MARYLAND ENERGY ADMINISTRATION
HIGH RESOLUTION GEOPHYSICAL RESOURCE SURVEY
FINAL REPORT OF INVESTIGATIONS

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Prepared for:

Maryland Energy Administration
Powering Maryland's Future

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EXECUTIVE SUMMARY

Coastal Planning & Engineering, Inc., a CB&I Company, was contracted by the Maryland Energy Administration to conduct a high-resolution geophysical survey of the Outer Continental Shelf offshore Maryland in an area designated by the U.S. Department of Interior as the Maryland Wind Energy Area. The main objective of the survey was to collect and compile a comprehensive geophysical dataset as well as identify potential hazards and submerged cultural resources in support of the future development of a large utility-scale wind farm that will supply Maryland electricity consumers with a sustainable source of clean renewable energy. The high-resolution geophysical survey was planned prior to the federal government’s leasing of the Outer Continental Shelf Maryland Wind Energy Area in an effort to streamline and jumpstart the development process.

Geophysical and hydrographic surveys were conducted between July 4, and August 31, 2013. The surveys consisted of 150 meter spaced survey lines together with 900 meter spaced perpendicular tie lines covering the entire Wind Energy Area and a surrounding 304.80 meter (1,000 foot) buffer zone. The survey included multibeam hydrographic data, sidescan sonar, magnetometer, shallow-penetration chirp sub-bottom profiler, and medium-penetration multi-channel sparker seismic-reflection geophysical systems. There were a total of fifty-three (53) geophysical/hydrographic survey days with an additional six (6) hydrographic-only survey days.

Survey operations were conducted in two concurrent stages. During the first stage, multibeam, sidescan sonar, magnetometer, chirp sub-bottom profiler, and multi-channel sparker seismic-reflection data were collected covering the entire survey area during daylight hours only to mitigate for potential marine mammal impacts. The second stage was conducted concurrently with the first, but consisted strictly of multibeam data collection in the shallowest half of the study area to fill in data coverage gaps to meet contractual hydrographic guidelines and provide 100% coverage of the seafloor at 1 meter resolution.

The high-resolution geophysical survey spanned the inner- to mid-continental shelf between 16 km and 42 km offshore the central Delmarva Peninsula. Approximately 2,800 km of geophysical data, and nearly 5,200 km of hydrographic data were collected from July 4, to August 31, 2013. Results of the multibeam hydrographic data indicated seafloor elevations ranging from approximately -10 meters to -45 meters mean lower low water and a regional basinward (east) dip of the survey area. High-relief ridges at the west and low-relief ridges at the east are present across the survey area.

The sidescan sonar, chirp sub-bottom profiler and multi-channel sparker seismic-reflection data indicate that the bottom material across the survey area is predominately unconsolidated sand with some gravel overlaying a layer of unconsolidated to consolidated muds with occasional organic material. The layer of unconsolidated to consolidated muds with occasional organic material becomes exposed on the seafloor in the eastern and northern sections of the study area.

Using the sidescan sonar data, three (3) main seafloor bottom types were mapped across the survey area including exposed mud/clay, sand ridges and/or sand waves, and sand with some gravel. The sidescan sonar data yielded 104 sonar contacts on the seafloor ranging from small unidentified objects to larger-scale shipwrecks. The magnetometer data revealed 1,142 total magnetic anomalies. It should be noted that all potential magnetic anomalies, no matter how small and/or isolated, have been included as potential hazards as the widely-spaced survey line spacing does not support eliminating any magnetic anomalies from consideration as potential hazards or cultural resources.

Three (3) major seismic facies were identified throughout the study area; Unit 1 and Unit 2 (visible in both the chirp sub-bottom profiler data and the multi-channel sparker seismic-reflection data) and Unit 3 (visible in the multi-channel sparker seismic-reflection data only). Unit 1 was interpreted as sandy sediments deposited and/or reworked during the Holocene and ranged in thickness from 0 meters to 10 meters. Unit 2 was interpreted to represent multiple paleochannel erosional and depositional complexes containing a mixture of muds, sands and gravels which were deposited by a combination of fluvial, tidal, estuarine, and marine processes during the Pleistocene. Unit 3 was interpreted to be Neogene in age (1.8 million years old to 23.03 million years old) and likely comprised of predominantly coastal and marine sediments with some fluvial or estuarine sediments mixed in.

In total, the survey data does indicate the potential for the existence of some hazards that must be considered in any future development plans. These potential hazards included active zones of sediment transport, including one particular area in the southwest corner of the study area that appears to be indicative of active scouring. Steep slopes approaching 10 degrees, mainly associated with the sand ridge and swale topography of the survey area, exist throughout the western and southern section of the study area. As mentioned above, there is significant evidence of widespread paleochannels throughout the study area, together with areas where potential silt and/or clay are exposed on the seafloor. The presence of these interbedded clays, silts, and sands on the seafloor and within paleochannel complexes may prove hazardous to certain types of development activities and planned structures. Finally, two distinct and adjacent high-amplitude anomalies exist in the southwestern corner of the study area. These anomalies are indicative of a very hard, or reflective target at or very close to the seafloor. While these anomalies are small (approximately 25 meters long), their presence is confirmed by multiple geophysical systems, and as such, should be considered a hazard until ground-truthing can be done to positively identify the anomaly.

Based upon cultural resource interpretation of magnetometer and sidescan sonar data, a total of 1,142 magnetic anomalies and 91 sidescan sonar contacts were identified in the survey area. In addition, a total of eight (8) documented wrecks and obstructions on NOAA Chart 12200 Cape May to Cape Hatteras lie within the survey area. Anomalies associated with those charted wrecks and charted obstructions have been identified as “Buffered for Avoidance” to protect them from project-related construction activities. The recommended buffers are the largest and most conservative buffers possible based on the current 150 meter data coverage. Subsequent, design-level (detailed) cultural-resource data coverage and analysis would likely lead to the reduction in the size of these buffers.

Cultural resource review of the sub-bottom data indicate two highly organized buried channel complexes, one large poorly organized buried tidal complex and one smaller poorly organized buried channel and tidal complex. The highly organized buried channel could be associated with relatively intact prehistoric resources. While data from this survey confirms the high cultural resource sensitivity of the Maryland Wind Energy Area, the 150 meter line spacing is not sufficient for reliably identifying submerged cultural resources. As such, detailed site-specific magnetometer investigations will be required for specific development sites prior to any development activity in order to full understand the potential for cultural resource impacts.

CB&I is unable to conduct an official Constructability Assessment for the Maryland WEA due to a lack of geotechnical and proposed construction methodology information, CB&I is able to conduct a cursory comparison of the subsurface geology of the Maryland WEA to other offshore areas that have been, or are being considered, for offshore wind farm construction. As there are no existing bottom-founded offshore wind farms constructed within the United States, CB&I must look to Europe for comparable sites.

While there are some significant geological differences between the Maryland WEA and European offshore wind farm locations, including the fact that most of the European subsurface geology has significant glacial influences, there are noteworthy similarities as well. In particular, most of the North Sea and English Channel sites have a mobile Holocene marine sand/gravel unit underlain by Plio-Pleistocene strata with multiple paleochannels and infilling events, filled predominantly by silts and clays. Beneath that, some sites contain an older, open marine stratigraphy beneath the Plio-Pleistocene strata. These are all very similar subsurface geophysical conditions to the Maryland WEA. As these conditions have proven conducive to offshore wind farm construction in Europe, they would likely be suitable for offshore wind farm development of the Maryland WEA. That said, no formal constructability determinations can be made on the Maryland WEA until after detailed geotechnical investigations are completed and specific construction methodologies developed

The information gained from this high-resolution geophysical survey will be helpful to all parties involved with the future of Maryland's offshore wind farm program. These data and analysis will provide the foundation upon which future design, engineering, and site-location decisions will be made. The quality of the geophysical data acquired during the Maryland Energy Administration high-resolution geophysical survey and the detailed analysis presented herein should inspire confidence in any potential developers as they decide how to invest in Maryland's energy future. Follow-on surveys, including design-level cultural resource and geotechnical investigations, conducted off Maryland's coast will only serve to strengthen the results and analysis presented here.

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ACRONYMS AND ABBREVIATIONS

AGC	automatic gain control
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CASIUS	calibration of attitude sensors
CAD	computer-aided design
cm	centimeter
CTD	conductivity, temperature, and depth
CZM	coastal zone management
DGNSS	differential global navigation
DNR	Department of Natural Resources
DOI	United States Department of Interior
GIS	geographic information system
GPS	global positioning system
GW	gigawatt
HRG	high-resolution geophysical
Hz	hertz
ka	thousand years ago
kHz	kilohertz
km	kilometer
m	meter
m/s	meters per second
ms	milliseconds
MEA	Maryland Energy Administration
MLLW	mean lower low water
MW	megawatt
MYA	million years ago
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
nT	nanotesla or gamma
NTL	notice to lessees and operators
NTP	notice to proceed
NRHP	National Register of Historic Places
OARS	Offshore Analysis and Research Solutions
OCS	outer continental shelf

Phase 1	Mobilization and Equipment Calibrations
Phase 2	Excursion Operations
Phase 3	Post-Excursion Operations
P-P	peak to peak
PSO	protected species observers
QA	quality assurance
QC	quality control
rms	root mean square
RTG	real time gypsy
RTK	real time kinematic
SBP	sub-bottom profiler
SCR	submerged cultural resource
SEG-P1	simple ASCII files that contain seismic data navigation shotpoints
SEG-Y	Society of Exploration Geophysicists standard format for digital geophysical data storage
STBD	starboard
TAR	Tidewater Atlantic Research
TVG	time varying gain
TWTT	two-way travel time
UGC	user-defined gain control
UMES	University of Maryland, Eastern Shore
USBL	ultra-short baseline
WEA	Wind Energy Area
WLR	water level recorder
XTF	extended triton Format (digital file format for sidescan sonar data)

INTRODUCTION

Coastal Planning & Engineering, Inc., a CB&I Company (CB&I), was contracted by the Maryland Energy Administration (MEA) to conduct a High-Resolution Geophysical (HRG) survey of the Outer Continental Shelf (OCS) offshore Maryland in an area designated by the United States Department of Interior (DOI) as the Maryland Wind Energy Area (WEA).

The Maryland WEA encompasses nine (9) whole OCS blocks (6624, 6674, 6724, 6774, 6725, 6775, 6825, 6776, and 6826) and eleven (11) partial OCS blocks (6623, 6673, 6723, 6773, 6625, 6675, 6676, 6726, 6777, 6827, and 6828) for a total of 94 square nm (79,706 acres; 32,256 hectares). This includes a 304.80 meter (1,000 foot) buffer beyond the limits of the Maryland WEA. The western extent of the Maryland WEA is approximately 19 km (10 nm) east of Ocean City, Maryland and the eastern edge is approximately 50 km (27 nm) from the same point (Figure 1). Water depths within the Maryland WEA range from approximately 10 meters (m) to 45 m.

The MEA contracted CB&I to conduct a HRG survey to describe the geological environment within the Maryland WEA and to identify any potential hazards to development and submerged cultural resources that may be present. CB&I received signed contract number 2013-02-513S1 and Notice to Proceed (NTP) for MEA Project Number DEXR240005, HRG Resource Survey, on January 3, 2013. Geophysical and hydrographic survey operations were conducted between July 4, and August 31, 2013. CB&I, under the contractual agreement of the MEA, collected and compiled a comprehensive dataset to describe the geological environment and identify any potential hazards and submerged cultural resources within the Maryland WEA.

The ultimate objective of the geophysical survey is to support the future development of a large utility-scale wind farm that will supply Maryland electricity consumers with a sustainable source of clean renewable energy, provide significant economic development benefits, and secure price stability for the future. The goal was to collect and compile a comprehensive geophysical dataset prior to the federal government's leasing of the area to a private energy developer in an effort to streamline and jumpstart the development process. Any future development of the Maryland WEA will be done by private developers after successful bidding and negotiation of a federal OCS lease.

This report describes the HRG survey which consisted of remote-sensing data acquisition along pre-determined tracklines using towed and vessel-mounted instrumentation. The survey equipment included sidescan sonar, magnetometer, shallow-penetration chirp sub-bottom profiler, multibeam echosounder, Ultra-Short Baseline (USBL) positioning and tracking system and a medium-penetration multi-channel sparker seismic-reflection system. The results of the investigation are also discussed in this report.

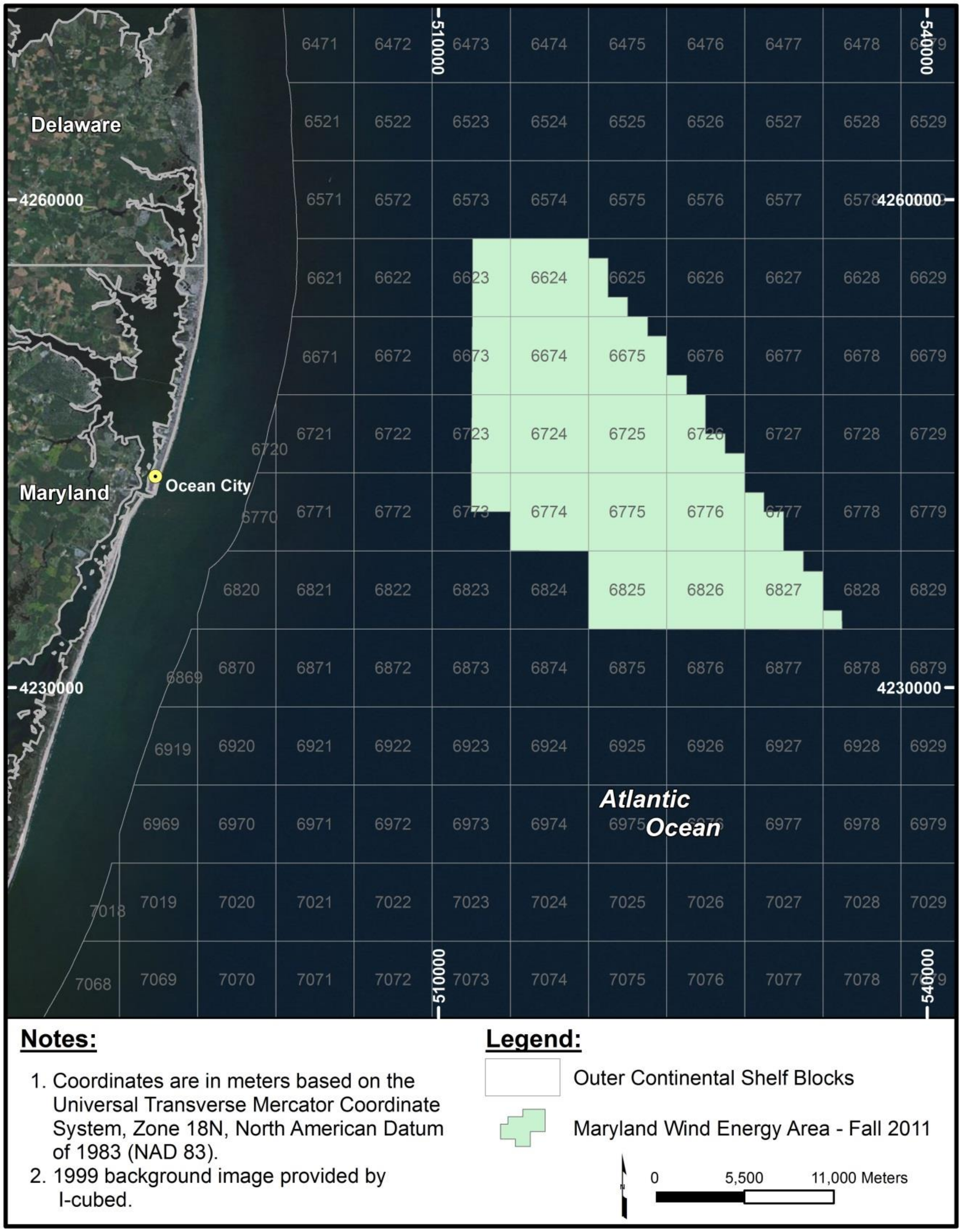


Figure 1: Location of the Maryland Wind Energy Area.

GEOLOGIC BACKGROUND

Developing an understanding of the geologic setting of an investigation area is important to the survey as it provides a description of the regional geologic setting and basis for the detailed HRG investigation. The geologic framework required for a successful understanding includes descriptions of the pertinent geologic research related to both the deep-seated geologic foundation of the region, the surficial seafloor sediments that sit upon it, as well as the processes that resulted in the existing geology.

The coasts of Maryland, Delaware and Virginia are part of a regional feature known as the Delmarva Peninsula. The Delmarva Peninsula makes up a portion of the Mid-Atlantic coast which is bordered to the east by the Atlantic Ocean and to the west by the Chesapeake Bay. The formation of the Delmarva Peninsula occurred over millions of years through many geologic processes. The core of the peninsula developed as a series of river deltas and braided-river outwash plains which deposited coarse sediments (Ramsey, 1990; Pazzaglia, 1993).

As a result of interglacial sea-level highs and eustatic changes in sea level, the Delmarva Peninsula evolved by the reworking of deltaic deposits followed by the formation of major spits (Oertel and Foyle, 1995; Hobbs, 2004; Oertel and Overman, 2004). The major rivers of the area also helped shape the Delmarva Peninsula and continental shelf by delivering sediment to the coastal plain, and by excavating valleys in the continental shelf generally trending southeast towards the offshore submarine canyons (Hobbs et al., 2008). Sediment deposits from periods of high sea level along with several paleochannels beneath the peninsula and across the continental shelf constitute the framework geology of the present coastal zone and continental shelf (Hobbs et al., 2008).

