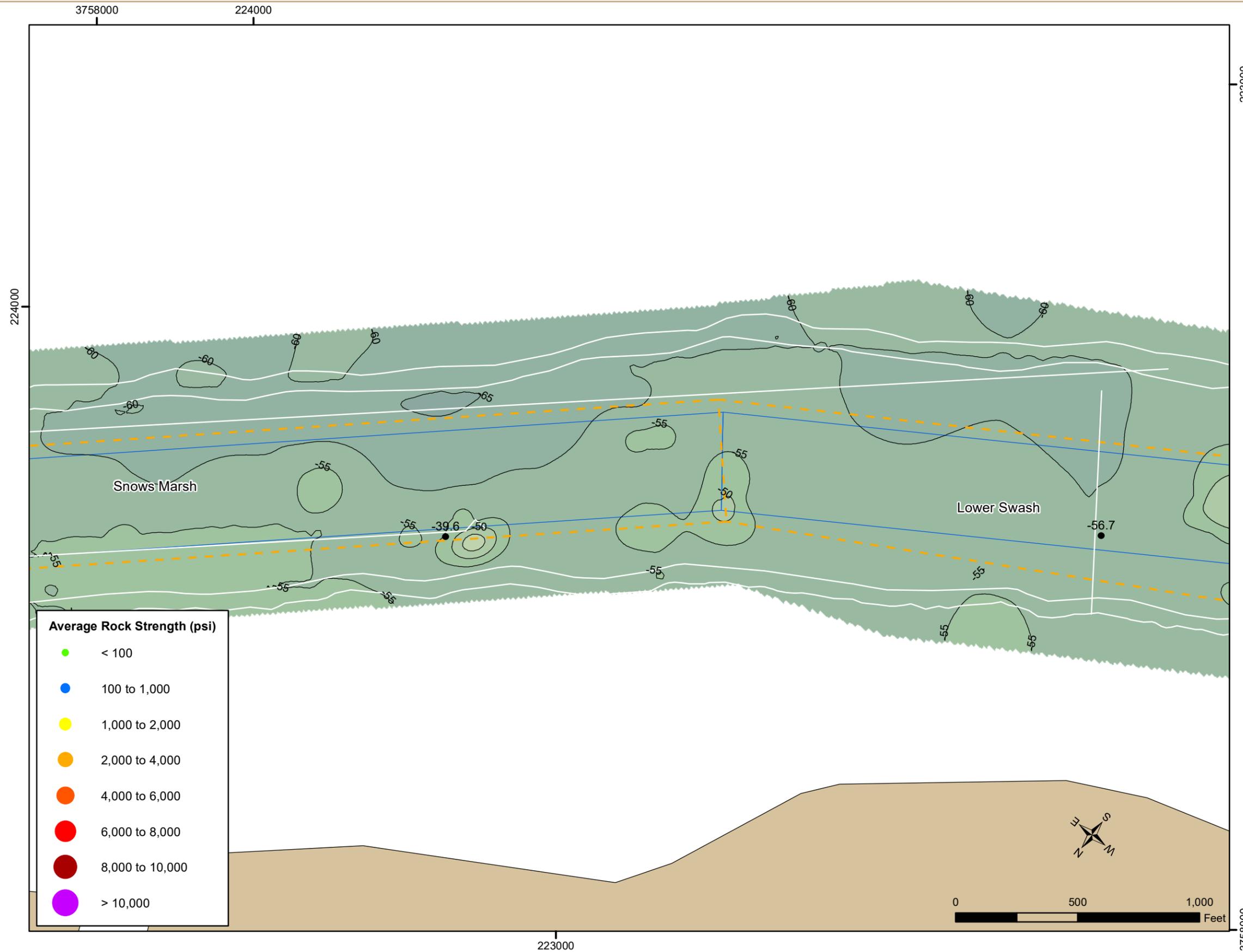


INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-37



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
-
- - - Proposed Channel Modifications (provided by Moffatt & Nichol)
- USACE Channel Reach Boundary
- ▬ Fugro 2017 Chirp Survey Trackline

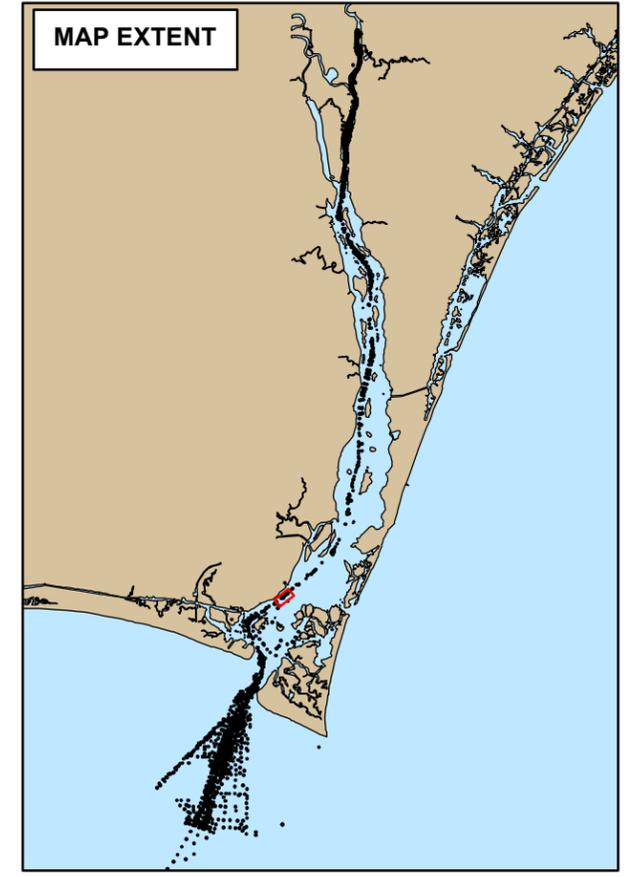
Interpreted Top of Rock Elevation (ft, Re. MLLW)

-20 to -25	-55 to -60
-25 to -30	-60 to -65
-30 to -35	-65 to -70
-35 to -40	-70 to -75
-40 to -50	-75 to -80
-45 to -50	-80 to -85
-50 to -55	< -85

— 5 foot contour interval

Average Rock Strength (psi)

- < 100
- 100 to 1,000
- 1,000 to 2,000
- 2,000 to 4,000
- 4,000 to 6,000
- 6,000 to 8,000
- 8,000 to 10,000
- > 10,000



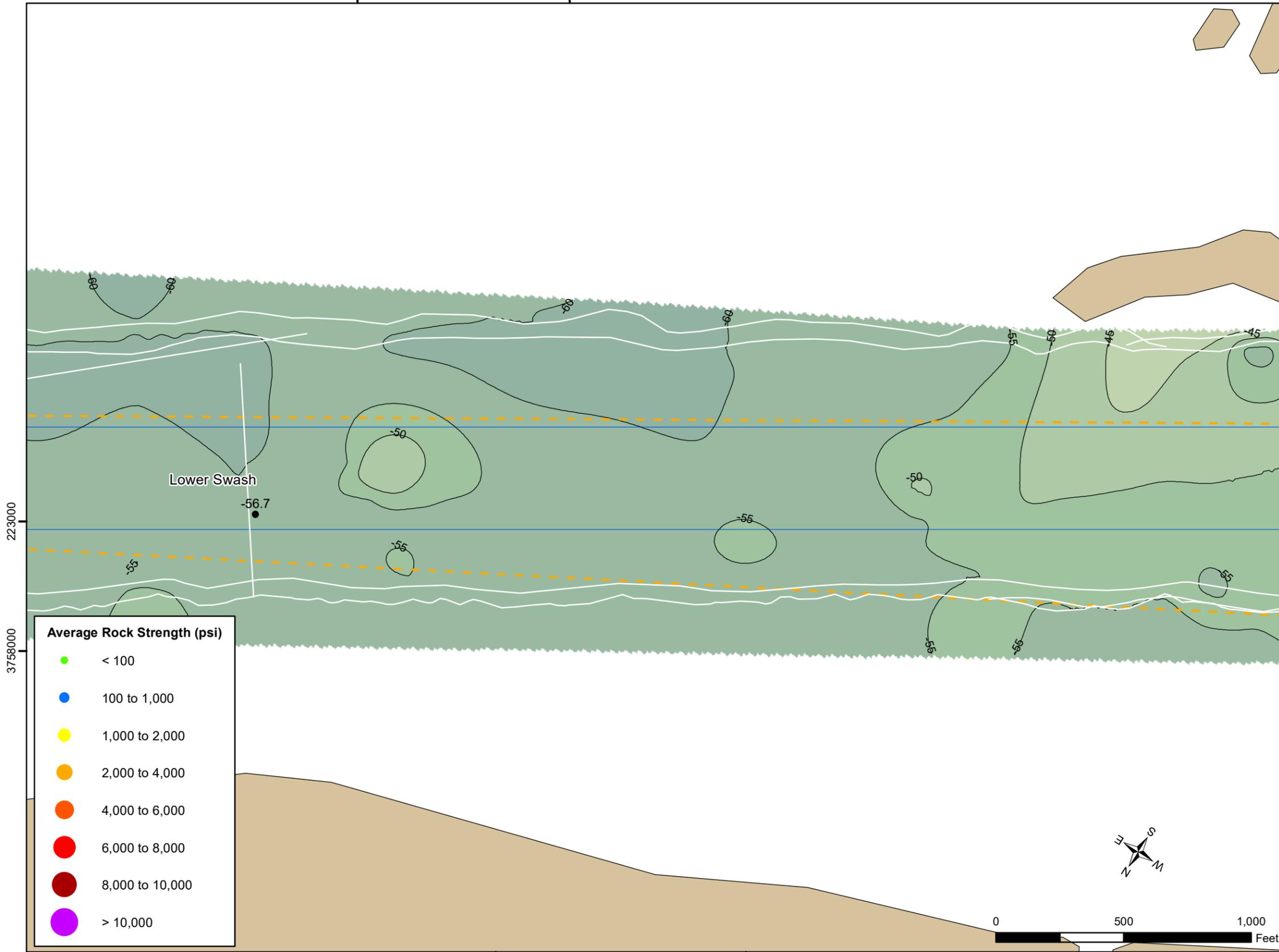
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-39

223000 3757000

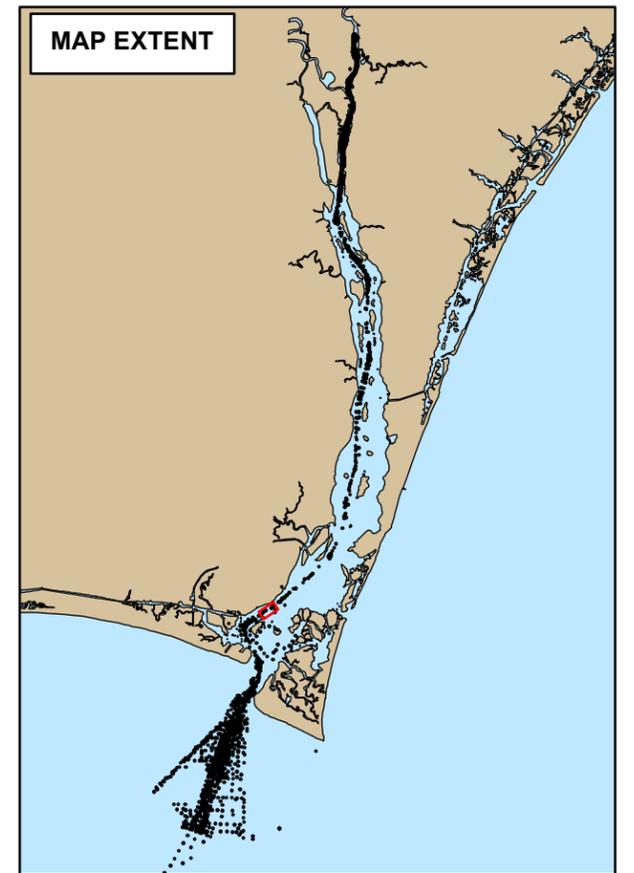
Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
 - Proposed Channel Modifications (provided by Moffatt & Nichol)
 - USACE Channel Reach Boundary
 - Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft, Re. MLLW)**
- | | |
|------------|------------|
| -20 to -25 | -55 to -60 |
| -25 to -30 | -60 to -65 |
| -30 to -35 | -65 to -70 |
| -35 to -40 | -70 to -75 |
| -40 to -50 | -75 to -80 |
| -45 to -50 | -80 to -85 |
| -50 to -55 | < -85 |
- 5 foot contour interval



Average Rock Strength (psi)

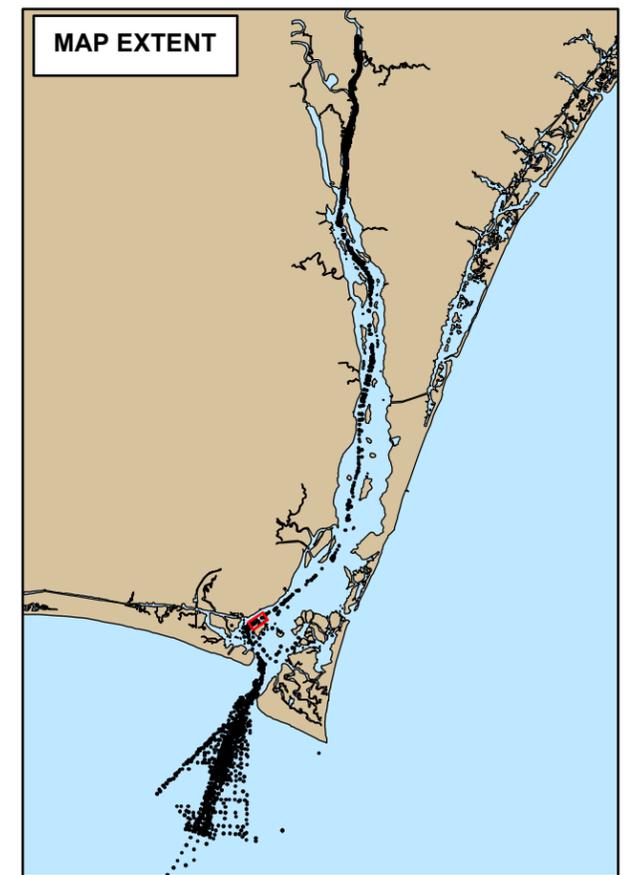
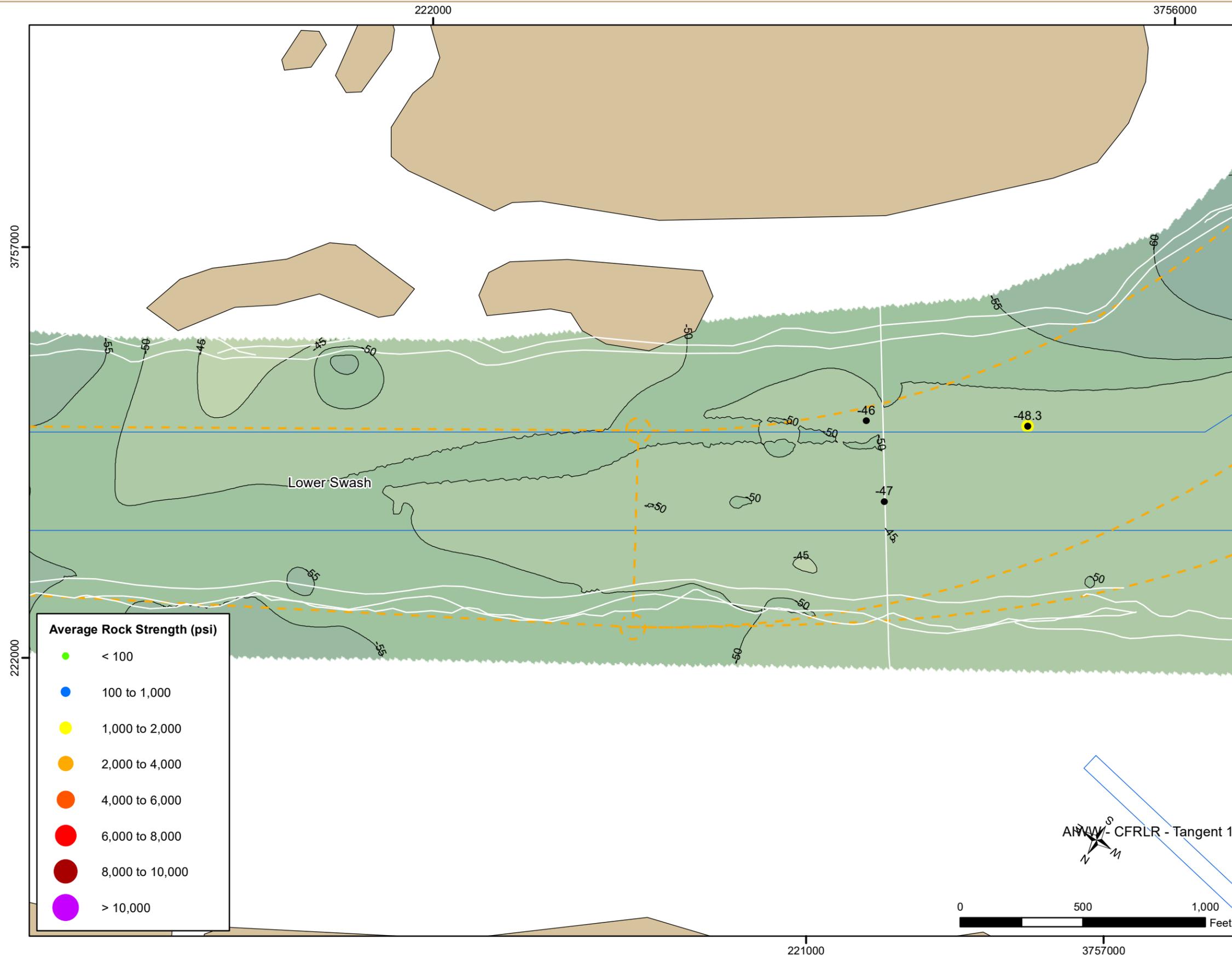
- < 100
- 100 to 1,000
- 1,000 to 2,000
- 2,000 to 4,000
- 4,000 to 6,000
- 6,000 to 8,000
- 8,000 to 10,000
- > 10,000



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

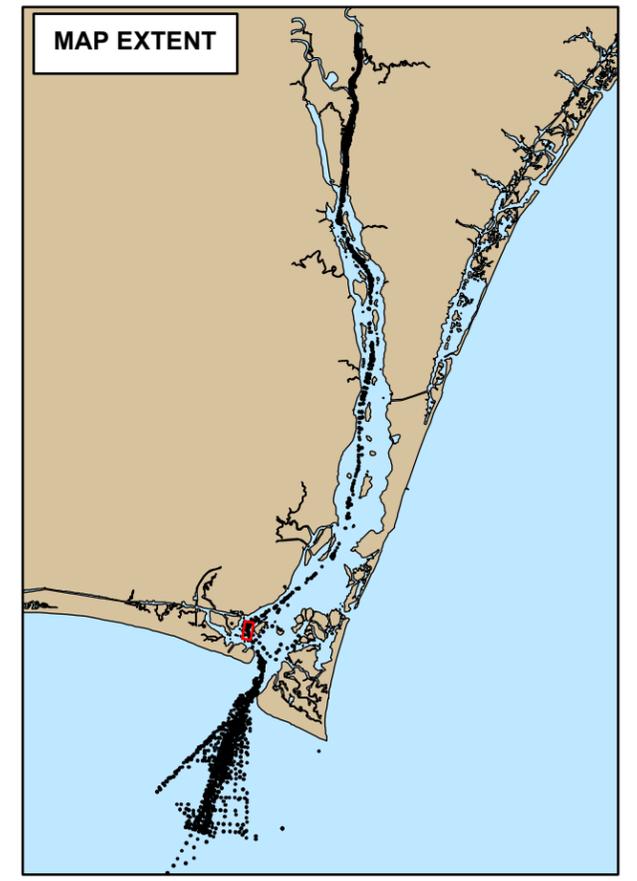
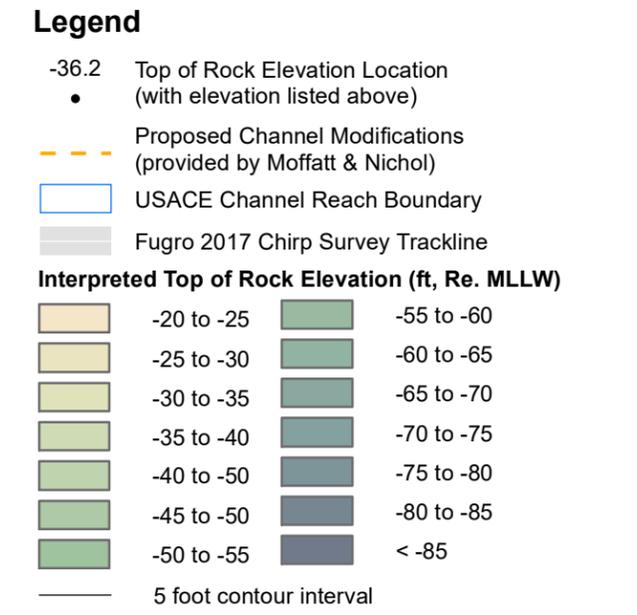
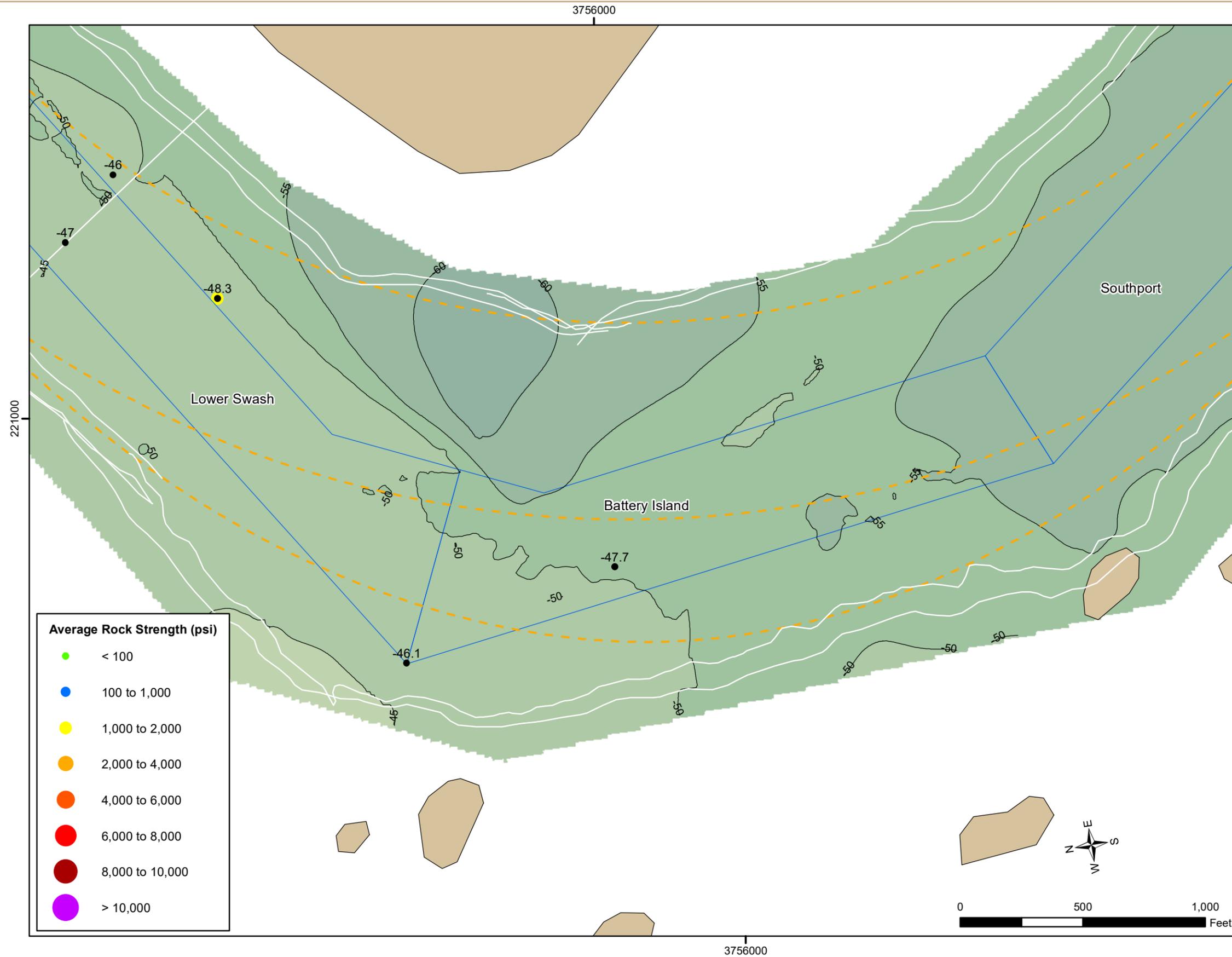
3758000 222000

FIGURE 3-40



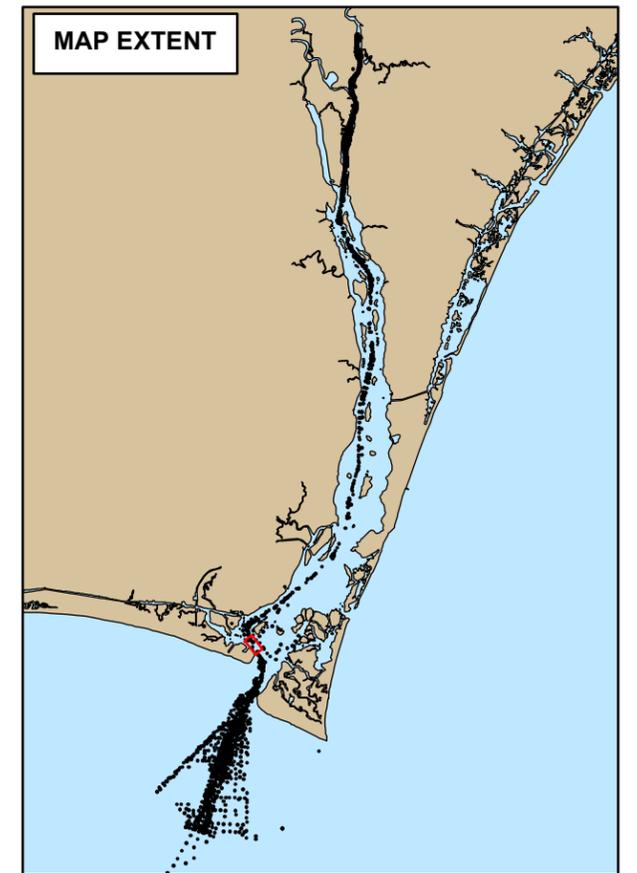
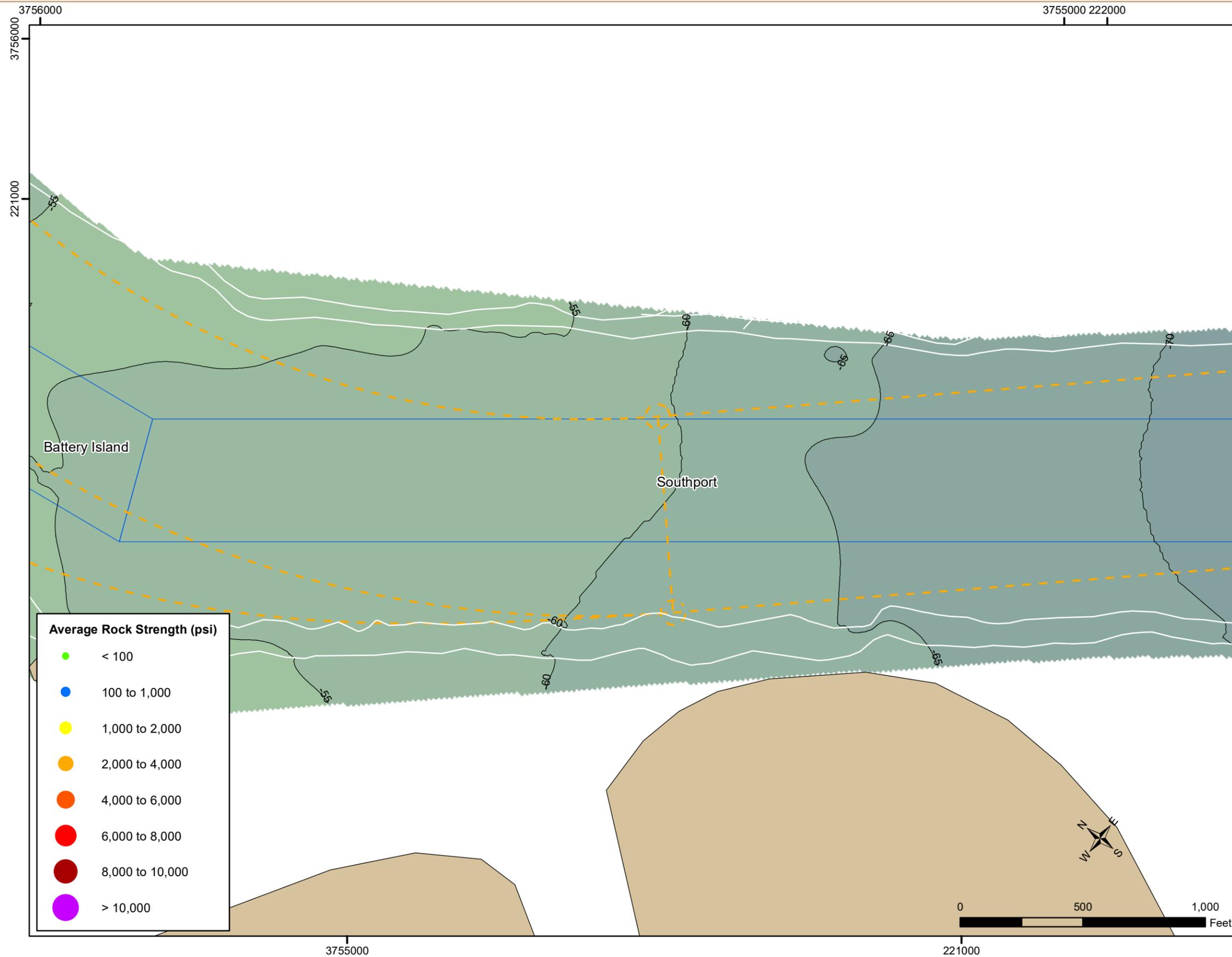
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-41



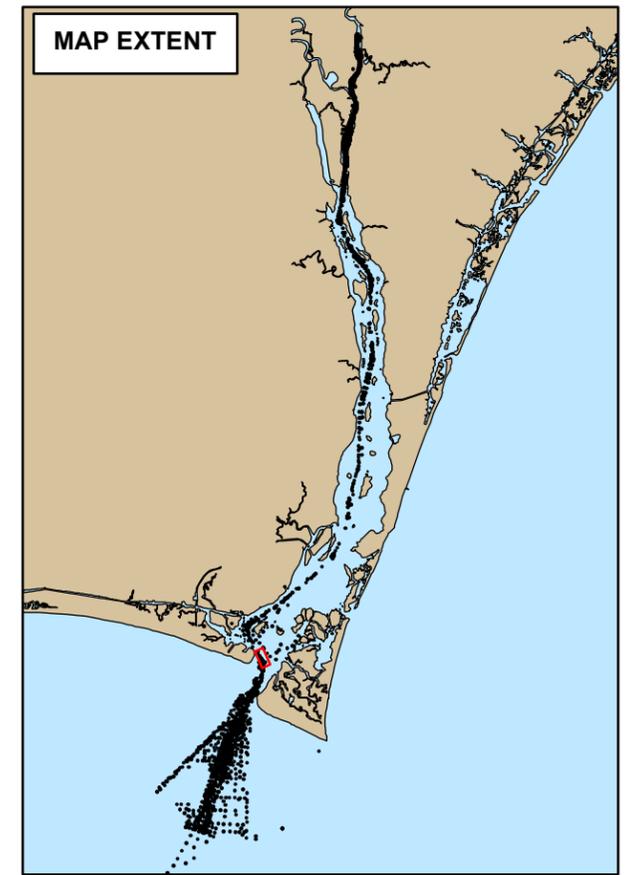
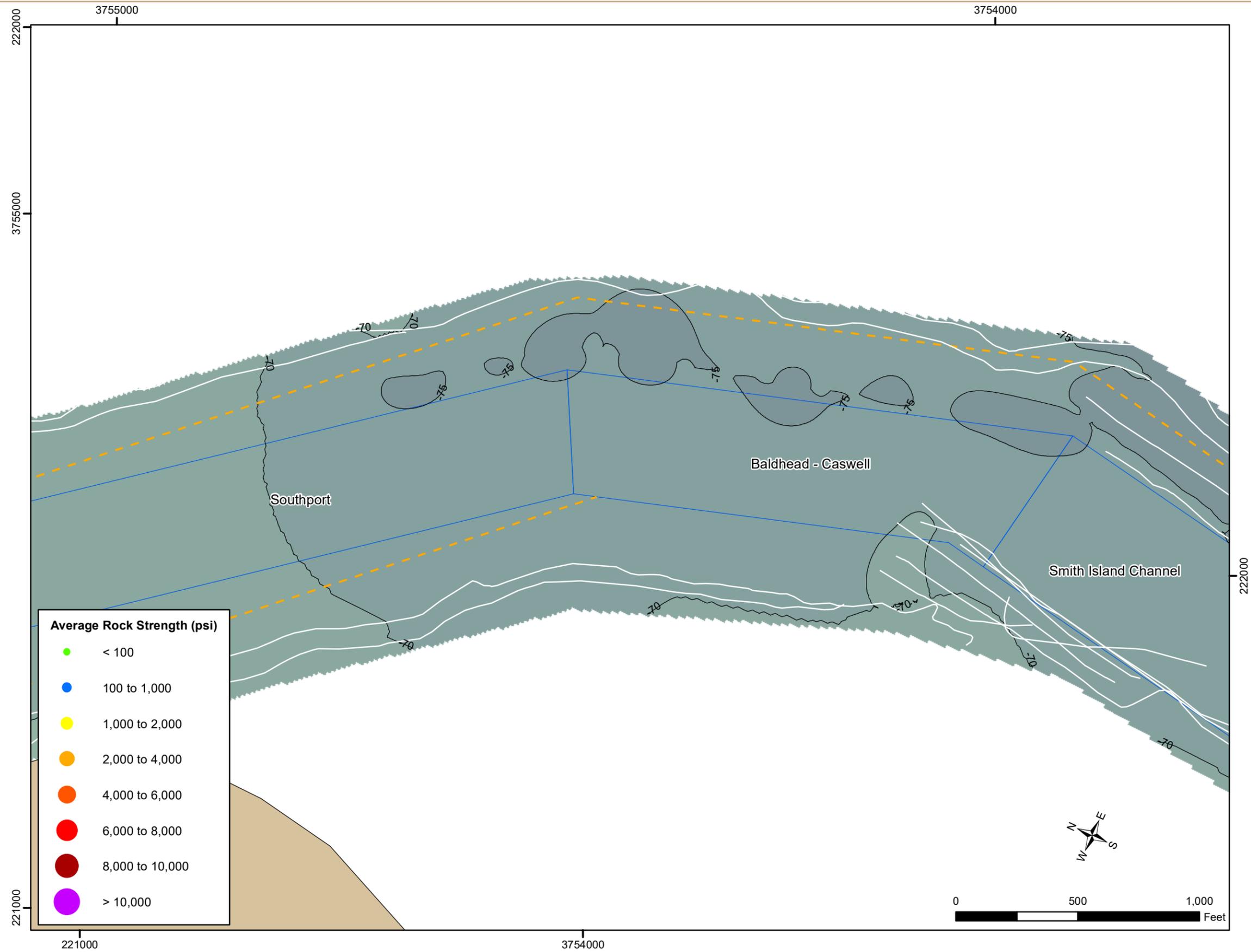
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-42



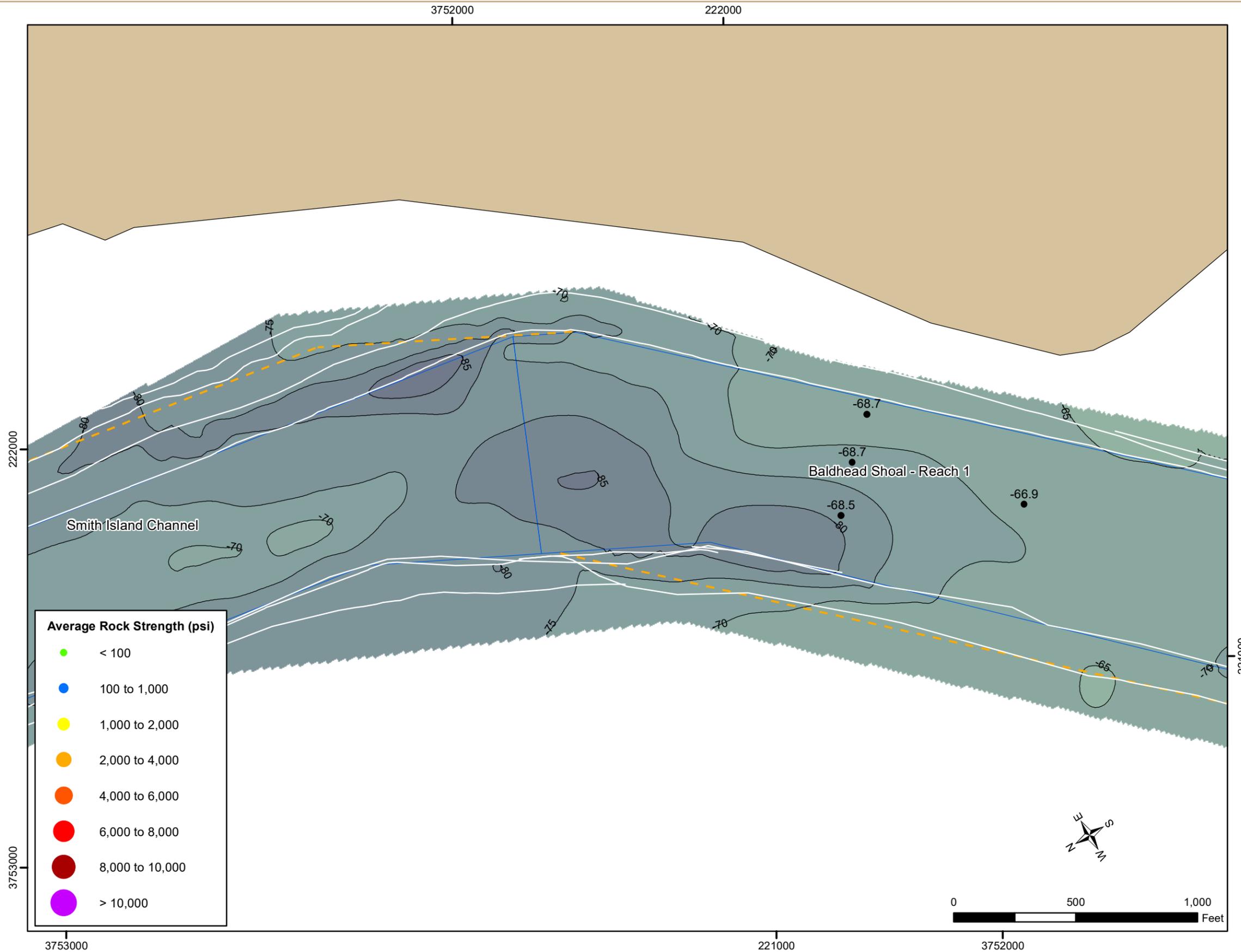
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-43



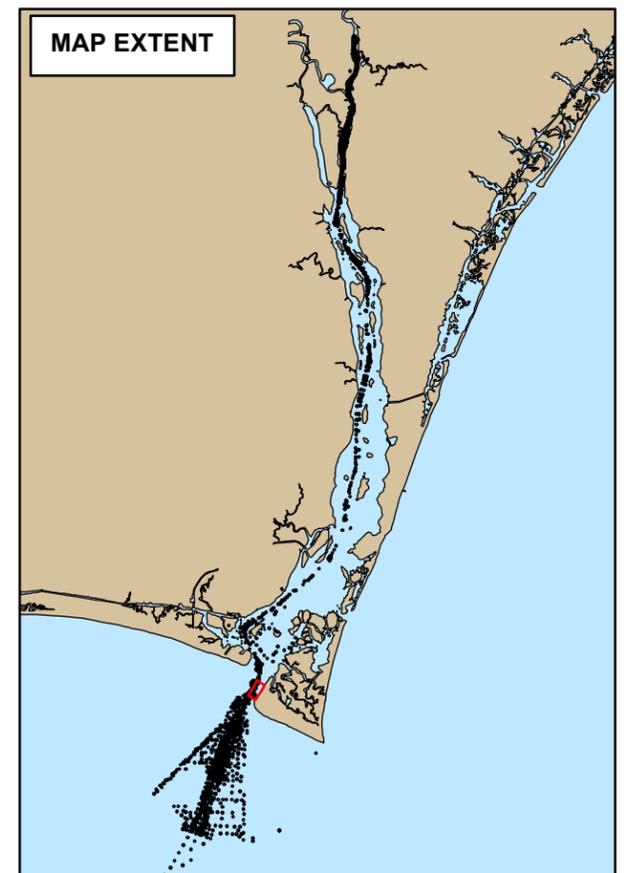
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-44



Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
 - Proposed Channel Modifications (provided by Moffatt & Nichol)
 - USACE Channel Reach Boundary
 - Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft, Re. MLLW)**
- | | |
|------------|------------|
| -20 to -25 | -55 to -60 |
| -25 to -30 | -60 to -65 |
| -30 to -35 | -65 to -70 |
| -35 to -40 | -70 to -75 |
| -40 to -50 | -75 to -80 |
| -45 to -50 | -80 to -85 |
| -50 to -55 | < -85 |
- 5 foot contour interval



