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Richard A. Ortt, Director

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Conversion of Maryland's Offshore Mineral Resources Data for GIS Applications and Baseline Acoustic Seafloor Classifications of Offshore Borrow Areas
Technical Report

by

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Introduction

The task of assessing and responsibly managing offshore resources is largely aided by the availability of high quality continuous data, from which coastal geologists can make interpretations and provide guidance for resource management. For over thirty years the Maryland Geological Survey (MGS) has been collecting data from Maryland's coastal region, ranging from the near-shore littoral zone, to as far as ~38 km (~23.5mi) offshore, on the inner continental shelf. These data, which include side scan sonar, seismic, vibracore, and seafloor classification datasets, are used to map areas of potential sand and gravel resources, manage offshore habitat, and to track the changes to these resources over time. In a continuing effort to better characterize Maryland's Atlantic coastal geology, these data have been compiled into a geodatabase for use in a GIS, and will be discussed in the following sections (Figure 1).

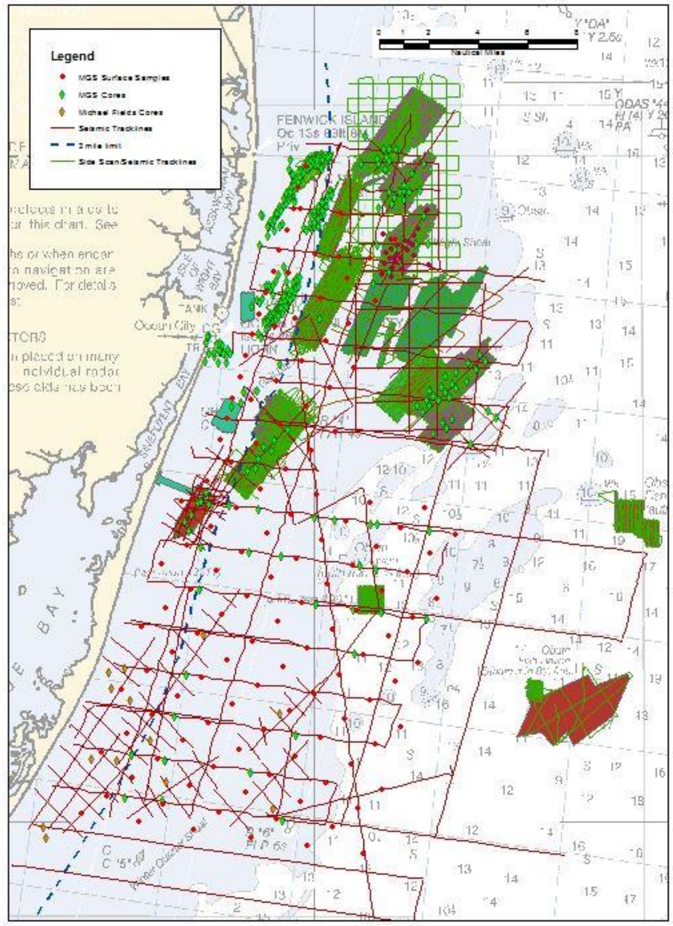

Figure 1. Map of the MGS digital data inventory, including side scan sonar, seismic, core and grab

Side Scan Sonar

The most useful product for acoustic seafloor classifications is the side scan sonar backscatter. Varying seafloor components such as texture, hardness, and benthic organisms affect the reflectivity of the acoustic signal. The Maryland Geological Survey has collected over three thousand kilometers of side scan sonar data between 2004 and 2011. These data exist as raw digital data files, in both .XTF and .JSF file formats, and as a post-production product: GeoTIFF mosaic raster. These rasters are useful for visualizing and interpreting macro-features on the sea floor, such as ripples and ridge-and-swale topography. Some areas, like Fenwick Shoal and Great Gull Bank, were re-surveyed in years following the initial survey in order to record the changes those regions underwent. In total MGS has compiled forty-one GeoTIFF rasters, forty were processed using data from MGS field surveys, and one additional raster processed using NOAA data. The MGS total coastal side scan coverage is roughly 584 km^2.