The Delmarva coast has been divided into four general segments (Figure 2):

- cuspate spit
- eroding headland
- wave dominated barrier islands (barrier spits and linear barrier islands), and
- tide-dominated barrier islands (short barrier islands with tidal inlets).

The HRG study area for this investigation lies seaward of the eroding headland segment.

Much of the Delmarva Peninsula and nearshore OCS is composed of unconsolidated sediments (sand and silt) and is generally shaped by high wave energy from the Atlantic Ocean leading to sedimentary processes such as erosion, transportation and deposition (Hobbs et al., 2008). Storm events also help drive the sedimentary forces of Maryland’s coast. Overwash fans, which are typically storm driven events, can be identified along the coast.

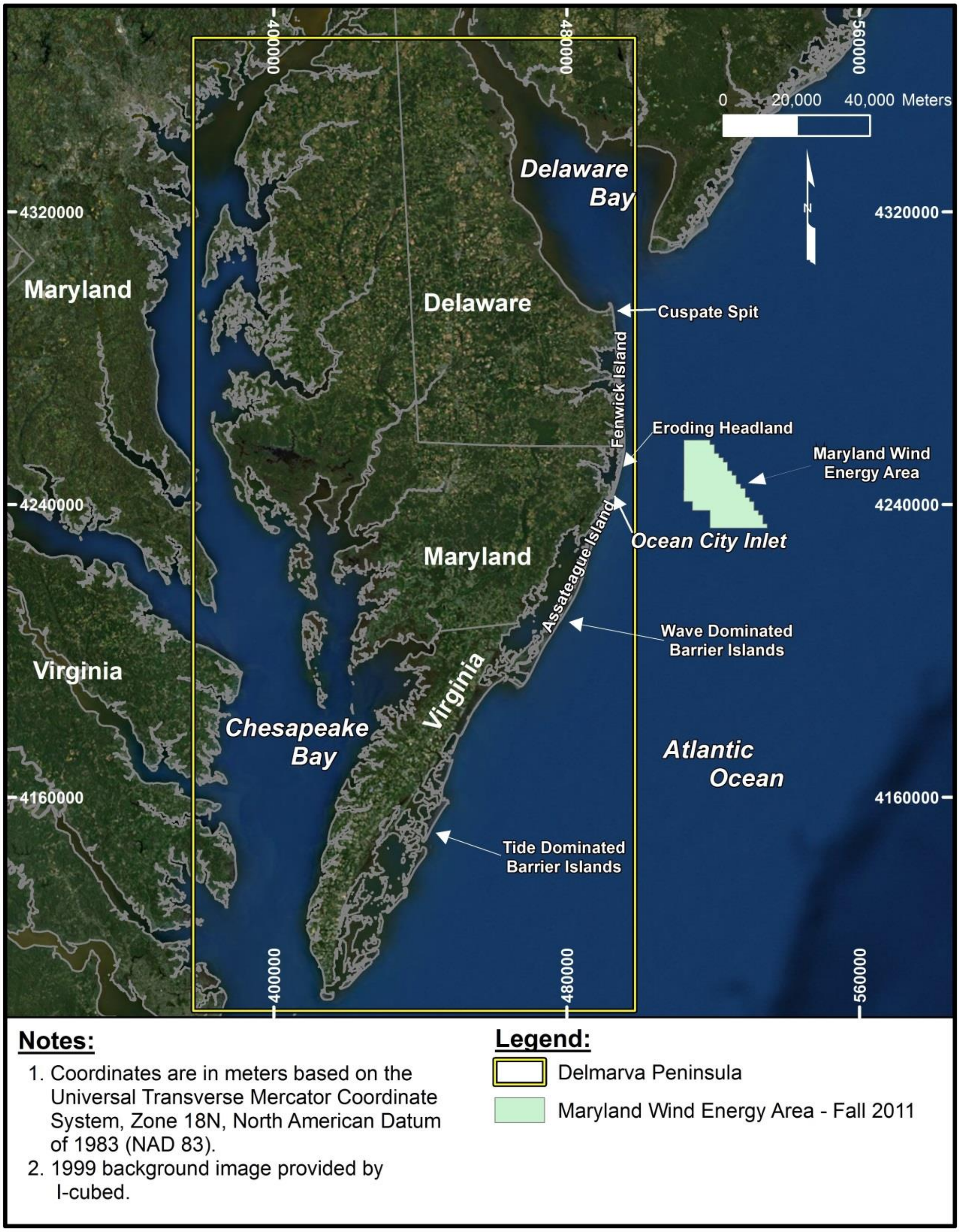


Figure 2: Regional geomorphology of the Delmarva Peninsula.

The Maryland coast of the Delmarva Peninsula is characterized by two long, narrow, wave dominated barrier islands; Assateague Island and Fenwick Island (Oertel and Kraft, 1994). Typical coastal features can be identified such as dune systems, back-bay lagoons and salt marshes; sedimentary features such as overwash fans are also commonly identified. Historically these two islands were connected, however storm events have reshaped the coast by opening and closing breaches or inlets between and through the barrier islands (Langley and Jordan, 2008). The Ocean City Inlet, which separates the northern portion of Assateague Island and the southern portion of Fenwick Island, was formed by a major hurricane in 1933 when wave energy breached the island, forming the inlet. The inlet was immediately stabilized and is now maintained by the U.S. Army Corps of Engineers (Hobbs et al., 2008; Riggs et al., 1996). Since the stabilization of the Ocean City Inlet, the landward migration of Assateague Island can be easily recognized from aerial photographs (Langley and Jordan, 2008) and is illustrated by the historical coastline map below (Figure 3).

The Maryland coast is also strongly influenced by sediment transport. Longshore sediment transport along the Maryland coast can be characterized by regional and local transport. Regional net longshore sediment transport is generally south-southwest and is driven both by moderate wave activity, to a water depth of approximately 20 m, and variations in the regional weather systems (Belknap and Kraft, 1985; Hobbs et al., 2008). Locally, wave refraction and transformation can result in reversal of the longshore current during coastal storms, dependent upon shallow local features such as shoals and tidal deltas. Although the northern portion of Assateague Island appears to be moving landward, other forces such as longshore sediment transport act upon the island. Since the stabilization of the Ocean City Inlet, the south portion of the inlet has been prone to erosion, the sediment erodes from the north portion of Assateague Island and migrates southward (Langley and Jordan, 2007), erosion of the northern portion of the island can be seen in Figure 4. Regional net across-shelf transport is generally offshore, including transport over storm-generated shoreface sand ridges. However, net across-shelf transport averaged over decadal time intervals has an onshore component; this includes major storms as identified by the overwash fans on the barrier islands.

The nearshore shelf off the coast of Maryland is a discontinuous sheet of medium- to fine-grained sand in shore-oblique features and swales, spaced approximately 2 to 4 km apart and extending tens of kilometers (km) (Swift et al, 2003) forming what are called ridges. These ridges are a dominant feature of the shelf (Conkwright, n.d.), generally oriented southwest-northeast with a maximum relief of 5 to 10 m (Hobbs et al., 2008), are well defined off the Maryland coast, and are constantly being formed and modified in modern time. The ridges have been reworked by wave and current processes acting on previously deposited sediments. Generally, across the continental shelf of Maryland, the surficial sediments are predominantly sand with mean grain sizes ranging from 0.40 to 2.89 phi. The mappable components of the surficial sand are mud and gravel. Muds are distributed along a north-south trending band seaward of the shoreface while gravels are mapped farther offshore (Kerhin, 1989).

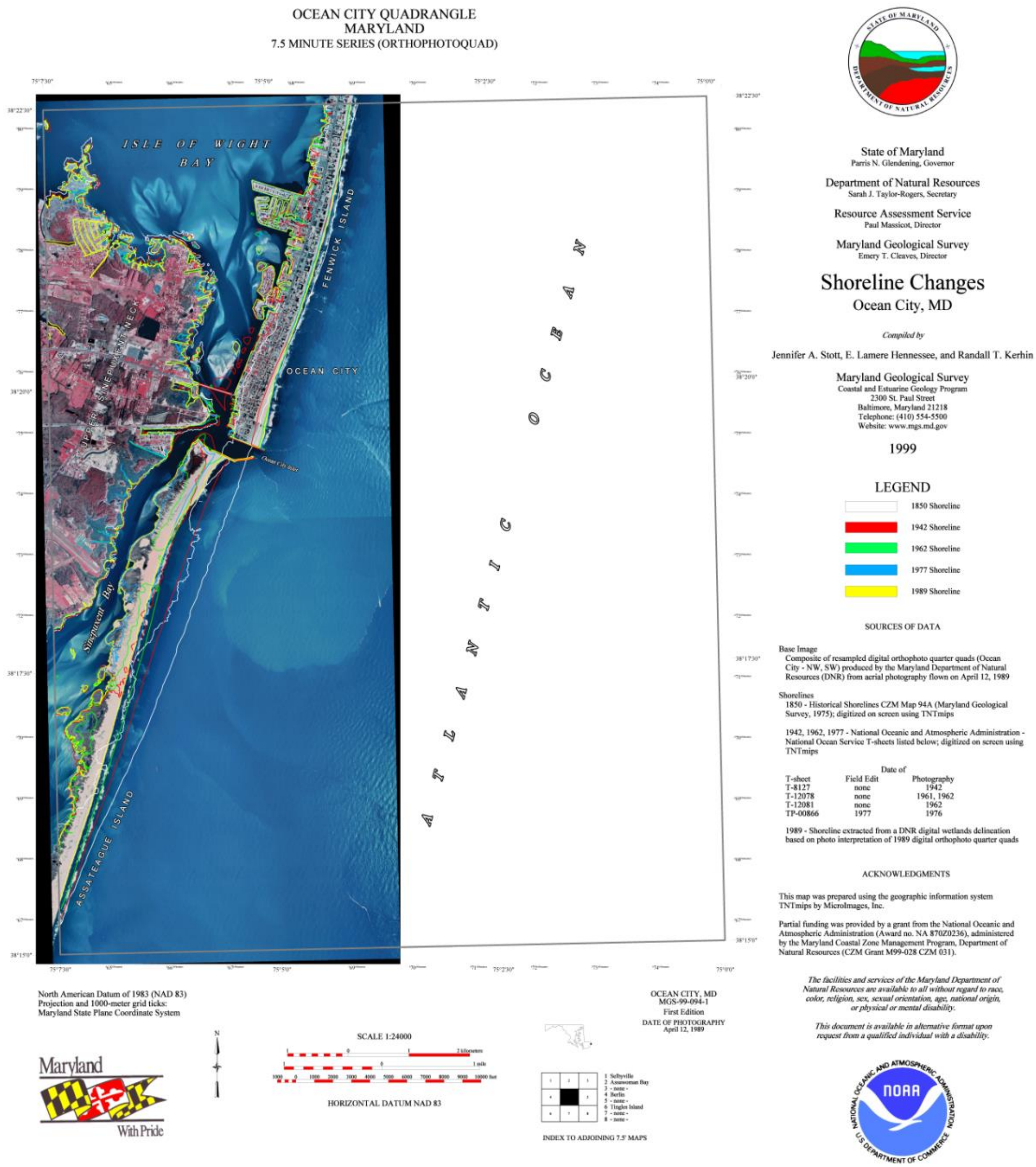


Figure 3: Historical coastline map of Maryland's barrier island coast (Stott et al., 1999).

Figure 4: Aerial Photograph looking north from Assateague Island toward Ocean City. This image shows erosion at the northern part of the island (south of the Ocean City Inlet), contributing to the appearance of landward migration (Zimmerman, 2000).

Hardbottom exists in areas of the shelf where unconsolidated sediment is absent. Hardbottom is defined by Street et al. (2005) as "exposed areas of rock or consolidated sediments, distinguished from surrounding unconsolidated sediments". Hardbottom varies in surface relief from smooth, flat surfaces to scarped surfaces with up to 10 m relief and their distribution is generally from shoreface to shelf edge. The morphology, dependent upon geometry and spatial relationships, weathering and erosion and lithology and patterns of stratification, range from sloping and stepped erosional ramps to vertical and undercut scarps with associated broad rubble ramps. These geologic features are characteristic of little terrigenous input with low sediment accumulation rates and a high volume of carbonate sediments, due to biological activities.

The OCS east of the Maryland coastline contains several lithostratigraphic units which are pre-Holocene in age. These pre-Holocene formations are indicative of a vast range of environments and depositional and erosional systems prior to the formation of the modern shelf. Moreover, it appears that a pre-Holocene erosional surface, which is incised into earlier Pleistocene sediments of the shelf, displays paleochannel migration and evidence that some deeper paleochannels may reach formations that could be Tertiary in age (Sheridan et al., 1974).

The pre-Holocene formations from oldest to youngest are:

- St. Marys Formation
- Manokin Formation
- Bethany Formation
- Beaverdam Formation
- Omar Foundation

The St. Marys Formation is a late Miocene fossiliferous, clayey sediment formation mainly consisting of clay to fine sandy-clay sediments. This indicates deposition on a shallow marine shelf that received little sand supply. The St. Marys Formation sits conformably to unconformably on the Choptank Formation with a sharp clay to sand boundary (Hansen, 1981;

Andres, 1986). The St. Marys Formation abruptly to gradually transitions into a characteristically sandy unit named the Manokin Formation (Groot et al., 1990).

The Manokin Formation contains late Miocene coarse sand and silty and clayey sands with beds of clay and silt and occasional woody material and lignite (Groot et al., 1990). A decrease or absence of shelly material and an increase of wood and lignite material indicate a transition from a muddy marine to a sandy fluvial/estuarine environment, possibly being a deltaic system (Andres, 1986).

The Bethany Formation is differentiated from the Formations below and above it by being primarily clay or silt and interbedded with fine to very coarse sand. The downdip characteristic features indicate that the Bethany Formation was deposited in a deltaic system with distributary channels made up of lobes, channels, and laterally graded sand sheets into inter-channel and prodelta clays. The Bethany Formation was likely deposited in a warm temperate climate during the late Miocene and early Pliocene as indicated by previous lithostratigraphy and palynology investigations (Groot et al., 1990).

The Beaverdam Formation generally overlies the Bethany Formation on an irregular contact, which likely results from erosion of the Bethany Formation by streams prior to channel filling with Beaverdam sands. In areas where there is no evidence of the Bethany Formation, it is assumed that the Beaverdam Formation sits directly above the Manokin Formation from either truncating the Bethany Formation or where the Bethany Formation has “pinched” out. However, due to the sedimentary similarities between them, it is hard to tell the boundary between the Beaverdam Formation and Manokin Formation (Groot et al., 1990).

The Beaverdam Formation consists of medium sand with scattered beds of coarse sand, gravelly sand and silty clay. This formation can be separated into two facies: the lower and upper. The lower facies is characterized by coarse sands with scattered gravel and frequent clay beds. The upper facies consists of silty medium to coarse sand with a fining upward sequence and sporadic clay beds. The Beaverdam Formation is considered to have been deposited in a sand-dominated fluvial and estuarine environment where the lower facies represents the fluvial portion and the upper facies represents the estuarine system. The lower Beaverdam facies is thought to be early Pliocene or late Miocene in age and deposited during a warm temperate climate. The upper Beaverdam facies was deposited in a temperate climate during the late Pliocene based on previous lithostratigraphy and palynology investigations (Groot et al., 1990).

Above the Beaverdam Formation lies the Tertiary/Quaternary boundary (Rasmussen and Slaughter, 1955 and Weigle, 1974). This boundary likely represents the first major global cooling event (Zimmerman, 1984). This event is thought to have occurred during the deposition of the Beaverdam Formation, resulting in a dramatic sea level regression creating a large scale erosional event traceable to the shelf edge (Toscano et al., 1989).

The Formation overlying this Tertiary/Quaternary erosional surface is the Omar Formation. This unit consists of interbedded fine sands, clayey silts and silty clays that fill valleys (likely formed by the erosional sea level regression) that have cut into the underlying Beaverdam Formation (Groot et al., 1990). The Omar Formation is Quaternary in age (Groot et al., 1990) and is the unit with the most mapped paleochannels which can be correlated to the major glacial-interglacial cycles known as the Illinoian and the Wisconsin.

The OCS offshore the Delmarva Peninsula contains significant evidence of multiple paleochannel complexes. Offshore Delaware (north and east of the MEA HRG survey area) previous investigations have mapped the trellis paleo-drainage system of the ancestral Delaware River (Colman and Mixon, 1988; Colman and Hobbs, 1987; Mixon, 1985). Offshore the southern Delmarva Peninsula (south and southeast of the MEA HRG survey area), previous investigations have identified three (3) major paleochannels of the Susquehanna River. These three (3) paleochannels – oldest/northernmost to youngest/southernmost – are identified as the Exmore, Eastville and Cape Charles. While the age of the Exmore is objective, it is believed to be 300 thousand years old (ka) to 500 ka. The Eastville, approximately 150 ka, is believed to be associated with the Illinoian glacial maximum (Toscano et al., 1989). The southernmost, Cape Charles, 8 ka to 15 ka, is believed to be associated with the last, Wisconsin glacial maximum. Each of the three paleochannels shows characteristics consistent with a successive southward displacement of the Susquehanna River sediments during three (3) major glacial-interglacial cycles. It can then be inferred that the Susquehanna River sub-channels were formed during glacial sea level low-stands (Schubel and Zabawa, 1973), which were then filled and aggraded during inter-glacial sea level transgressions. During the succeeding sea-level regression, each estuarine channel was forced southward by the barrier/strand line deposit of the sea level climax (Toscano et al., 1989 and Colman and Mixon, 1988).

