Announcement M13AS00014: Hurricane Sandy Coastal Recovery and Resiliency - Resource Identification, Delineation and Management Practices

Cooperative Agreement M14AC00013: Assessment of Offshore Sand Resources for Virginia Beachfront Restoration

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Summary Report

Cooperative Agreement Outputs including Project Deliverables:

Berquist, C. R., Jr., Lassetter, W.L. and Goodwyn, M.H., 2016, Grain size distribution and heavy minerals content of marine sands in Federal waters offshore of Virginia: DMME Division of Geology and Mineral Resources Open-File Report 2016-01.

Marine sediment samples collected in 2013 in the offshore Virginia Wind Energy Area (WEA) were analyzed for grain size statistics and heavy minerals content. These analyses provide valuable geotechnical and economic information that is relevant to the identification of potential offshore sand borrow areas for beach re-nourishment, an objective of the BOEM-Virginia State Cooperative Agreement M14AC00013. The sediments were collected as seafloor grab and vibracore samples at locations ranging from about 3.5 nautical miles from shore out to about 35 nautical miles within the WEA. Water depths ranged from about 11 meters to 34 meters MLLW (mean lower low water). A total of 73 large-volume sediment samples were dried, screened and *sieved for textural analysis, and of these 60 were processed through a three-turn Humphrey Spiral concentrator to separate the total heavy minerals (THM) fraction for laboratory mineralogical analysis. Thirteen additional grab samples were processed for THM only. The heavy minerals of interest in this study are characterized by specific gravity greater than about 2.9 and include ilmenite ($FeTiO_3$), rutile (TiO_2), leucoxene (altered ilmenite), monazite (Ce,La,Nd,Y,Dy,Sm,Th)(PO_4), and zircon (Zr,Hf,U)(SiO_4). These minerals have economic value as sources of titanium- and zirconium-oxides, rare earth elements and thorium that could provide significant cost benefits if co-recovered during sand mining operations for coastline protection projects.*

Grain size analysis indicated most samples consist of medium- to coarse sand with low percentages of mud averaging less than 2% and gravel less than 2.5%. The THM fractions for all samples averaged 0.93% by weight, but there were notable enrichments in samples with higher percentages of fine-grain sediments. In 6 samples where the total sand fraction consisted mainly of fine- to very-fine sand, THM averaged 2.63% by weight with a maximum value of 4.10%. Lab results from Mineral Liberation Analyzer (MLA) scans indicated garnet, titanium-bearing minerals, and amphibole to be the most abundant components of the THM concentrates. On a mass percent basis, ilmenite and rutile averaged about 18.21% and 1.49%, respectively in the concentrates. Minerals containing rare earth elements (REE), such as monazite and apatite were generally low in abundance, although REE-bearing zircon ranged as high as 5.73% and averaged 2.21% for all samples.

The lab results for these samples will expand the catalog of offshore data that is available to help identify beach-quality sand resources for dredging operations and coastal restoration projects. The heavy minerals analyses compliment data from earlier offshore mineral assessments that showed very promising potential for economic deposits of coexisting industrial minerals (Figure 1). THM concentrations were generally lower than those reported by Berquist and Hobbs (1988) and Berquist (1990) for 390 sediment samples from Virginia's offshore region (average THM = 3.3% with a maximum value of 14.7%), but also underscored the importance of the depositional environment on the distribution of heavy mineral sands. Based upon the minimum economic threshold concentration of about 2% THM for heavy mineral sand deposits in coastal environments worldwide (Van Gosen and others, 2014), additional data gathering is warranted to better understand the tonnage potential, key depositional factors, and mineralogical compositions of Virginia's offshore sand resources.