Through the 2004 to 2006 field seasons, MGS collected side scan data using a rented towfish, usually an Edgetech 272 analog duel-frequency system, which records both high and low frequency. Beginning in 2008, MGS conducted surveys using their own Edgetech 4200 FS towfish. Often, geologists at the MGS processed data shortly after the completion of the field survey, and those data were not reprocessed unless needed. As a result, many of the older GeoTIFFs in the MGS digital archive were of relatively coarse resolution, having been processed using software with

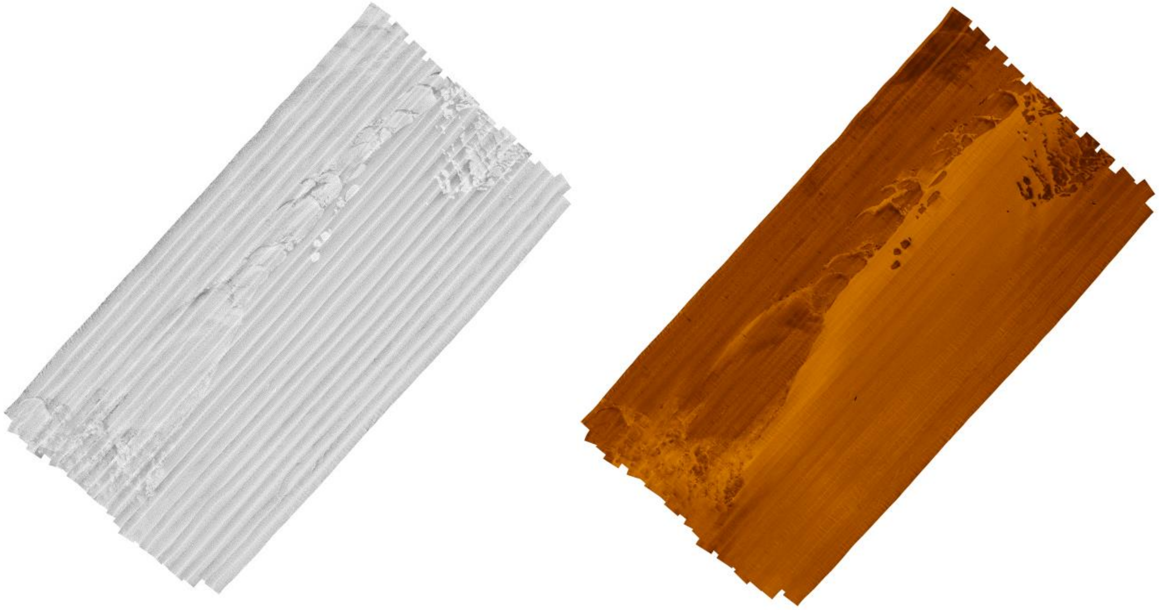

Figure 2.(Above) An example of a side scan sonar GeoTIFF raster processed shortly after collection in 2008 (left) and the same data reprocessed in 2015 with SonarWiz 5 (right).