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-46

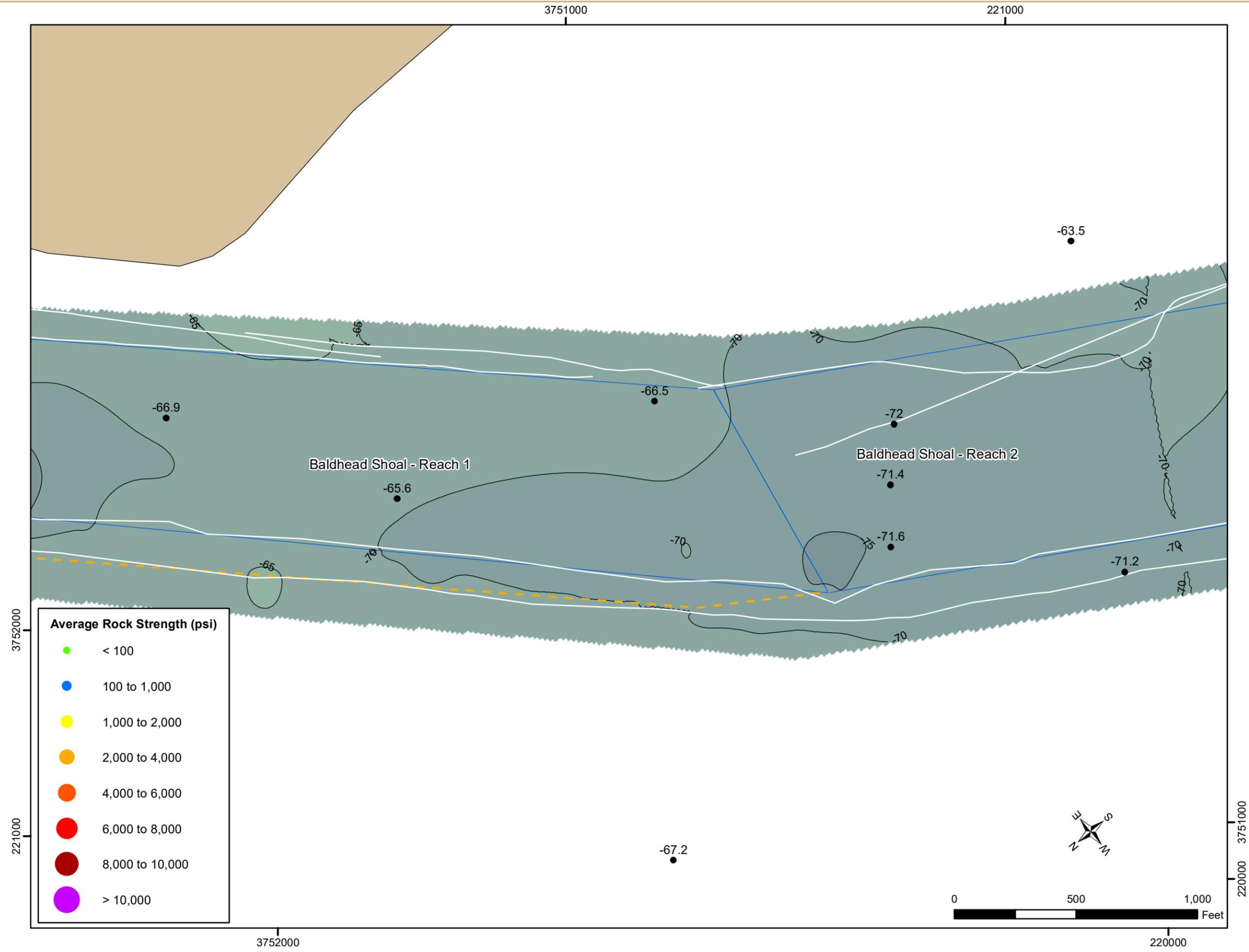


FIGURE 3-47

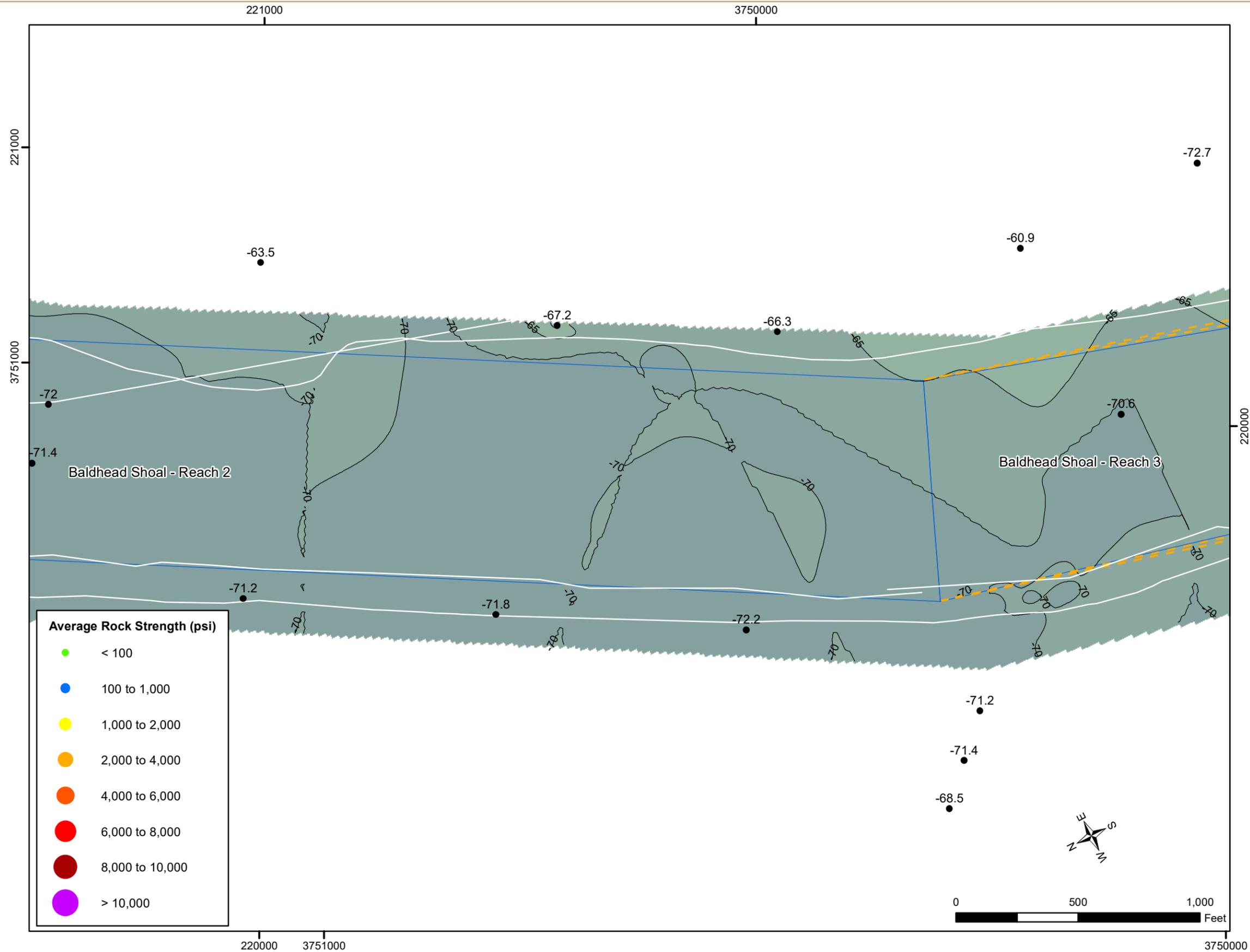


FIGURE 3-48



FIGURE 3-49

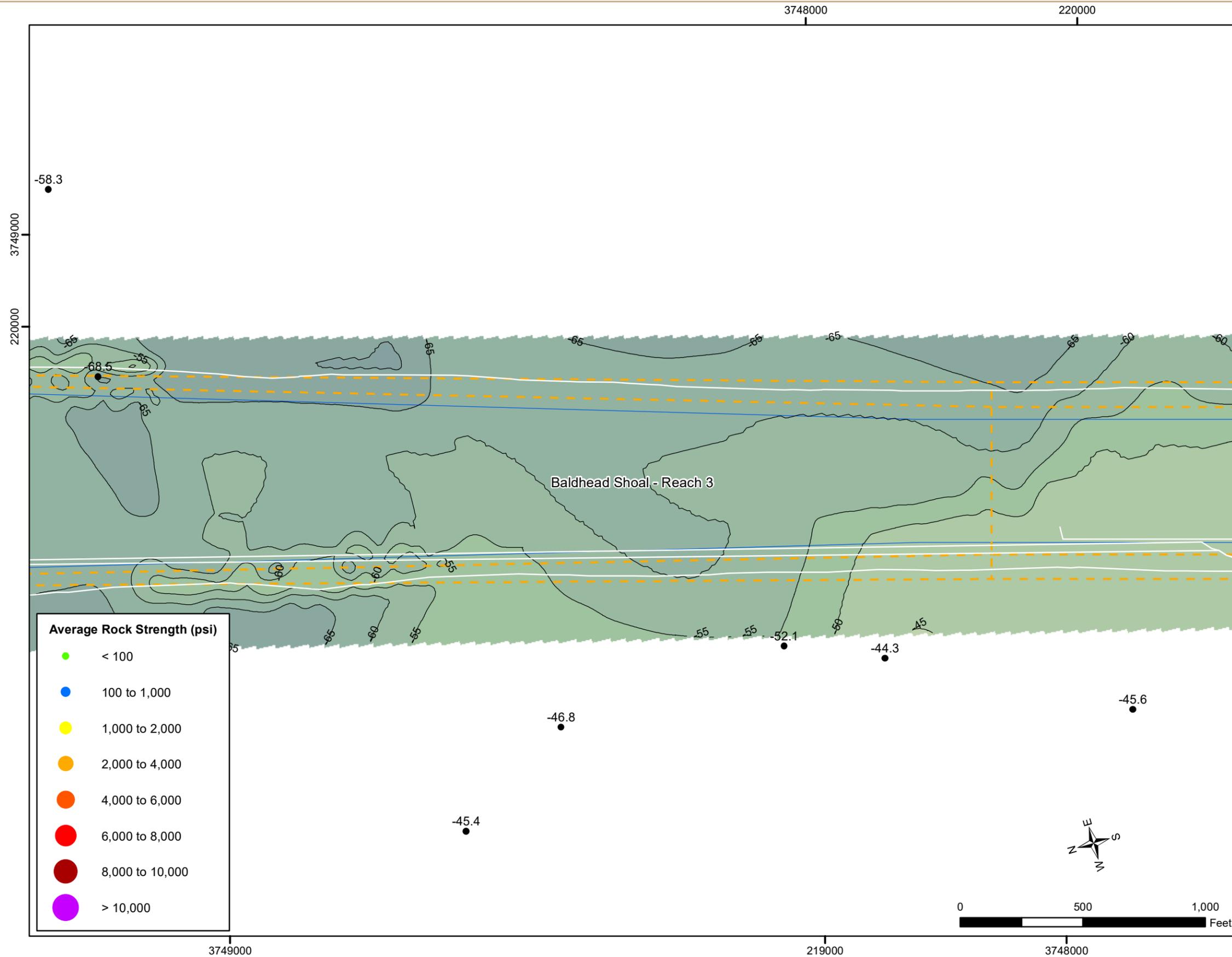


FIGURE 3-50

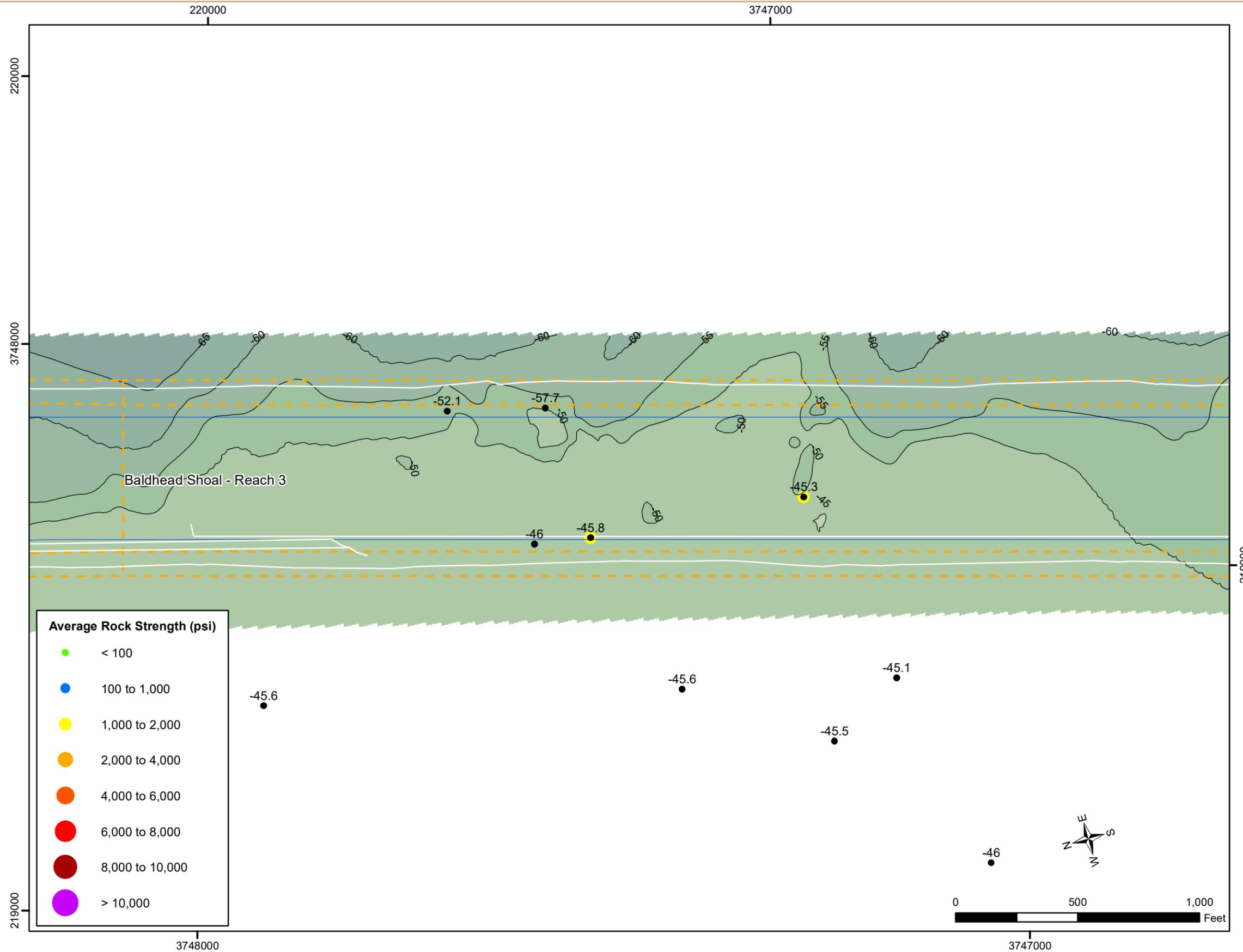


FIGURE 3-51

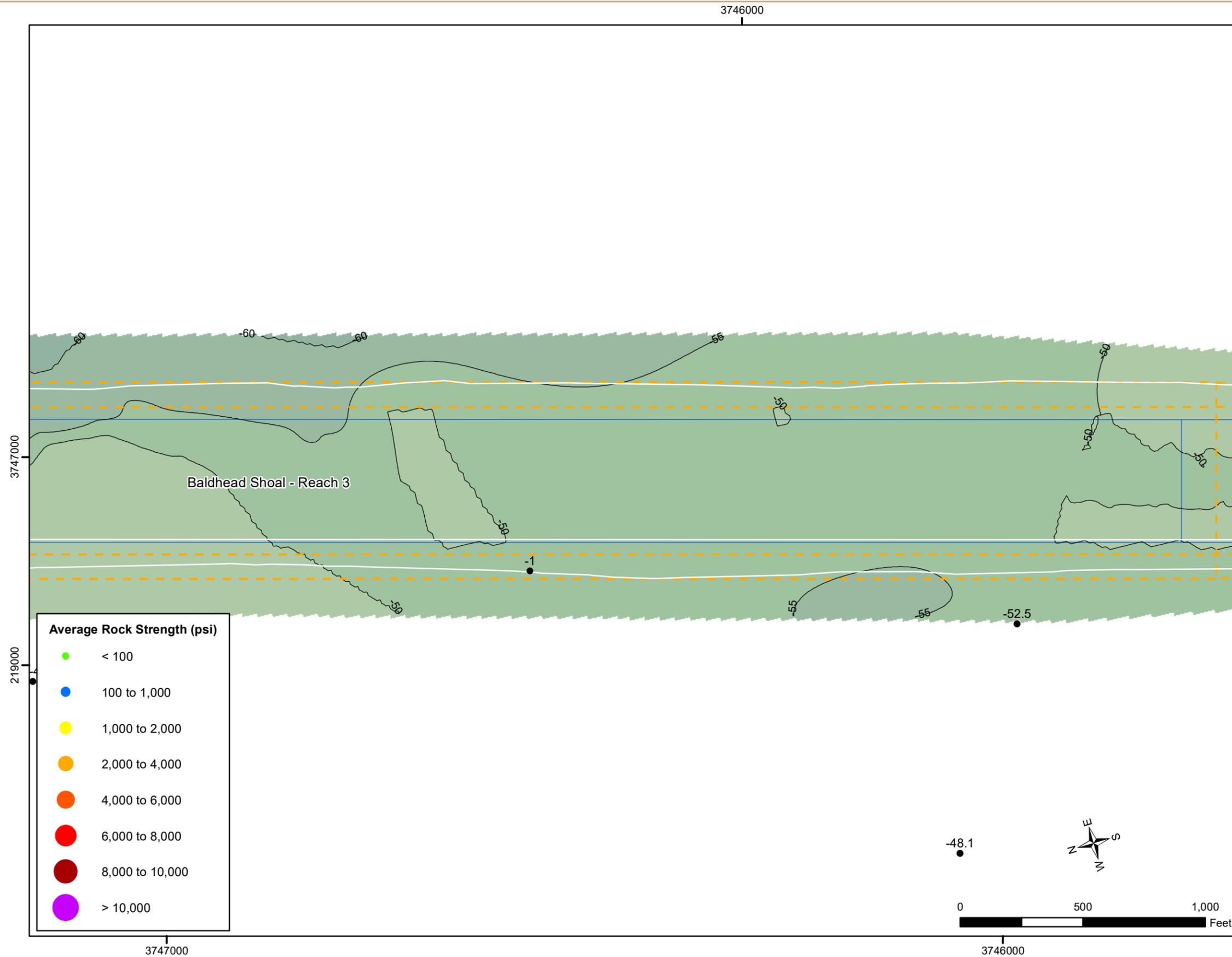


FIGURE 3-52

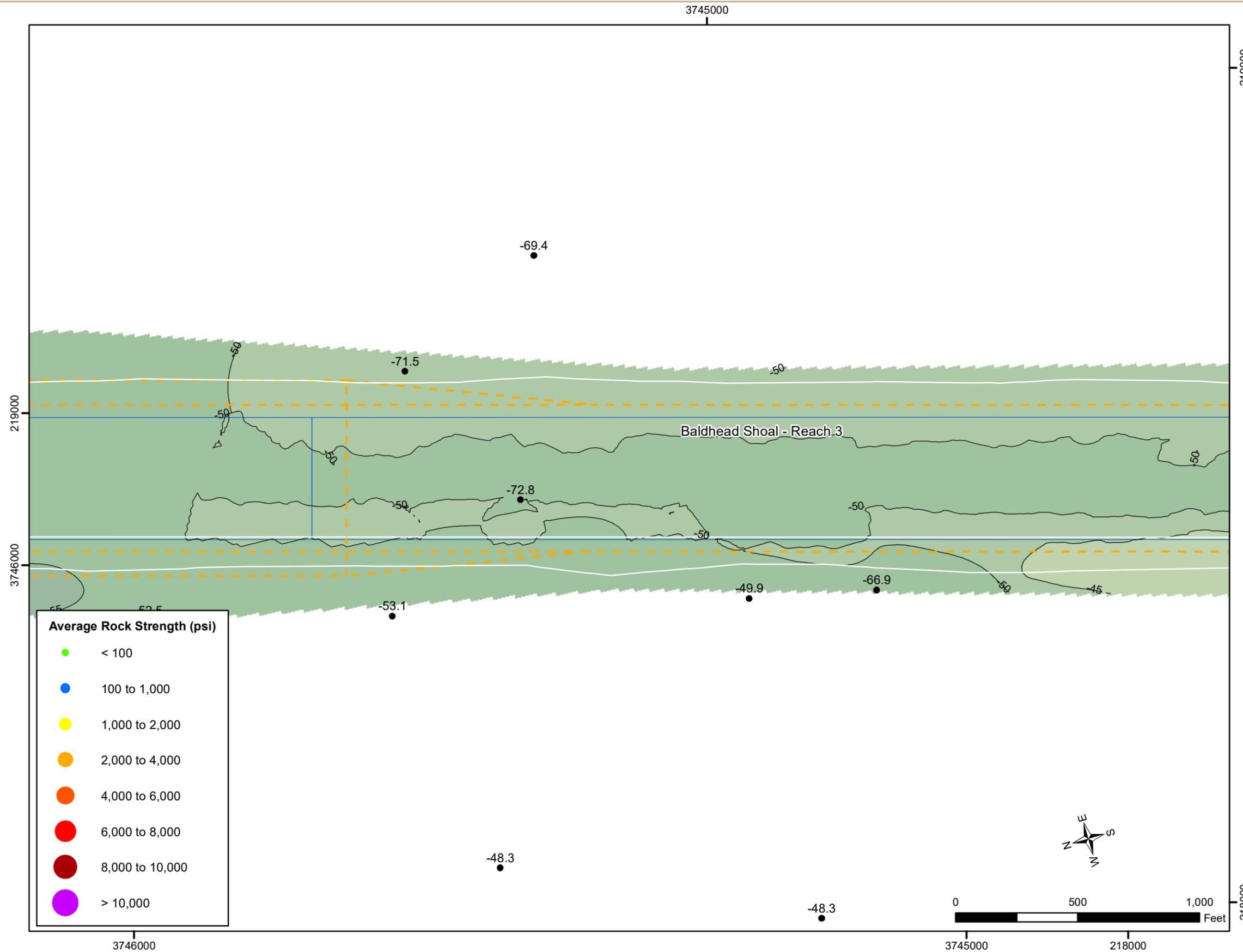


FIGURE 3-53

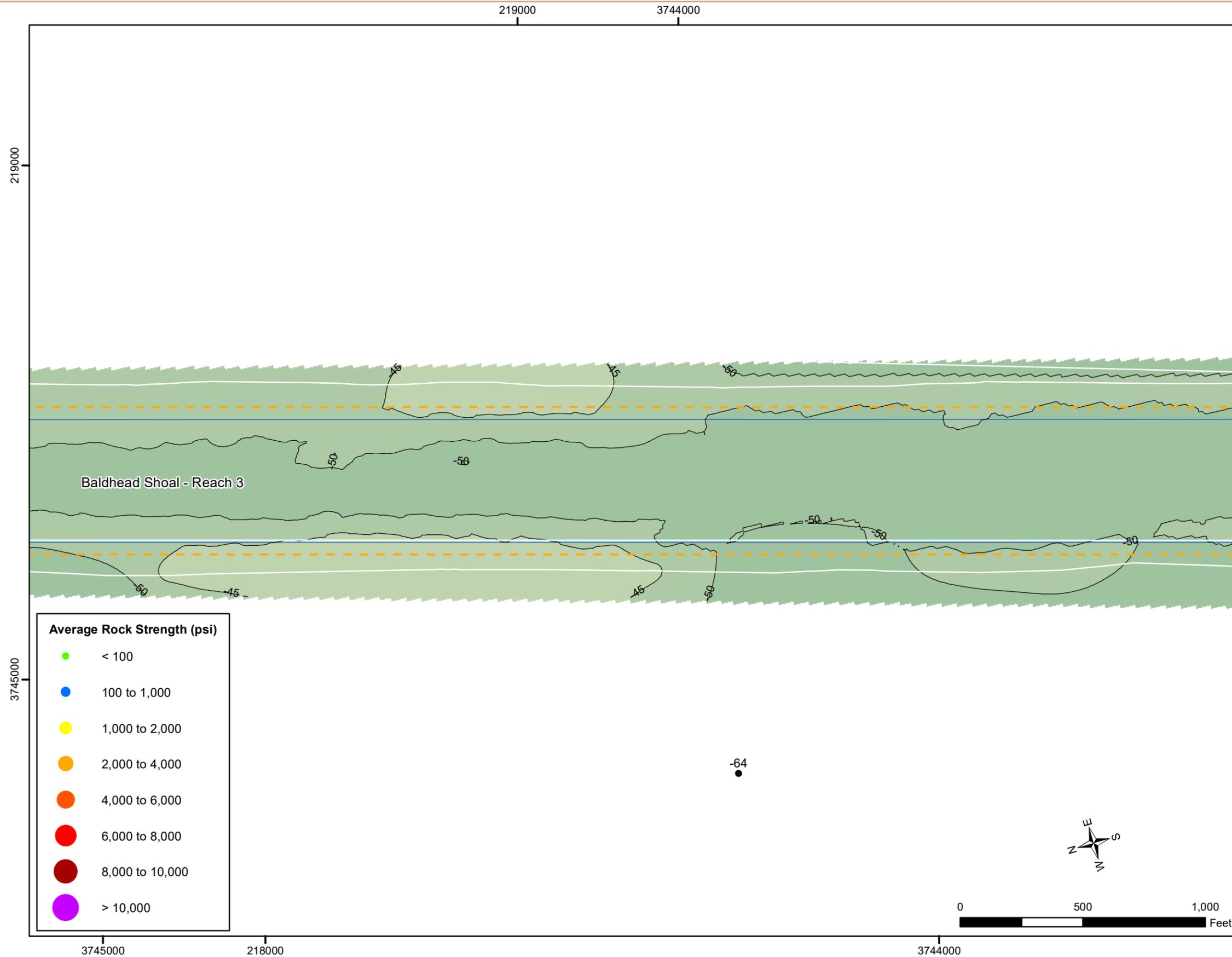
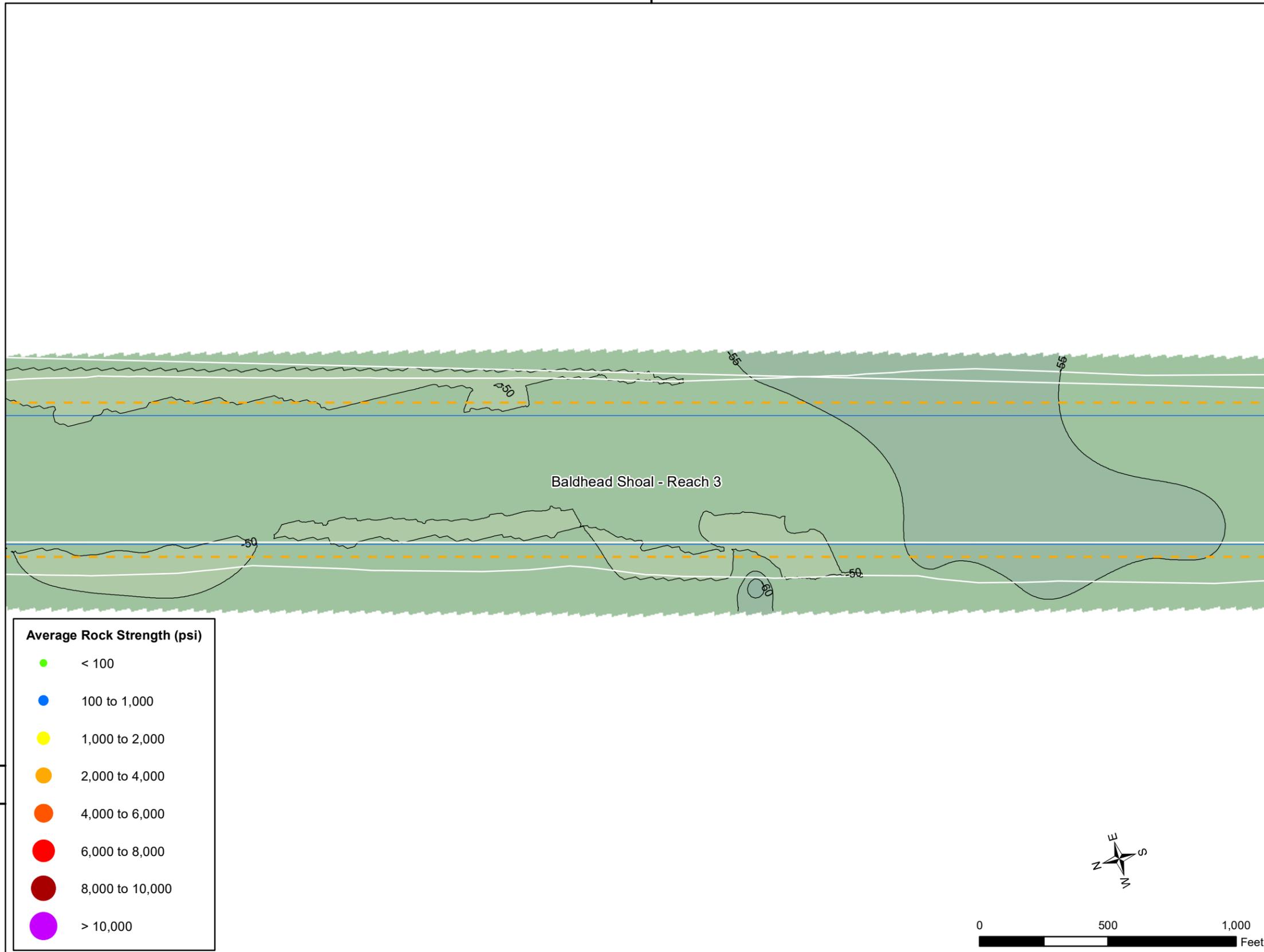


FIGURE 3-54

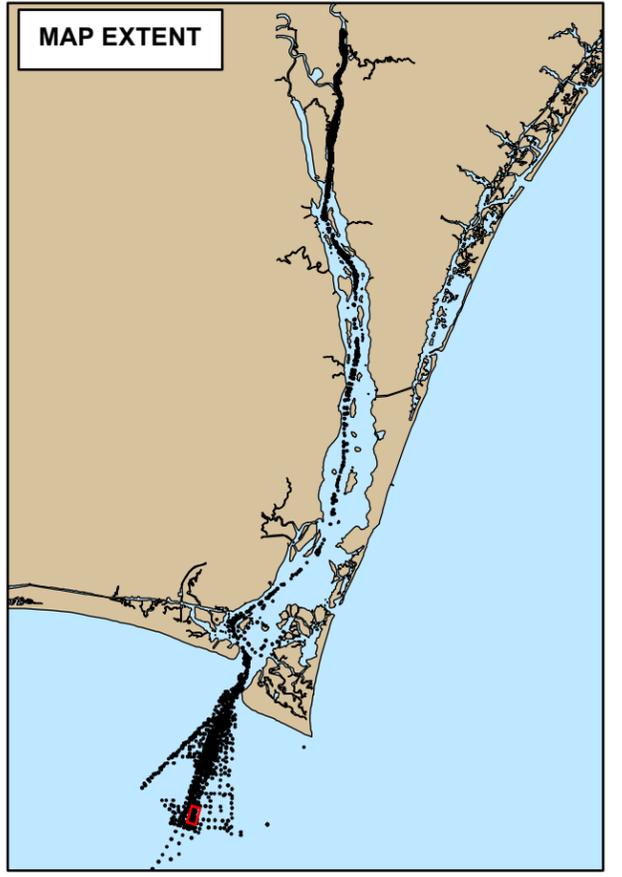
3743000



Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
-
- - - Proposed Channel Modifications (provided by Moffatt & Nichol)
- USACE Channel Reach Boundary
- ▨ Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft, Re. MLLW)**
- -20 to -25
- -25 to -30
- -30 to -35
- -35 to -40
- -40 to -50
- -45 to -50
- -50 to -55
- -55 to -60
- -60 to -65
- -65 to -70
- -70 to -75
- -75 to -80
- -80 to -85
- < -85
- 5 foot contour interval

- Average Rock Strength (psi)**
- < 100
 - 100 to 1,000
 - 1,000 to 2,000
 - 2,000 to 4,000
 - 4,000 to 6,000
 - 6,000 to 8,000
 - 8,000 to 10,000
 - > 10,000



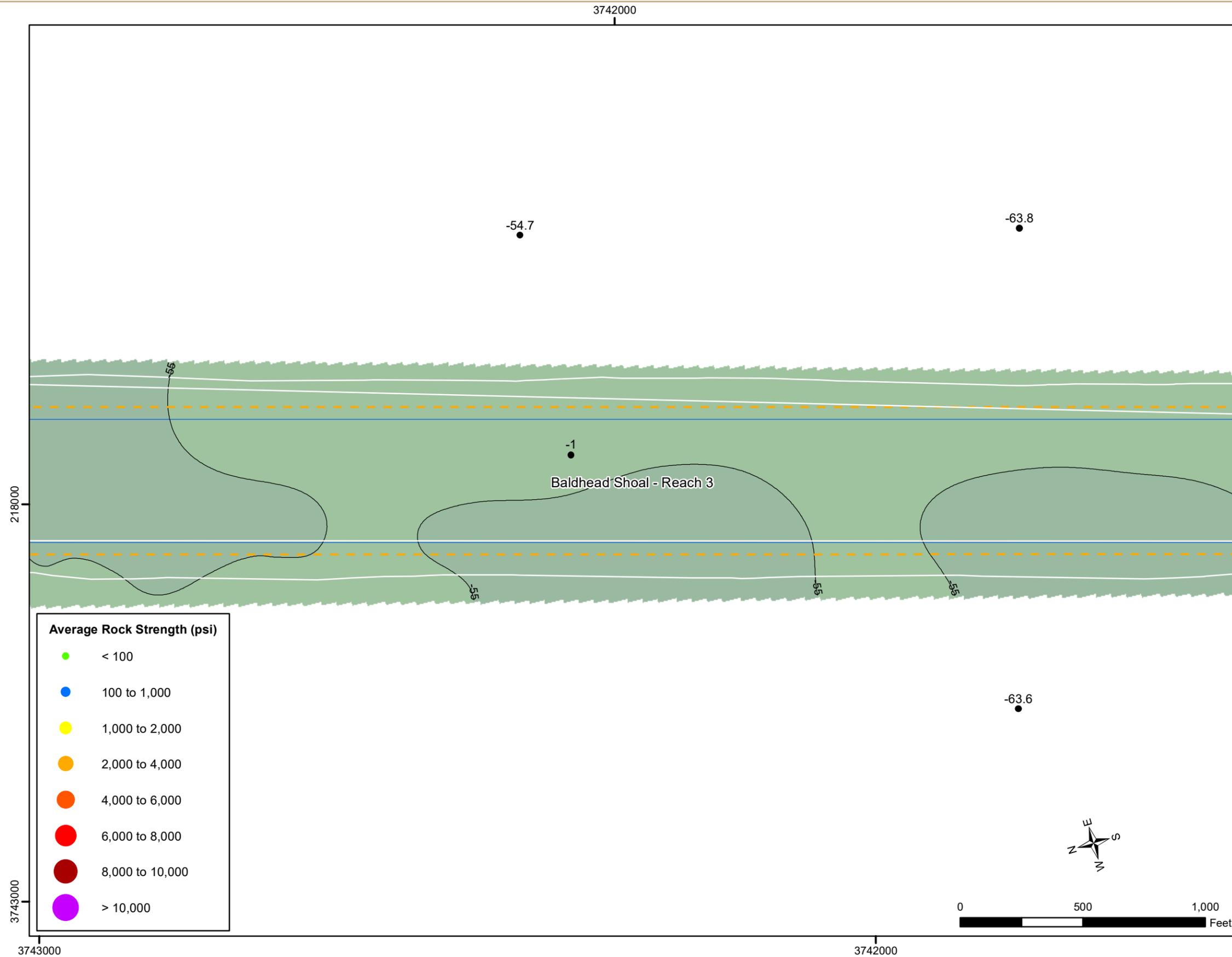
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



3744000

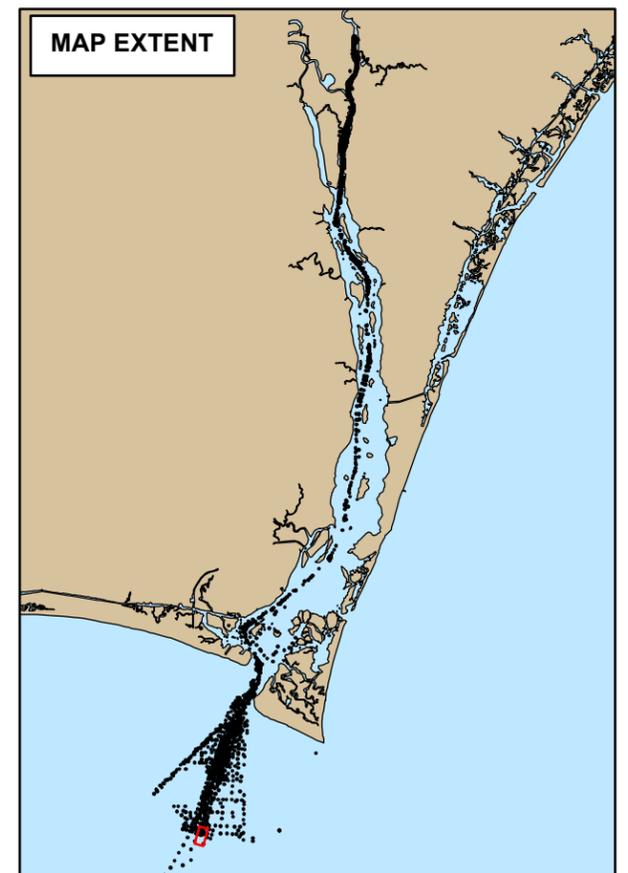
3743000

FIGURE 3-55



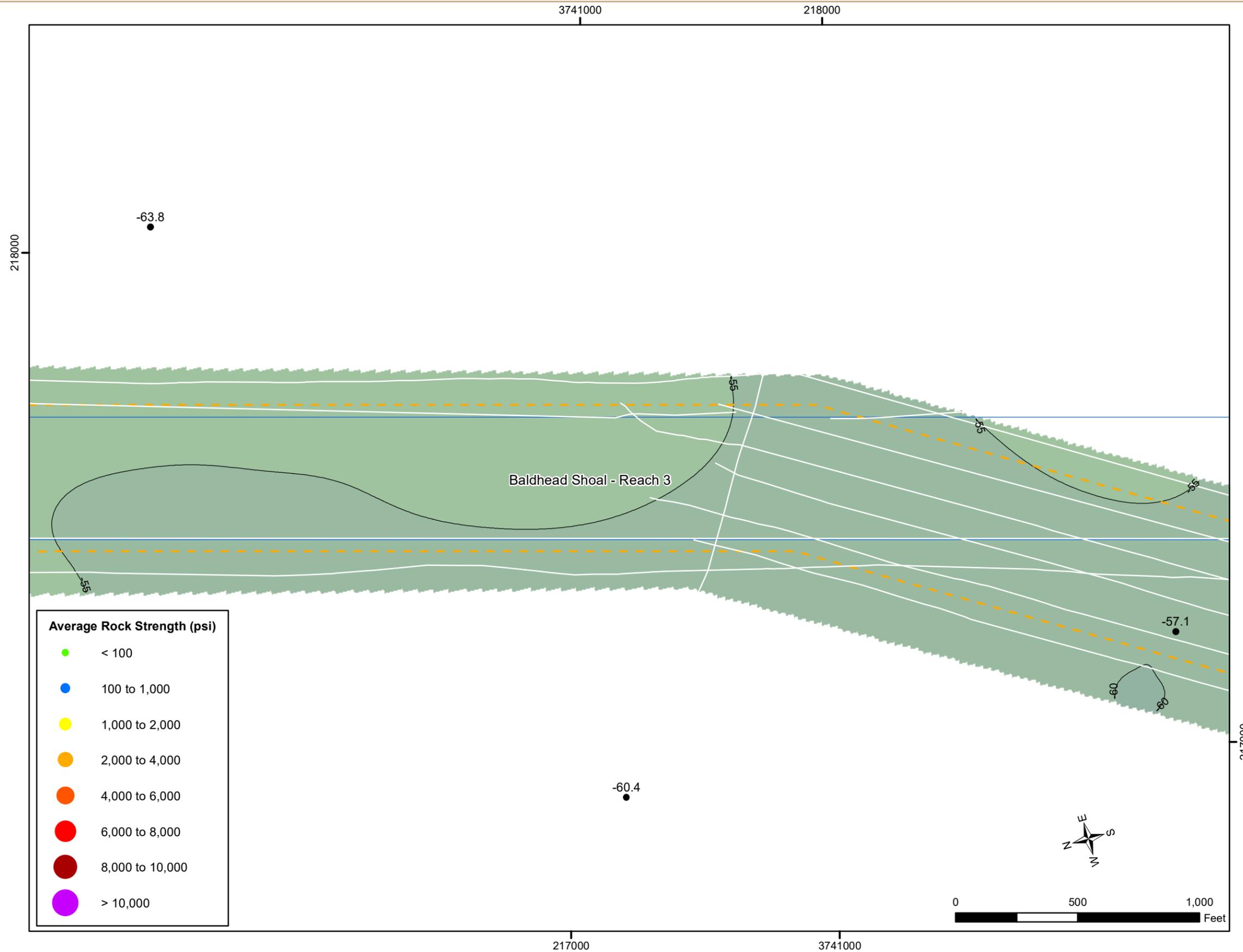
Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
-
- - - Proposed Channel Modifications (provided by Moffatt & Nichol)
- ▭ USACE Channel Reach Boundary
- ▭ Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft, Re. MLLW)**
- ▭ -20 to -25 ▭ -55 to -60
- ▭ -25 to -30 ▭ -60 to -65
- ▭ -30 to -35 ▭ -65 to -70
- ▭ -35 to -40 ▭ -70 to -75
- ▭ -40 to -50 ▭ -75 to -80
- ▭ -45 to -50 ▭ -80 to -85
- ▭ -50 to -55 ▭ < -85
- 5 foot contour interval



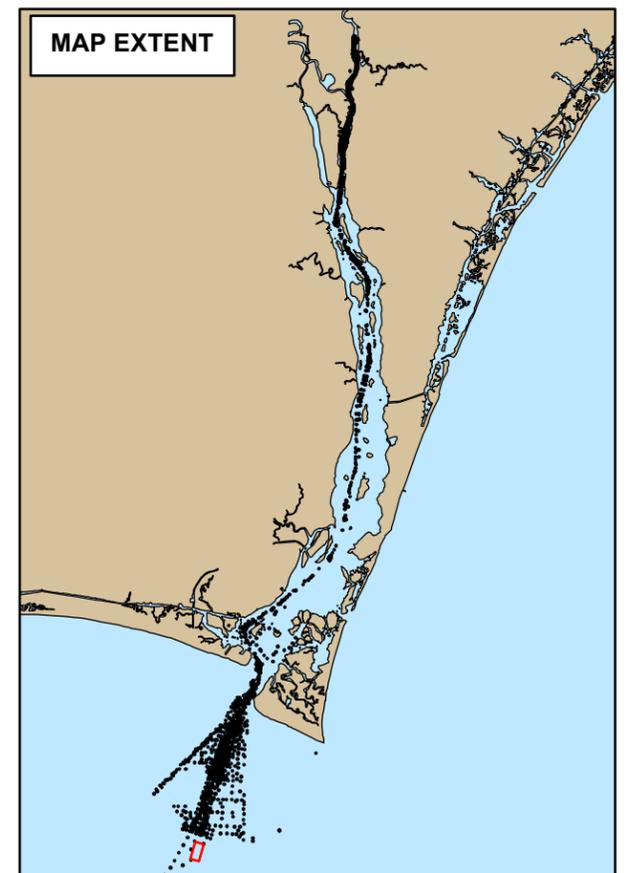
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-56



Legend

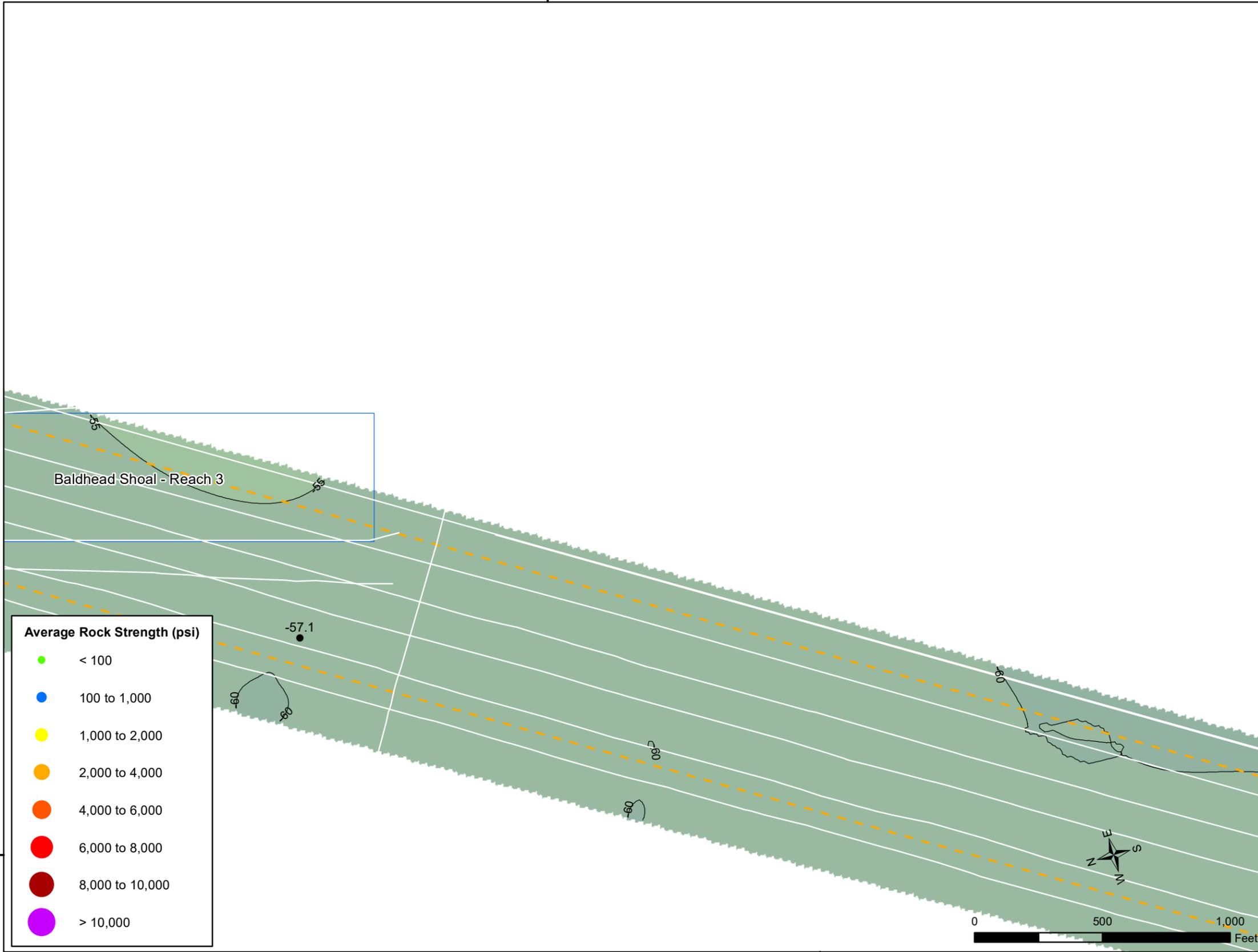
- 36.2 Top of Rock Elevation Location (with elevation listed above)
 - Top of Rock Elevation Location (with elevation listed above)
 - - - Proposed Channel Modifications (provided by Moffatt & Nichol)
 - USACE Channel Reach Boundary
 - ▬ Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft. Re. MLLW)**
- | | |
|------------|------------|
| -20 to -25 | -55 to -60 |
| -25 to -30 | -60 to -65 |
| -30 to -35 | -65 to -70 |
| -35 to -40 | -70 to -75 |
| -40 to -50 | -75 to -80 |
| -45 to -50 | -80 to -85 |
| -50 to -55 | < -85 |
- 5 foot contour interval



INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-57

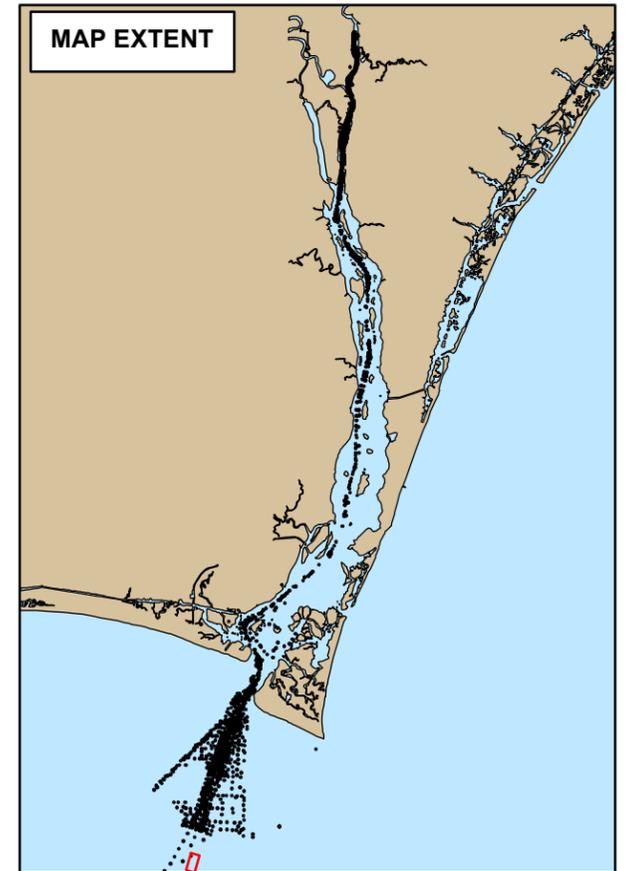
3740000



Legend

- 36.2 Top of Rock Elevation Location (with elevation listed above)
 -
 - Proposed Channel Modifications (provided by Moffatt & Nichol)
 - USACE Channel Reach Boundary
 - Fugro 2017 Chirp Survey Trackline
- Interpreted Top of Rock Elevation (ft. Re. MLLW)**
- | | |
|------------|------------|
| -20 to -25 | -55 to -60 |
| -25 to -30 | -60 to -65 |
| -30 to -35 | -65 to -70 |
| -35 to -40 | -70 to -75 |
| -40 to -50 | -75 to -80 |
| -45 to -50 | -80 to -85 |
| -50 to -55 | < -85 |
- 5 foot contour interval

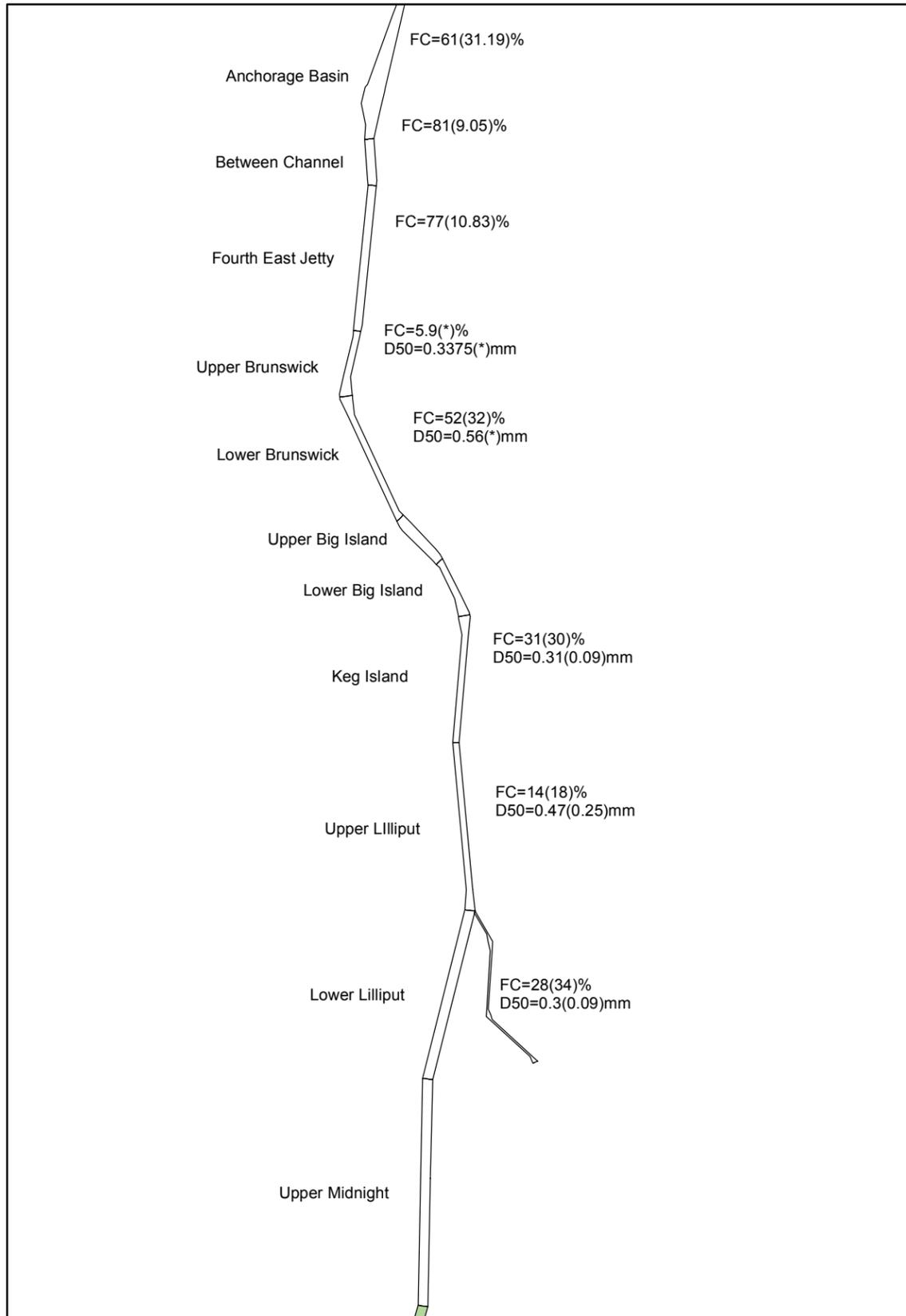
- Average Rock Strength (psi)**
- < 100
 - 100 to 1,000
 - 1,000 to 2,000
 - 2,000 to 4,000
 - 4,000 to 6,000
 - 6,000 to 8,000
 - 8,000 to 10,000
 - > 10,000