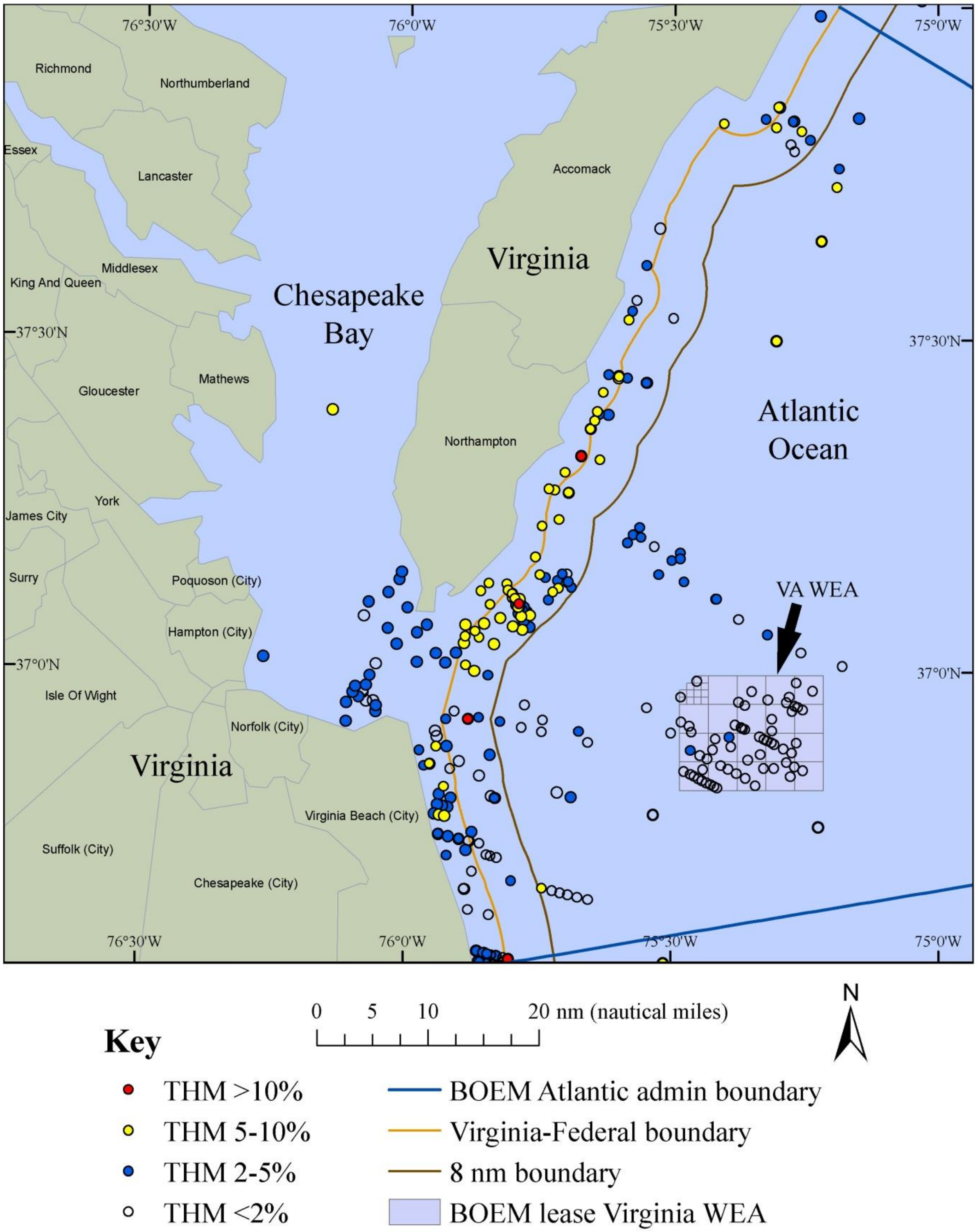

Figure 1 – Map showing sample locations from Berquist (1990), Luepke (1990), and the present study analyzed for total heavy minerals (THM) offshore of Virginia.

Goodwyn, M.H., Enomoto, M.R., Lassetter, W.L., and Kuehl, S.A., 2016, GIS compilation of geophysical data on Virginia's Outer Continental Shelf: DMME Division of Geology and Mineral Resources Open-File Report 2016-02.

Legacy geophysical data from Virginia's Outer Continental Shelf (OCS) were compiled in an ESRI ArcGIS geodatabase to enable future spatial and resource analysis using on-line geographic information system (GIS) tools. Primary data sources included: the Virginia Institute of Marine Science (VIMS), Virginia Department of Mines, Minerals and Energy (DMME), National Oceanic and Atmospheric Administration (NOAA), National Geophysical Data Center (NGDC), Marine Geoscience Data System at Lamont-Doherty Earth Observatory (LDEO), the U.S. Bureau of Ocean Energy Management (BOEM), and the U.S. Geological Survey (USGS) (Figure 2). The geodatabase contains location and collection details, water depth, sediment description and other available geotechnical attributes.