HIGH-RESOLUTION GEOPHYSICAL SURVEY

High-Resolution Geophysical Survey Details

The Maryland WEA, together with a 304.80 m (1,000 ft) buffer beyond the WEA boundary), encompasses nine (9) whole OCS blocks (6624, 6674, 6724, 6774, 6725, 6775, 6825, 6776, and 6826) and eleven (11) partial OCS blocks (6623, 6673, 6723, 6773, 6625, 6675, 6676, 6726, 6777, 6827, and 6828) for a total of 94 square nm (79,706 acres; 32,256 hectares). The western extent of the Maryland WEA is approximately 19 km (10 nm) east of Ocean City, Maryland and the eastern edge is approximately 50 km (27 nm) from the same point (Figure 1).

Figure 5: Back deck and "H" frame of the *m/v Scarlett Isabella* in Ocean City, Maryland during mobilization. Oceanographic winch, sparker sled, and chirp towfish can all be seen on deck.

The survey consisted of 150 m spaced tracklines covering the entire Maryland WEA and surrounding buffer zone. The survey included multibeam hydrographic data, and sidescan sonar, magnetometer, shallow-penetration chirp sub-bottom profiler, and medium-penetration multi-channel sparker seismic reflection geophysical systems (Figure 5). The main survey lines were collected at an average heading of 0 degrees and 180 degrees, oriented parallel to each other over the entire survey area and roughly parallel to the predominant offshore bathymetric contours. By orienting the lines parallel to the main bathymetric contours the need to adjust the towfish heights was reduced (but not eliminated) due to the reduced changes in seafloor topography. Tie lines were collected perpendicular to the main survey lines at 900 m spacing at an average heading of 90 degrees and 270 degrees. The as-run geophysical navigation post-plot tracklines for the entire survey area are included in this report as Appendix A (*Map Series 1, Geophysical Navigation Post-Plot Map*).

In order to collect all multibeam bathymetry data pursuant to the standards specified by the National Oceanic and Atmospheric Administration (NOAA), intermediate lines, collected in-between the planned survey lines resulting in a final survey line spacing of 75 m or less, were collected aboard the *m/v Scarlett Isabella* using the multibeam bathymetry system **only** over the shallowest approximately one half of the survey area at a rough heading of 0 degrees and 180 degrees. This was required due to a reduced swath width of the multibeam system in shallower water. These intermediate lines, collected in the shallowest one half of the survey area only, ensured that the entire seafloor of the Maryland WEA had swath bathymetry data collected to NOAA standards. The as-run bathymetry (multibeam) navigation post-plot tracklines for the entire survey area are included in this report as Appendix B *(Map Series 2, Bathymetry Navigation Post Plot Map*).

All geophysical data were collected in accordance with the *"Guidelines for Providing Geological and Geophysical, Hazards, and Archaeological Information pursuant to 30 CFR Part* 285" (Department of Interior, 2012b). The sole exception being that the survey line spacing required for site-specific cultural resource site clearance was not followed. This exception was a result of the MEA's desire to satisfy as many regulatory requirements as possible while limiting the survey line spacing to 150 m. As such, prior to any future development activity, site-specific cultural-resource-level survey activities and cultural resource site clearance will be required in order to satisfy archaeological information pursuant to 30 CFR Part 285 and Section 106 of the National Historic Preservation Act of 1966.

The survey crew was comprised of five (5) CB&I geophysicists/geologists/experienced Protected Species Observers (PSO), one (1) CB&I surveyor, one (1) BZT Corporation (BZT) surveyor/PSO, one (1) UMES oceanographic student intern to assist as needed, and one (1) designated UMES PSO (Figure 6). It should be noted that all proposed PSO crewmembers completed a BOEM certified PSO certification course pursuant to BOEM and Bureau of Safety and Environmental Enforcement (BSEE) Joint Notice to Lessees and Operators (NTL) of Federal Oil, Gas, and Sulphur Leases in the OCS, Gulf of Mexico (GOM) OCS Region, No. 2012-JOINT-G02 (Department of Interior, 2012c). In addition, CB&I submitted a PSO Plan for approval of PSO personnel by the National Marine Fisheries Service (NMFS) on April 30, 2013. CB&I received written NMFS approval for all proposed PSO personnel on June 6, 2013.

During Excursion Operations, the CB&I project team utilized a Boston Harbor Cruises crew boat (the *mlv Bunker Hill)* in Ocean City, Maryland. The crew boat provided logistical support to the offshore survey vessel in an effort to maximize the offshore survey time of the survey vessel. The crew vessel was used to provision the survey vessel as well as for crew transfers as needed.

CB&I conducted the Excursion Operations in two concurrent stages due to the swath limitation of the multibeam echosounder in shallow waters.

Stage One Excursion Operations

Stage One of the Excursion Operations utilized the multibeam, sidescan sonar, magnetometer, shallow-penetration chirp sub-bottom profiler, and medium-penetration multi-channel sparker seismic-reflection systems at 150 m survey line spacing covering the entire MEA survey area. This stage provided preliminary multibeam coverage over the entire area and satisfied the 150 m survey line spacing and coverage requirements for all other geophysical survey systems (sidescan sonar, magnetometer, shallow-penetration chirp sub-bottom profiler, and medium-penetration multi-channel sparker seismic reflection).

Figure 6: Survey office aboard the *m/v Scarlett Isabella* during mobilization in Ocean City, Maryland. Pictured crew is setting-up and interfacing all geophysical systems Photo Credit: Ed Chambers, www.IamTheCamera.com.

In order to comply with the *"Commercial Wind Lease Issuance and Site Assessment Activities on the Atlantic Outer Continental Shelf Offshore New Jersey, Delaware, Maryland and Virginia Final Environmental Assessment"* (BOEM EA) (U.S. Department of the Interior, 2012a) as required by the MEA RFP, all Stage One Excursion Operation surveys were conducted **during daylight hours only** with BOEM certified and NMFS approved PSO. This ensured that sufficient light was available to conduct PSO monitoring of the exclusion zone around the seismic sound sources and vessel during geophysical survey operations. At any time during the survey operations when lighting or weather conditions (darkness, rain, fog, sea state etc.) prevented the monitoring of the exclusion zone, CB&I shut-down geophysical operations as dictated by the BOEM EA (U.S. Department of the Interior, 2012a; U.S. Department of the Interior, 2012c).

BOEM implements numerous procedures for seismic survey operations in order to limit or eliminate harassment to marine mammals. These procedures include visual clearance of an exclusion area for a 60 minute period prior to commencing survey operations, ramp-up procedures for acoustic seismic devices prior to the survey, and most importantly, the use of BOEM certified PSO on board the vessel during survey operations monitoring for marine mammals within the seismic sound source exclusion zones.

CB&I utilized approved PSO during all Stage One operations (which included daylight-only seismic operations). The PSO used were certified BOEM PSO as required by BOEM/BSEE JOINT NTL 2012-JOINT-G02 (Department of Interior, 2012c). The PSO monitored the required exclusion zones to make sure no protected marine mammals entered the zones during operations. If a protected species entered the exclusion zone, the PSO called for an immediate shut-down of the seismic sound sources. The vessel and survey operators complied immediately with any such call by a PSO. Any disagreement or discussion regarding the shut-down occurred only after full seismic system shut-down. A minimum of three (3) PSO's were be onboard during survey operations to satisfy BOEM guidelines. Each observer was allowed no more than four (4) consecutive hours on watch as a visual observer. Each visual observation period was followed by a two (2) hour break (U.S. Department of the Interior, 2012c). The final PSO report and associated field reports from the survey are attached to this report as Appendix M.

Stage Two Excursion Operations

Stage Two of the Excursion Operations was conducted concurrent with Stage One and consisted strictly of multibeam data collection in the shallowest approximate one half of the study area. Due to the requirement that all data be collected to NOAA hydrographic guidelines, additional data needed to be collected due to the shallower water depths in the nearshore portion of the survey area. Based upon existing, publicly available bathymetry data, approximately one half of the survey area was in shallow enough water that there would have been "holidays" (data-coverage gaps) in the multibeam data from the 150 m spaced lines. These areas were filled in at 75 m spacing (or tighter spacing as needed) to meet the NOAA hydrographic guidelines and provide 100% coverage of the seafloor at 1 m resolution. Because multibeam surveys are not bound by the marine mammal monitoring requirements outlined in the BOEM EA (U.S. Department of the Interior, 2012a), CB&I conducted Stage Two survey activities during the night (while seismic operations were shut-down) with a second survey crew of two (2) CB&I surveyors. During concurrent Stage One and Stage Two operations, the CB&I field crew numbered 11, instead of nine (9), to accommodate the two (2) additional CB&I surveyors required for nighttime multibeam-only operations. This second crew slept during the day while the first crew was conducting geophysical and PSO operations.

During Excursion Operations, all systems were constantly monitored and adjusted to ensure quality data collection. All positioning, navigation, geophysical and hydrographic data were digitally backed up to two (2) separate digital media drives. Back-up occurred at the end of each survey day. The back-up devices were stored onboard the vessel in a spot that was designated for the safe and secure storage of data. When the crew boat made trips out to service the survey vessel (no less than once per week), one full set of digital data back-up was transferred to the crew boat for transportation to shore. Once on shore, the raw data were duplicated, with a digital copy being stored locally and a second copy being uploaded to CB&I's network servers.

CB&I personnel began mobilizing from St. Petersburg, Florida; Boca Raton, Florida, and Buffalo, New York on June 18, 2013. All CB&I personnel and survey equipment, together with the required subcontractors and team members, arrived in Ocean City, Maryland on June 19, 2013. Survey preparations commenced immediately following the arrival of the *m/v Scarlett Isabella* the evening of June 19, 2013. Following a short weather delay, CB&I completed mobilization and systems calibration on July 3, 2013.

Excursion Operations began on July 4, 2013. Geophysical data collection was completed on August 25, 2013 and the survey vessel returned to port on August 26, 2013. Geophysical system demobilization was complete on August 28, 2013. Following geophysical systems demobilization, the vessel returned offshore to collect additional multibeam hydrographic data to fill-in multibeam data "holidays" throughout the survey area to ensure 100% seafloor coverage. The additional multibeam data collection effort was completed on August 31, 2013 and the vessel returned to port to begin phase 2 of systems demobilization. The survey vessel was released from the MEA project on September 1, 2013. On September 2, 2013 the survey vessel, CB&I crew, and survey equipment left Ocean City, Maryland and returned to their home offices. There were a total of 53 geophysical/hydrographic survey days with an additional six (6) hydrographic-only survey days. During the length of this project, Monthly Status Reports were submitted to the MEA describing project activities. These Monthly Status Reports are attached to this report as Appendix N. In addition, during offshore survey operations, Weekly Field Status Reports were submitted to the MEA describing field work activities. These Weekly Field Status Reports are attached to this report as Appendix O.

Logbook Summary

All survey details were recorded in a series of field logbooks, separated into geophysical and hydrographic systems. Copies of all logbooks can be found attached to this report in Appendix K (*Excursion Operations Geophysical Logbook Pages*) and Appendix L (*Excursion Operations Bathymetric Logbook Pages*). The logbooks provide information on the daily operations during the excursion operations. Information within in the logbooks include daily start and end times, PSO shut-down/power-downs, all equipment matters/observations, survey line progress, weather delays, crew transfer information as well as vessel port calls. Geophysical survey days started with a one hour visual clearance for marine mammals by the PSO. This typically occurred between 5:00 am and 6:00 am. The geophysical survey day typically ended at sunset (7:00-8:00 pm). On average, 62,565 m (63 km) of geophysical data were collected each day. Several days exceeded this. In the month of July there were seven (7) inoperable days (due to weather and/or equipment maintenance), an average daily collection rate of 44,639 m (45 km) and a total production of 1,383,806 m (1,384 km) for the month of July. In August, there were three (3) inoperable days (due to weather and/or equipment maintenance) and an average daily collection rate of 57,264 m (57 km), equaling a total mileage of 1,431,618 m (1,432 km) for the month of August. Total geophysical survey production for the entire survey equaled approximately 2,816 km.

Personnel

The survey team included personnel from CB&I and its subcontractors. CB&I's subcontractors included the University of Maryland Eastern Shore (UMES), Offshore Analysis & Research Solutions (OARS), Sonographics Inc., BZT Corporation (BZT), Tidewater Atlantic Research (TAR), and Paragon Project Resources. Personnel from UMES assisted with field operations and served as PSO. Personnel from Sonographics, Inc. assisted with daily geophysical systems deployment and operation during excursion operations. Personnel from OARS assisted with daily geophysical systems deployment and operation during excursion operations and with medium-penetration multi-channel sparker seismic reflection data reduction and interpretation and hazard assessment development. Personnel from BZT provided survey mobilization assistance, daily survey control verification assistance, and served as PSO. Personnel from TAR conducted cultural resource data review and analysis of the geophysical data after excursion operations. Paragon Project Resources provided vessel procurement and vessel operations related services and land based logistical support during excursion operations.

CB&I Personnel

Mr. Beau Suthard has a Master of Science Degree in Geological Oceanography, a Bachelor of Science Degree in Marine Science (Geology) and is a licensed Professional Geologist in Delaware, Virginia, and Florida. Mr. Suthard is a Client Program Manager for CB&I and served as the Project Manager for the MEA HRG survey. Mr. Suthard led all pre-survey planning tasks including budgeting, subcontractor procurement, mobilization, excursion operations and demobilization, and post-survey data processing and report preparation oversight. Mr. Suthard oversaw mobilization activities and assisted with geophysical systems set-up and calibrations during Phase 1, Mobilization. During Phase 2, Excursion Operations, Mr. Suthard served as scientific Crew Chief, assisted with daily deployments and retrieval of geophysical systems, and operated and monitored chirp sub-bottom profiler data acquisition on an alternating crew schedule. He also assisted in vessel demobilization during Phase 3, Post-Excursion Operations. Mr. Suthard assisted with and oversaw sidescan sonar and sub-bottom data reduction in addition to report preparation and project related fiscal responsibilities. Mr. Suthard was the main client contact and project administrator for CB&I.

Mr. Jeffrey L. Andrews has a Master of Science Degree in Ocean Science, a Bachelor of Science Degree in Marine Biology and an Associate of Science Degree in Marine Technology. Mr. Andrews is the Vice President of Coastal Geology and Geometrics for CB&I and provided general oversight of all project related activities including project planning, survey operations, and data processing. In addition, Mr. Andrews assisted in multibeam data processing and report preparation.

Mr. Christopher Dougherty (Figure 7) has a Master of Science Degree in Coastal Zone Management and a Bachelor of Science Degree in Biology. Mr. Dougherty is a Coastal Geologist for CB&I and served as a Crew Chief for the MEA HRG survey. Mr. Dougherty assisted in all pre-survey planning tasks including budgeting, subcontractor procurement, mobilization, excursion operations and demobilization, post-survey data processing and report preparation oversight. Mr. Dougherty oversaw mobilization activities and assisted with geophysical systems set-up and calibrations during Phase 1, Mobilization. During Phase 2, Excursion Operations, Mr. Dougherty served as

Figure 7: Jeff Helgerson (L) and Chris Dougherty (R) deploying the sparker sound source sled from the stern of the *m/v Scarlett Isabella* in the Maryland WEA.

scientific Crew Chief, assisted with daily deployments and retrieval of geophysical systems, and operated and monitored chirp sub-bottom profiler and sidescan sonar data acquisition on an alternating crew schedule. He also assisted in vessel demobilization during Phase 3, Post-Excursion Operations. Mr. Dougherty assisted and oversaw sidescan sonar data reduction and project related fiscal responsibilities.

Mr. Michael Lowiec is a licensed Florida Professional Surveyor and Mapper, and Hydrographer for CB&I. Mr. Lowiec served as lead Hydrographer for the MEA HRG survey and was responsible for assisting in mobilization and operation of the Reson SeaBat 7125 multibeam echosounder during Phase 1, Mobilization, and Phase 2, Excursion Operations. Mr. Lowiec was also responsible for mobilization and operation (during Phases 1 and 2) of both the RTK GPS and C-NAV GPS on the vessel to maintain “on the fly” tide corrections as well as accurate vessel navigation. Mr. Lowiec was also responsible for post-excursion data processing for the multibeam, tide, and GPS datasets.

Mr. Jeff Helgerson (Figure 7) has a Bachelor of Science Degree in Marine Science (Geology) and is a Marine Geologist for CB&I. Mr. Helgerson assisted in pre-survey planning, organization and logistics. During Phase 1, Mobilization, Mr. Helgerson transported geophysical survey equipment and assisted with geophysical systems set-up and calibration. In addition to daily deployment and retrieval of geophysical systems during Phase 2, Excursion Operations, Mr. Helgerson operated and monitored Hypack navigation control, the USBL tracking system, sidescan sonar, magnetometer, and chirp sub-bottom profiler systems on an alternating crew schedule. Upon completion of data collection, Mr. Helgerson assisted in the demobilization of the survey vessel and transportation of geophysical survey equipment. As part of Phase 3, Post-Excursion Operations, Mr. Helgerson processed and interpreted the sidescan sonar data and assisted in final report preparation.

Ms. Alexandra Valente has a Bachelor of Science Degree in Marine Science (Geology) and is a Marine Geologist for CB&I. Ms. Valente assisted in pre-survey planning, organization and logistics. During Phase 1, Mobilization, Ms. Valente transported geophysical survey equipment and assisted with geophysical systems set-up and calibration. In addition to daily deployment and retrieval of geophysical systems during Phase 2, Excursion Operations, Ms. Valente operated and monitored Hypack navigation control, the USBL tracking system, sidescan sonar, magnetometer, and chirp sub-bottom profiler systems on an alternating crew schedule. Upon completion of data collection, Ms. Valente assisted in the demobilization of the survey vessel and transportation of geophysical survey equipment. As part of Phase 3, Post-Excursion Operations, Ms. Valente processed and interpreted the chirp sub-bottom profiler data and assisted in final report preparation.