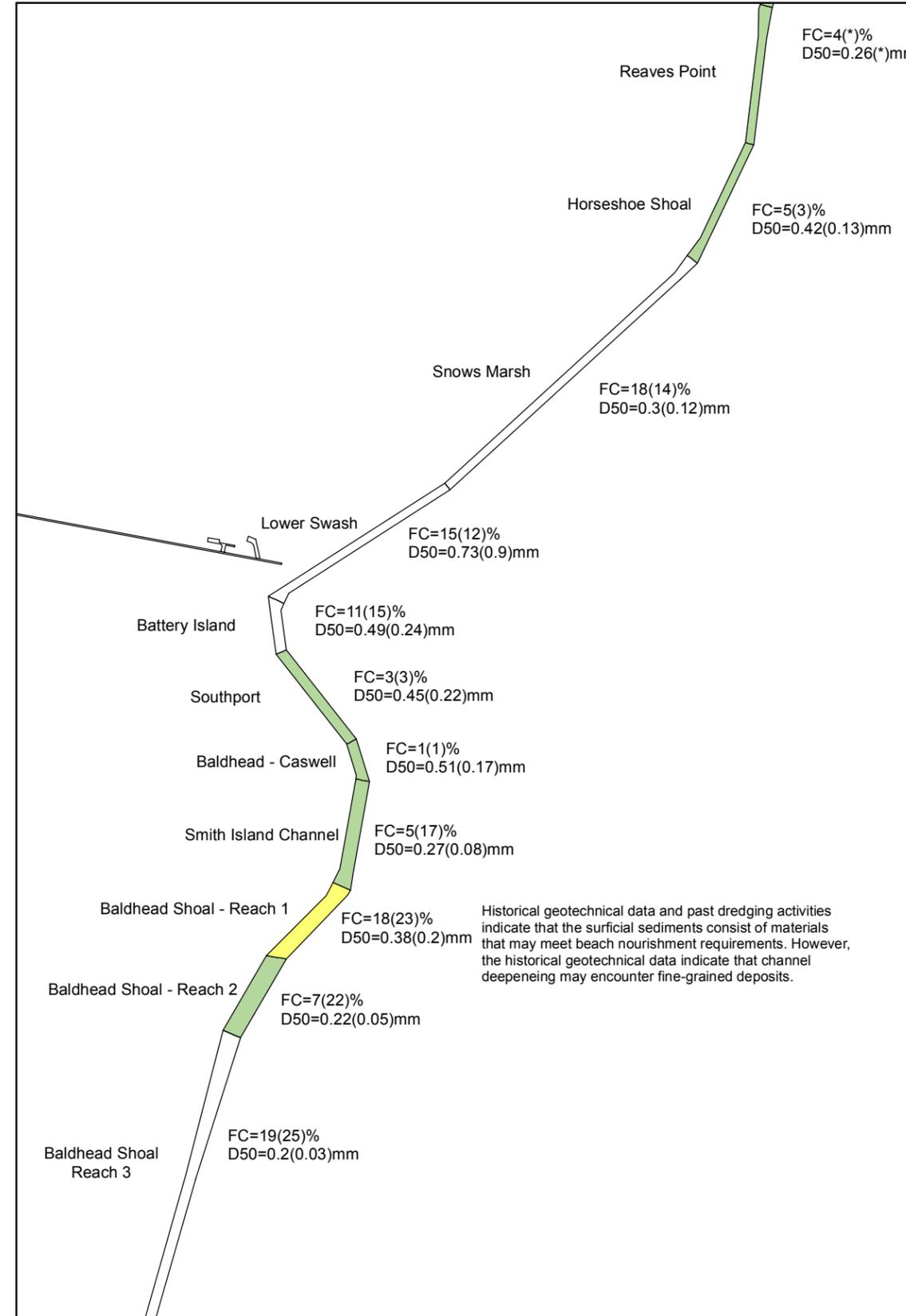
INTERPRETED TOP OF ROCK ELEVATION AND ROCK STRENGTH
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 3-58

Northern Wilmington Harbor



Southern Wilmington Harbor



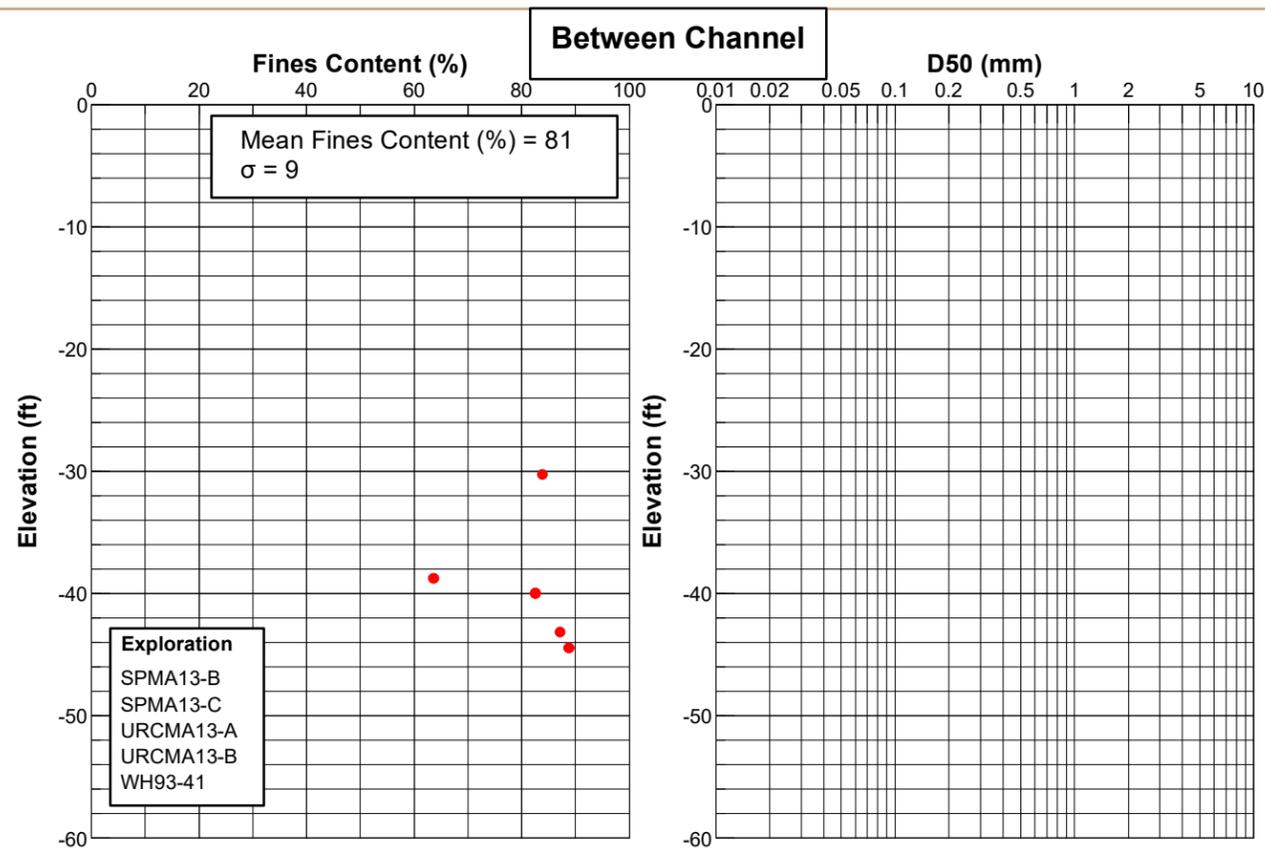
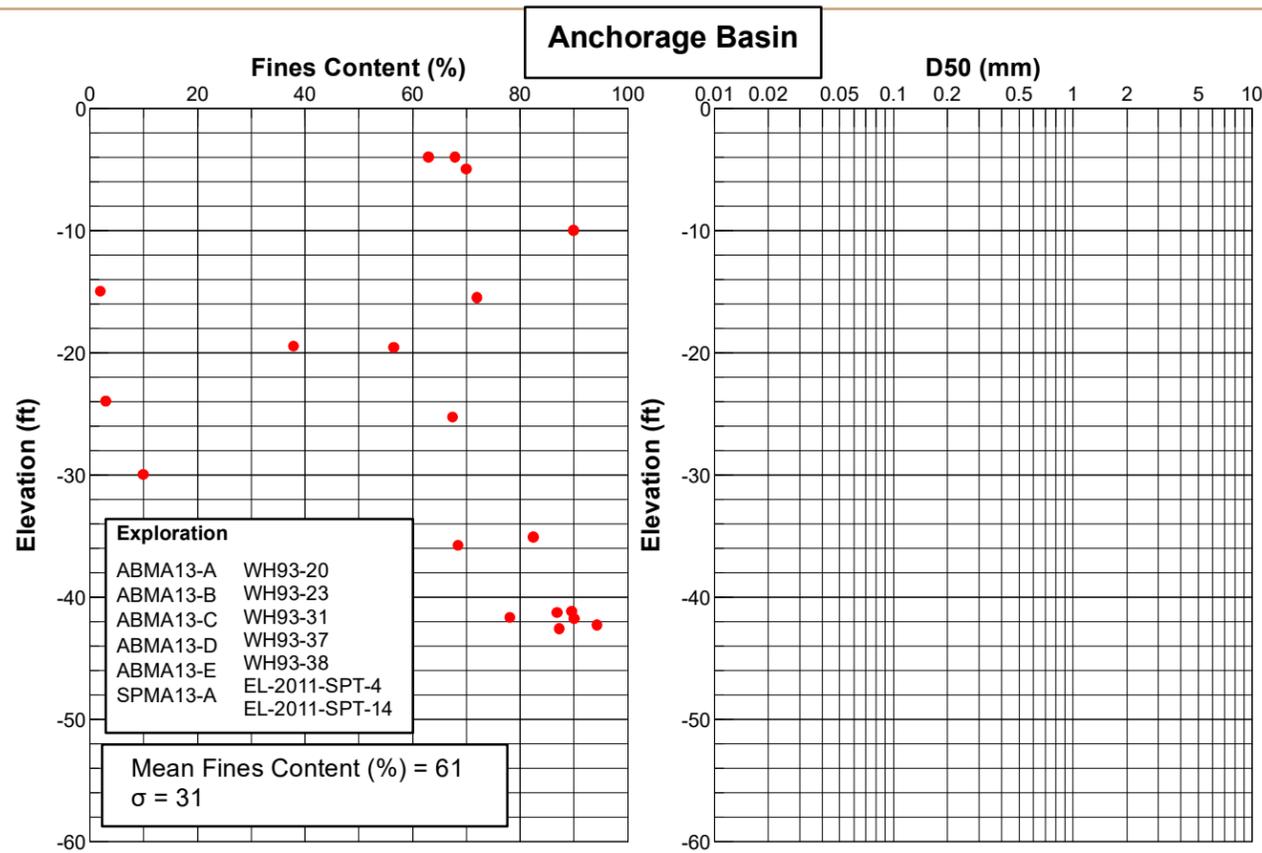
Legend

- Wilmington Harbor Channel Reaches
- Channel Reaches with ideal values of Fines Content and D50 for beach nourishment, Fines Content <10% and D50=0.25mm

Notes:

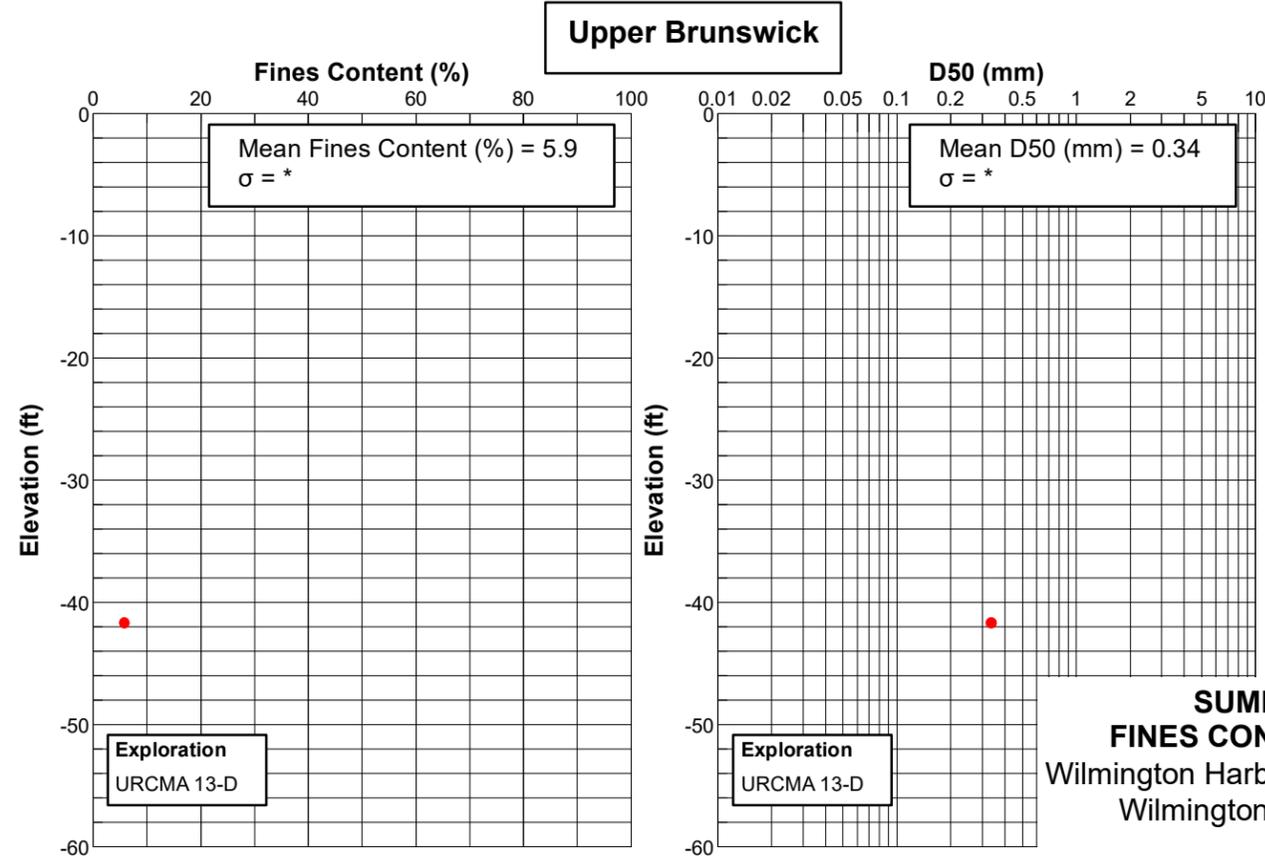
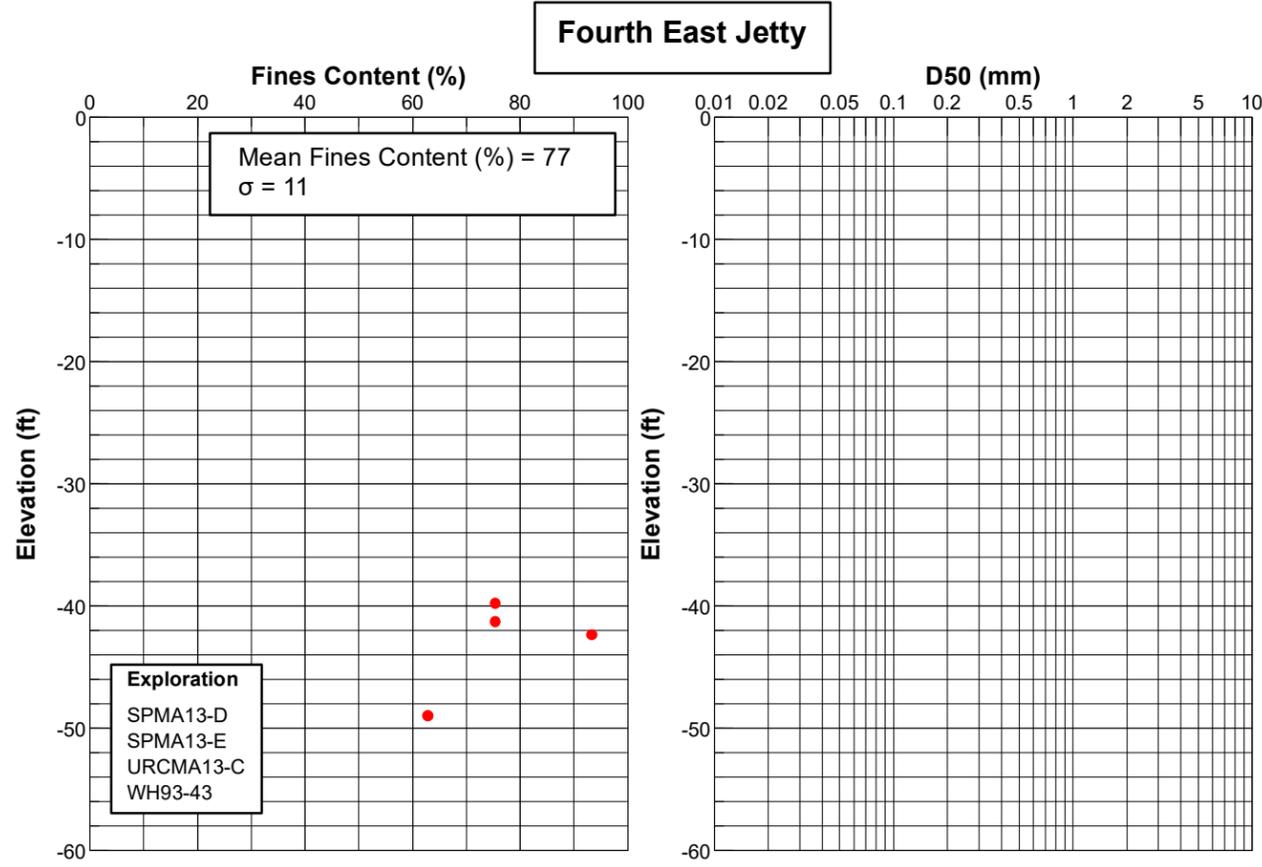
- 1) FC = Average Fines Content (one standard deviation)%
- 2) D50 = Average D50 (one standard deviation)mm
- 3) * = insufficient number of data records to determine standard deviation

SUMMARY OF FINES CONTENT AND D50
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



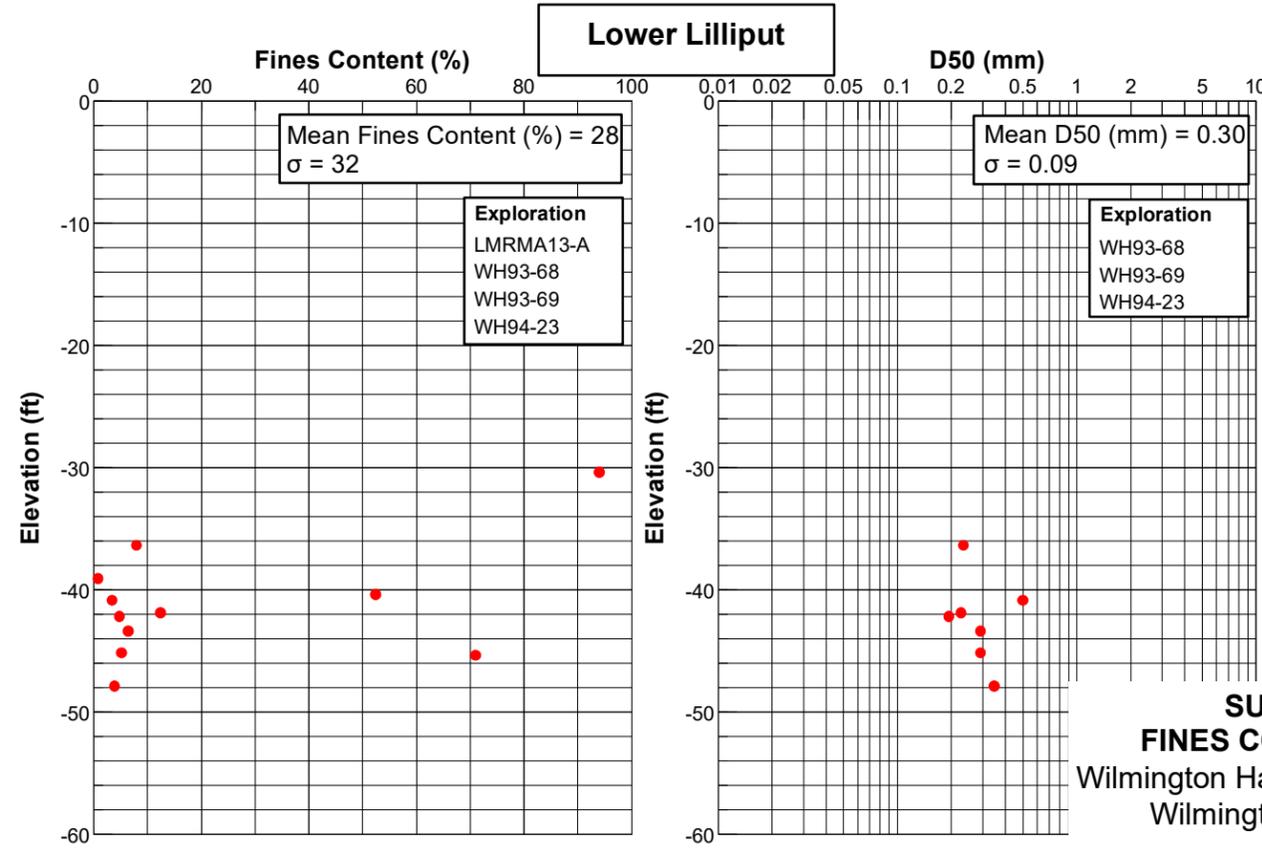
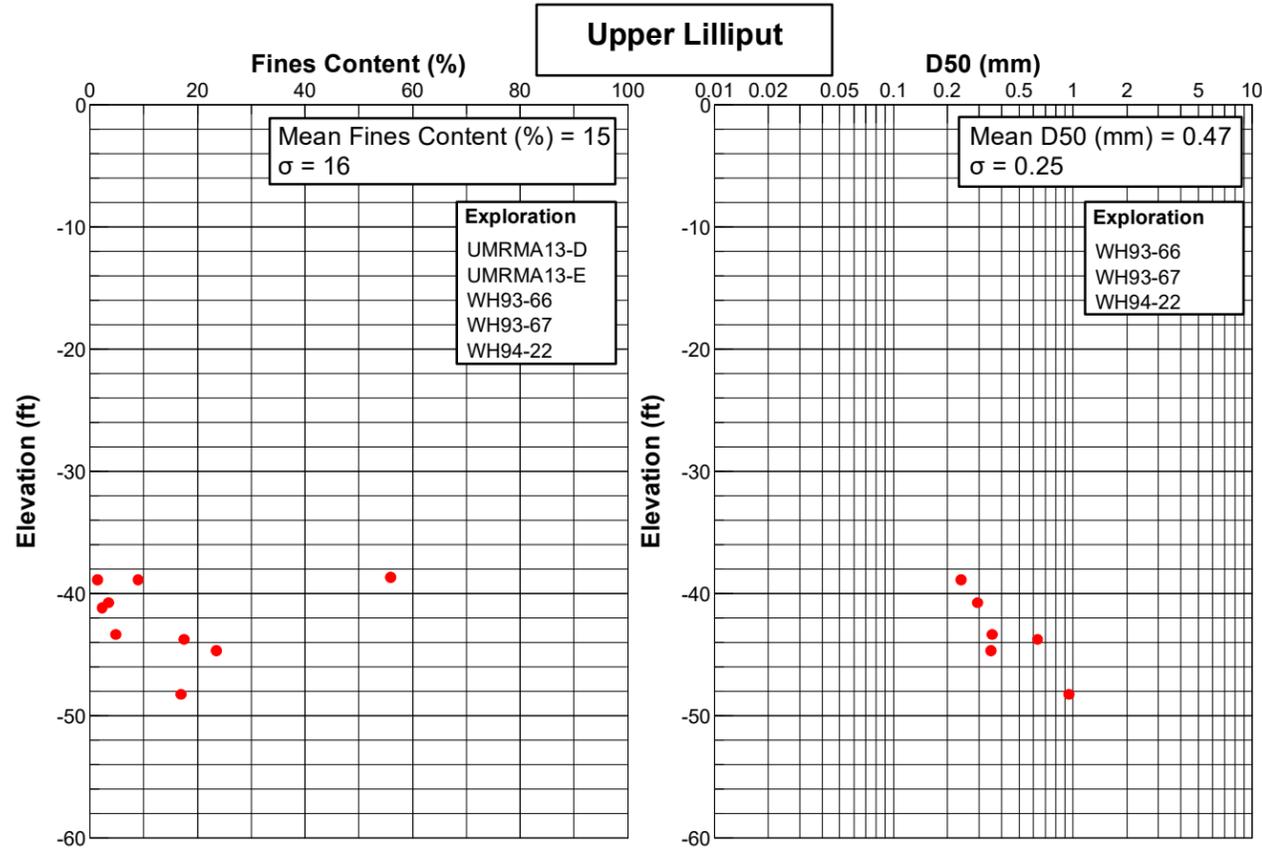
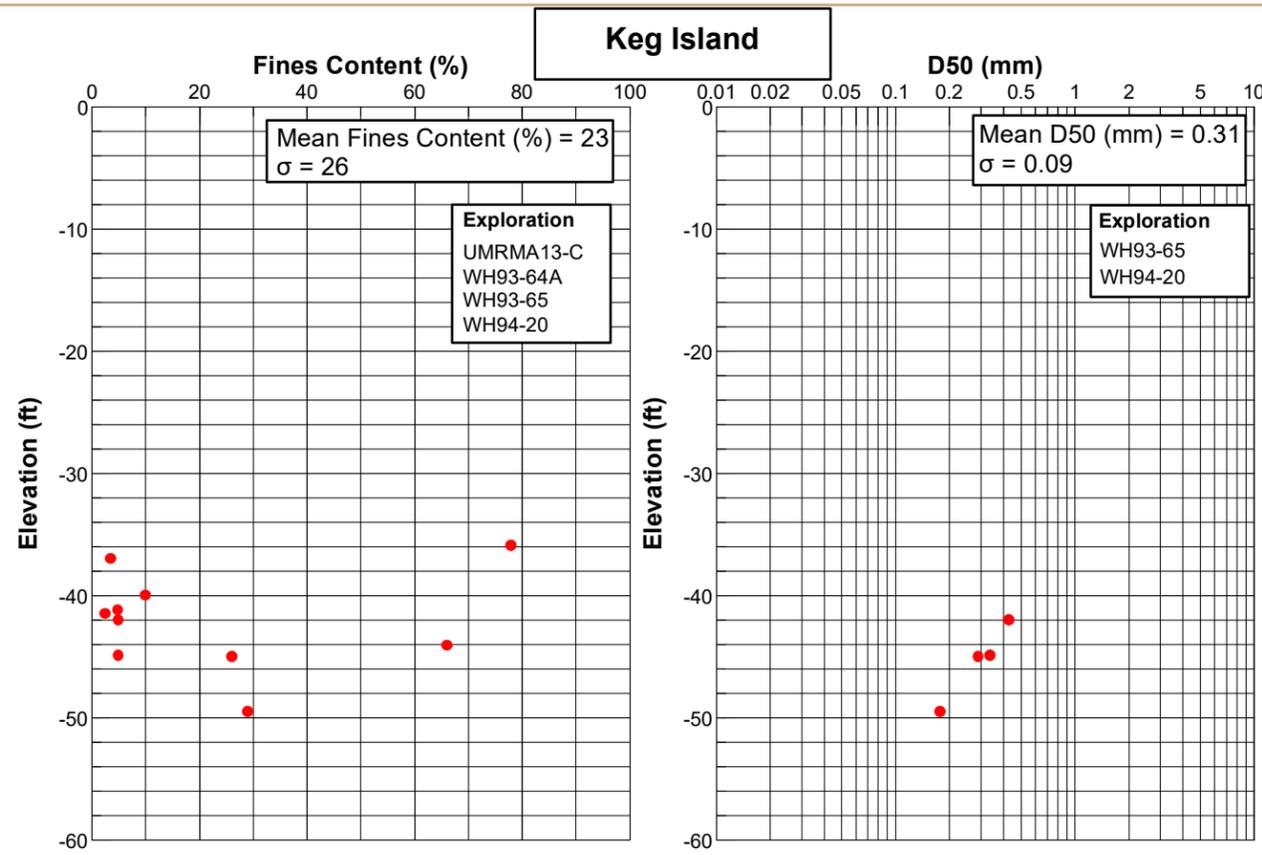
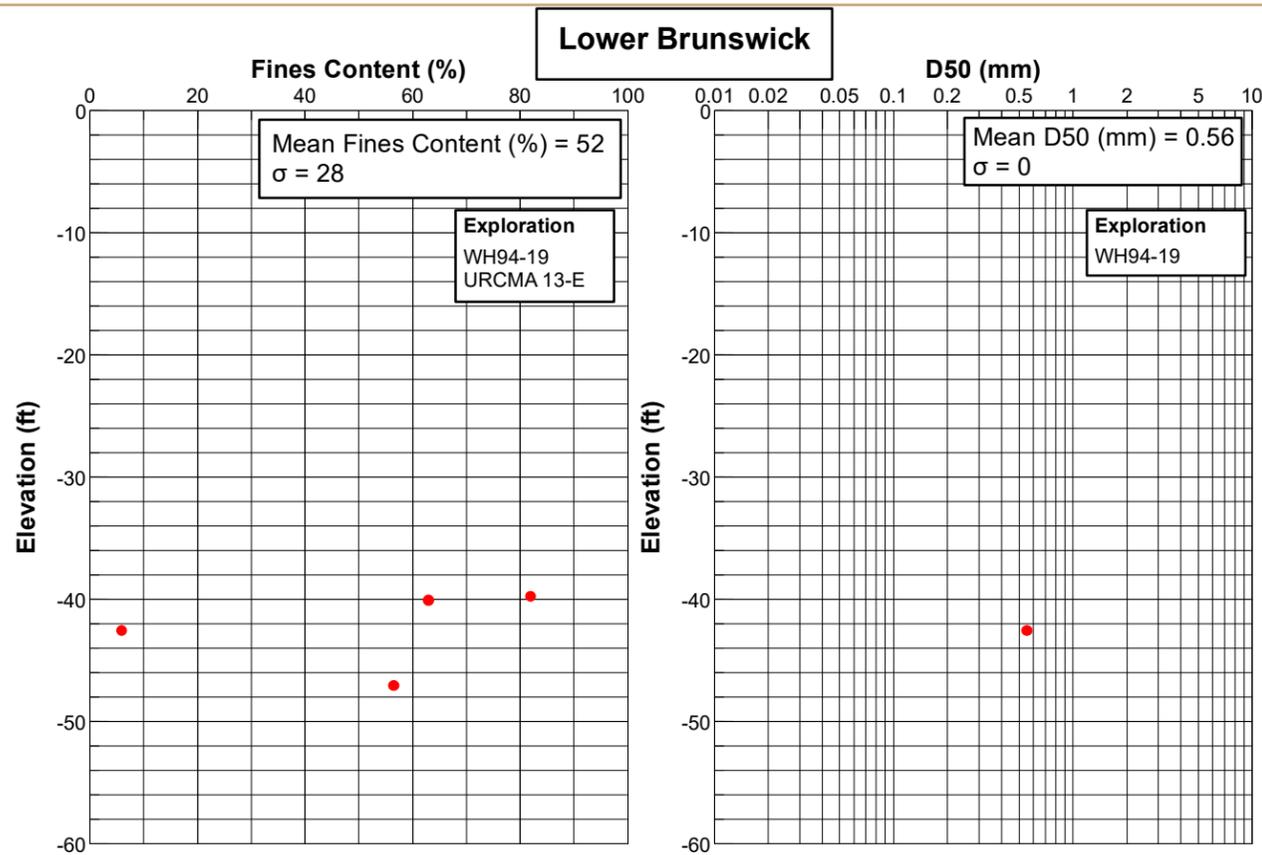
Notes:

- 1) Mean Fines Content (%) = the average value of fines content in the channel reach. Ideal values for beach nourishment material would be fines content <10%
- 2) Mean D50 (mm) = the average D50 value of all laboratory tests conducted in that reach.
- 3) σ = one standard deviation
- 4) Elevation in feet is referenced to MLLW.
- 5) Each data point represents a result from a discrete laboratory test conducted on a discrete sample.
- 6) Fines content and D50 test results displayed on these graphs are derived from sieve analyses. For fine-grained sediments (sediments with >50% particles less than 0.075mm diameter by weight) the fines content can be determined but it is not possible to determine the D50 value.



**SUMMARY OF
FINES CONTENT AND D50**
Wilmington Harbor Deepening Survey
Wilmington, North Carolina

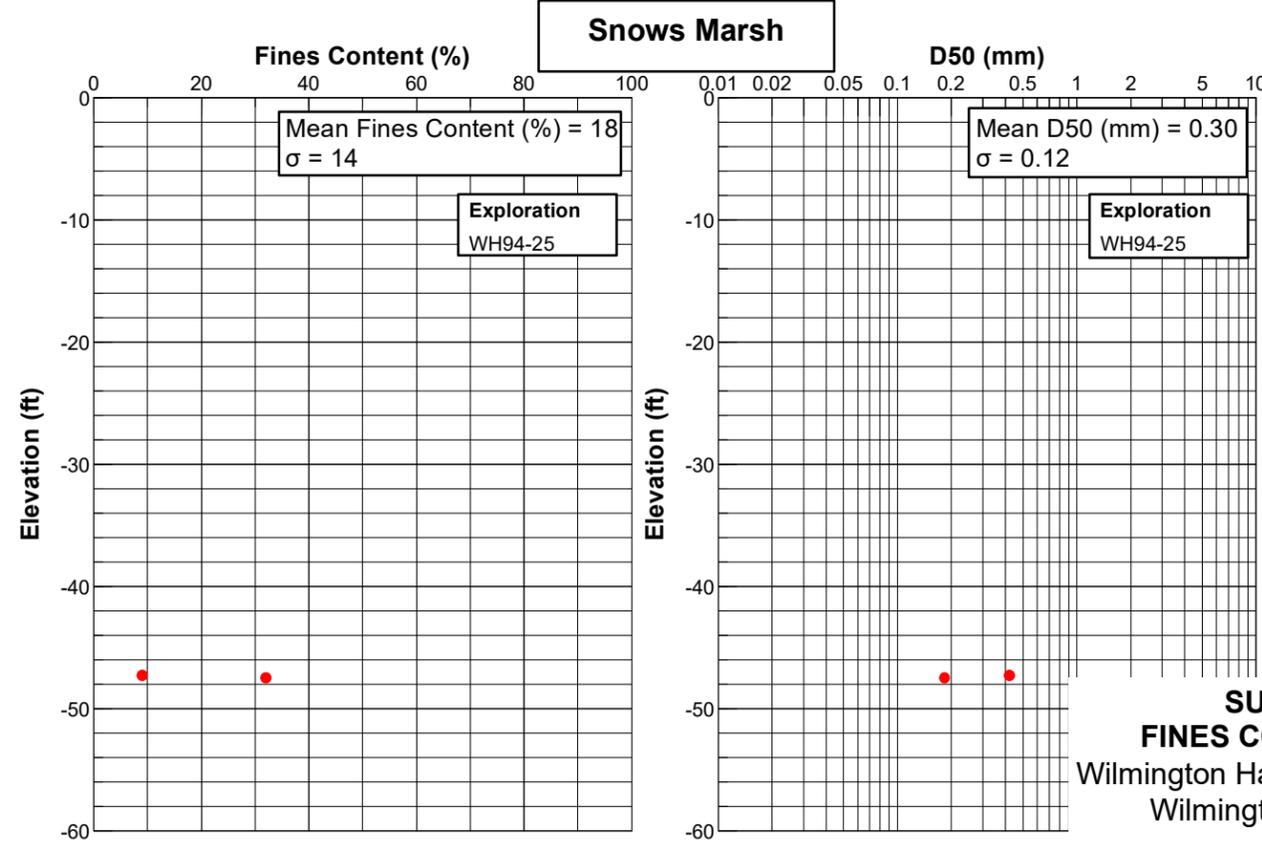
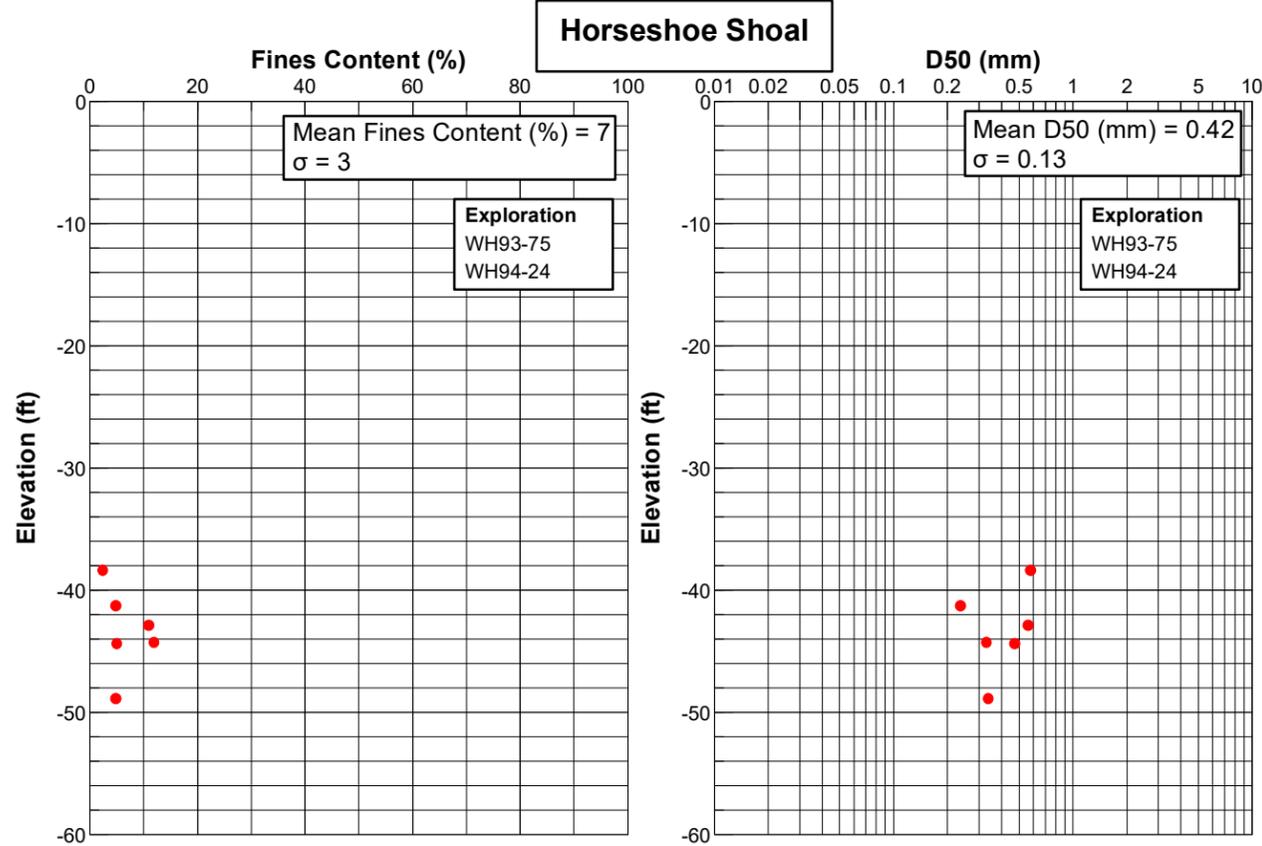
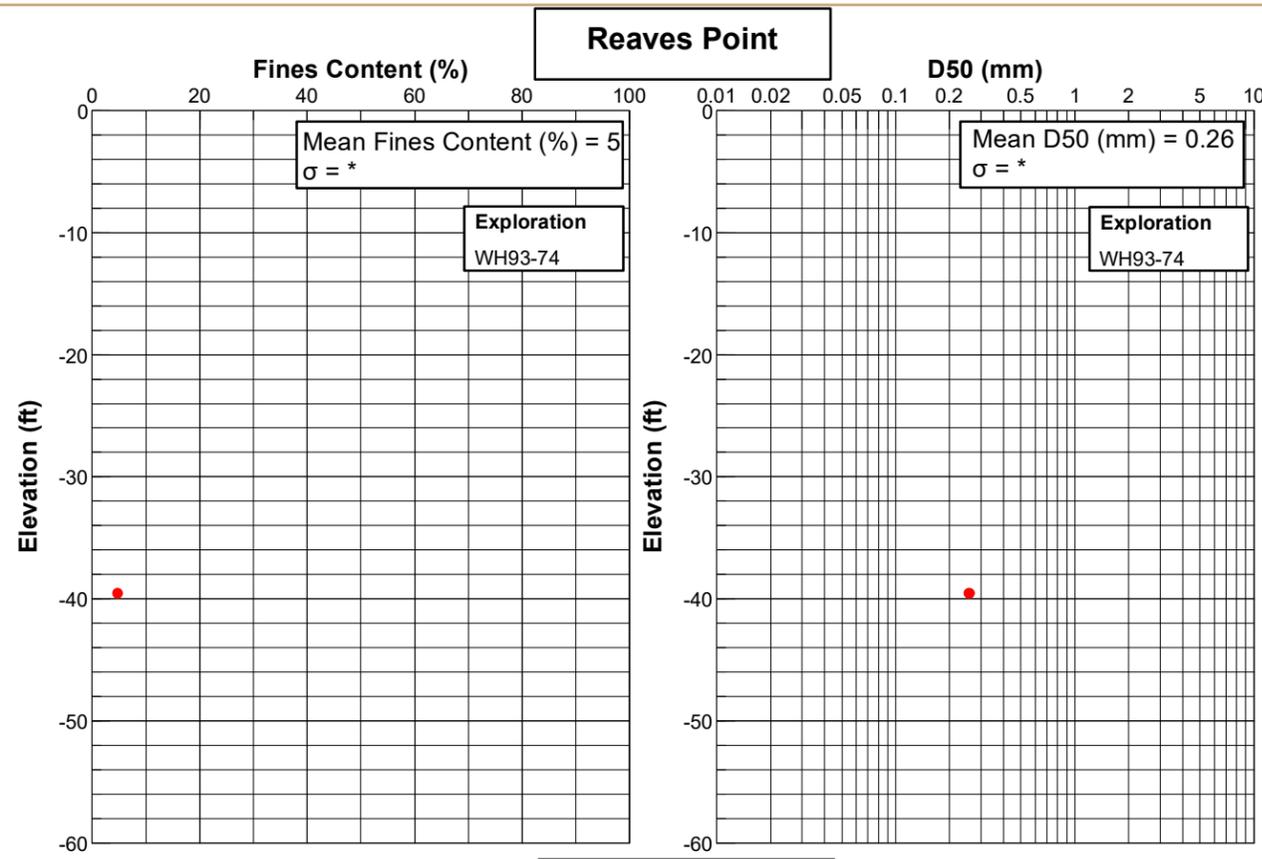
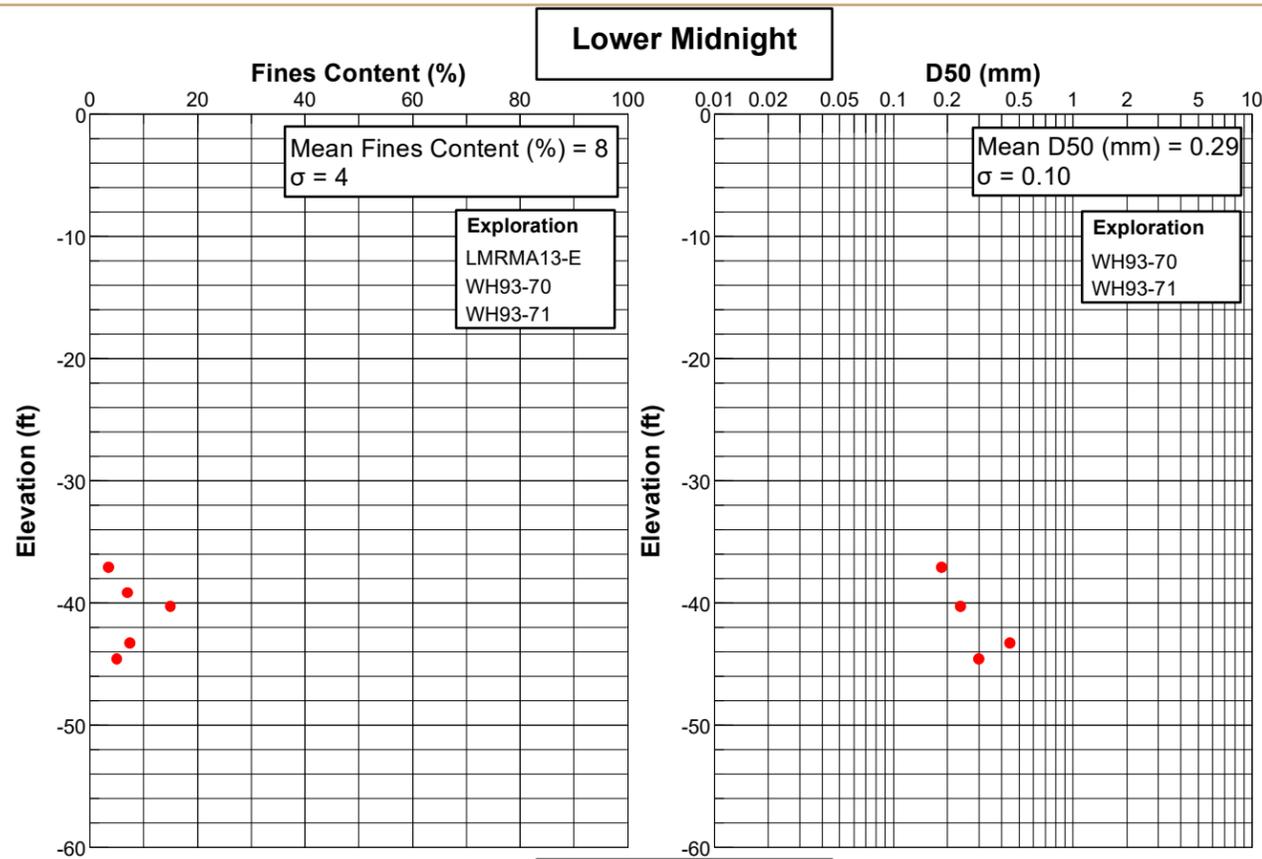
FIGURE 4-2



Notes:

- 1) Mean Fines Content (%) = the average value of fines content in the channel reach. Ideal values for beach nourishment material would be fines content <10%
- 2) Mean D50 (mm) = the average D50 value of all laboratory tests conducted in that reach.
- 3) σ = one standard deviation
- 4) Elevation in feet is referenced to MLLW.
- 5) Each data point represents a result from a discrete laboratory test conducted on a discrete sample.
- 6) Fines content and D50 test results displayed on these graphs are derived from sieve analyses. For fine-grained sediments (sediments with >50% particles less than 0.075mm diameter by weight) the fines content can be determined, but it is not possible to determine the D50 value.