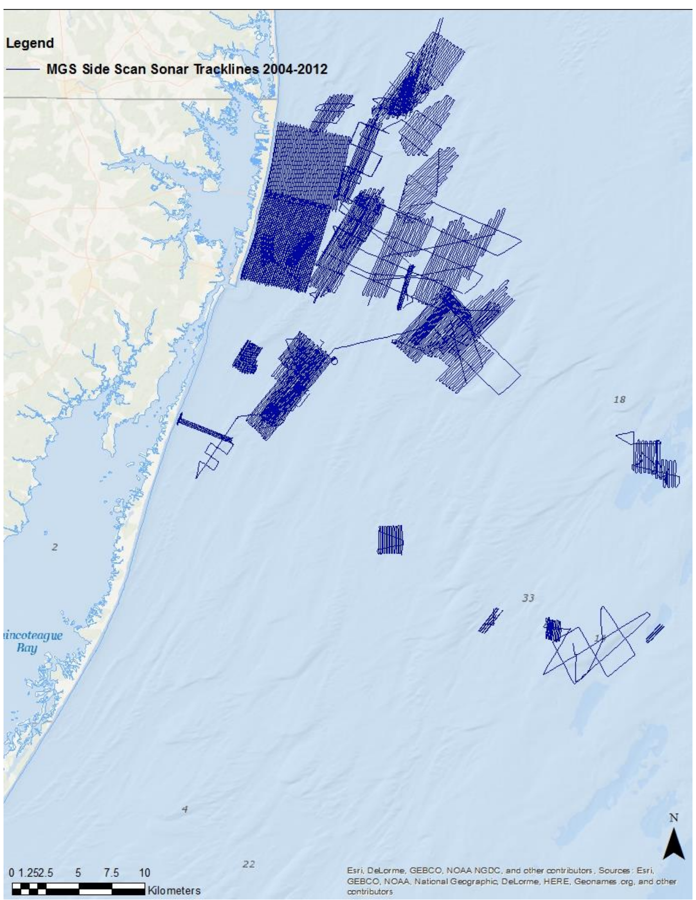

Figure 3. Map of the MGS side scan sonar data inventory coverage. Data were collected digitally beginning in 2004, and on paper rolls pre-2004.

limited capabilities compared to the current version of the same processing software.

In late-2015 and early-2016, geologists at MGS reprocessed side scan datasets from 2004 through 2009, using the most recent release of the sonar processing software (SonarWiz 5) to produce updated GeoTIFF rasters. The processing capability of SonarWiz 5 provides higher quality mosaics than did previous releases, resulting in significantly improved GeoTIFF image resolution. Reprocessing also eliminated much of the image distortion, or "striping", that was apparent on many of the original GeoTIFFs (Figure 2). During reprocessing, most individual side scan files were imported using a 2x gain import setting, however some older (2004-05) data displayed poor resolution at that setting, so were loaded using a 6x-8x import gain. The reprocessed GeoTIFF rasters were exported at 0.5x0.5 meter/pixel, with 32 bit resolution. The reprocessed GeoTIFF rasters can also be used for bottom classification. The high quality, and consistency, of the reprocessed GeoTIFFs helps ensure accuracy and consistency of the classifications.

In addition to the reprocessed side scan sonar GeoTIFFs, MGS also has compiled a digital archive of the raw data collected in the field, in both Edgetech's dual-frequency .JSF format, and the non-proprietary .XTF format. The latter format is single-frequency, with individual .XTF files for high and low frequency data. Finally, MGS has archived two analog side scan datasets, on paper rolls, in the MDNR Weaver Building, which have not been digitized. These datasets are from 1985-86, and are both in fairly poor physical condition, and by contemporary standards, poor data resolution. The 1985-86 side scan datasets, in their current format, are available by request and MGS does not have plans to digitize them. Tracklines for digital side scan sonar coverage are shown in Figure 3.

Seismic Profiles

Between 1984 and 2012, MGS coastal geologists collected nearly 5,000 km of seismic profiles while field surveying in the Atlantic coastal region. Early surveys logged seismic data on paper rolls, which are archived in the MDNR Weaver Building in Baltimore City. These seismic profiles have been inventoried, and some have been digitized. Beginning in 2004, MGS began collecting seismic surveys in digital format. The collection method also changed slightly during the shift from analog to digital surveying. MGS seismic data, beginning around 2004, were collected simultaneously with side scan sonar data, which required relatively close line spacing (typically 100-150 ft.) to facilitate appropriate side scan data overlap. As a result, the seismic data collected from 2004 onward were densely clustered within the survey areas, whereas the pre-2004 seismic survey lines covered significantly more area, yet were spaced much further apart (Figure 4).