Mr. Francis Stankiewicz has a Bachelor of Science Degree in Marine Science with a minor in Coastal Geology and is a Marine Geologist for CB&I. Mr. Stankiewicz assisted in pre-survey planning, mapping and/organization. During Phase 2, Excursion Operations, Mr. Stankiewicz, operated and monitored Hypack navigation control, the USBL tracking system, sidescan sonar, magnetometer, and chirp sub-bottom profiler systems on an alternating crew schedule. In addition, Mr. Stankiewicz assisted with daily deployments and retrieval of geophysical systems.

Mr. Jason Walker has a Master of Science and Bachelor of Science Degree in Geology with a background in geophysics and fluvial/coastal geomorphology and is a Hydrographic Surveyor for CB&I. During Phase 2, Excursion Operations, Mr. Walker assisted with the operation and data collection of the Reson SeaBat 7125 multibeam echosounder for the MEA HRG survey. He made frequent conductivity, temperature, and depth (CTD) casts for updated sound velocity measurements for frequent minor calibrations to the echosounders. Upon completion of data collection, Mr. Walker assisted in the demobilization of the survey vessel as well as data processing and product development for the multibeam bathymetry dataset.

Mr. Judd French has a Bachelor of Science Degree in Marine Science (Geology) and is a Survey Party Chief for CB&I. Mr. French assisted in transportation of the survey equipment, established the RTK GPS control network, and deployed the nearshore and offshore tide gauges for water level data during Phase 1, Mobilization and Equipment Calibration. During Phase 2, Excursion Operations, Mr. French operated both the RTK GPS and C-Nav GPS on the vessel to maintain “on the fly” tide corrections as well as accurate vessel navigation. Mr. French also operated and monitored data collection of the Reson SeaBat 7125 multibeam echosounder and made frequent CTD casts for updated sound velocity measurements for frequent minor calibrations to the echo sounders.

Ms. Kitrina Godding has a Bachelor of Science Degree in Geology/Geography and an Advanced Diploma in Marine Geomatics and is a Hydrographic Surveyor for CB&I. Ms. Godding operated both the RTK GPS and C-Nav GPS on the vessel to maintain “on the fly” tide corrections as well as accurate vessel navigation. In addition, Ms. Godding operated and monitored data collection of the Reson SeaBat 7125 multibeam echosounder and made frequent CTD casts for updated sound velocity measurements for frequent minor calibrations to the echo sounders.

Mr. Felipe Catanzaro Zarzour is a hydrographic surveyor for CB&I. Mr. Zarzour assisted in operation and monitoring of data collection of the Reson SeaBat 7125 multibeam echosounder during Phase 2, Excursion Operations; and assisted in demobilization of hydrography systems during Phase 3, Pose-Excursion Operations. In addition to survey operations, Mr. Zarzour assisted in post excursion data processing of the multibeam data.

Mr. Jeffrey Smith has an Associate of Science Degree in Natural Resources and is an Environmental Scientist and BOEM certified PSO for CB&I. During Phase 1, Mobilization and Equipment Calibration, Mr. Smith assisted with mobilization-related tasks and assisted in deploying offshore tide gauges. During Phase 2, Excursion Operations, Mr. Smith served as a lead PSO for the MEA HRG Survey. Mr. Smith’s responsibilities were to develop and coordinate a PSO schedule with the participating PSO staff and himself to ensure constant observation of protected species during seismic operations. Mr. Smith maintained visual surveillance prior to and/or during all seismic activities during his scheduled shift, completed the associated paperwork, and coordinated ramp-up, power-down and shut-down events with the scientific crew in compliance with BOEM and NMFS PSO requirements. In addition to PSO duties, Mr. Smith also monitored all associated PSO forms for completeness, organized, and ensured delivery of PSO forms to the appropriate agencies within the allotted timeframe.

Mr. Drew Atchison has a Bachelor of Science Degree in Marine Science (Biology) and is an Environmental Scientist and BOEM certified PSO for CB&I. Mr. Atchison served as a lead PSO during Phase 2, Excursion Operations, for the MEA HRG survey. Mr. Atchison's responsibilities were to develop and coordinate a PSO schedule with the participating PSO staff and himself to ensure constant observation of protected species during seismic operations. Mr. Atchison maintained visual surveillance prior to and/or during all seismic activities during his scheduled shift, completed the associated paperwork, and coordinated ramp-up, power-down and shut-down events with the scientific crew in compliance with BOEM and NMFS PSO requirements. In addition to PSO duties, Mr. Atchison also monitored all associated PSO forms for completeness, organized, and ensured delivery of PSO forms to the appropriate agencies within the allotted timeframe during his involvement with the MEA survey.

Mr. Fabio Moreira is a Field Technician and a BOEM certified PSO for CB&I. Mr. Moreira served as a PSO for the MEA HRG survey. His responsibilities included monitoring the exclusion zone for protected species prior to and during all seismic activities. Prior to seismic operations, Mr. Moreira was responsible for maintaining visual surveillance prior to and/or during all seismic activities during his scheduled shift. Mr. Moreira completed the associated PSO paperwork, and coordinated ramp-up, power-down and shut-down events with the scientific crew in compliance with BOEM and NMFS PSO requirements.

Dr. William (Quin) Robertson has a Ph.D. in Geosciences, a Master of Science Degree in Geology and a Bachelor of Arts Degree in Geology with a Minor in Environmental Studies. Dr. Robertson is a Project Manager for CB&I and assisted in multibeam data processing and report preparation. In addition to preparation, Dr. Robertson provided technical review, QA/QC and formatting assistance for report items

Dr. Beth Forrest-Vandera has a Ph.D. in Geology, a Master of Science Degree in Geology-Geochronology and a Bachelor of Science degree in Geology. Dr. Forrest-Vandera is a Project Geologist for CB&I and assisted in preparation of the Survey Plan and final report. In addition to preparation, Dr. Forrest-Vandera provided technical review, QA/QC and formatting assistance for report items.

Ms. Angela Belden has an Associate of Science Degree in Business Management and several advanced certifications in data management, GIS, CAD, Autodesk, Eaglepoint and Microstation. Ms. Belden is the Director of GIS/CAD for CB&I and oversaw all GIS/CAD for the MEA HRG survey. Ms. Belden designed and provided support for the development of the MEA HRG survey Map Series for the final report.

Ms. Heather Vollmer has a Master of Science Degree and Bachelor of Science Degree in Environmental Studies and has a GIS Professional Certification. Ms. Vollmer is a GIS

Analyst for CB&I and assisted with all GIS/CAD for the MEA HRG survey. Ms. Vollmer assisted in the design and production of the MEA HRG survey Map Series for the final report.

BZT Corporation (BZT) Personnel

Mr. Edwin Hirsch is the President of BZT (a veteran owned small business) who assisted CB&I with professional services and miscellaneous survey tasks. Mr. Hirsch was responsible for coordinating all services needed to administer and coordinate BZT's assigned tasks including data sharing, liaison, invoicing and reporting related to land surveying and other tasks on an as-needed basis.

Mr. Charles Young served as BZT's Team Leader for BZT involvement on the MEA HRG survey. Mr. Young is a licensed Professional Land Surveyor and was responsible for logistical coordination of BZT's assigned tasks. As Team Leader, Mr. Young provided daily guidance to BZT team members and assured timely completion of assigned tasks. Mr. Young was also responsible for daily monitoring and sustaining accuracy (dependent upon shift schedule) of the RTK GPS base station positioned in Ocean City, Maryland.

Mr. Doug Guare served as BZT's Field Party Chief for the MEA HRG survey. Mr. Guare assisted in monitoring and completing BZT's assigned land survey tasks. Mr. Guare was responsible for daily monitoring and sustaining accuracy (dependent upon shift schedule) of the RTK GPS base station positioned in Ocean City, Maryland. Mr. Guare also assisted in surveying the location of oceanographic device tow points aboard the survey vessel prior to embarkation for systems calibration during Phase 1, Mobilization.

Mr. Sam Provost served as part of BZT's field team for the MEA HRG survey. Mr. Provost was responsible for daily monitoring and sustaining accuracy (dependent upon shift schedule) of the GPS RTK base station positioned in Ocean City, Maryland. Mr. Provost assisted in surveying the location of oceanographic device tow points aboard the survey vessel prior to embarkation for systems calibration during Phase 1, Mobilization.

Mr. Robert Rigdon is a licensed Professional Land Surveyor for BZT. In addition to daily monitoring (dependent upon shift schedule), Mr. Rigdon assisted in sustaining the required accuracy of the RTK GPS base station positioned in Ocean City, Maryland.

Mr. Ben Young is a BOEM certified PSO and Field Technician for BZT. Mr. Young served as a PSO for the MEA HRG survey whose responsibilities were to monitor the exclusion zone for protected species prior to and during (dependent upon PSO schedule) all seismic activities. Prior to seismic operations, Mr. Young was responsible for maintaining visual surveillance prior to and/or during all seismic activities during his scheduled shift. In addition to visual monitoring, Mr. Young completed the associated PSO paperwork, and coordinated ramp-up, power-down and shut-down events with the scientific crew in compliance with BOEM and NMFS PSO requirements.

Mr. Jared Young is a BOEM certified PSO and Field Technician for BZT. Mr. Young served as a PSO for the MEA HRG survey whose responsibilities were to monitor the exclusion zone for protected species prior to and during (dependent upon PSO schedule) all seismic activities. Prior to seismic operations, Mr. Young was responsible for maintaining visual surveillance prior to and/or during all seismic activities during his scheduled shift. In addition to visual monitoring, Mr. Young completed the associated PSO paperwork, and coordinated ramp-up, power-down and shut-down events with the scientific crew in compliance with BOEM and NMFS PSO requirements.

Offshore Analysis and Research Solutions (OARS) Personnel

Mr. David Sinson has a Bachelor of Science Degree in Geology and was subcontracted through OARS for the MEA HRG survey. Mr. Sinson assisted CB&I with mobilization and calibration of the Reson SeaBat 7125 multibeam echosounder during Phase 1, Mobilization.

Ms. Amanda Bittinger has a Master of Science Degree in Coastal Zone Management and a Bachelor of Science Degree in Oceanography. Ms. Bittinger was subcontracted through OARS for the MEA HRG survey. During Phase 2, Excursion Operations, Ms. Bittinger operated and monitored data collection of the Reson SeaBat 7125 multibeam echosounder and made frequent CTD casts for updated sound velocity measurements for frequent minor calibrations to the echosounders.

Mr. Shane Dunn has a Master of Science Degree in Geologic Oceanography and a Bachelor of Science Degree in Environmental Science. Mr. Dunn was subcontracted through OARS for the MEA HRG survey. Mr. Dunn assisted CB&I with mobilization and calibration of the geophysical systems during Phase 1, Mobilization. During Phase 2, Excursion Operations, he operated and monitored data collection of the medium-penetration multi-channel sparker seismic-reflection system and assisted with daily geophysical systems deployment and retrieval, on an alternating crew schedule. Following survey operations, Mr. Dunn assisted with demobilization of the vessel during Phase 3, Post-Excursion Operations. Mr. Dunn interpreted the medium-penetration multi-channel sparker seismic-reflection data and assisted in report preparation.

Paragon Personnel

Mr. Enrique Melendez is a Project Manager and Principal Consultant at Paragon Project Resources. Mr. Melendez assisted CB&I on all contractual and technical matters relating to vessel procurement. Mr. Melendez provided QA/QC efforts on the development of vessel company evaluation, vessel logistical planning and deployment/operations management of vessel activities during survey operations.

Mr. Ken Sanders is a Field Support Technician at Paragon Project Resources. Mr. Sanders assisted with vessel charter research activities and selection/evaluation of Boston Harbor Cruises. Mr. Sanders assisted in the development of the Vessel's Safety Plan, Deployment Plan and the Operations Plan. During the entirety of the mobilization, excursion operations and demobilization Mr. Sanders provided extensive local land-based logistical support regarding supplies, equipment, and personnel on the ground in Ocean City, Maryland.

Captain Timothy Tilghman is a veteran of the United States Coast Guard. Captain Tilghman assisted Paragon Project Resources with vessel charter research. Captain Tilghman also assisted with the initial documentation for vessel procurement during pre-survey planning.

Sonographics Personnel

Mr. Fredrick (Rick) Horgan has a Bachelor of Science Degree in Mechanical Engineering, a Diploma in Physical Oceanography, Navy Class A Electronics School Diploma, Class A Sonar School Diploma, Class C Oceanography Diploma and a Diploma in Hydrography. Mr. Horgan is the President of Sonographics, Inc. and provided back-up/stand-by geophysical equipment for the duration of the MEA HRG survey. During Phase 2, Excursion Operations, Mr. Horgan assisted by operating and monitoring data collection of the medium-penetration multi-channel sparker seismic-reflection system and assisted with daily geophysical systems deployment and retrieval on an alternating crew schedule.

Tidewater Atlantic Research (TAR) Personnel

Dr. Gordon Watts is the director of TAR and the Institute for International Marine Research. Dr. Watts received his Ph.D. in Nautical Archaeology from St. Andrews University, Fife, Scotland. He is a marine archaeologist who meets the professional qualification standards as set forth in the Secretary of the Interior's *Standards and Guidelines for Archaeology and Historic Preservation* (Federal Register 48: 190:44716-44742). Dr. Watts provided archaeological research and cultural resource management services during this project. He provided land-based assistance and guidance during the geophysical surveys. After completion of the field investigations, Dr. Watts processed all geophysical data for cultural resource significance interpretation and produced a summary cultural resource report.

Ms. Robin Arnold is the senior historian and Section 106 Compliance Specialist for TAR. She has a B.A. in History and Political Science from East Carolina University and completed the course requirements for an M.A. in History at that institution. Ms. Arnold conducted the historical research for the cultural resource report and assisted Dr. Watts with cultural resource interpretation and summary report production.

University of Maryland, Eastern Shore (UMES) Personnel

Mr. Blake Bussard is a certified BOEM PSO and a University of Maryland Eastern Shore intern. During Phase 1, Mobilization, Mr. Bussard assisted the CB&I scientific crew with miscellaneous mobilization tasks and offshore tide gauge deployment. Mr. Bussard primarily served as a PSO during Phase 2, Excursion Operations of the MEA HRG survey. Mr. Bussard's responsibilities were to monitor the exclusion zone for protected species prior to and during all seismic activities. Prior to seismic operations, Mr. Bussard was responsible for maintaining visual surveillance prior to and/or during all seismic activities during his scheduled shift. Mr. Bussard completed the associated PSO paperwork, and coordinated ramp-up, power-down and shut-down events with the scientific crew in compliance with BOEM and NMFS PSO requirements.

Mr. Miaohua Mao is a certified BOEM PSO and a University of Maryland Eastern Shore (UMES) intern. Mr. Mao assisted in coordinating UMES's PSO program and assisted CB&I scientific crew during Phase 1, Mobilization. Mr. Mao completed miscellaneous mobilization tasks prior to embarkation for systems calibration.

Ms. Melissa Freese is a certified BOEM PSO and a University of Maryland Eastern Shore intern who served as a PSO during Phase 2, Excursion Operations of the MEA HRG survey. Ms. Freese monitored the exclusion zone for protected species prior to and during all seismic activities. Prior to seismic operations, Ms. Freese was responsible for maintaining visual surveillance prior to and/or during all seismic activities during her scheduled shift. Ms. Freese completed the associated PSO paperwork, and coordinated ramp-up, power-down and shut-down events with the scientific crew in compliance with BOEM and NMFS PSO requirements.

Ms. Qianru Niu is a certified BOEM PSO and a University of Maryland Eastern Shore intern who served as a PSO during Phase 2, Excursion Operations of the MEA HRG survey. Ms. Niu monitored the exclusion zone for protected species prior to and during all seismic activities. Prior to seismic operations, Ms. Niu was responsible for maintaining visual surveillance prior to and/or during all seismic activities during her scheduled shift. Ms. Niu completed the associated PSO paperwork, and coordinated ramp-up, power-down and shut-down events with the scientific crew in compliance with BOEM and NMFS PSO requirements.

Ms. Viviana Taylor is a certified BOEM PSO and a University of Maryland Eastern Shore intern who served as a PSO during Phase 2, Excursion Operations of the MEA HRG survey. Ms. Taylor monitored the exclusion zone for protected species prior to and during all seismic activities. Prior to seismic operations, Ms. Taylor was responsible for maintaining visual surveillance prior to and/or during all seismic activities during her scheduled shift. In addition, Ms. Taylor completed the associated PSO paperwork, and coordinated ramp-up, power-down and shut-down events with the scientific crew in compliance with BOEM and NMFS PSO requirements.

EQUIPMENT AND METHODS

The Maryland WEA HRG survey collected geophysical (sidescan sonar, magnetometer, shallow-penetration chirp sub-bottom profiler, medium-penetration multi-channel sparker seismic reflection) data, ultra short baseline (USBL) positioning data, hydrographic (multibeam echosounder) data, navigation (C-Nav DGNSS) data, and vessel orientation (Coda F-185+) data. The sidescan sonar, magnetometer, shallow-penetration chirp sub-bottom profiler, and medium-penetration multi-channel sparker seismic-reflection systems were towed from the vessel and positioned using the C-Nav DGNSS and USBL acoustic beacons with supplemental Hypack layback positioning recorded as a backup. Instruments affixed to the vessel (not towed) included the multibeam echosounders, USBL receiver, and navigation and positioning (Hypack, Coda F-185+, C-Nav DGNSS) systems. Please refer to Table 1 for a list of equipment used.