**SUMMARY OF
 FINES CONTENT AND D50**
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

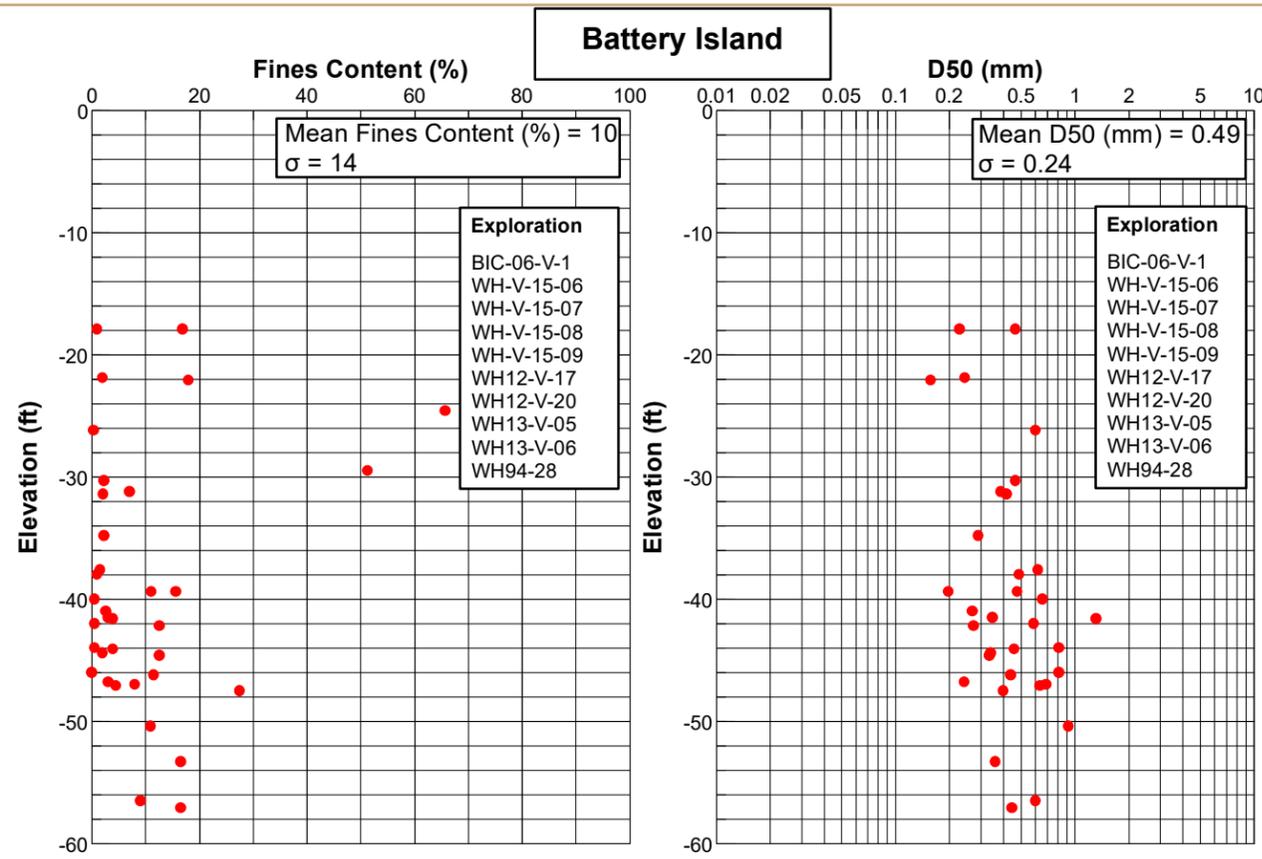
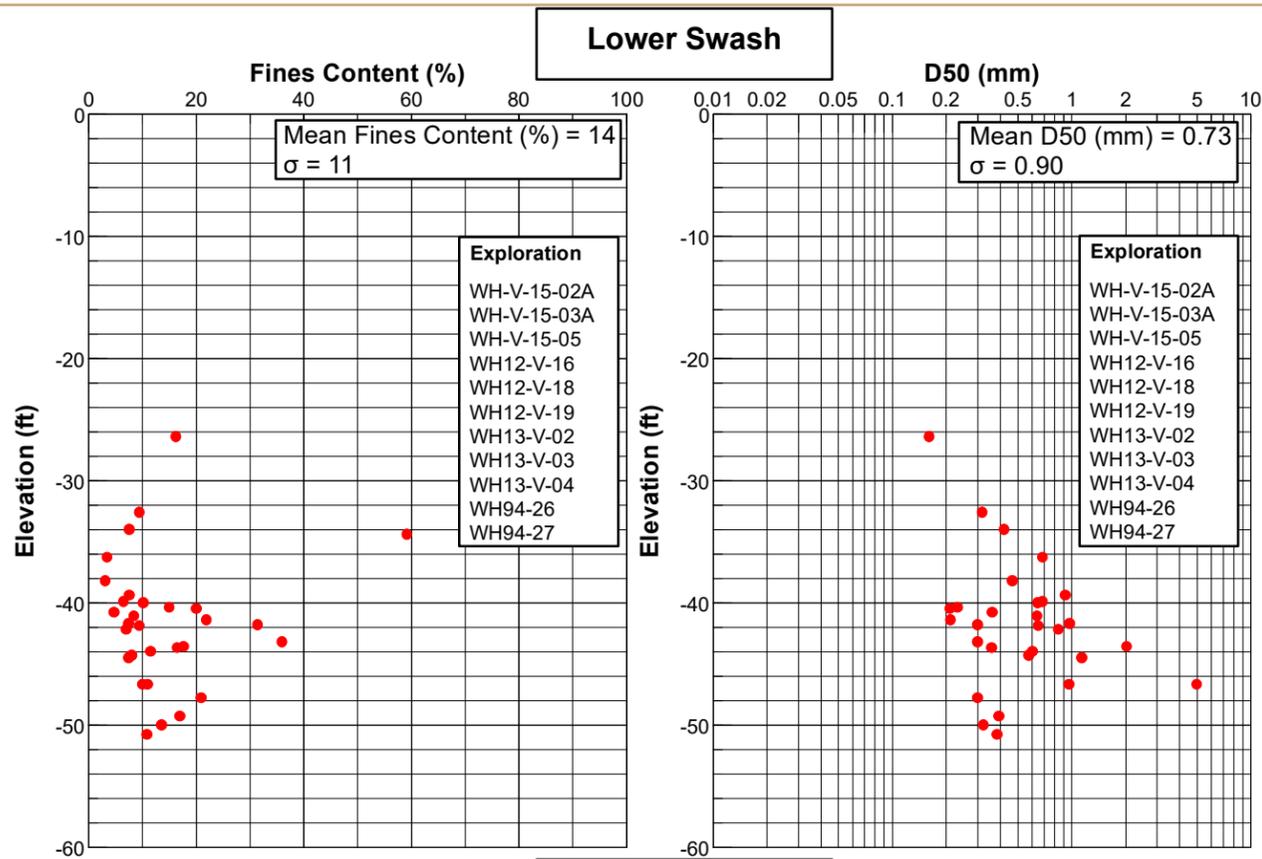


Notes:

- 1) Mean Fines Content (%) = the average value of fines content in the channel reach. Ideal values for beach nourishment material would be fines content <10%
- 2) Mean D50 (mm) = the average D50 value of all laboratory tests conducted in that reach.
- 3) σ = one standard deviation
- 4) Elevation in feet is referenced to MLLW.
- 5) Each data point represents a result from a discrete laboratory test conducted on a discrete sample.
- 6) Fines content and D50 test results displayed on these graphs are derived from sieve analyses. For fine-grained sediments (sediments with >50% particles less than 0.075mm diameter by weight) the fines content can be determined, but it is not possible to determine the D50 value.

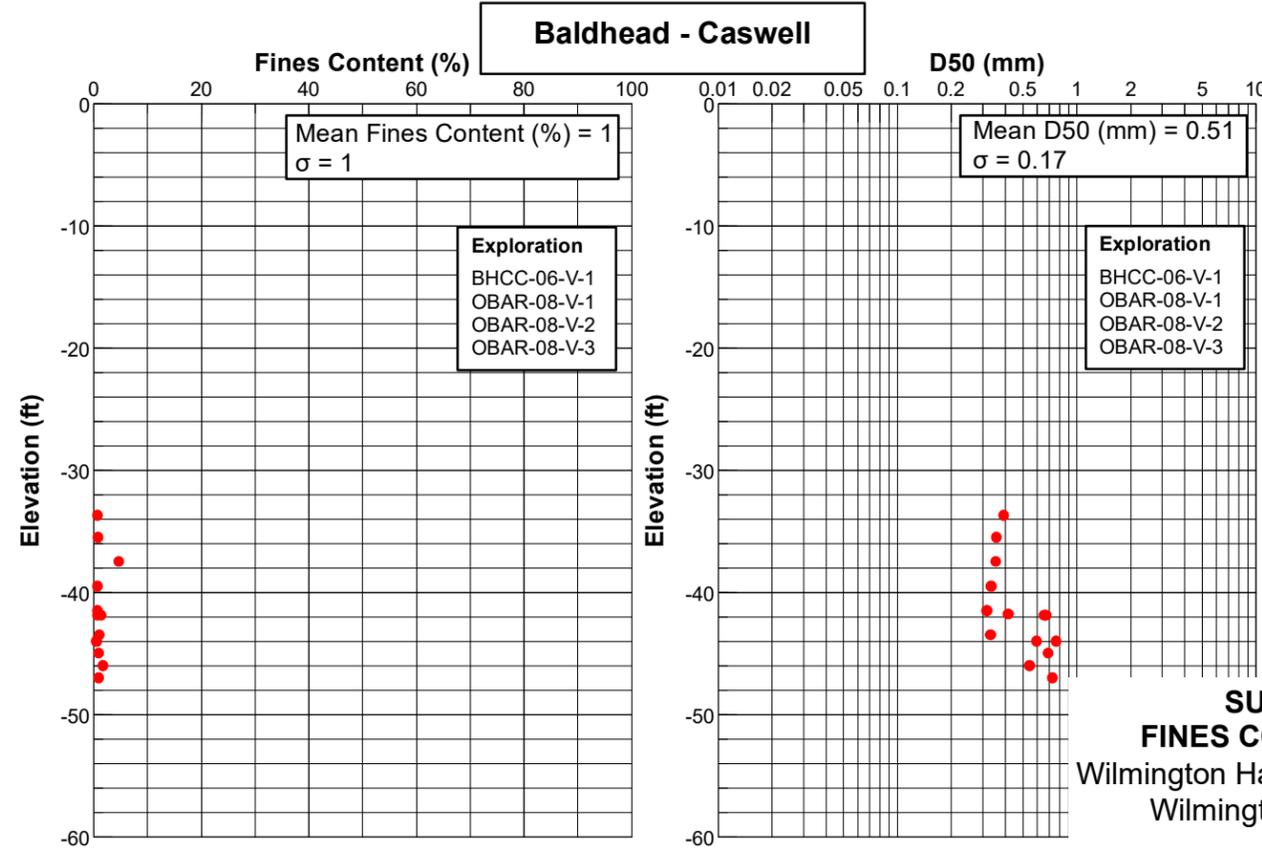
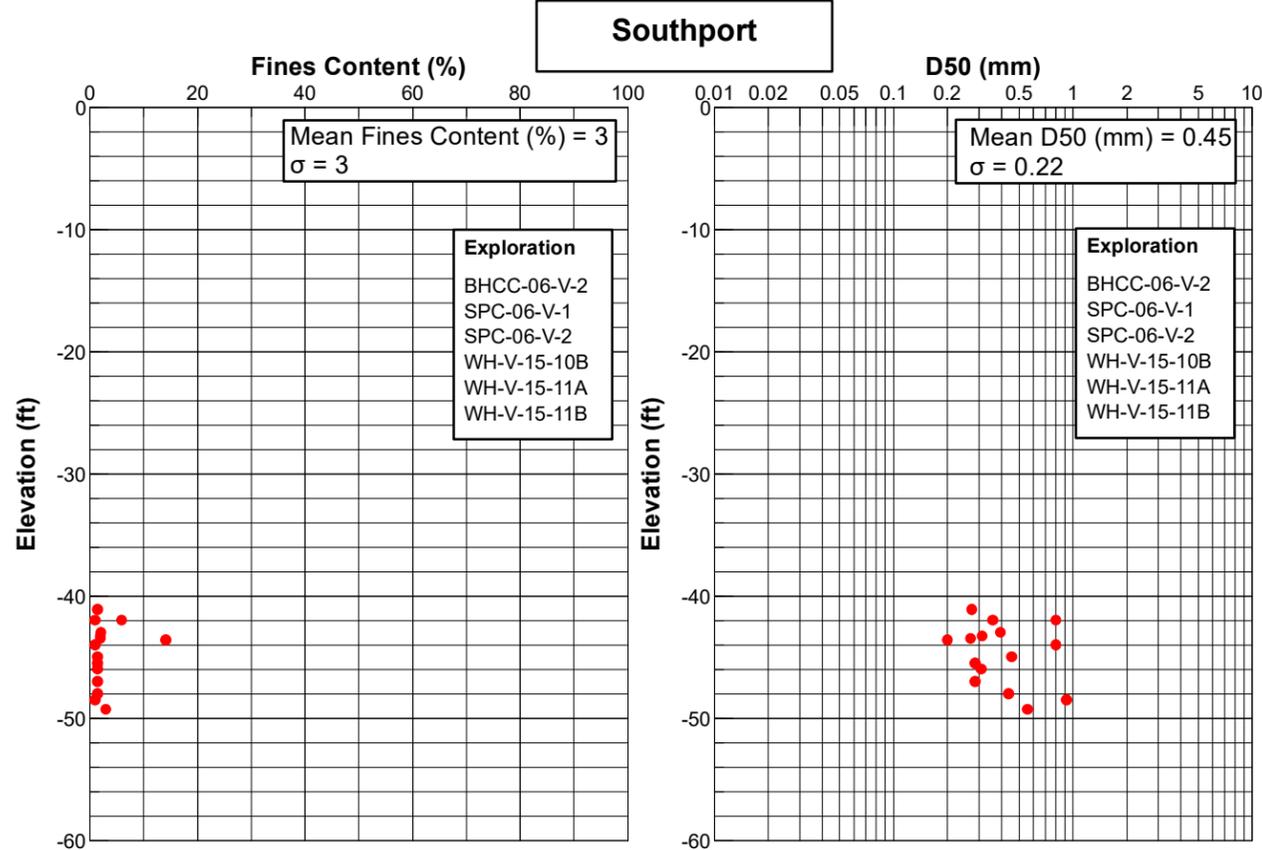
**SUMMARY OF
 FINES CONTENT AND D50**
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 4-4

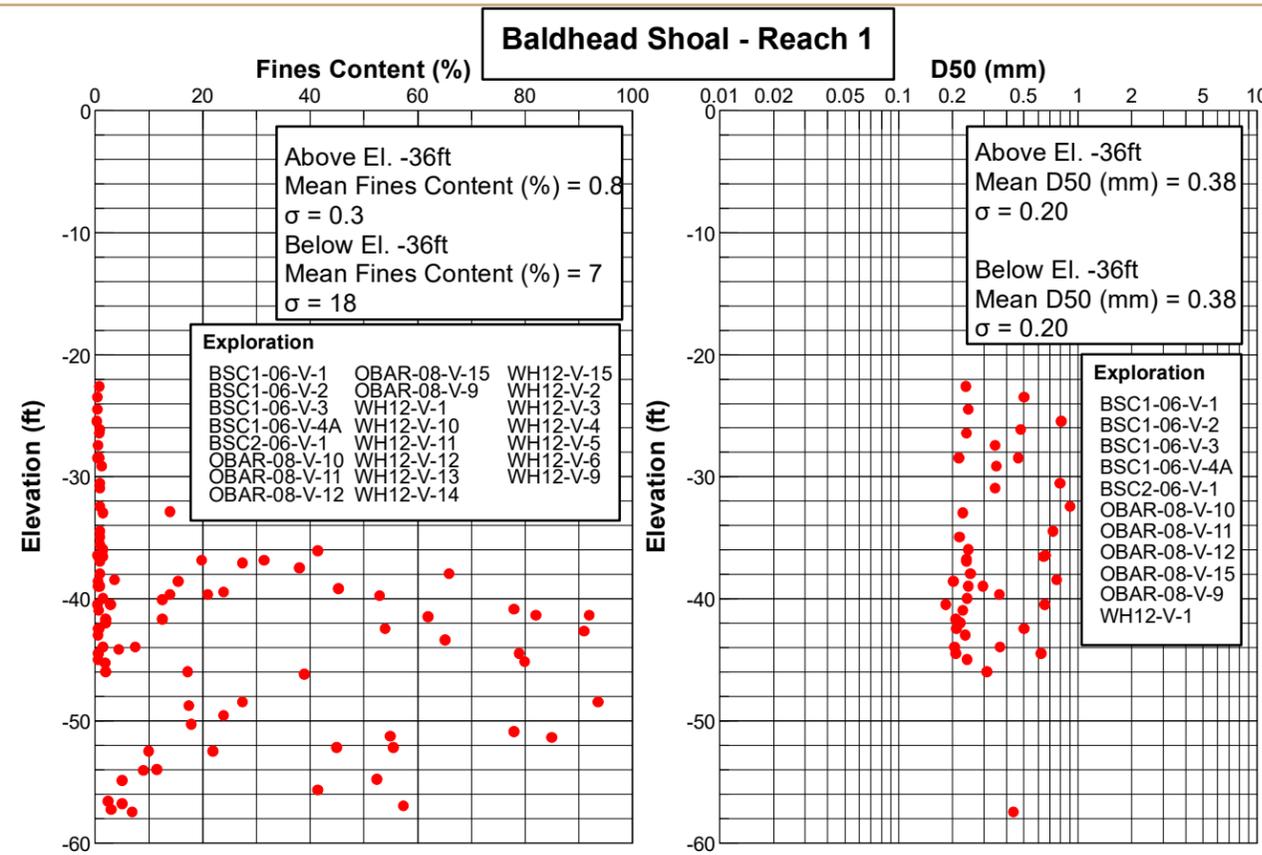
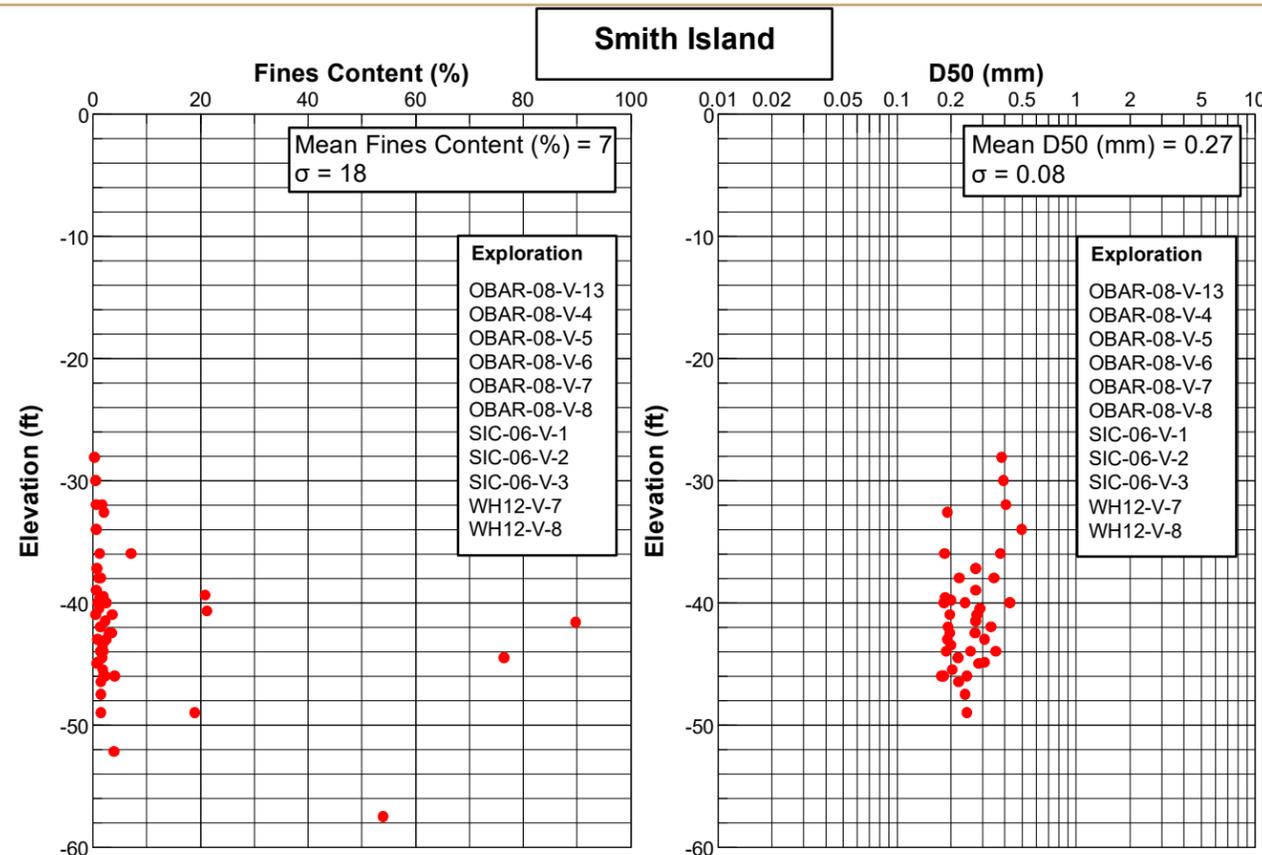


Notes:

- 1) Mean Fines Content (%) = the average value of fines content in the channel reach. Ideal values for beach nourishment material would be fines content <10%
- 2) Mean D50 (mm) = the average D50 value of all laboratory tests conducted in that reach. Ideal values for beach nourishment material would be D50 = 0.25mm
- 3) σ = one standard deviation
- 4) Elevation in feet is referenced to MLLW.
- 5) Each data point represents a result from a discrete laboratory test conducted on a discrete sample.
- 6) Fines content and D50 test results displayed on these graphs are derived from sieve analyses. For fine-grained sediments (sediments with >50% particles less than 0.075mm diameter by weight) the fines content can be determined but it is not possible to determine the D50 value.

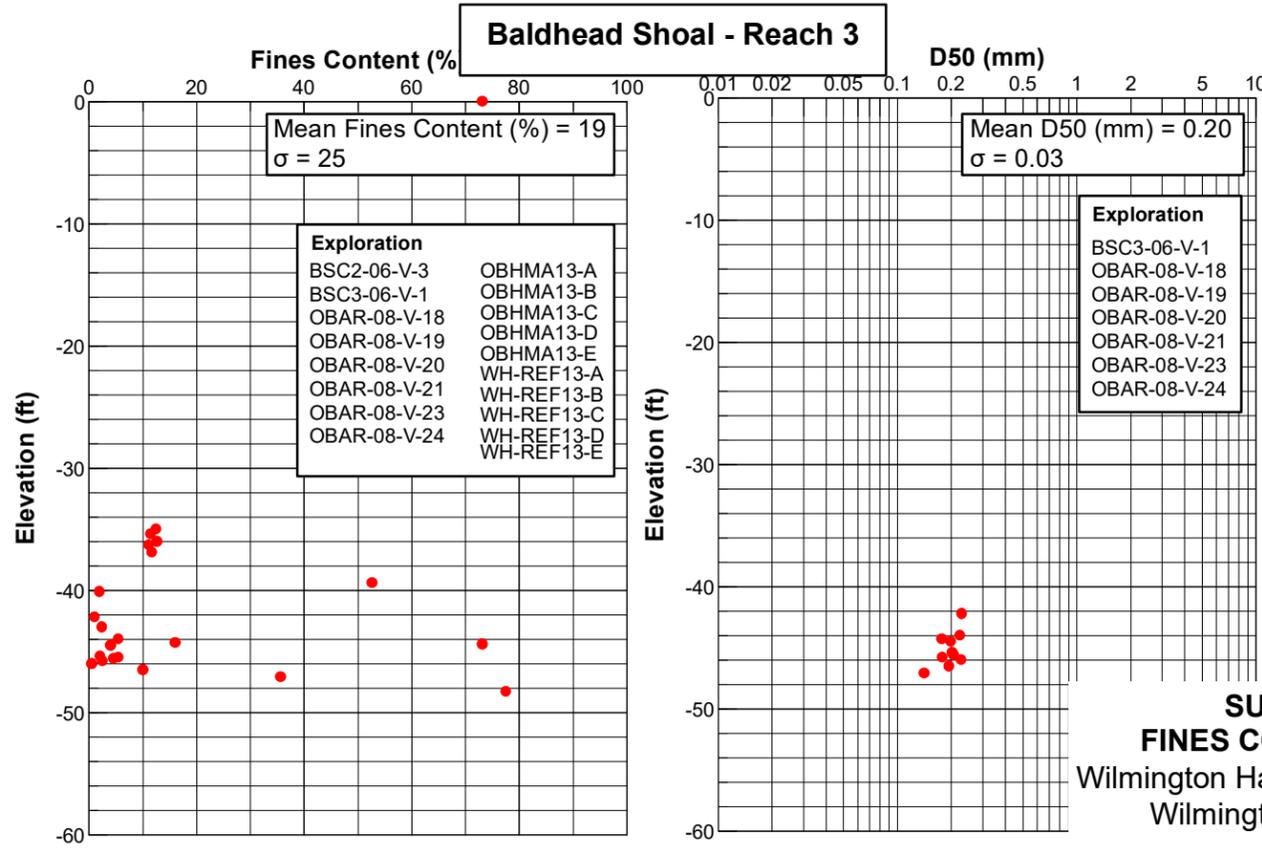
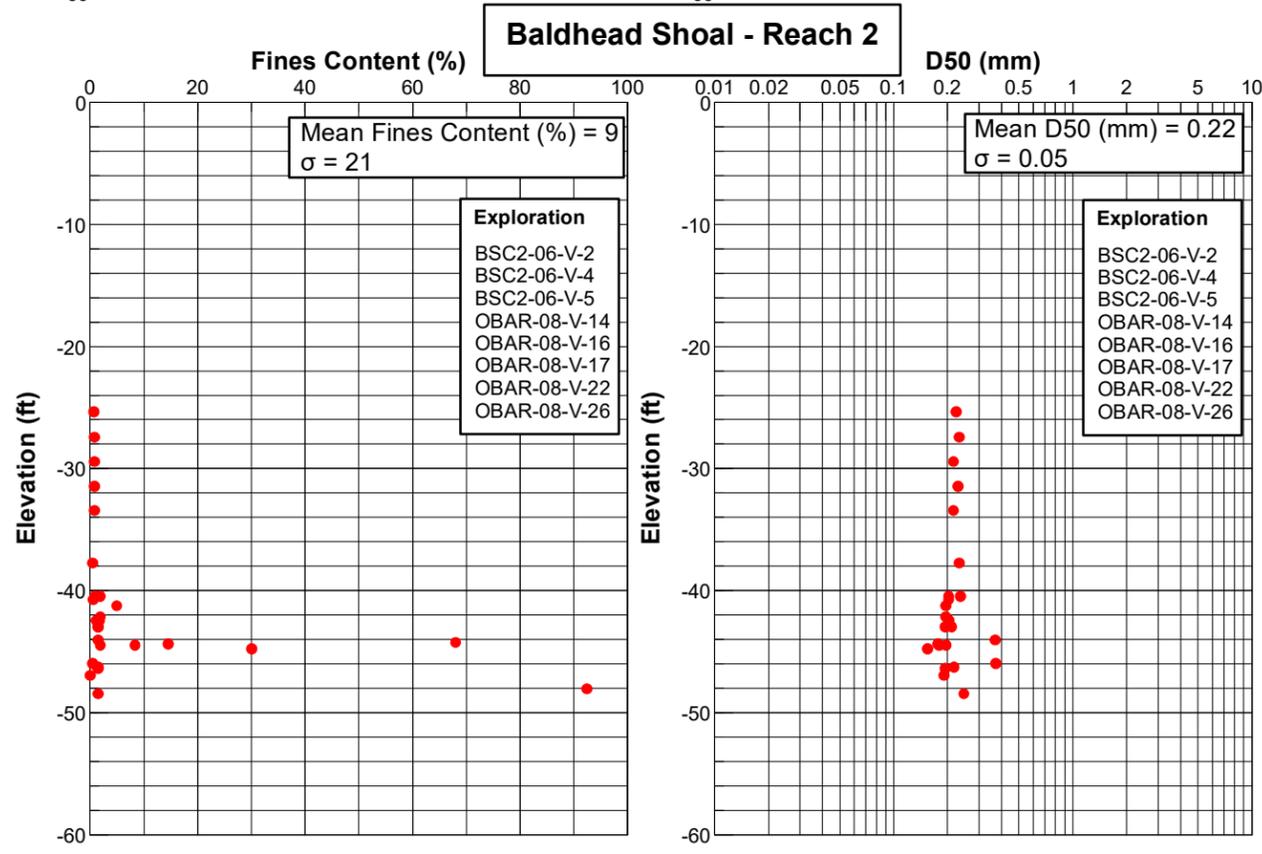


**SUMMARY OF
 FINES CONTENT AND D50**
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



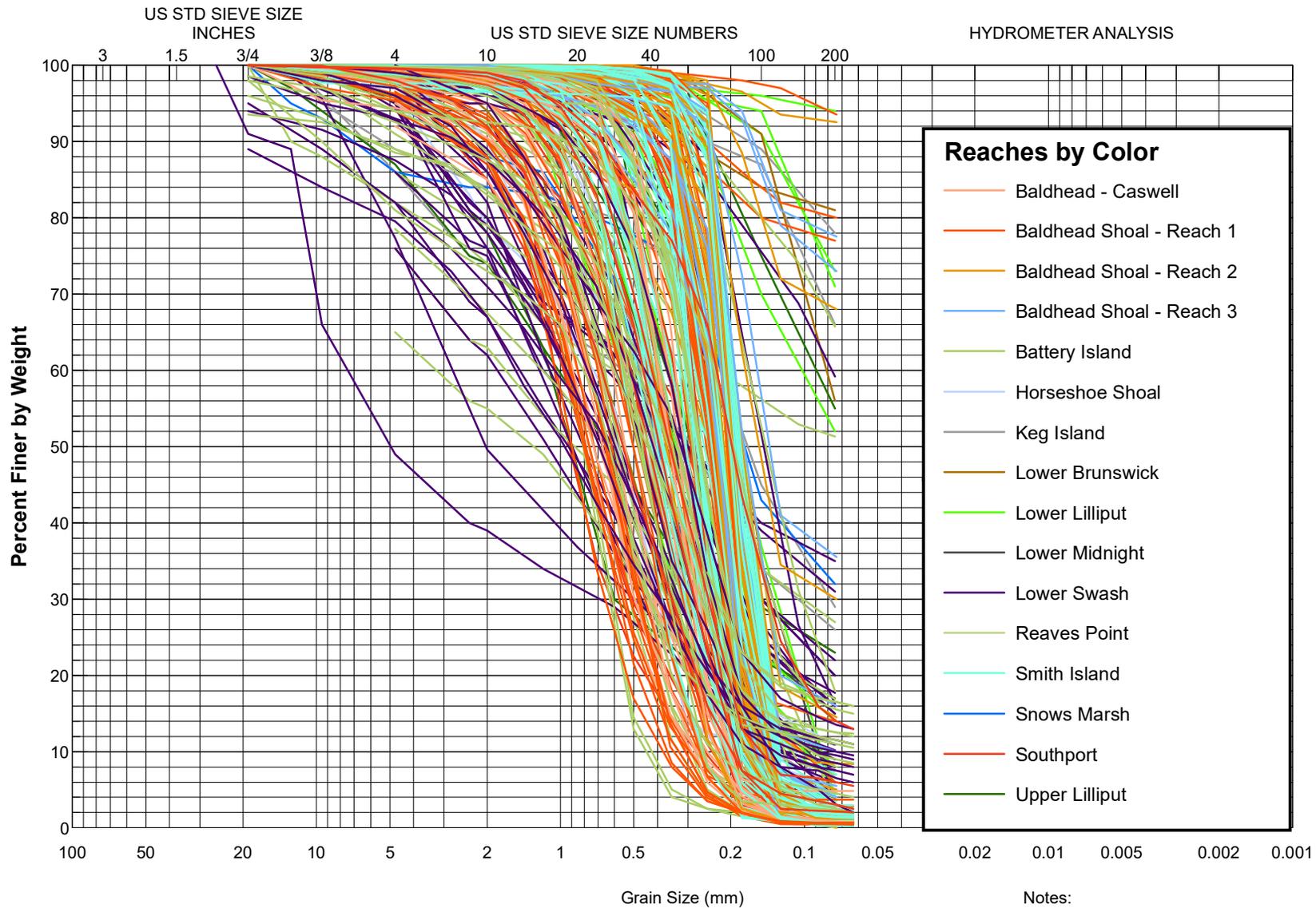
Notes:

- 1) Mean Fines Content (%) = the average value of fines content in the channel reach. Ideal values for beach nourishment material would be fines content <10%
- 2) Mean D50 (mm) = the average D50 value of all laboratory tests conducted in that reach.
- 3) σ = one standard deviation
- 4) Elevation in feet is referenced to MLLW.
- 5) Each data point represents a result from a discrete laboratory test conducted on a discrete sample.
- 6) Fines content and D50 test results displayed on these graphs are derived from sieve analyses. For fine-grained sediments (sediments with >50% particles less than 0.075mm diameter by weight) the fines content can be determined, but it is not possible to determine the D50 value.



**SUMMARY OF
 FINES CONTENT AND D50**
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



Notes:

1) Each curve represents a discrete laboratory test.

FIGURE 5-1

GRAIN SIZE CURVES
Global
Wilmington Harbor Deepening Survey
Wilmington, North Carolina



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	

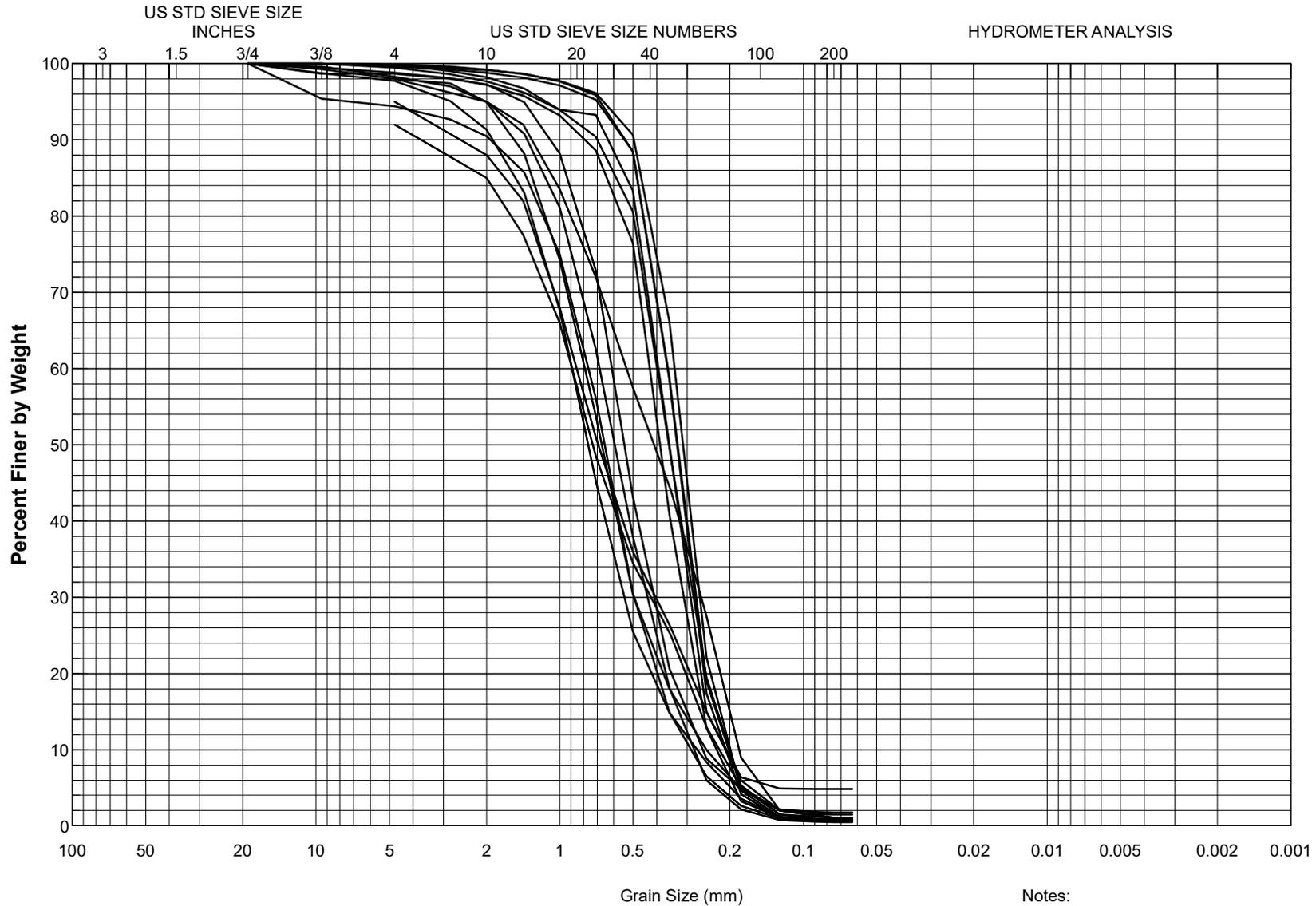


FIGURE 5-2

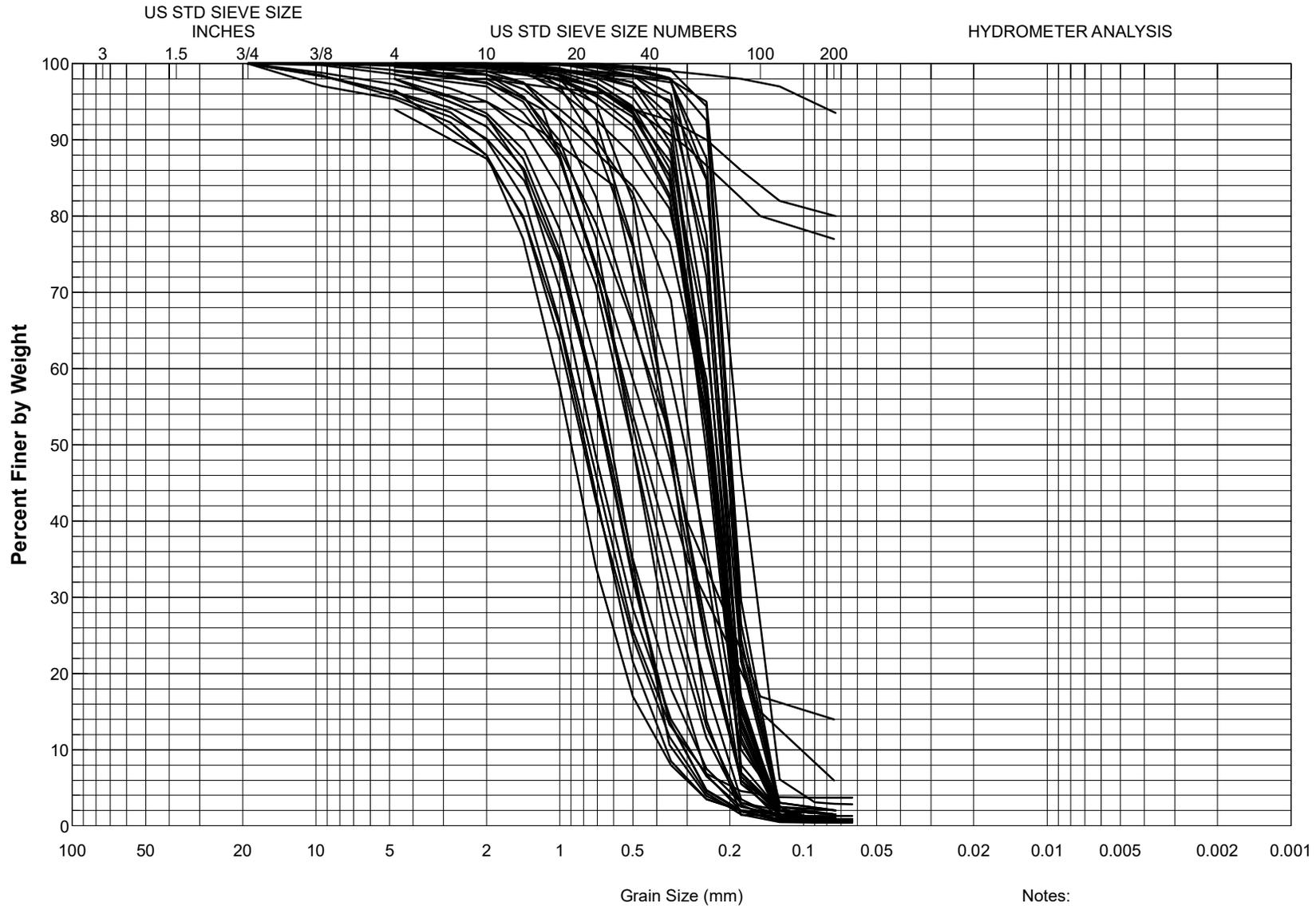
GRAIN SIZE CURVES
 Baldhead - Caswell
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

Notes:

1) Each curve represents a discrete laboratory test.



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



Notes:

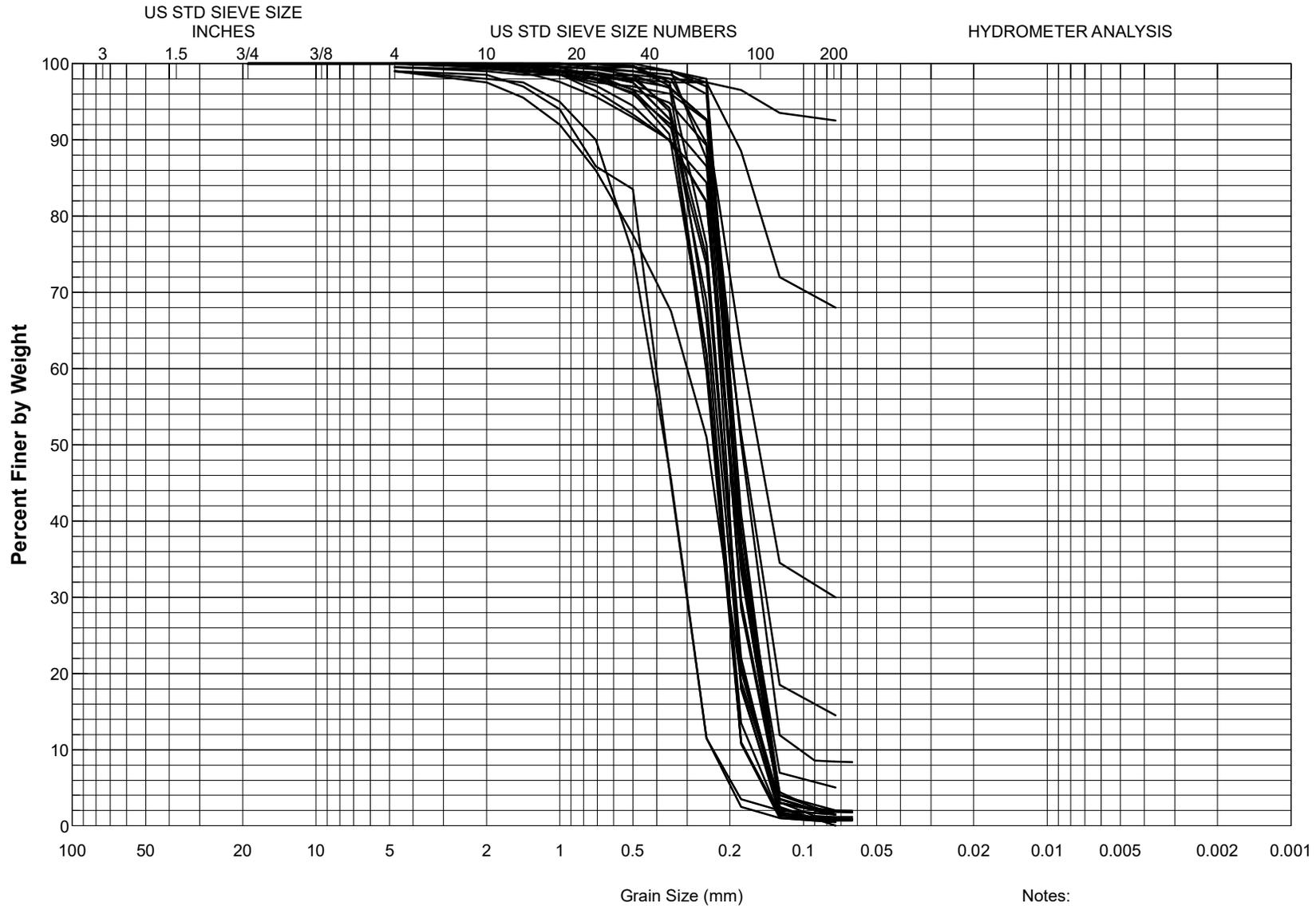
1) Each curve represents a discrete laboratory test.

GRAIN SIZE CURVES
 Baldhead Shoal - Reach 1
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 5-3



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



Notes:

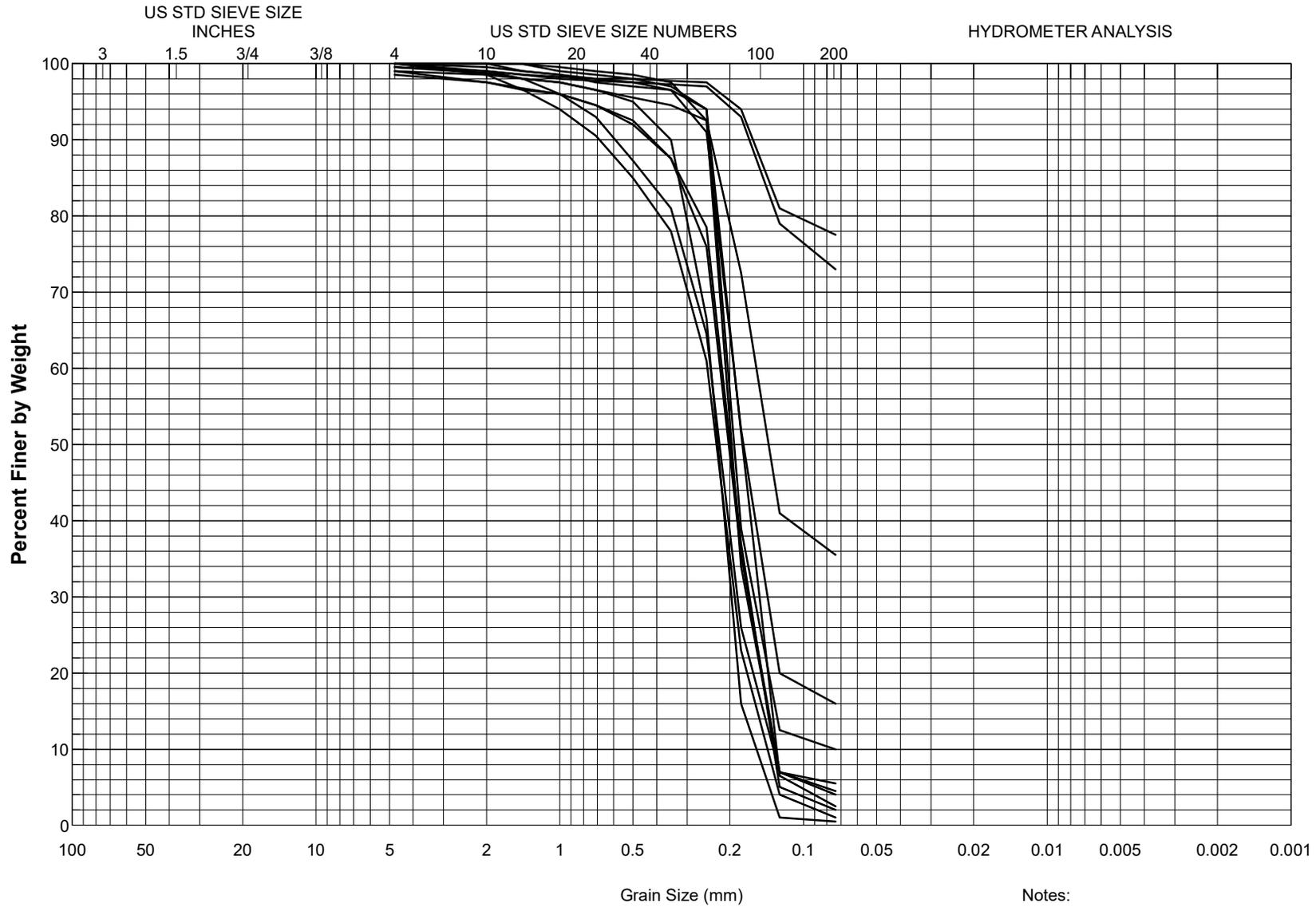
1) Each curve represents a discrete laboratory test.