The VIMS sources contain seismic data, core descriptions and grab samples collected by the U.S. Army Corp of Engineers and VIMS from 1970 to present. Most of the core samples are located at the mouth of the Chesapeake Bay or within 8 nautical miles (nm) of the current coastline near Virginia Beach. The VIMS seismic data were scanned from paper archives and varies in quality from poor to excellent. The NOAA and NGDC data were downloaded from the url: http://maps.ngdc.noaa.gov/viewers/geophysics/. Most of these datasets were collected farther offshore than the 8 nm limit of the present study. Geophysical data acquired from the USGS included side-scan and sub-bottom profile data collected in 2014-15 as part of a broad survey covering the 1-20 mile offshore region of the Delmarva Peninsula. This dataset is of very high quality and covers nearly the entire length of the peninsula. Whereas there is good coverage for both seismic and cores in the vicinity of Virginia Beach and Sandbridge, significant data gaps are present to the north and south of this area. In particular, although the recent USGS survey collected high-quality geophysical data from the Eastern Shore, very little coring has been performed in this area, thus limiting the ability to assess the quality, extent and thickness of sand resources. The geodatabase provides an essential tool for identifying prospective sand resource areas and where there are data gaps that need to be addressed by future studies (Figure 3).

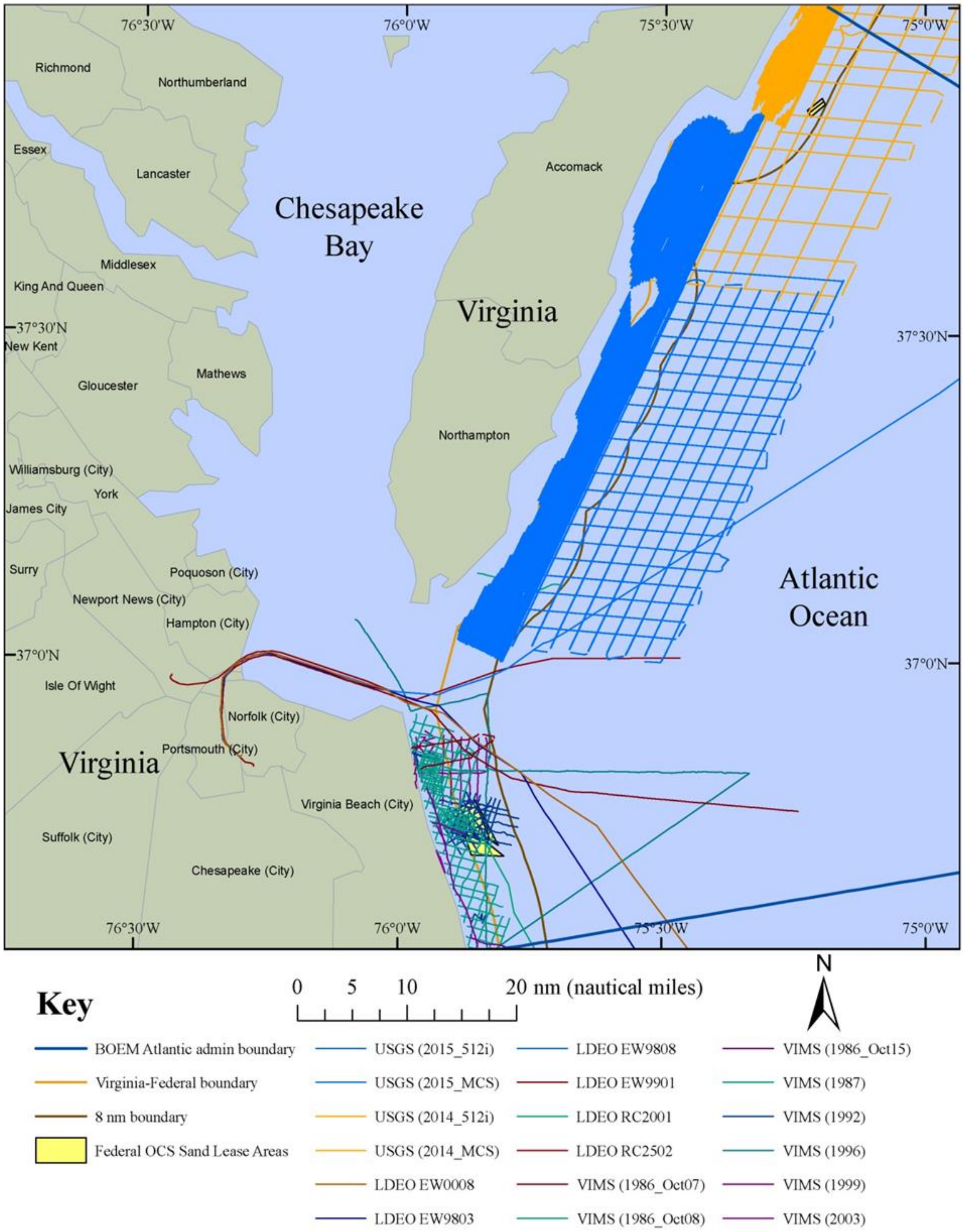

Figure 2 – Map showing locations of key geophysical data collection tracklines offshore of Virginia.

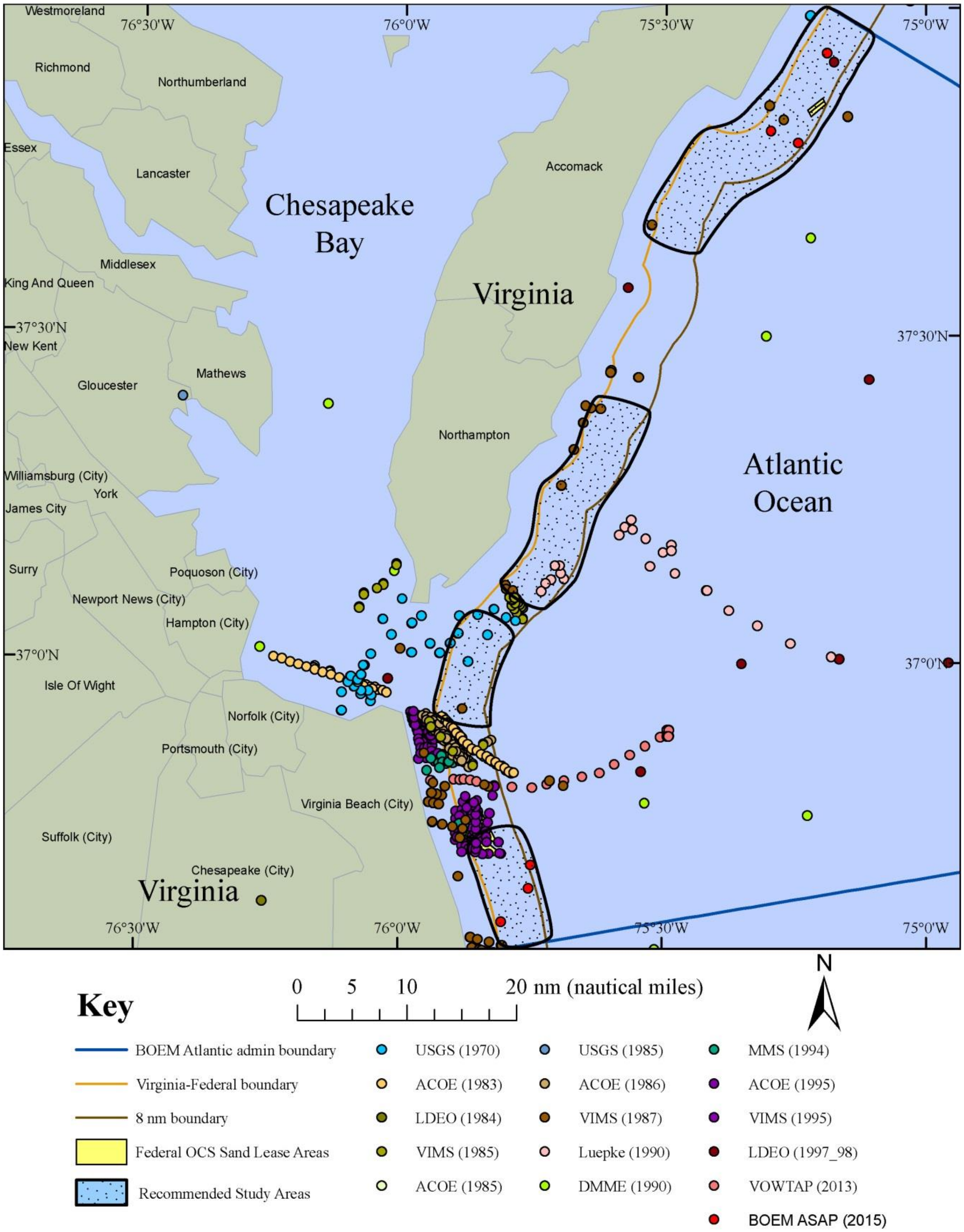

Figure 3 – Map showing sediment core locations and areas recommended for additional data collection and study.

Milligan, D.A., Hardaway, C.S., Wilcox, C.A., and Wilcox, D., 2016, Digital conversion of geologic core data, modeling, and visualization of sand resources on Virginia's continental shelf: DMME Division of Geology and Mineral Resources Open-File Report 2016-03.

Geologic data from nearly 500 scanned geologic logs of marine sediment cores taken from Virginia's continental shelf were converted to a digital format to facilitate data quality assessments, analysis, and modeling using geospatial software. The original paper logs had been previously scanned to an image file format (.tif) as part of an earlier project partnership between the Virginia Institute of Marine Science (VIMS) and the U.S. Minerals Management Service (now BOEM). Sedimentological classifications and descriptions along the length of each core were input to Microsoft Excel which was then imported to ESRI ArcGIS in order to model sediment type and location on Virginia's continental shelf and define areas of suitable sand.

The ArcGIS model uses both analysis and visualization to describe the locations and types of sediments on Virginia's continental shelf. The analysis sampled the core at one meter intervals and used statistical analysis to determine the likely area around the core that contains the same type of sediment in each layer. The resulting depth planes were stored in raster grids that were used to visualize the data in 3D in ArcScene. The presence of significant thicknesses of sand in the uppermost sediment layers with little overburden were considered suitable sand for mining (Figure 4). This assessment provides a more accurate spatial definition of the sand resources there as well as areas where key data gaps exist.

Several next steps are proposed. The first is obtaining new cores from areas that have potential for sand but have little existing data. The second is leveraging the existing seismic data to extend the reach of the cores. Previous studies analyzed individual seismic data lines offshore of Virginia's southeast coast, but trying to determine how the individual lines fit together spatially is a challenge. Including these data into the model would provide a detailed geophysical analysis of the continental shelf.

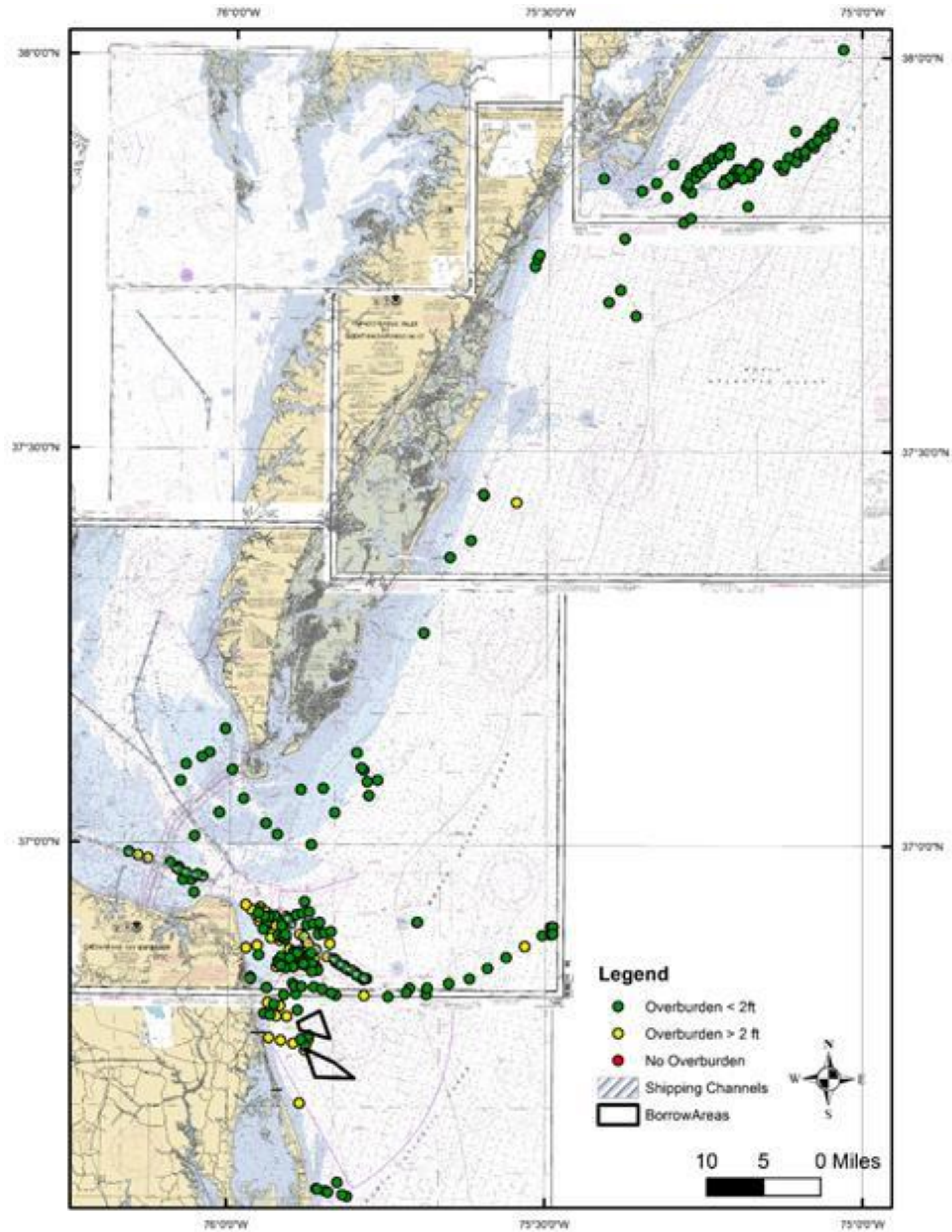

Figure 4 – Map showing locations of cores with suitable sand shown by overburden amount.

Oral presentations:

Lassetter, W.L., and Berquist, C.R., 2016, Assessment of offshore sand and heavy minerals on Virginia's continental shelf: 2016 Virginia Geologic Research Symposium, sponsored by the Department of Mines, Minerals and Energy, April 28, Charlottesville, VA.

Other Related Virginia OCS Reports:

Berquist, C. R., Jr. [ed], 1990, Heavy-Mineral Studies – Virginia Inner Continental Shelf: Virginia Division of Mineral Resources Publication 103, 124 p.

Berquist, C.R., Jr., and Hobbs, C.H., III, 1986, Assessment of economic heavy minerals of the Virginia inner continental shelf: Virginia Division of Mineral Resources Open-File Report 86-1, 17 p.

Berquist, C.R., Jr., and Hobbs, C.H., III, 1988, Study of economic heavy minerals of the Virginia inner continental shelf: Virginia Division of Mineral Resources Open-File Report 88-4, 149 p.

Diaz, R.J., Wikel, G.L., Browder, A.G., Y-Maa, J.P., Milligan, D.A., Hardaway, C.S., Tallent, C.O., McNinch, J.E., Ha, H.K., Nestlerode, J.A., and Hobbs, C.H., III, 2006, Field Testing of a Physical/Biological Monitoring Methodology for Offshore Dredging and Mining Operations: Prepared for U.S. Department of the Interior, Minerals Management Service, Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia.

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Hardaway, Jr., C.S., Milligan, D.A., Thomas, G.R., and Hobbs, C.H., III, 1998, Environmental Studies Relative to Potential Sand Mining in the Vicinity of the City of Virginia Beach, Virginia - Part 2: Preliminary Shoreline Adjustments to Dam Neck Beach Nourishment Project Southeast Virginia Coast: Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia, 72 p. + app.

Hardaway, C.S., Hobbs, C.H., III, and Milligan, D.A., 1995, Investigations of Offshore Beach Sands: Virginia Beach and Sandbridge, Virginia: Technical Report prepared for Minerals Management Service, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia.

Kimball, S.M. and Dame, J.K., 1989, Geotechnical evaluation of sand resources of the inner shelf of southern Virginia: Virginia Institute of Marine Science Final Report to the City of Virginia Beach, VA.

Kimball, S.M., Dame, J.K., and Hobbs, C.H., III, 1991, Investigation of isolated sand shoals on the inner shelf of southern Virginia: Virginia Institute of Marine Science Final Report.

Luepke, G., 1990, Economic heavy minerals in sediments from an offshore area east of Cape Charles, Virginia: U.S. Geological Survey Open File Report 90-451, 10 p.

McNeilan, T.W., Smith, K.R., and Fisher, J.E., 2013, Regional geophysical survey and interpretive report: Virginia Wind Energy Area offshore southeastern Virginia: US Dept. of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, Herndon. OCS Study BOEM 2013-220, 240 p.

Van Gosen, B.S., Fey, D.L., Shah, A.K., Verplanck, P.L., and Hoefen, T.M., 2014, Deposit model for heavy-mineral sands in coastal environments: U.S. Geological Survey Scientific Investigations Report 2010-5070-L, 51 p., http://dx.doi.org/10.3133/sir20105070L.