Laybacks for instruments fixed to the vessel were referenced to the center of reference (x: 0.00, y: 0.00). Please refer to Figure 9 for a diagram of the survey vessel and sensor configurations.

Table 1: MEA HRG geophysical investigation equipment.

System	Type
Navigation/Positioning	Hypack 2013 Coda F-185+ Sonardyne Ranger USBL
Magnetometer	Geometrics G-882
Bathymetry (Multibeam Echosounder)	Reson SeaBat 7125
Sidescan Sonar	EdgeTech 4200-HFL (300 kHz/600 kHz)
Shallow-Penetration Seismic Reflection	EdgeTech 3200 Sub-Bottom Profiler with a 512i towfish
Medium-Penetration Seismic Reflection	Geo-Source 200 Light Weight Marine Multi-Tip Sparker System 24 channel GeoEel streamer and recording system

Survey Vessel

The *m/v Scarlett Isabella* of Boston Harbor Cruises was used for the Maryland HRG survey. The *m/v Scarlett Isabella* is an offshore work boat 41 m in length with a 10 m beam and a maximum 4 m draft (Figures 8 and 9). The vessel is equipped with adjustable ballast tanks to allow for draft adjustments when needed. The vessel was built in 2010, and as such, represents a quality offshore work vessel for the United States eastern seaboard. The *m/v Scarlett Isabella* operates with a crew of five (5) and can comfortably accommodate a scientific crew of 14 members. The

Boston Harbor Cruises personnel who crewed the *m/v Scarlett Isabella* on an alternating basis during the MEA HRG survey are listed in Table 2.

Jeff Taylor	Senior Captain
Nick Peterson	Second Captain
Chris Gibbons	Senior Captain
Sean Tobin	Second Captain
Peter Frager	Engineer
Ken Berry	Deckhand
Robert Walcott	Cook/Deckhand
Ed Cunnie	Port Engineer

Table 2: List of *m/v Scarlett Isabella* crew.

Survey equipment was positioned appropriately throughout the vessel (Figure 9). Please refer to this figure for a visual description of the vessel and layout of sensor configuration.

The vessel traveled at a speed ranging from 3.5 to 4.5 knots during survey operations; in an effort to maximize the resolution of the data, survey speed varied depending upon winds, sea state and ocean currents.

Vessel course changes occurred at the northern and southernmost extent of the planned survey lines and the easternmost and westernmost extent of the tie lines The planned survey lines were oriented in a generally north to south direction on a heading of 0 degrees and 180 degrees and the tie lines were oriented perpendicular to the planned survey lines in a generally east to west direction on a heading of 90 degrees and 270 degrees.

Figure 8: Photograph of the *m/v Scarlett Isabella* fully mobilized, transiting out of Ocean City Inlet on the way to the Maryland WEA to commence survey operations. Photo Credit: Ed Chambers, www.IamTheCamera.com.

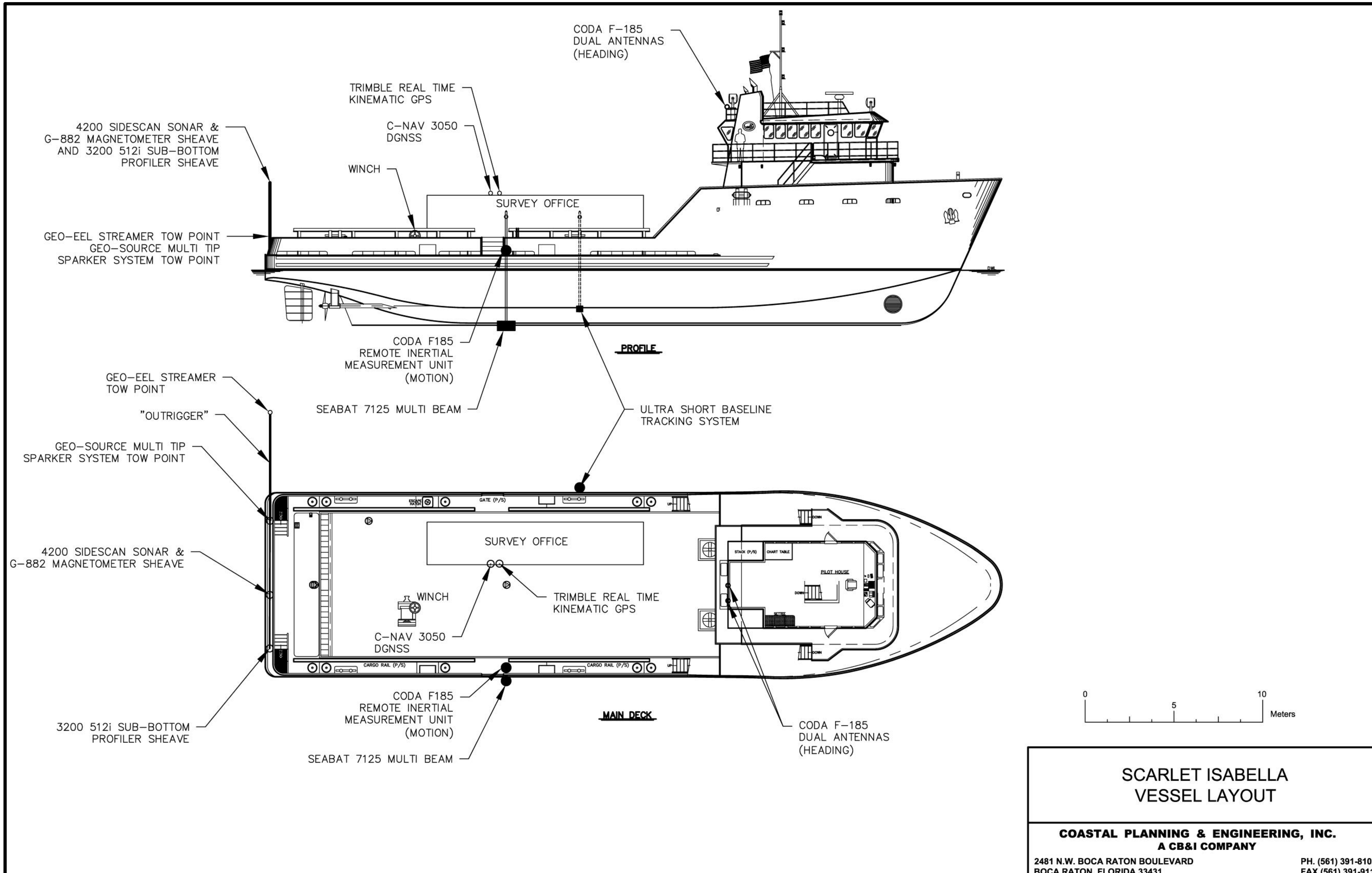


Figure 9: Diagram of geophysical and hydrographic systems deployment aboard the survey vessel.

Hypack Inc.'s Hypack 2013 Data Collection and Processing Program

Navigation, magnetometer, and depth sounder systems were interfaced with an onboard computer, and the data were integrated in real time using Hypack Inc.'s Hypack 2013 software. Hypack is a state-of-the-art navigation and hydrographic surveying system. Locations of the tow points on the vessel for each towed instrument in relation to the primary GPS antenna and the length of cable between the tow point and each towed instrument was measured and entered into Hypack. The real time position of each towed instrument was monitored and displayed by Hypack. Online screen graphic displays included the pre-plotted survey lines, the updated boat track across the survey area, adjustable left/right indicator, as well as other positioning information such as boat speed, quality of fix measured by Position Dilution of Precision (PDOP), and line bearing. The digital data were merged with positioning data (C-Nav), video displayed and recorded to the acquisition computers.

Sonardyne Ranger Ultra Short Baseline Tracking System

A Sonardyne USBL system was used for this investigation to provide in-water acoustic towfish tracking of the four towed geophysical systems (sidescan sonar, magnetometer, shallow-penetration chirp sub-bottom profiler, medium-penetration multi-channel sparker seismic reflection). The USBL system calculates the position of the towfish by acoustically measuring the range and bearing from the towfish-mounted beacons to the vessel-mounted receiver.

Figure 10: Image of Sonardyne USBL receivers. The receiver on the far right best represents the model used for the MEA HRG survey.

The USBL system was calibrated using Sonardyne's dynamic calibration procedures (CASIUS). The calibration was carried out with a reply channel of 32 kHz or higher and by incorporating speed of sound measurements, precise positioning of the beacon, and the receiver offset from the primary GPS antenna. Speed of sound through water and other selected parameters was adjusted throughout the survey to accurately reflect physical water conditions during data collection.

The Sonardyne system was run using wideband beacons (Figure 10) on both the tandem sidescan sonar/magnetometer towfish and the chirp sub-bottom towfish. The beacons were charged overnight while systems were at rest and attached to the tow cable/rope directly forward of each system daily. The USBL was set at high power with a one (1) to two (2) second ping rate, dependent upon thermocline interference. The power level and/or the update rate were adjusted in real time by the systems operators if the system was not tracking accurately, likely due to a strong thermocline that interrupted the signal between the USBL and remote beacon.

The USBL positioning data were collected as part of survey operations between July 4 and August 8, 2013. On August 8, 2013, the USBL pole-mount system (attaches the receiver to the vessel) malfunctioned and was rendered nonfunctional. In the early morning hours of August 8, the pole-mount stiffener (attached to the outside hull of the survey vessel below the water line) broke free from the vessel resulting in a loose USBL pole mount. This issue was reported to the MEA. At the time of this incident, all planned sidescan sonar and magnetometer data had been completed using the USBL positioning system. The remaining data to be collected was approximately 36% of the chirp sub-bottom profile data. As a solution, CB&I proposed to continue chirp sub-bottom profiler survey operations using the Hypack layback positioning option as opposed to the USBL positioning system. CB&I conducted a comparison of the two positioning systems and determined that the Hypack layback system would provide as, if not more, accurate positioning data as compared to the USBL system. CB&I notified the MEA and asked for a survey plan deviation in order to use the Hypack layback positioning system in place of the USBL system. The MEA acknowledged the request and sent the request to BOEM for review and consideration. Mr. Andrew Krueger of BOEM provided information to Mr. Andrew Gohn of the MEA suggesting that the Hypack Layback positioning should be adequate for the survey on August 13, 2013 at 12:51 pm. Mr. Andrew Gohn provided the approval to CB&I to use the Hypack layback positioning for the remainder of the survey on August 13, 2013 at 12:53 pm.

Coda F-185+ Inertial Navigation System and C-Nav 3050 DGNSS Receiver

A Coda F-185+ inertial navigation system was coupled with a C-Nav 3050 differential global navigation satellite system (DGNSS) receiver to provide horizontal (navigation) and vertical positioning for the vessel (Figure 11). The Coda F-185+ is a dual antenna and dual frequency (L1/L2) system that can provide rapid heading and precise dynamic motion (heave, pitch, roll) updates. The C-Nav 3050 is an augmented DGNSS system using proprietary dual frequency satellite corrections (C-NavC1/C-NavC2). The corrections are based on a global network of tracking stations. Each station has a minimum of two active receivers with quality controlled feedback loops. Each satellite typically tracks seven (7) stations. The corrections are also fed directly to two independent control centers that constantly monitor and maintain data quality for a precise GPS solution. The system has a specified horizontal accuracy of 5-10 cm and vertical accuracy of 10-15 cm when receiving corrections in 'Real Time Gypsy" (RTG) mode.

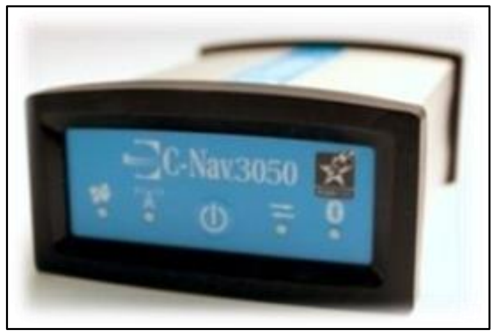


Figure 11: Image showing a C-Nav 3050 DGNSS receiver.

Navigation antennas were located at the highest possible location on the vessel to minimize shadowing and multipathing. The secondary separation was a measured distance away from the primary antenna to maximize the accuracy of the system. All signals received from the navigation antenna were transmitted to the navigation software (Hypack). Hypack processed positioning data to provide real time layback-corrected positions to each of the hydrographic and geophysical data acquisition systems.

Real Time Kinematic Global Positioning System (RTK GPS) and Control Network

A Trimble RTK GPS system was used onboard the survey vessel to collect supplemental water level height measurements. A land based RTK GPS radio base station was established by surveyors from CB&I and BZT on the roof of the Princess Royale Hotel in Ocean City, Maryland. The point was established using RTK GPS control procedures as well as static GPS observations to ensure network accuracy. The RTK GPS network was tied into NGS second order control monuments SPEICHER (PID HU0266), REEDY 2 AZ (PID HU1256), and Z103 (PID HU0372). A temporary bench mark (TBM), "Princess", was set from the above mentioned monuments on the roof of the Princess Royale Hotel to maximize radio range to the vessel offshore. The final height of the TBM was 32.23 m (NAVD88 GEOID12). All horizontal positions were transmitted in NAD83 (2011) and vertical positions in NAVD88. Control checks were performed twice daily on REEDY 2 AZ and SPEICHER for the duration of the survey by personnel from BZT to ensure system stability. Control check summaries are presented in Tables 3 and 4.

Table 3: Monument and control information for "Speicher".

NGS Published Control Horizontal Datum: UTM North Zone 18 (meters) Vertical Datum: NAVD88 Geoid 2012A (meters)			
Designation	**Northing**	**Easting**	**Elevation**
Speicher	4241894.686	492296.429	2.985
Number of Shots	**Δ Northing**	**Δ Easting**	**Δ Elevation**
246	-0.059	-0.053	0.072

Table 4: Monument and control information for "Reedy 2 AZ Mk3".

NGS Published Control Horizontal Datum: UTM North Zone 18 (meters) Vertical Datum: NAVD88 Geoid 2012A (meters)			
Designation	**Northing**	**Easting**	**Elevation**
Reedy 2 AZ Mk3	4248680.567	493500.994	3.005
Number of Shots	**Δ Northing**	**Δ Easting**	**Δ Elevation**
255	0.012	-0.028	0.074

Reson SeaBat 7125 Multibeam Bathymetry System

A dual-transducer Reson SeaBat 7125 multibeam bathymetry system was mounted on a pole mount off the vessel's starboard side (Figure 12). The dual-head system was deployed to increase swath width and best utilize time on the water. 512 beams were collected per head for a total of 1024 beams per sweep. The heads were mounted with an approximate 15 degree tilt to port and starboard. Head alignment is discussed in more detail in the Patch Test section below.

Figure 12: Image showing a single Reson SeaBat Multibeam Bathymetry transducer.

Horizontal and vertical offsets from the transducers to the navigation antennas were measured and applied in the navigation software. BZT measured offsets from a central reference point at the vessel midship using a Topcon total station. Several TBM were set for supplement measurements as well as alternative tow points.

A total 5,190 km of multibeam data were collected. The swath width of multibeam systems is based on depth, therefore line spacing increased as depth increased. Data were collected on all 150 m spaced lines in conjunction with the other geophysical systems onboard. Supplemental 75 m (or less) “holiday” lines were also collected in shallow areas to ensure 100% bottom coverage. The as-run bathymetry (multibeam) navigation post-plot tracklines for the entire survey area are included in this report as Appendix B *(Map Series 2, Bathymetry Navigation Post Plot Map*).

Hypack was used to collect the multibeam data. Navigation and supplemental system information is stored in Hypack RAW files while multibeam sounding data and real time sound velocity measurements were sent into the multibeam acquisition software, Hysweep, and stored as an HSX file. Speed of sound measurements at the multibeam transducer head are critical for beam forming and accurate soundings, as such, CB&I utilized a Sea-Bird Electronics Inc. sound velocity probe to record real-time sound velocity at the transducer head. Sound velocity profiles (SVP) of the entire water column were also collected while underway to account for the speed of sound variations with depth that result from changes in temperature and salinity in the water column. Sound velocity profiles were collected several times per hour, using an Ocean Sciences UnderwayCTD system and embedded directly into the .HSX files

The multibeam bathymetry data were collected between July 4 and August 31, 2013. Data collection was limited to daylight hours between July 4, and July 20, 2013. Beginning the evening of July 20, multibeam bathymetry data were collected on a 24 hour basis until the completion of bathymetric data collection.

<u>Patch Test</u>

Patch testing is a critical part of all multibeam system installations. The patch test is designed to fine tune the measured offsets and compensate for misalignment of the sonar heads. Patch testing quantifies bias values for latency, roll, pitch, and yaw of each head. The patch test for a dual head transducer system required collection of three lines in alternating and common direction perpendicular to a slope. The roll test required three lines in alternating direction over a flat bottom.

Multiple patch tests were collected throughout the survey. A patch test was collected each time the side mount was taken in or out of the water to ensure the mount remained stable. Patch tests were also collected for quality control and assurance purposes during the survey to ensure a stable system. A summary of the patch test results are listed in Table 5. Patch test values were generally stable throughout the survey. It is important to note that patch testing with DGPS will result in variation in the final values. Due to the inherent variability of the bias values, an average value was used as the final correction.

Table 5: Summary of patch test results.