GRAIN SIZE CURVES
 Baldhead Shoal - Reach 2
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

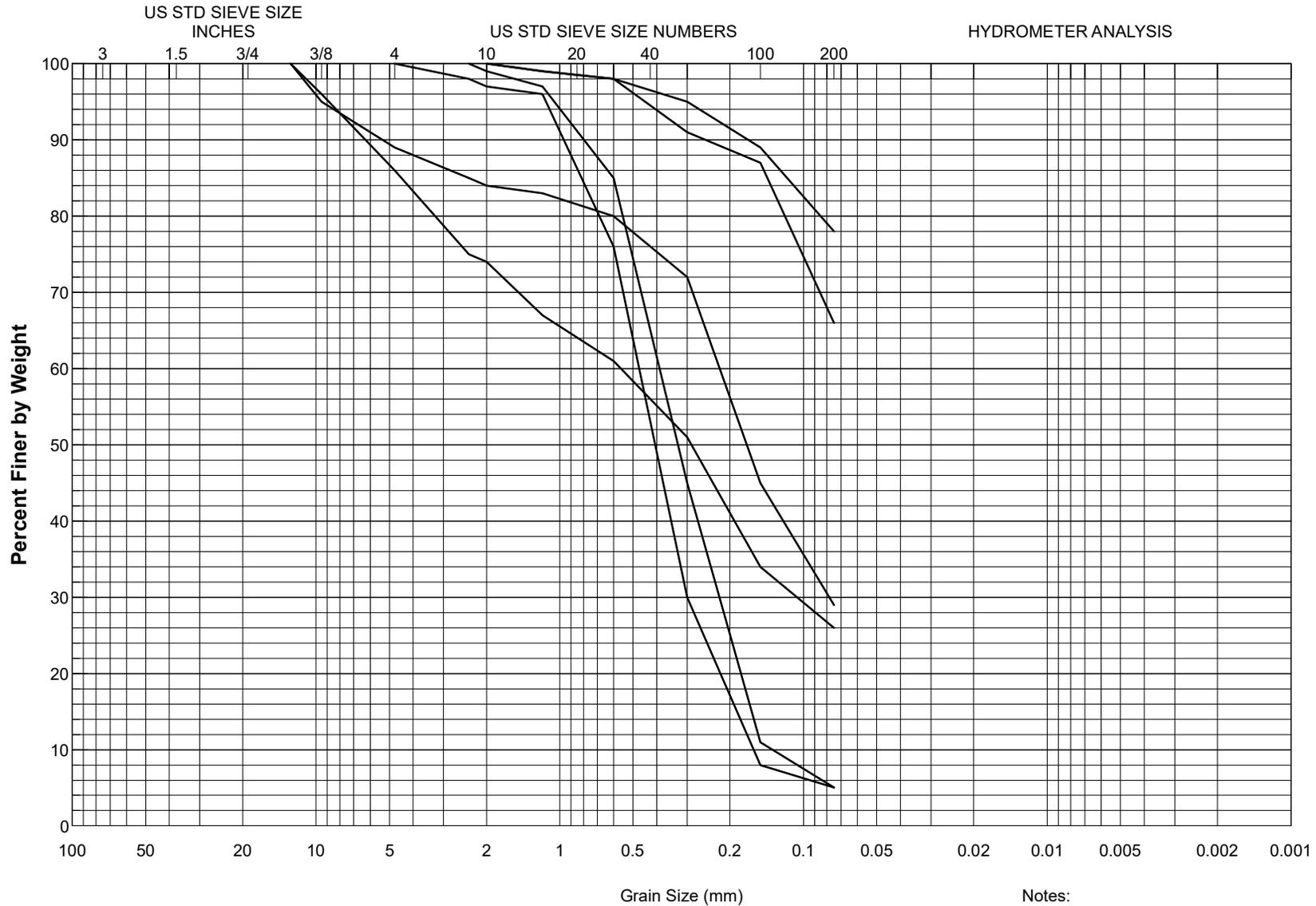
FIGURE 5-4



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



Notes:

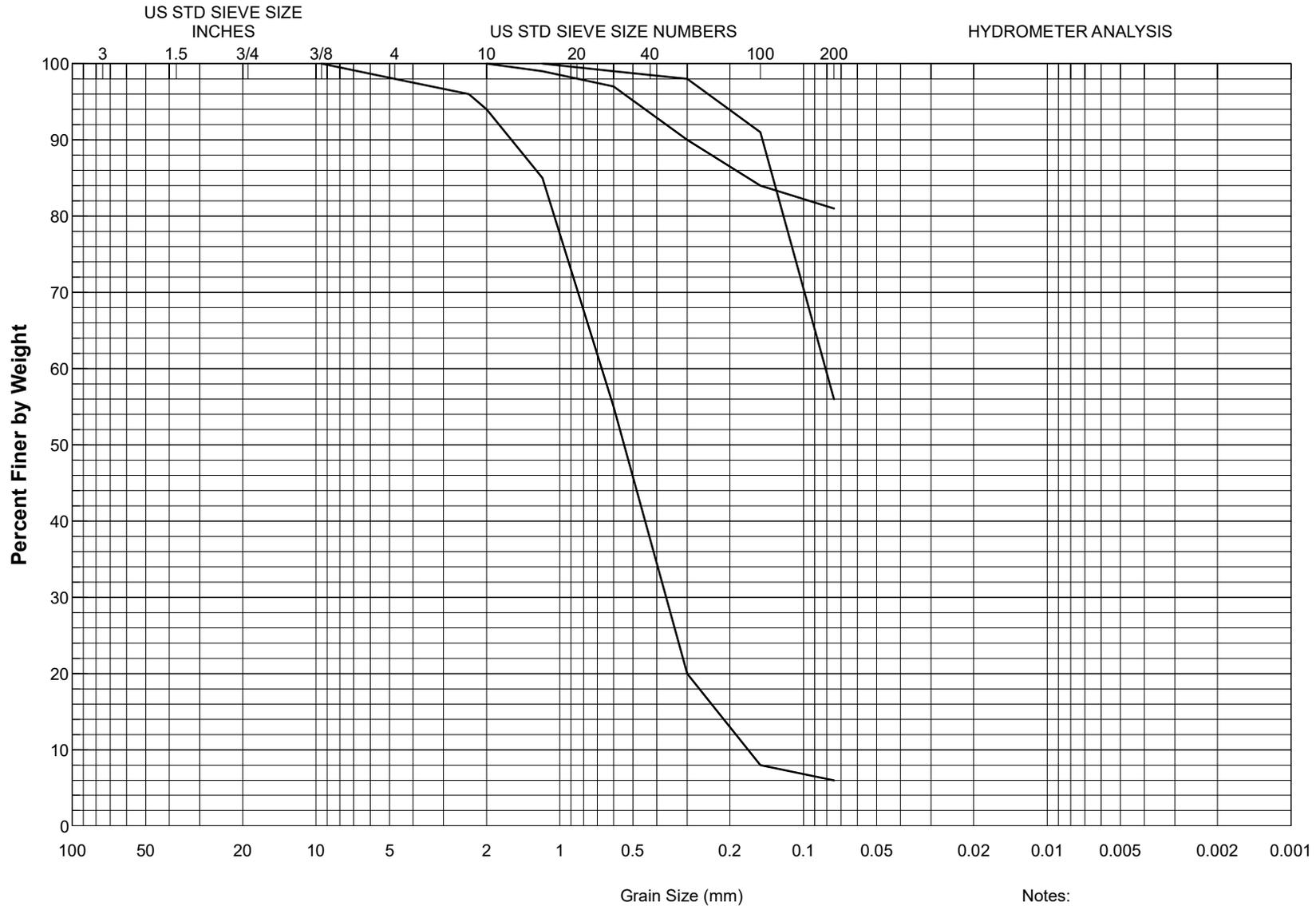
1) Each curve represents a discrete laboratory test.

GRAIN SIZE CURVES
 Keg Island
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 5-8



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



Notes:

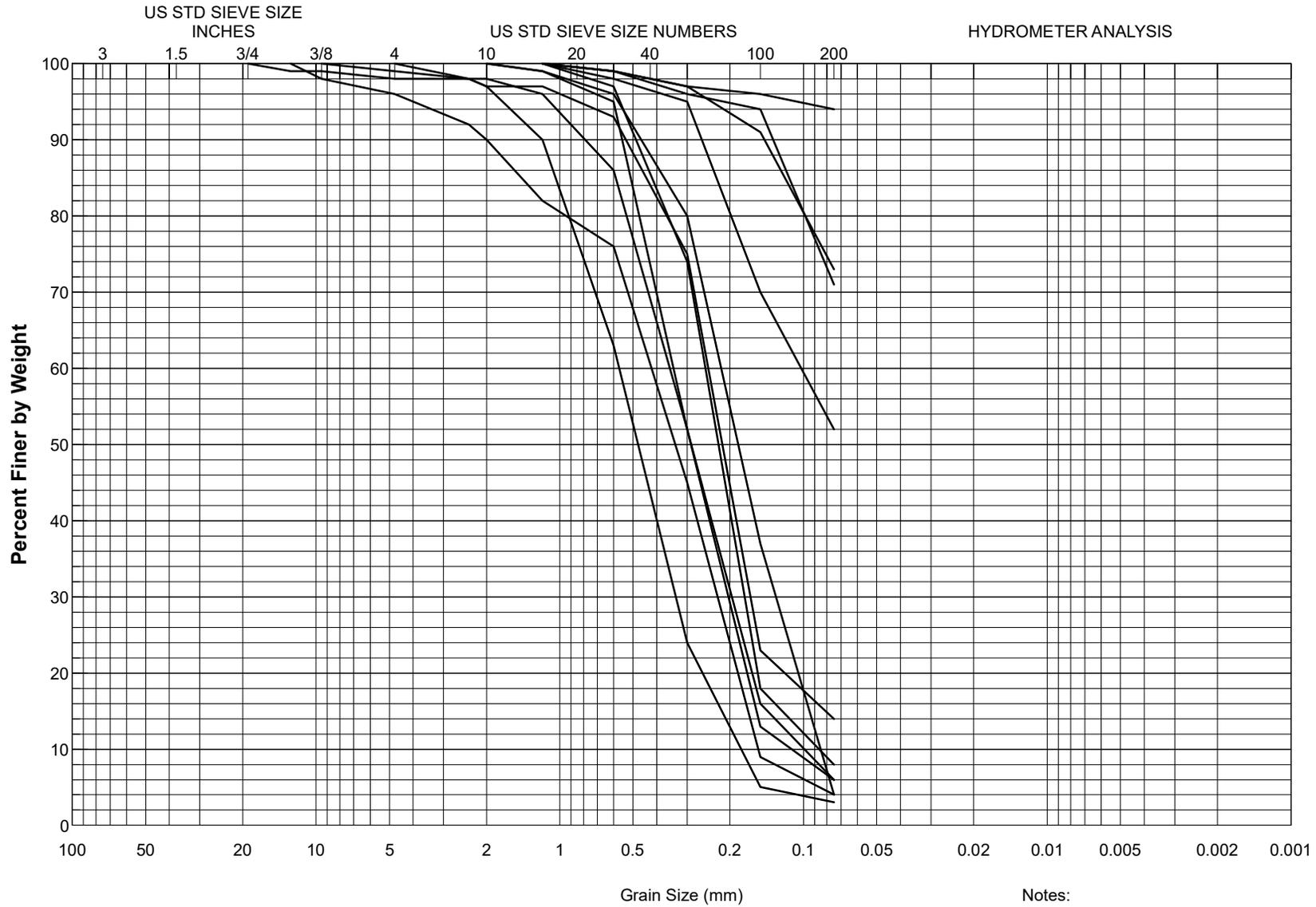
1) Each curve represents a discrete laboratory test.

GRAIN SIZE CURVES
 Lower Brunswick
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 5-9



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



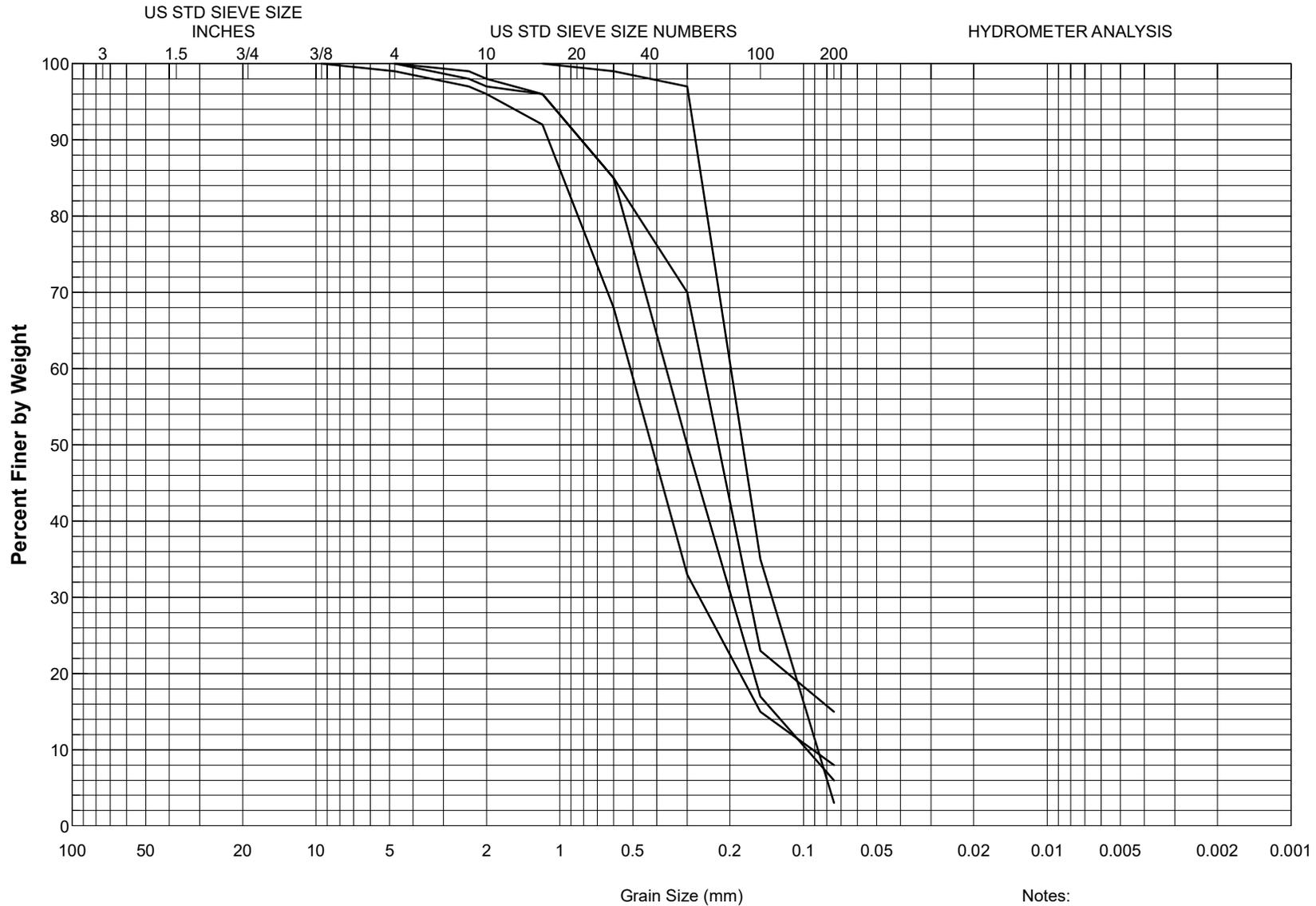
Notes:
 1) Each curve represents a discrete laboratory test.

GRAIN SIZE CURVES
 Lower Lilliput
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 5-10



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



Notes:

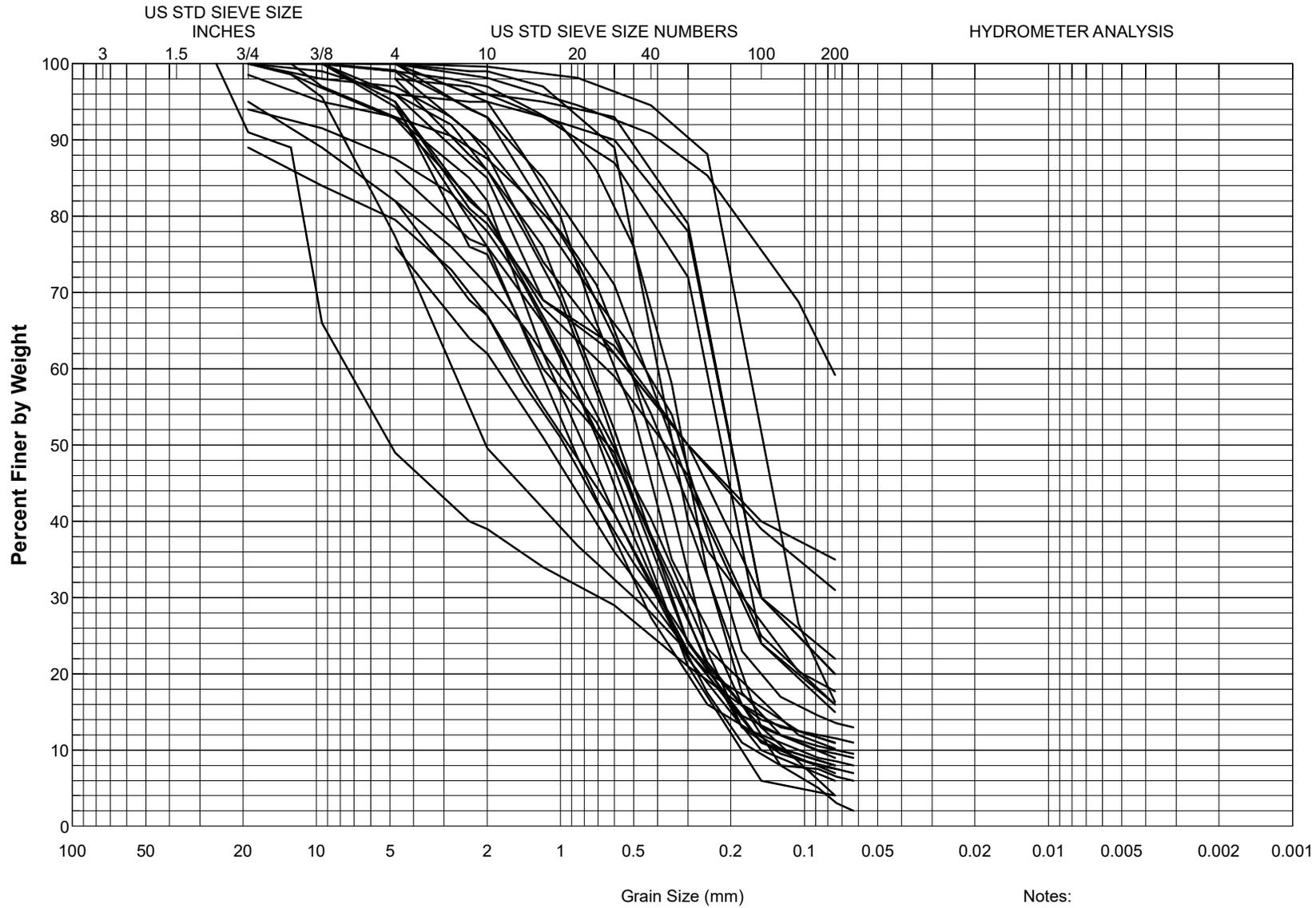
1) Each curve represents a discrete laboratory test.

GRAIN SIZE CURVES
 Lower Midnight
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 5-11



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



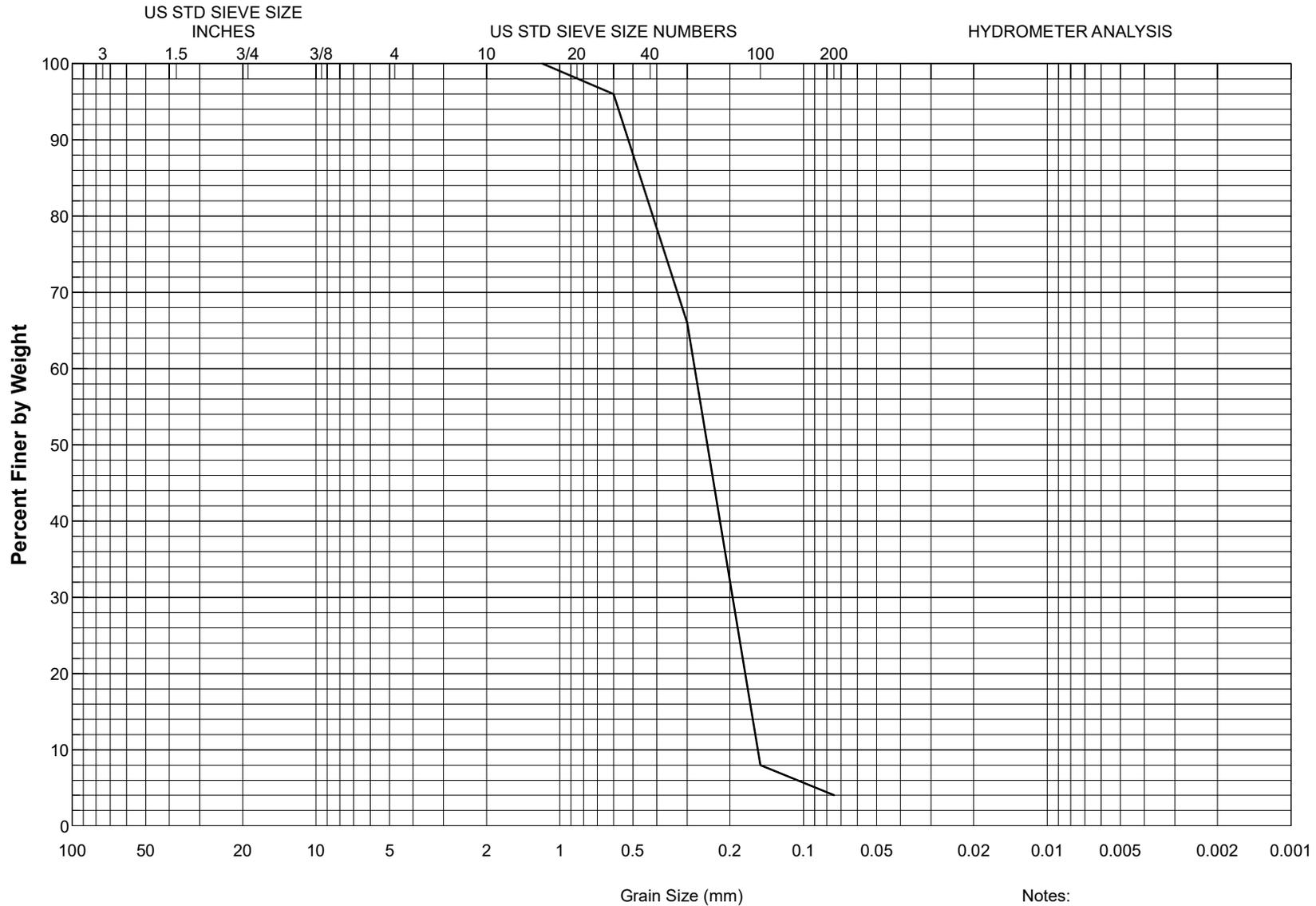
Notes:
 1) Each curve represents a discrete laboratory test.

GRAIN SIZE CURVES
 Lower Swash
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 5-12



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



GRAIN SIZE CURVES

Reaves Point

Wilmington Harbor Deepening Survey
Wilmington, North Carolina

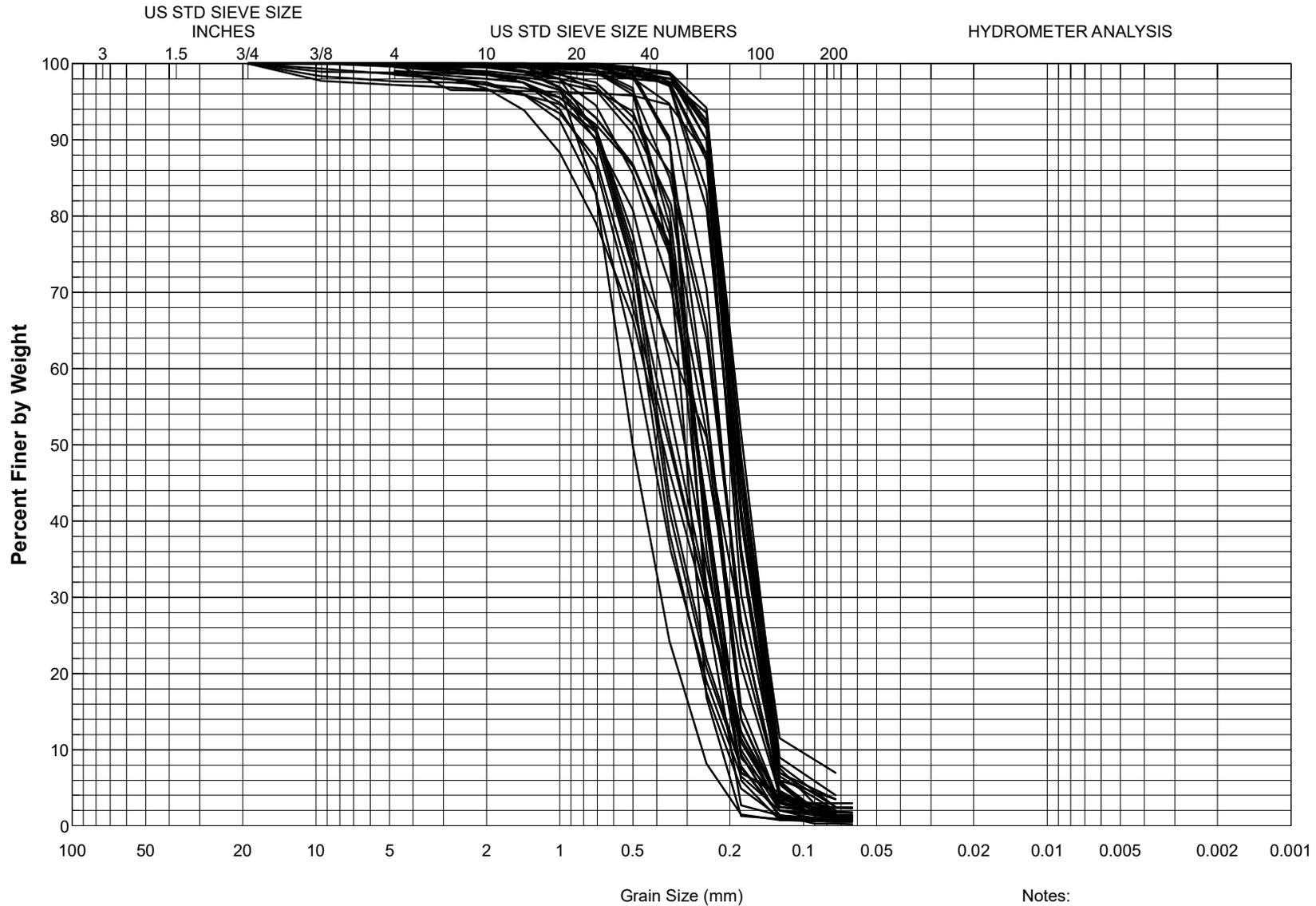
Notes:

1) Each curve represents a discrete laboratory test.

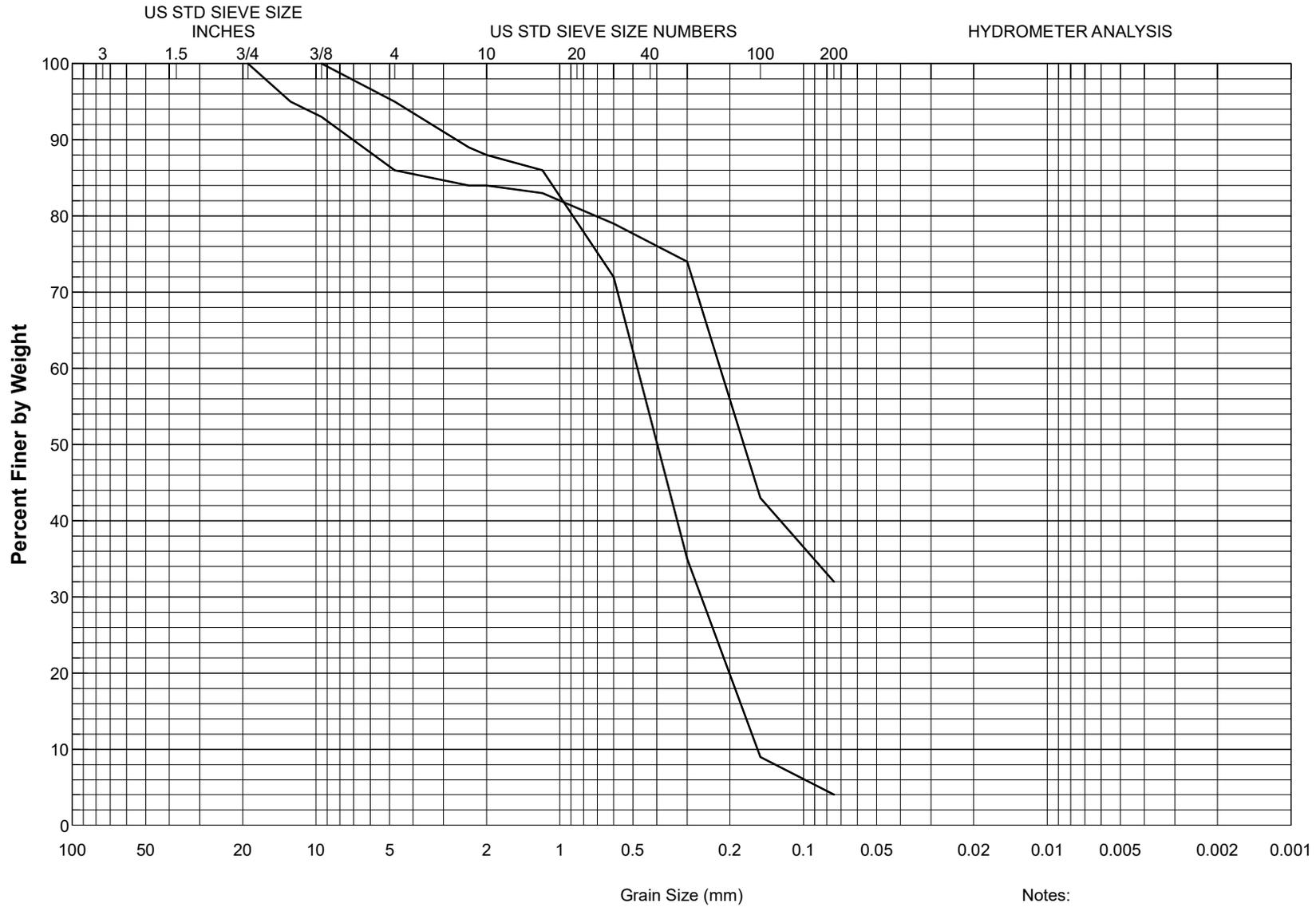
FIGURE 5-13



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



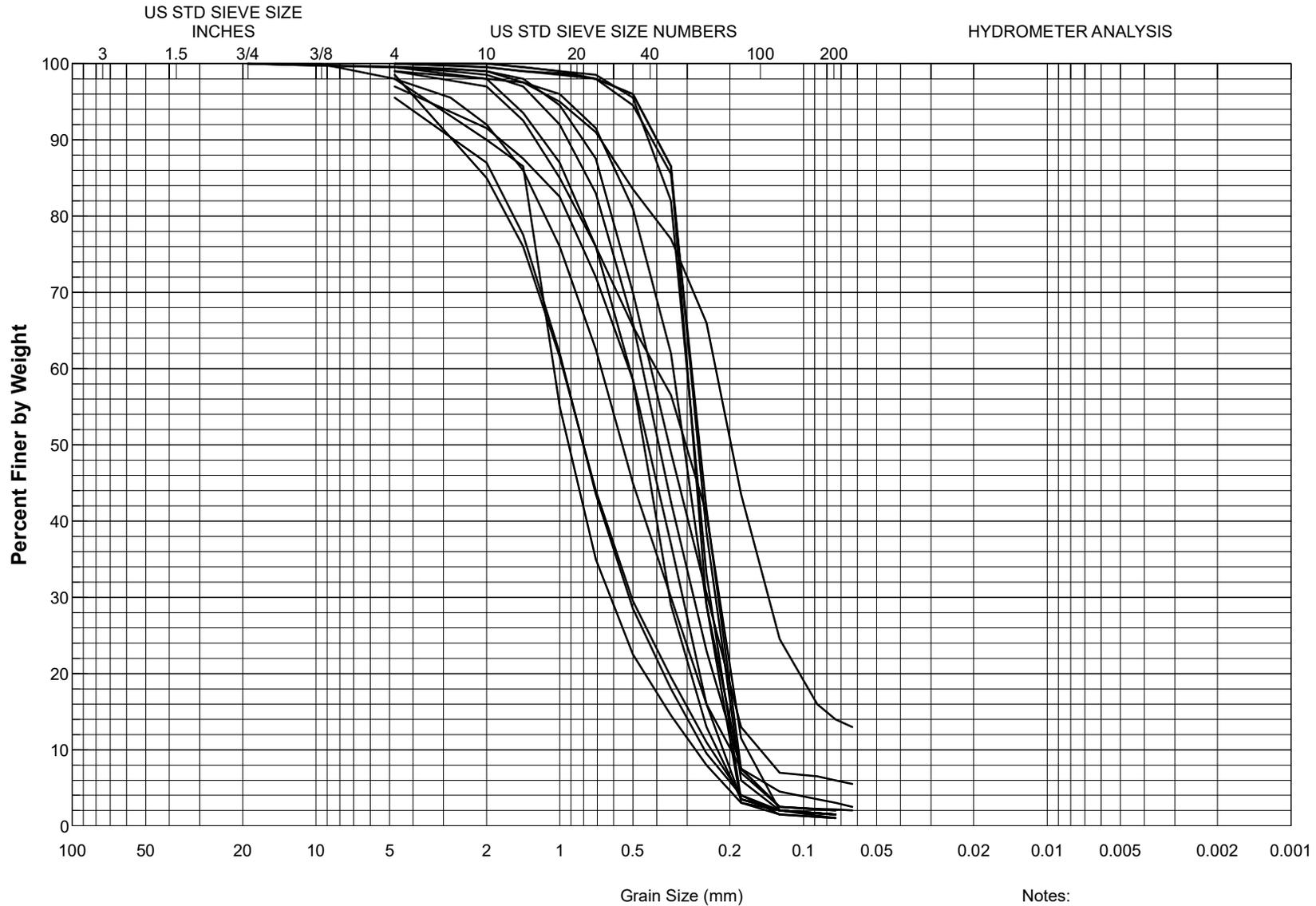
Notes:
1) Each curve represents a discrete laboratory test.

GRAIN SIZE CURVES
 Snows Marsh
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 5-15



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



Notes:

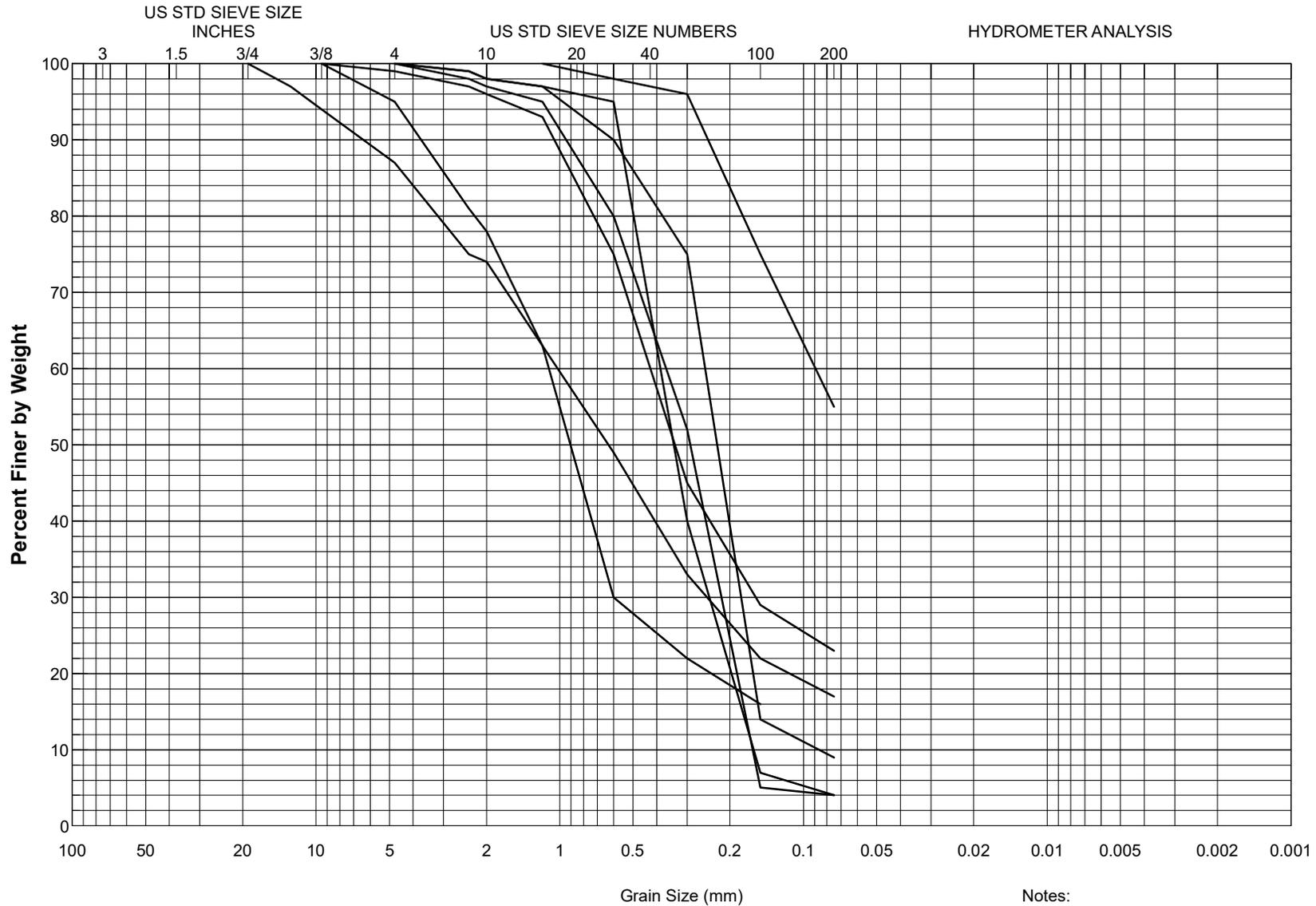
1) Each curve represents a discrete laboratory test.

GRAIN SIZE CURVES
 Southport
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 5-16



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	



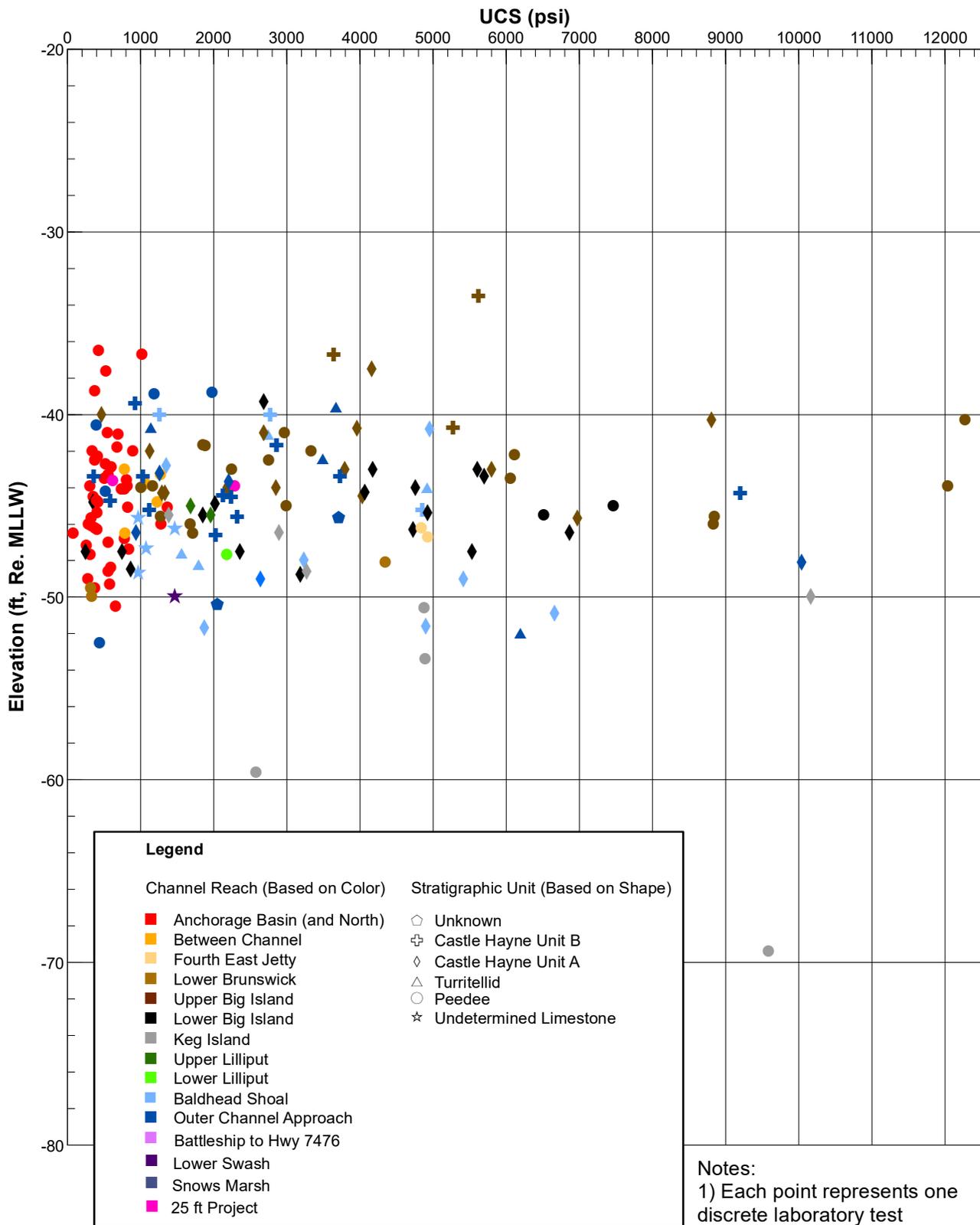
Notes:

1) Each curve represents a discrete laboratory test.

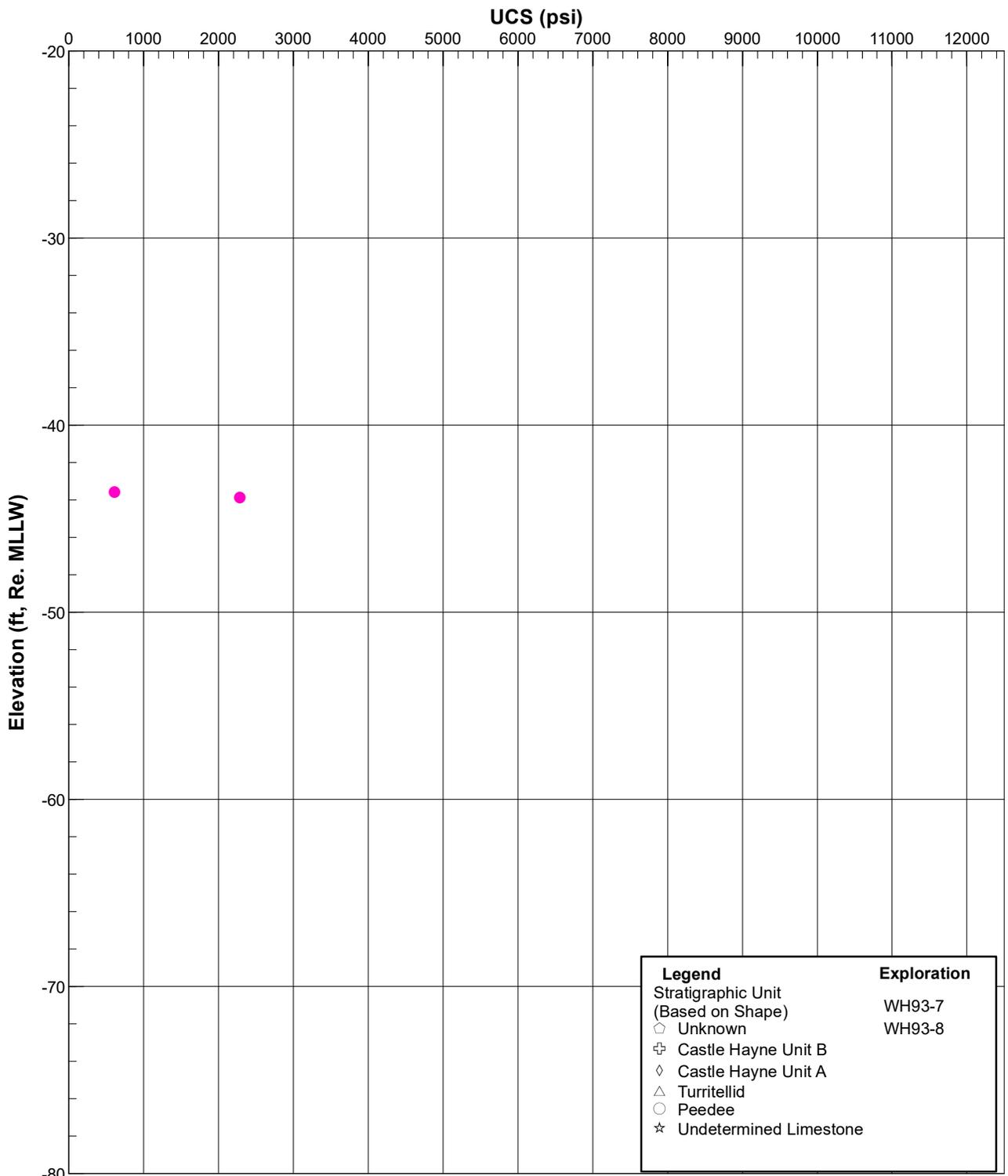
GRAIN SIZE CURVES
 Upper Lilliput
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 5-17





UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
 Wilmington Harbor Deepening Survey
 Wilmington North Carolina



Notes:

- 1) Each point represents one discrete laboratory test

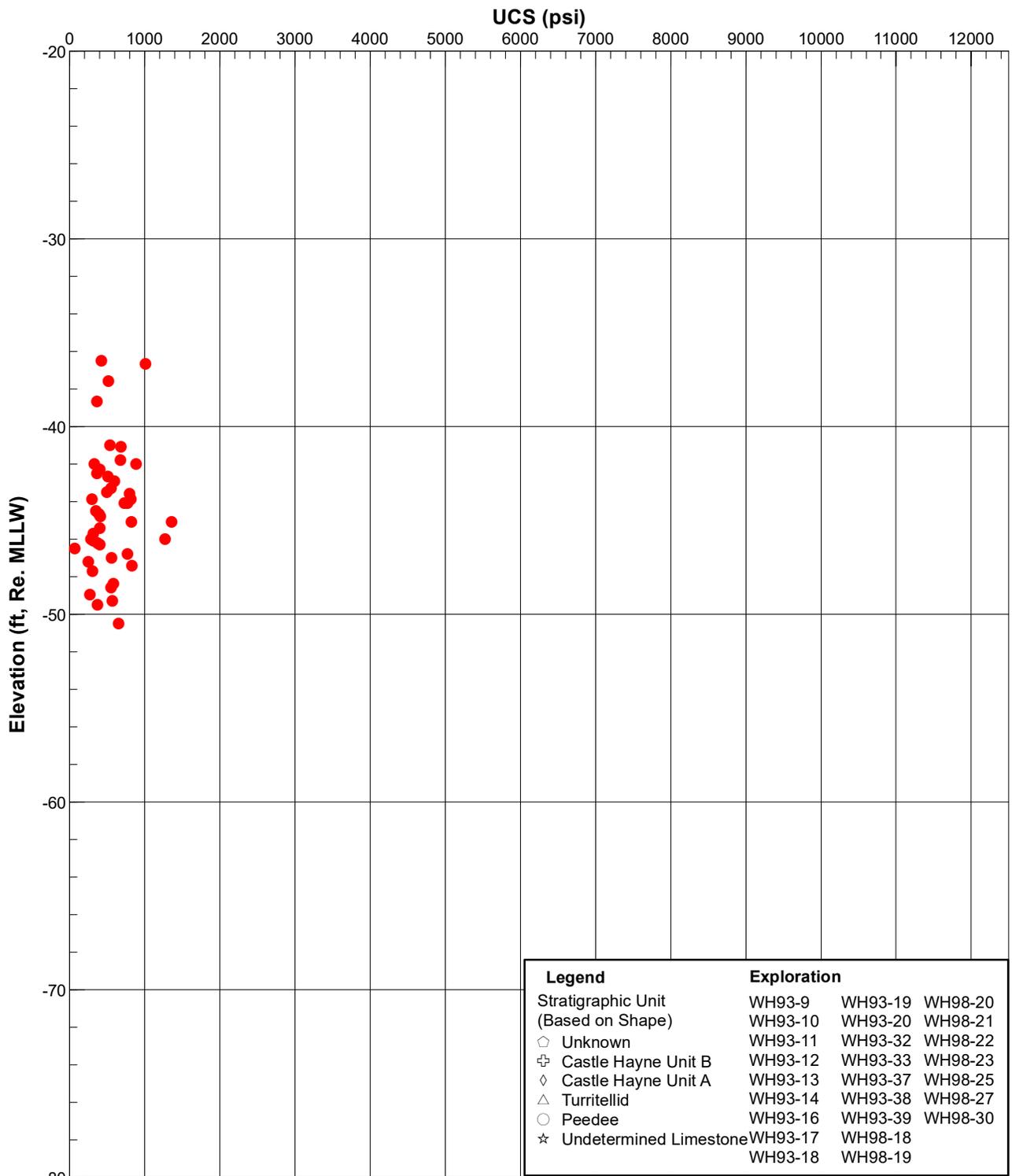
UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION

25 ft Project

Wilmington Harbor Deepening Survey

Wilmington, North Carolina

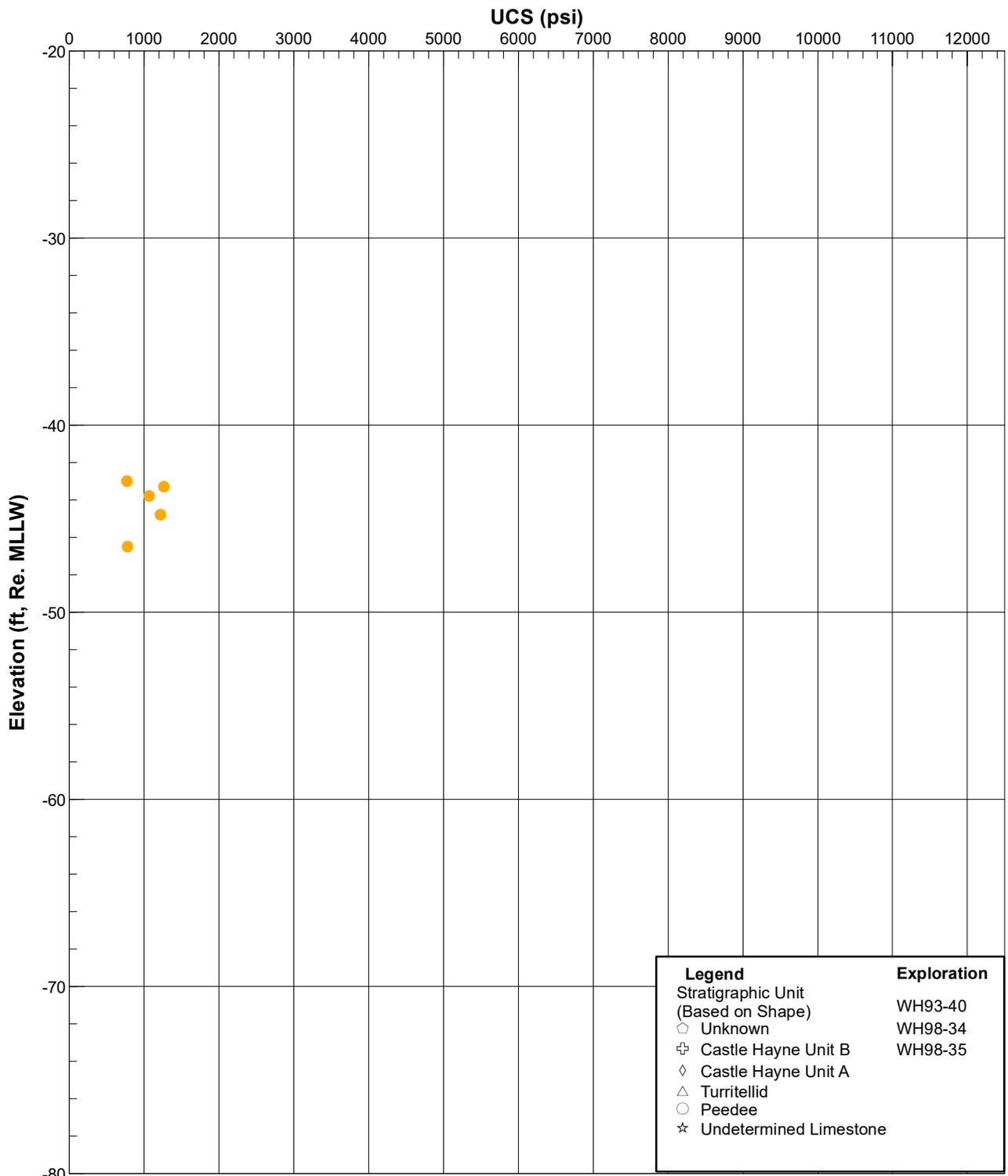
FIGURE 6-2



Notes:

- 1) Each point represents one discrete laboratory test

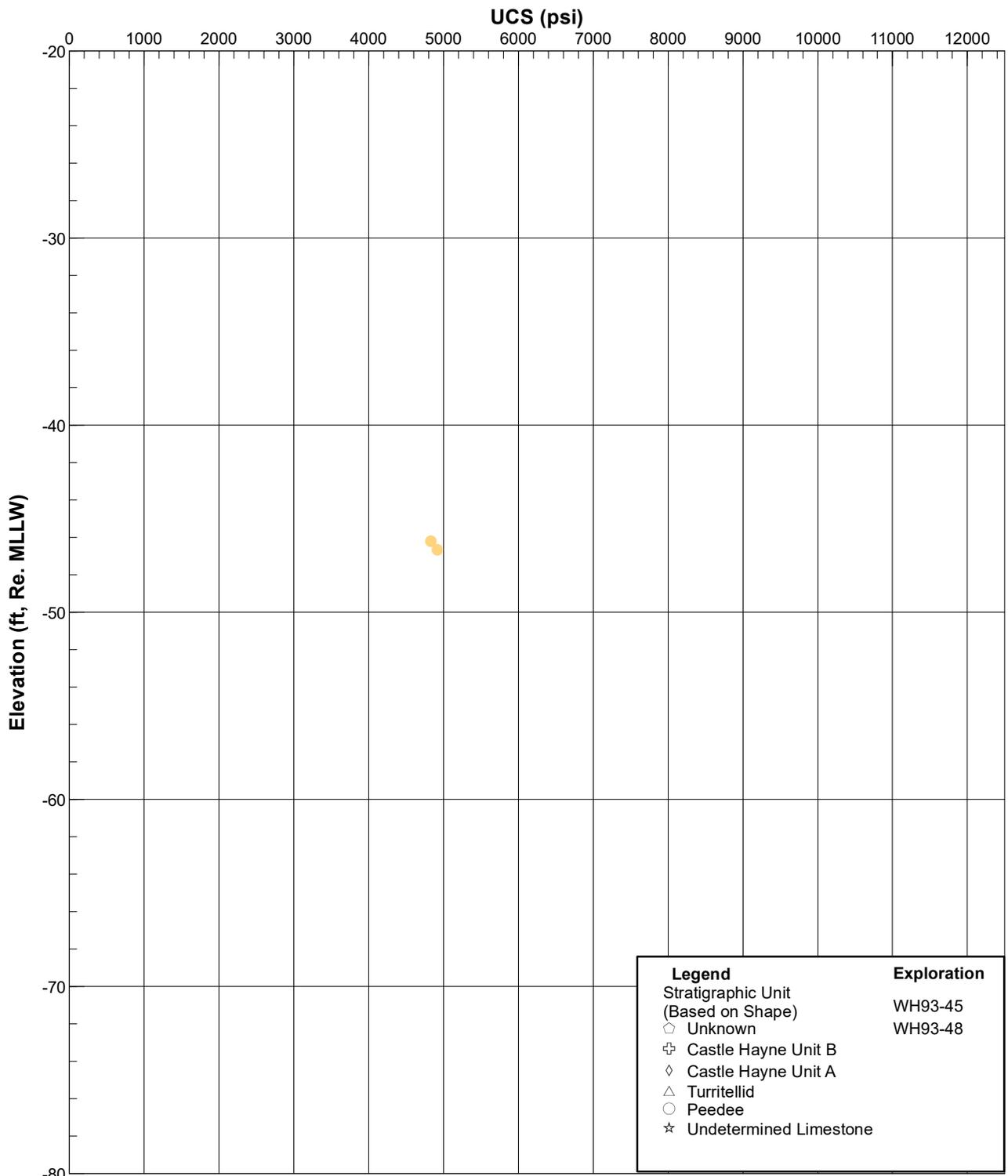
UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
 Anchorage Basin
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



Notes:
 1) Each point represents one discrete laboratory test

UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
 Between Channel
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

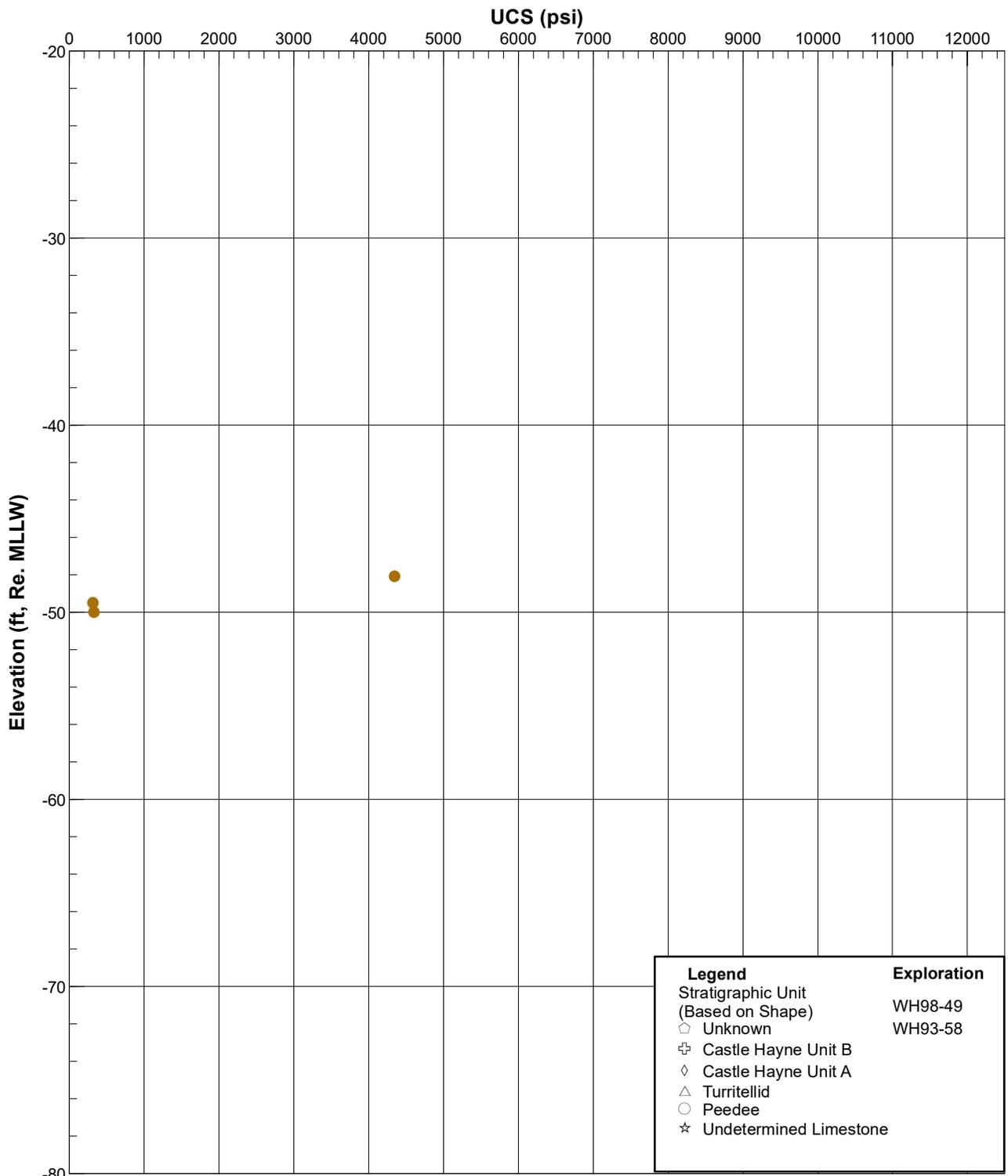
FIGURE 6-4



Notes:
 1) Each point represents one discrete laboratory test

UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
 Fourth East Jetty
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 6-5

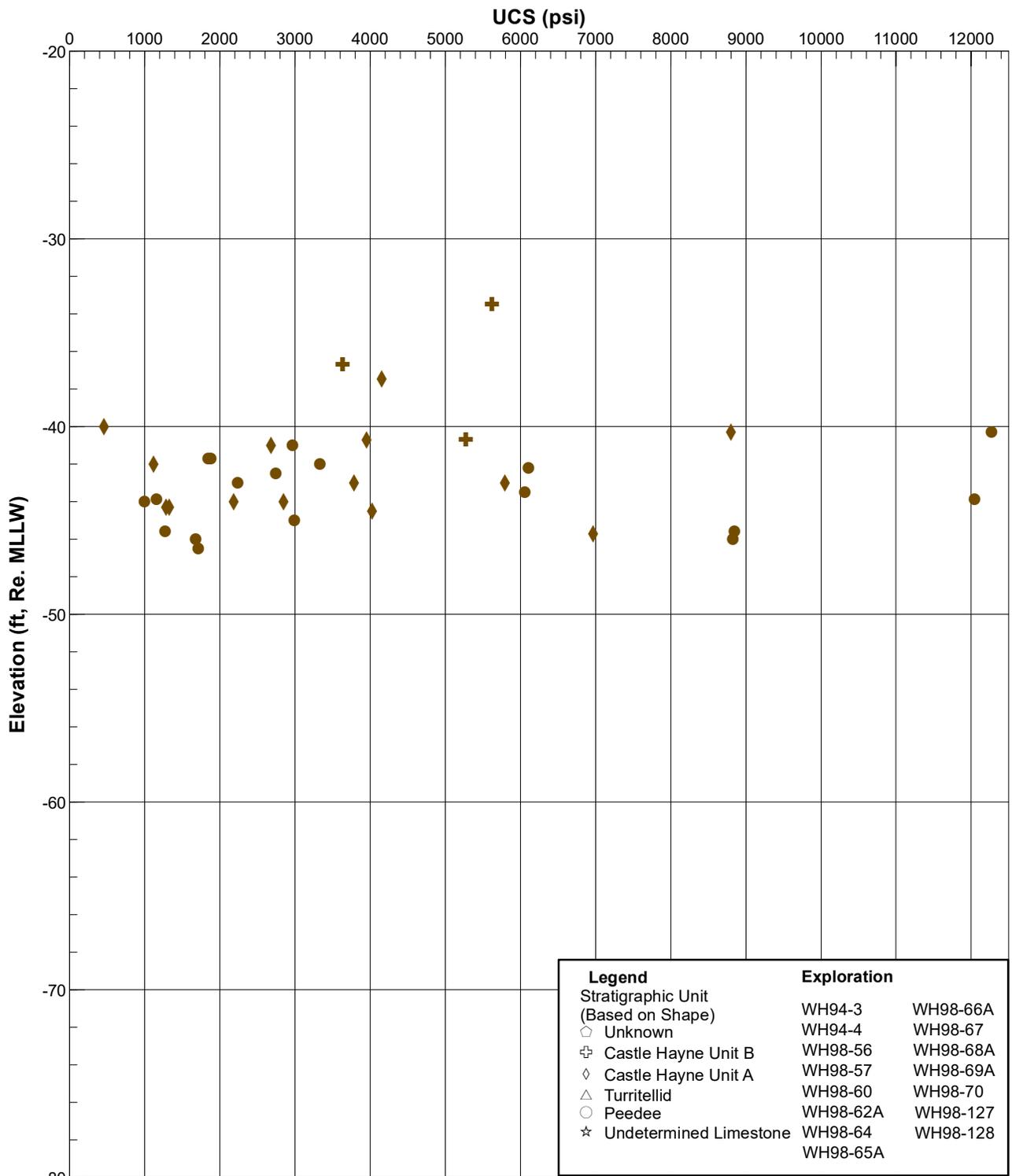


Notes:
 1) Each point represents one discrete laboratory test

UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION

Lower Brunswick
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 6-6



Notes:

1) Each point represents one discrete laboratory test

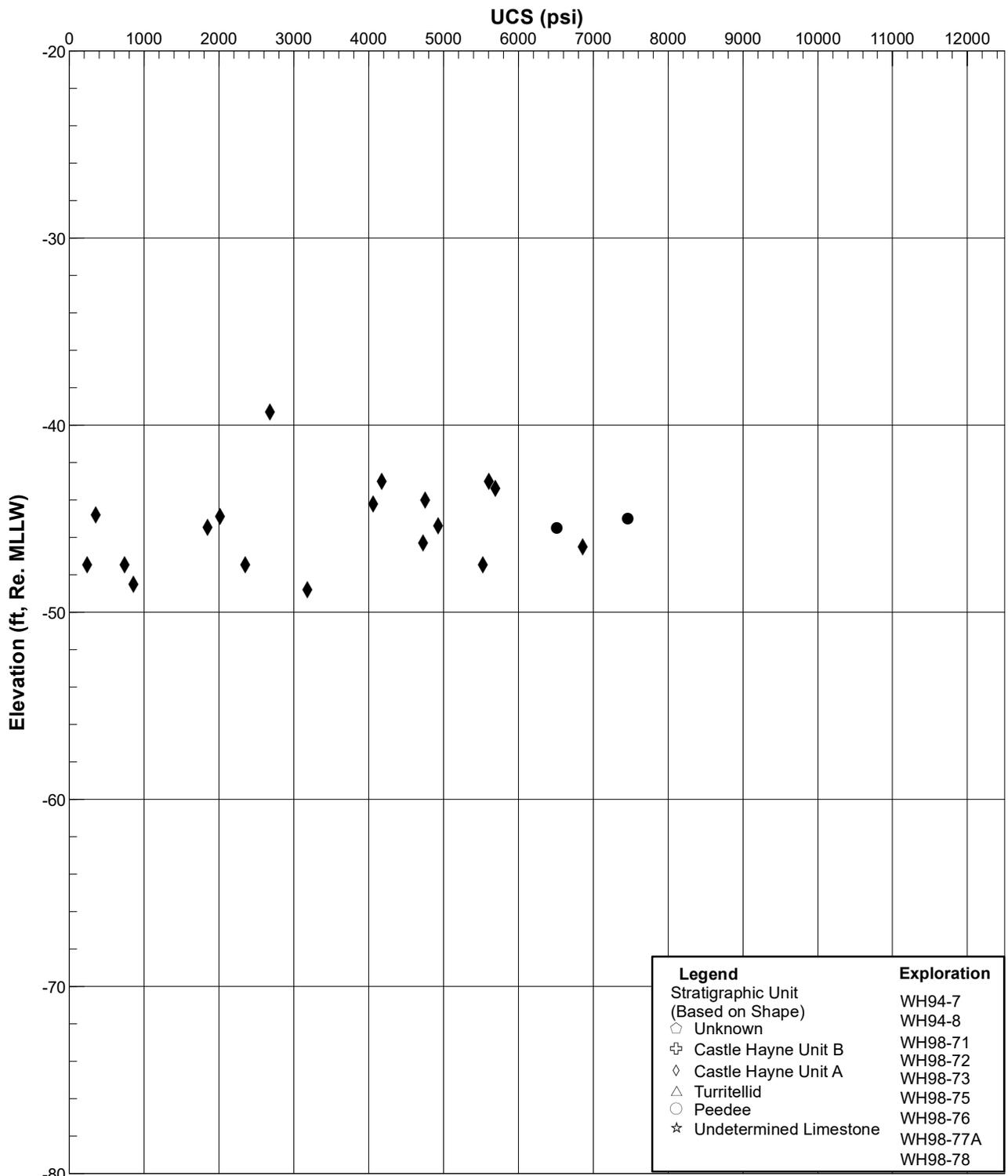
UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION

Upper Big Island

Wilmington Harbor Deepening Survey

Wilmington, North Carolina

FIGURE 6-7



Notes:

1) Each point represents one discrete laboratory test

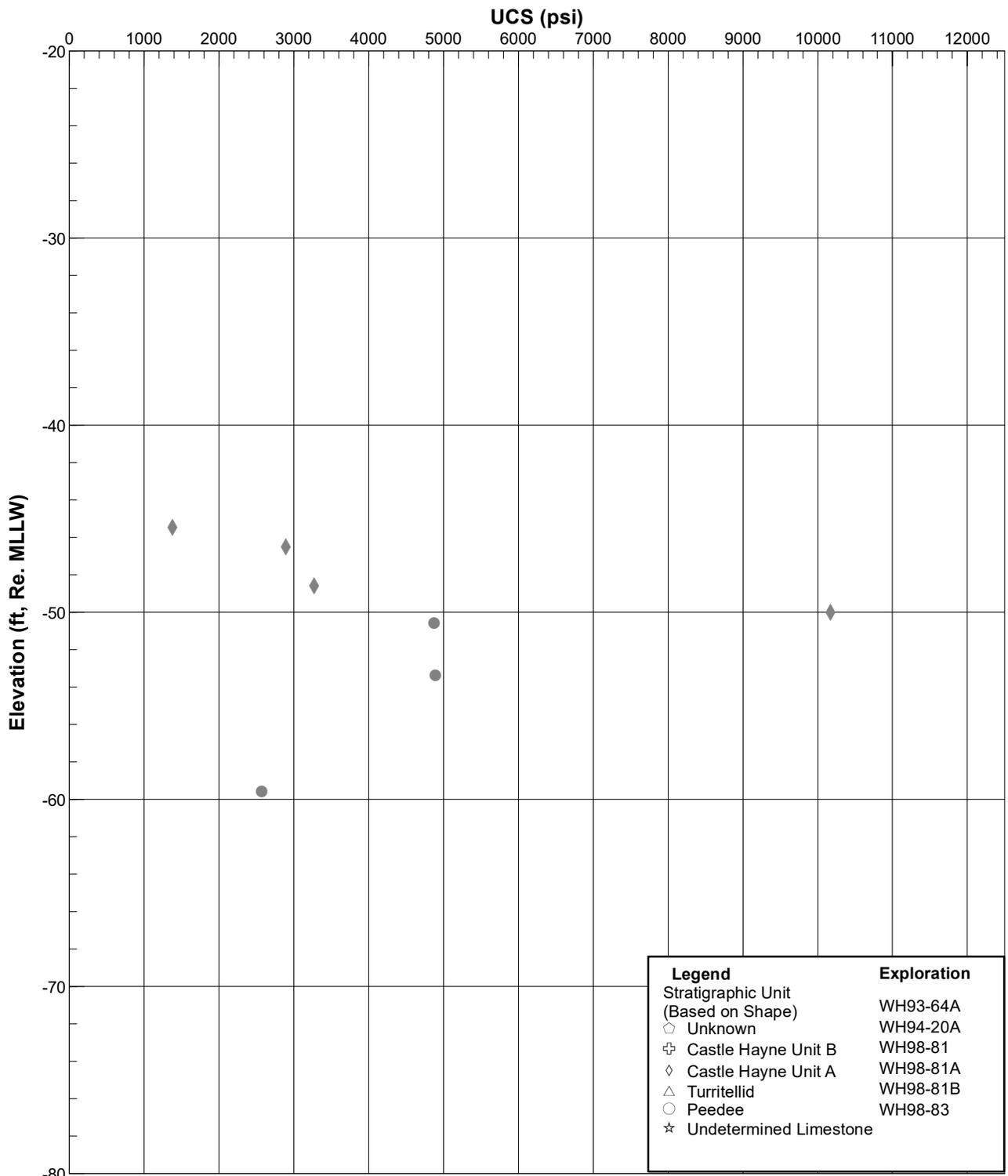
UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION

Lower Big Island

Wilmington Harbor Deepening Survey

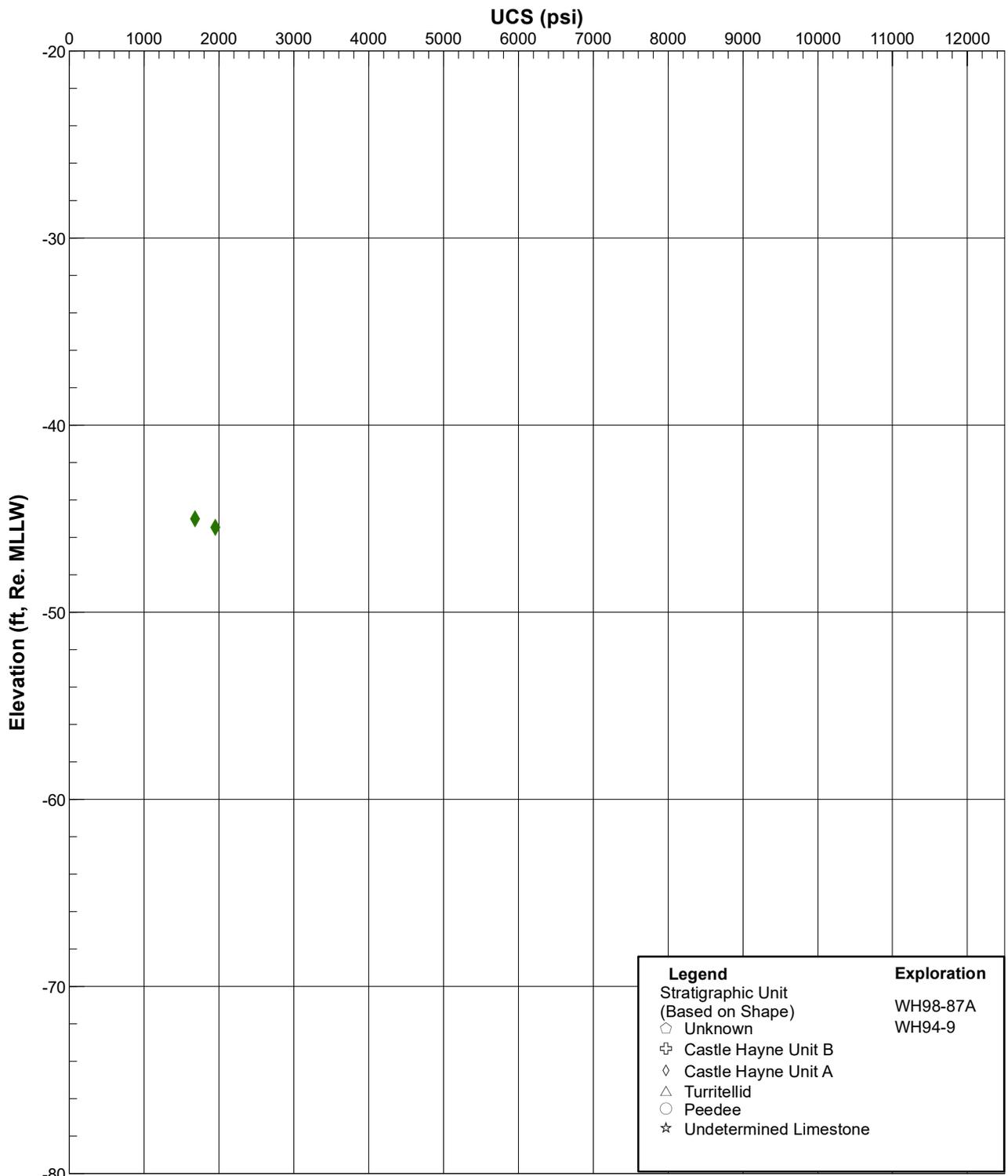
Wilmington, North Carolina

FIGURE 6-8



Notes:
 1) Each point represents one discrete laboratory test

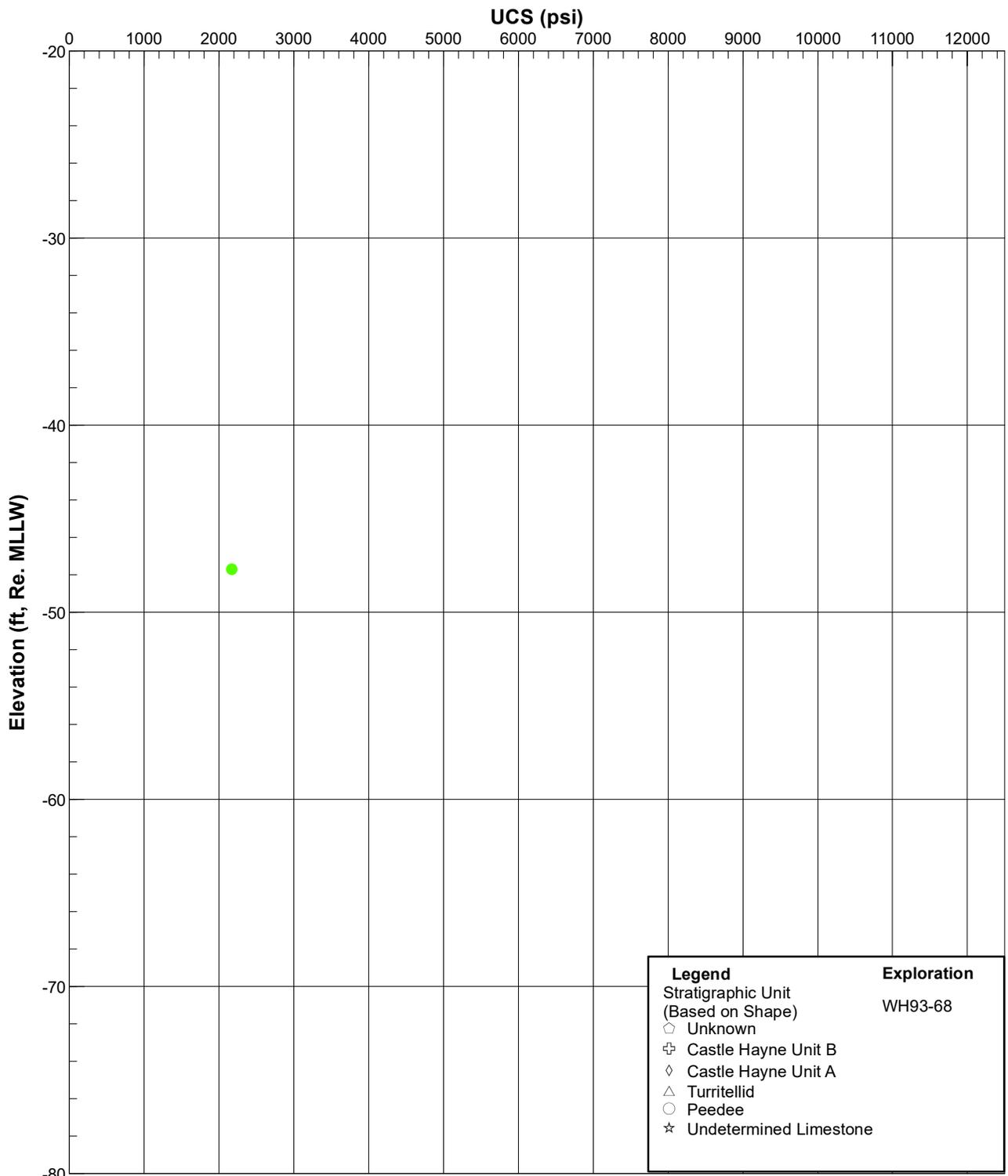
UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
 Keg Island
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



Notes:
 1) Each point represents one discrete laboratory test

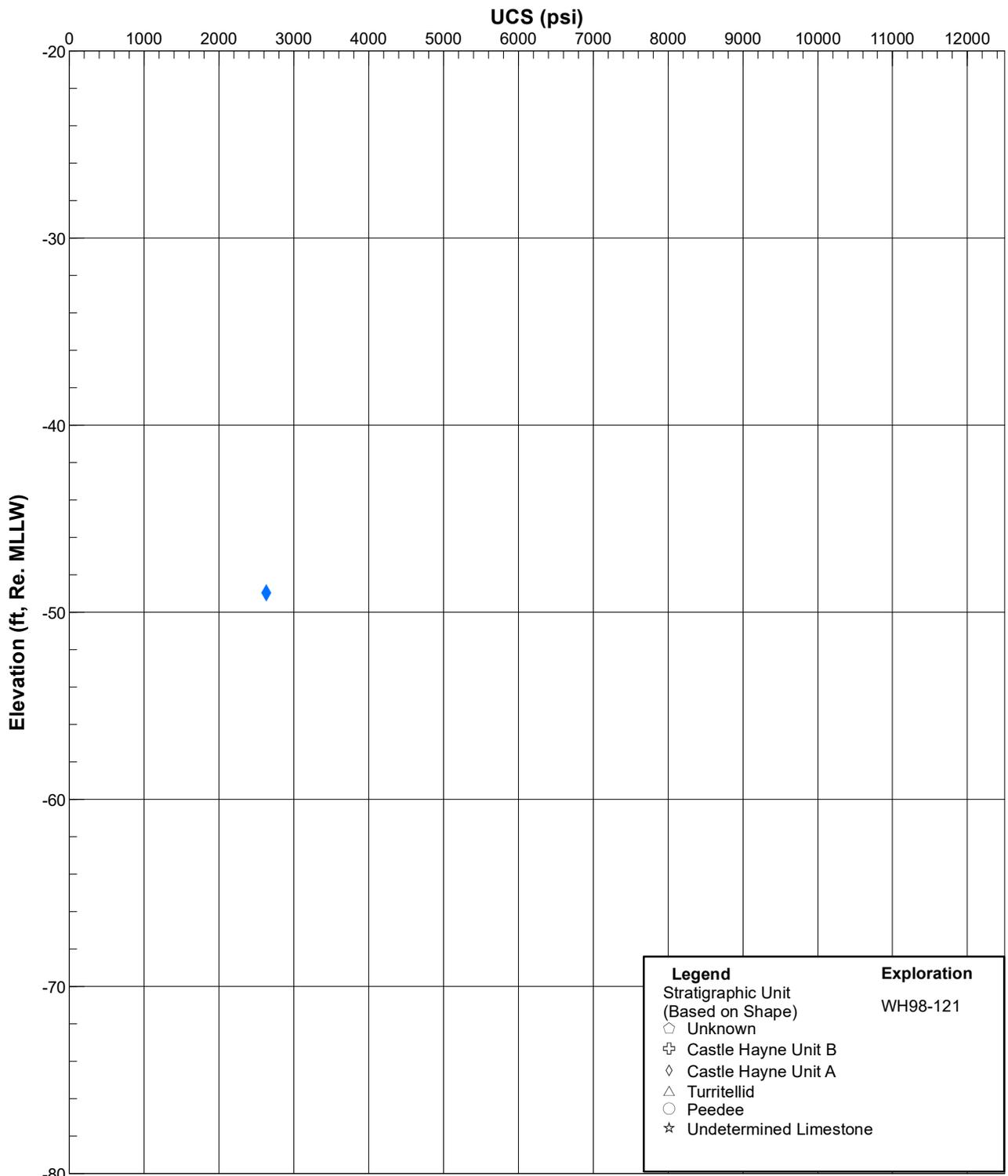
UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
 Upper Lilliput
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 6-10



Notes:
 1) Each point represents one discrete laboratory test

UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
 Lower Lilliput
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



Notes:

- 1) Each point represents one discrete laboratory test

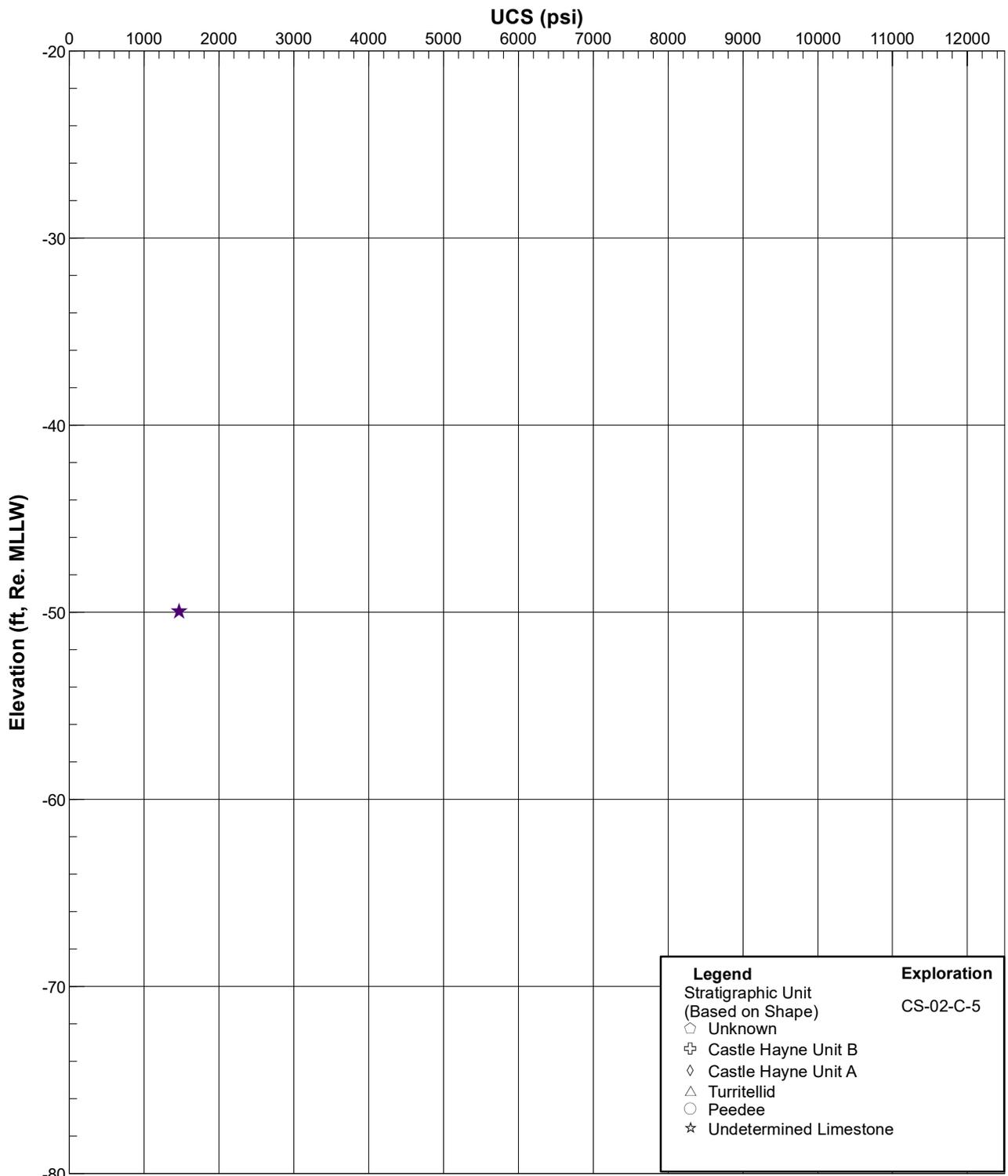
UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION

Snows Marsh

Wilmington Harbor Deepening Survey

Wilmington, North Carolina

FIGURE 6-12



Notes:

1) Each point represents one discrete laboratory test

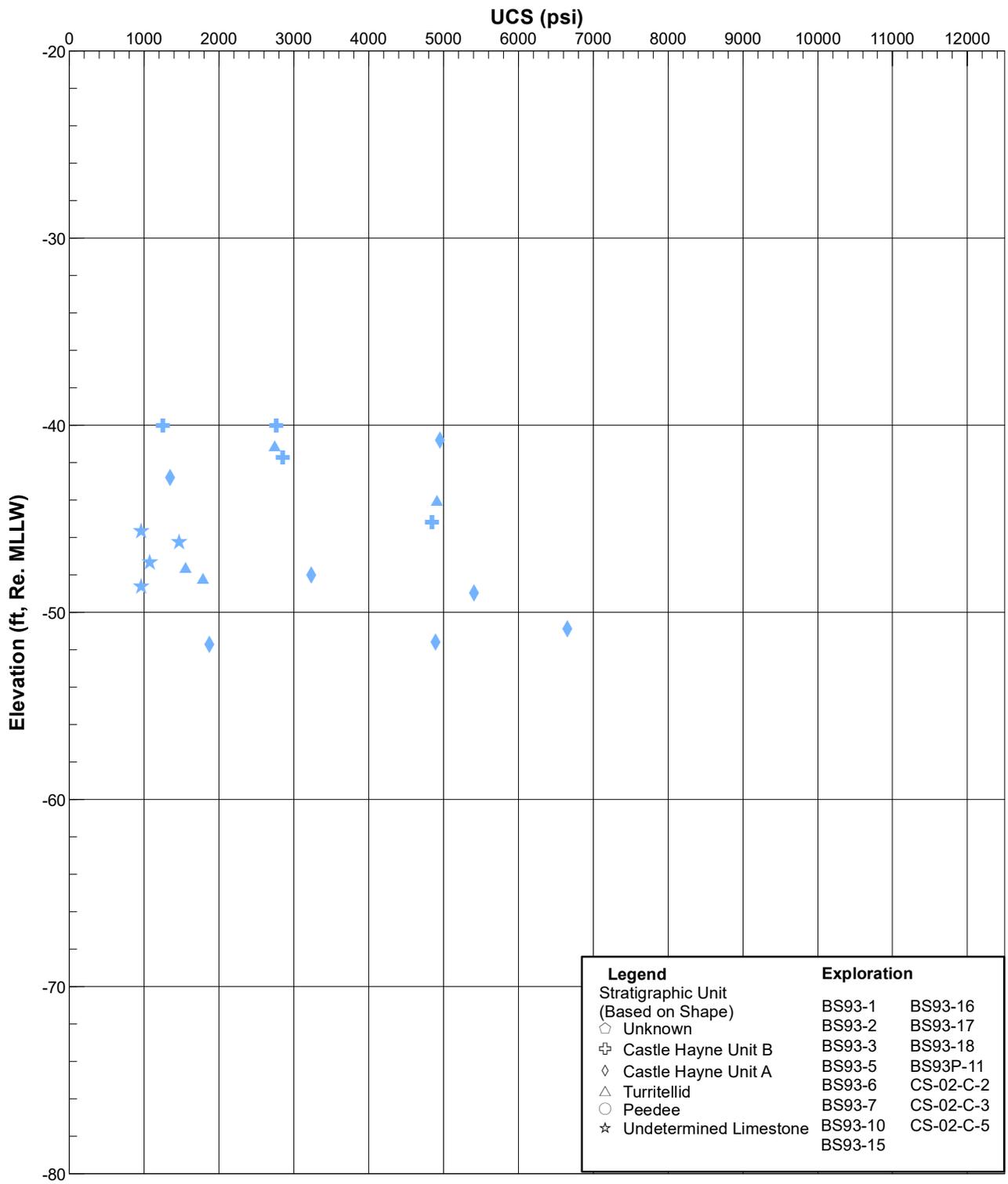
UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION

Lower Swash

Wilmington Harbor Deepening Survey

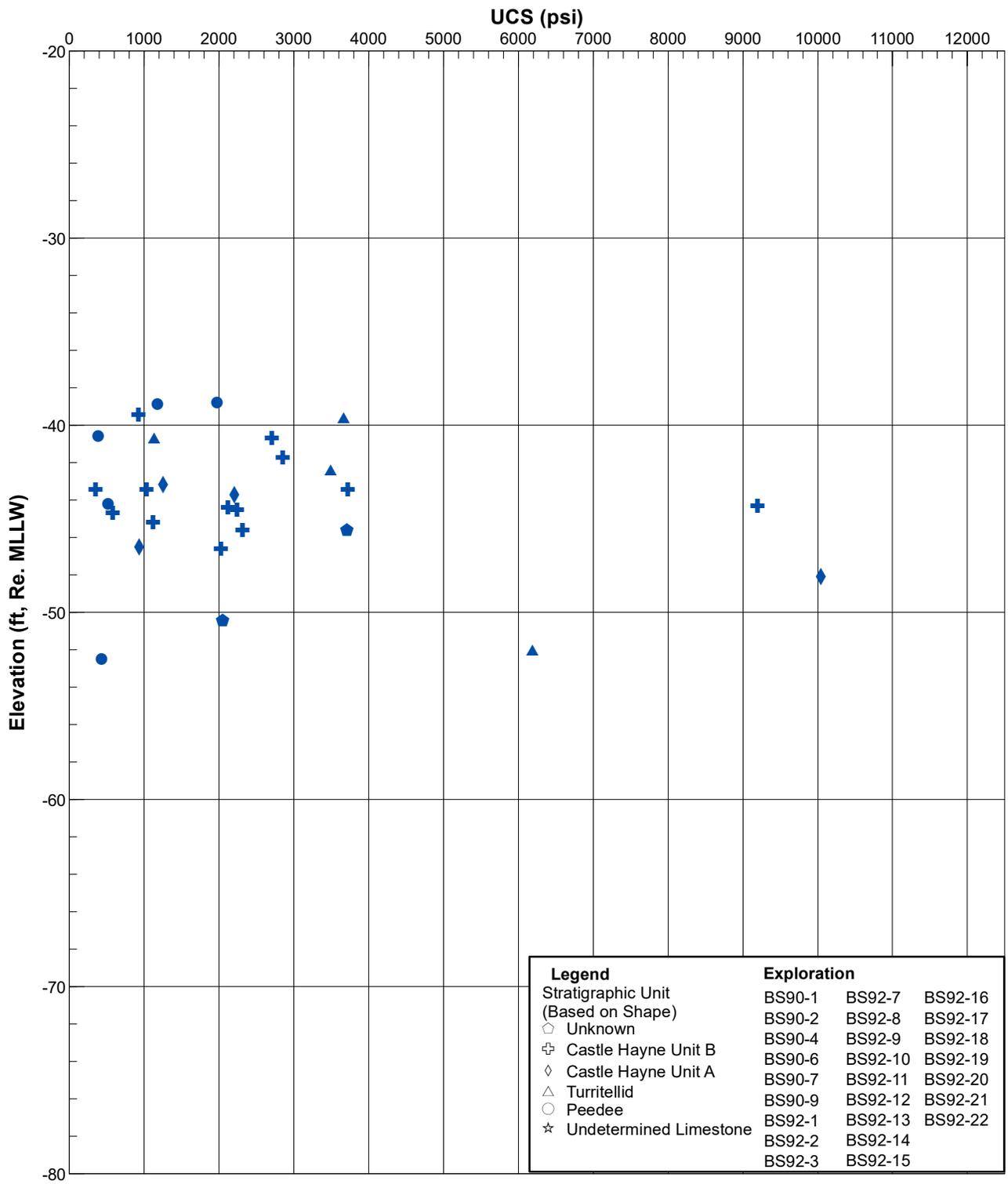
Wilmington, North Carolina

FIGURE 6-13



Notes:
 1) Each point represents one discrete laboratory test

FIGURE 6-14

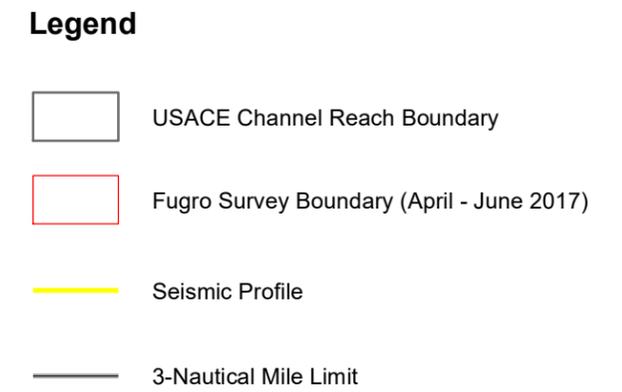
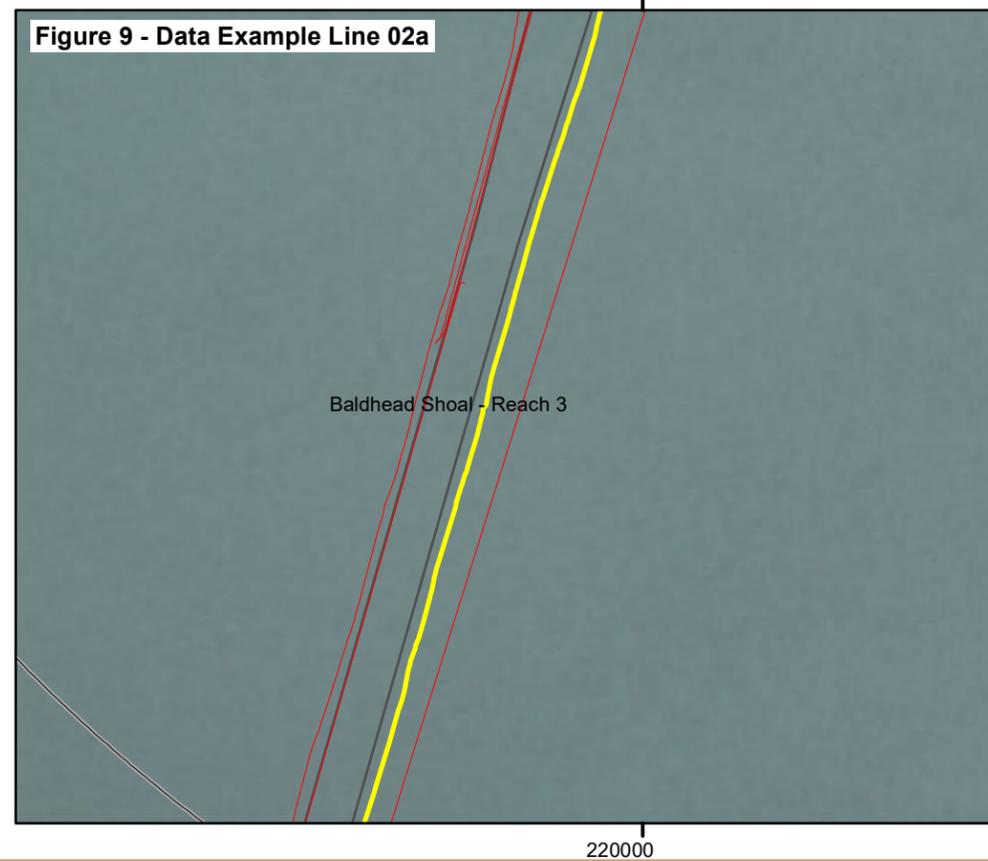
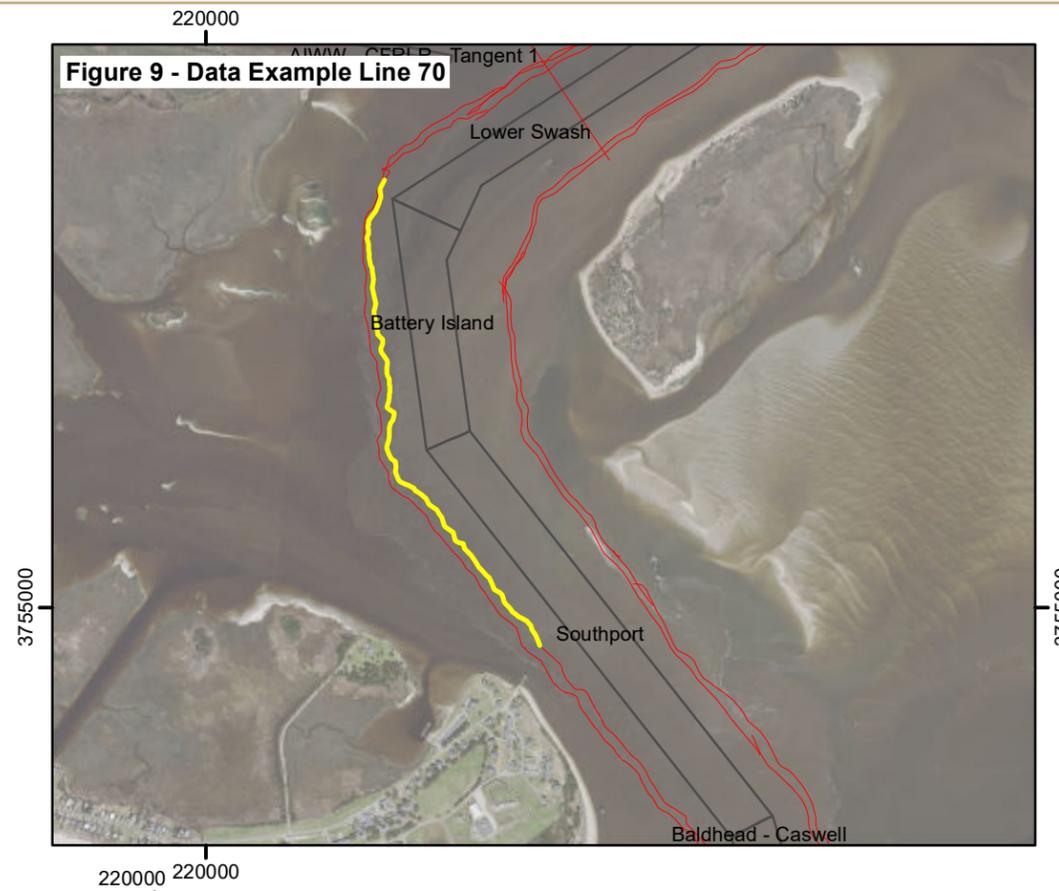
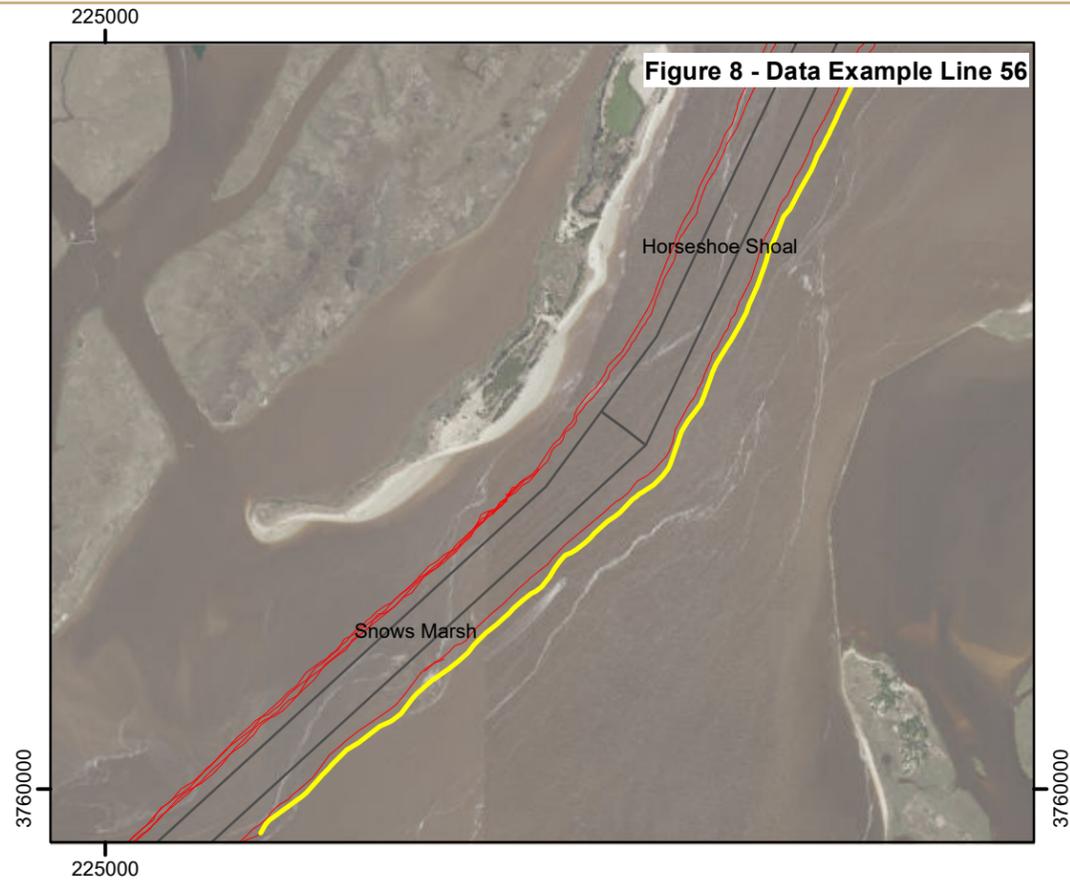