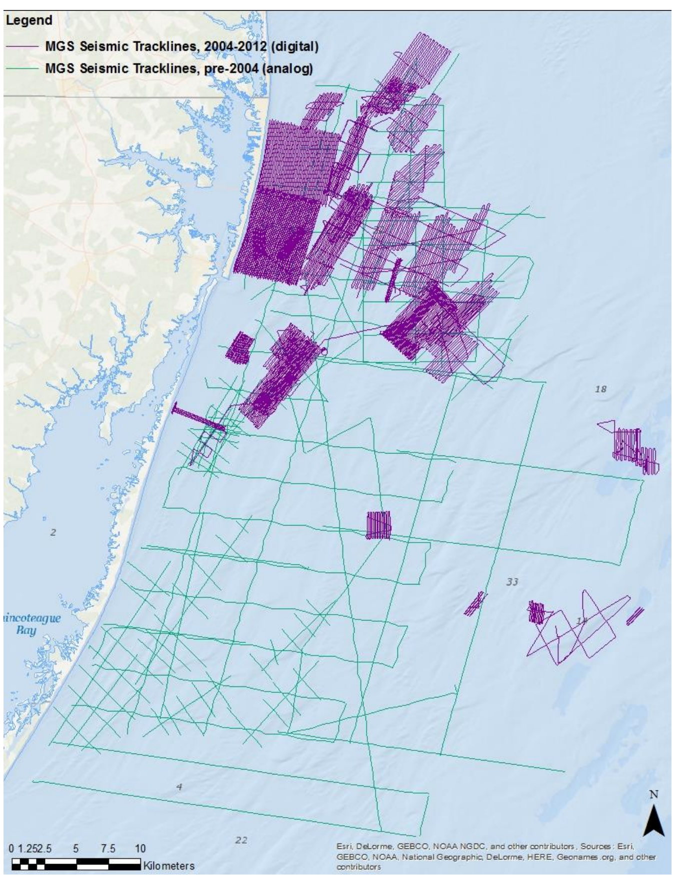

Figure 4. Map of the MGS digital and analog seismic data inventory coverage. Data were collected digitally beginning in 2004, and on paper rolls pre-2004.

Geologists at the Maryland Geological Survey have recently cataloged their inventory of paper archives of older seismic and side scan surveys. These older data have been evaluated for data quality, and preservation of the physical paper rolls upon which the data are printed, and some have been scanned into digital .JPEG or .BMP format. Datasets that show poor data resolution, or the paper records upon which the data were recorded show poor preservation, will not be digitized nor included with the MGS geodatabase.

The Maryland Geological Survey's

digital seismic data are archived in Edgetech's proprietary .JSF file format, as well as .SGY format, and .JPEG or .BMP image file format. In some cases, the Discover SB 3200 software was used to generate .SGY files during post processing for datasets where seismic data were only collected in .JSF format. Similarly, seismic data collected using the Knudsen chirp system (2004, 2006) was converted to .SGY format from their proprietary .KEA/.KEB file format. The locations of seismic tracklines and fixmarks are included in the MGS geodatabase. Any of the older, analog seismic data that the MGS decides to digitize will also be converted from .JPEG to the .SGY format, and archived along with the more recent seismic data.

Currently, MGS has 3248.5 km of digital seismic data, both profile images and raw digital data from 2004 to 2012, and 1366.5 km of analog seismic data collected between 1984 and 1995. Both the digital and analog data are represented in the MGS geodatabase by the seismic tracklines (Figure 4), however some of the analog data have yet to be scanned and digitally archived.

Sediment Samples

The Maryland Geological Survey has collected 310 vibracores on the inner continental shelf off the Atlantic coast of Maryland between 1986 and 1997. The cores were originally analyzed in conjunction with seismic profile data, photographed (some were x-rayed), and underwent textural analysis. Some cores also underwent radiographic analysis, amino acid racemization and/or ^{14}C dating, light/heavy mineral analysis, or paleofossil analysis. The locations where cores were extracted are recorded in a GIS pointshape file, in the MGS geodatabase (Figure 5). The laboratory analysis data and project information for each core is included in the pointshape file, taken from Wells and Conkwright (1996) “Physical Inventory and Repository of Vibracores Collected on Maryland's Continental Shelf”. The physical cores are in storage at the MDNR Matapeake facility in Stevensville, MD.