Patch Test Summary							
Date	***Roll-1 (Port)***	***Roll-2 (STBD)***	***Pitch-1 (Port)***	***Pitch -2 (STBD)***	***Yaw (Port)***	***Yaw (STBD)***	***Comments***
8/28/2103	16.05	-13.3	13.4	13.5	6.5	6	
8/20/2013	15.5	-13.35	13.2	n/a	6	n/a	Pitch 2 Ignored
8/11/2013	15.4	-13.1	n/a	n/a	6	6.5	Pitch Ignored
8/7/2013	15.3	-13.4	13.4	13.4	8.5	6.5	
7/27/2013	15.6	-13.3	13.5	n/a	n/a	n/a	Yaw Ignored
7/20/2013	15.4	-13.25	14	14.65	n/a	n/a	Yaw Ignored
7/9/2013	n/a	n/a	14	13.8	6.5	n/a	Roll Lines not Collected (yaw ignored)
7/4/2013	15.3	-13.3	13.4	13.5	6	6.5	
Averages:	***15.51***	***-13.29***	***13.56***	***13.77***	***6.58***	***6.38***	

Water Level Corrections

Water levels were collected using redundant systems including offshore telemetry gauges, nearshore hydrostatic gauges, and GPS water level data from GPS systems onboard the survey vessel. Two Valeport water level recorders (WLR) were set offshore by personnel from CB&I after notifying the United States Coast Guard (USCG) and the Army Corps of Engineers. The gauges were set to the bottom with weighted aluminum stands and marked with USCG approved lighted navigation buoys. The gauges were both lost during the course of the survey with no data recovered. A nearshore gauge was set at the southern extent of the survey area immediately offshore of Assateague Island. The gauge was recovered in good condition. Water level measurements were also derived from the GPS systems onboard to provide an onsite tidal measurement. While the WLRs in the project area were lost during the survey, the redundant GPS derived water levels, nearshore tide gauge data, and published NOAA tide gauge data provided sufficient vertical control for the survey to achieve the required accuracy as identified in the NOAA NOS Hydrographic Specifications and Deliverables document (U.S. Department of Commerce, 2013).

Data from all systems were reviewed for errant measurements and plotted against local NOAA gauges for quality control and datum verification. The final water level corrections were based on RTK GPS and the adjusted nearshore water level measurements. All water level data were relative to mean lower low water (MLLW).

Processing and Sources of Error

All data were reviewed, processed and reduced using Hypack software and MB-Max 64bit, the Hypack multibeam reduction program. MB-Max 64bit has a two stage processing scheme. Stage 1 processing involves loading the files to review navigation, tide, speed, and motion data. Stage 2 processing takes the data to soundings and save final results as HS2x and XYZ files. Several filters were applied to the data in Stage 2 to efficiently eliminate false soundings. All data were manually reviewed for additional noise and other errors.

Outer beam overlap is a typical source of error for offshore multibeam surveys. To limit outer beam error, data were only accepted up to 56-60 degrees from nadir (port/starboard) from each head to eliminate beam flutter and noise. This limited the combined swath to 5-6 times water depth. HS2x files were saved as well as reduced XYZ files. Per NOAA National Ocean Service (NOS) standards for object detection coverage in Section 5.2.2.1, XYZ data were output with 0.5 m spacing over sidescan sonar contacts, 1 m spacing in areas under 18 m of water depth, and 2 m spacing in areas greater than 18 m of water depth (U.S. Department of Commerce, 2013).

EdgeTech 4200-HFL Sidescan Sonar System

Sidescan sonar data were required to verify the location and extent of unconsolidated sediment and to map ocean bottom features such as benthic habitats, exposed pipelines, cables, underwater wrecks, potential cultural resources, and other bottom substrate boundaries that may affect development area delineation, introduce hazards to potential foundations, or adversely impact the environment.

Figure 13: Image of the EdgeTech 4200 Sidescan Sonar towfish used in the MEA HRG.

The EdgeTech 4200-HFL sidescan sonar system included a laptop computer running the Discover acquisition software and a 300/600 kHz dual frequency towfish (Figure 13). Discover served as the digital image processing, display, storage, and surface control station for the sidescan sonar system. The 4200-HFL used full-spectrum chirp technology that delivered wide-band, high-energy pulses coupled with high resolution and superb signal-to-noise ratio echo data. The digital sidescan data were merged with positioning data from the USBL and C-Nav DGNSS (recorded for secondary, backup navigation purposes) systems via Hypack, video displayed, and recorded to the acquisition computer's hard disk for post processing and/or replay. To accurately track the towfish position within the water column, Hypack utilized USBL data to display real time corrected towfish positioning.

The sidescan sonar data were collected between July 4 and August 6, 2013. Data collection was limited to daylight hours between July 4 and July 20, 2013. Beginning the evening of July 20, sidescan sonar data were collected on a 24 hour basis until the completion of sidescan sonar data collection.

CB&I surveyed approximately 2,800 km of sidescan sonar survey lines comprised of 157 planned lines spaced at 150 m and 28 tie lines spaced at 900 m throughout the survey area. The planned survey lines were oriented in a generally north to south direction on a heading of 0 degrees and 180 degrees. Tie lines were oriented perpendicular to the planned survey lines in an east to west direction. The planned survey lines were oriented parallel to each other over the entire investigation area and roughly parallel to the predominant offshore bathymetric contours. By orienting the lines parallel to the main bathymetric contours, the need to adjust the towfish height was reduced (but not eliminated) due to the reduced changes in seafloor topography along individual survey lines.

The sidescan sonar data were collected in high definition mode with a 100 m range scale (200 m swath). The sensor was towed at an altitude above the seafloor that was within 10% to 20% of the range scale (10 m to 20 m) to provide sufficient overlap and duplication of the seafloor at the survey line spacing of 150 m. The sidescan sonar was deployed each morning and retrieved each evening using an electric winch which was wired into the survey office so that the sidescan sonar operator could adjust the cable out/layback (i.e. altitude above the seafloor) with changes in bathymetry and/or known obstructions. Changes in cable length throughout the survey were accounted for in the navigation software via the USBL system to correct for accurate layback. The towfish water depth was recorded for each survey line and embedded in each XTF file.

A variety of environmental variables factored into the overall positioning and data quality of the sidescan sonar throughout the survey. Predominately, water properties such as thermoclines and haloclines produced artifacts in the outer bands of the range scale of the sidescan sonar data throughout the entirety of the survey area. A strong thermocline was noted across the project area throughout the investigation, resulting in streaking in the mid-outer bands of the data. A thermocline is a layer of water where the vertical temperature gradient is greater than that in the water above it or in the water below it. Thermoclines affect the ray path of acoustic signals underwater and can result in a range-limiting type of banding visible in sidescan sonar data. A halocline is a vertical zone in the oceanic water column in which salinity changes rapidly with depth, located below the well-mixed uniformly saline surface water layer. Similarly, both a thermocline and a halocline, result in the most evident banding at the outer ranges of sonar data where the beam’s angle of incidence to the thermocline/halocline is high.

In addition, weather was variable at times generating higher sea states and in some cases caused some minor streaking in the data. Sea conditions ranged from 0 m to approximately 2.5 m throughout the duration of the survey. As would be expected, data quality and fish positioning accuracy were improved during smaller sea states. Sidescan sonar data were not collected when sea states resulted in less than desirable data quality.

Post collection processing of the sidescan sonar data were completed using Chesapeake Technology, Inc.’s SonarWiz 5 software. This software allows the user to apply specific gains and settings in order to produce enhanced sidescan sonar imagery that can be interpreted and digitized for specific benthic habitat features and debris throughout the survey area. The first step in processing was to import and bottom track the data. This was achieved using an automated bottom tracking routine and in some cases, where needed, done manually. Bottom tracking provides the data with an accurate baseline representation of the seafloor and eliminates the water column from the data.

After bottom tracking, the data were processed to reduce noise effects (commonly due to the vessel, sea state, or other anthropogenic phenomenon) and enhance seafloor definition. In most cases automatic time-varying gain (TVG) was sufficient to provide the best imagery. Time-varying gain divided the data into parallel swaths and equalized backscatter of each swath to create a normalized image highlighting contrast change throughout the image, which created an improved sidescan sonar mosaic image and allowed the processer to pick out areas with similar acoustic properties. Automatic gain control (AGC) was applied to noisy data which normalized the data by strengthening quiet regions/soft returns while simultaneously reducing/eliminating overly strong returns by obtaining a local average at a given point. Each line of sidescan sonar data were then inspected to determine if any debris, pipelines or culturally significant targets existed in the survey area as well as the presence of any significant geologic features or bottom types. Once the data were sufficiently processed, a mosaic was produced in the form of a Geotiff along with an HTML web project to allow for a line by line view of each waterfall.

Geometrics G-882 Magnetometer

The Geometrics G-882 Magnetometer (Figure 14) was integrated through, and towed in tandem with the EdgeTech 4200 sidescan sonar towfish. The magnetometer was towed 12.09 m behind the sidescan sonar and was adjusted simultaneously via adjusting the oceanographic winch. Changes in cable length throughout the survey were accounted for in the navigation software via the USBL system to provide an accurate layback distance. The magnetometer varied in terms of depth and height off the seafloor based on various factors, including vessel speed, oceanographic, and meteorological conditions affecting the tow configuration. To meet survey requirements, the towfish depth was adjusted to keep the fish within 6 m of the seafloor at all times. Factory set scale and sensitivity settings were used for data collection (0.004 nT/ πHz rms [nT = nanotesla or gamma]. Typically 0.02 nT P-P [P-P = peak to peak] at a 0.1 second sample rate or 0.002 nT at 1 second sample rate.). Sample frequency was factory-set at up to 10 samples per second.

Figure 14: Image of a Geometrics G-882 Magnetometer.

The magnetometer data were collected between July 4 and August 6, 2013, in conjunction with the sidescan sonar data. Data collection was limited to daylight hours between July 4 and July 20, 2013. Beginning the evening of July 20, magnetometer data were collected on a 24 hour basis until the completion of magnetometer data collection.

EdgeTech 3200 Sub-Bottom Profiler with 512i Towfish

Chirp sub-bottom profilers are used to image shallow (<20 m) subsurface sedimentary stratigraphy and to identify potential cultural resources and features that may affect future development. The use of chirp sub-bottom profilers allows for imaging and mapping of paleochannel complexes and common stratigraphic layers throughout the study area. In addition, it allows for the determination of stratigraphic layer thicknesses, including the thickness of the Holocene sediment cover. An EdgeTech 3200 Sub-Bottom Profiler with 512i towfish was used to conduct the Seismic-Reflection Profile surveys (Figure 15).

The EdgeTech 3200 Sub-Bottom Profiler with 512i towfish is operated by the Discover-SB software program which collects and stores sub-bottom data in a digital form. This Full Spectrum Sonar is a versatile wideband FM sub-bottom profiler that collects digital normal incidence reflection data over many frequency ranges; this instrumentation generates cross-sectional images of the seabed. The 512i transmits an FM pulse that is linearly swept over a full spectrum frequency range (also called a “chirp pulse”). The tapered waveform spectrum results in images that have virtually constant resolution with depth. In order to minimize noise related to the survey vessel and sea conditions, the seismic towfish (which operates as both the source and receiver for the sub-bottom system) was deployed and towed behind the research vessel. The sub-bottom data were merged with positioning data from the USBL and C-Nav (recorded for supplemental, backup navigation purposes) systems via Hypack, video displayed, and recorded to the acquisition computer's hard disk for post processing and/or replay.

The sub-bottom seismic-reflection data were collected between July 4 and August 25, 2013. Data collection was limited to daylight hours under the supervision of certified PSO throughout the duration of the HRG survey.

CB&I surveyed approximately 2,800 km of chirp sub-bottom profiler survey lines comprised of 157 planned lines spaced at 150 m and 28 tie lines spaced at 900 m throughout the survey area. The planned survey lines were oriented in a generally north to south direction on a heading of 0 degrees and 180 degrees. Tie lines were oriented perpendicular to the planned survey lines in an east to west direction.

Figure 15: Image of the sub-bottom profiler 512i towfish used in the MEA HRG.

The chirp sub-bottom profiler was operated using a pulse with a frequency sweep of 1.0 kHz to 10.0 kHz with a 5 ms pulse length. The system was set to ping at a rate of 7 Hz and was run with a 60% pulse power level. The 512i towfish was deployed each morning and retrieved each evening by a hydraulic knuckle crane operated by the captain of the vessel. Cable length and layback varied from 10 m (between July 4 and July 16, 2013), 20 m (between July 16 and August 15, 2013) and 16 m (August 25, 2013). Cable length was adjusted in the field to maximize data quality and was accounted for in the navigation software via the USBL system, or within the navigation software directly, to correct for adequate layback. At the end of each day, all sub-bottom data were recorded on the acquisition computer's hard disk and transferred to a portable hard drive to back-up raw survey data.

A variety of environmental variables factored into the overall positioning and quality of the chirp sub-bottom data throughout the survey. Weather and sea state were variable at times and in some cases caused some minor streaking in the data. Sea conditions ranged from 0 m to approximately 2.5 m throughout the duration of the survey. As would be expected, data quality and fish positioning accuracy were improved with the smaller sea states. However, in most cases, sub-bottom data were not collected when sea states resulted in less than desirable data quality.

It should be noted that the USBL positioning data were unusable for several whole and partial seismic lines. The errors in the USBL positioning data were due to signal interruption from a persistent strong thermocline (Figure 16) within the water column, preventing consistent USBL communication and causing the towfish positions to update at an irregular rate. The irregular rate caused the position of the USBL beacon to jump sporadically due to the irregular signals the transponder received. In cases where USBL data were unusable, CB&I geophysicists used the backup Hypack layback positioning in its place in order to get accurate, chirp sub-bottom towfish positioning for the survey. CB&I conducted a comparison of the two positioning systems and determined that the Hypack layback system would provide as, if not more, accurate positioning data as compared to the USBL system

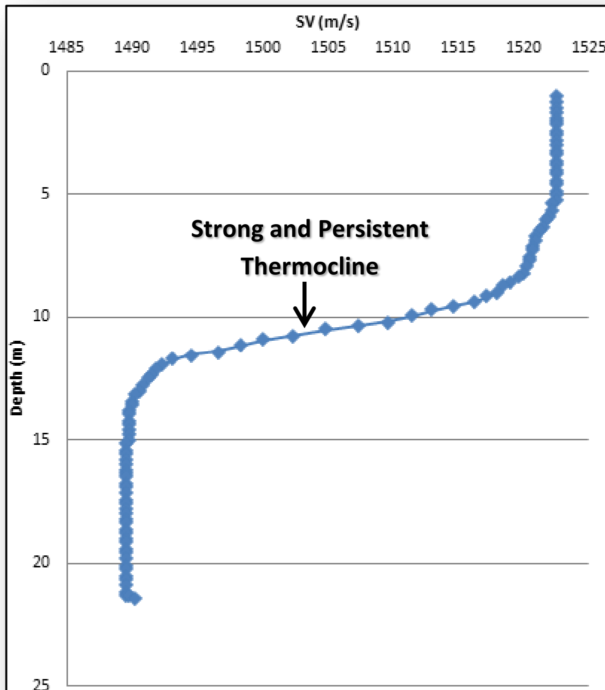


Figure 16: Sound velocity cast from the MEA HRG survey showing the strong and persistent thermocline that was present throughout the survey area and survey duration.

The data were continuously bottom-tracked to allow for the application of real-time gain functions in order to have an optimal in-the-field view of the data. Automatic gain control (AGC) was used to normalize the data by strengthening quiet regions/soft returns while simultaneously reducing/eliminating overly strong returns by obtaining a local average at a given point. A time-varying gain (TVG) was used to increase the returning signal over time in order to reduce the effects of signal attenuation.

Post collection processing of the seismic data were completed using Chesapeake Technology, Inc.'s SonarWiz 5 software. This software allows the user to apply specific gains and settings in order to produce enhanced sub-bottom imagery that can then be interpreted and digitized for specific stratigraphic facies relevant to the project goals. CB&I geophysicists processed the imagery to reduce noise effects (commonly due to the vessel, sea state, or other natural and anthropogenic phenomenon) and enhance stratigraphy. This was done using the processing features available in SonarWiz 5, including AGC, swell filter, and a user-defined gain control (UGC). In order to appropriately apply the swell filter and UGC functions, the sub-bottom data were bottom-tracked to produce an accurate baseline representation of the seafloor. Once this was done through a process of automatic bottom tracking (based on the high-amplitude signal associated with the seafloor) and manual digitization, the swell filter and UGC were applied to the data. The swell filter is based on a ping averaging function that removes vertical changes in the data due to towfish movement caused by the sea state and/or towfish motion. The swell filter was increased or decreased depending on the period and frequency of the sea surface wave conditions, however, special care was taken during this phase to not remove, or smooth over geologic features that are masked by the sea state noise. The final step was to apply the UGC. The SonarWiz 5 UGC feature allows the user to define amplitude gains based on either the depth below the source, or the depth below the seafloor. For this survey, the UGC was adjusted so that the gain would increase with depth below the imaged seafloor (and not the source), mimicking a time-varying gain. The user was able to remove the noise within the water column, increase the contrast within the stratigraphy, and increase the amplitude of the stratigraphy with depth, accounting for some of the signal attenuation normally associated with sound penetration over time.

Geo-Source 200 Light Weight Marine Multi-Tip Sparker System

Table 6: Multi-channel sparker seismic-reflection system acquisition parameters.

Seismic Acquisition Parameter	Value
Shot Interval	3.125 m
Hydrophone Spacing Interval	3.125 m
Number of Channels	24
Data Fold	12
Source Power Level	1,000 joules
Source Tow Depth	0.25 m
Streamer Tow Depth	≤1.0 m
Low Cut Filter in Acquisition	8 Hz
Record Length	0.5 seconds
Sample Rate	0.125 ms

The high-resolution multi-channel sparker seismic-reflection data were acquired using a state-of-the-art sparker sound source and a 24 channel digital streamer. The seismic spread was configured to maintain a shallow tow depth and minimize any towing induced noise. Positioning of the seismic array was achieved using a combination of measured offsets, computed layback, and DGPS. The seismic data files were recorded in standard SEG-Y format.

