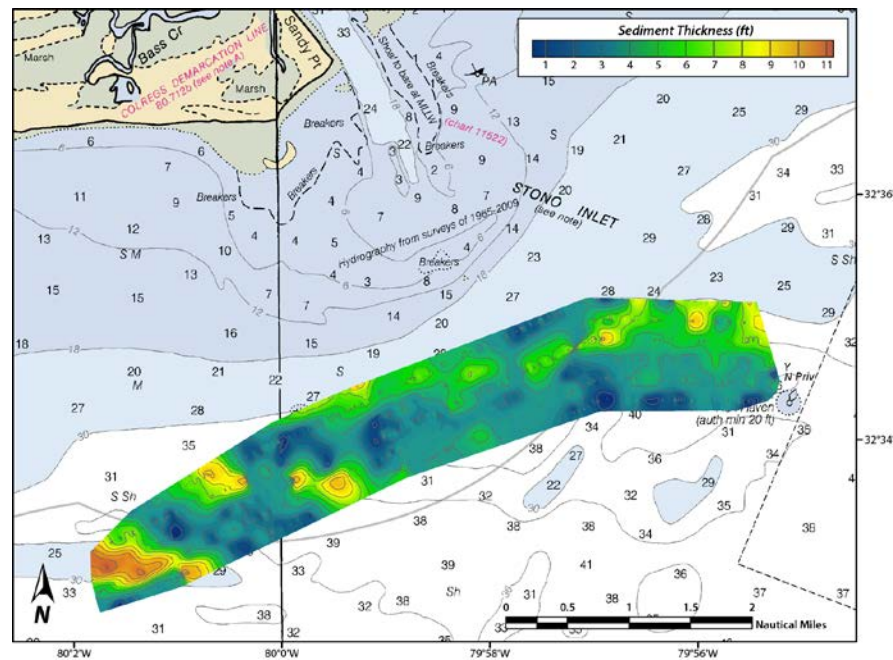
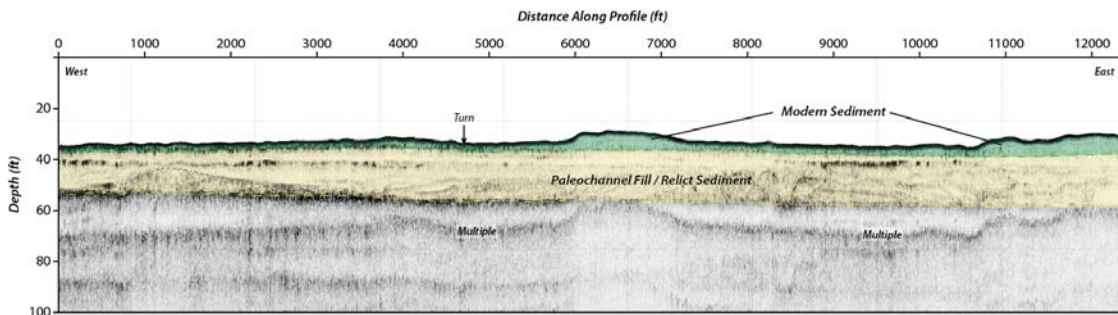


Geophysical Study of the Inner Shelf in the Vicinity of Stono Inlet South Carolina.

Generated for the
US Army Corps of Engineers
By
Center for Marine and Wetland Studies
School of Coastal and Marine Systems Science
Coastal Carolina University



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1. Introduction.

Several South Carolina beaches where there is a commitment to use beach nourishment to manage coastal erosion threats to property and infrastructure are challenged by limited, patchy sand resources suitable for beach nourishment. The nourishment resources offshore of Folly Beach, South Carolina are limited and additional resources are being sought to support future beach nourishment projects at Folly Beach.

Researchers at Coastal Carolina University have completed extensive geophysical work in the Charleston region in concert with the US Geological Survey, USACE and SCDNR. These efforts spanned from habitat mapping to framework geology studies to sand resource assessment across the region. In 2002, CCU in concert with the US Geological Survey completed a geophysical survey offshore of Folly Beach that was used by the Corps of Engineers as a basis for defining potential sand borrow sites for past beach nourishments at Folly Beach (Schwab, Gayes and Denny, 2002). CCU has recently aided the Corps with a hard bottom and cultural resource study for the Charleston Harbor Post 45 study (Gayes et al., 2013) as well as with Regional Sediment Management studies at the Charleston Harbor Entrance.

Subsequent to that work the university has brought a new research vessel on line specifically designed to support the considerable geophysical instrumentation suite and is ideally suited for inshore geophysical survey and studies. CCU is at present working on a range of shallow geologic framework and habitat resource studies for BOEM in the Grand Strand area of South Carolina as well as new studies in concert with the USGS off Cape Canaveral, Florida and Fire Island, N.Y.

Coastal's unique, state-of-art geophysical mapping system is ideally suited to respond to the Corps desire to find additional sand resources for Folly Beach nourishment projects and help the Corps refine their vibracoring plan to access and validate sand resource potential. These unique capacities form part of the basis for a MOU between the Corps and CCU to facilitate support of Corps missions where appropriate. It also well suited to engage our students as part of their academic training in collection, processing and interpretation of real world geophysical data.

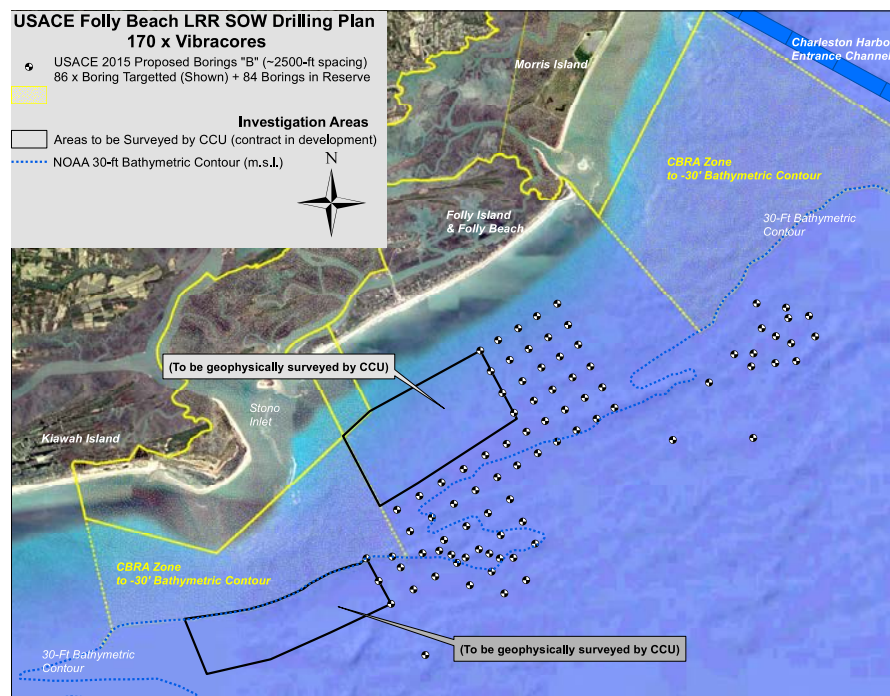
1. Scope of Work.

CCU and The Corps of Engineers have established an MOU outlining mutual interest and agreement to collaborate (AGREEMENT NUMBER W912HP-15-2-0001). The Wilmington and Charleston Districts have designated a series of areas for a planning vibracoring

campaign in the summer of 2015. Two areas identified for vibracoring were recommended from the CCU/USGS 2002 study (Schwab, Gayes and Denny, 2002). Two additional areas have been identified by the Corps where comprehensive geophysical survey would greatly aid their efforts to find suitable sand resources for upcoming renourishment of Folly Beach, South Carolina.

CCU was engaged to undertake a geophysical survey and subsequent interpretation in the direct training of a graduate student who is interested in inner shelf geologic framework) and working with similar data sets from other locations along the SC coast.

These study areas were initially defined by the Corps are identified in Figure 1.



The final survey area was refined to focus on a site in greater than 30 feet of water depth along the southern distal edge of the Stono Inlet ebb tidal delta. This represents an area of approximately 1x 4 n. miles.

Geophysical Survey Plan.

An integrated geophysical survey of the defined survey areas off of Folly Beach is proposed to be completed with a 300-meter line spacing in an alongshore orientation and 500-meter spacing in a shore perpendicular orientation. This will allow three primary data-types to be used to provide an integrated three-dimensional characterization of the shallow sub-bottom sediment deposits that may be suitable for potential beach nourishment applications.

The data-types to be acquired include:

Side Scan Sonar

CCU operates a Klein 3000 dual frequency (100/300 kHz) side scan sonar; which has consistently acquired 190-200 meter swath widths in shallow shelf settings such as the study area in clear water conditions (absence of whitecaps and wave noise). In such shallow water settings wave noise in the outer ranges is often enhanced. Under optimal conditions there would be approximately 33% coverage of the sea floor under the 300-meter trackline spacing.

Chirp Sub-bottom Profiles;

CCU's Edgetech 512i Chirp sub-bottom profiler has produced excellent results imaging the shallow sub-surface stratigraphy in the region. This system has a vertical resolution of 40-50 centimeters and is generally superior to the system used in the 2002 report in sea floor penetration (10-50 m) and resolution of surficial stratigraphy in sandy settings such as the study area.

Multibeam Sonar

CCU uses a Kongsberg EM 3002b dual head multibeam sonar. The sonar backscatter to provide swath bathymetric coverage on the order of 5-times the water depth for each line. Backscatter is also collected using the multibeam. In the water depths of the study areas the multibeam, under clear water conditions, would provide ~15% bathymetric coverage of the study areas with some additional coverage and validation at along the proposed tie-lines.

Data Processing Workflow

Side scan Sonar

CCU data post processing procedures includes navigation merging, demultiplexing, slant range correction, destriping, beam pattern correction, and mosaic construction with Xsonar and ShowImage software packages developed by the USGS Woods Hole Science Center (Danforth, 1997). The nadir was removed from each line of data prior to mosaicing, allowing port and starboard channels to be merged, thus removing the water column portion of the data record. Mosaics were output as 25 cm pixel resolution geotiffs for import to ESRI ArcGIS. Raw records at full resolution were used for cultural resources interpretation. Side Scan Work Flow is provided in Appendix 1.

CCU Chirp Acquisition and Data Processing.

Chirp data is acquired using an EdgeTech sb512i CHIRP sub-bottom reflection sonar with Edgetech Discover acquisition software. Data are typically acquired at a ship speed of approximately 4 knots. Towfish navigation is obtained by a the GPS system on the Coastal Explorer with in these distances from land are expected to be able to work in DGPS mode. Sub-bottom reflection profiles will be acquired using a 0.5-8 kHz CHIRP signal with a 5 ms sweep.

Sub-bottom Data Processing

CCU CHIRP sub-bottom data is processed using SIOSEIS and Seismic Unix seismic processing software packages. The final processed data are heave corrected and trace balanced for noise reduction. The data are also depth corrected to account for tidal variations in water depth and the depth of the fish in the water column. Since fish depth is not directly recorded in the CHIRP data, the approximate fish depth is determined by correlating seafloor depth in the CHIRP data with measurements made by a georeferenced multibeam survey of the trackline also collected during the survey. In the shallow water depths of this study area, CCU may elect to use a survey tow sled which will aid in alignment of the sea floor return in bathy and chirp data.

CHIRP sub-bottom data is recorded in two-way-travel time (TWT) in seconds, or the time it takes for a sound wave to travel down to the seafloor and be reflected back to the instrument. In general, an average sound velocity in seawater of 1525 m/s is used to convert TWT to depth, keeping in mind that TWT represents twice the reflector depth (e.g., $\text{Depth} = \{\text{TWT} * 1525 \text{ m/s}\}/2$).

The CCU Chirp Acquisition and Work Flow are shown in Appendix 3

Multibeam Data acquisition and processing.

CCU's dual heads for the multibeam are installed on a mount affixed to the front of the Coastal Explorer which also hosts a Motion Reference Unit very near the heads. Velocity of sound cast are typically taken at the beginning and end of the survey day unless evidence of significant refraction issues become evident in the data.

Bathymetric data is post-processed using CARIS HIPS ver. 9.0 hydrographic data processing software. Post-survey data cleaning, as well as Bathymetry Surface creation using CUBE algorithm, were applied in CARIS HIPS. Soundings (xyz) were exported from a Surface as xyz text file. The xyz were imported into Fledermaus Dmagic ver. 7.4 to grid. In Dmagic, the xyz text files were interpolated into digital elevation model (DEM) grids. The Fledermaus grids were exported as Arc/Info grids. Final x,y,z soundings, surface models, and derived products are relative to the NAVD88 vertical datum.

Survey Notes:

The Coastal Explorer transited to Charleston on June 22, 2015 and returned to North Myrtle Beach on July 2, 2015. A strong sea breeze set up every day, earlier in the day than experienced in the area in the past limiting data quality and survey time each day. Weather conditions suitable to collect geophysical data on site were present approximately 50% of the time available. The table below shows the days of operation. In total ~80% of the planned survey shore parallel lines at 300m spacings were completed and 25% of shore perpendicular lines at 500-meter

spacing were able to be completed. Nonetheless this allowed for a reasonable characterization of the three-dimensional of the shoals and subsurface within the study area.

Table 1. Operation Schedule for Folly / Stono Inlet Survey

Date	Operations
June 22	Transit North Myrtle Beach to Charleston
June 23	Survey Off Stono Inlet
June 24	Survey Off Stono Inlet
June 25	Weather-Operations suspended
June 26	Weather-Operations suspended
June 27	Weather-Operations suspended
June 28	Weather-Operations suspended
June 29	Survey Off Stono Inlet
June 30	Survey Off Stono Inlet
July 1	Load Nancy Ship Foster
July 2	Transit Charleston to North Myrtle Beach

DATA:

Figure 2 shows the geophysical tracklines completed at Stono Inlet.

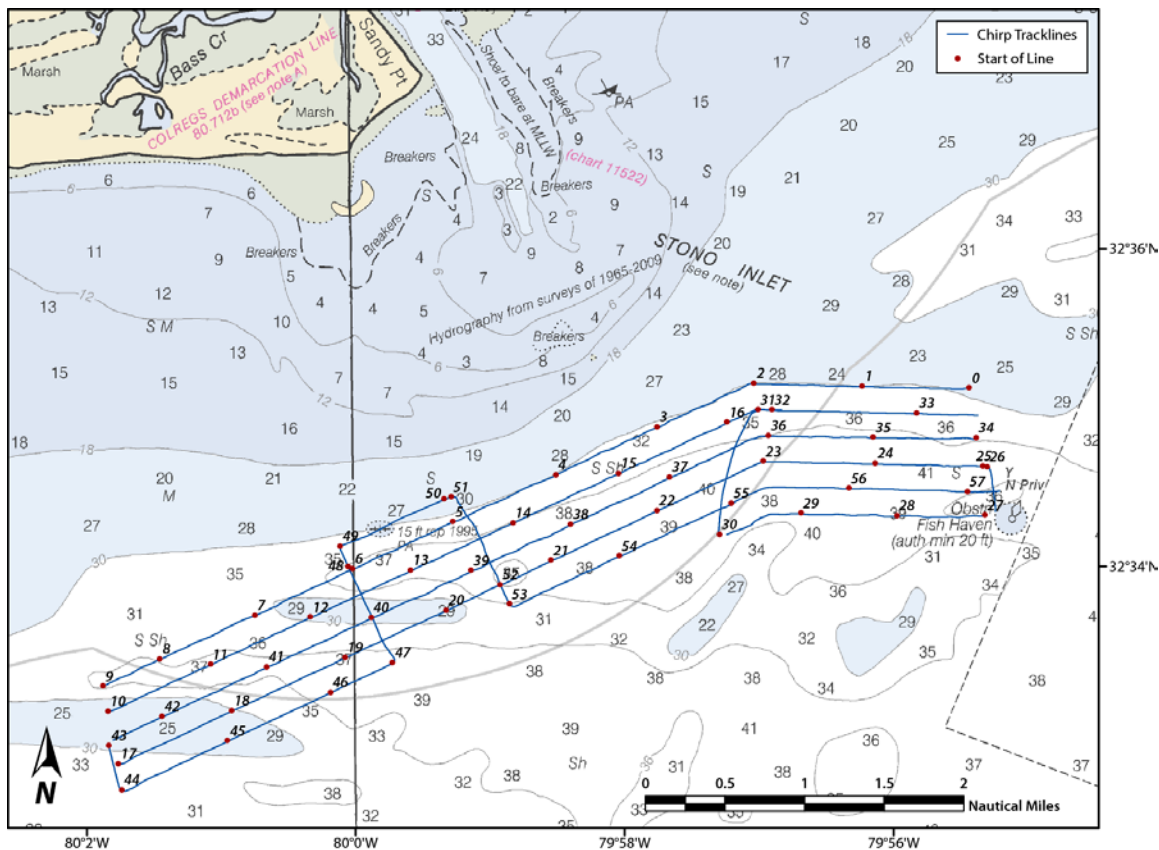


Figure 2. Geophysical tracklines completed off Stono Inlet June 23-30.

A total of 63.6 line kilometers of geophysical survey was completed. Of that (excluding turns) 60 line-kilometers of survey were used in all gridded polygons shown in this report.

Bathymetry of the Study Area:

Figure 3 shows a bathymetric map of the study area generated from gridding the multibeam data. With 300-meter line spacing there was considerably less than 100% coverage of the sea floor but major bathymetric features appear well represented. The distal apron of the Stono Inlet ebb tidal delta is readily defined as a rapidly shoaling of the sea floor along the northern boundary of the study area. Two-shore oblique ridges area also well defined in the southwestern third of the study area. The central and eastern section portion of the study area exhibit irregular bathymetry typical of the transition to inner shelf in the region in the vicinity of a large tidal delta.

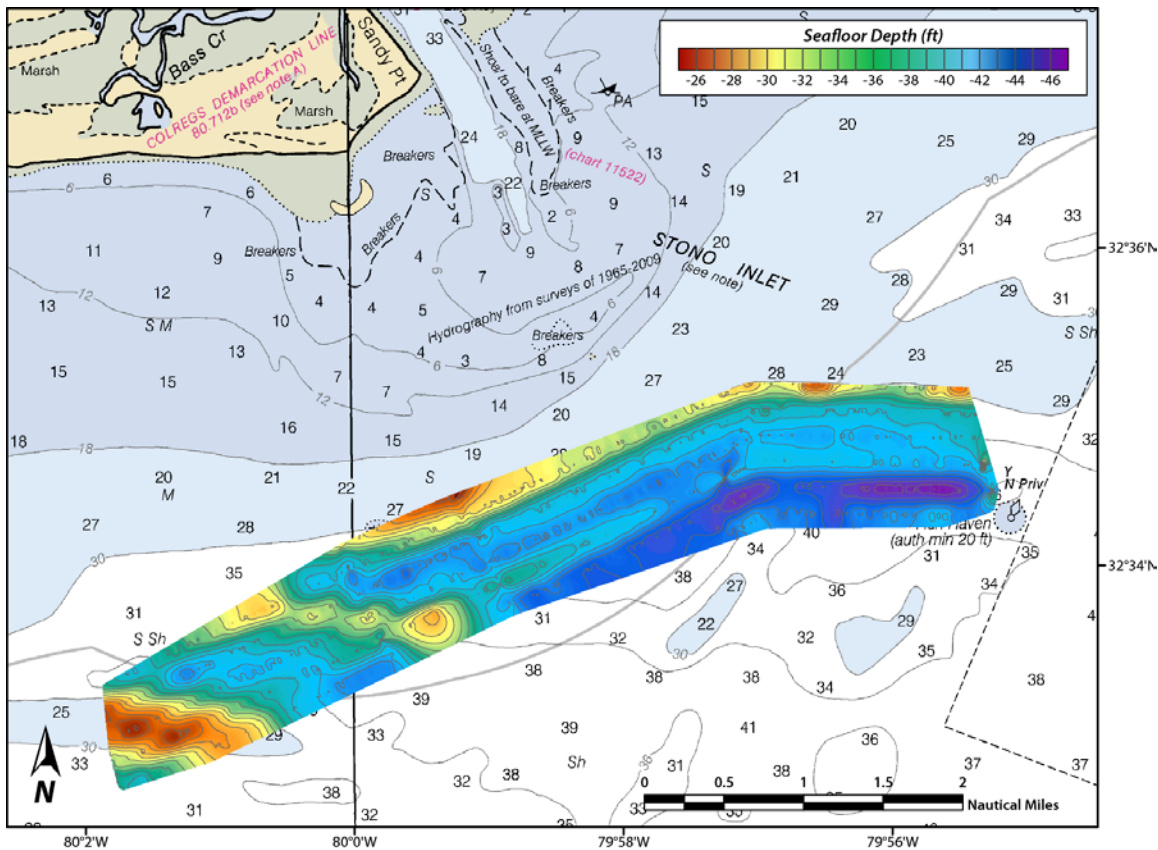


Figure 3. Bathymetric Map of the study areas generated from gridding of multibeam sonar data.

Chirp Sub-bottom Profiles:

Figure 4 shows a representative chirp sub-bottom profile from the study area. A surficial veneer of modern sediment is mappable overlying a transgressive unconformity. This unit is of variable thickness ranging from near the resolution of

the chirps system (~50cm) to 3-5 meters thick within the oblique shoals trending northwest-southeast from the distal portion of Stono Inlet (See Figure 4 Isopach Map of Modern Surficial Sediment). The surficial sediment unit overlies a section of relict (older) sediment which is extensively cut in fill by paleochannel complexes as might be expected within a large tidal delta system such as Stono Inlet.

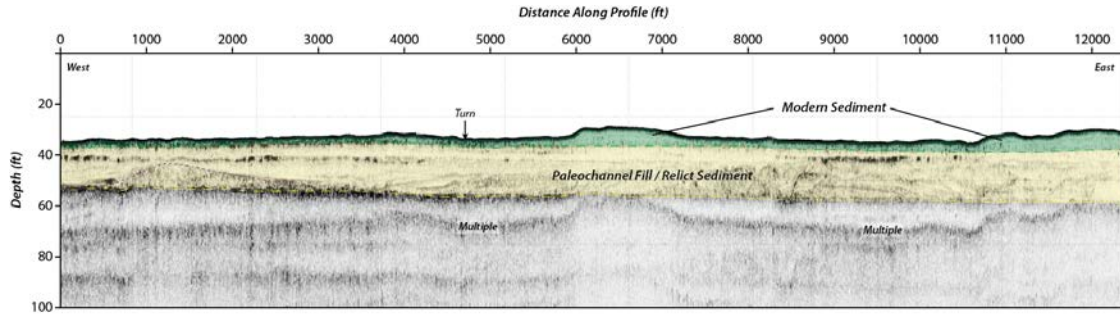


Figure 4. Characteristic CHIRP sub-bottom profile showing a variable veneer of modern surficial sediment overlying

Stratigraphic Units: Surficial Modern Sediment

Figure 5 shows an isopach map of the surficial sediment unit defined as the volume difference between the gridded interpreted base of the surficial sediment layer from the chirp data and the sea floor defined by gridding of the multibeam data. A significant volume of coherent, acoustically consistent sediment is defined within the two oblique sand shoals southwest of the main Stono Inlet Ebb tidal delta.

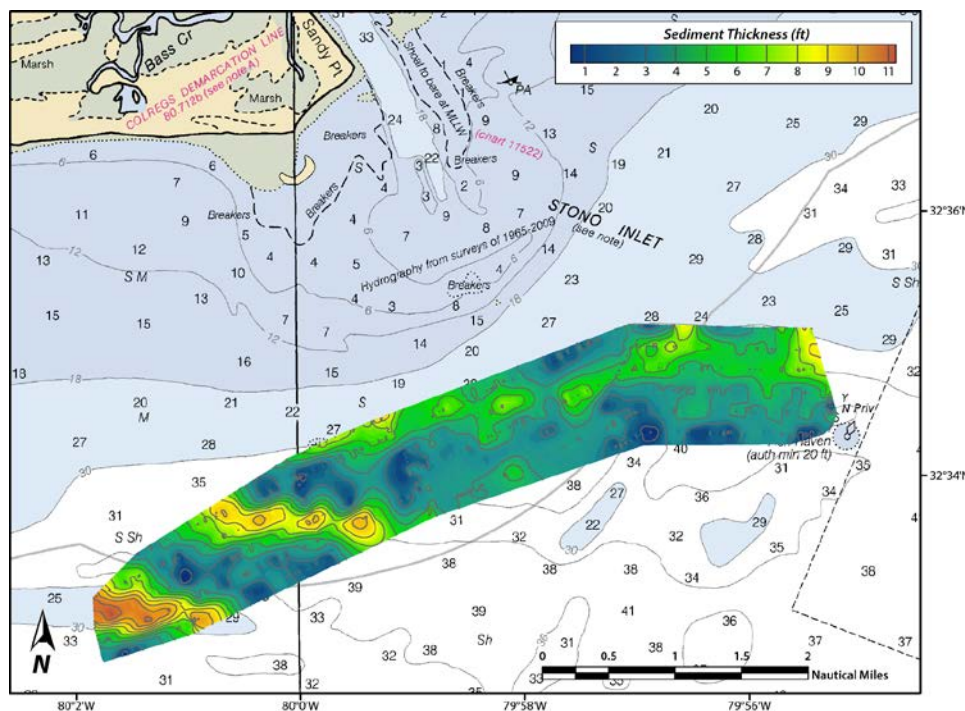


Figure 5. Isopach of Surficial Sediment Veneer Interpreted from CHIRP sub-bottom profiles.

A second area of significant surficial sediment volume can be identified along the distal edge of the modern Stono ebb tidal delta along the northern edge of the study area. This distal shield of the ebb tidal delta system appears to feed an easterly trending shoal already targeted for coring in the USACE Folly Beach vibracoring plan (see Figure 1).

Using the volumetric calculation in Kingdom Suite and assuming a sound speed of 5000 ft/s (~1525 m/s), the total volume of sediment within the modern surficial veneer within the study area is 19,339,604 m³. The volume of sediment within the oblique sand ridges extending onto the inner shelf from the Stono Inlet ebb tidal delta is 6,274,104 m³. The volume of sediment in the modern surficial veneer along the Stono inlet ebb tidal delta shield (distal portion of the modern delta) forming a modest shoal is 2,753,052 m³.

These two shoal complexes represent a substantial volume of sand relative to a typical Folly Beach nourishment cycle. The northern border of the survey area along the distal apron of the Stono Inlet ebb tidal delta exhibited a low backscatter response consistent with the modern surficial veneer along the distal edges of the ebb tidal delta being fine sand at the sea floor. As an extension of the main ebb tidal delta this frontal lobe is a strong candidate for potential beach nourishment resources but will frequently shoal to depths shallower than 30 feet, which may preclude utilization by the federal project. It is an area the Town of Folly Beach might seriously consider in its projection for likely coherent, consistent quality beach sediment resources.

Relict / Paleochannel Facies

The modern surficial sediment overlies older relict substrate that has been extensively channeled with acoustic characteristics similar to that described for AREA 3 in Schwab, Gayes and Denny (2002) from the inner shelf offshore of the northern end of Folly Beach. The underlying the surficial sediment veneer is extensively incised by paleochannels of a range of scales from small-localized channel fills to channel complexes.

Figure 6 shows the distribution of paleochannel fills below the modern surficial sediment veneer. Clearly there is a more extensive and organized channel complex looked directly offshore of the apex of the Stono Inlet ebb tidal delta; with multiple cut and fills and some incisions reached depths -17 meters depth and up to 11 meters below the sea floor. A second set of small paleochannels exist in the vicinity of the surficial sediment shoals in the southwestern portion of the study area potentially associate with a smaller southwesterly trending secondary tidal channel position of the Stono system in the past that likely supplied sediment supporting formation of the oblique sand ridges similar to the early stages of the model of McBride and Moslow, 1991 representing former positions of the seaward edge of the ebb tidal delta being modified by shelf processes with transgression.

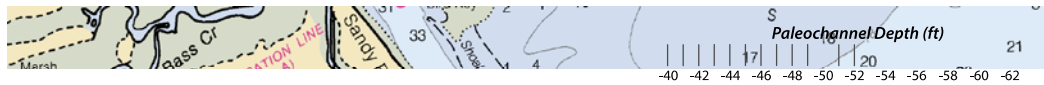


Figure 6. Distribution and thickness of channel incisions below the surficial sediment veneer within the Study Area.

Figure 7 shows an isopach map of the relict and paleochannel facies which is relatively thick within the extensively paleochannelled section due offshore of the main Stono Inlet Channel, apex of the ebb tidal delta. This thins to the southwest in the vicinity of the modern oblique sand shoals.

The integrated, interpreted chirp profiles are provided in Figure 8 as a fence diagram created in Fleadernaus software. This shows the overall three-dimensional architecture of the study are and transition of the Stono Inlet ebb tidal delta system to the inner shelf of the region. The GIS layers from the geophysical survey will be conveyed in GIS ready format in the associated disk as well as JPEG images of the processed Chirp profiles.

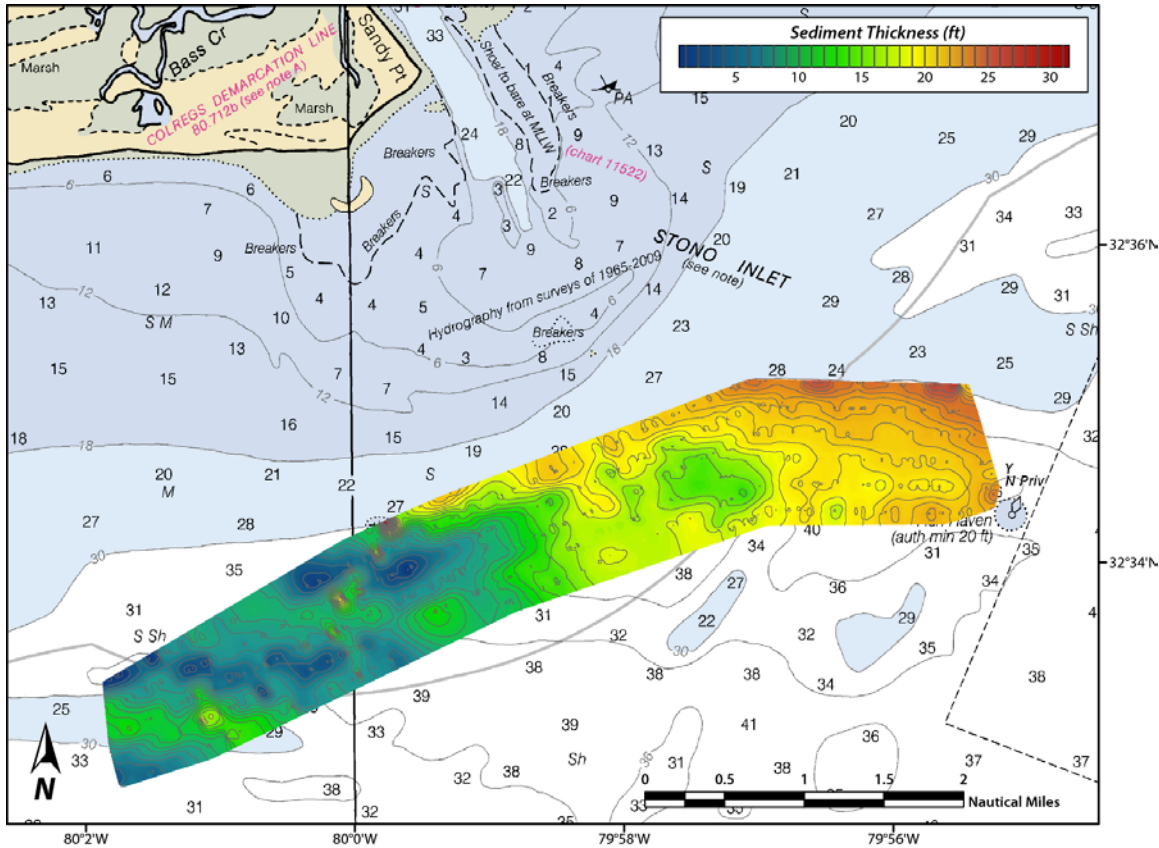
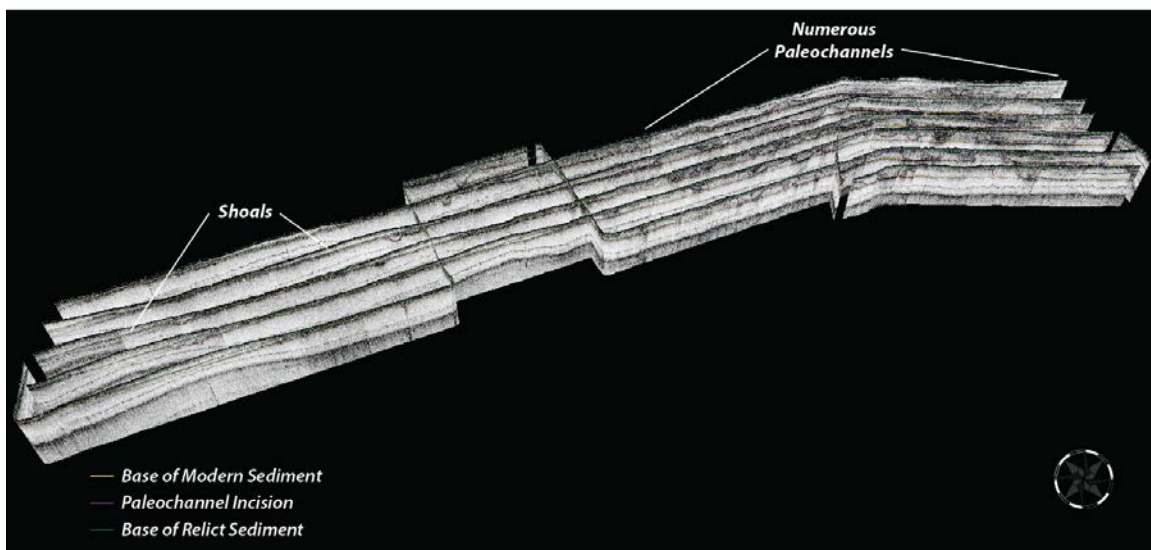


Figure 7. Isopach map of Relict and Paleochannel section underlying the modern surficial sediment veneer.

Figure 8 shows the integrated sub-bottom profile fence diagram showing 3-dimensional relationships



Side Scan Sonar Records

High backscatter response of the sea floor in the region has typically be found to result from outcropping low relief hardgrounds or coarse shell hash sediments. Low backscatter response tends to correlate with fine sandy sediment deposits. Within the study area, sub-bottom profiles suggest a minimum of .5-1 meter of modern sediment veneer across the study area and as a result low probability of hard bottom outcrops. The extensive channeling in the next stratigraphic unit further supports the likely absence hard bottom habitat in the study area particularly in the eastern portion of the study area. Thus, high backscatter on side scan sonar records likely correlates to shell hash lags and low backscatter likely correlates to fine sand at the sea floor. This signature is common in the inner shelf of the region; except where there is clear relief and irregular backscatter signature characteristic of region inshore low relief hardbottoms.

Figure 9 shows the side scan sonar tracklines and backscatter map for the completed survey. Subsequent figures are enlargements of different sections of the overall mosaic.

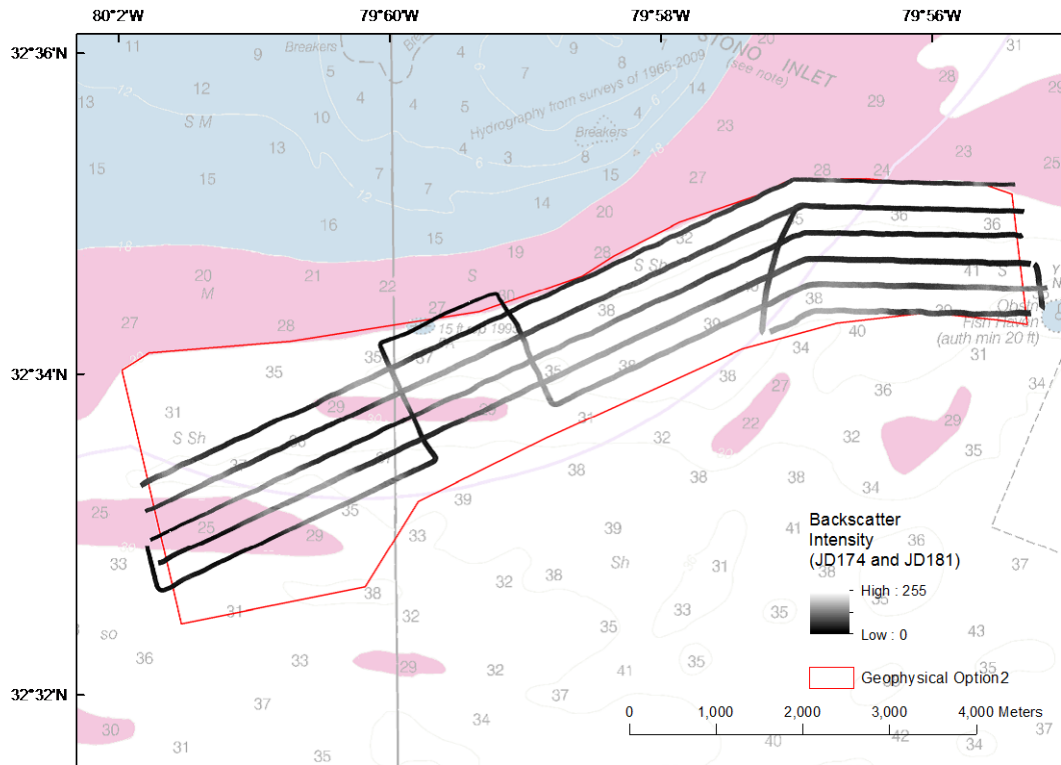


Figure 9. Side scan sonar backscatter response along tracklines in study area.

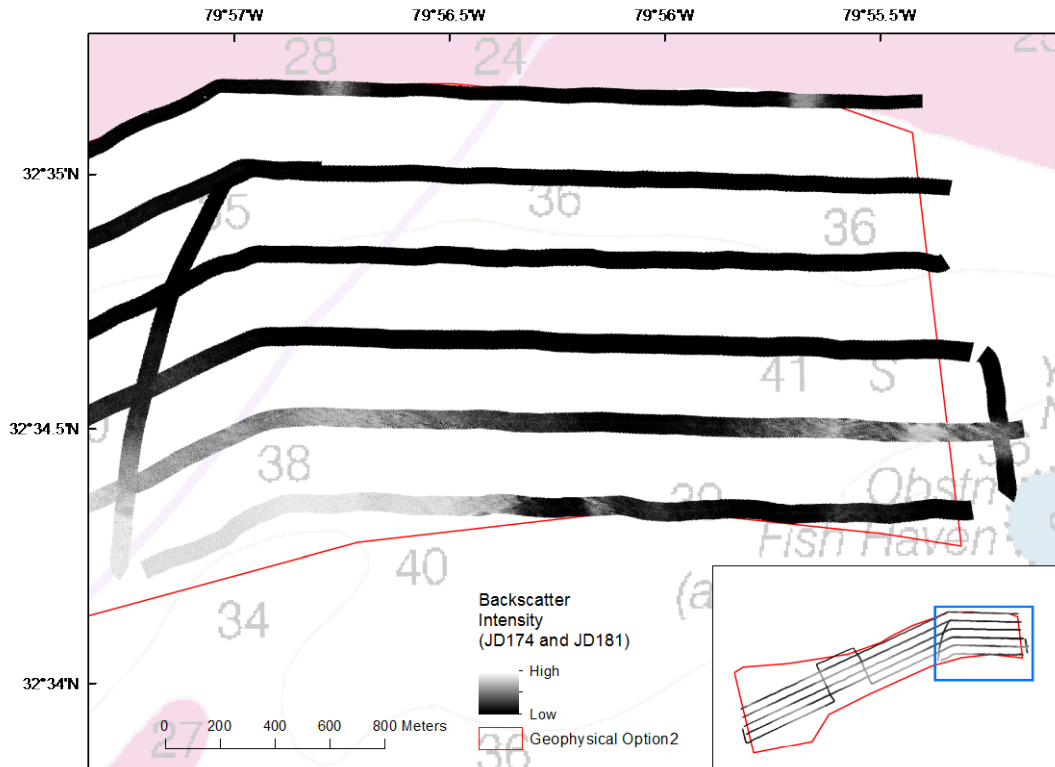


Figure 10. Side Scan Back Scatter along geophysical tracklines in the eastern section of the study area.

The shoaling at the distal edge of the Stono Inlet ebb tidal delta, northern 70% of the sub-area, is characterized by low backscatter response is consistent with fine sand deposits to be expected associated with ebb tidal delta processes. Along the southern third of this area, in deeper water, where the modern surficial veneer is thinner higher surficial backscatter consistent with present of shell hash and surficial lags become more prominent.

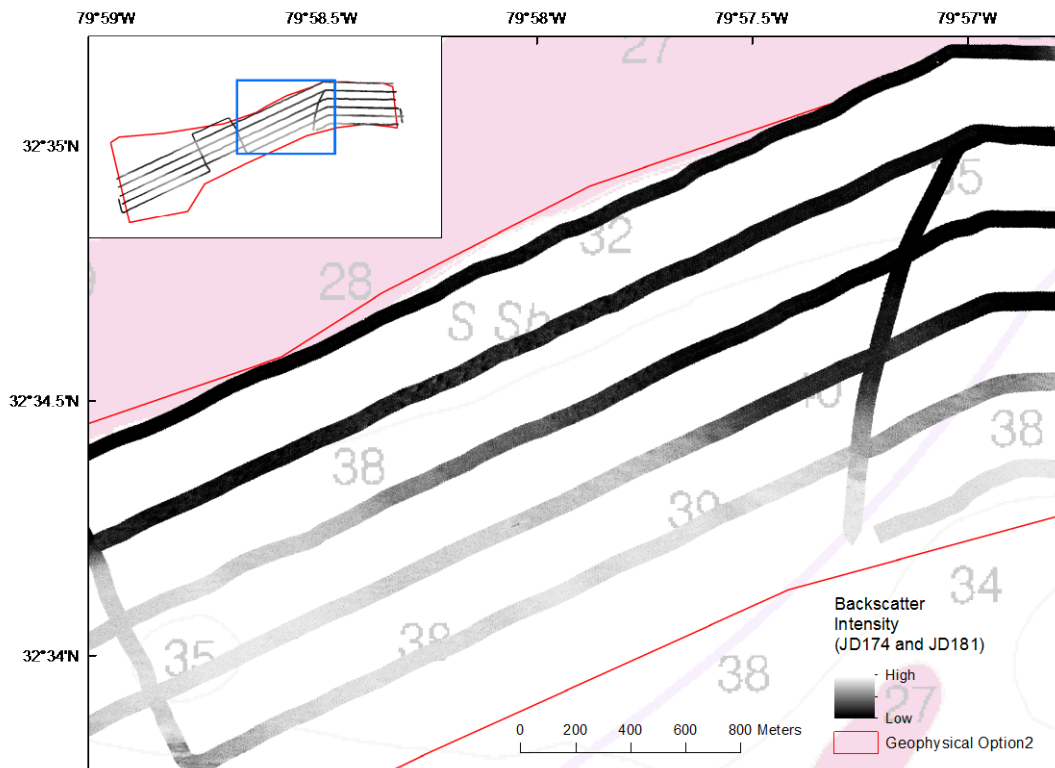


Figure 11. Side scan sonar backscatter reponse of the sea floor along geophysical tracklines in the east-central portion of the study area (inset).

Within the east-central portion of the survey area, low backscatter response on the side scan sonar records is more restricted to the northern third of the survey area representing a smaller percentage of the ebb tidal delta shield extending into the study area and a more extensive area of high backscatter lag within this area.

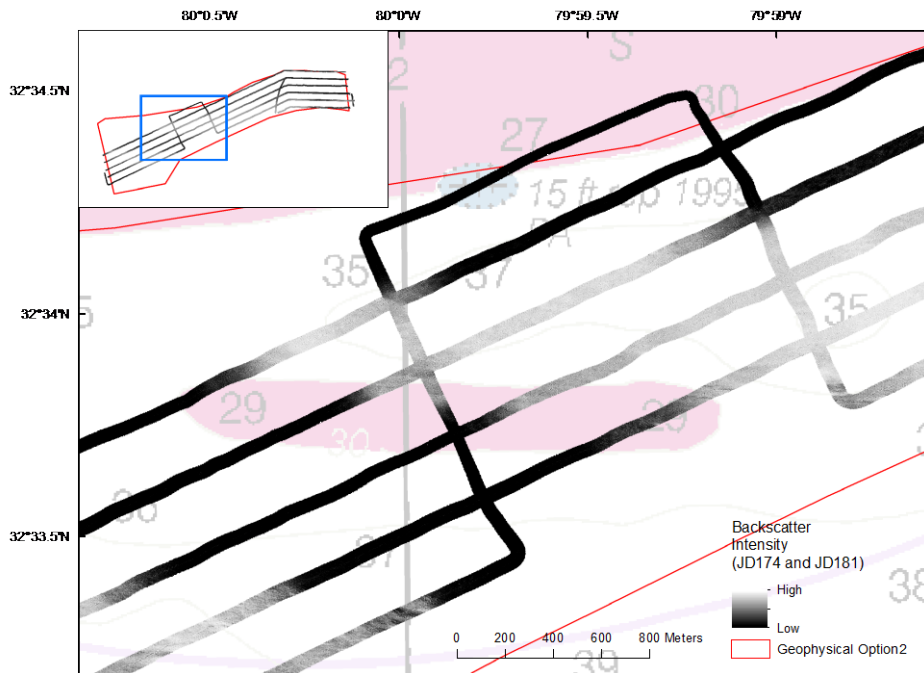
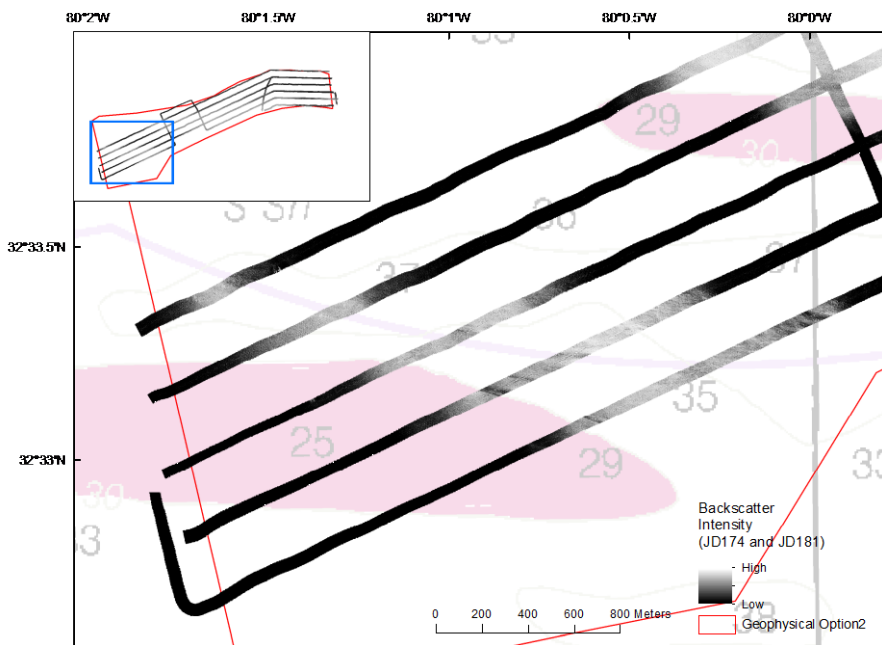


Figure 12a. Side scan sonar backscatter response of the sea floor along geophysical tracklines in the west-central portion of the study area (above-inset). The backscatter response for tracklines in the western portion of the study area is shown in Figure 12b (below-inset).



In the western portion of the study area, dominated by two oblique sand ridges, the backscatter response is consistent with these ridges being composed of fine sand likely an extension of the ebb tidal delta system in the process of being abandoned on the inner shelf with transgression and subject to shelf processes. In general, the shoals show a higher backscatter response on their north-eastern flanks suggesting they are actively interacting with wave and shelf currents (tidal) resulting in sediment lags in the swales between ridges and a probable reworking by westerly setting shelf (tidal) currents.

Recommendations for Sand Resource Potential, Quality, and Volume.

Integrating multibeam, chirp sub-bottom profiling and side scan sonar data sets the following areas are identified as potential beach nourishment resources and should be considered for vibracoring validation of sand resource quality and potential.

1. The best potential area for USACE purposes would be to target coring campaign on the two oblique shoals on the western section of the study area. These shoals represent a significant volume of sediment standing in positive relief and could be utilized and limit excavation of a depression with a higher potential for trapping fines or result in change in bottom sediment (habitat) characteristic.
2. The second priority area recommended from the geophysical survey would be the seaward shield of the modern Stono Inlet ebb tidal delta along the northern area of the study area and particularly well expressed from the central to eastern section of the study area. This shoal continues to extend to the east and inshore beyond this study area where it is already targeted for vibracoring by the Corps (Figure 1). Within the study area, however, the inshore section of this deposit shoals to depths of less than 30 feet and may present accessibility issues for the federal project. This site may remain of potential interest to the City of Folly Beach, less constrained by COBRA limitations particularly considering the, slightly, less transportation distances to the nourishment site.
3. The third area recommended for consideration would be the heavily channeled section located in the eastern portion of the study area. This area has similar character as an area identified in the previous study by Schwab, Gayes and Denny (2002) focused on the inner shelf off central and northern sections of Folly Beach. Overall the shoal and complexes associated with the delta system area anticipated to be more consistently sandy. The channel complexes represent a very large volume potential but can be expected to be more variable in sediment texture and would also require excavation of variable thicknesses of surficial sediment overburden to access and would result in a borrow site depression on the inner shelf likely to generate concern for change in sediment character infilling the borrow pit.

McBride, RA and Moslow, TF, 1991,, Origin, evolution, and distribution of shoreface sand ridges, Atlantic inner shelf, USA, Marine Geology, v. 97 (1) , P 57-85