Notes:

- 1) Each point represents one discrete laboratory test

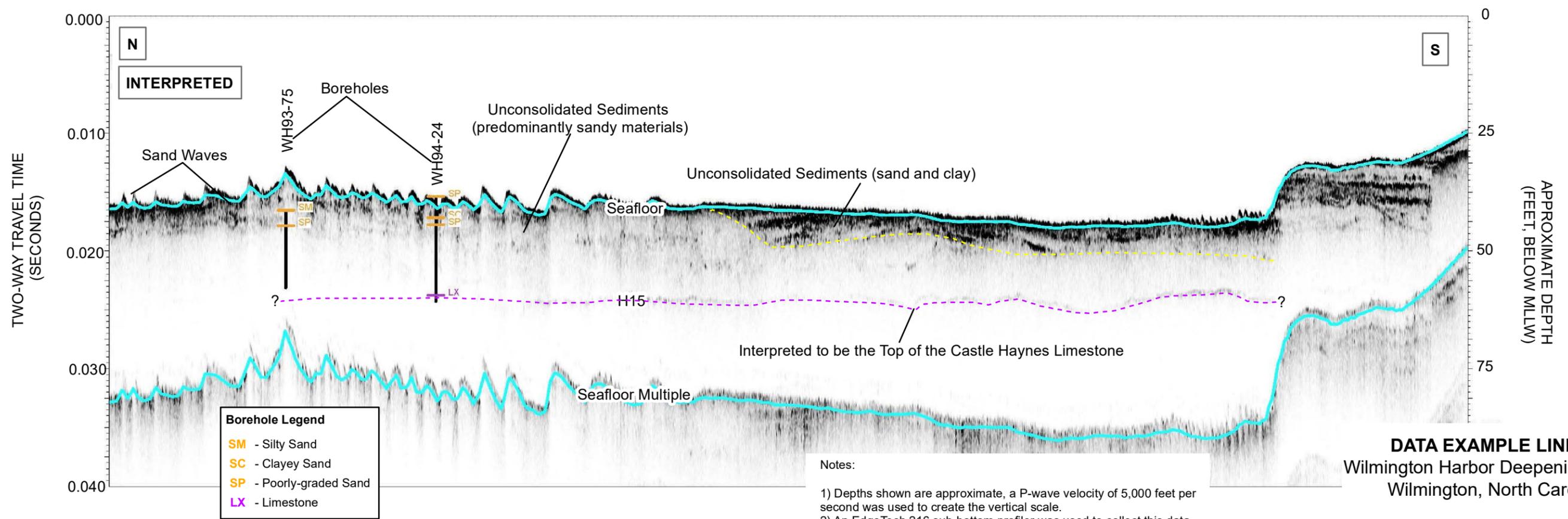
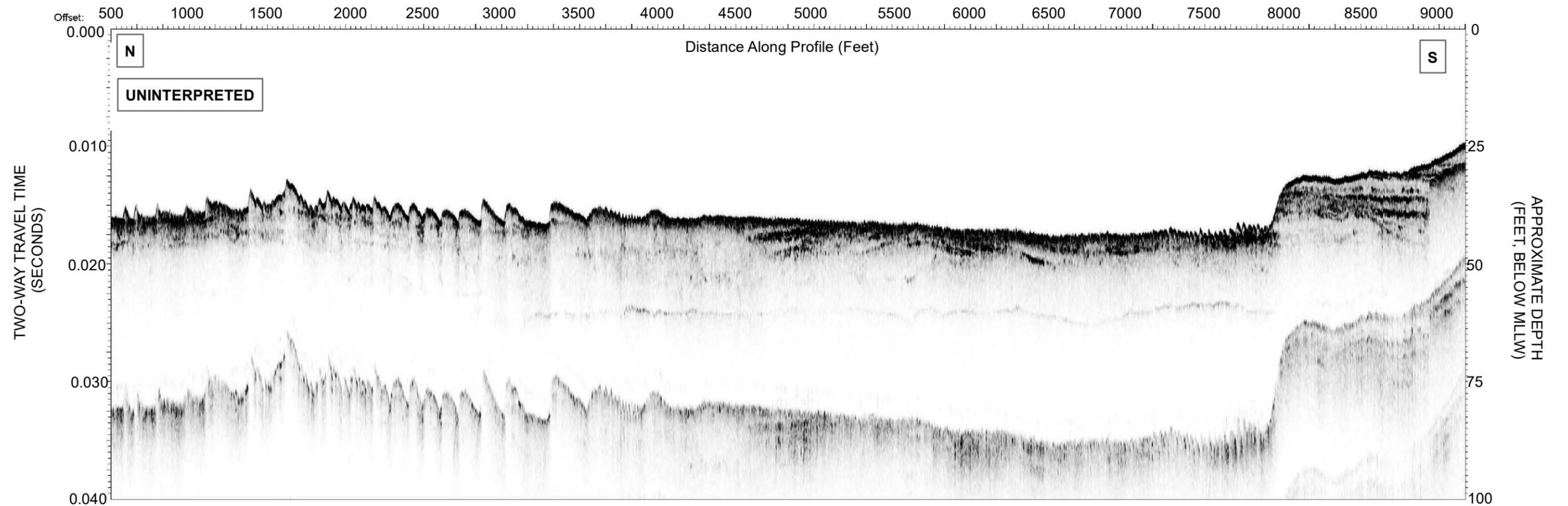
UNCONFINED COMPRESSIVE STRENGTH VERSUS ELEVATION
 Outer Channel Approach
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 6-15



Coordinate Grid: UTM 18N, NAD83, Meters

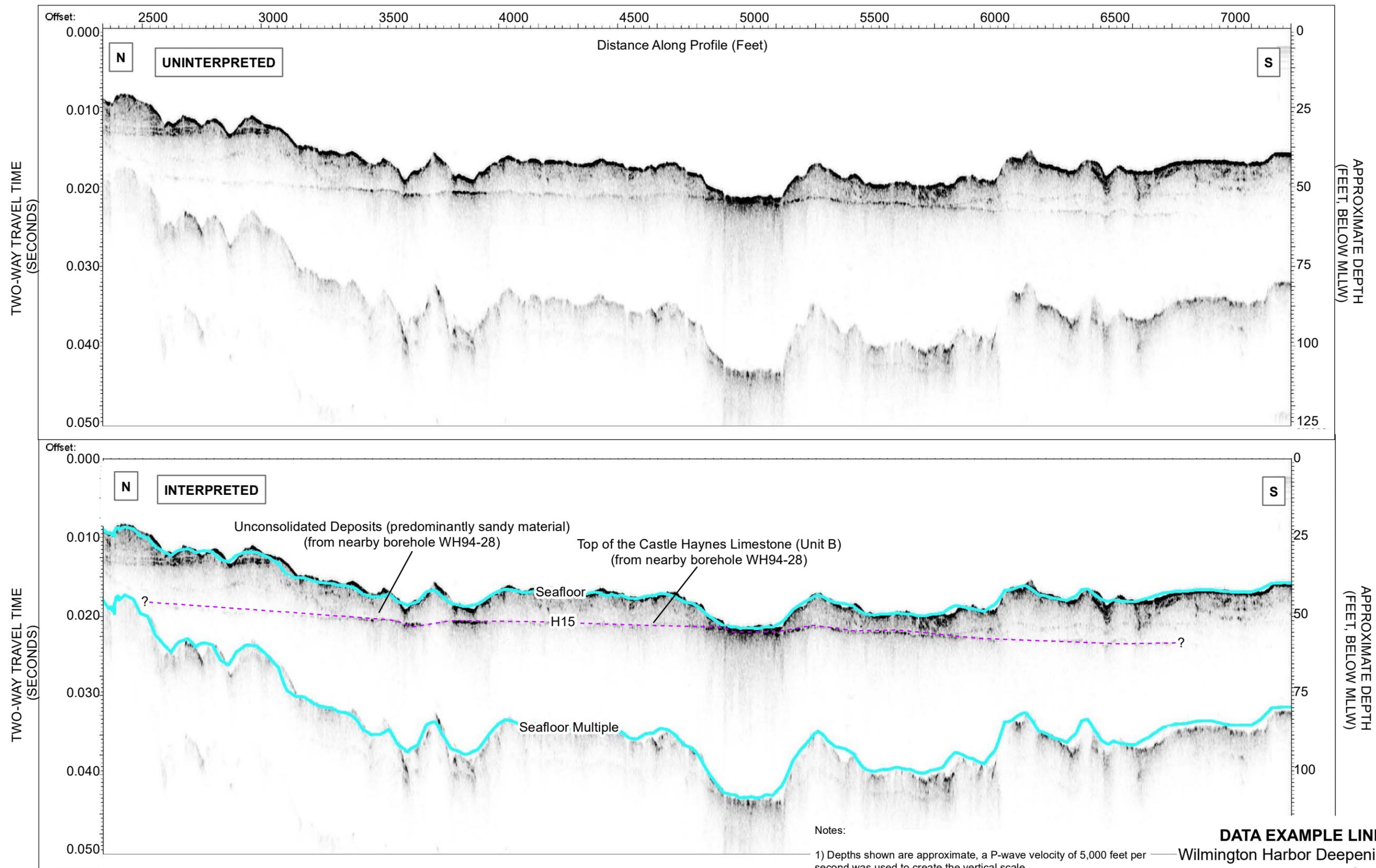
Seismic Profile Locations
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



Notes:

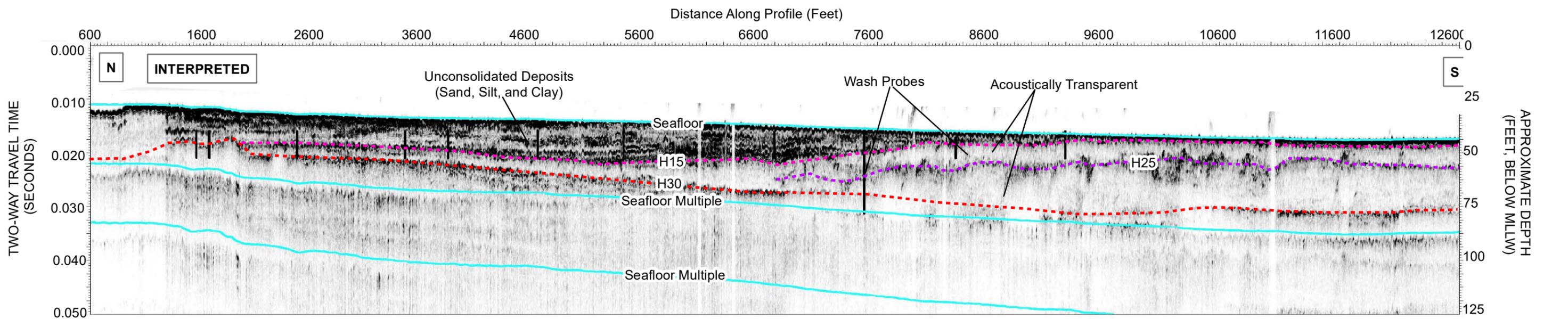
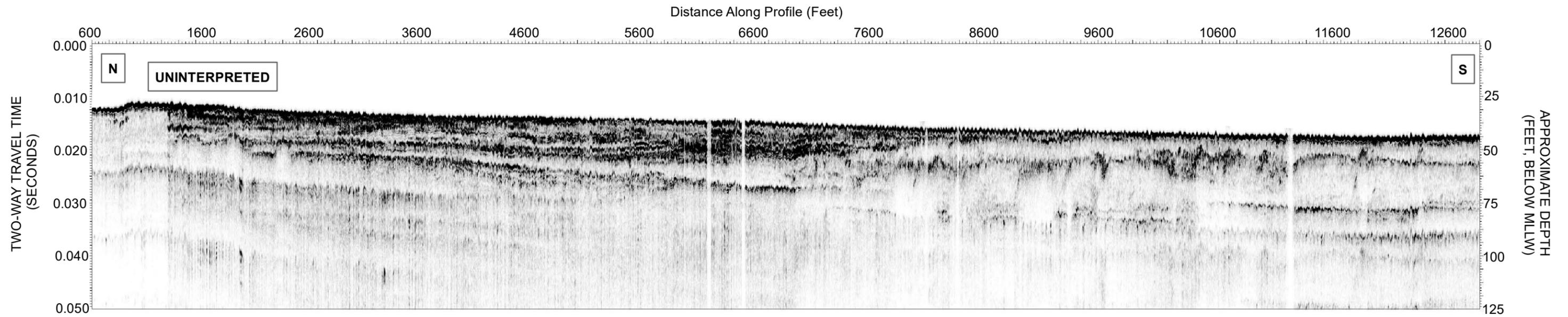
- 1) Depths shown are approximate, a P-wave velocity of 5,000 feet per second was used to create the vertical scale.
- 2) An EdgeTech 216 sub-bottom profiler was used to collect this data.

DATA EXAMPLE LINE 56
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



DATA EXAMPLE LINE 70
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 9



Interpreted Seismic Horizons

H15 - Interpreted to be the Top of the Castle Haynes Limestone

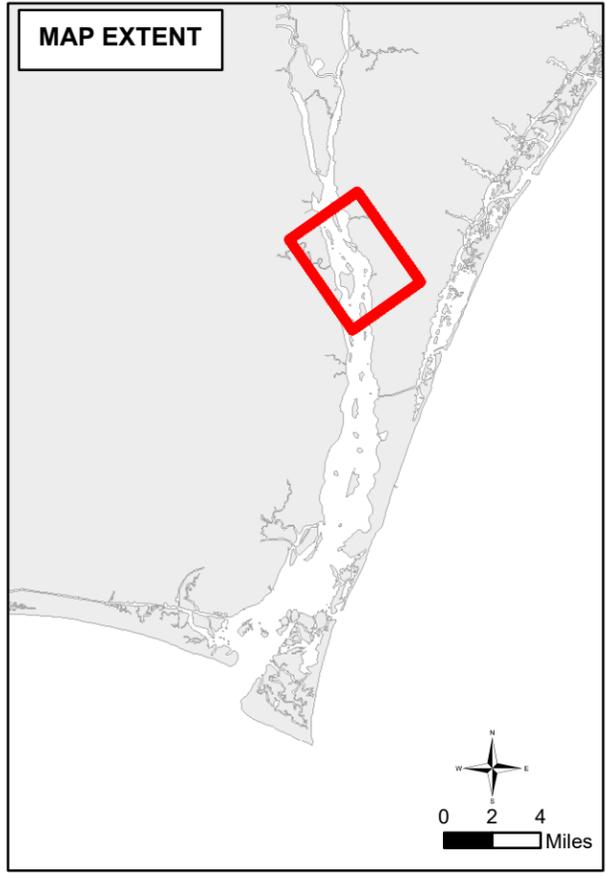
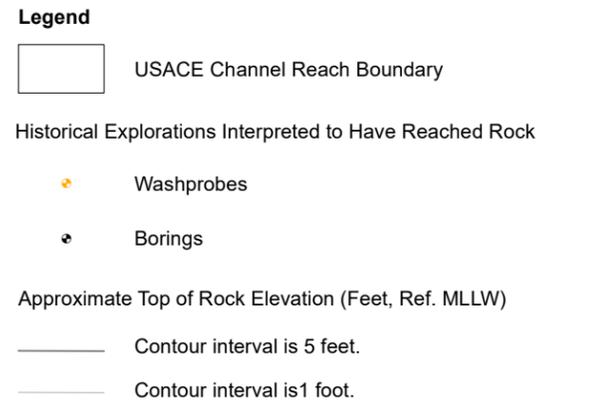
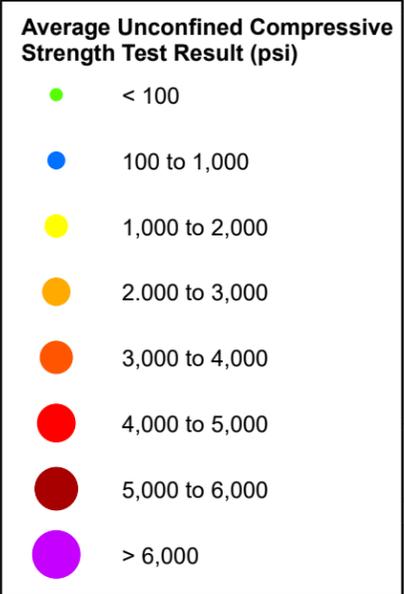
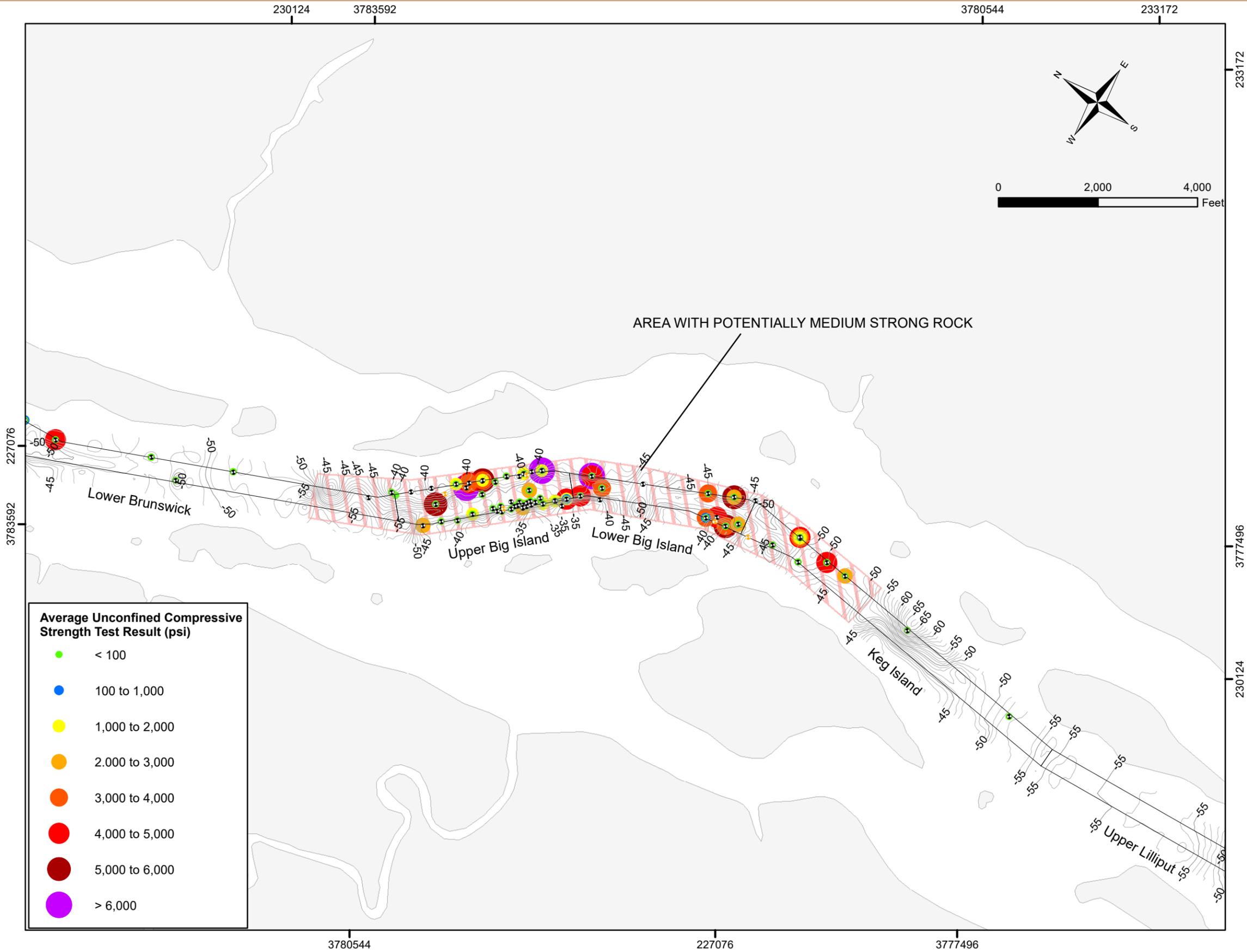
H25 - Interpreted to be an internal reflector within the Castle Haynes Limestone (Possibly a separation between Units A and B)

H30 - Interpreted to be the Top of the Turrillid Limestone

Notes:

- 1) Depths shown are approximate, a P-wave velocity of 5,000 feet per second was used to create the vertical scale.
- 2) An EdgeTech 512 sub-bottom profiler was used to collect this data.

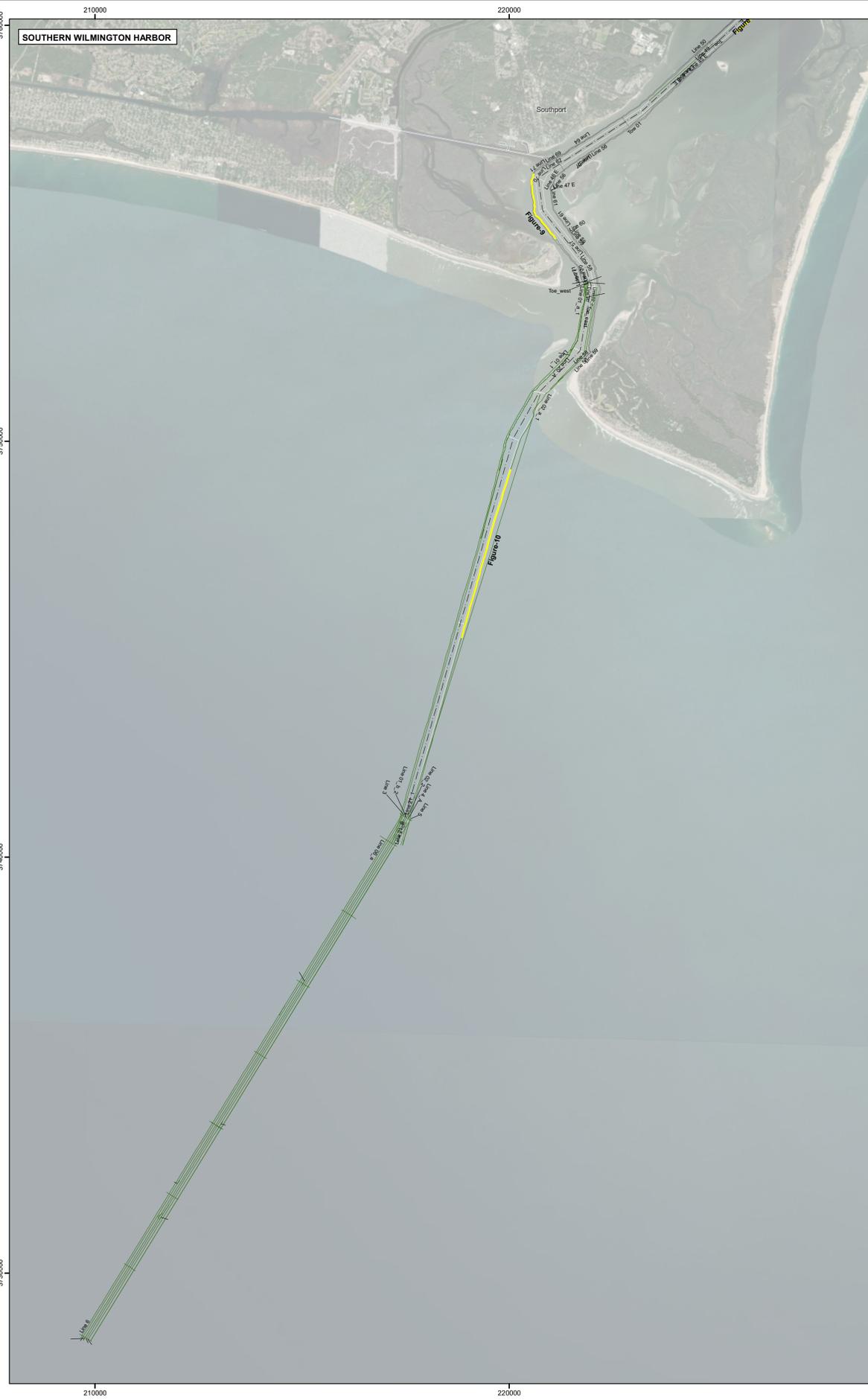
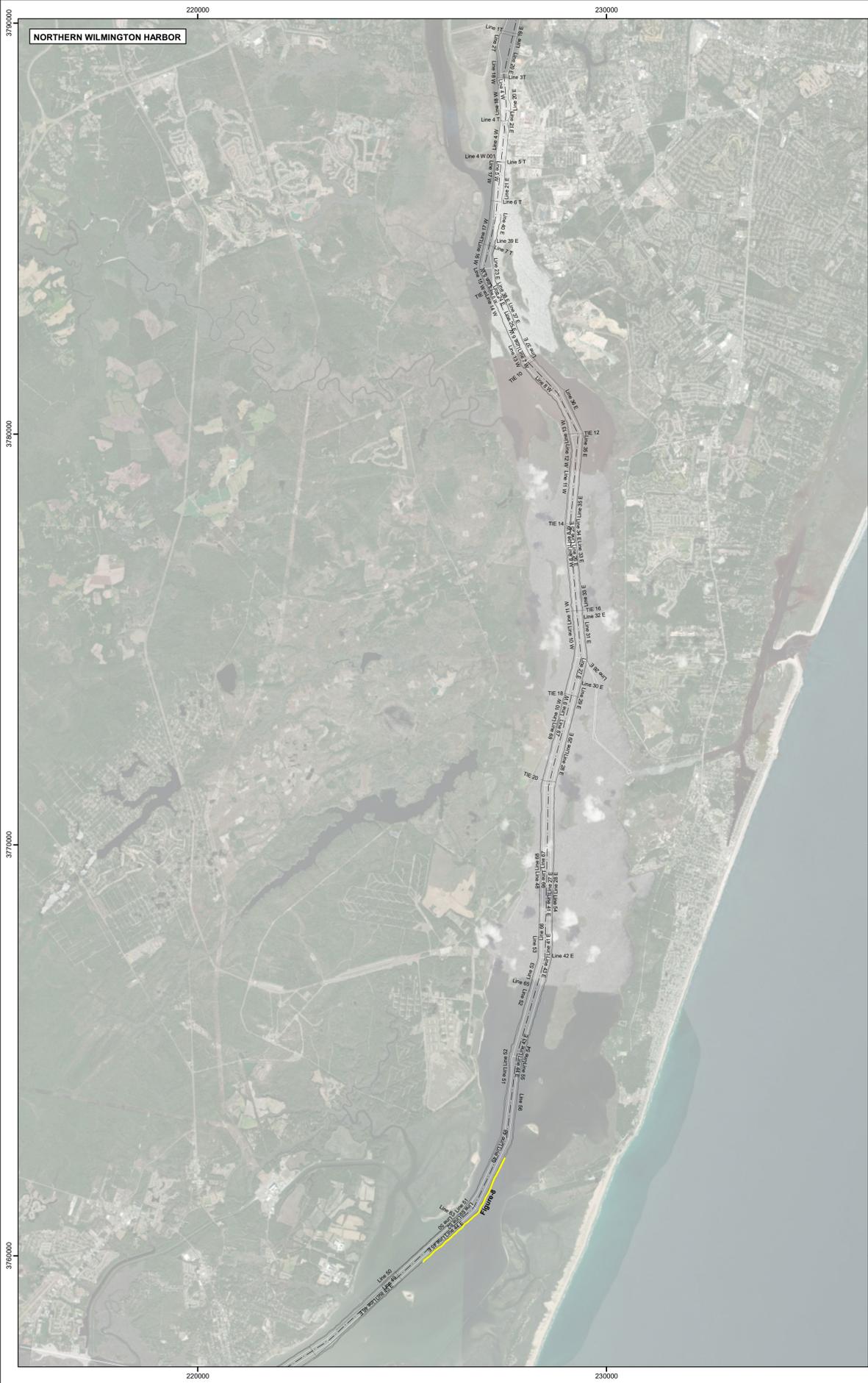
DATA EXAMPLE LINE 02a
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



AREA WITH POTENTIALLY MEDIUM STRONG ROCK
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

FIGURE 11

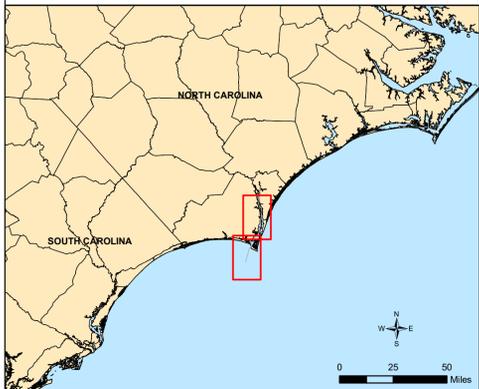
CHARTS



LEGEND

- Inner Harbor Trackline (May 2017)
- Outer Harbor Trackline (July 2017)
- Seismic Data Example Figure Location
- - - Channel Centerline
- ▭ Channel Boundaries

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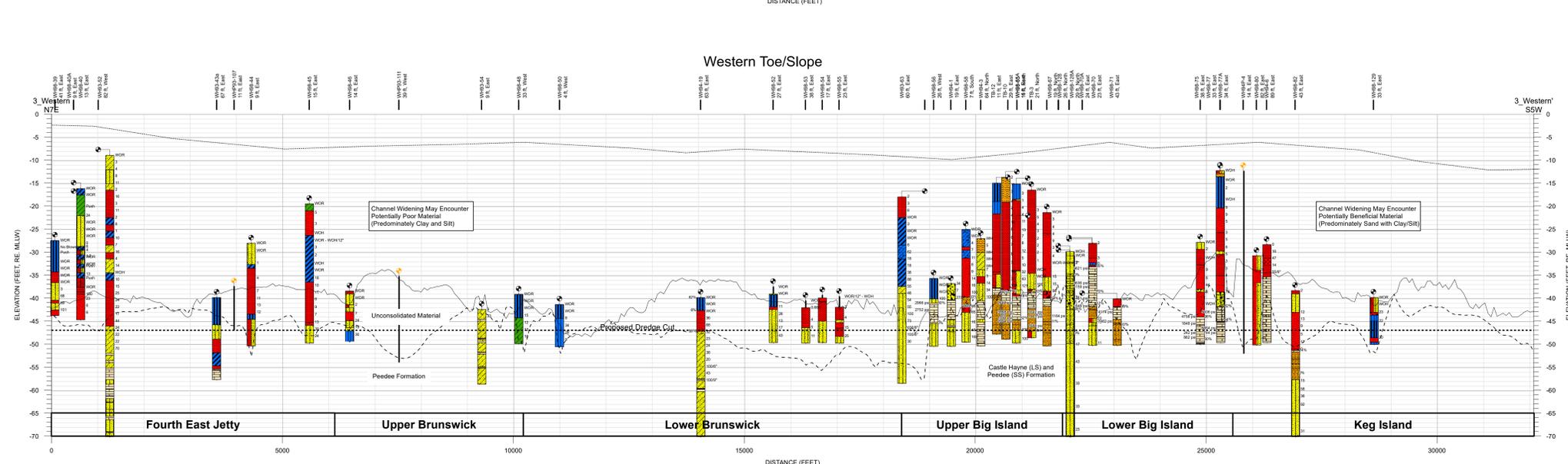
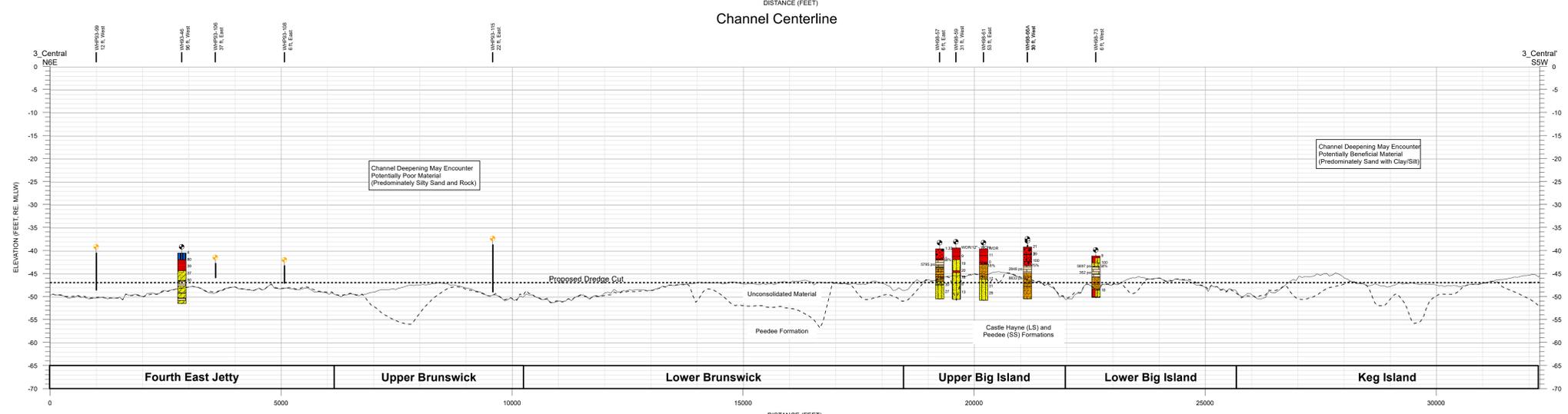
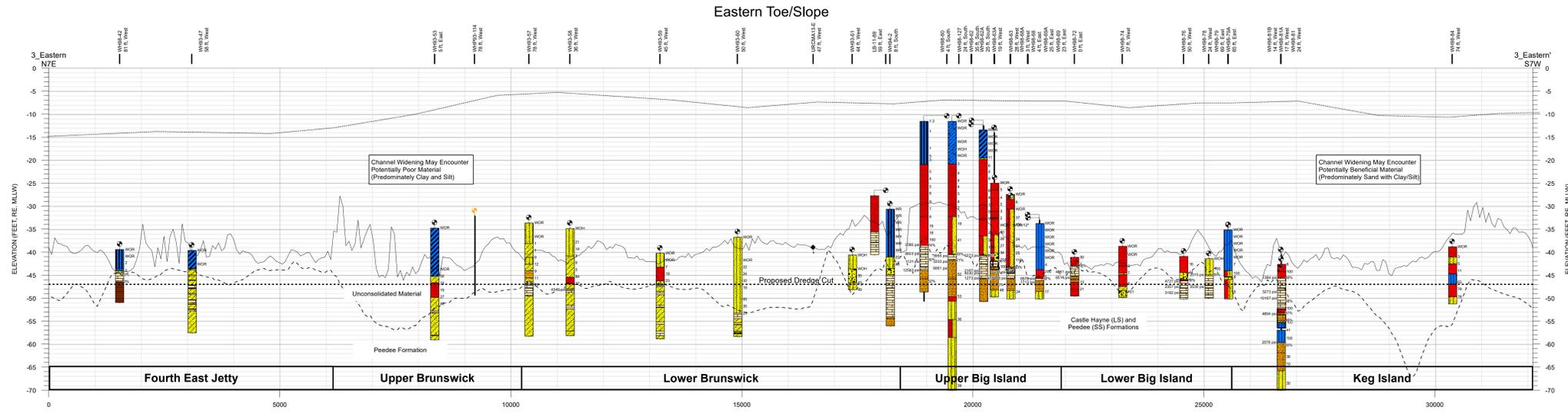
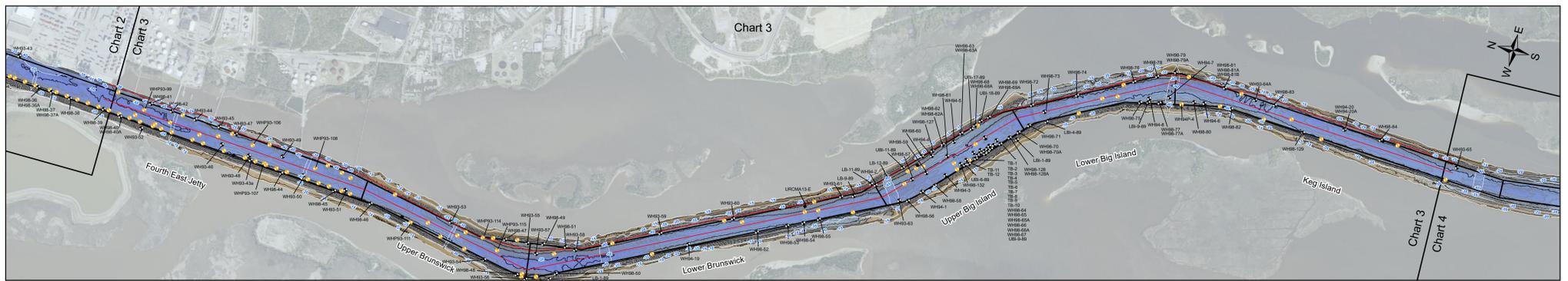


SURVEY VESSEL TRACKLINES
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

HORIZONTAL SCALE

NO.	DATE:	DESCRIPTION:	DRAWN:	CHKD:	APPR:
1	Sept. 2017	Survey Post-Plot			
2	Sept. 2018	Survey Post-Plot			
3					

JOB NUMBER: 02.17041145 SHEET NO. 1



LEGEND

PLAN VIEW
 Bathymetry (Fwd, MLLW)
 Refer to report text for description of data sources.
 High - 5
 Low - 45
 Contour Interval is 5 feet
 Contour Interval is 1 foot
 Fugro Survey Boundary (May 2017)
 Profile Location
 Channel Reach Boundary

CROSS SECTION
 Bathymetry (Fugro May 2017 and USACE)
 Approximate Top of Rock (Interpreted by USACE, QSI, and Chance & Chance)
 Surface was derived from point elevations and contour lines of interpreted top of rock from previous investigators.
 Top of Slope Bathymetry (Interpreted using Fugro May 2017 and USACE hydrographic survey data)

General Lithology Type

High-Plasticity Organic	PEAT
Low-Plasticity Organic	Silty Fat CLAY
Fat CLAY	Lean CLAY
Elastic Silt	Silt
Poorly-Graded SAND	Poorly-Graded SAND with Silt
Clayey SAND	Poorly-Graded SAND with Clay
Well-Graded SAND	Gravelly Poorly-Graded SAND
Silt SAND	Well-Graded SAND with Silt
Poorly-Graded GRAVEL	Well-Graded GRAVEL with Silt
Silty GRAVEL	Well-Graded GRAVEL with Silt
Sandy GRAVEL	SANDY GRAVEL
Limestone	Sandstone
Mudstone	

Boring Symbology

Finest Content
 Standard Penetration Test to Value
 6500' 151'
 ROD
 Unconfined Compressive Strength

10' R
 1000' R
 Vertical Exaggeration is 100x

Notes:

1) Bathymetry conducted by USACE is a composite of seabeam surveys conducted from 2014 to 2017.
 2) Soil and rock classifications and descriptions were adopted as they were presented on the exploration logs in the report as received. We have not verified the classifications or modified the classifications to be consistent with published systems (e.g. USCS) based on laboratory test results.
 3) Locations that were mapped are estimates, and were calculated using a two-way travel time (TWT) of 5,000 feet per second.

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GEODETIC INFORMATION

SPHEROID: GRS 1980
 SEMI-MAJOR AXIS: 6378137.000
 SEMI-MINOR AXIS: 6356752.314
 INVERSE FLATTENING: 298.25722101
 ECCENTRICITY: 0.006812139
 PROJECTION: UNIVERSAL TRANSVERSE MERCATOR
 ZONE: 18 NORTH
 LOCATION OF ORIGIN: 81
 FALSE EASTING: 500,000
 FALSE NORTHING: 0.0

SUBSURFACE CROSS SECTIONS

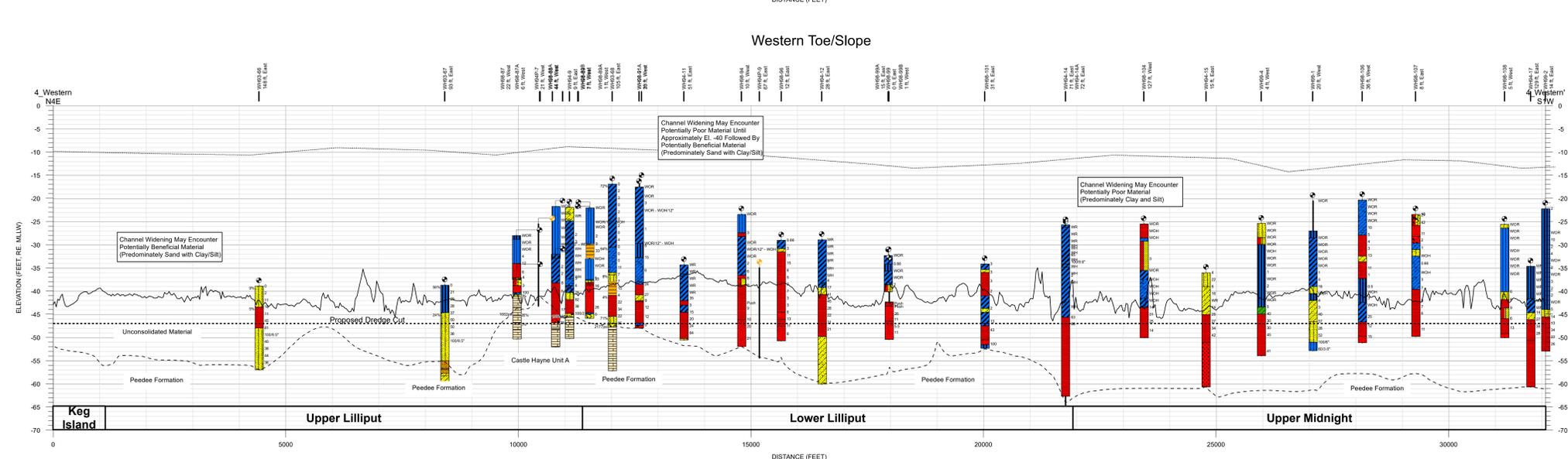
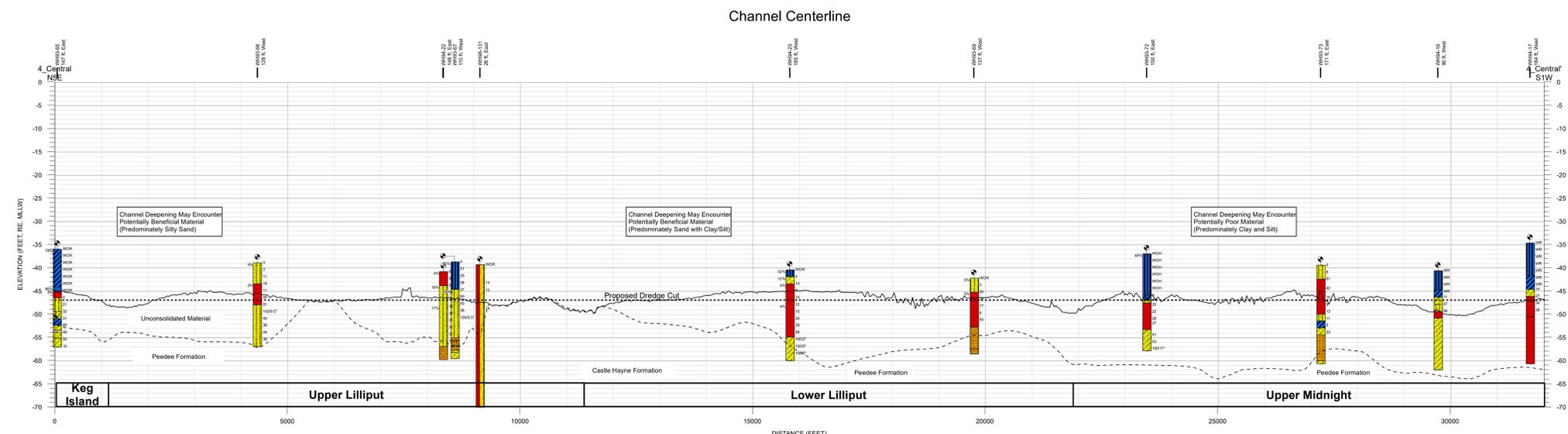
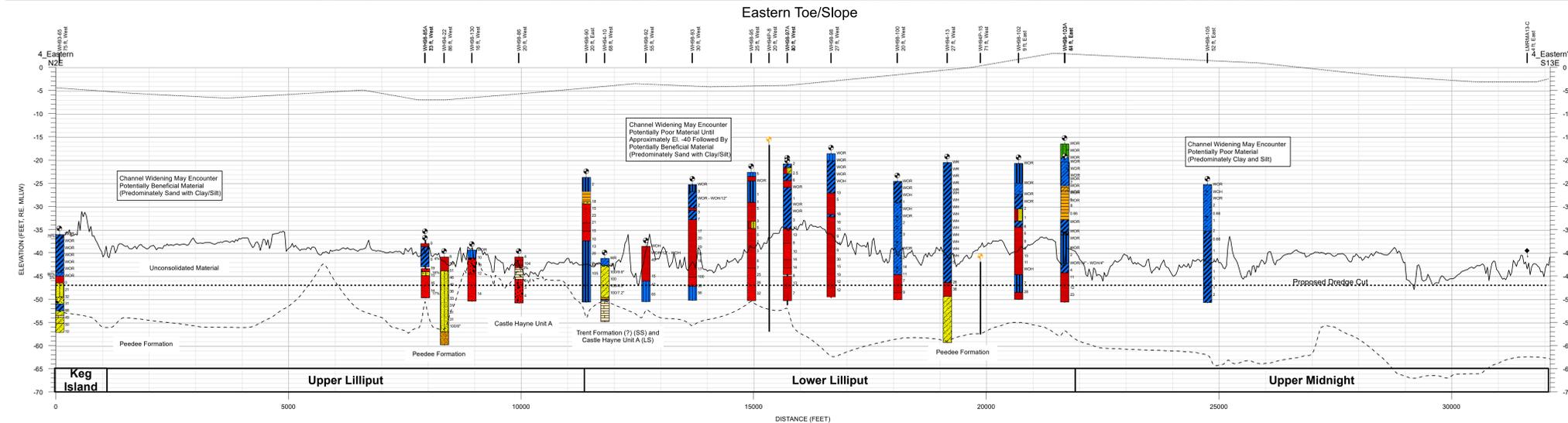
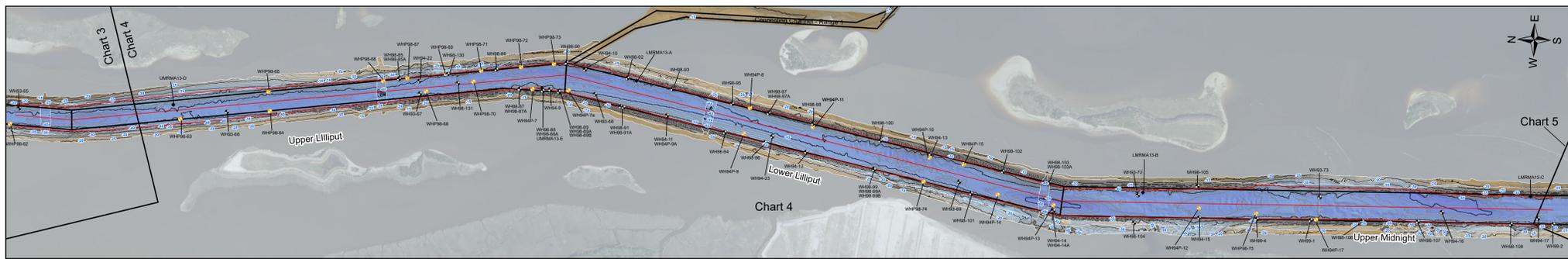
Wilmington Harbor Deepening Survey
 Wilmington, North Carolina

0 0.125 0.25 0.5 Miles
 0 500 1,000 2,000 Feet

NO.	DATE	DESCRIPTION	DRAWN	CHKD	APPR
1					
2					
3					

JOB NUMBER: CHART NO.:

N:\Projects\2017\2017_04_Wilmington_Harbor_Deepening_Survey\CHART_3\CHART_3.dwg, 10/10/2017, 10:48:00 AM



LEGEND

PLAN VIEW

Bathymetry (Feet, MLLW)
Refer to report text for description of data sources.