The seismic acquisition equipment employed in the MEA HRG Survey was chosen based on CB&I's previous experience, the stated survey objectives laid out by the MEA and BOEM guidelines. The two primary elements of the seismic spread, the source (sparker) and the receivers (hydrophone streamer) were chosen to achieve maximum resolution of the near surface geology (<100 m) while maintaining penetration in excess of 250 m into the seabed. Obtaining the proper balance of resolution and penetration required a broadband sound source and a recording system with adequate dynamic range to capture the full seismic signal. Seismic acquisition parameters of the selected system are shown in Table 6 and a brief description of the main components of the seismic acquisition system is contained in this section of the report. The multi-channel seismic-reflection data were collected between July 4 and August 25, 2013. Data collection was limited to daylight hours under the supervision of certified PSO throughout the duration of the HRG survey.

Sparker Sound Source

The optimum sound source for the MEA HRG Survey was determined to be a Geo-Source 200 Marine Multi-Tip Sparker System (Figure 17). The Geo-Source Sparker, manufactured by GEO Marine Survey Systems in The Netherlands, represents the cutting-edge of sparker technology. The Geo-Source sparker is unique in the sense that it does not require regular maintenance of its 200 individual tips. Other sparker systems require daily maintenance and electrode tip "trimming" which result in a non-stable and non-repeatable source signature. The geometry of the Geo-Source electrode array is designed to deliver a short, sharp, primary pulse and to focus the outgoing acoustic energy downward into the seabed. The result is that the Geo-Source sparker provides a clean, stable, and repeatable source signature with reduced surface reflection interference.

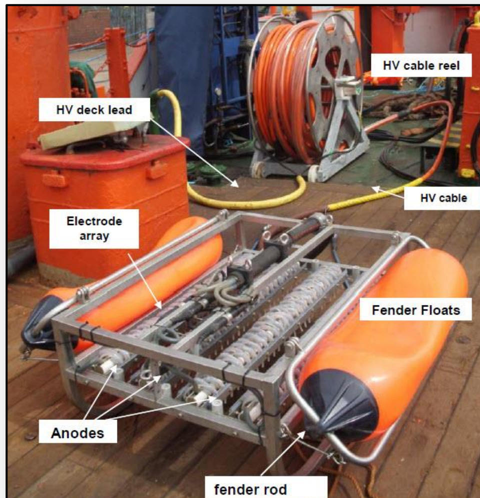


Figure 17: Geo-Source 200 Sparker Sound Source and high voltage cable reel assembly (Bielic de Jong, 2014).

Hydrophone Streamer and Recording System

Figure 18: GeoEel Solid Digital Streamer, eight-channel section (three continuous sections used for this 24-channel survey).

CB&I selected a GeoEel Streamer (Figure 18) and recording system, manufactured by Geometrics of San Jose, California, for the MEA HRG Survey. The GeoEel is a solid, digital, marine streamer. "Solid" hydrophone streamers are a relatively recent development in streamer design and eliminate the need for hydrocarbon-based filler fluids. Fluid-filled streamers require additional maintenance and often develop leaks and air bubbles which degrade data quality. Leaks and changes in streamer fluid pressure, i.e. over and under filled liquid streamers, also affect towing performance and data quality adversely.

In addition to its solid construction, the GeoEel is also a digital streamer, meaning the analog to digital (A/D) conversion takes place within the streamer itself. Digital streamer technology removes the need for a traditional top-side seismograph containing A/D boards and in doing so reduces electronic interference/noise and increases data quality. The GeoEel streamer has a modular design. The streamer is “built” in sections, each section contains eight (8) channels. A single channel is comprised of eight (8) individual hydrophones referred to as a group. Each eight (8) channel active streamer section requires a single 24 bit A/D converter module with 120 dB of dynamic range (Figure 19). For the MEA HRG Survey a 24 channel GeoEel streamer was used, composed of three (3) active sections and the required three (3) in-line A/D conversion modules.

Figure 19: GeoEel analog to digital (A/D) converter module.

In addition to the hydrophone sections and A/D modules, the streamer used on the MEA HRG Survey also had depth sensor capability and a vibration isolation lead-in section. The depth sensor modules were placed in-line with the active hydrophone sections at the head, middle, and tail of the streamer. A real-time depth readout was broadcast from the streamer during data acquisition. The three (3) independent depth values (head, mid, tail) were continually monitored to ensure streamer balance and that proper tow depths were maintained. The vibration isolator, deployed between the head of the streamer and Channel 1, was used to decouple ship motion and cable strumming from the active hydrophone sections of the streamer. Removing the effect of cable strum in data acquisition can dramatically decrease noise levels.

Initial setup and on-line survey control for the GeoEel system was provided by Geometrics’ CNT-2 Marine Controller software. This software was run from a laptop computer in the survey office aboard the survey vessel. Acquisition parameters such as sample rate, record length, hydrophone interval, filters, and gains can be set in this software. Quality control of seismic data during acquisition is also conducted in this software. The program offers a variety of real-time quality assurance (QA) and quality control (QC) tools which assist in optimizing data quality in the field. Several of the key QA/QC features are:

- Real-time shot record displays (with available filter, gain, and display option controls)
- Noise monitoring displays for each active channel in streamer
- Source energy level monitoring
- Trigger timing monitor
- Gather window for single channel seismic records (with available filter, gain, and display option controls)

Survey Design

Seismic survey design was focused on maintaining near-surface high resolution without forgoing moderate penetration rates. Maximum effort was made to acquire clean, noise free data in the field, thereby delivering the best possible data for processing and eventual interpretation. Implementation of survey design began with gear selection and was carried forward throughout the survey by in-the-field practices and constant QA/QC of raw seismic data.

A great deal of effort was placed on obtaining the quietest towing configuration possible. The streamer was ballasted with a combination of buoyant foam tubing and small collar-style weights. Proper streamer ballast is essential for achieving quiet, level towing at the desired depth. The streamer was towed from an outrigger fixed to the port aft corner of the vessel. The optimum layback for the streamer was determined to be 45 m from the stern of the vessel. Towing from the outrigger placed the hydrophones outside the turbulent, aerated prop wash reducing noise levels and erratic streamer movement. The streamer towing depth was approximately 0.5 m to 1 m. Maintaining a very shallow towing depth was important to reduce sea surface “ghosting” and preserve the highest possible frequency content. A “ghost” is energy that travels upward from the shot and is reflected downward from the sea surface. Ghost energy may join with the downward traveling primary pulse changing its waveform and adding a tail. Ghost energy, if further separated from the primary pulse, may introduce spurious reflections into the seismic record (Sheriff, 1973).

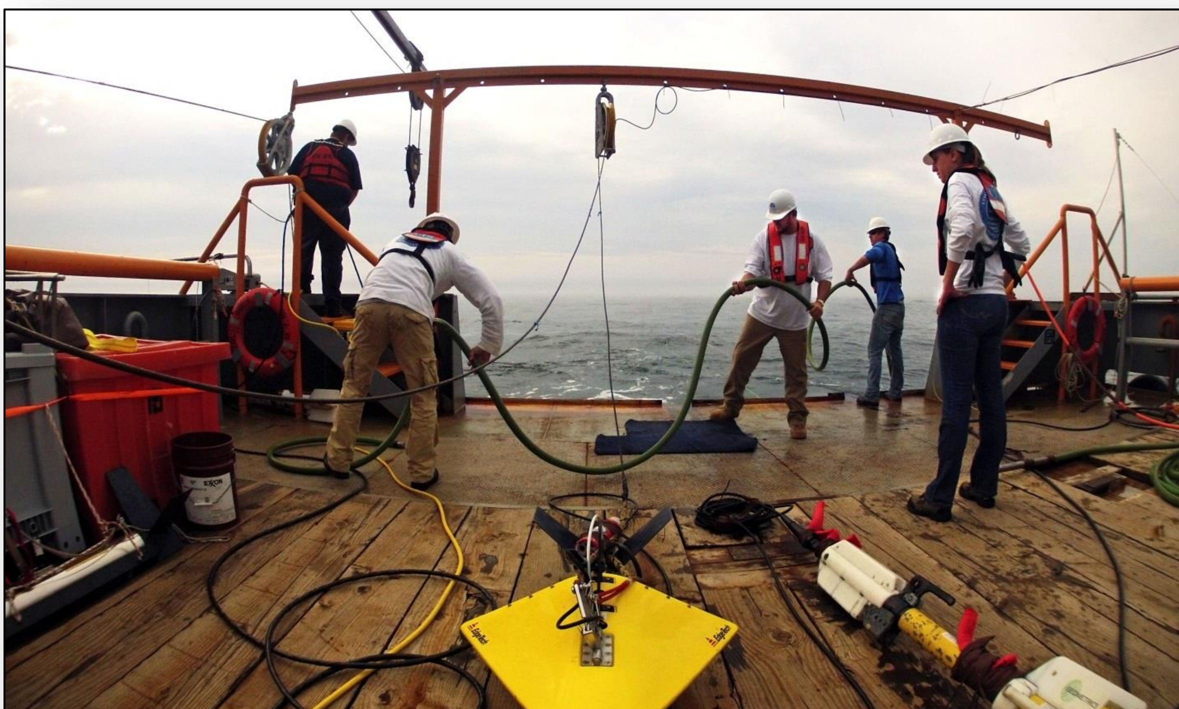


Figure 20: Scientific crew retrieving geophysical systems after a successful day of surveying offshore in the Maryland WEA.

The sparker sled was towed from the vessel's port-side aft corner. The source layback was 40 m from the stern of the vessel. The lateral offset between the source and receiver was 5 m. The source towing depth was maintained at a constant 0.25 m. The towing depth of 0.25 m was recommended by the manufacturer to achieve constructive interference between the primary pulse and the source ghost. After acquiring several test records at various power settings a determination was made to set power levels to 1000 joules.

All seismic data were acquired by the "shooting on distance" method. Distance shooting requires continuous measurement of the distance the seismic spread travels down the preplanned survey line. This measurement was made using the Hypack navigation software. The shot interval was 3.125 m, the same spacing as the hydrophone groups in the streamer. This shot interval was chosen to maximize "fold" in these data and maintain the highest possible horizontal resolution. Increasing fold corresponds to improvements in signal-to-noise ratio in seismic data. The Hypack navigation software was configured to deliver two (2) triggers to the seismic system upon traveling 3.125 m down-line. The timing triggers are generated within the software and transmitted as low voltage signals via external Hypack event boxes. Simultaneously, the two (2) triggers activate both the recording system and the sound source (sparker).

Fold as given by: $(\boldsymbol{number\ of\ channels} * \boldsymbol{channel\ separation})/(\mathbf{2} * \boldsymbol{shot\ interval})$

HIGH-RESOLUTION GEOPHYSICAL SURVEY RESULTS

Multibeam Bathymetry Survey Results

Multibeam data were collected between July 4, and August 31, 2013. Approximately 441,633,695 soundings from 2,759 survey-line segments collected over 59 days measured the elevation over 100% of the MEA HRG survey area seafloor. Elevations ranged from approximately -10 m to -45 m MLLW.

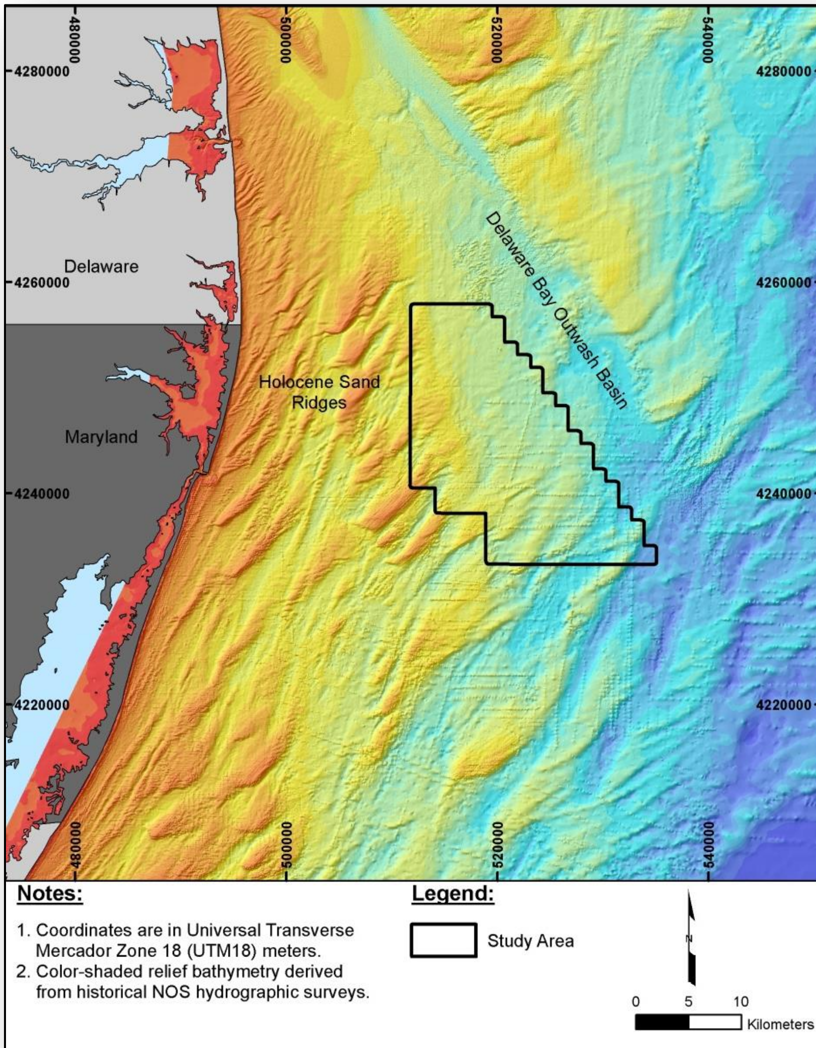


Figure 21: Regional NOS bathymetry surrounding the study area.

Duane et al. (1972) describe Maryland's outer continental shelf as fine and occasionally peaty Pleistocene base sediments overlain by long linear sand ridges that trend northeast. The sand ridges represent reworked Holocene deposits that have been formed and continuously altered since the last ice age. These sand ridges are clearly displayed in the reds and yellows in Figure 21. The study area is located immediately southwest of the Delaware Bay outwash basin and at the eastern transition area between nearshore late-Holocene sand ridges and the lesser-relief early-Holocene ridges located further offshore. The ridge orientation is generally south-southwest to north-northeast. Since sand ridges form perpendicular to the direction of flow, the ridge orientations agree well with Duane et al.'s (1972) finding that the dominant sediment transport for the area is south and offshore.

Features captured in this study agree well with previous NOS data collections (Figures 21 and 22). The 2013 MEA HRG survey multibeam data clearly show the transition area between high-relief late-Holocene ridges to the west from the low-relief early-Holocene ridges offshore (Figure

22). The eastern and southeastern sections of the study area are deeper (i.e. less than -25 meters MLLW), contain less relief and represent the shallow edges of the Delaware outwash basin shown in Figure 21. The western section is the eastern edge of the high-relief late-Holocene sand ridges, but this area is not well organized and essentially joins multiple ridges at their respective eastern ends.

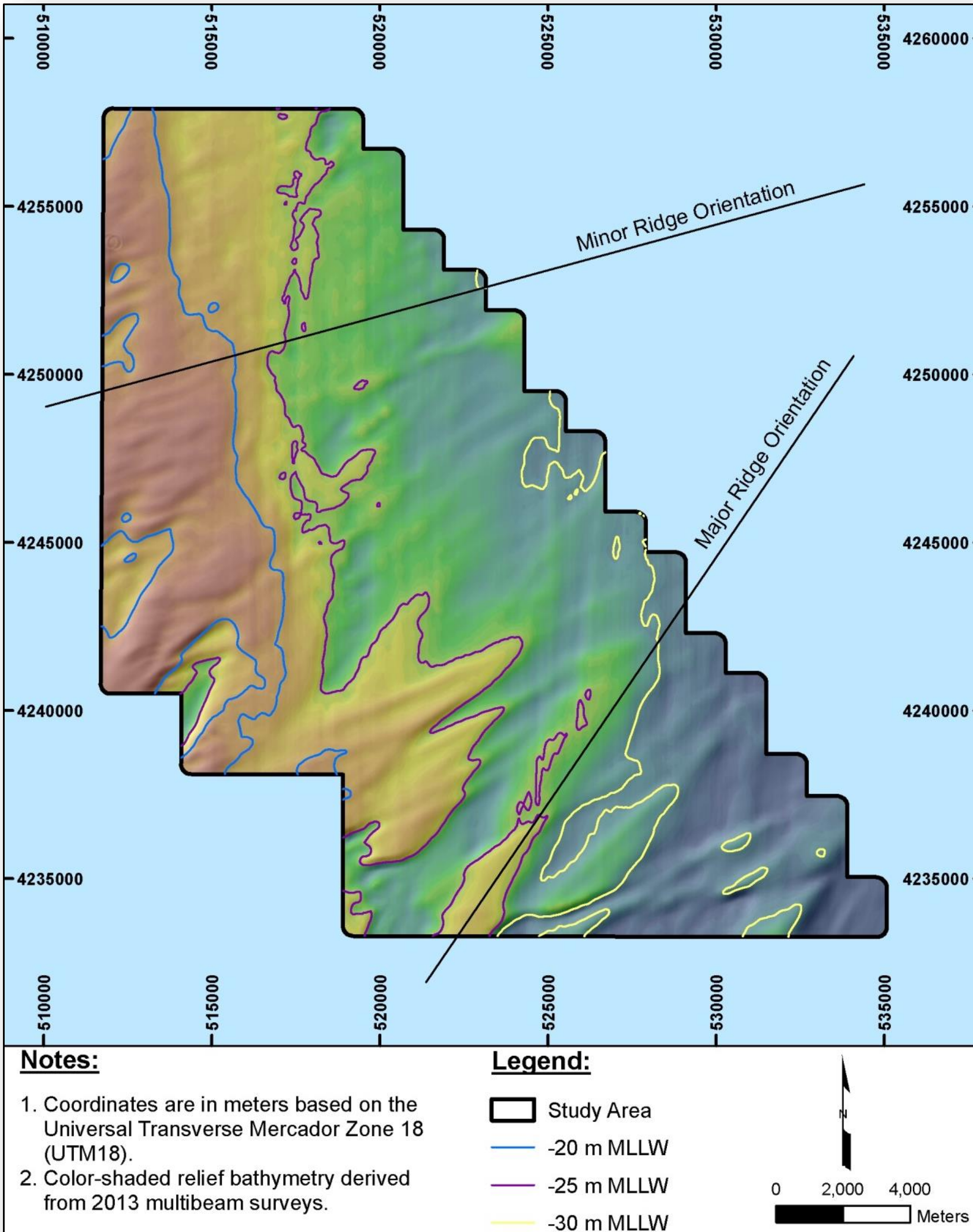


Figure 22: Color-shaded relief map showing study area derived from 2013 MEA HRG multibeam data.