Project partners for many of the studies which included vibracoring within the scope of work included U.S. Army Corps of Engineers, the Delaware Geological Survey, and the U.S. Geological Survey. The extent of analysis depended on the needs of the project, and the availability of funding to conduct laboratory analysis. Cores were originally collected and reported in units of feet, seen in Wells and Conkwright (1996), but have since been converted and reported in the pointshape file using meters. Core lengths range from sub-meter to over 6 meters in length, with the mean core length measuring roughly 5 meters. Cores were collected from seafloor depths ranging from 3 to 21 meters, with the mean depth at roughly eleven meters. Additional information about the collection and analysis of the cores is

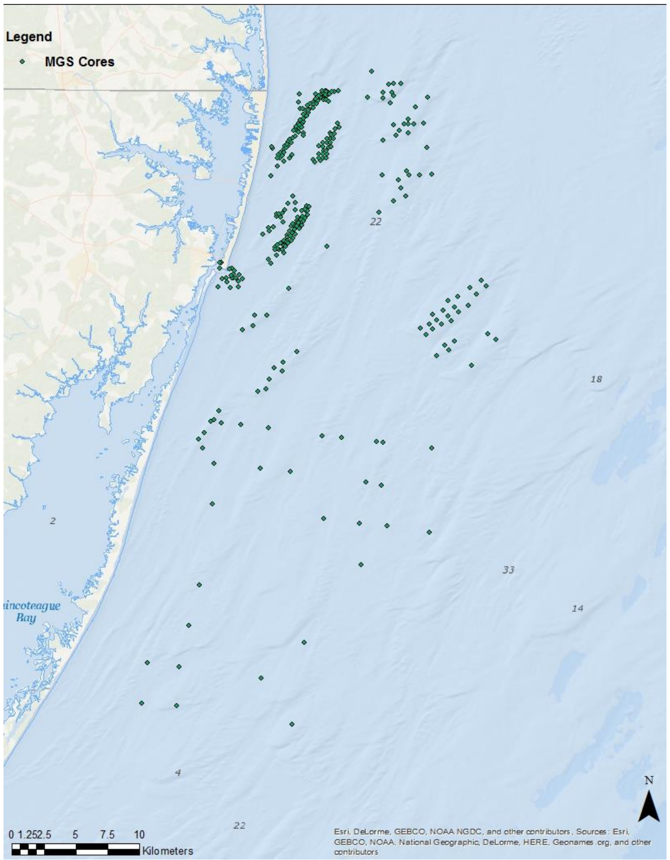

Figure 5. Map of the distribution of 310 vibracores collected on Maryland’s Atlantic continental shelf. Cores were collected by MGS between 1986-1997.

available in the original publications (Conkwright and Gast, 1994; Wells, 1994; Conkwright and Gast, 1995, Conkwright and Williams, 1996; Wells and Conkwright, 1996; Conkwright, Williams and Christiansen, 2000).

Other sediment sample data included in the geodatabase are grab samples, collected between 1984 and 2012. Grabs are collected typically using a Van Veen grab sampler, and samples are often collected and analyzed in the field, qualitatively, to reaffirm the acoustic data from side scan or bottom classification. In these cases, the grab sample served as a 'ground-truth' for the acoustic data being collected on the research vessel (Conkwright, Van Ryswick and Sylvia, 2014). In the past, grab samples have also been analyzed, along with vibracores, to characterize heavy mineral concentration (Brooks, 1988; Toscano et al., 1989). Grab samples are often photographed in the field; the sample photos are archived in the MGS database.

Seabed Classification

Bottom sediment composition is influenced by bottom geomorphology, water depth, substrate composition and biologic activity. The interaction of these factors with water column energy, such as waves and currents, determines in part the seafloor surface composition. Maryland Geological Survey performed acoustic seafloor surveys off Ocean City Maryland in 2011 and 2012 as part of a continuing effort to characterize bottom habitats in state waters. A series of roughly 3-mile by 3-mile square survey blocks (OCS blocks) were laid out along the Maryland coastline, extending from the shoreline out to the 3-mile state limit, and from Ocean City inlet to the Maryland/Delaware border. OCS Block 1, covering the seafloor from Ocean City Inlet north to 68th Street, was surveyed in 2011 and measures 3.8 nautical miles (7 km) miles. OCS Block 2, covering the ocean floor from 66th Street to 131st Street, was surveyed in 2012, and measures 3 nautical miles (5.6 km).

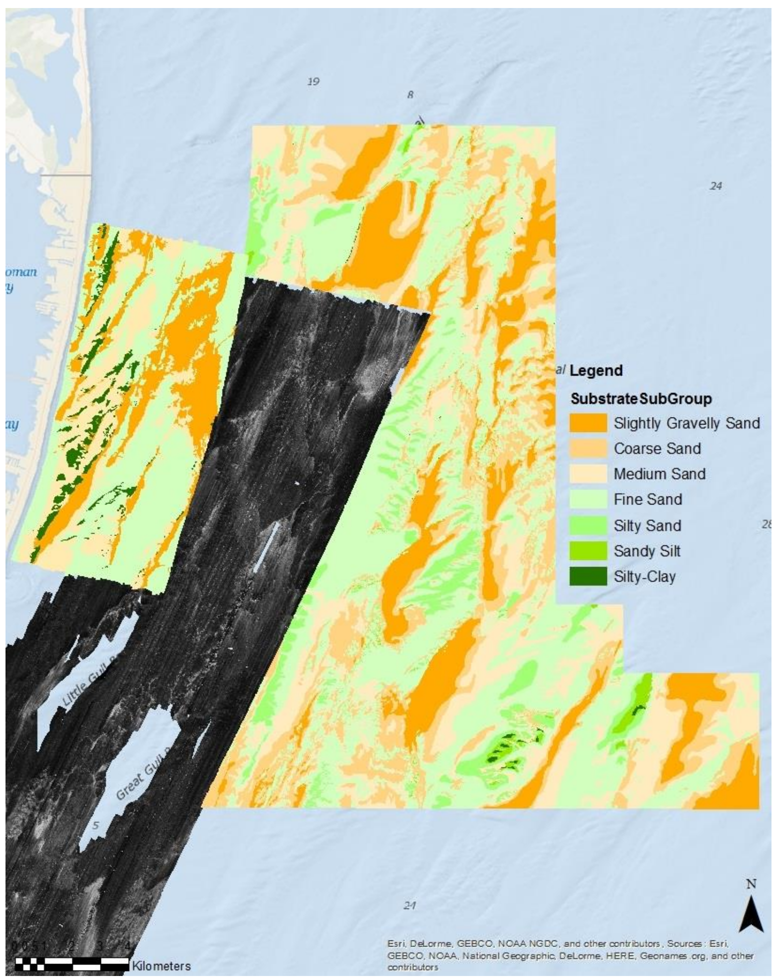

Figure 6. Bottom Classification map shows near-shore Ocean City Blocks 1 & 2 (left). "Z" shaped image (right) represents the NOAA collected, MGS reprocessed & classified block. The gray scale image shows the USGS surveyed backscatter (pending seabed classification from USGS).

For the 2011 and 2012 OCS datasets, geologists at MGS used QuesterTangent's SWATHVIEW seabed classification software to process the 410 kHz side scan sonar signal. This software analyzes the side scan sonar backscatter to produce a classification map based on the acoustic reflectivity characteristics of bottom sediments. Employing proprietary algorithms, SWATHVIEW uses multivariate analysis to find patterns in the side scan acoustic backscatter signal, which reflect bottom textural parameters. Cluster analysis then grouped together regions of similar acoustic backscatter characteristics, or classes. Once the acoustic classes were determined, they were correlated with bottom samples and imagery. Geologists at MGS then used the Image Classification tool in ArcGIS to classify the two OCS blocks, as well as an additional dataset compiled from NOAA data, which is located to the east of the OCS blocks. The classified NOAA data can be seen in Figure 6 as a large Z-shaped area.

The ArcGIS classification tool extracts information classes from the multiband mosaic raster image to produce a raster that represents bottom classes using graded colors. Geologists at MGS performed two supervised classifications to create rasters with four and six classes based on training sample signature files. By comparative analysis of the four and six class rasters, MGS identified seven major acoustically distinct bottom classes. These types were correlated with bottom grab samples and bathymetry to produce a map of the seven bottom classes, based on dominant sediment types.

The seafloor bottom types were digitized as a polygon shapefile in ArcGIS to indicate the areas of distinct bottom classes. Each class was then classified based on the Federal Geographic Data Committee (FGDC) Coastal and Marine Ecological Classification Standard (CMECS) substrate classification for unconsolidated mineral substrates. The resulting Substrate Sub Group bottom class map contains seven bottom classes ranging from slightly gravelly sand to silty-clay (Figure 6). The area in Figure 6 containing the gray-scale backscatter raster, located between the OCS blocks and the Z-shaped area, and continuing to the south, was surveyed by USGS in 2014 and the backscatter classification is pending from USGS.

Sand Volume Estimates

Between 1994 and 2000, geologists at MGS estimated sand volumes on shoals off of Maryland's Atlantic coast. To determine shoal volumes, MGS used a combination of bathymetric, core, and seismic data to define the upper and lower surfaces of the shoals, and their flanking boundaries. Shoal edges were defined by either the pinch-out of shoal sediments (< 1m), or a significant fining in flank sediment texture. Once the shoal boundaries were defined, MGS used a TIN model to calculate an estimate of the sand volume on each shoal. This model relies on an interpolated bottom bounding surface, the determination of which is largely aided by data from cores. In some areas, specifically the southern shoal field, core data is sparse, which limits our ability to accurately estimate shoal sand volumes. Some shoals, such as Shoal S, Charlene Shoal, and Shoal R, did not have volumetric estimates calculated for them. Because these estimates are now between 15 and 20 years old, recalculating the volumes using contemporary software and bathymetric data would likely yield a more precise measurement of sand resources off Maryland's coast. More information about methodology and results for volumetric estimates can be found in Conkwright and Gast (1994), Conkwright and Gast (1995), Conkwright and Williams (1996), and Conkwright, Williams, and Christiansen (2000).

Metadata

Using information from published reports, field notes, and all available written and digital records, geologists at the MGS completed metadata for all feature classes currently compiled in the geodatabase. Metadata generation was completed in ArcCatalog (ESRI ArcGIS v. 10.3.1), using the

FGDC-compliant metadata standard template that is available in ArcCatalog. Information included in the metadata serves the purpose of contextualizing the data for use both within and outside of the MGS, so that users know when the data were collected, using which equipment, and how the data were processed. Users will also be informed which publications to review for additional information, laboratory data, and interpretations. Exported metadata can be parsed in a variety of ways using transformational stylesheets (.xsl), and exported to individual XML metadata files (.xml). NOAA National Centers For Environmental Information, formerly the National Coastal Data Development Center, has more information about XML transformations (http://www.ncddc.noaa.gov/metadata-standards/metadata-xml/).

Data Gaps

The Maryland Geological Survey's coastal data contain a few potential data gaps. Some of these potential gaps are spatial, or coverage gaps, and others are temporal gaps, where survey data are old and possibly out of date.

MGS estimates of shoal sand volumes are now 15-20 years old, and may not reflect the present volumes and locations of those resources. As shown in the example of updated GeoTIFF images from side scan data, as software capability advances, so does our capability for upgrading products derived from field survey data. It is likely that, if revisited, a refined and more representative estimate of Maryland's offshore sand resources could be calculated with a greater degree of precision, and spatial accuracy. Additionally, new core and seismic data collected by CB&I from Maryland's southern shoals should be included in the volumetric estimates. A more accurate assessment of Maryland's offshore sand resources could be of great use in planning and executing targeted dredging operations for beach re-nourishment on Maryland's coast.

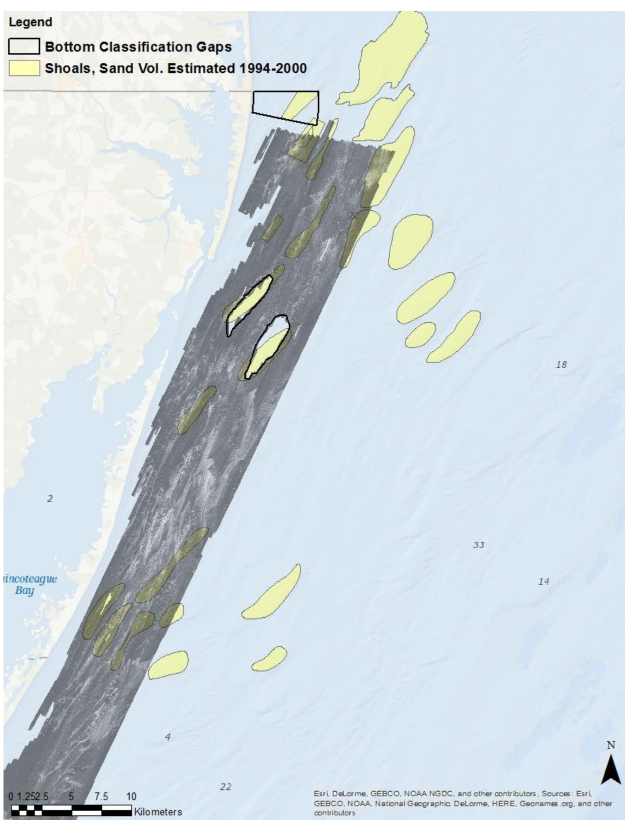

Figure 7. Map showing data gaps in bottom classification and volumetric estimations.

The MGS database contains some minor regions that lack continuous seabed classification data; these are areas where further data processing should be completed. The areas outlined in black, seen in Figure 7, show data gaps in MGS seabed classification along the state's Atlantic coast. The areas of no-data are near the coast, and to the north of CZM Blocks 1 and 2, extending north to the state line, and one of the two small irregularly shaped gaps in the USGS backscatter image. The gaps in the USGS backscatter are in the location of two prominent shoals: Little Gull Bank, in MD state waters closer to the mainland, and Great Gull Bank, in federal waters further from the mainland. The Maryland Geological Survey does have QTC bottom classification data from 2004 for Great Gull Bank, which covers a majority, but not all, of the outlined gap in the USGS raster in Figure. 7. There is no bottom classification coverage for Little Gull Bank. In order to ensure continuous coverage, bottom classification for these locations can be completed using existing NOAA data, in a manner similar to bottom classification that MGS completed for the Maryland Wind Energy Area (Conkwright, Van Ryswick and Sylvia, 2015).

Finally, the large USGS backscatter mosaic raster, seen in grayscale in Figure 7, lacks bottom classification data for that coverage area. It is unclear whether the USGS intends to classify that dataset. The region covered by the USGS backscatter represents a large data gap, until such time that the USGS, or another agency, processes those data for bottom classification. The MGS has the capability to process those data in a manner similar to the aforementioned NOAA dataset that MGS classified for the Maryland Wind Energy Area.

Summary

Geologists at the Maryland Geological Survey, in an ongoing effort to better facilitate data preservation and accessibility, have compiled the sum of over thirty years of survey data from Maryland's coastal regions into a central data repository. The aggregation of these data, and the metadata that informs end-users of the uses and limits of the datasets, maximizes the data's usefulness, and strives to minimize data loss. The curation of these geological and geospatial data is crucial to both managing Maryland's coastal resources, and allowing for ease in inter-agency cooperation and data sharing. The Maryland Geological Survey will continue refining and curating their coastal data repositories, and ensuring that any data coverage gaps that are identified are addressed. The analysis and compilation of existing datasets revealed several small areas that need further seabed classification analysis in addition to the pending classification of the USGS 2014 survey area. These areas include portions of Little Gull Bank and Great Gull Bank and a quadrant inside the 3 mile state water zone just to the south of the Maryland/Delaware state line. Additionally, some of the older seismic records pose a potential for data gaps as a product of deterioration of the paper media upon which the data are printed. If the data are judged to be deteriorated beyond use or determined that newer digital seismic records would provide higher resolution data for the assessment of offshore resources, the coverage areas of those data should be re-surveyed.

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