- High - 5
- Low - 45
- Contour Interval is 5 feet
- Contour Interval is 1 foot
- Profile Location
- Channel Reach Boundary

Exploration

- Explosion
- Under
- Borehole
- Washprobe
- Vibracore

CROSS SECTION

- Bathymetry (Fugro May 2017 and USACE)
- Approximate Top of Rock (Interpreted by USACE, QSI, and Chance & Chance)
- Surface was derived from point elevations and contour lines of interpreted top of rock from previous investigations.
- Top of Slope Bathymetry (Interpreted using Fugro May 2017 and USACE hydrographic survey data)

General Lithology Type

High-Plasticity Organic	PEAT
Low-Plasticity Organic	Silty Fat CLAY
Fat CLAY	Lean CLAY
Elastic Silt	Silt
Poorly-Graded SAND	Poorly-Graded SAND with Silt
Clayey SAND	Poorly-Graded SAND with Clay
Well-Graded SAND	Grovelly Poorly-Graded SAND
Silty SAND	Well-Graded SAND with Silt
Poorly-Graded GRAVEL	Well-Graded GRAVEL with Silt
Silty GRAVEL	Sandy GRAVEL
Clayey GRAVEL	Sandstone
Limestone	
Mudstone	

Boring Symbology

Notes:

- 1) Bathymetry conducted by USACE is a composite of singlebeam surveys conducted from 2014 to 2017.
- 2) Soil and rock classifications and descriptions were adopted as they were presented on the exploration logs in the reports as received. We have not verified the classifications or modified the classifications to be consistent with published systems (e.g. USCS) based on laboratory test results.
- 3) Horizontal distances that were mapped are estimates, and were calculated using a two-way travel time (TWT) of 5,000 feet per second.

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GEODETIC INFORMATION

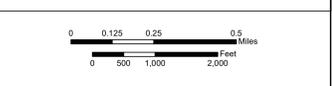
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SEMI-MINOR AXIS	6,356,752.114
INVERSE FLATTENING	0.000000000
PROJECTION	UNIVERSAL TRANSVERSE MERCATOR
ZONE	18 NORTH
UNIQUE ORIGIN	833000.000
FALSE EASTING	500,000
FALSE NORTHING	0.0



SUBSURFACE CROSS SECTIONS

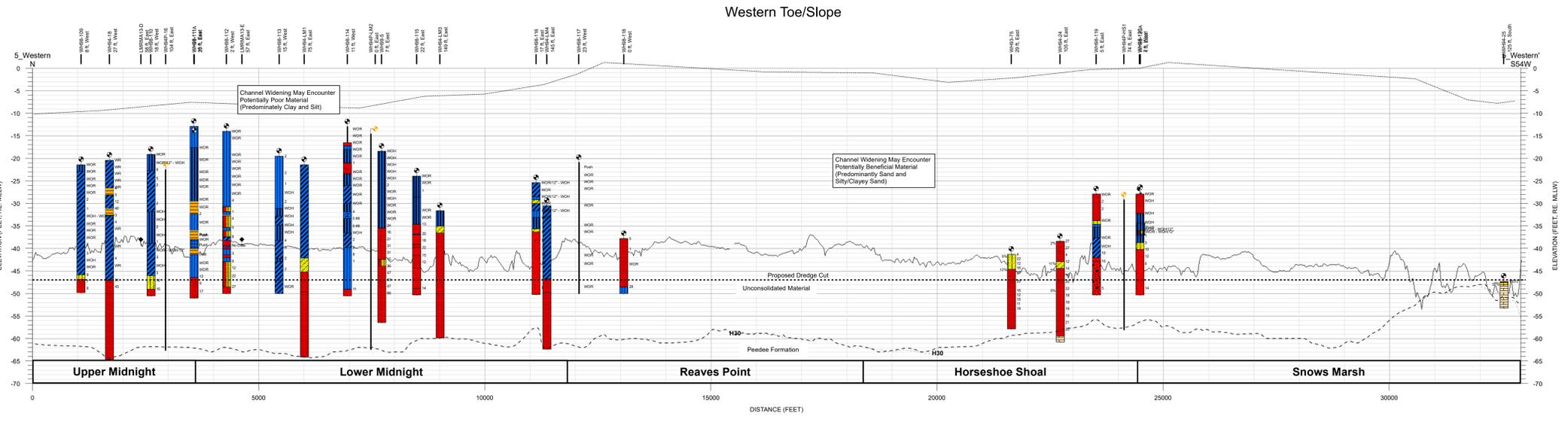
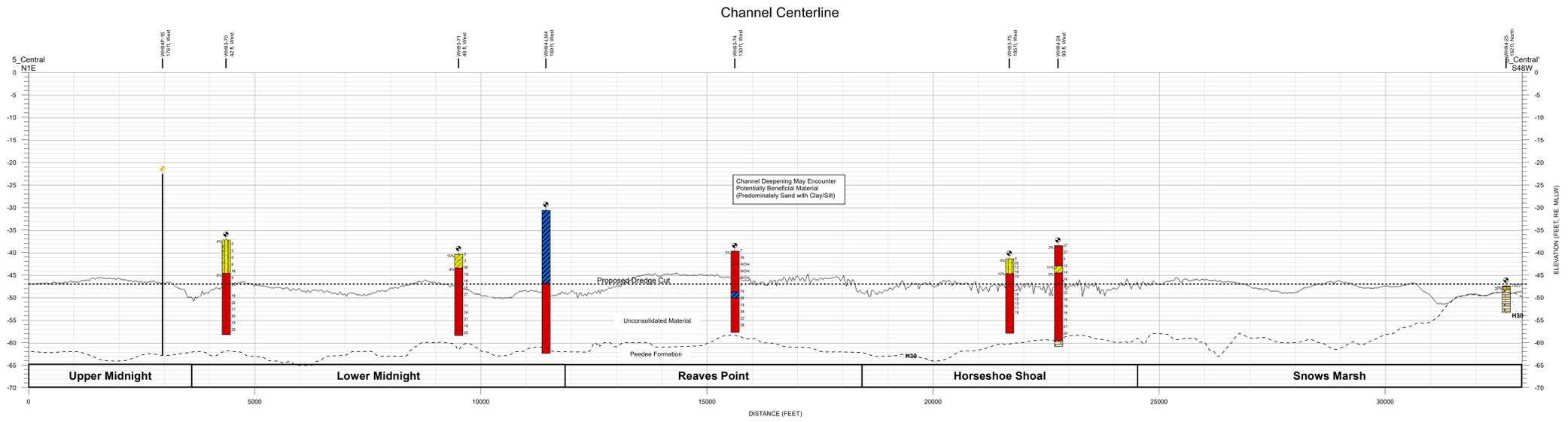
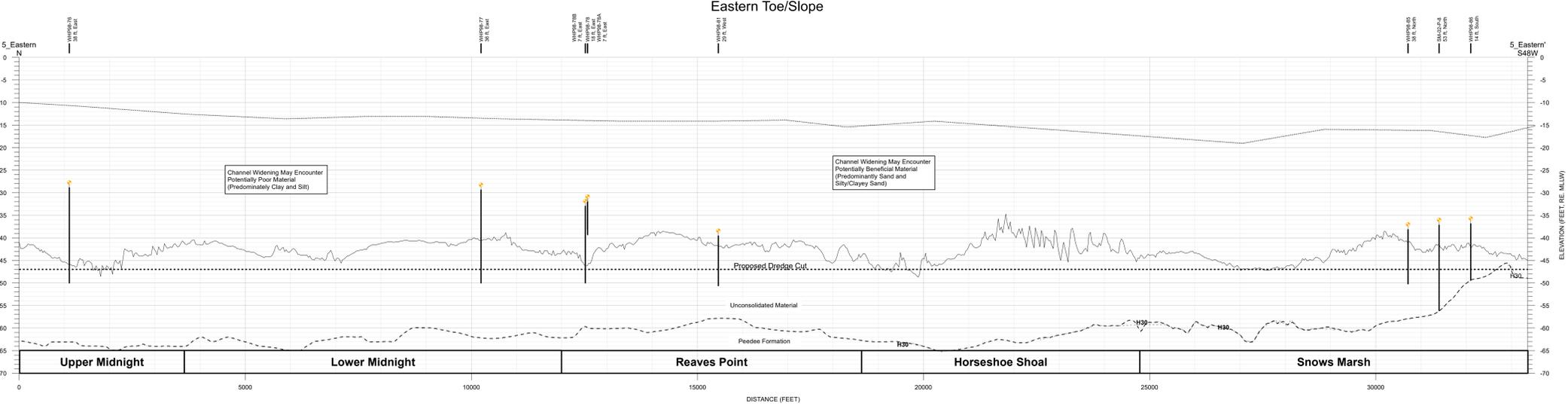
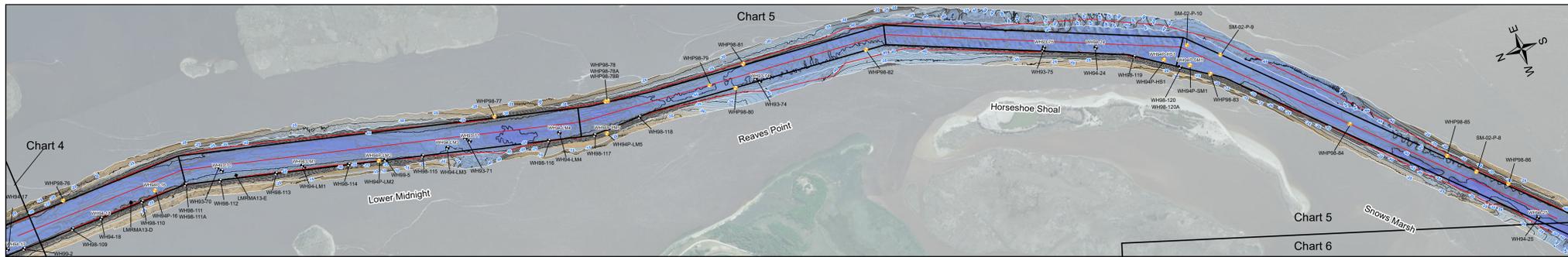
Wilmington Harbor Deepening Survey

Wilmington, North Carolina



NO.	DATE	DESCRIPTION	DRAWN	CHKD	APPR
1					
2					
3					

JOB NUMBER: _____ CHART NO.: _____



LEGEND

PLAN VIEW

Bathymetry (Feet, MLLW)
Refer to report for description of data sources.

- High - 5
- Low - 45
- Contour Interval is 5 feet
- Contour Interval is 1 foot
- Fugro Survey Boundary (May 2017)
- Profile Location
- Channel Reach Boundary

Exploration

- Explosion
- Anchor
- Borehole
- Washprobe
- Vibracore

CROSS SECTION

- Bathymetry (Fugro May 2017 and USACE)
- Approximate Top of Rock (Interpreted by USACE, QSI, and Chance & Chance)
- Surface was derived from point elevations and contour lines of interpreted top of rock from previous investigations.
- Top of Edge Bathymetry (Interpreted using Fugro May 2017 and USACE hydrographic survey data)
- Horizon H30 is a high-amplitude reflector which we interpret to be an approximate top of rock. These horizons were mapped using the sub-bottom profile data collected during the 2017 survey. Historical geotechnical data and previous interpretation of the top of rock (interpreted by others) were loaded into a seismic workstation and used to support our mapping.

General Lithology Type

High-Plasticity Organic	PEAT
Low-Plasticity Organic	Silty Fat CLAY
Fat CLAY	Lean CLAY
Elastic Silt	Silt
Poorly-Graded SAND	Poorly-Graded SAND with Silt
Clayey SAND	Poorly-Graded SAND with Clay
Well-Graded SAND	Gravelly Poorly-Graded SAND
Silty SAND	Well-Graded SAND with Silt
Poorly-Graded GRAVEL	Well-Graded GRAVEL with Silt
Silty GRAVEL	Sandy GRAVEL
Limestone	Sandstone

Boring Symbology

Vertical Exaggeration is 100x

Notes:

- 1) Bathymetry conducted by USACE is a composite of seabeam surveys conducted from 2014 to 2017.
- 2) Soil and rock classifications and descriptions were adopted as they were presented on the exploration logs in the report as reviewed. We have not verified the classification or modified the classification to be consistent with published systems (e.g. USCS) based on laboratory test results.
- 3) Horizons that were mapped are estimates, and were calculated using a two-way travel time (TWT) of 5,000 feet per second.

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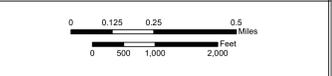
GEODETIC INFORMATION

SPHEROID:	GRS 1980
SEMI-MAJOR AXIS:	6,378,137.000
SEMI-MINOR AXIS:	6,356,752.114
INVERSE FLATTENING:	298.25722101
ECCENTRICITY:	0.00669438
PROJECTION:	UNIVERSAL TRANSVERSE MERCATOR
ZONE:	18 NORTH
LOCATION OF ORIGIN:	87
FALSE EASTING:	500,000
FALSE NORTHING:	0.0



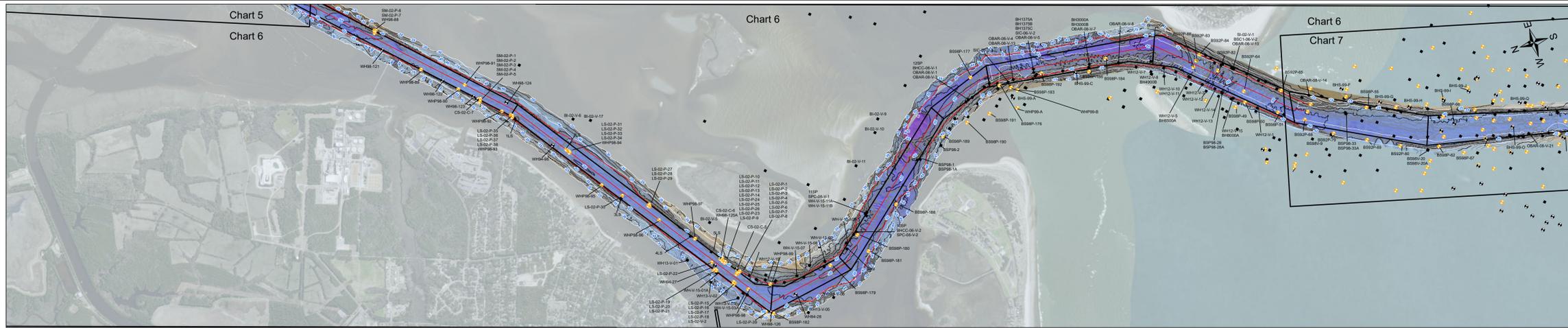
SUBSURFACE CROSS SECTIONS

Wilmington Harbor Deepening Survey
Wilmington, North Carolina



NO.	DATE	DESCRIPTION	DRAWN	CHKD	APPR
1					
2					
3					

JOB NUMBER: CHART NO.:



LEGEND

PLAN VIEW

Bathymetry (Feet, MLLW)
 Refer to report text for description of data sources.
 High - 5
 Low - 45
 Contour Interval is 5 feet
 Contour Interval is 1 foot
 Fugro Survey Boundary (May 2017)
 Profile Location
 Channel Reach Boundary

CROSS SECTION

Bathymetry (Fugro May 2017 and USACE)
 Approximate Top of Rock (Interpreted by USACE, QSI, and Chanco & Chance)
 Surface was derived from point elevations and contour lines of interpreted top of rock from previous investigations.
 Top of Edge Bathymetry (Interpreted using Fugro-May 2017 and USACE hydrographic survey data)
 Horizon H30 is a high-amplitude reflector which we interpret to be an approximate top of rock. These horizons were mapped using the sub-bottom profile data collected during the 2017 survey. Historical geotechnical data and previous interpretation of the top of rock (interpreted by others) were loaded into a seismic workstation and used to support our mapping.

General Lithology Type

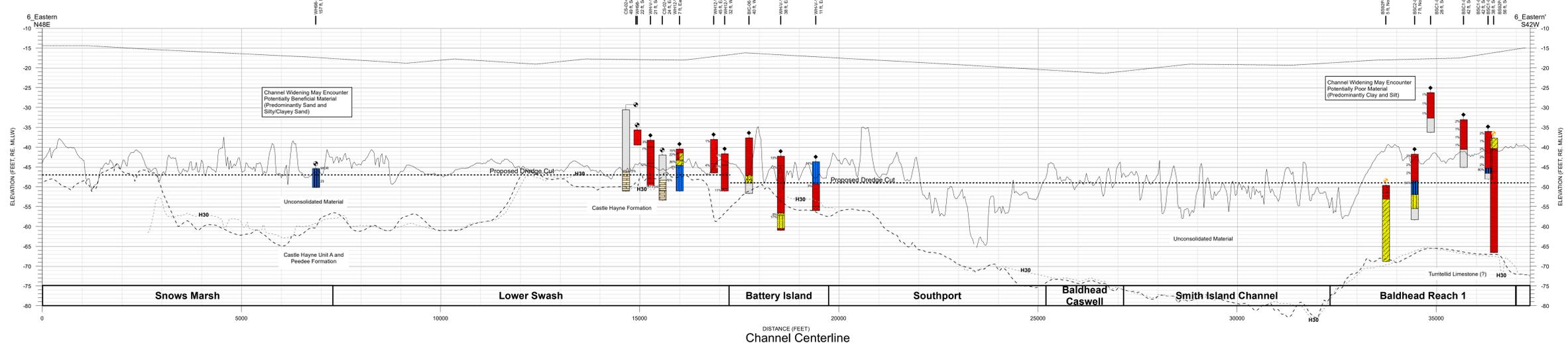
High-Plasticity Organic	PEAT
Low-Plasticity Organic	Silty, Fat CLAY
Fat CLAY	Lean CLAY
Elastic Silt	Silt
Poorly-Graded SAND	Poorly-Graded SAND with Silt
Clayey SAND	Poorly-Graded SAND with Clay
Well-Graded SAND	Gravelly Poorly-Graded SAND
Silty SAND	Well-Graded SAND with Silt
Poorly-Graded GRAVEL	Well-Graded GRAVEL with Silt
Silty GRAVEL	Sandy GRAVEL
Limestone	Sandstone
Mudstone	Not Sampled

Boring Symbology

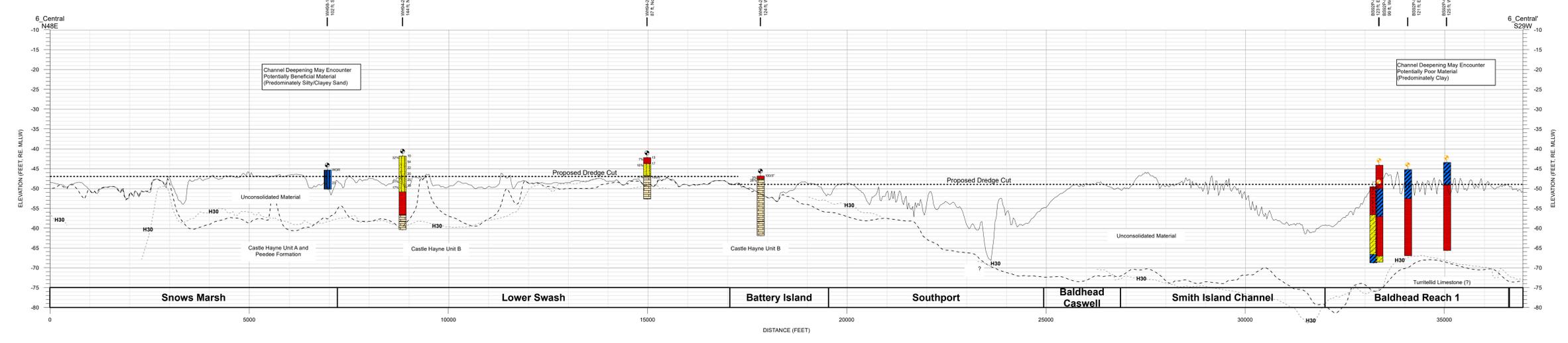
Finest Content
 Standard Penetration
 Test (SPT) Value
 6000
 1500
 1500
 ROD
 Unconfined Compressive Strength

10 ft
 1000 ft
 Vertical Exaggeration is 100x

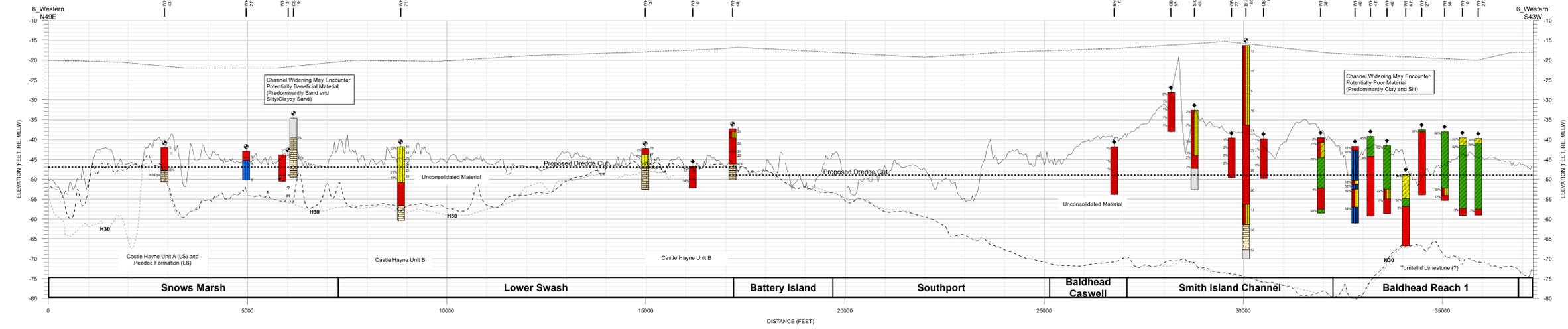
Eastern Toe/Slope



Channel Centerline



Western Toe/Slope



Notes:

1) Bathymetry conducted by USACE is a composite of seabed surveys conducted from 2014 to 2017.
 2) Soil and rock classifications and reactions were adopted as they were presented on the exploration logs in the reports we reviewed. We have not verified the classification or modified the observations to be consistent with published systems (e.g. USCS) based on laboratory test results.
 3) Hydraulic fall were mapped as estimates, and were calculated using a two-way travel time (TWT) of 5,000 feet per second.

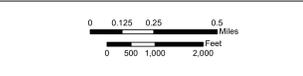
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GEODEIC INFORMATION

SPHEROID: GRS 1980
 SEMI-MAJOR AXIS: 6378137.000
 SEMI-MINOR AXIS: 6356752.144
 INVERSE FLATTENING: 0.004471014
 ECCENTRICITY: 0.004471014
 PROJECTION: UNIVERSAL TRANSVERSE MERCATOR
 ZONE: 18NORTH
 LENGTH OF MERIDIAN: 6378137.000
 FALSE EASTING: 500,000
 FALSE NORTHING: 0.0

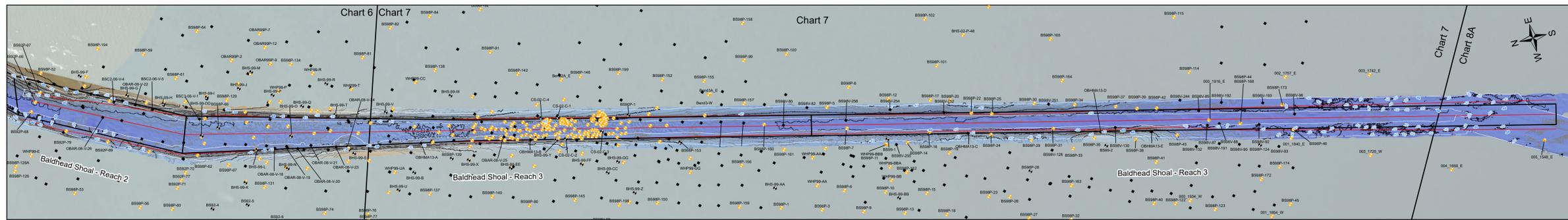


SUBSURFACE CROSS SECTIONS
 Wilmington Harbor Deepening Survey
 Wilmington, North Carolina



NO.	DATE	DESCRIPTION	DRAWN	CHKD	APPR
1					
2					
3					

JOB NUMBER: CHART NO.: 6

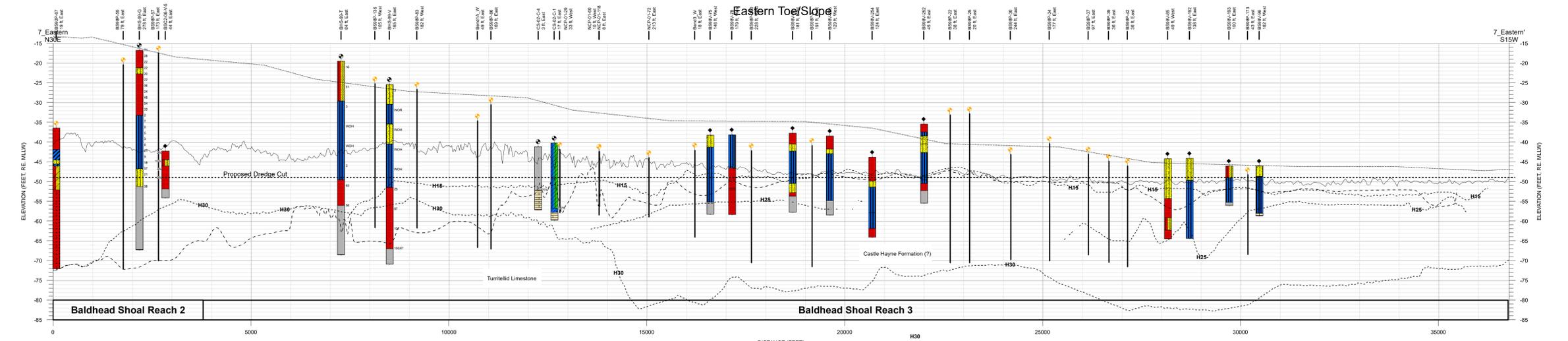


LEGEND

PLAN VIEW
 Bathymetry (Fwd, MLLW)
 Refer to report for description of data sources.
 High - 0
 Low - 65
 Contour Interval is 5 feet
 Channel Interval is 1 foot
 Fugro Survey Boundary (May 2017)
 Profile Location
 Channel Reach Boundary

CROSS SECTION
 Bathymetry (Fugro May 2017 and USACE)
 Approximate Top of Rock (Interpreted by USACE, OSL, and Chance & Chance)
 Surface was derived from point elevations and contour lines of interpreted top of rock from previous investigations.
 Top of Slope Bathymetry (Interpreted using Fugro May 2017 and USACE hydrographic survey data)

Exploration
 Borehole
 Washprobe
 Vibracore



General Lithology Type

High-Plasticity Organic	PEAT
Low-Plasticity Organic	Silty Fat CLAY
FAT CLAY	Lean CLAY
Elastic SILT	SILT
Poorly-Graded SAND	Poorly-Graded SAND with SILT
Clayey SAND	Poorly-Graded SAND with CLAY
Well-Graded SAND	Gravely Poorly-Graded SAND
Silty SAND	Well-Graded SAND with SILT
Poorly-Graded GRAVEL	Well-Graded GRAVEL
Silty GRAVEL	Well-Graded GRAVEL with SILT
Limestone	SANDY GRAVEL
Mudstone	SANDSTONE
	Not Sampled

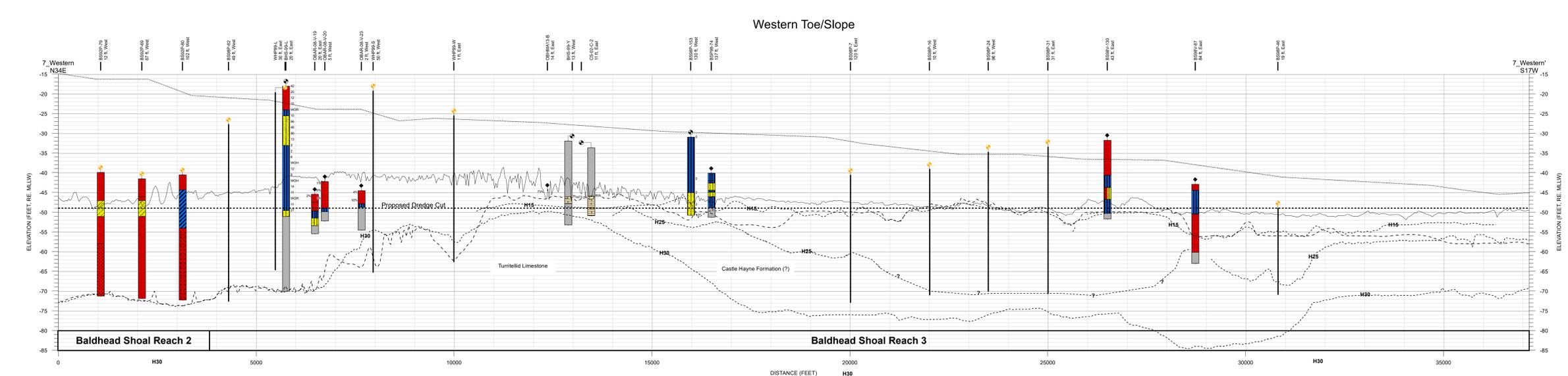
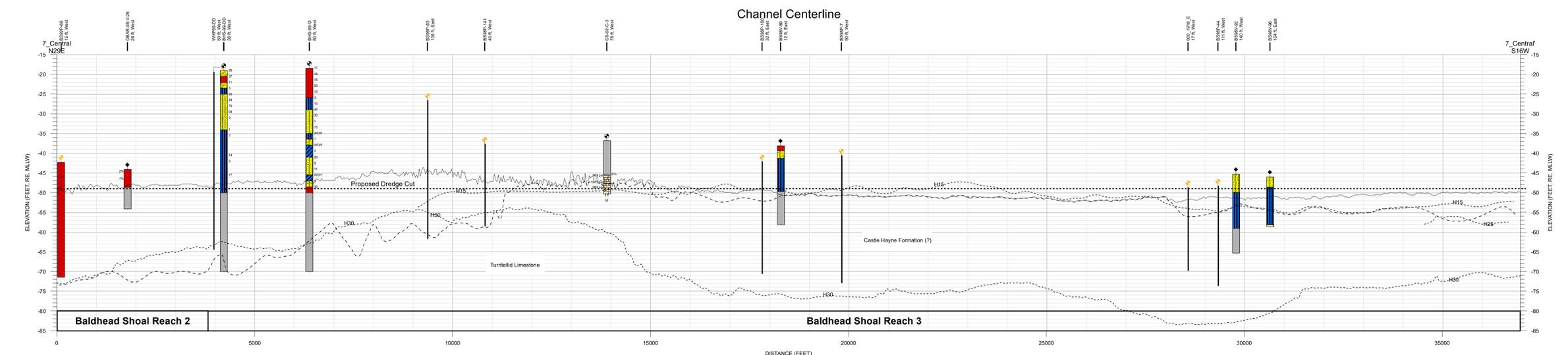
Boring Symbology

Finest SAND
 Constant
 Standard Penetration
 Test N-Value
 6000
 150
 ROD
 Unconfined Compressive Strength

Vertical Exaggeration = 100x

Notes:

- 1) Bathymetry conducted by USACE is a composite of singlebeam surveys conducted from 2014 to 2017.
- 2) Soil and rock classifications and descriptions were added as they were presented on the exploration logs in the reports as reviewed. We have not verified the classifications or modified the classifications to be consistent with published systems (e.g. USC3) based on laboratory test results.
- 3) Horizons that were mapped are estimates, and were calculated using a two-way travel time (TWT) of 0.0001 feet per second.



GEODETIC INFORMATION

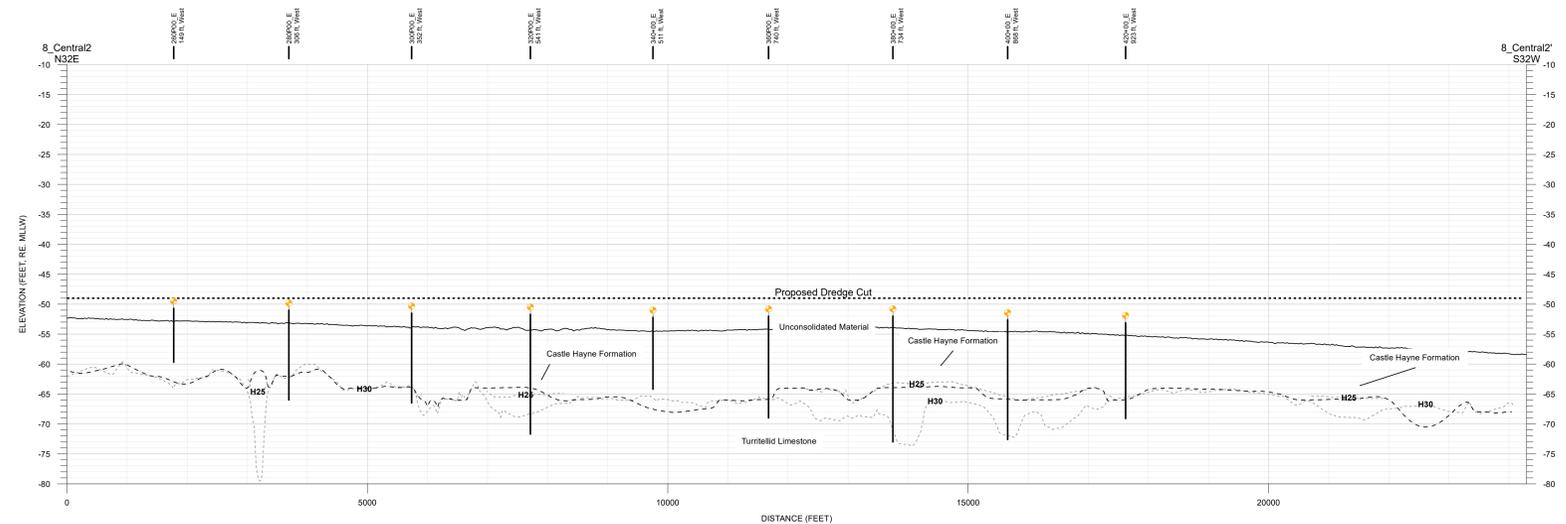
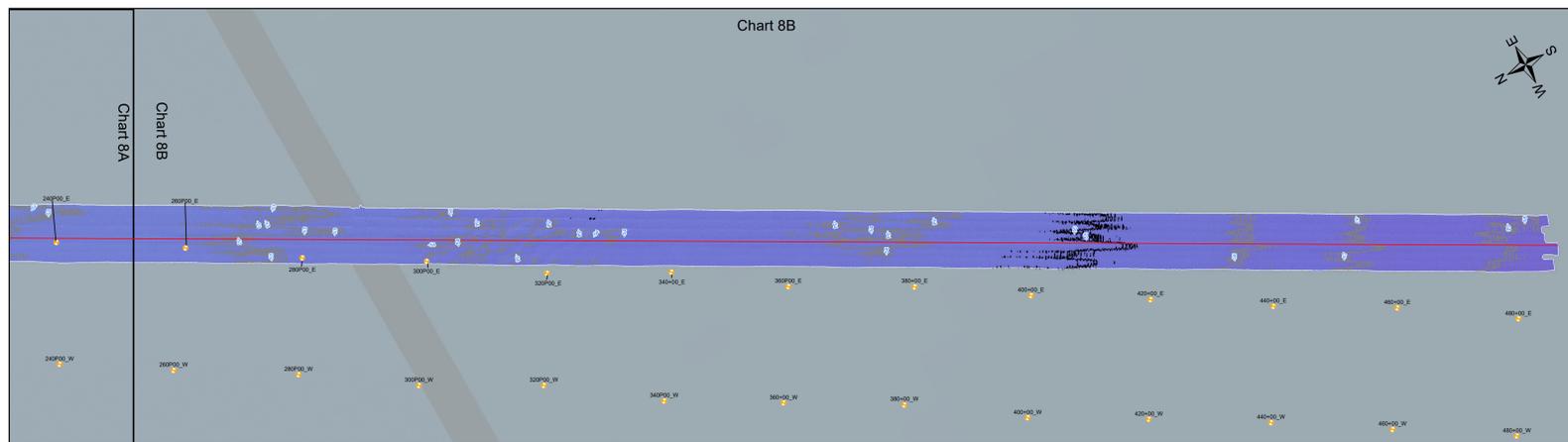
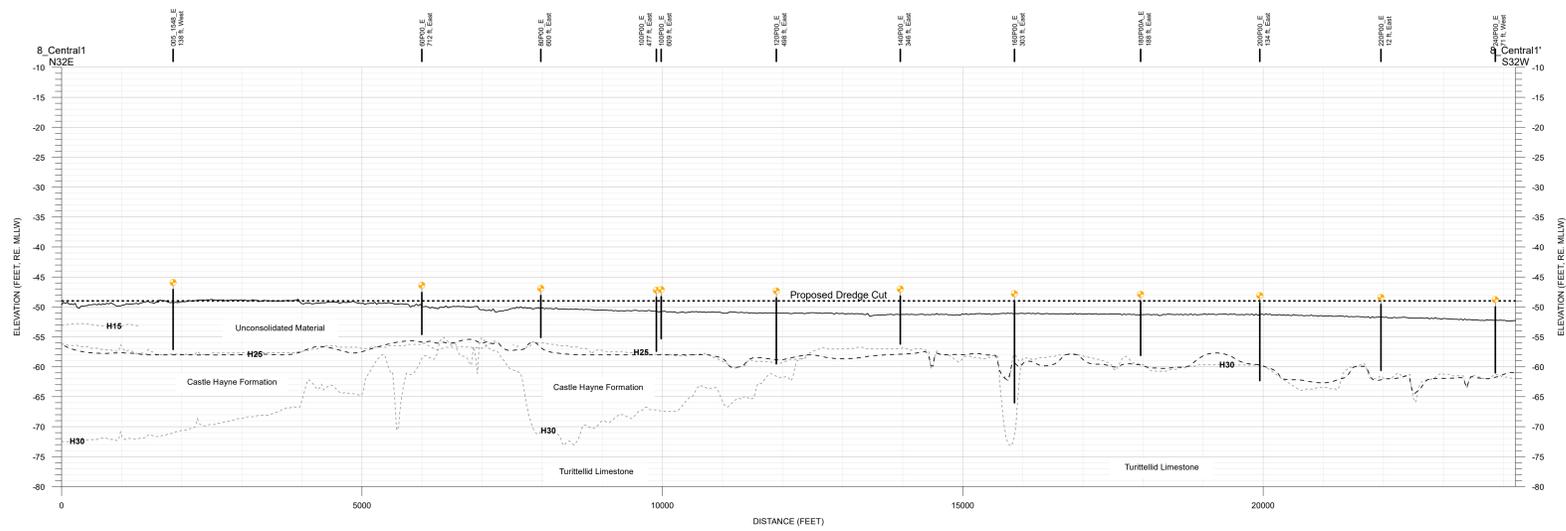
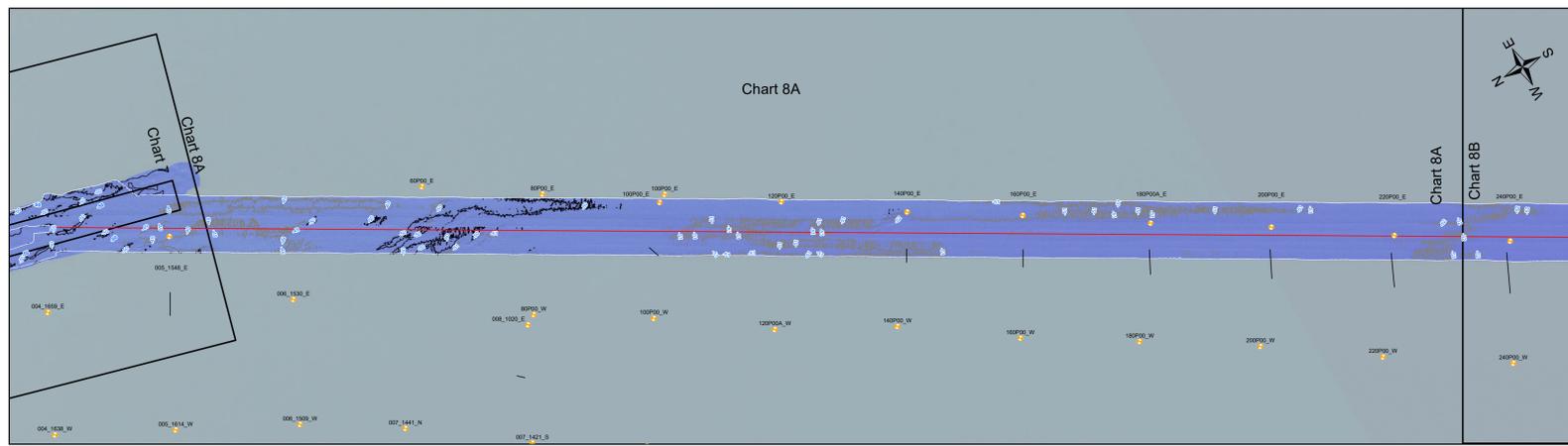
SPHEROID: GRS 1980
 SEMI-MAJOR AXIS: 6378137.000
 SEMI-MINOR AXIS: 6356752.114
 INVERSE FLATTENING: 298.25722101
 ECCENTRICITY: 0.00694380
 PROJECTION: UNIVERSAL TRANSVERSE MERCATOR
 ZONE: 18N
 LENGTH OF ORIGIN: 817
 FALSE EASTING: 500000
 FALSE NORTHING: 0.0

SUBSURFACE CROSS SECTIONS
 Wilmington Harbor Deepening Survey
 Wilmington North Carolina

0 0.125 0.25 0.5 Miles
 0 500 1,000 2,000 Feet

NO.	DATE	DESCRIPTION	DRAWN	CHKD	APPR
1					
2					
3					

JOB NUMBER: CHART NO.: 7



LEGEND

PLAN VIEW

Bathymetry (Feet MLLW)
Refer to report text for description of data sources.

- High - 0
- Low - .65
- Contour Interval is 5 feet
- Channel Interval is 1 foot
- Fugro Survey Boundary (May 2017)
- Profile Location
- Channel Reach Boundary

CROSS SECTION

Bathymetry (Fugro May 2017 and USACE)

Approximate Top of Rock (Interpreted by USACE, QSI, and Chance & Chance)
Surface was derived from point elevations and contour lines of interpreted top of rock from previous investigations.

Horizon H15 is a high-amplitude reflector which we interpret to be an approximate top of rock. These horizons were mapped using the sub-bottom profiler data collected during the 2017 survey. Historical geotechnical data and previous interpretation of the top of rock (interpreted by others) were loaded into a seismic workstation and used to support our mapping.

Horizon H25 is a high-amplitude reflector which we interpret to be an approximate top of rock. These horizons were mapped using the sub-bottom profiler data collected during the 2017 survey. Historical geotechnical data and previous interpretation of the top of rock (interpreted by others) were loaded into a seismic workstation and used to support our mapping.

Horizon H28 is a high-amplitude reflector which we interpret to be an approximate top of rock. These horizons were mapped using the sub-bottom profiler data collected during the 2017 survey. Historical geotechnical data and previous interpretation of the top of rock (interpreted by others) were loaded into a seismic workstation and used to support our mapping.

Horizon H30 is a high-amplitude reflector which we interpret to be an approximate top of rock. These horizons were mapped using the sub-bottom profiler data collected during the 2017 survey. Historical geotechnical data and previous interpretation of the top of rock (interpreted by others) were loaded into a seismic workstation and used to support our mapping.

Horizon H33 is a high-amplitude reflector which we interpret to be an approximate top of rock. These horizons were mapped using the sub-bottom profiler data collected during the 2017 survey. Historical geotechnical data and previous interpretation of the top of rock (interpreted by others) were loaded into a seismic workstation and used to support our mapping.



Notes:

- 1) Bathymetry conducted by USACE is a composite of singlebeam surveys conducted from 2014 to 2017.
- 2) Soil and rock classifications and descriptions were adopted as they were presented on the exploration logs in the report as received. We have not verified the classifications or modified the classifications to be consistent with published systems (e.g. USCS) based on laboratory test results.
- 3) Horizons that were mapped are estimates, and were calculated using a two-way travel time (TWT) of 5,000 feet per second.

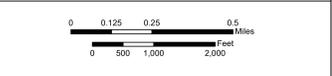
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GEODETTIC INFORMATION

SPHEROID: GRS 1980
SEMI-MAJOR AXIS: 6378137.000
SEMI-MINOR AXIS: 6356752.124
INVERSE FLATTENING: 298.25722101
ECCENTRICITY²: 0.00694380
PROJECTION: UNIVERSAL TRANSVERSE MERCATOR
ZONE: 18NORTH
LONGITUDE OF ORIGIN: 81°
FALSE EASTING: 500,000
FALSE NORTHING: 0.0



SUBSURFACE CROSS SECTIONS
Wilmington Harbor Deepening Survey
Wilmington North Carolina



NO.	DATE	DESCRIPTION	DRAWN	CHKD	APPR
1					
2					
3					

JOB NUMBER: CHART NO.: