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Technical Report on Geological & Geophysical Data Analysis and Delineation of Potential Sand Borrow Areas

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Stony Brook University's COAST Institute

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COAST has been called upon to assist in resolving coastal problems at home on Long Island, throughout the U.S. and in many parts of the world. COAST also provides a real world, action-learning laboratory for graduate students at MSRC. Each year students who are interested in coastal management and policy take part in gathering and analyzing data, in transforming data into information, and in synthesizing information-all targeted at identifying and evaluating management alternatives to attack the problems that COAST is helping to solve.

Technical Report on Geological & Geophysical Data Analysis and Delineation of Potential Sand Borrow Areas

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In fulfillment of the U.S. Bureau of Ocean Energy Management (BOEM) – New York Second Round Cooperative Agreement for Sand Resource Assessment, this report presents the results of survey data collected by BOEM in targeted areas, primarily sand ridges, and identifies four sand resource areas according to BOEM's required analytical framework. This framework includes categorizing the likelihood of using the identified sand resource areas for future dredging activities based on the availability of existing data. The four identified sand resource areas are classified as "probable." Additional scientific studies will be necessary, as well as regulatory review, prior to a sand resource area being classified as "proven", which is a category generally reserved for shoals that have already been authorized as part of a lease.

BOEM's targeted survey areas consist largely of sand ridges given the high volume of sand available for dredging. However, sand ridges are important morphological features and may serve as natural pathways for sand transport. The U.S. Geological Survey has hypothesized that sand ridges, especially in near-shore settings, act as conduits for offshore to onshore sand movement and natural beach replenishment. Sand deposits, including sand ridges, farther offshore may also be a source of sediments moving onshore. Removal of sand resources from ridges for dredging activities could severely disrupt this flow of sand and the sustainability of New York's sand resources. Additional research is essential for understanding these physical processes and minimizing disruption to natural sand movement.

In addition, ecological data on the characteristics of these sand ridges and inter-ridge areas and the habitat significance for fish and invertebrate populations is scarce. The Department of State had submitted a research proposal to BOEM's Marine Minerals Program for funding consideration, and additional research opportunities should be pursued to enhance understanding of these environments.

Summary

The Bureau of Ocean and Energy Management (BOEM) conducted design-level surveys of three portions of the Outer Continental Shelf (OCS) in Federal waters from 3 to 8 nautical miles (5.6 to 14.8 km) off New York's south shore of Long Island during 2016 as part of the BOEM Atlantic Sand Assessment Project (ASAP) initiative (Figure 1). The survey collected about 1,112 km of high-resolution subbottom (chirp) profiles, 300 kHz side-scan sonar records, 550 kHz of interferometric bathymetry and side-scan sonar records and magnetometer records. In addition, vibracores up to about 20 ft (6.1 m) long were collected at 59 stations in one of the three study areas. The tracks supplement reconnaissance-level geophysical tracks and sediment samples that were collected by the BOEM ASAP initiative during 2015 (768 km of geophysical data, vibracores at 31 stations and grab samples at 18 stations). The primary purpose of the 2016 ASAP design-level surveys was to provide data needed to characterize and quantify sand potentially available for beach nourishment projects located in the surveyed Federal waters. Details of the ASAP surveys, which includes data collected during reconnaissance surveys done in 2015 and design-level surveys done in 2016, have been described in prior reports (BOEM, 2016; Flood et al., 2016, 2017a, 2017b; APTIM, 2018). The primary objective of this Technical Report is to use the ASAP geophysical and geological data to identify, delineate, characterize and quantify potential sand resources in Federal waters surveyed south of Long Island (Figure 2).

Sand resources are delineated in four areas based on this ASAP data. The areas BOEM selected for the ASAP surveys, especially the design-level surveys, targeted primary surficial geological features on the inner portion of the OCS south of Long Island, namely large sand ridges, with heights of 1 to 5 m (3 to 16 feet) and spacings of about 1.5 to 2 km (5,000 to 6,600 feet). The crests of these sand ridges are generally characterized by a sandy deposit up to 3.6 m (12 feet) thick with a nearly flat-lying basal layer observed on seismic profiles. This sandy deposit is likely to be of Holocene age (less than about 10,000 years old). While the geophysical surveys imaged both sand ridges and areas between sand ridges, vibracores were only collected from a subset of the sand ridges. Since vibracore data is essential to characterize the nature of sand resources, areas delineated to date are along the crests of sand ridges where vibracores were taken. Significant sand resources are likely to occur elsewhere on sand ridges and between the sand ridges, but additional vibracores will be needed before any additional areas can be characterized. The basal layer that underlies each of these delineated deposits lies above an erosional unconformity which occasionally contains

fragments of wood and peat. Sediments in and below this basal layer may contain possible cultural resources and should be deemed dredging avoidance areas.

The four areas delineated in this report are Fire Island Design SR1 (FID_SR1), Fire Island Design SR2 (FID_SR2), Fire Island Inlet Design SR1 (FIID_SR1) and Moriches Inlet Design SR1 (MID_SR1). Areas FID_SR1 (10.01 million cubic yards, mean size 1.80 phi; medium sand) and FID_SR2 (4.19 million cubic yards, mean size 2.15 phi; fine sand) are delineated based on dense seismic coverage and numerous cores whereas areas FIID_SR1 (1.52 million cubic yards, mean size 2.28 phi; fine sand) and MID_SR1 (2.11 million cubic yards, mean size 1.63 phi; medium sand) are delineated based on dense seismic coverage but there is only one vibracore in each area.

In addition to delineating sand resource areas, resource areas were classified according to the BOEM Marine Minerals Information System (MMIS) data classification scheme provided in the file MMISDataDictionaryV5.xls dated 01/30/2018. Available sand resource classes, in order of decreasing likelihood that the area can be used as a future dredging, are: proven; probable; potential; possible, and; unusable. The two most suitable categories for the identified sand resource areas are "proven"[1] for areas where there is both dense seismic data and numerous cores and "probable"[2] where there is dense seismic coverage but only one core. However, the definition of the "proven" category includes the statement that the category is "generally reserved for shoals that have already been authorized as part of a lease." This is not the case for any of the sand resource areas identified in this study and additional data analysis and regulatory review will be needed before any of these area are authorized as part of a lease. Thus all four of the identified sand resource areas are classified as "probable."

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[1] "Proven" = resource areas whose thickness and lateral extent have been fully determined through the use of vibracore and/or push cores. Generally reserved for shoals that have already been authorized as part of a lease.

[2] "Probable" = resource areas whose existence has been established through the use of vibracores, push cores and/or grab samples. Thickness and/or lateral extent has not been fully determined. These are reserves that could be viable if additional coring is done.

Introduction

The Bureau of Ocean and Energy Management (BOEM) conducted design-level surveys of three portions of the OCS in Federal waters from 3 to 8 nautical miles (5.6 to 14.8 km) off New York's south shore of Long Island during 2016 as part of the BOEM Atlantic Sand Assessment Project (ASAP) initiative (Figure 1). The survey collected about 1,112 km of high-resolution subbottom (chirp) profiles, 300 kHz side-scan sonar records, 550 kHz of interferometric bathymetry and side-scan sonar records and magnetometer records in the Fire Island, Fire Island Inlet and Moriches Inlet Design Areas. In addition, vibracores up to about 20 ft (6.1 m) long were collected at 59 stations in the Fire Island Design Area. These 2016 tracks supplement the reconnaissance-level geophysical tracks and sediment samples that were collected by the BOEM ASAP initiative during 2015 (768 km of geophysical data, vibracores at 31 stations and grab samples at 18 stations). BOEM contracted with CB&I (now ATPIM) to conduct the ASAP studies, including geophysical surveys and sediment sampling and analysis. ATPIM reported results of the surveys, sample analysis and raw geophysical data to BOEM (ATPIM, 2018).

The primary surficial geological features on the inner portion of the OCS south of Long Island are large sand ridges with heights of 1 to 5 m (3 to 16 feet) and spacings of about 1.5 to 2 km (5,000 to 6,600 feet; Foster et al., 1999; Schwab et al., 2000a,b; 2014a, b). The crests of these sand ridges are generally characterized by a sandy deposit up to 3.6 m (12 feet) thick with a nearly flat-lying basal layer observed on seismic profiles. This sandy deposit is likely to be of Holocene age (less than about 10,000 years old) but the sand ridges are only one of many types of sedimentary features that developed south of Long Island as a result of the glacial and post-glacial evolution of the inner portion of the OCS. The new geophysical and geological data being collected in this area as part of this study is providing new insights into the evolution of this important area.

The primary purpose of the ASAP 2016 design-level surveys was to provide data needed to delineate, characterize and quantify sand resources located in surveyed Federal waters that could potentially be available for beach nourishment projects. Details of ASAP surveys - which includes the data collected during reconnaissance surveys done in 2015 and the design-level surveys done in 2016 - have been described in prior reports (BOEM, 2016; Flood et al, 2016, 2017a, 2017b; ATPIM, 2018). The primary objective of this Technical Report is to use the project geophysical and geological data to identify, delineate, characterize and quantify likely sand resources in Federal waters south of Long Island (Figure 2). In addition, the studies conducted on these data provide new insights into the nature and evolution of the inner portion of the OCS in this area.

ASAP Data Sets

Sand resources are being delineated primarily using data collected during the ASAP studies. The available ASAP data sets include seismic data, vibracore data, side-scan sonar data and bathymetry.

Seismic Data and Thickness Maps

The primary tool for imaging the sub-seabed structure is the subbottom profiler. For this study an EdgeTech 3200 subbottom profiler was towed along the survey lines. The subbottom profiler can show layering patterns in the sediment which can help to identify the nature of the subbottom layering and the distribution and thickness of the various layers that are imaged (Figure 3). This unit is a chirp subbottom profiler which transmits an acoustic pulse that is directed downwards and sweeps from 700 Hz to 12 kHz, thus the name "chirp". Sound reflects off the sea-floor surface and also penetrates into the seafloor and can reflect off of materials within the sediment. Reflections are determined by correlating the received signal with the swept-frequency output pulse. Sub sea-floor reflections can come from layers of differing density or sound velocity (i.e., acoustic impedance) that result from different sedimentary materials. As suggested by Flood et al. (2016, 2017a), sound can also be reflected from gas bubbles in the sediment as well as features in the water column, especially from individual fish and schools of fish.

The initial processing of the chirp subbottom profiles (in jsp format) was done using SonarWiz (Chesapeake Technologies, Inc.; program versions 5, 6 and 7 were used). The processing steps included reading the trace envelope, tracking (or picking) the first return, applying a wave-motion filter to remove the vertical movement of the sonar unit to better align the reflections on the subbottom profiles, and, where needed, applying a time-varying gain to the subbottom data that started at the sea floor. The seismic profiles were converted to images and annotated with time or shot number and with depth scale lines assuming a sound speed of 1,500 m/s. These annotated chirp images can be used to evaluate data quality and to identify and locate subbottom features. In addition, the profile images can be hot-linked to the GIS track navigation so that seismic profiles can be viewed in GIS. Many of the long seismic lines have been made into several shorter lines and some of the profile images have been reversed so that the profiles consistently have North or West on the left-hand end of the profile. These steps facilitate processing and reduce some confusion about profile orientation and scales when the individual profiles are viewed.

Sediment layers of interest were manually traced in SonarWiz and the thickness of this layer (in milliseconds, from the sediment surface to the reflector) was calculated and the sediment layer thickness (in meters) was determined using a sound velocity in sediment of 1,500 m/sec. This is a common choice for sediment sound velocity, although the actual sound velocity in sandy sediments is likely to be somewhat higher. Increasing the sound velocity by 10% (to 1,650 m/s) will have the effect of making the sediment layer being studied thicker by 10%. Seismic lines were spaced about 30 m (100 feet) apart in the design-area surveys. Every 4th profile was picked in the Fire Island Design Area while every profile was picked in the Fire Island Inlet and Moriches Inlet Design Areas. Profiles from reconnaissance-level surveys were also picked where they were collected in the design areas.

Values of layer thickness and positon were processed using Surfer software into a grid with a cell size of 50 m x 50 m (164 ft x 164 ft) using a "moving average" with a radius of 50 m (164 ft). Grids were projected in NAD83 UTM Zone 18W (meters). These grids were imported into ArcMap 10.3 and sediment thicknesses were converted from meters to feet. Layer thicknesses, areas and volumes were determined in ArcMap.

Sediment Vibracores

Vibracores that sampled the upper approximately 20 feet (6.1 m) of sediment were collected using a 271b Alpine Pneumatic Vibracore. 41 vibracores were taken at 31 locations in 2015 and 123 vibracores were taken at 59 locations in 2016, with up to three cores being taken at a station if needed to penetrate to 20 feet; however, 20 feet was not reached at all stations. At many sites the complete sediment record was apparently not sampled because the length of the recovered sediment is almost always less than the depth that was cored. The gaps in the recovered sediment record are perhaps due to the presence of coarse material such as sand or gravel in the sediments. These kinds of materials can be difficult to sample using a vibracore. The cores have been split in half length-wise into an archive, or unsampled, half and a working, or sampled, half. The archive halves of the cores have been sent by BOEM to the Core Laboratory at Lamont-Doherty Earth Observatory of Columbia University (LDEO) in Palisades, NY. The working halves of the cores collected from offshore NY in 2015 are at the School of Marine and Atmospheric Sciences at Stony Brook University, and we have requested that the working halves of the cores collected from offshore NY in 2016 also come to Stony Brook. The cores in both the Core Lab and at SoMAS are stored in D-tubes to protect them from degrading over time. The working halves of cores at SoMAS will be sent to LDEO for long-term storage when there is no further need for them at SoMAS.

The cores were split, photographed and described by ATPIM and grain size samples were analyzed by ATPIM at several depths in each core. Graphic records of each grab, core and grain-size sample were delivered in pdf format. The data on the pdfs is also provided in gpj files which are used in the gINT geotechnical software program that aids in the reporting of core descriptions and grain size data (https://www.bentley.com/en/products/brands/gint). As described in Flood et al. (2016) the data in the gpj files can be read by database programs such as Access, and the data present on the pdf images can be recovered from the gINT files and transferred to Excel spreadsheets or other formats. The vibracore grain size results from 2015 and 2016 have been further manipulated to create Excel spreadsheets where all of the sample-related information (e.g., position, depth, sediment classification, summary grain size information and the complete grain size distribution) is available on one line of the file.

While the grain-size results are reported in phi units, the textural descriptions used on the ATPIM core descriptions use terms in the ASTM system rather than in the Wentworth system which has been more commonly used in the study area. These two systems assign sample names based on the sediment phi size, but the names assigned are different. Thus a sediment described as a "coarse sand" in the ASTM system would be called a "pebble" or a "granule" in the Wentworth system; a sediment described as a "medium sand" in the ASTM system would be called a "very coarse sand", a "coarse sand" or a "medium sand" in the Wentworth system; and a sediment described as a "fine sand" would be called a "medium sand", "fine sand" or "very fine sand" in the Wentworth system. As a result, care must be used when using the ATPIM core descriptions. The Wentworth system is used in this report, and the size range for sediments described as "sand" ranges from 4 phi to -1 phi (62.5 microns to 2 mm).

The cores were photographed in 2-foot sections with an image size of 2827 x 1885 pixels; however, the images were collected with a jpeg compression of 80 or 85 which results in a core image with a degraded resolution. The photographs show the general character of the recovered sediments, but the photograph resolution is not sufficient to show many important details of those sediments. High-quality core images are an important source of data being used to understand the sediment sequences recovered so additional studies are being undertaken to provide better images of the sediment cores and to collect additional data to characterize the recovered sediments. Selected vibracores collected in 2015 and 2016 are being analyzed using a newly available core scanner at the LDEO Core Lab to provide additional information on sediment sequences, provenance and properties. The core analysis included core imaging, magnetic susceptibility profiling, GRAPE (a gamma-ray sediment porosity analyzer) profiling, and XRF (X-Ray fluorescence) profiling. The cores currently being analyzed included those collected at sites 2015-VC23, 2015-VC24, 2015-VC26, 2015-VC28, 2015-VC32, 2016-VC18 and 2016-VC19, but we anticipate working with other cores also.

The ASAP vibracores and grab samples collected in 2015 and 2016 sampled many environments along the inner portion of the OCS and collected sediments that are broadly similar to those described from earlier studies (Schwab, 2000; Figures 4 and 5). The mean sediment size for most samples lies in the range of 1 phi to 3 phi (medium sand and fine sand) but some samples have mean grain sizes as coarse as -1 phi (very coarse sand). Most samples have standard deviations in the range of 0.3 to 1 phi, but the standard deviation increases to 3 phi for the coarser samples. Schwab (2000) reports that finer-grained sandy sediments (mean size finer than 2 phi) can also have high standard deviations due to the presence of muddy sands in some areas. No grain sizes are reported in these kinds of materials for the ASAP samples in part because grain-size measurements were not made in fine-grained sediments. Also, vibracores and grab samples generally targeted sandy sediments rather than fine-grained sediments.

The ASAP vibracores recovered surficial sands at nearly all core sites and they also recovered sands at depth in many cores. Fine grained (silt and clay) layers are common at depth in the western portion of the study area (west of the midpoint of Jones Beach Island) but less common in the eastern portion of the study area. The surficial and deep sand layers are commonly separated by a distinct layer of somewhat different sediment type and grain size that can be finer or coarser and which can contain clay, peat, wood fragments or small rocks as well as sand. A working hypothesis is that this distinct layer with variable composition is associated with the most recent post-glacial sea-level rise and marks the erosional boundary between a sand layer of Holocene age (created following post-glacial sea-level rise) and an older, deep sand layer of potential glacial (Pleistocene) age. Studies are underway to better characterize the sediment stratigraphy in this area.

Surface Sediment Samples

In 2015 the ASAP program collected surface grab samples south of Long Island in addition to vibracores, but only one of those surface samples was in one of the 2016 design study areas. The USGS has published the results of available grain-size analyses of grab samples previously collected (Reid et al., 2005; USGS, 2011) and several of the reported samples occur in the design areas. The top sample of each 2015 and 2016 vibracore also includes the surface and those surface samples were included with other available surface samples.

Bathymetric and Side-scan Sonar Data

The depth of the sediment surface and the depth of any subbottom layers need to be referred to the elevation datum NAVD 88 which is an orthorhombic datum that is an approximation of mean sea level (Zilkoski et al., 1992). For this project water depths are available from bathymetry data collected during the ASAP surveys in 2015 and 2016 and from National Ocean Survey bathymetric surveys collected in the region (see https://maps.ngdc.noaa.gov/viewers/bathymetry/). The bathymetric data collected during the ASAP surveys was delivered after being processed. The ASAP bathymetric files as delivered could not be used directly since they contained a number of possible errors and inconsistencies (Figure 6). In particular, the depths in the reconnaissance bathymetry data from 2015 are not consistent because depths can vary by more than a meter when lines cross. Depths in the design-level bathymetry data from 2016 are more consistent, but an offset is needed to adjust the depths to the NAVD 88 datum. In addition, there are numerous examples where digital depths are contaminated by spurious depths due to fish or instrumental errors and there are other unexplained anomalies such as unrealistic cross-track slopes. The raw bathymetric files only recently became available to project participants and we are currently working with the raw bathymetric data to try to resolve many of these problems.

Each of the design-level surveys overlaps one or more recent multibeam NOS surveys so it is possible to determine the offset necessary for the 2016 bathymetric data. The comparison between the NOS surveys (reported with respect to MLLW and offset to NAVD 88 using VDatum at vdatum.noaa.gov) and 2016 ASAP surveys (nominally reported with respect to NAVD 88) suggests that the 2016 ASAP bathymetric data is about 1.4 m too deep. Specific offsets were determined for each of the design survey areas, and the offsets are 1.31 m for Fire Island Inlet, 1.40 m for Fire Island and 1.44 m for Moriches Inlet. The ASAP bathymetric data for 2016 need to be made shallower by these offsets to agree with the NOS survey data from the same area. The 2016 ASAP bathymetric data as delivered was gridded at 50 m (the limits of the 50 m bathymetric grid are identical to the limits of the 5o m sediment thickness grid) and the 50 m grid was used in this study. The offset, gridded ASAP 2016 bathymetric data agree quite well with the NOS survey results.

The sediment surface was imaged during surveys in 2015 and 2016 with a towed side-scan sonar (Edgetech4200; 300 kHz in 2015, 300 and 600 kHz in 2016) and with a binned, pole-mounted multibeam backscatter in 2015 and 2016 (Edgetech 6205; 550 kHz). The side-scan sonar and backscatter mosaics are used to determine variability in the nature of surficial sediments in any potential sand resource areas. The mosaics of binned multibeam backscatter appear to be useful for characterizing surface sediment variability in the design areas and preliminary backscatter mosaics are shown for each of the design areas. Processing is continuing to improve resolution and to reduce along-track striping in the backscatter mosaics.

Characterization of Sand Resources in Design-Level Survey Areas

The ASAP sand resources study has focused on settings where there are well-defined layering patterns on seismic profiles and where sediment cores show sandy sediments. Because of the need to image and map sand layers using seismic profiles, the surface sand layer needs to be more than about one meter thick to be reliably imaged. Suitable sand deposits may exist that don't have the needed seismic signature since nearly all of the ASAP cores contain primarily sandy sediments, even in areas where no distinct sand layer is identified at the surface on seismic profiles. However, the core data recovered during the ASAP studies is not sufficient to identify sand resources in those areas.

The base of a Holocene sand layer appears to be clearly imaged throughout the inner portion of the OCS south of Long Island (e.g., Foster et al., 1999; Schwab et al., 2000a,b; 2014a, b) and the ASAP seismic surveys and vibracores were collected to map and characterize this Holocene sand layer in three distinct areas in Federal waters in order to assess the sand resources that may exist in this layer. The methodology followed in each design-level survey area was to identify the generally flat-lying seismic reflection at the base of the Holocene sand layer and to map this layer throughout the survey area. The thickness of sediment above this layer was determined and used to create a grid of the layer thickness. Vibracores were used to characterize the sediments within the surficial sand layer, the nature of sediments at the depth of the base of the Holocene sand layer, and the sediments that lie beneath the Holocene sand layer. Sand resources were then delineated on the basis of there being adequate sediment thickness, generally thicker than about 1 m to 1.5 m (3.3 feet to 4.8 feet), in the upper (Holocene) sand layer.

The delineated sand resources are being identified by an ID that includes the name of the design area, the morphology of the deposit, and the number of that deposit. The design areas are the Fire Island Design Area (FID), the Fire Island Inlet Design Area (FIID) and the Moriches Inlet Design Area (MID). The delineated sand resources are associated with sand ridges (SR), and more than one such sand resource can be identified in any one area. Other kinds of sand resources can potentially be identified, such as in inter-ridge areas (IR), in deep sands beneath the surficial sand layers (DS), or in some other setting. Using this code, FID_SR1 is in the Fire Island Design Area, is on a sand ridge, and is the first such deposit identified in that setting. Delineated deposits reported here are FID_SR1, FID_SR2, FIID_SR1 and MID_SR1 (Figure 2).

Design-Level Survey Areas and Sand Resources

Fire Island Design Area

The Fire Island Design Area is located from 5.7 km to 7.5 km (3 nm to 4 nm) south of Fire Island, NY in water depths of 19.9 m to 27.6 m (65 ft to 90 ft) referenced to NAVD 88 (Figures 7 and 8). The area contains two prominent ridges spaced 2.7 km (1.45 nm) apart that trend WNW to ESE. The larger, eastern ridge has a height of about 3.5 m (11.5 ft) and the smaller, western ridge has a height of about 2.5 m to 3 m (8 ft to 11.5 ft). Several yet smaller ridges are present between the larger ridges, and the smaller ridges have a general NW to SE orientation and have heights of about 1 m (3.3 ft). Multibeam backscatter mosaic (Figure 9) shows that the two prominent sand ridges tend to have higher backscatter on their north-east flanks suggesting sediments there are somewhat coarser than in other areas. There are also several smaller areas of high backscatter between the primary ridges. Surface grain size ranges from ASAP and USGS samples suggest that the surface sediment is somewhat coarser on the north-east flanks and crests of the sand ridges than on the south-west flank (Figure 9).

Seismic profiles show that the two larger ridges have prominent, nearly flat-lying reflections at a depth of up to 3.5 m (11.5 ft) and that a distinct but much shallower near-surface reflection is present between the larger ridges (Figure 10). This near-surface reflection was traced throughout the area to determine the thickness of the layer (Figure 11). The thickness map shows two distinct sand deposits up to 3.5 m thick (11.5 ft) that correspond to the two prominent sand ridges. A somewhat less distinct sand deposit up to 2 m (6.5 ft) thick is present between the two prominent ridges and that deposit corresponds to one of the two smaller ridges. The remainder of the area has a sediment thickness of about a meter or less.

While an uppermost reflection is well-resolved on the seismic profiles, the seismic character of the sediments below the base-of-sand reflection is generally not well resolved (Figure 10). While the lack of layering in sediments on seismic profiles can be due to many factors, reflections when visible are often steeply dipping suggesting that initially flat-lying reflections may have been deformed. These apparently deformed deeper sediments are described as "chaotic deposits" based on this observation, but additional study will be needed to more fully characterize these deposits. Laminated deposits are observed in depressions lying above the potentially deformed sediments suggest that any deformation occurred prior to deposition in these depressions. The dipping reflections of these laminated deposits can be truncated by the base-of-sand reflection demonstrating the erosional nature of the contact between the lower and upper sand layers. Many of the depressions with laminated fill can be followed on seismic data, and the depressions are generally of limited extent and oriented in an ENE-WSW direction (Figure 12). This direction does not align with channels mapped nearby by USGS (Foster et al., 1999; Schwab et al., 2000a,b; 2014a, b) which trend NNW-SSE. It is possible that the acoustically chaotic or deformed deposits are sediments of glacial age which were deposited in advance of a glacier and which have been deformed by a glacial advance. The common occurrence of laminated (perhaps varved) sediments recovered in cores from the lower sand layer (see vibracore descriptions discussed later) is consistent with this observation. No cores sampled the laminated depressions, but they could be deposits that were deposited in glacial-aged lakes. One or more layers can occasionally be observed on seismic profiles between the base-of-sand reflection and the chaotic or laminated interval, but the distribution of these layers appears to be quite variable. The layers occasionally observed below the base-of-sand reflection may have been formed during the post-glacial sea-level rise. Clays and peats might be expected to be preserved where depressions (possibly estuaries) existed at the coastline when sea-level rose here. The settings in which these layers were deposited could be sites of possible occupation by native peoples present in the region about 10,000 years ago.

A map of the elevation of the base of the sand layer can be constructed by subtracting the sand-layer thickness from the water depth (Figure 13). The base-layer elevation map suggests that the sediment surface at that time was somewhat flatter than the modern sea floor with NW-SE trending ridges spaced about 1 km (0.5 nm) apart that are between 0.5 m and 2 m (1.5 ft and 6.5 ft) high. Some of the details of the sediment thickness distribution appear to be caused by the surficial sand layer filling in low areas of pre-existing topography.

A total of 61 vibracores were collected from the Fire Island Design Area during ASAP studies in 2015 and 2016. Coring was concentrated on the two larger sand ridges and 47 vibracores were collected from the larger, eastern ridge and 14 vibracores were collected from the smaller, western ridge (Figure 11). In general, the cores all recovered sandy sediments at the surface and (if long enough) at depth, but many cores recovered sediments between surficial and deep sand layers that were considerably finer (including clay and peat) or coarser (including small rocks). The mid-depth layer with a variable sediment type appears to correspond to the seismic reflection at the base of the sand deposit or to the sediments that immediately underlie that reflection.

The subbottom depth range of the sand layer as determined by the seismic profiler can be used to assign the grain size analyses done by ATPIM in the recovered sediments to the surficial sand layer, the deep sand layer, or the layer immediately below the base-of-sand reflection (Figures 14 and 15).

On the eastern sand ridge, sediments in the surficial sand layer are moderately sorted, medium to fine sands with mean sizes ranging from about 1.2 phi to 2.5 phi (about 0.4 mm to 0.18 mm; Figure 14). 80% of the cores (38 out of 47) contained sand layers where the mean size is coarser than 1.7 phi (0.30 mm); however, there is no clear pattern in the distribution of the coarser layers. Sediments in the deep sand layer are also moderately sorted, medium to fine sands with mean sizes ranging from about 1.0 phi to 2.9 phi (about 0.5 mm to 0.13 mm). The coarser samples in this layer (mean size coarser than about 2.0 phi (0.25 mm) are found primarily in the central (crestal) and eastern portions of the deposit while the finer samples can be found in most areas of the deposit. The deeper sand layers are mostly quite thick, are generally restricted to the eastern and western flanks of the eastern ridge and are often in sediments with mean sizes of 2.0 phi to 2.5 phi (0.25 mm to 1.8 mm).

The term "silt distributed in laminae" is used to describe thin beds (on the order of 1 cm thick (0.03 ft) in many of the deeper sand layers in this area, for example NY_BOEM_2016_VC22 from 7.9 to 15.2 ft. While these sediment intervals have not been studied in any detail, the laminated character is reminiscent of varved sediments which are sediments where a layering pattern is generated as a result of annually varying sediment input. In glacial settings, the layering often results from a high sediment influx of coarser sediments during the summer melting followed by a layer formed by finer sediment settling during the winter when sediment influx is low and lakes are frozen. Other processes, including sediment transport by currents, can also create laminated sediments so additional work in these deeper beds is needed.

A cross-section of sediment size for the eastern sand ridge can be constructed from vibracores that cross the ridge (Figure 16). This cross-section suggests that the upper part of the surficial sand layer is somewhat coarser than the lower part since mean size is coarser than 2.0 phi (larger than 0.25 mm) in the upper part and finer than 2.0 phi (smaller than 0.25 mm) in the lower part. Sediments immediately below the base of the surficial sand layer have more variable size, ranging from clay and peat to very coarse sand with rocks. Sediments in the deeper sand layer have a somewhat variable distribution, but can be coarser or finer.

On the western sand ridge, sediments in the surficial sand layer are also moderately sorted, medium to fine sands with mean sizes ranging from about 1.5 phi to 2.7 phi (about 0.35 mm to 0.15 mm; Figure 15). Only 43% of the cores (6 out of 14) contained sand layers where the mean size is coarser than 1.7 phi (0.30 mm) and the coarser layers are restricted to the eastern and crestal regions of the sand ridge. Sediments in the deep sand layer are also moderately sorted, medium to fine sands with mean sizes ranging from about 2.0 phi to 3.1 phi (about 0.5 mm to 0.12 mm). The coarser sediment samples generally are from the crestal or eastern portions of the deposit while the finer sediment samples are more commonly on the flanks of the deposit. The term "silt distributed in laminae" is also used to describe many of the deeper sand layers from the western sand ridge, and these sand layers are mostly found in crestal and western regions of the sand ridge.

Sediments in the base-of-sand layer are quite variable and range in size from clay and mud to granules and pebbles. The sediments in this layer are poorly to very poorly sorted and descriptions mention peat, wood fragments and rocks. This complex layer was not recovered in all cores that penetrated the base-of-sand reflection, but the absence of the sediment in any particular core may be due to the coring process rather than the layer not being present.

Two resource sand areas have been delineated on the basis of the seismic profile and vibracore data in this area (Figure 17). Resource area FID_SR1 includes the eastern sand ridge and resource area FID_SR2 includes the western sand ridge. The bottom depth of both areas is set by the depth of the prominent base-of-sand seismic reflection which generally corresponds to the top of the coarse base-of-sand horizon.

Fire Island Inlet Design Area

The Fire Island Inlet Design Area is located 5.6 km to 8.3 km (3 nm to 4.5 nm) south of Jones Beach Island, NY in water depths of 15.9 m to 23.1 m (52.2 ft to 75.8 ft) referenced to NAVD 88 (Figures 18 and 19). The area contains two prominent ridges spaced 1.7 km (0.91 nm) apart that trend WNW to ESE that have heights ranging from about 3 to 5 m (10 ft to 16 ft). The multibeam backscatter mosaic shows a large swath of higher backscatter trending WNW to ESE in the center of the study area with smaller regions of higher backscatter to the east and west (Figure 20). Three surface samples fall in or at the edge of the high-backscatter area and have mean grain sizes of 1.4 phi to 2.0 phi (0.37 mm to 0.5 mm). One nearby surface sample to the north appears to fall in an area of lower backscatter when USGS and NOAA backscatter data is also studied, and that sample has a mean size of 2.2 phi (0.22 mm). The regions of higher backscatter are located on the eastern flanks of the mapped sand ridges.

Seismic profiles show that there are two primary sediment deposits separated by a prominent, nearly flat-lying reflection at depths of about 1 m to 2.5 m (3 ft to 8 ft; Figure 21). It can be difficult to trace the near-surface seismic reflection in the region between the sediment deposits since the layer is thin, and as a result there are many areas where no reflection depth is reported (Figure 22).

Seismic profiles generally do not resolve layering within the deeper section except to show the presence of depressions with numerous fine laminations (Figures 21 and 23). The laminations are truncated where they intersect the prominent, nearly flat-lying reflection at the base of the surficial sand layer demonstrating the erosional nature of the contact. At the eastern edge of the survey these laminated deposits are apparently in a prominent channel that crosses from NW to SE (Foster et al., 1999; Schwab et al., 2000a,b; 2014a, b) but smaller regions of laminated sediments are observed throughout the survey area. One depression that is about 120 m (395 ft) wide has been traced laterally for about 360 m (1,180 ft). This depression is oriented ENE-WSW and does not align with channels mapped nearby. This deposit is similar in form to the laminated depressions described in the Fire Island Design Area and may have a similar origin, being formed when sediments are deformed by a glacial advance and then being filled by laminated sediments when the ice front is landward of this site. The interface between the surficial sand layer and the deeper layers is generally quite sharp suggesting that sedimentary units deposited during the post-glacial sea-level rise are not well preserved.

The map of the elevation of the base of the sand layer shows that ridges similar to the present topography existed prior to the base-of-sand layer. The mapped surficial sand deposits that were mapped were deposited on the southwest flank of the prior ridge and in depths greater than about 20 m (65.6 ft), NAVD 88 (Figure 24).

Only one vibracore has been collected from this study area, and that core is from the eastern ridge and sediment deposit (vibracore NY-BOEM-2015-VC20; Figure 25). Three grain-size samples that correspond to the surficial sand layer are moderately sorted with mean sediment sizes of 2.01 phi to 2.59 phi (0.25 mm to 0.17 mm) and two grain-size samples that correspond to the deeper sand layer are well sorted with mean sediment sizes of 1.47 phi to 1.96 phi (0.36 mm to 0.26 mm). One sediment sample from a subbottom depth of 2.3 m (7.6 ft) is from a layer described as having coarse grains, shell hash and large shell fragments. This poorly sorted sample has a mean size of 0.65 phi (0.64 mm) and may have been formed as the underlying sediment was eroded during the post-glacial sea-level rise. It is not known how the nature of the sediments at or immediately below this interface varies throughout the area since only core was collected in the region.

One sand resource area has been delineated on the basis of the seismic profile and vibracore data in this area (Figure 26). Resource area FIID_SR1 includes the eastern mapped sediment deposit. A resource area could potentially be delineated at the site of the western mapped sediment deposit; however, there is no vibracore sample available to characterize this deposit.

Moriches Inlet Design Area

The Moriches Inlet Design Area is located from 5.7 km to 8.9 km (3.0 nm to 4.8 nm) off Moriches Inlet, NY in water depths of 25.2 to 32.4 m (82.6 ft to 106.3 ft; NAVD 88; Figures 27 and 28). This area contains two prominent ridges oriented WNW to ESE up to 4 m high that are spaced 0.8 km to 1.7 km (0.43 nm to 0.92 nm) apart. The multibeam backscatter image shows a more complex pattern of surficial sediments than in the other design areas with numerous, smaller patches of higher backscatter (Figure 29). The regions of higher backscatter are primarily on the crests and north-east flanks of the prominent ridges. Four surface grain-size analyses are available from this area. One sample from the central region of lower backscatter has a mean size of 2.43 phi (0.18 mm), one sample from a region of higher backscatter in the southwest has a mean size of 0.93 phi (0.52 mm), one sample from a center-east region of high backscatter has a mean size 0f -0.74 phi (1.67 mm), and one sample in an area of variable backscatter has a mean size of 1.96 phi (0.26 mm). While surface samples show that the two sampled areas of high backscatter are coarse sand and very coarse sand, the thicknesses of these coarse surface sediments are not known.

Seismic profiles show that sediment deposits up to 3 m (10 ft) thick with flat-lying reflections at their bases are present in several areas, but that much of the region is characterized by a surface sediment layer thickness that is less than 2 m (6.8 ft) (Figures 30). In some areas the near-surface reflection is difficult to follow, apparently because sound from the profiler is scattered or attenuated by coarser surface sediment. The thickness map shows four areas where the surficial sand layer is about 3.0 m (10 ft) thick (Figure 31). One is on the western end of the study area while the other three are on the eastern end.

Seismic profiles from the Moriches Inlet Design Area show the presence of several layers beneath the surficial sand layer (Figure 30). These layers are quite variable in thickness and the interfaces between layers may indicate past erosional events. Also, no laminated deposits are observed within this deeper sand layer. The fact that deeper reflections can be observed in this unit suggests that sediments here have not been deformed by glacial movement.

A map of the base-of-sand reflection shows that the pre sand-layer sediment surface had few of the large sand ridges, and a small channel-like depression may exist crossing from WNW to ESE (Figure 32). The upper sand deposits have little relationship to the underlying topographic surface suggesting that the modern ridges have developed as a response to the modern sedimentary regime.

Only one vibracore has been collected from this study area, and that core is from the flank of the north-eastern sediment deposit (vibracore NY-BOEM-2015-VC35; Figure 33). Medium sands are recovered in the core to a depth of 2.5 m (8.2 ft). Mean size ranges from 1.19 phi to 1.96 phi (0.44 mm to 0.26 mm). The quartz sands are generally moderately sorted, but a layer with large shell fragments and a clayey pocket described at a depth of 1.24 m to 1.8 m (4.1 ft to 6.0 ft) is poorly sorted. Sediments recovered from 2.5 m to 3.4 m (8.2 ft to 11.3 ft) are poorly sorted coarse sands and very coarse rocky sands. Mean sizes range from 0.41 phi to -0.89 phi (0.75 mm to 1.85 mm) and rocks with lengths up to 3.2 mm (1.25 inches) are reported. Sediments recovered deeper than 3.4 m (11.3 ft) are similar to the upper sands being moderately sorted quartz sands. One grain size analysis reports a mean size of 2.22 phi (0.21 mm). The layers with rocky sands from 2.5 m to 3.4 m, and possibly the layer with the clayey pocket from 1.24 m to 1.8 m, were perhaps formed as erosional deposits during a post-glacial sea-level rise.

The vibracore available in this area lies at the edge of an area of thicker sediment and the seismic reflection that marks the base of the upper sand layer is at a depth of about 1.7 m. This is somewhat shallower than the top of the interval with the rocky very coarse sands at 2.5 m, but it is about at the depth of the described clayey pocket. Perhaps the reflection at the base of the sandy layer aligns with the clayey pocket and marks the time when the surface sand layer started to develop. The rocky, very coarse sands and coarse sands thus mark the erosional unconformity that occurred earlier during this sea-level rise. Perhaps the upper sandy layer would not have started to deposit until the water depth at this site was deep enough for sediments to accumulate.

One sand resource area has been delineated on the basis of the seismic profile and vibracore data in this area (Figure 34). Resource area MID_SR1 includes the sediment deposit in the north-east quadrant of the study area. Additional sand resource areas could potentially be delineated at sites of thicker sand in this area; however, there is no vibracore sample available to characterize those deposits.

Summary of Sand Resources Identified in Design-Level Survey Areas

Four sand resource areas have been identified based on the analysis of the design-level geological and geophysical data collected in three ASAP design-level survey areas south of Long Island, New York (FID_SR1, FID_SR2, FIID_SR1 and MID_SR1; Figures 2, 17, 26, 34 and 35; Table 1). The base of each sand resource is marked by a prominent seismic reflection which marks the time when each sand layer started to develop. This development started in a nearshore setting somewhat after the shoreline moved past the site during the post-glacial sea-level rise. The deposits underlying this seismic reflection often contain rocks and shells and/or clays, peats and wood fragments suggesting that they were once at or near the shoreline. The clays, peats and wood fragments suggest that some nearshore deposits from this time may be preserved and these deposits may contain potential cultural artifacts. Thus these are likely to be dredging avoidance depths or areas if these sand resources are exploited.

The dense network of seismic lines in the mapped design areas could lead to the characterization of additional sand resource areas. Additional likely sand resource areas include sand ridges where the surficial sand layer is thicker in the Fire Island Inlet and

Moriches Inlet Design Areas and areas between sand ridges where a surficial sand layer can be mapped in the Fire Island and Moriches Inlet Design Areas. However, the nature of the sediment in these areas is not known in the detail needed to support delineation.

Sandy sediments that lie below the surficial sand layer could also be likely sand resource areas. However, the structure of these deeper deposits is often difficult to resolve on the available seismic profiles. Many more long cores and higher-resolution seismic profiles will be needed to better understand the resource potential of these deeper sand layers.

In addition to delineating sand resource areas, we need to classify the resource areas according to the BOEM Marine Minerals Information System (MMIS) data classification scheme provided in the file MMISDataDictionaryV5.xls dated 01/30/2018. Available choices in order of decreasing likelihood that the area can be used as a future dredging confidence are proven, possible, potential, probable, and unusable. The two most suitable categories for the identified sand resource areas are "proven" for areas where there is both dense seismic data and numerous cores and "probable" where there is dense seismic coverage but only one core. However, the definition of the "proven" category includes the statement that the category is "generally reserved for shoals that have already been authorized as part of a lease." This is not the case for any of the sand resource areas identified in this study and additional data analysis and regulatory review will be needed before any of these areas are authorized as part of a lease. Thus all four of the identified sand resource areas are classified as "probable."

Characterization of Sand Resources in Reconnaissance-Level Survey Areas

The ASAP reconnaissance-level geophysical and geological data can potentially also be used to delineate sand resources outside of the ASAP design areas. In particular, Schwab et al. (2000a,b; 2014a, b) mapped the thickness of a Holocene layer likely to be sandy along the inner portion of the OCS south of Long Island based on USGS seismic data, and at least 20 distinct sand bodies are shown on their maps. ASAP vibracores collected in 2015 sampled nine of the USGS sand bodies and those cores give essential additional information about the nature of the sand layers (Table 2). The vibracores confirm the presence of sands, and cores that penetrated into the underlying sediments generally showed a layer with clayey pocks and/or rocks at the base of the surficial sand layer. Several of the ASAP grain-size analyses in this surficial sand layer showed mean grain sizes coarser than 0.75 phi (0.6 mm) suggesting that important sand resources likely exist in this area. While the Holocene sediment-thickness grid provided by USGS and the sediment data provided by the ASAP cores may give sufficient information to delineate sand resources near the ASAP cores, no sand resources are yet delineated based on these data. This is in part due to the large number of unsampled USGS-delineated potential sand deposits and the elongated nature of both sampled and unsampled deposits.

Surficial (Holocene) sand layer thickness patterns can also be mapped in the New York area using ASAP Reconnaissance-level seismic data. Initial results of this mapping show that the sand-layer sediment thickness patterns are generally consistent with the sand deposits delineated by Schwab et al. (2000a,b; 2014a, b).

Discussion and Conclusions

Our studies of the design-level data collected in three areas south of Long Island allow the identification of the characteristics of four potential sand resource areas and, along with reconnaissance-level data, provide important insights into the nature of sedimentation on this inner portion of the OCS. A surficial sand layer of probably Holocene (post-glacial) age can be identified and mapped with confidence based in the design-level areas. Details of the sediments that underlie the surficial sand layer are more difficult to determine but enough information is available to put forward a likely depositional history for these study areas. Our studies are consistent with there being a dramatic change in sedimentation processes and sediment layering that occurred during the most recent post-glacial sea-level rise that occurred about 10,000 years ago on the inner portion of the OCS south of Long Island. The detailed understanding of sediment deposits earlier than about 10,000 years ago will require a better understanding of terrestrial sedimentation patterns in these areas when sea-level was lower, including at or near the glacial terminus during times of maximum glaciation and during sea-level rise when the area was affected by the breaching of glacial lakes (Uchupi et al., 2001). Intense erosion occurred at the shoreline during the post-glacial sea-level rise, but sediments from shoreline settings may be preserved in some areas at times when sea level was rising at a high rate. Sediments continue to be modified in the modern sedimentary environment, but modern sedimentation patterns are not well understood. Efforts are continuing to study available geophysical and geological data in order to understand the resource potential of sediments and geological history of the inner portions of the OCS.

Our initial efforts to determine the extent, thickness and volume of surficial sand layers in the design-level survey areas have resulted in delineation and characterization of four sand resources up to 3.7 m (12.1 ft) thick and appear to contain a total of 17.8 x 10^6 cubic yards (13.6 x 10^6 cubic meters) of moderately sorted, fine to medium sand. There are other likely potential resource areas that could be described based on the design-level, reconnaissance-level and existing USGS-data from the region, but there are insufficient data to delineate more sand resource areas at this time.

It is important to better understand the layer at the base of the surficial sand layer, since this layer may limit the depth to which sands can be recovered. Additional information on the nature and origin of this layer may come through continuing detailed analysis of the seismic profiles and through the detailed study of sediment cores, including dating of shells and organic matter recovered in the cores. This important layer is apparently not consistently sampled by vibracore, and alternate sediment sampling techniques such as borings may be required to better sample this layer. This poorly defined and variable layer may contain sediments of potential cultural significance if they could be sites of potential prehistoric human occupation.

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Table 1
Details of Delineated Sand Resource Areas in Design Areas

New York Design Area	Fire Island	Fire Island	Fire Island Inlet	Moriches Inlet
Morphological Feature	Sand Ridge	Sand Ridge	Sand Ridge	Sand Ridge
Central Location	40° 35.86' N, 73° 05.03' W	40° 35.16' N, 73° 08.05' W	40° 33.54' N, 73° 20.58' W	40° 42.70' N, 73° 43.04' W
State	New York	New York	New York	New York
Year	2018	2018	2018	2018
Sediment Area ID	FID_SR1	FID_SR2	FIID_SR1	MID_SR1
Sand Unit Thickness (feet)	8.0	8.7	6.6	6.8
Range (feet)	3.8 to 11.3	4.2 to 12.1	4.8 to 7.7	4.8 to 7.7
Uncertainty (+/-)	10%	10%	10%	10%
Area (square feet)	33.96E+06	13.08E+06	6.243E+06	8.369E+06
Uncertainty (+/-)	5%	5%	5%	5%
Volume (cubic yards)	10.01E+06	4.190E+06	1.519E+06	2.111E+06
Uncertainty (+/-)	15%	15%	15%	15%
Confidence*	Probable	Probable	Probable	Probable
Number of Sediment Samples in Resource	152 +3?	56+4?	3	4
Mean Grain Size (Phi)	1.8	2.2	2.3	1.7
Range (Phi)	0.56 to 2.51	1.42 to 2.62	2.01 to 2.53	1.19 to 1.96
Munsell Color	5Y-5/1	5Y-4/1	5Y-4/1	5Y-4/1
Percent Sand	96.8	96.2	95.6	97.4
Range	82.0 to 99.0	88.8 to 98.8	94.1 to 96.7	95.2 to 98.7
Percent Carbonate	2.6	2.0	3.0	2.3
Range	0 to 27	0 to 8	2 to 4	1 to 5
Percent Carbonate Sand**	0	0	0	0
Uncertainty (%)	5	5	5	5
Global Resource ID				
Global Link ID				
CartographicRuleID				

*Confidence definitions (From BOEM):

Assessment of the likelihood that the area can be used as a future dredging area as a result of reconnaissance level studies. The more available environmental data, the more confidence there is in the presence of restoration quality sand.

Proven – resource areas whose thickness and lateral extent have been fully determined through the use of vibracore and/or push cores. Generally reserved for shoals that have already been authorized as part of a lease.

Probable – resource areas whose existence has been established through the use of vibracores, push cores and/or grab samples. Thickness and/or lateral extent has not been fully determined. These are reserves that could be viable if additional coring is done

Possible – features identified as a result of bathymetry delineation of a supposed shoal. No additional physical data exists to support these areas as a resource

Potential – resource areas hypothesized to exist on the basis of indirect evidence such as acoustic subsurface profile (seismic) character or sidescan sonar character. The presence of sand through direct sampling methods has not yet been confirmed.

Unusable – resource areas that as a result of additional surveys, prior dredging activity, or infrastructure development are not (or no longer) suitable for future dredging.

(adapted from Freedenberg and Hoenstine, 1999)

Disclaimer: Sand units appearing homogeneous may actually contain complex units of coarse shells or siliciclastic gravels that lie below seismic resolution

**Percent Carbonate Sand uncertainty:

No number reported for carbonate sand percentage, but shell hash is present in many sand layers.

Table 2

Grain Size Analyses in ASAP Cores from sand bodies delineated by USGS

Core Site (NY-BOEM-)	Easting UTM 18N	Northing UTM 18N	Sand Deposit Thickness* (m)	Grain Size** (mm)	Grain Size** (phi)
2015-VC12	627231	4488185.	1.3	0.23	2.12
2015-VC15	648724	4489407	3.7	0.22 to 0.47	2.18 to 1.09
2015-VC24	666436	4496957	2.1	0.34 to 0.59	1.56 to 0.76
2015-VC34	708139	4514453	3.0	0.20 to 0.67	2.32 to 0.58
2015-VC37	723276	4521211	1.1	0.30 to 0.37	1.74 to 1.43
2015-VC39	713060	4518065	3.2	0.20 to 0.50	2.32 to 1.00
2015-VC41	749002	4533412	2.2	0.21 to 0.62	2.25 to 0.69
2015-VC42	733138	4527706	1.1	0.32 to 0.37	1.64 to 1.43
2015-VC45	760648	4541924	3.6	0.17 to 0.66	2.56 to 0.60

* Thickness as determined by USGS (Schwab et al., 2014a, 2014b).

** Grain size results from ASAP cores in depth range of mapped deposit.

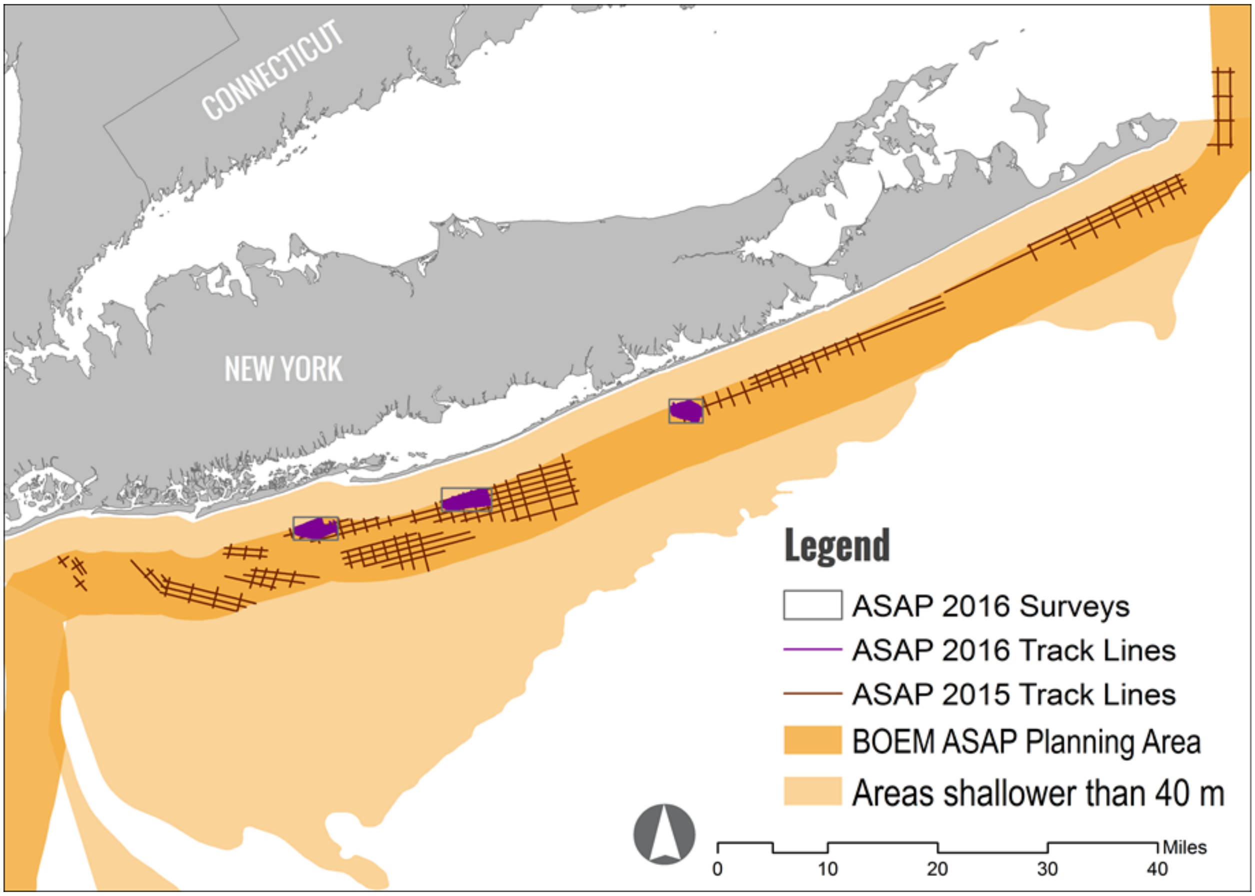

Figure 1. Map of the New York BOEM ASAP Planning Area showing the ASAP 2015 reconnaissance-level geophysical track lines and the ASAP 2016 design-level geophysical track lines and survey locations.

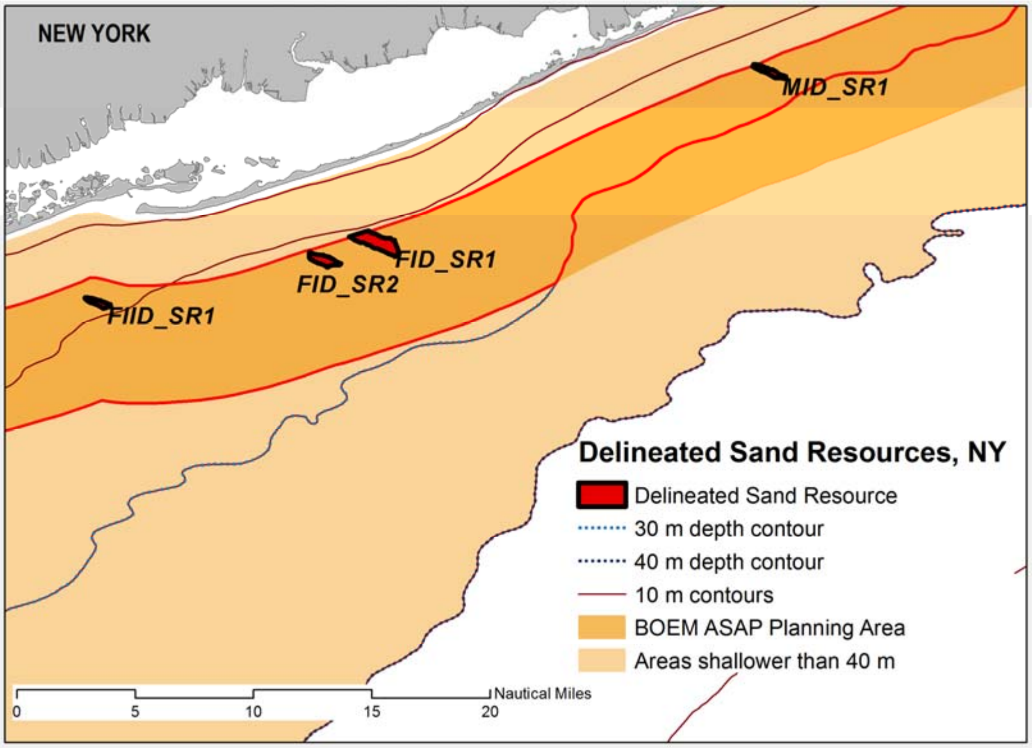

Figure 2. Locations of the sand resources delineated in Federal waters south of Long Island, NY, in this study: FID_SR1, FID_SR2, FIID_SR1 and MID_SR1.

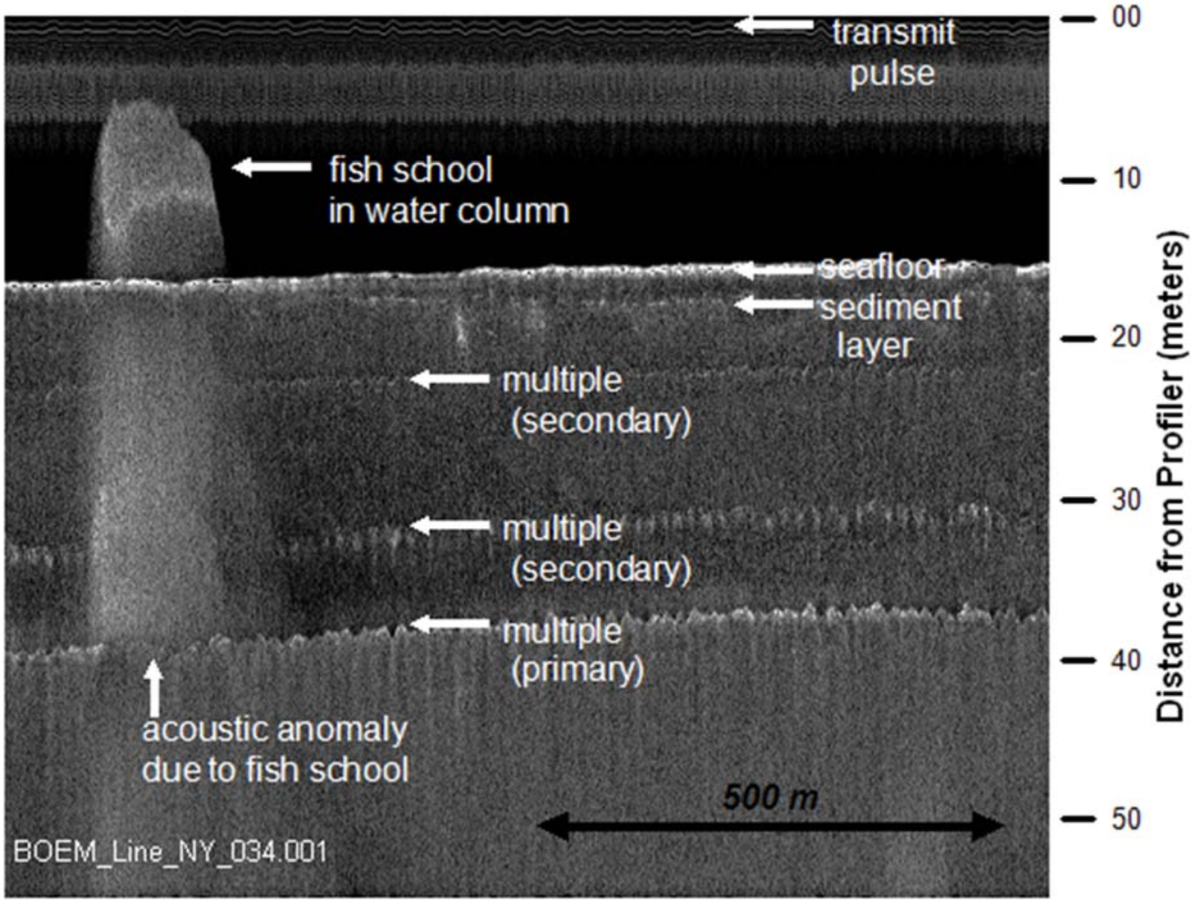

Figure 3. Example chirp subbottom profiles identifying the components of the ASAP seismic profiles. Sound is transmitted at the top of the record and the sound returns are plotted with time down the page. There is a strong return from the seafloor, and we expect that there will also be reflections from interfaces between layers within the sediment. Biogenic gas, deformed layers and coarse sediment, if present, can mask the sediment layering. Fish in the water column can affect the character of the profile by attenuating the seismic signal. The sound pulse returned from the sediment can also bounce of the sea-surface and the sediment surface before being recorded creating reflections called multiples. The depth scale is calculated assuming a sound velocity of 1,500 m/sec in the water column and in the sediment.

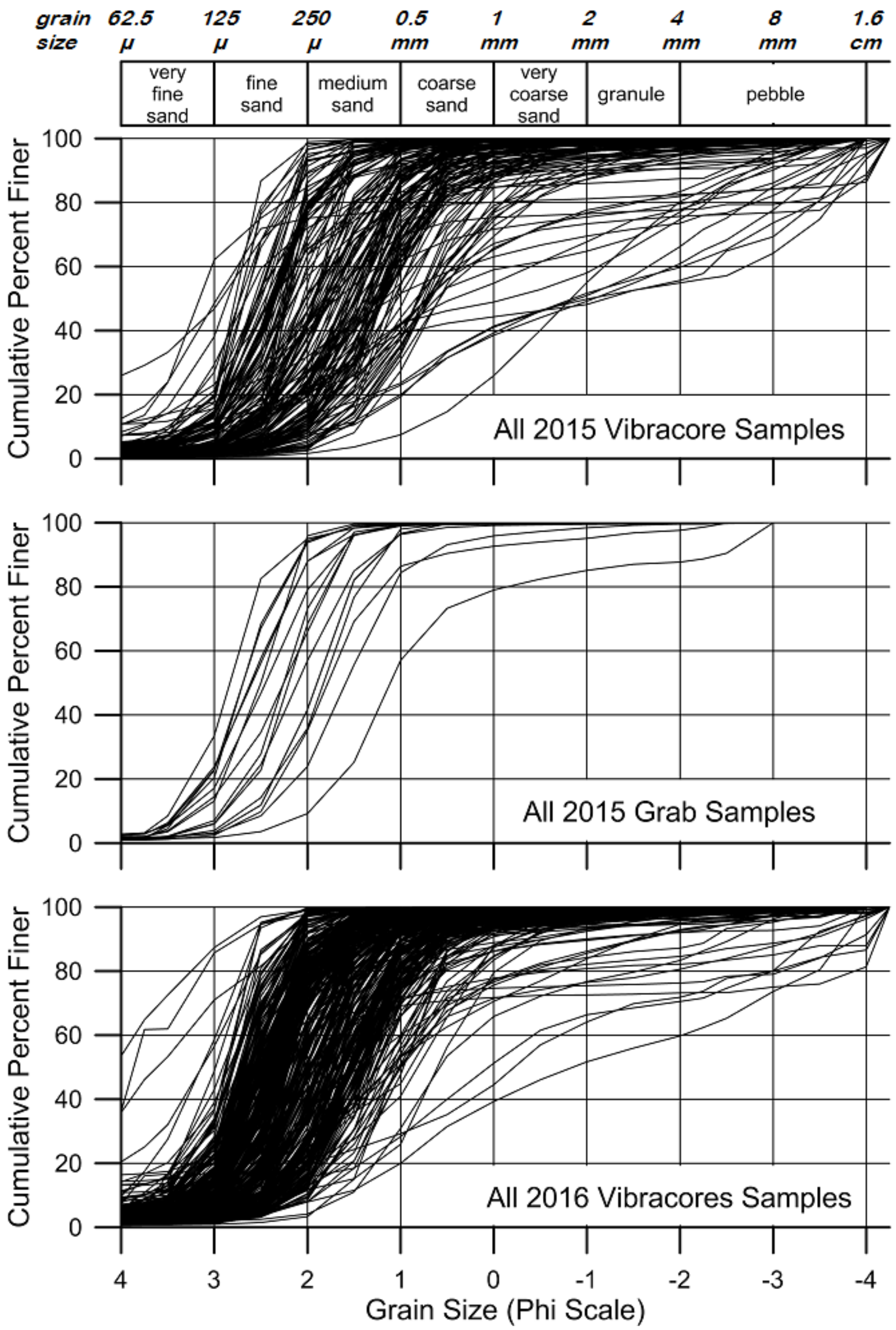

Figure 4. Compilation of all measurements of grain size distribution made on vibracore and grab samples collected during the 2015 and 2016 ASAP studies. The median sediment size is indicated where the cumulative grain size curve passes 50%. Grain size is plotted in phi units, where phi = 2^(-D) , D is in mm, and the top scale shows both the grain size in metric units and the names applied to sediment sizes. The category "sand" includes sediment with mean size from 4 phi to -1 phi. Top: 2015 vibracore samples. Middle: 2015 grab samples. Bottom: 2016 vibracore samples.

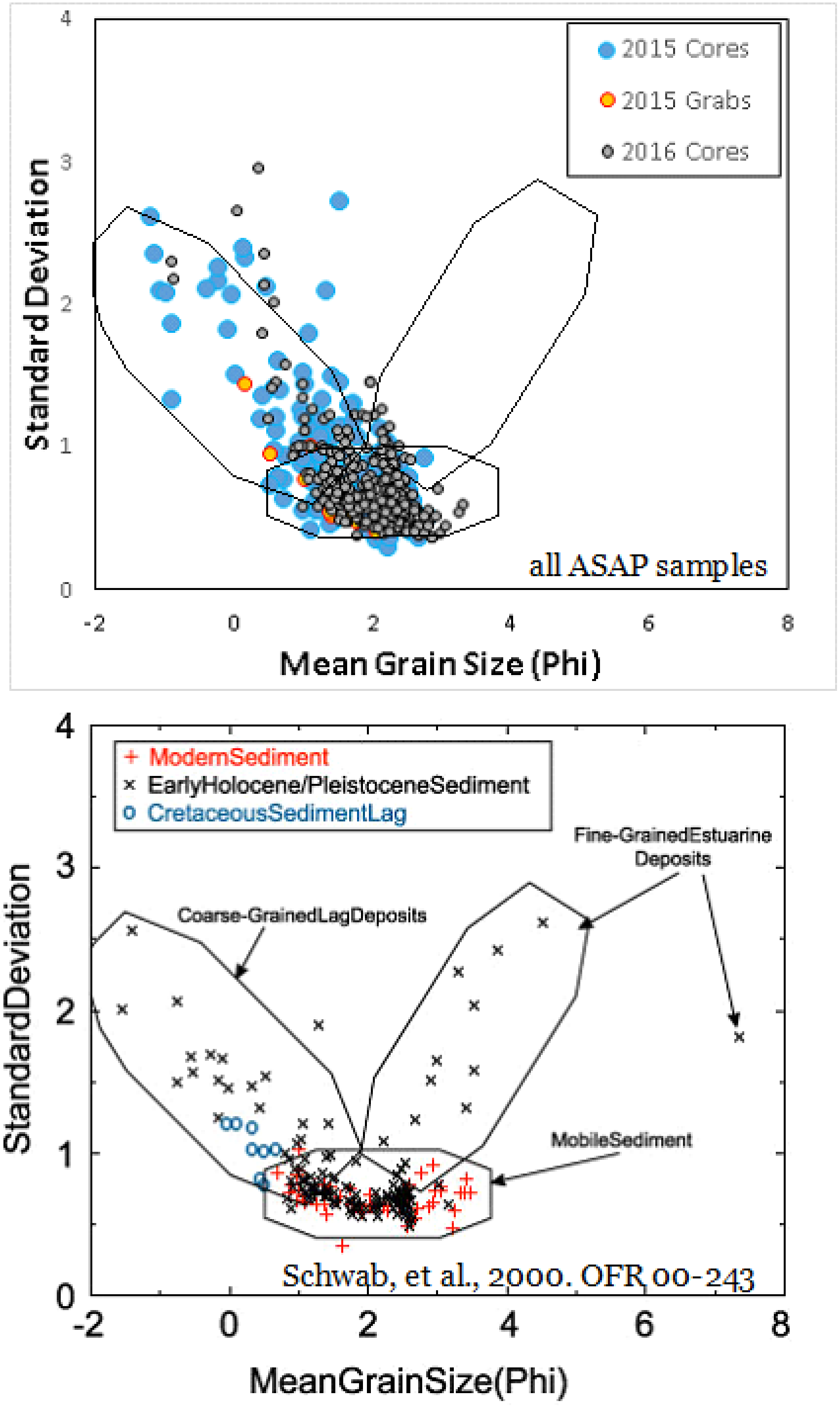

Figure 5. Summary plot of all ASAP sediment sizes with mean size in phi on the horizontal axis and the sample standard deviation in phi on the vertical axis (left). Summary plot of all grain size measurements reported by USGS from the inner shelf south of Long Island (Schwab et al. 2000; right). The distribution patterns are similar between the two data sets except that no grain size measurements were reported for fine-grained ASAP samples.

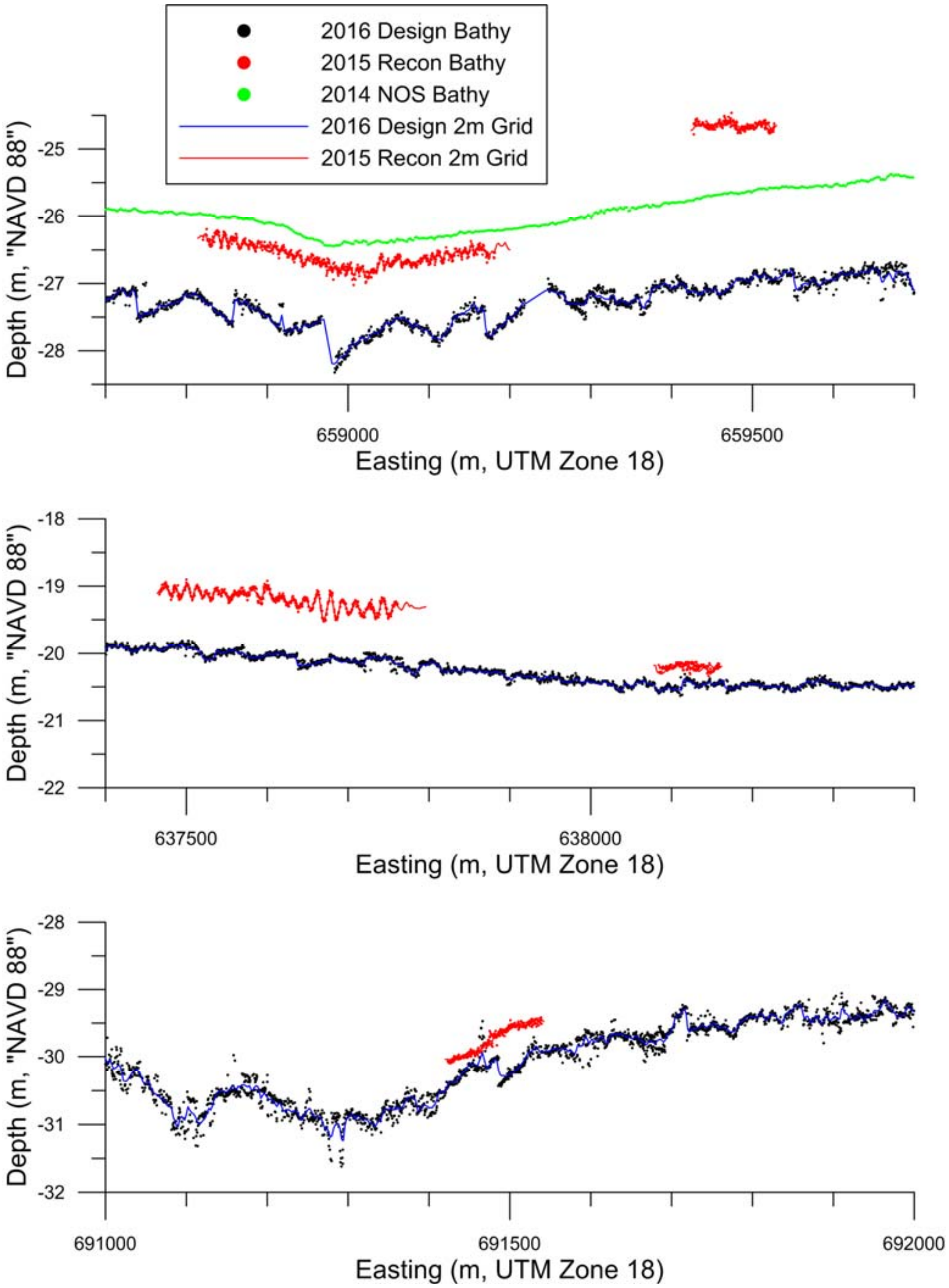

Figure 6. Comparison of bathymetric profiles from ASAP design areas showing vertical offsets between NOS multibeam surveys (where available), ASAP bathymetry reported in 2015 and ASAP bathymetry reported in 2016. The 2015 bathymetry data does not have a consistent relationship to the 2016 bathymetry and the 2016 bathymetry does not agree in detail with NOS bathymetric data. Offsets can be applied to the 2016 ASAP bathymetry data so that it aligns with the NOS bathymetric data when depths are referenced to NAVD 88.

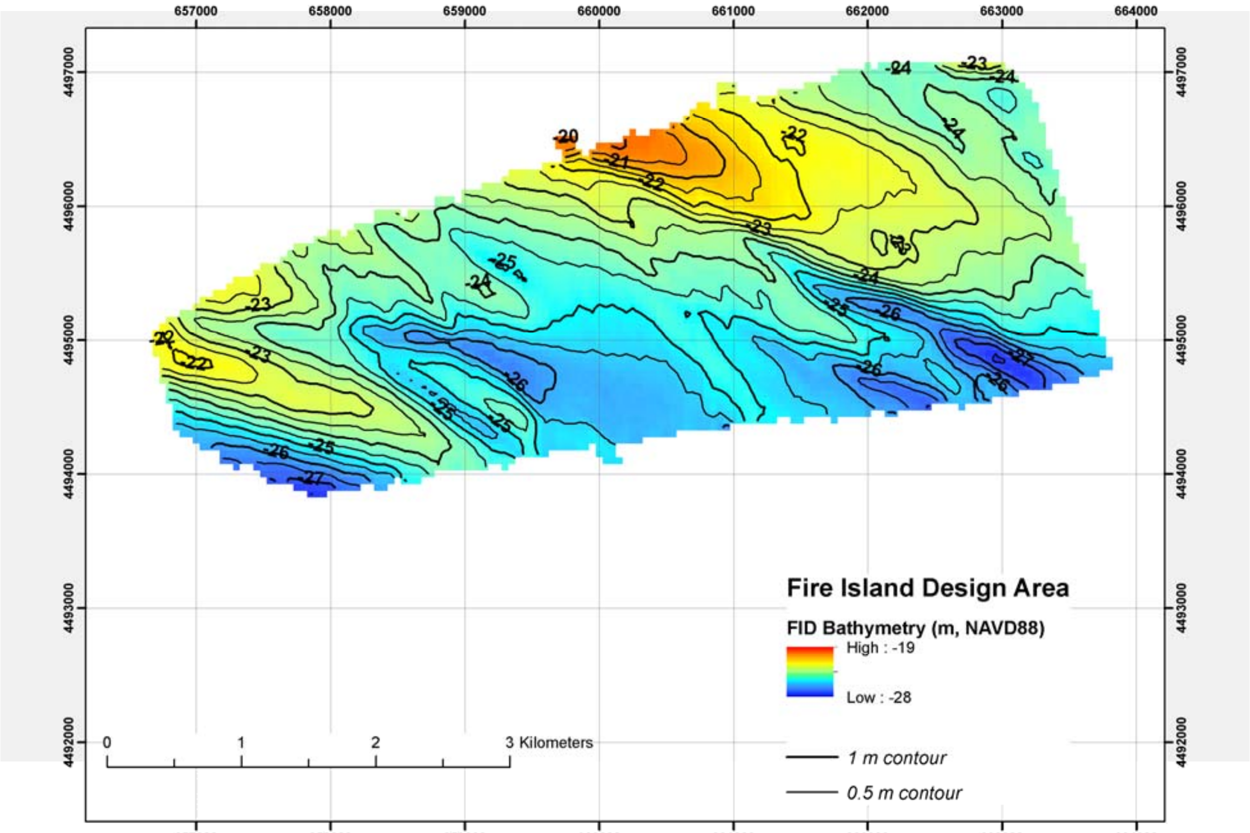

Figure 7. Bathymetric map of the Fire Island Design Area created using offset ASAP 2016 bathymetric data. Contour intervals are 0.5 m and 1.0 m. Depth datum is NAVD 88 and the ASAP bathymetric data has been gridded at 50 m.

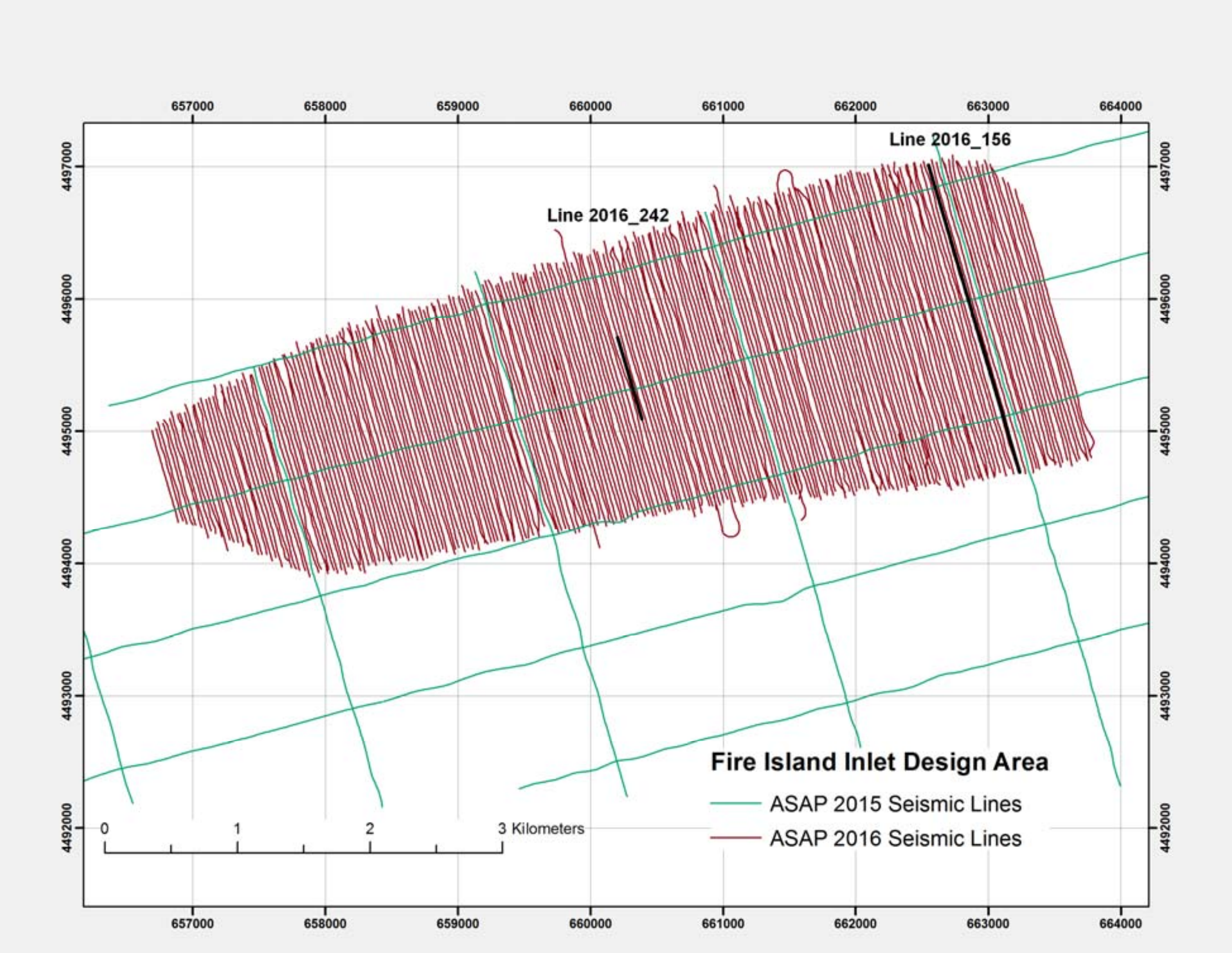

Figure 8. Track lines for seismic (also called subbottom or chirp) profiles collected in the Fire Island Design Area in 2015 and 2016. The locations of the seismic profiles in Figure 10 are also shown.

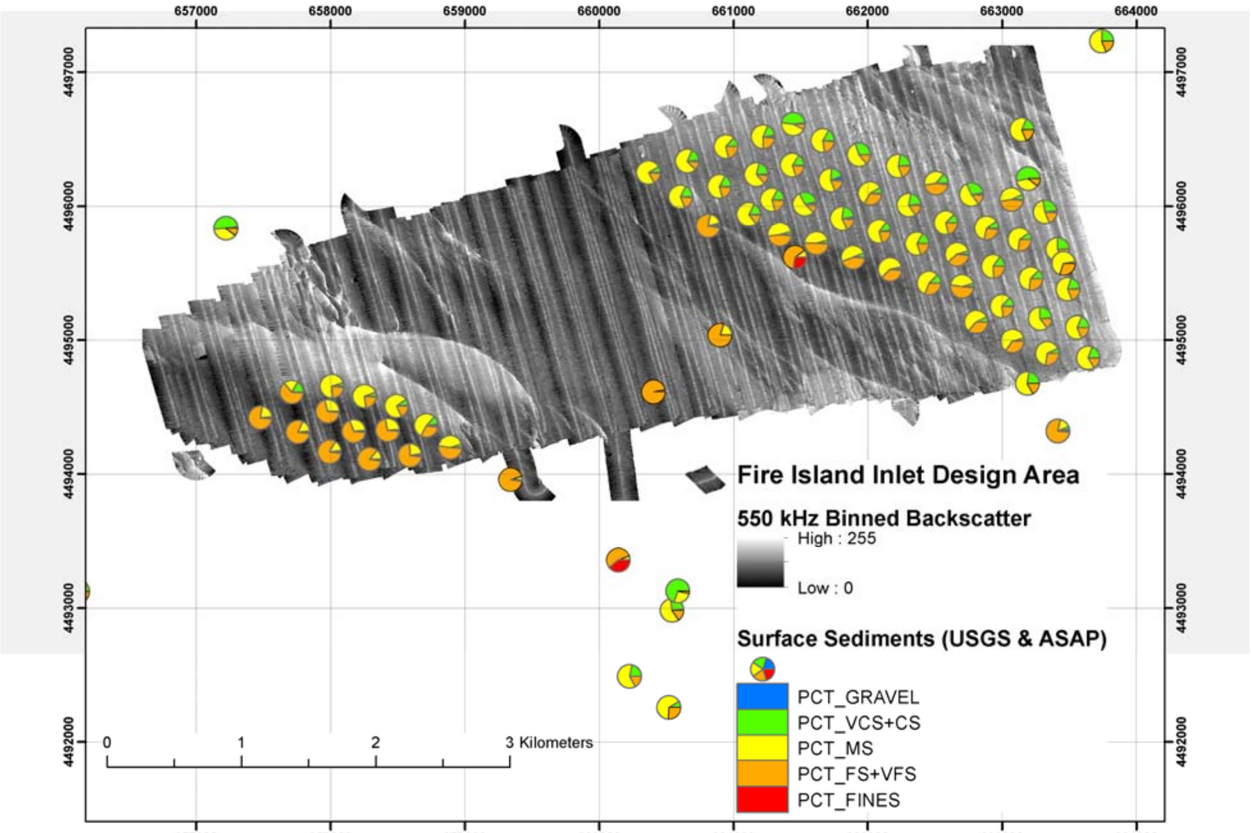

Figure 9. Mosaic of 550 kHz binned backscatter along with size distributions of surface sediment samples in the Fire Island Design Area. Areas of higher backscatter are lighter while areas of lower backscatter are darker. The along-track lineations (NNE to SSW) are artifacts. Areas with coarser sediments tend to have higher backscatter, but samples are not available from some areas with higher backscatter. Note: some of the plotted surface samples do not fall within the area of the mosaic. PCT_GRAVEL is % gravel, PCT_VCS+CS is % very coarse sand and coarse sand, PCT_MS is % medium sand, PCT_FS+VFS is % fine sand and very fine sand, and PCT_FINES is % silt and clay.

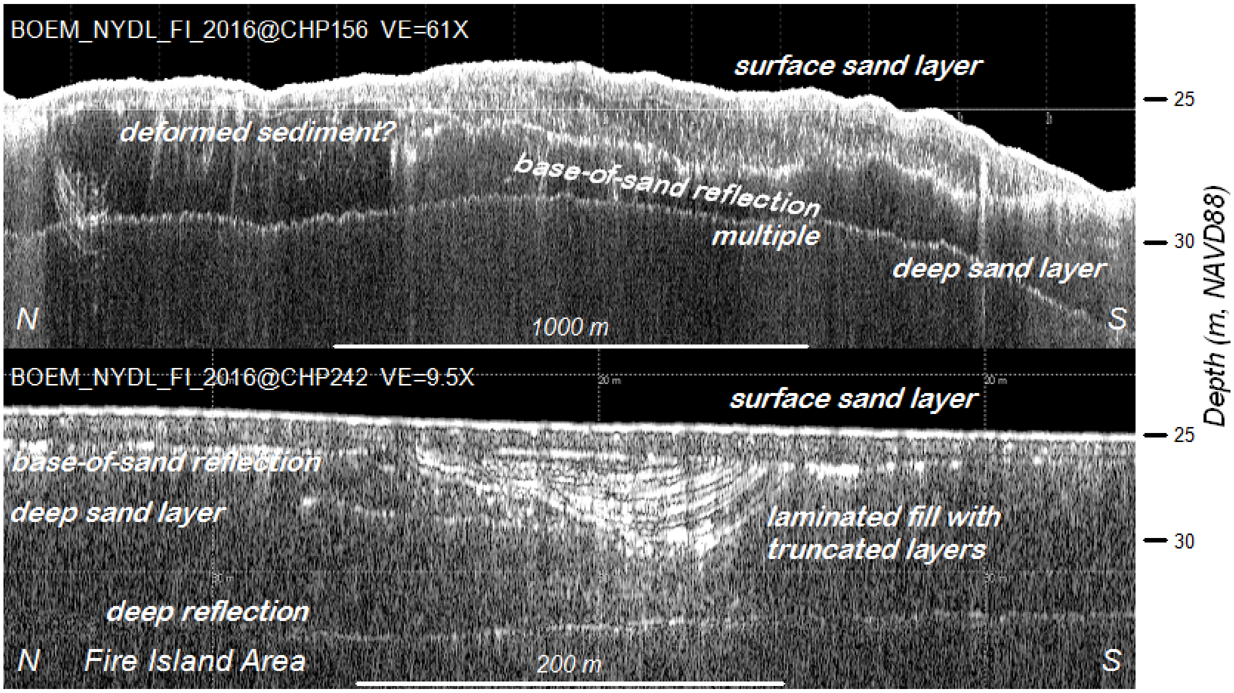

Figure 10. Annotated seismic lines from the Fire Island Design Area. Upper: Example of the surface sand layer, the base-of-sand reflection, the deep sand layer and indications of sediment deformation. Lower: Example of a depression with laminated fill. Note how the laminated fill is truncated by the base-of-sand reflection. The vertical scale of the seismic profiles is exaggerated and the maximum dips of the laminated fill are about 6°. Profiles are located on Figure 8.

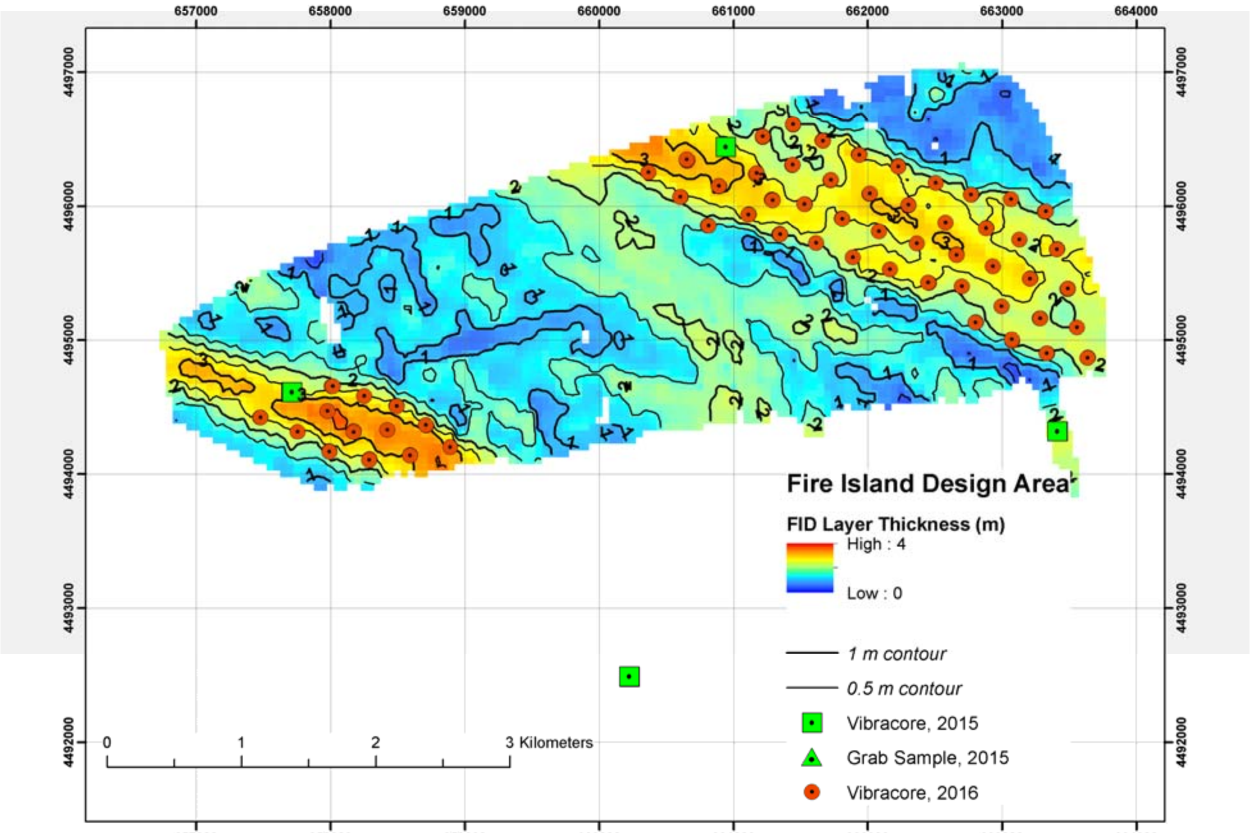

Figure 11. Map of the thickness of the surface sand layer in the Fire Island Design Area determined using seismic profiles. 0.5 m and 1.0 m contours are shown, and sediment thickness calculated using a sound velocity of 1,500 m/s. The locations of ASAP vibracores and grab samples are also shown.

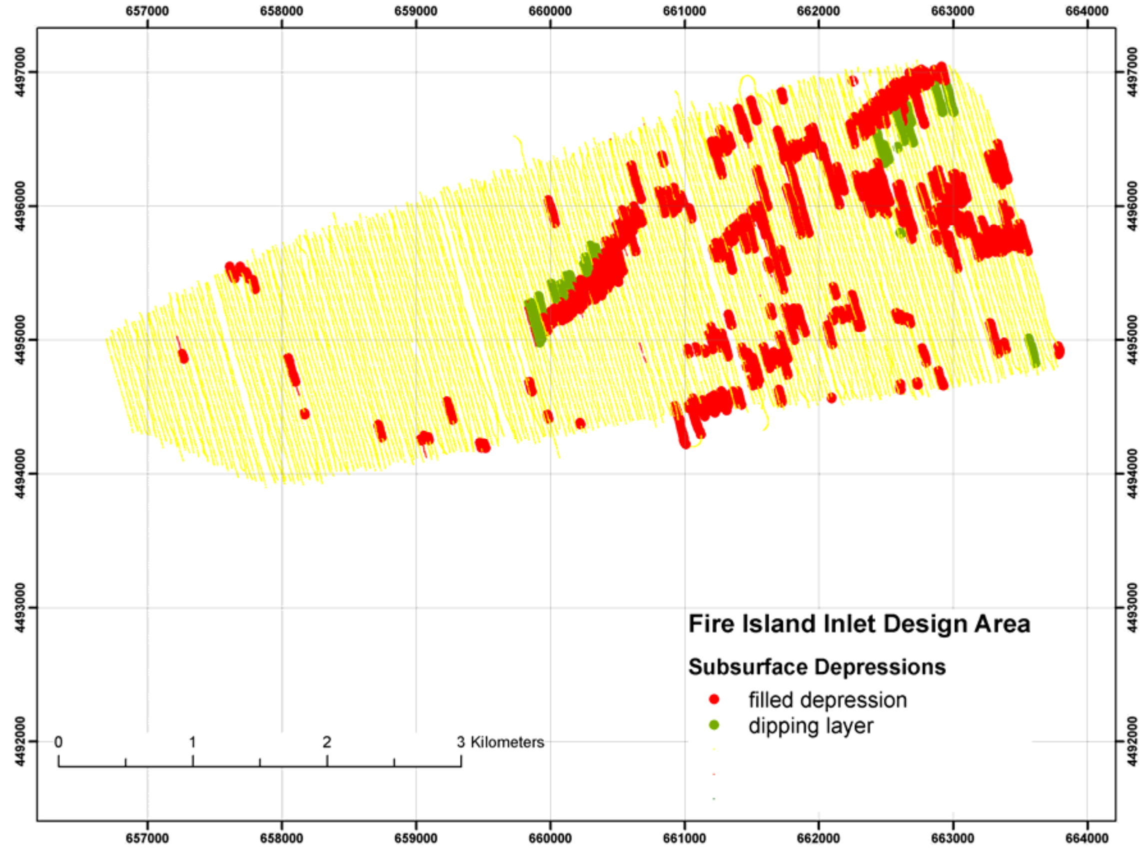

Figure 12. Map showing the distribution of depressions in the upper portion of the deep sand layer in the Fire Island Design Area that are filled with laminated sediments. Also shown are locations of dipping layers within the deep sand layer.

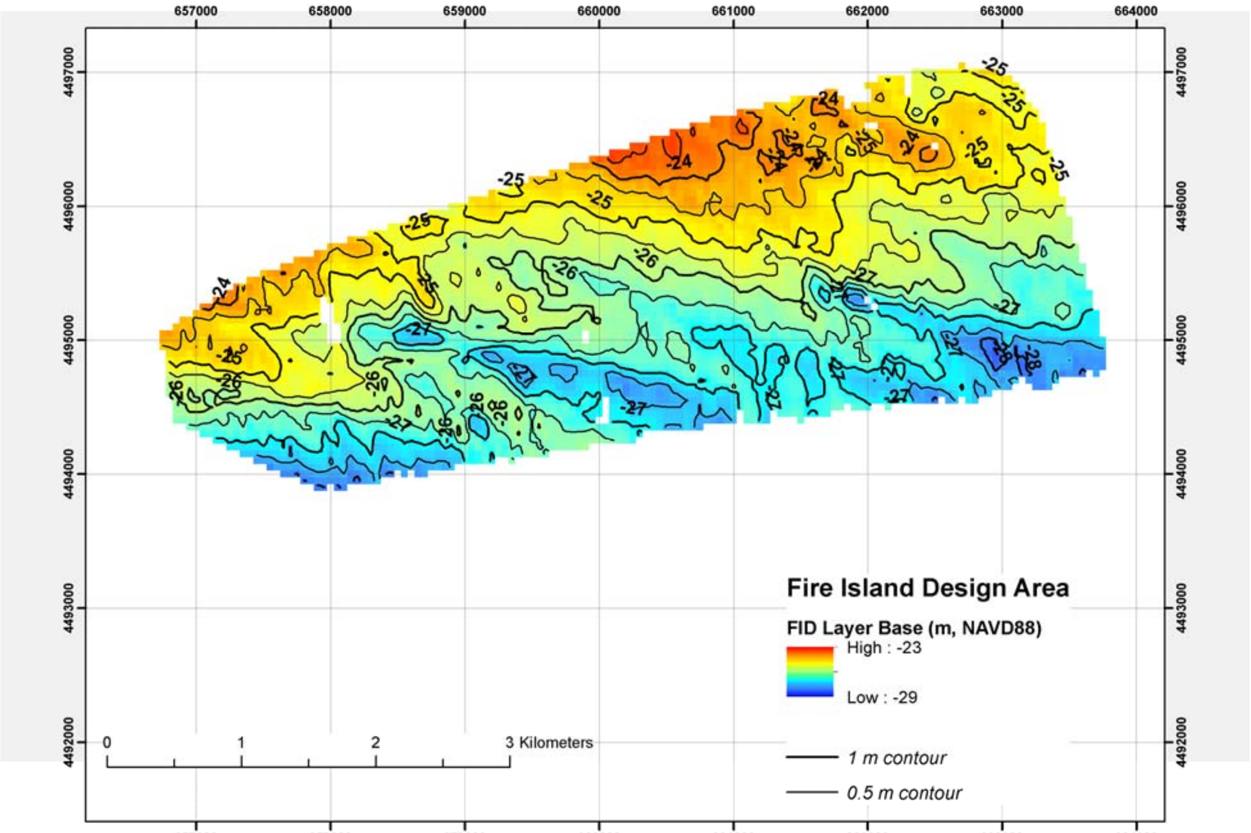

Figure 13. Elevation map of the base of the upper sand layer in the Fire Island Design Area with 0.5 m and 1.0 m contours. This map is created by subtracting the sediment thickness from the surface elevation.

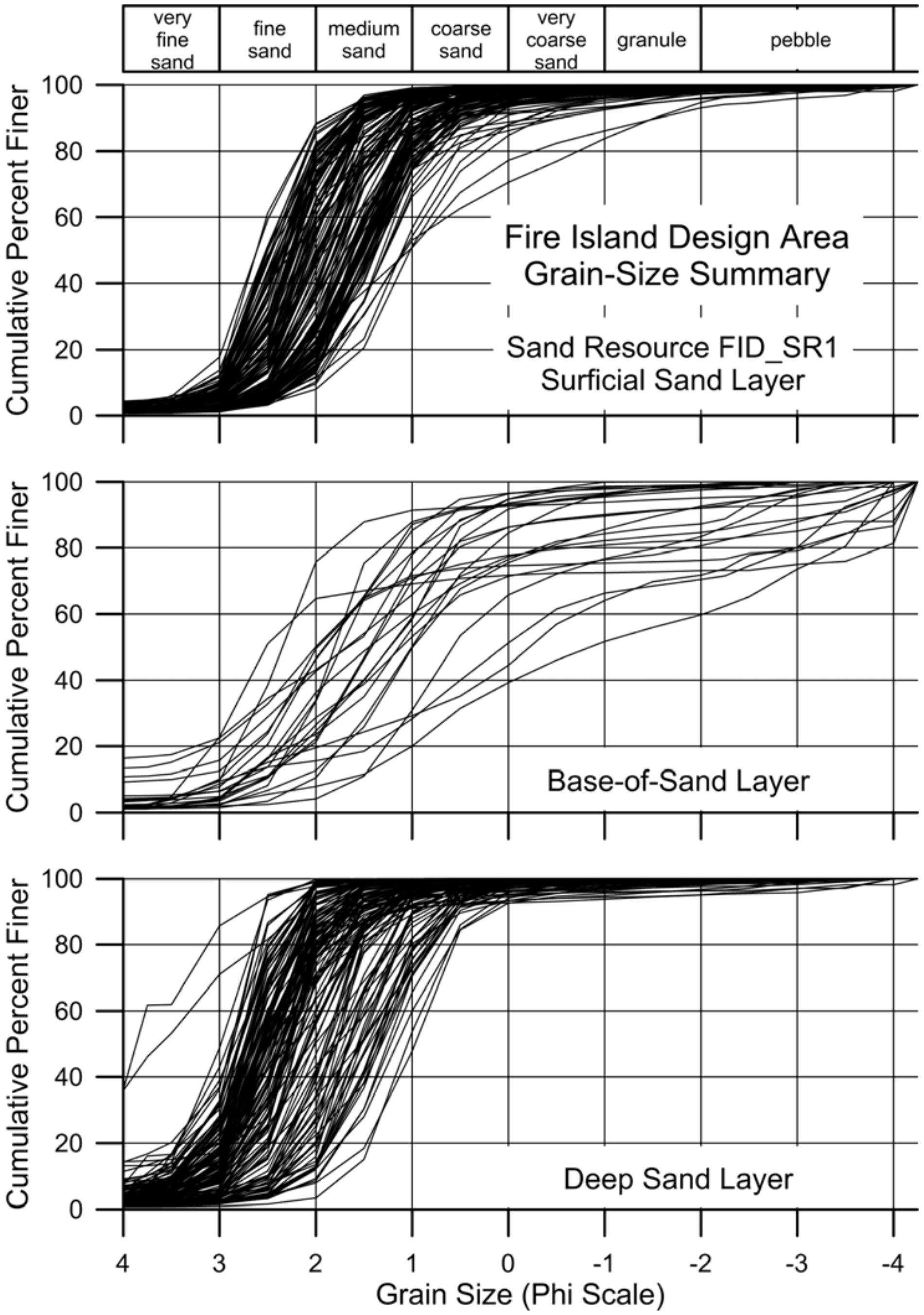

Figure 14. Compilation of grain size measurements from the eastern sand ridge in the Fire Island Design Area. ASAP vibracore samples are from the surface sand layer (top), from immediately below the base of the upper sand layer (middle), and from the deep sand layer (bottom). This surficial sand layer is delimited as the sand resource area FID_SR1.

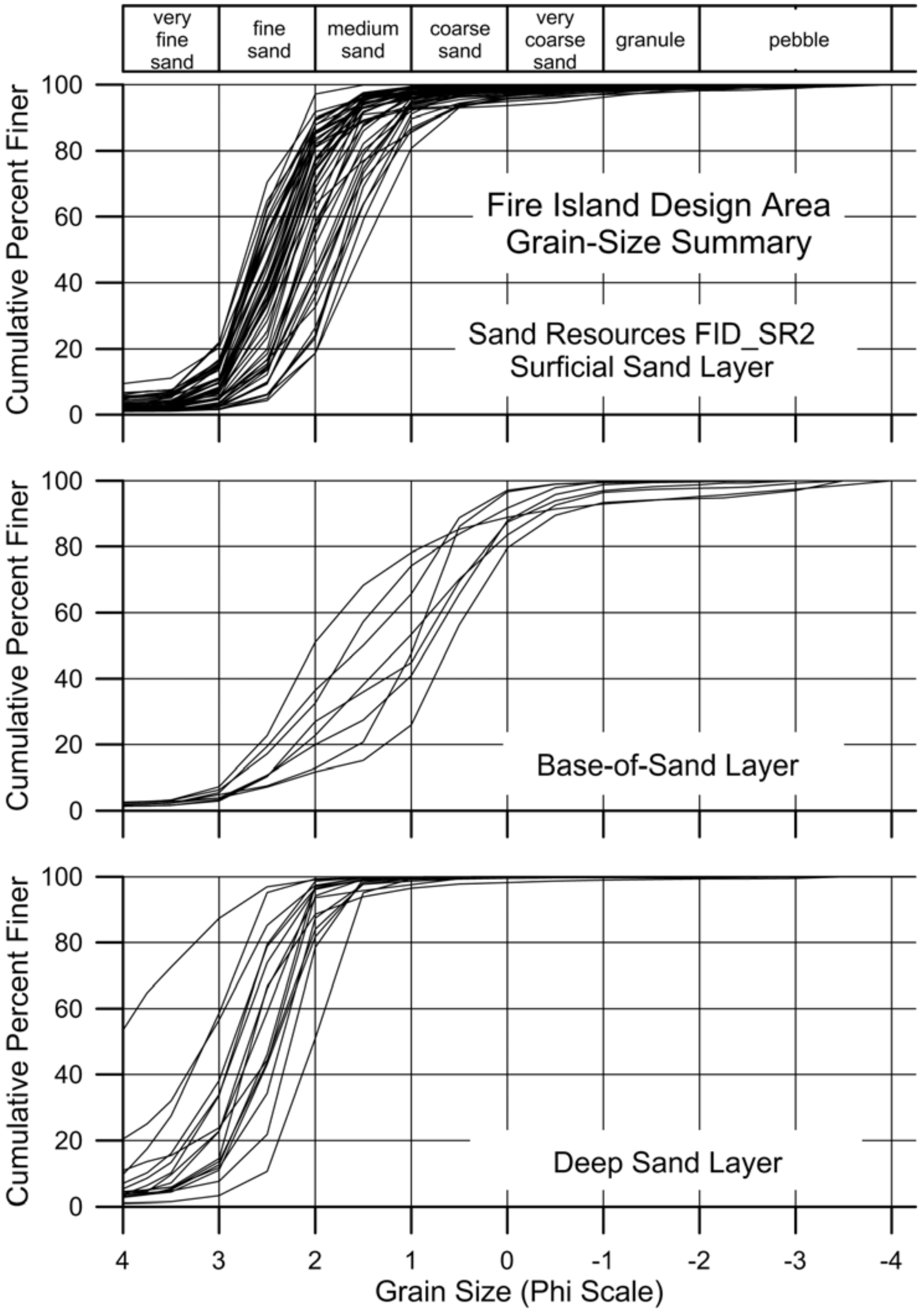

Figure 15. Compilation of grain size measurements from the western ridge in the Fire Island Design Area. ASAP vibracore samples are from the upper sand layer (top), from immediately below the base of the upper sand layer (middle), and from the deep sand layer (bottom). This surficial sand layer is delimited as the sand resource area FID_SR2.

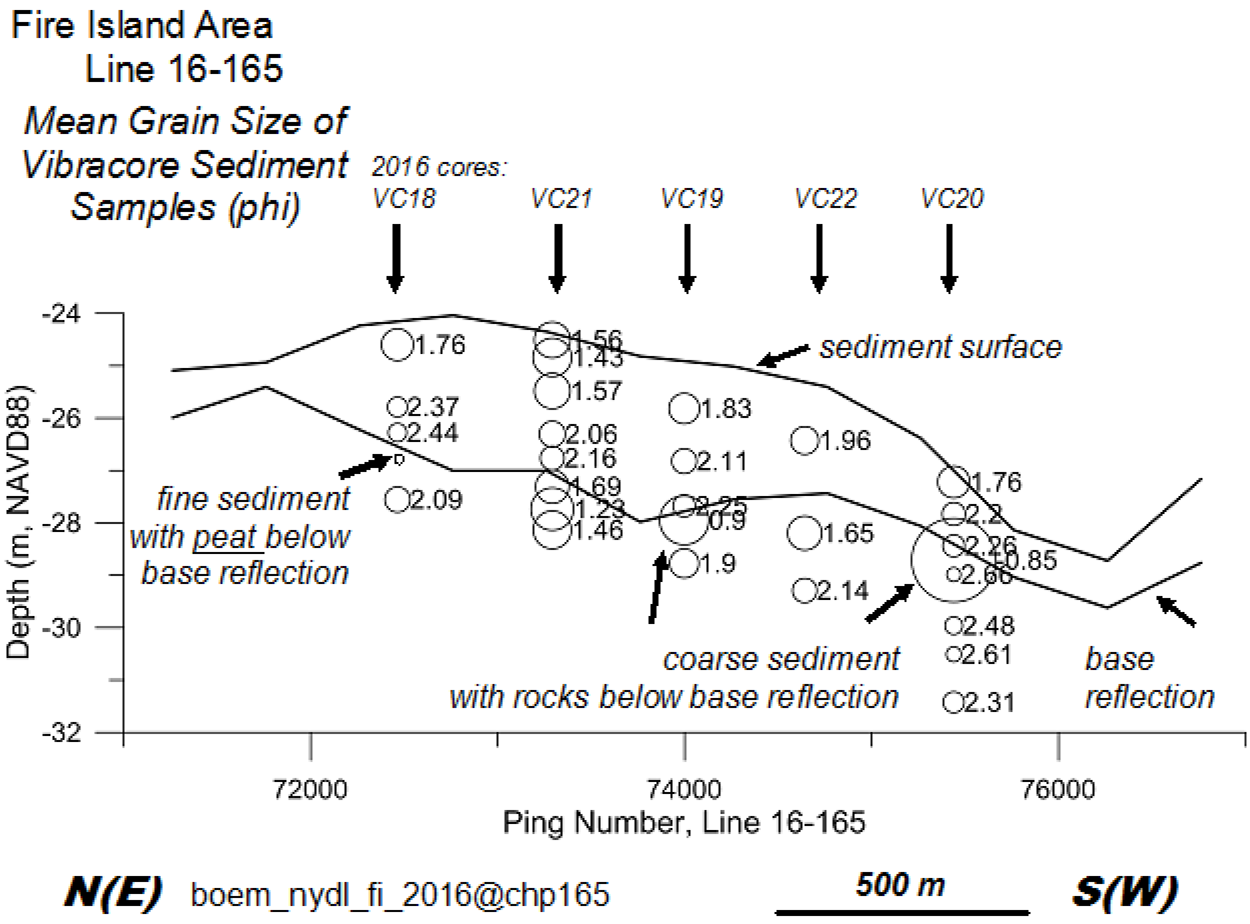

Figure 16. Mean grain size on the sand ridge cross-section in the Fire Island Design Area imaged by subbottom profile 16-165. Larger circles represent sediment samples with coarser grain sizes, and the mean grain size (in phi units) is indicated next to each circle. No grain size measurements were made on clay or peat samples. The north end of the profile is on the east side of the sand ridge and the south end of the profile is on the west side.

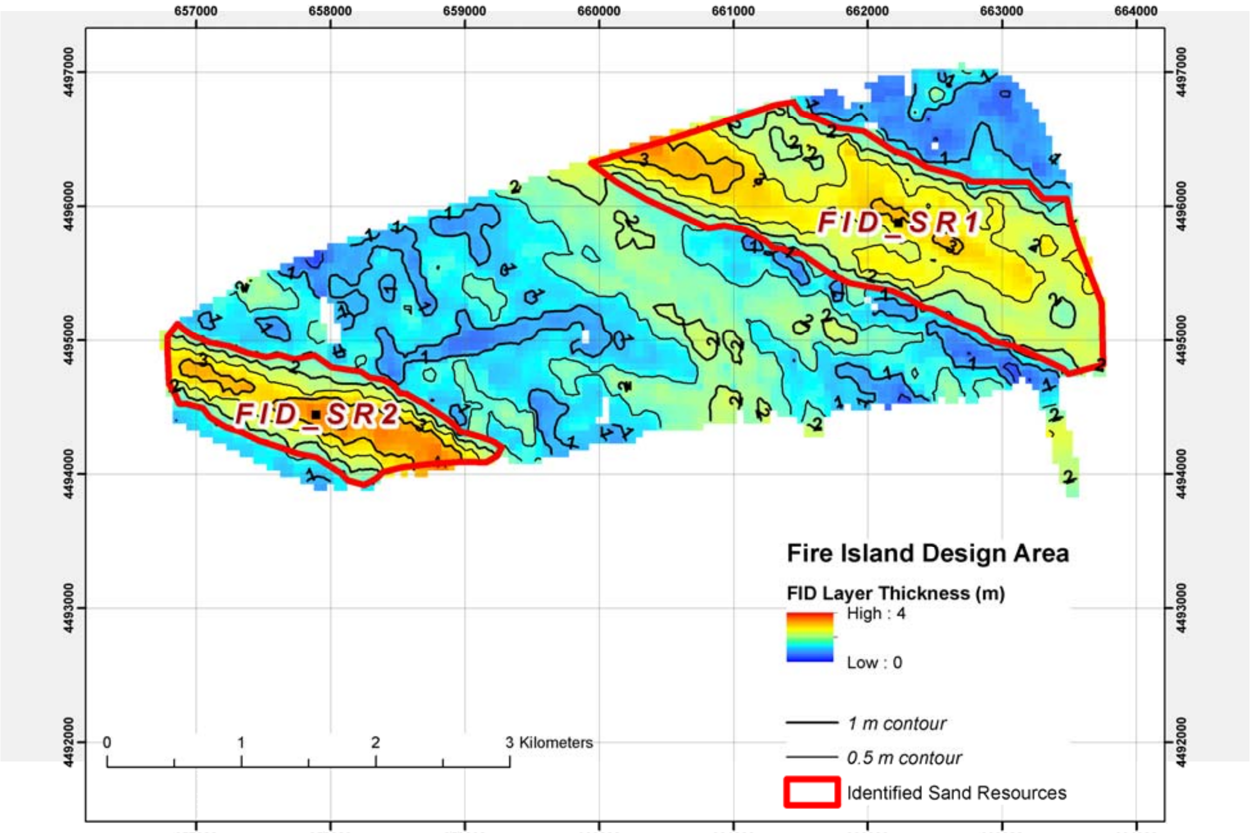

Figure 17. Two sand resource areas are identified in the Fire Island Design Area based on the seismic profile data and vibracore data collected in the area. FID_SR1 occupies the eastern sand ridge, and FID_SR2 occupies the western sand ridge.

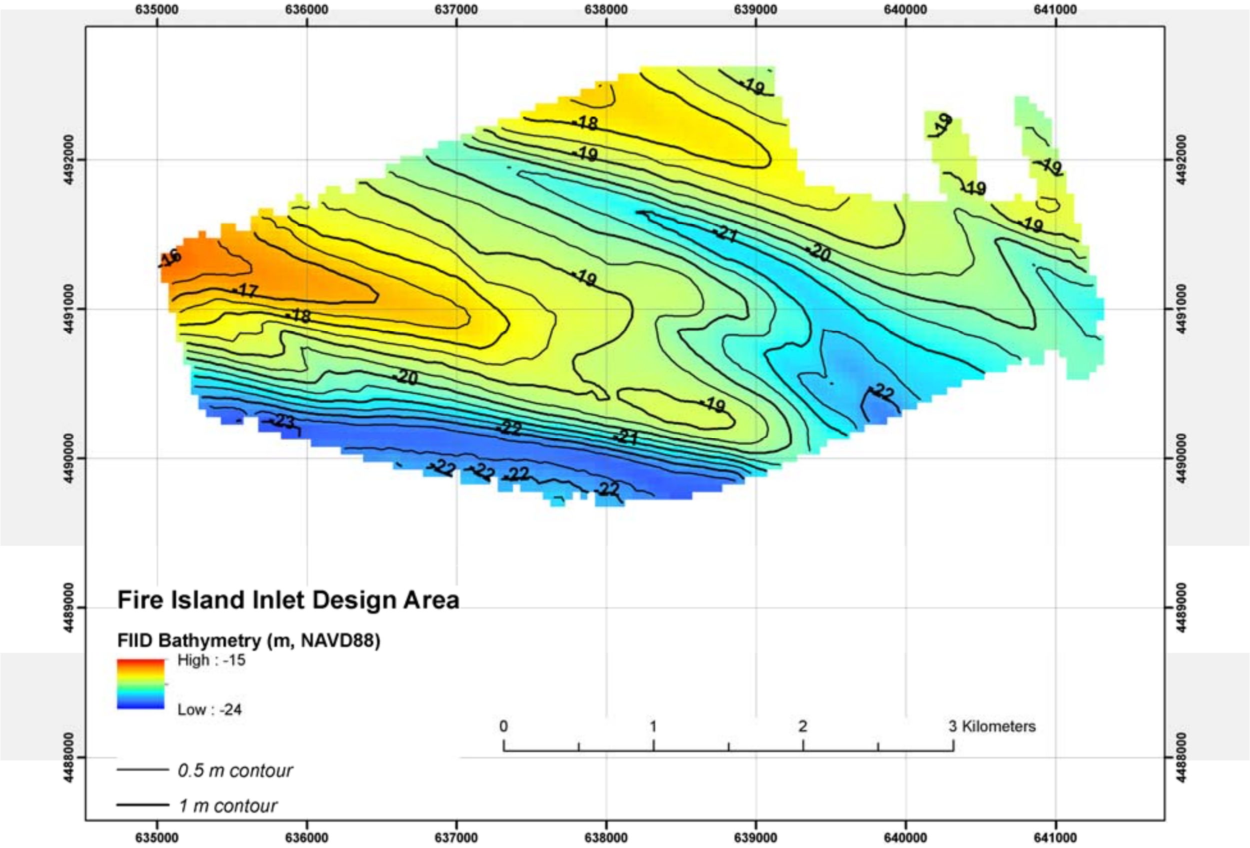

Figure 18. Bathymetric map of the Fire Island Inlet Design Area created using offset ASAP 2016 bathymetric data. Contour intervals are 0.5 m and 1.0 m. Depth datum is NAVD 88 and the ASAP bathymetric data has been gridded at 50 m.

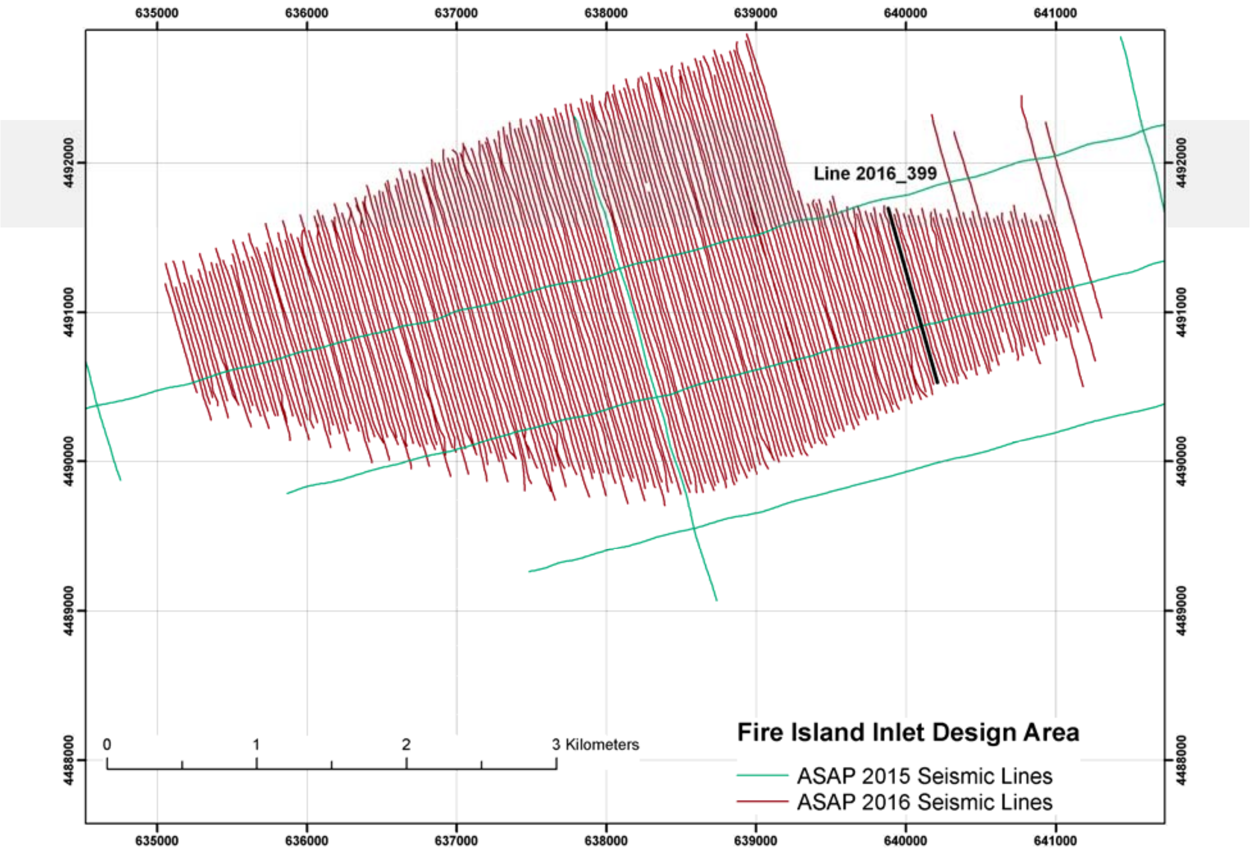

Figure 19. Track lines for seismic (also called subbottom or chirp) profiles collected in the Fire Island Inlet Design Area in 2015 and 2016. The location of the seismic profile in Figure 21 is also shown.

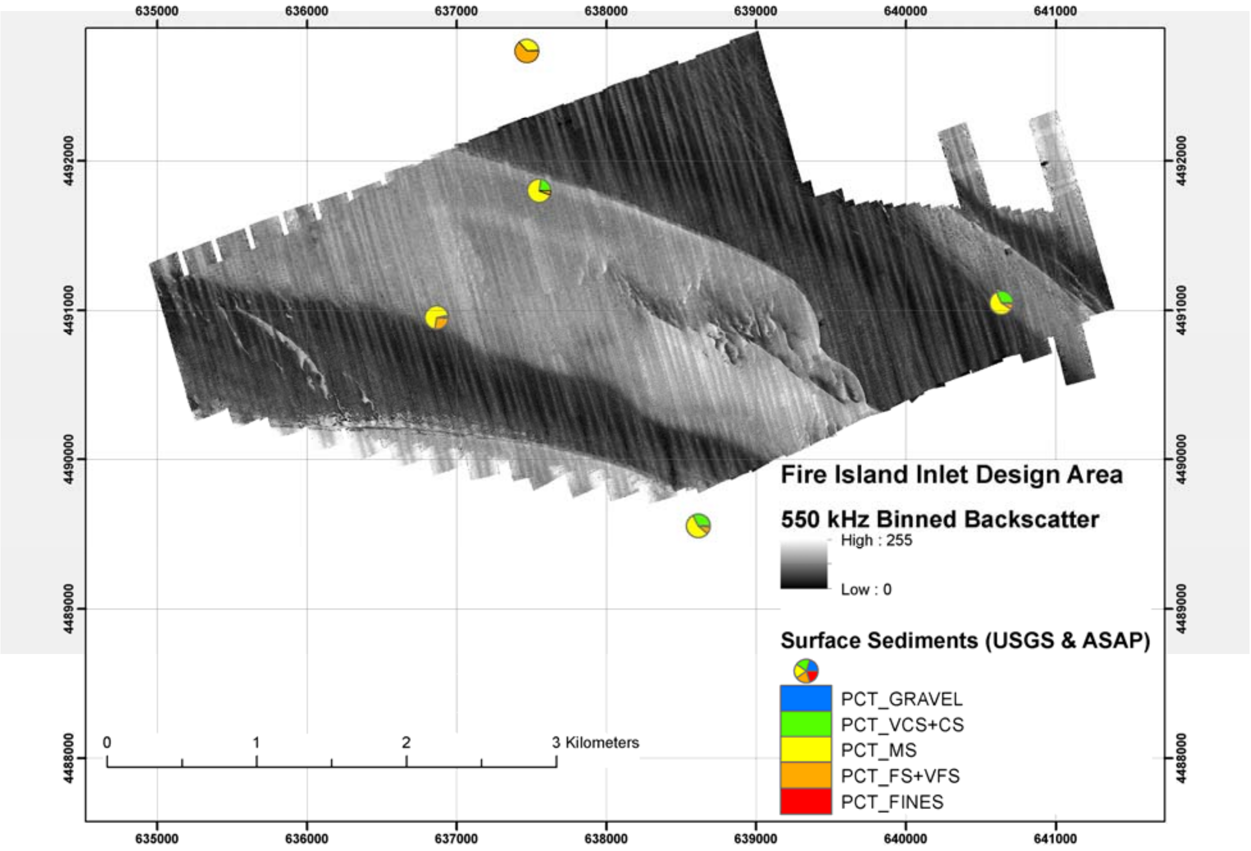

Figure 20. Mosaic of 550 kHz binned backscatter along with size distributions of surface sediment samples in the Fire Island Inlet Design Area. Areas of higher backscatter are lighter while areas of lower backscatter are darker. The along-track lineations (NNE to SSW) are artifacts. Areas with coarser sediments tend to have higher backscatter, but samples are not available from some areas with higher backscatter. Note: some of the plotted surface samples do not fall within the area of the mosaic.

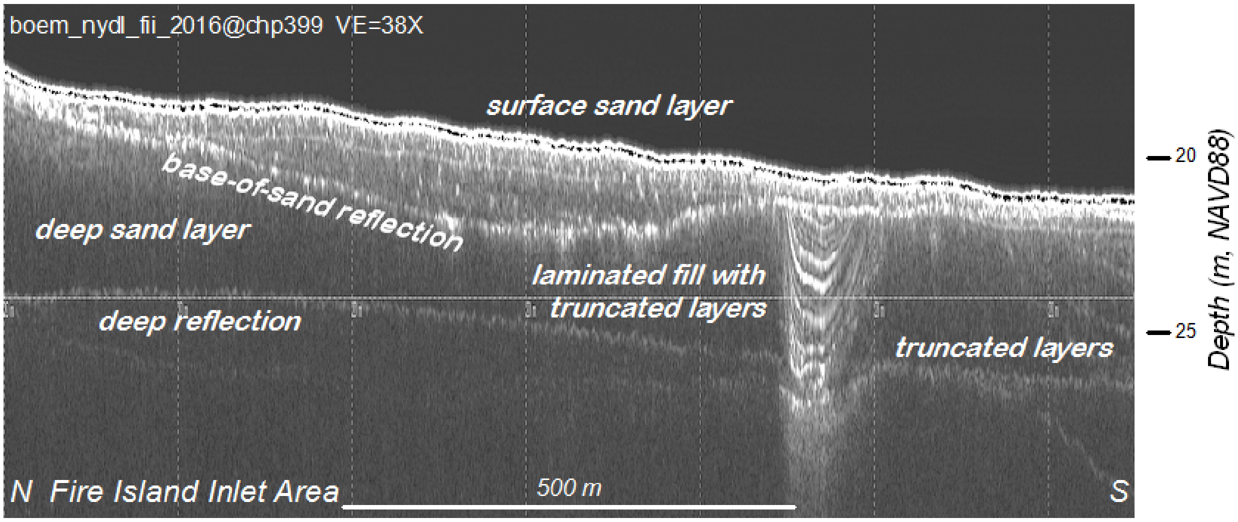

Figure 21. Example annotated seismic line from the Fire Island Inlet Design Area showing the surficial sand layer, the base-of-sand reflection, the deep sand layer, laminated fill in a depression, and deeper reflections with truncated layers. Note how the laminated fill is truncated by the base-of-sand reflection. The vertical scale of the seismic profile is exaggerated and the maximum dips of the laminated fill are about 2°. Profiles are located on Figure 19.

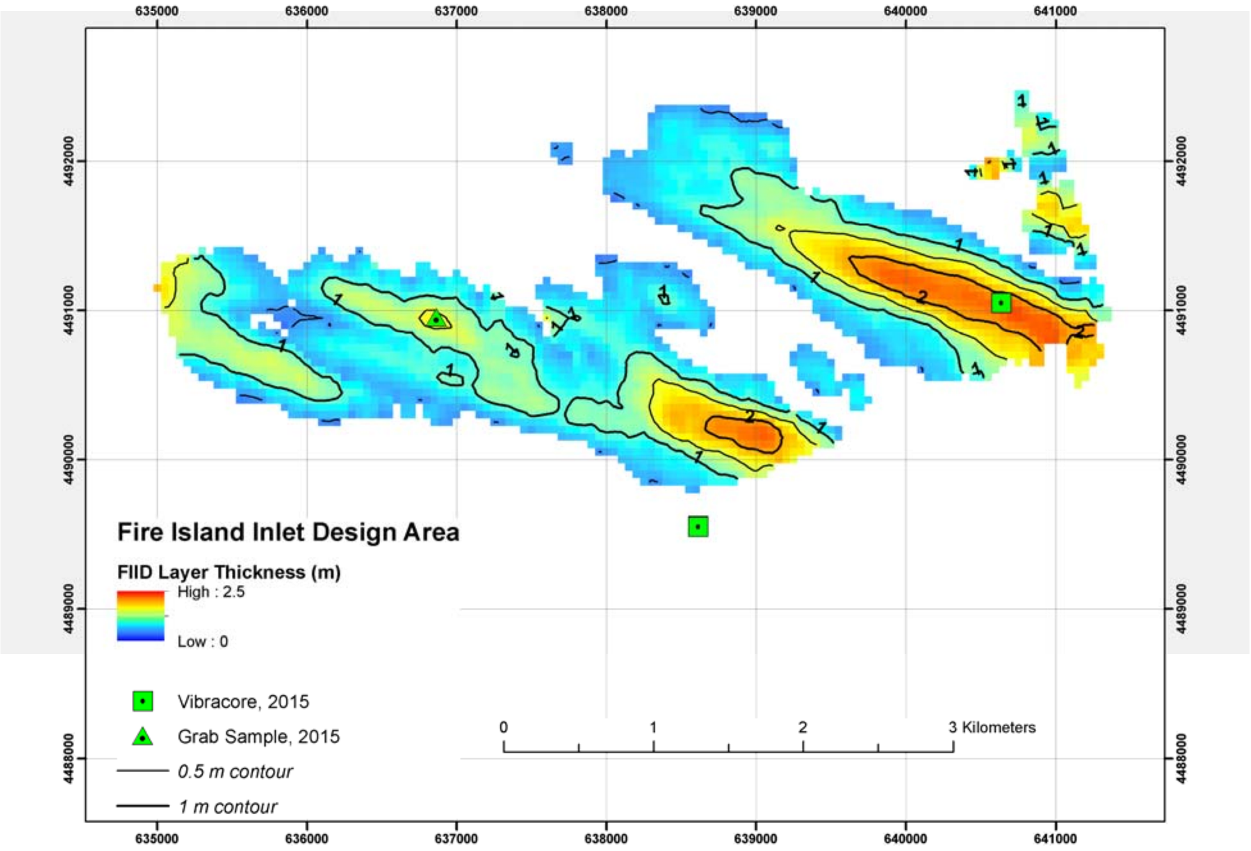

Figure 22. Map of the thickness of the uppermost sand layer in the Fire Island Inlet Design Area determined using seismic profiles. 0.5 m and 1.0 m contours are shown, and sediment thickness calculated using a sound velocity of 1,500 m/s. The locations of ASAP vibracores and grab samples are also shown.

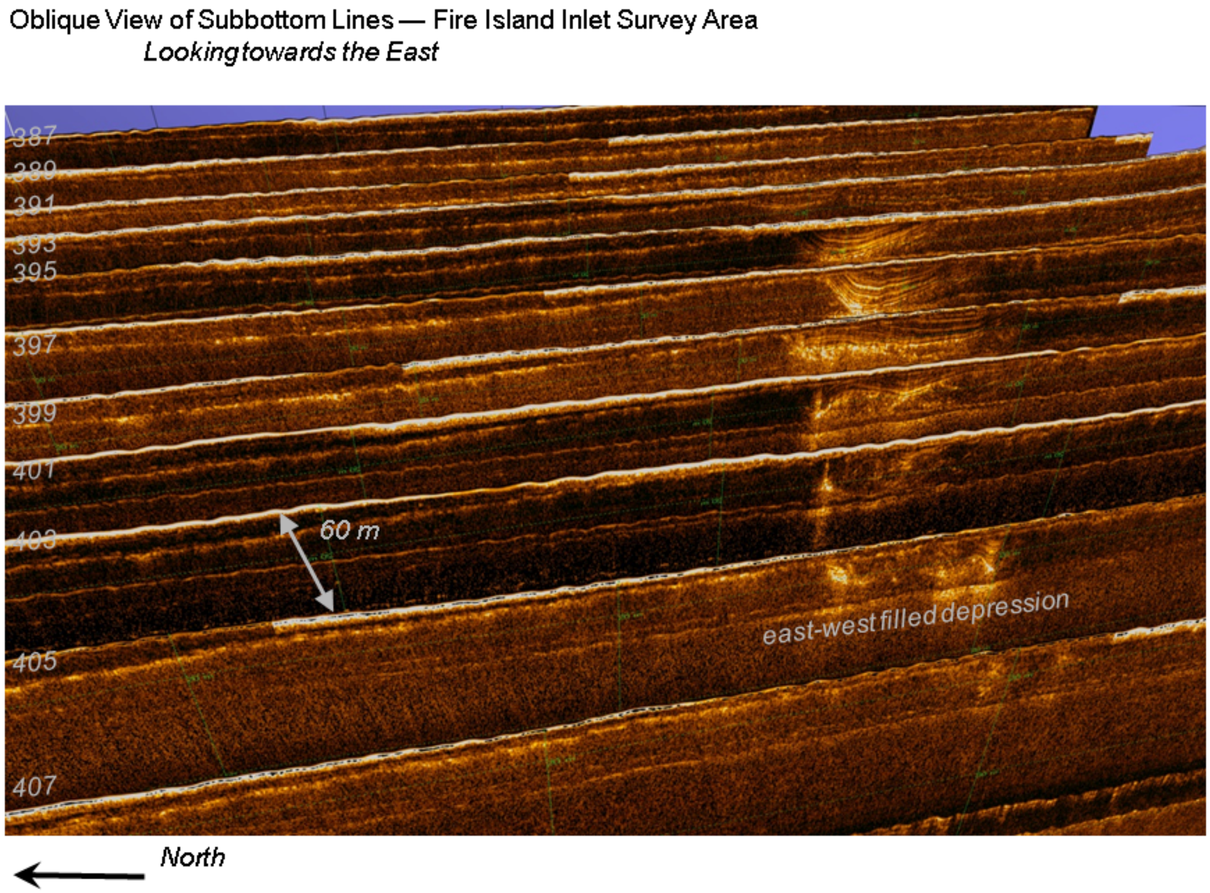

Figure 23. Oblique 3D view of seismic lines from the Fire Island Inlet Design Area showing that the filled depression is of limited lateral extend and oriented in an east-west direction. Note: every other seismic line is shown.

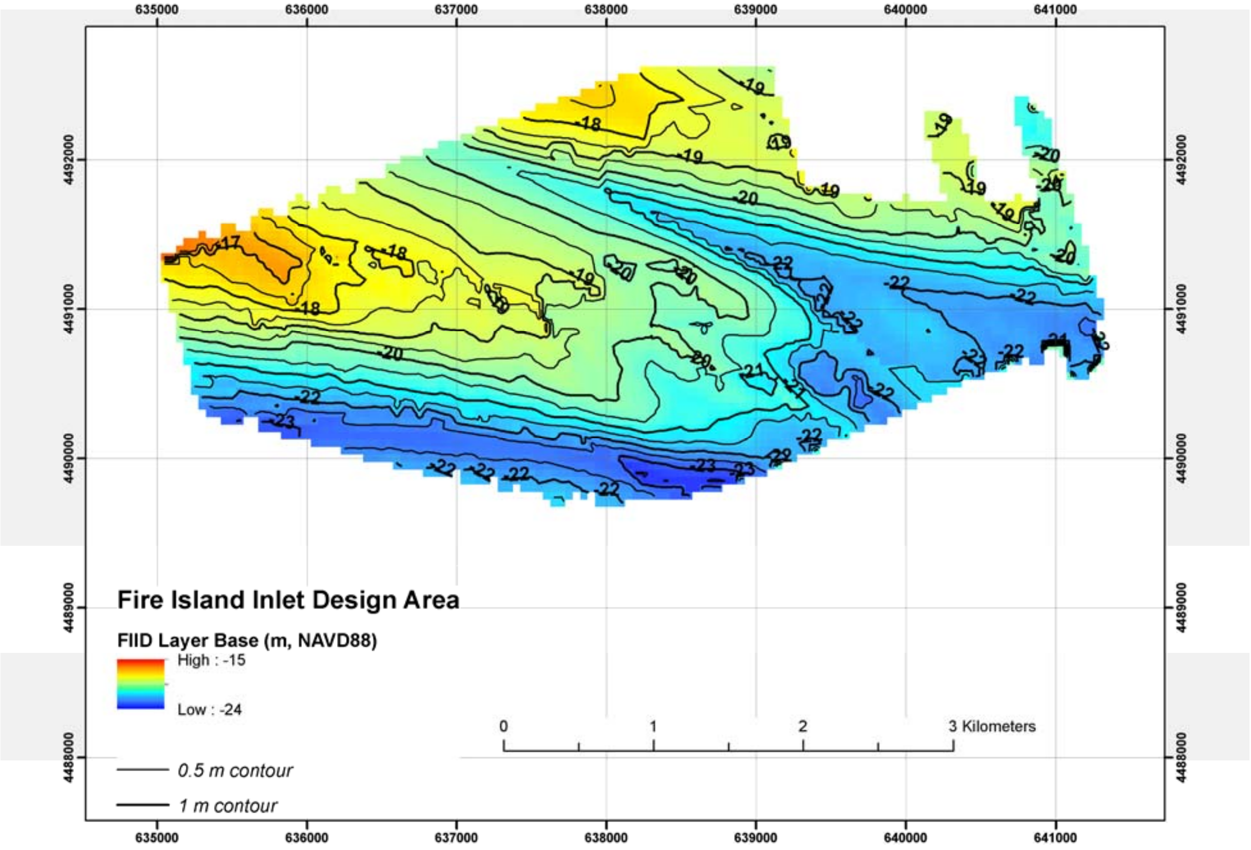

Figure 24. Elevation map of the base of the upper sand layer in the Fire Island Inlet Design Area with 0.5 m and 1.0 m contours. This map is created by subtracting the sediment thickness from the surface elevation.

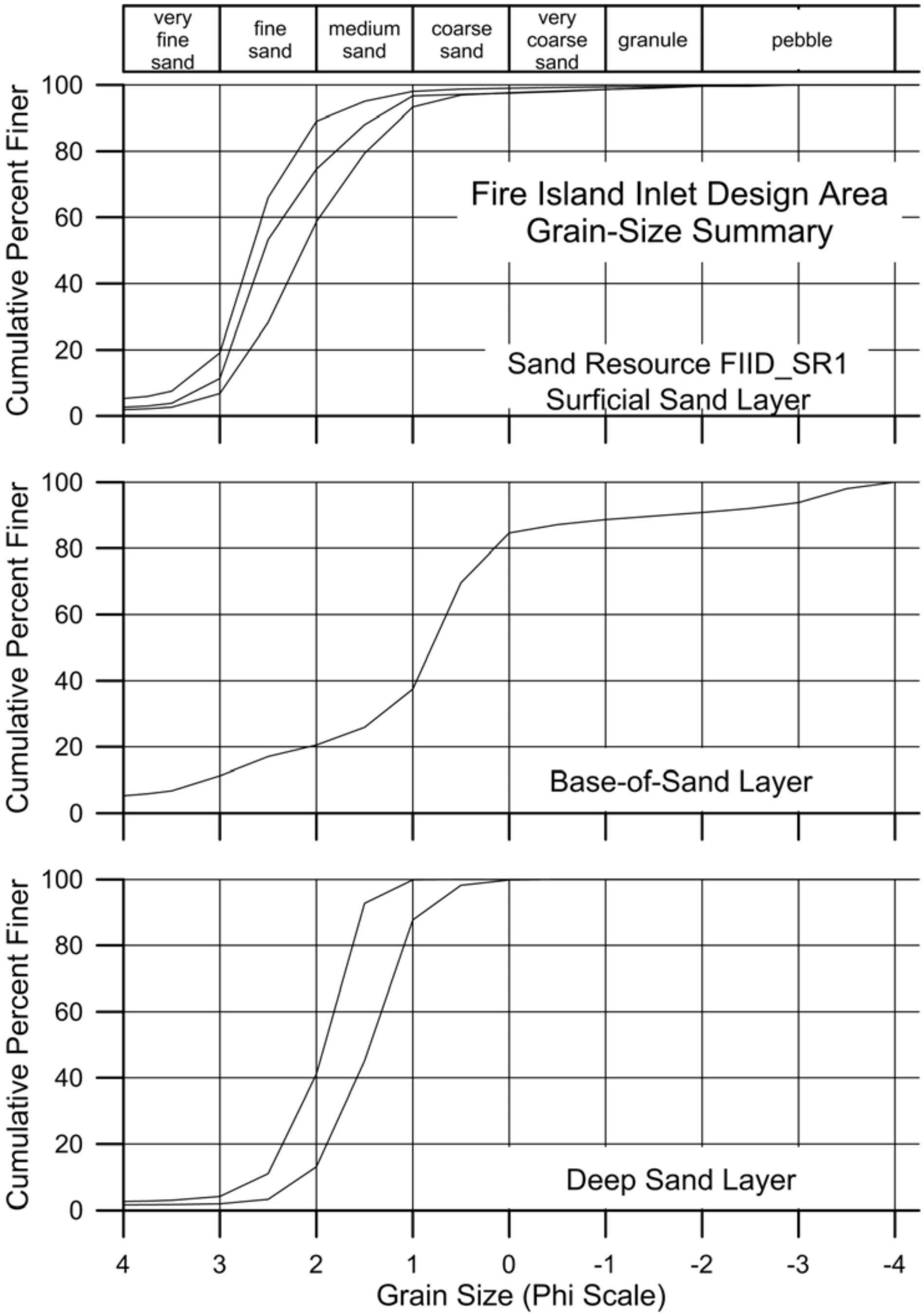

Figure 25. Grain size measurements from ASAP vibracore NY-BOEM-2015-VC20 from the Fire Island Inlet Design Area. Three samples are from the upper sand layer (top), one is from immediately below the base of the upper sand layer (middle), and two are from the deep sand layer (bottom). The surficial sand layer is delimited as the sand resource area FIID_SR1.

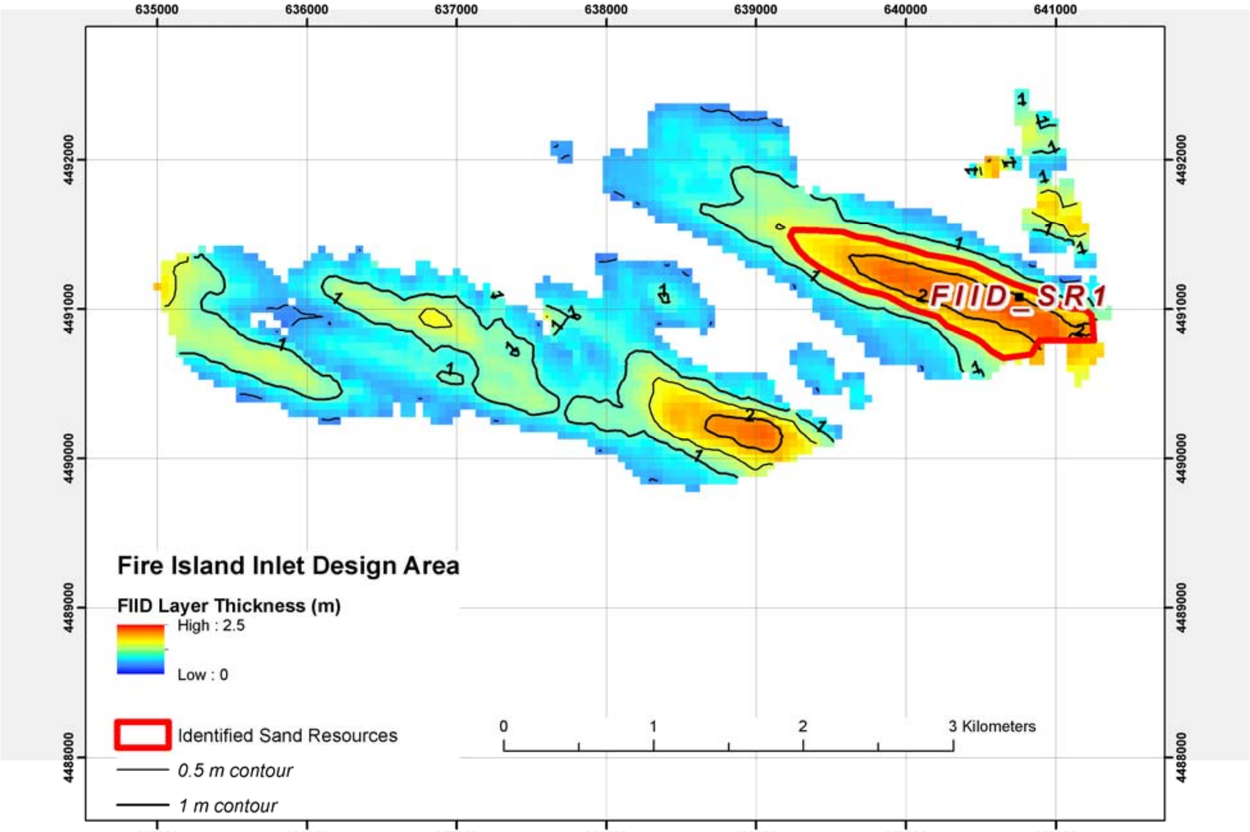

Figure 26. One sand resource areas is identified in the Fire Island Inlet Design Area based on the seismic profile data and vibracore data collected in the area. FIID_SR1 occupies the eastern sand ridge.

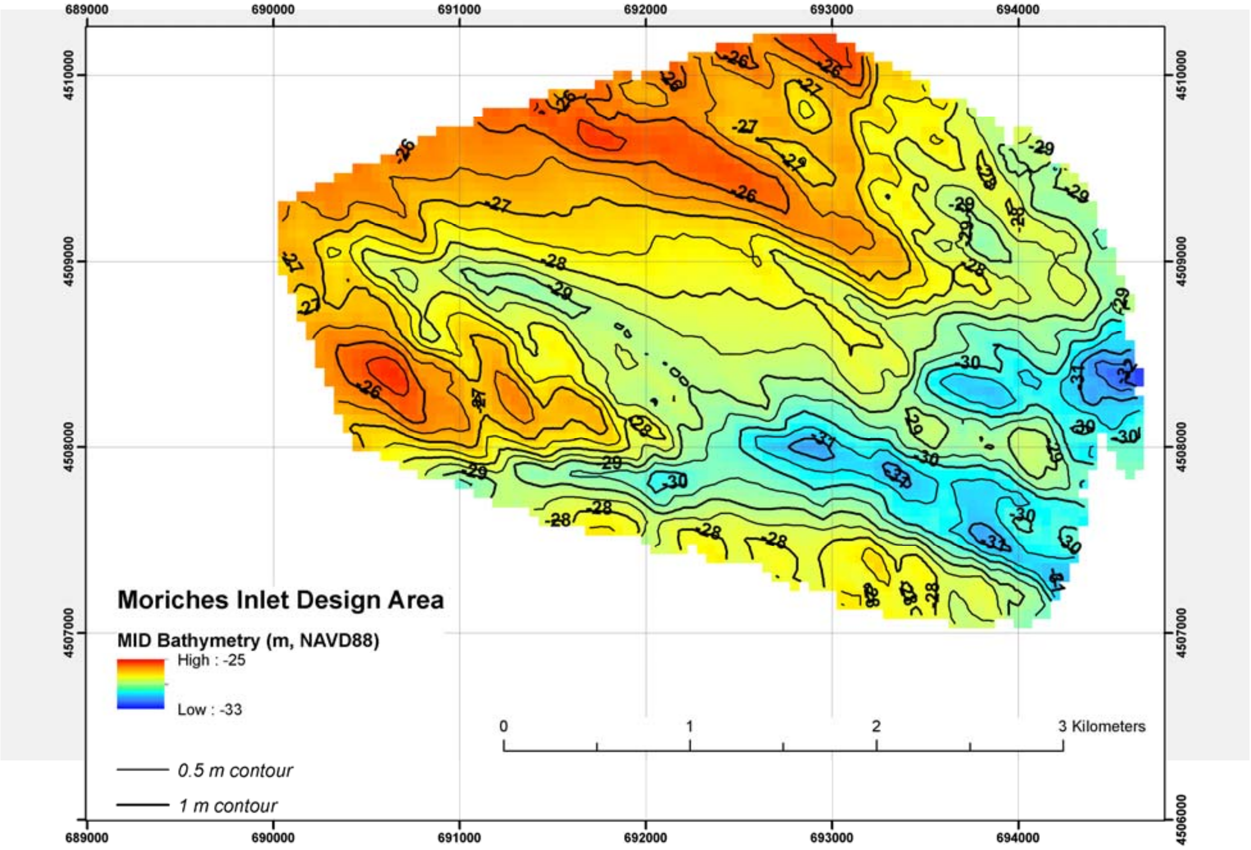

Figure 27. Bathymetric map of the Moriches Inlet Design Area created using offset ASAP 2016 bathymetric data. Contour intervals are 0.5 m and 1.0 m. Depth datum is NAVD 88 and the ASAP bathymetric data has been gridded at 50 m.

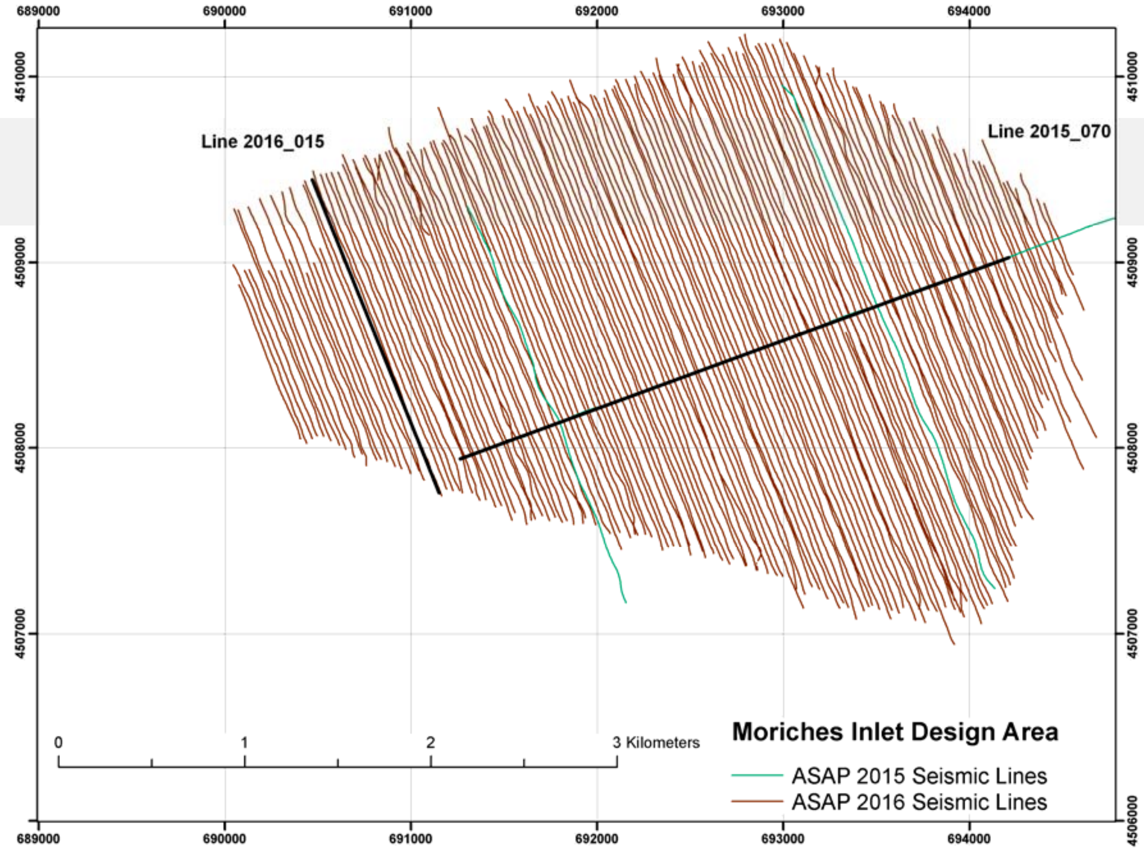

Figure 28. Track lines for seismic (also called subbottom or chirp) profiles collected in the Moriches Inlet Design Area in 2015 and 2016. The locations of the seismic profiles in Figure 30 are also shown.

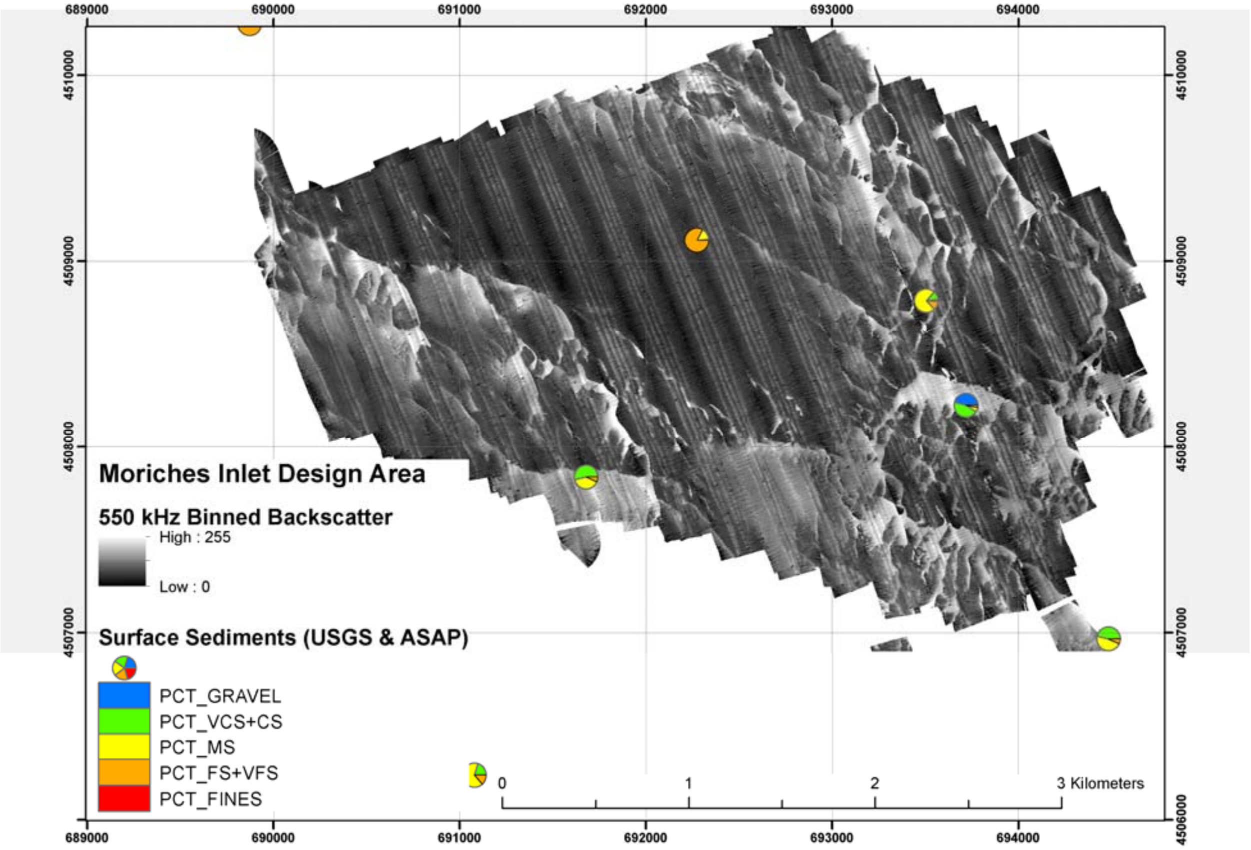

Figure 29. Mosaic of 550 kHz binned backscatter along with size distribution s of surface sediment samples in the Moriches Inlet Design Area. Areas of higher backscatter are lighter while areas of lower backscatter are darker. The along-track lineations (NNE to SSW) are artifacts. Areas with coarser sediments tend to have higher backscatter, but samples are not available from many areas with higher backscatter. Note: some of the plotted surface samples do not fall within the area of the mosaic.

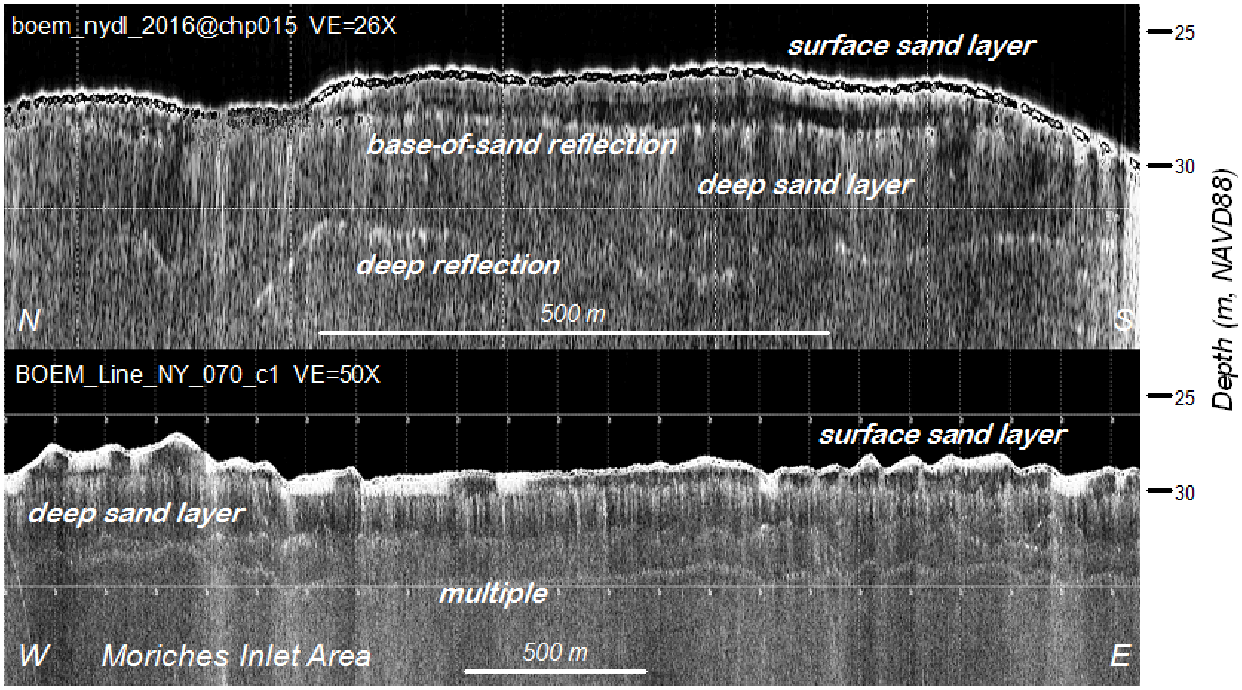

Figure 30. Annotated seismic lines from the Moriches Inlet Design Area. Upper: Example of the surface sand layer, the base-of-sand reflection, the deep sand layer and deep reflections. Lower: Example profile showing the variability of the surface sand layer across the area. Profiles are located on Figure 28.

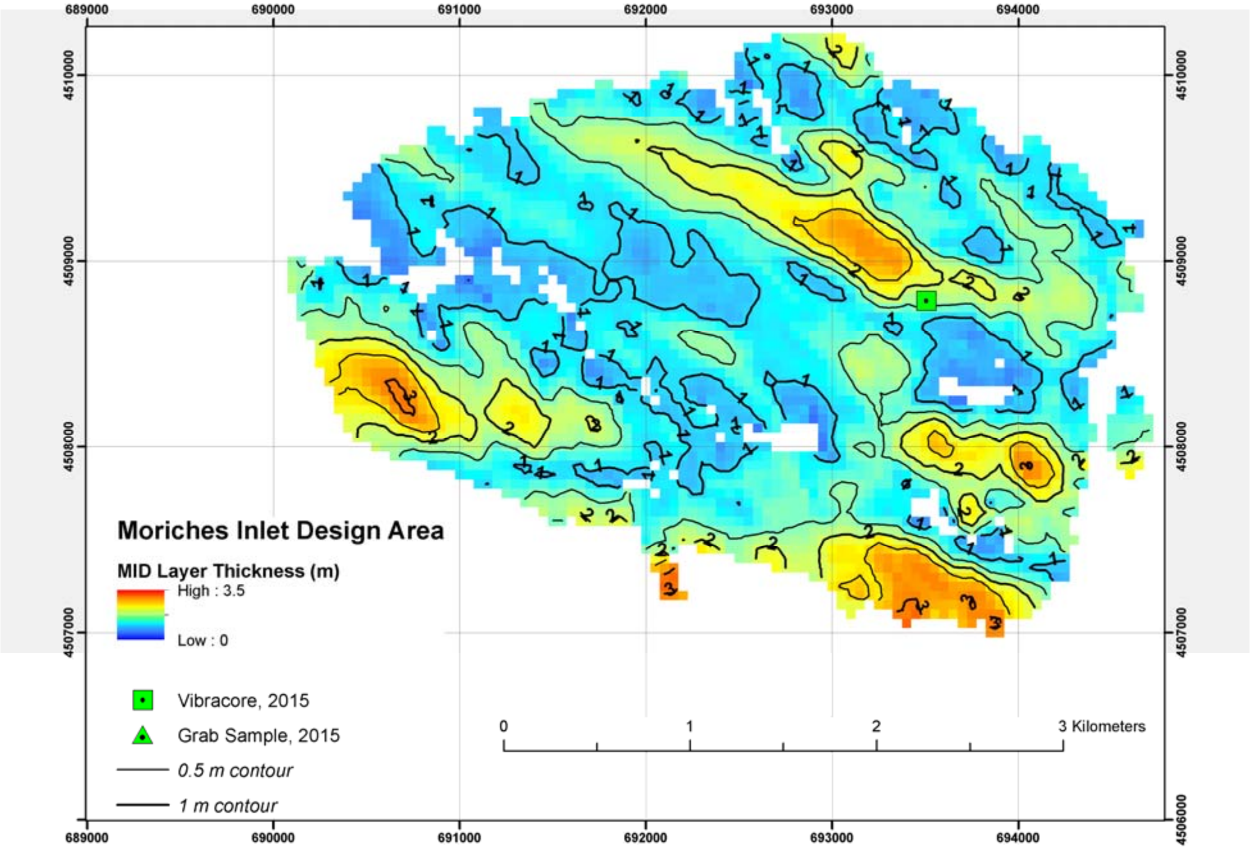

Figure 31. Map of the thickness of the uppermost sand layer in the Moriches Inlet Design Area determined using seismic profiles. 0.5 m and 1.0 m contours are shown, and sediment thickness calculated using a sound velocity of 1,500 m/s. The locations of an ASAP vibracore is also shown.

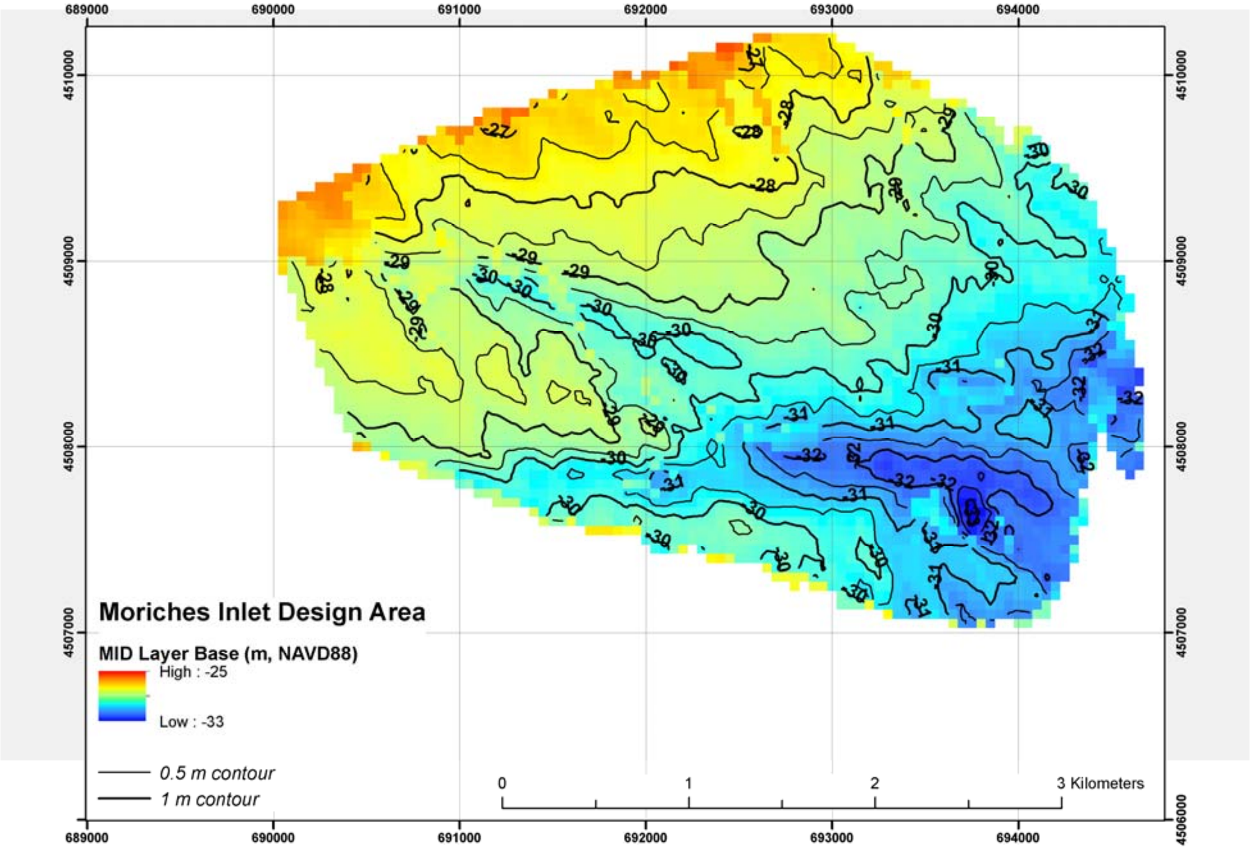

Figure 32. Elevation map of the base of the upper sand layer in the Moriches Inlet Design Area with 0.5 m and 1.0 m contours. This map is created by subtracting the sediment thickness from the surface elevation.

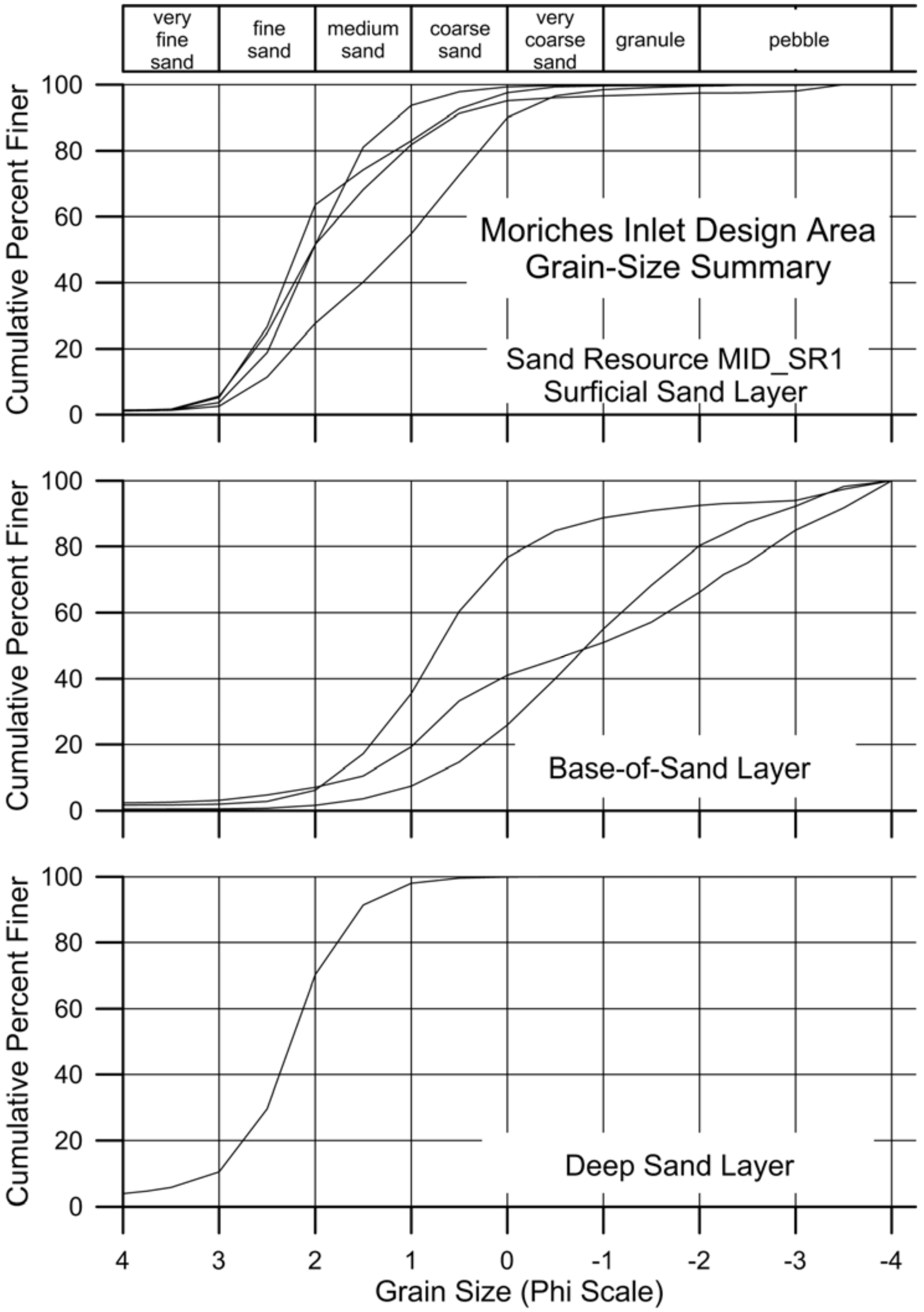

Figure 33. Grain size measurements from ASAP vibracore NY-BOEM-2015-VC35 in the Moriches Inlet Design Area. Four samples are from the upper sand layer (top), three are from immediately below the base of the upper sand layer (middle), and one is from the deep sand layer (bottom). The surficial sand layer is delimited as the sand resource area MID_SR1.

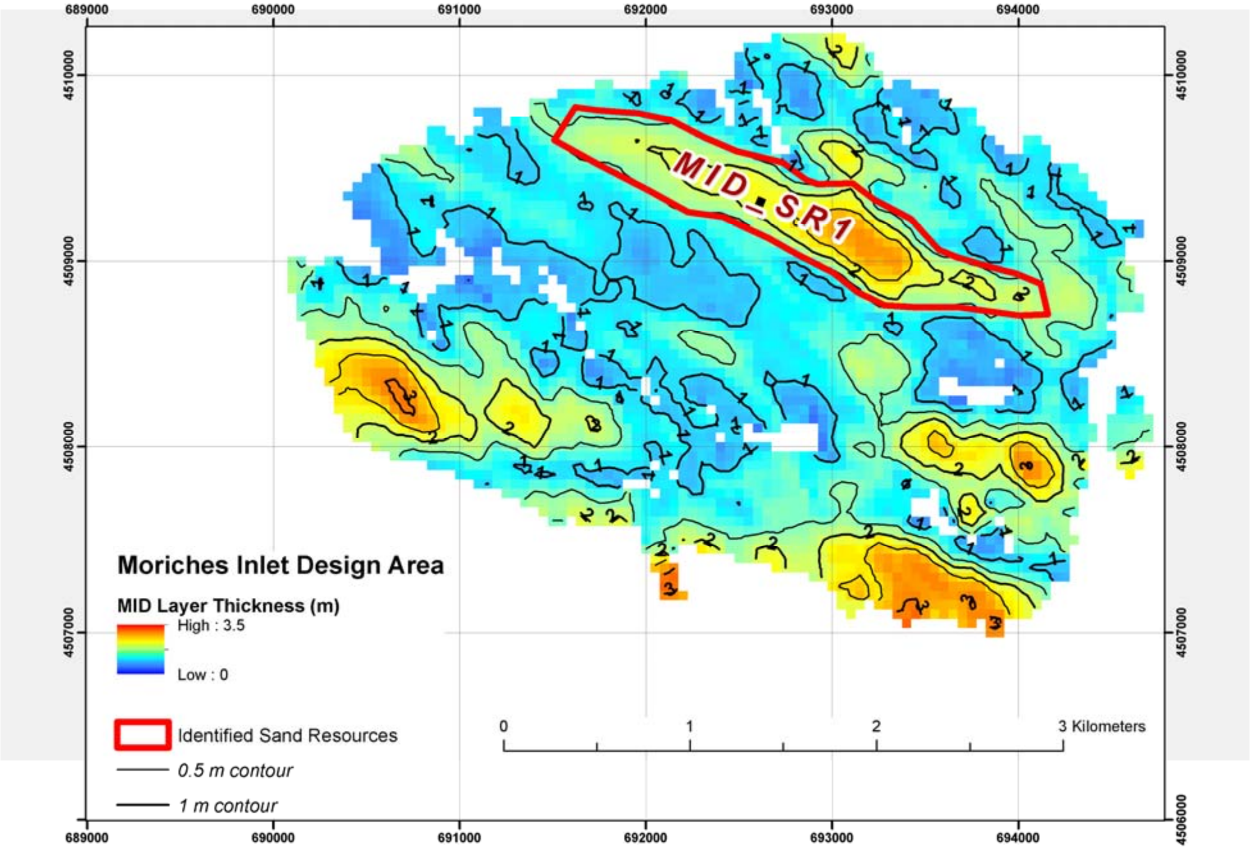

Figure 34. One sand resource areas is identified in the Moriches Inlet Design Area based on the seismic profile data and vibracore data collected in the area. MID_SR1 occupies the northeastern sand ridge.

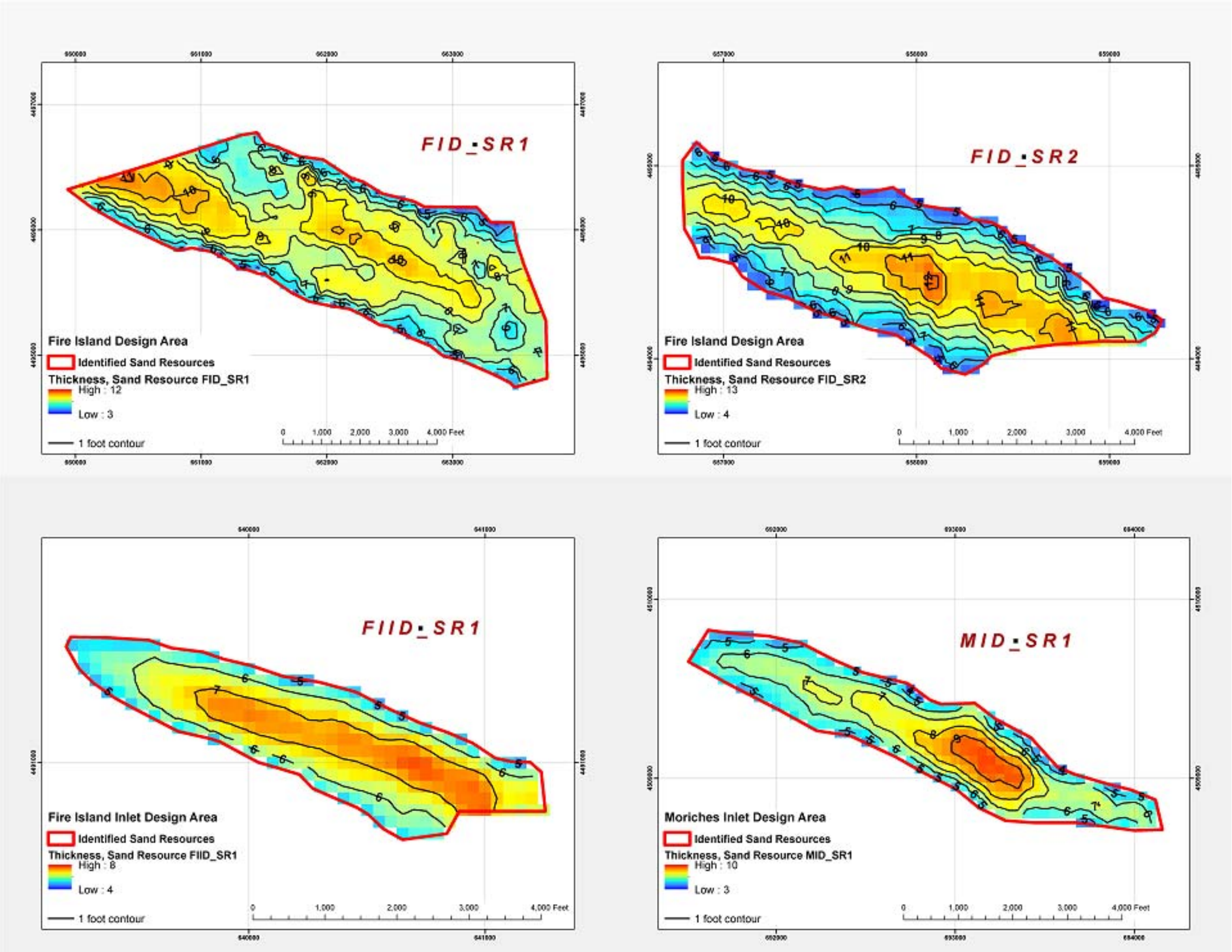

Figure 35. Contour maps of the four delineated sand resource areas in the New York study area. Contour interval is in feet.