The higher-density MEA HRG multibeam data show additional lower-relief (i.e. ~2 m) ridges within the larger-relief (i.e. ~8 m) ridges that are oriented more west-southwest to east-northeast (Figure 22). Why these smaller ridges are oriented more west-east is beyond the scope of this study. However, the smaller formations tend to be at shallower depths which suggest that typical wave and current action is more north to south and storm-induced wave and current action is more northwest to southeast when considering linear depth-limited wave theory. The change in orientation is also likely due to the close proximity to where the Delaware Bay drains through the Delaware Bay outwash basin.

Magnetometer Survey Results

Magnetometer data were analyzed by both CB&I personnel and a TAR registered professional archeologist. CB&I personnel analyzed the data for geologic and hazard purposes while TAR personnel further analyzed the data for potential cultural resource significance. Magnetometer anomalies with cultural resource significance are discussed in a separate section found later in this report.

The magnetometer data was both collected and processed in Hypack 2013. During processing, each survey line was viewed and interpreted for any potential magnetic anomalies. When potential magnetic anomalies were identified, a point was digitized to provide geographic coordinate information at the target location for integration into ArcGIS. The overall quality of the magnetometer data was good for the entire MEA HRG survey; however, there were a couple of minor factors that affected data quality during acquisition.

The first factor was interference caused by the multi-channel sparker seismic-reflection system. The sparker system was run simultaneously (during daylight hours) during the MEA HRG survey. As previously described, the sparker system emits electrical pulses to create an acoustic sound source for mapping subsurface geology. These sparker pulses, which are electrical arcs directly in the water column, are triggered on vessel distance traveled along the survey line. Every time the system was triggered, the electrical arc would produce a very short and distinct anomalous peak in the magnetometer data (Figure 23).

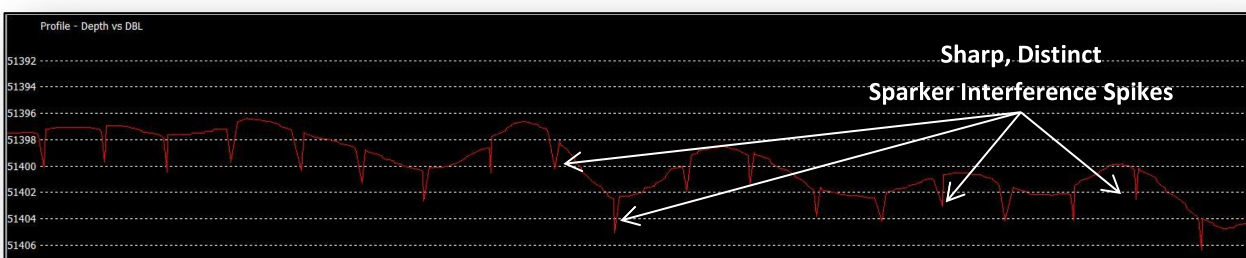


Figure 23: Short and distinct anomalous spikes produced by multi-channel seismic system.

While visible in the data, the nature of the anomalous spike allows it to easily be accounted for during data interpretation. These distinct peaks are quite sharp in expression, clearly representing a single, anomalous event within the water column and not indicative of a true magnetic anomaly. The fact that the anomalous spike was timed evenly based on distance and represented only one isolated point (instead of a smooth magnetic field anomaly peak) made it easy to differentiate these anomalous sparker peaks from other significant target peaks that contain more than one point.

The second factor affecting magnetometer data quality was the movement of the magnetometer through the water column during the survey line to keep the towfish no more than 6 m from the seafloor, which was a BOEM (Department of Interior, 2012b) and MEA RFP requirement. During the entire survey, the towfish was consistently towed at an altitude of less than 6 m from the seafloor 100% of the time. As the CB&I operators adjusted the towfish depth (using the oceanographic winch) to account for changing seafloor topography, the gamma readings produced by the system also fluctuated as a result of the natural magnetic properties of the survey area and water column, and the rapid change in distance between the magnetometer towfish and the seafloor. The artifacts produced by this activity resemble large stair steps as the gamma readings go up and down in relation to the previous depth setting (Figure 24). These large scale artifacts did not pose any problems for data interpretation as the depth changes are abrupt and easily identifiable when compared to true magnetic anomaly signatures.

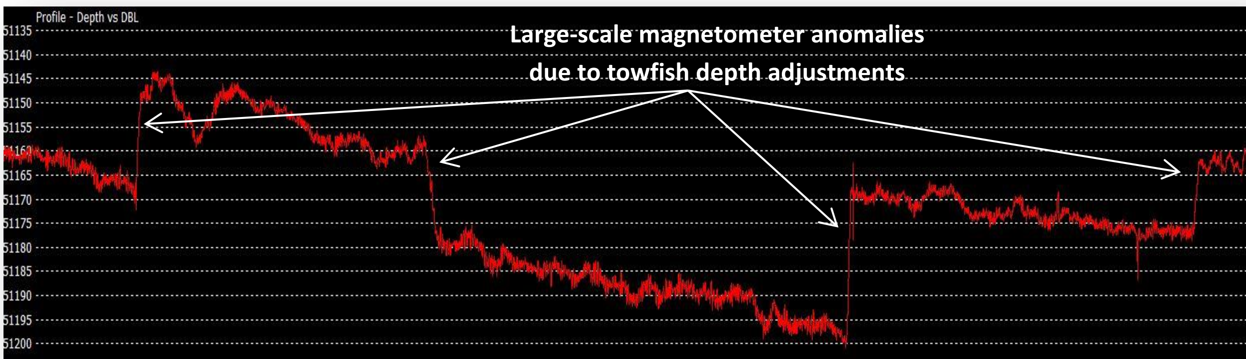


Figure 24: Fluctuation of gamma readings as a result of towfish depth adjustments.

As a result of the MEA HRG survey, 1,142 total magnetic anomalies were identified throughout the WEA. These targets are depicted on *Map Series 5: Sidescan Sonar Contact and Magnetic Anomaly Map* (Appendix E). In addition, all identified magnetic anomalies are listed in the *Magnetic Anomalies Table* (Appendix I), which includes details such as anomaly name, coordinates (X/Y m and Latitude/Longitude), line number, signature type, intensity, duration, assessment, and submerged cultural resource (SCR) potential.

While 1,142 magnetic anomalies is a large amount – even for a survey area of this large size and adjacent to significant maritime activities – it should be noted that ALL magnetic anomalies have been included as potential hazards as the survey line spacing does not support eliminating any from consideration. Due to the reconnaissance level (150 m) survey line spacing conducted for this survey, there was not enough magnetometer data to eliminate any of the magnetic anomalies from consideration as potential hazards. This is due to the fact that the 150 m survey line spacing does not provide enough adjacent line data to provide significant insight as to a magnetic anomaly's true spatial properties (including specific intensity and duration characteristics). This is further complicated by the fact that there is a high potential that unseen targets may exist between the 150 m survey line spacing that are invisible to the magnetometer. A majority of the identified targets are small in intensity and were either dipolar or multicomponent (Figures 25a and b). While no targets were able to be eliminated from hazard consideration, the low intensity of the majority of the targets is usually not indicative of any major hazards. As such, concern for hazards is low; however detailed site-specific magnetometer investigations will be required for specific development sites prior to any development activity in order to full understand hazard potential.

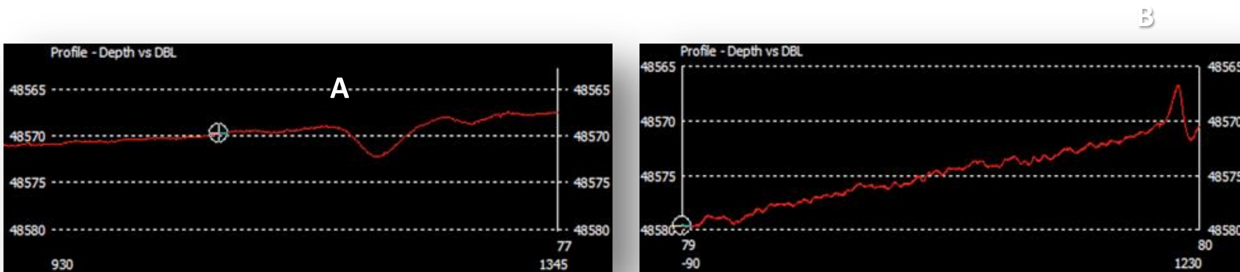


Figure 25: a) Small magnitude multicomponent target; and b) Small magnitude dipolar target.

Sidescan Sonar Survey Results

Sidescan sonar data collected as part of the MEA HRG survey were analyzed by both CB&I geologists and a TAR registered professional archeologist. CB&I personnel analyzed the sidescan sonar data for geologic, hazard, and benthic habitat potential while TAR further analyzed the data for potential cultural resource significance. The cultural resource potential interpretation and summary is provided in a separate section later in this report. During processing, each survey line was viewed and interpreted for any potential hazard contacts, geologic features, benthic habitat and sediment boundaries. When potential contacts were identified, a point was digitized to provide geographic coordinate information at the contact location for integration into ArcGIS and an image of the contact was produced. All geologic features and sediment boundaries were digitized in SonarWiz 5 by encapsulating the feature into a geographically referenced polygon shapefile for integration into ArcGIS. A mosaic image was also exported from SonarWiz 5 for integration into ArcGIS so further analysis of all data could take place. Overall, the quality of the sidescan sonar data was good, however, quality varied based upon vessel location within the survey area. The main factor affecting the sidescan sonar data quality was a strong and persistent thermocline that existed during the entirety of the survey and survey area, while interference from other geophysical systems occasionally caused minor artifacts within the sidescan sonar data.

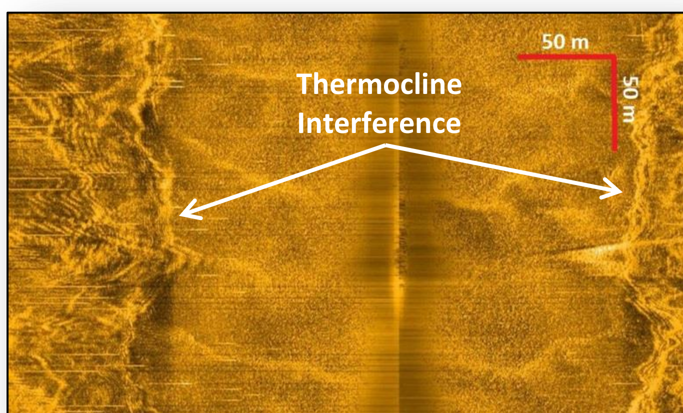


Figure 26: Sidescan sonar interference caused by thermocline

The primary concern with regard to data quality for MEA HRG sidescan sonar data was a strong and persistent thermocline that was present throughout the MEA HRG survey area (Figure 16). Thermoclines are a common challenge, particularly for swath acoustic systems such as sidescan sonars (Jollymore, 1974), as they act to scatter the acoustic signals at the outer beams due to changes in the speed of sound through water. As the outer beams are scattered, the sonar data becomes distorted (Figure 26). When experiencing this impact, the operator generally has to either reduce the range of the instrument, or adjust the tow depth to get the towfish below the thermocline. Because of the wide line spacing of the survey (150 m), reducing the range of the instrument was not an option due to the already limited overlap from line to line. Therefore, altering depth, while maintaining towfish altitude requirements in the MEA RFP and BOEM guidelines (U.S. Department of Interior, 2012b), was the only solution. In the deeper portions of the survey this was possible; however, due to the depth of the thermocline in the shallow water (Figure 16) it was impossible to tow the sidescan sonar towfish at such a depth to avoid thermocline effects.

The secondary concern affecting sidescan sonar data quality was impacts caused by the multi-channel sparker seismic-reflection system. The sparker system was run simultaneously (during daylight hours) during the MEA HRG survey. As previously described, the sparker system emits electrical pulses to create an acoustic sound source for mapping subsurface geology. These sparker pulses, which are electrical arcs directly in the water column, are triggered on vessel distance traveled along the survey line. Every time the sparker system was triggered, the electrical arc would produce a very short and distinct horizontal acoustic streak in the sidescan sonar data (Figure 27). While visible in the data, the nature of the streak did not mask any potential contacts or sediment boundaries in the data. The fact that the streak was timed evenly based on distance and had similar acoustic properties throughout the survey made it easy to differentiate between the anomalous streaks and real seafloor features.

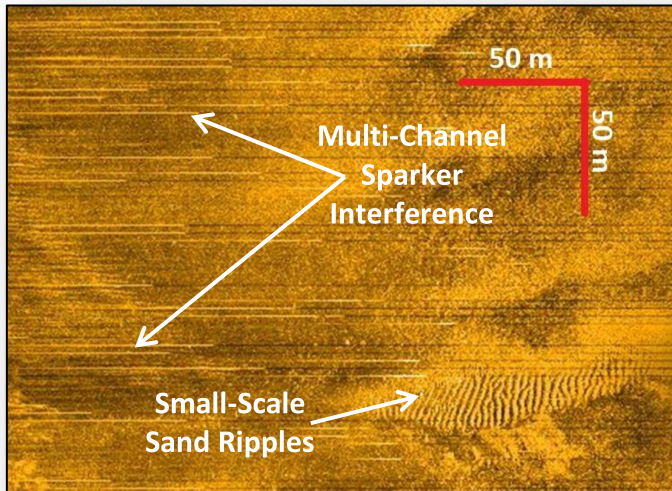


Figure 27: Acoustic interference caused by the sparker multi-channel seismic-reflection system.

A comprehensive sidescan sonar mosaic for the entire MEA HRG survey area was created and is attached to this report as *Map Series 5: Sidescan Sonar Contact and Magnetic Anomaly Map* (Appendix E). A total of 104 sidescan sonar contacts were identified during the MEA HRG survey. Contact reports for each individual sidescan sonar contact were created and are attached to this report as *Sidescan Sonar Contact Report* (Appendix J). In addition, each sidescan sonar contact was included as targets on *Map Series 5: Sidescan Sonar Contact and Magnetic Anomaly Map* (Appendix E). The contacts range from small unidentified objects to larger-scale contacts such as shipwrecks (Figure 28). While some contacts are easily identifiable such as shipwrecks, other smaller

Figure 28: NOAA charted shipwreck located within the MEA HRG survey area.

targets require further investigation to ascertain the nature of the contact. As such, detailed site-specific sidescan sonar investigations will be required for specific development sites that occur in proximity to sidescan sonar contacts prior to any development activity in order to fully understand hazard potential.

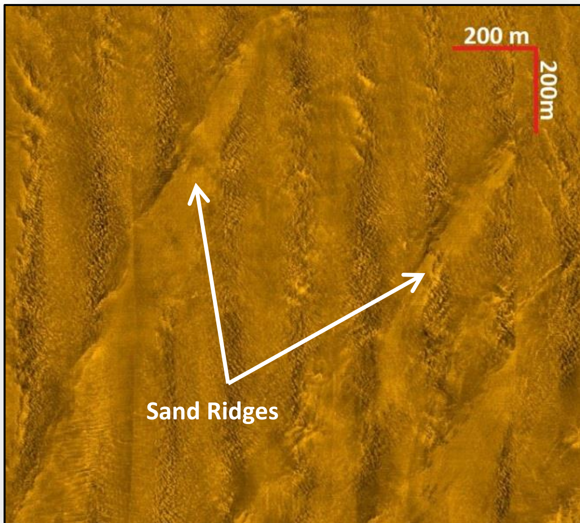


Figure 29: Representative sidescan sonar image of sand ridges found in the MEA HRG survey area.

Based on backscatter analysis of the individual sidescan sonar line files and the comprehensive MEA HRG sidescan sonar mosaic, CB&I geologists identified and mapped a total of three (3) significant bottom types throughout the MEA HRG survey area. These bottom-type interpretations have been included on *Map Series 4: Geologic Features Map*, attached to this report as Appendix D. These bottom types include:

- *Potential Exposed Mud/Clay;*
- *Sand Ridges and/or Sand Waves; and,*
- *Sand with Some Gravel.*

Of the three (3) bottom types identified, sand with some gravel is the prevailing substrate throughout the majority of the MEA HRG study area. Large scale sand ridges (Figure 29) identifiable in the sidescan sonar data are prevalent throughout the entire western end of the MEA HRG survey area as well as some in the southern section of the study area. Areas of potential exposed mud/clay (Figure 30) are found in the north-central section, as well as the southeastern corner of the MEA HRG survey area. These bottom types are described a “potential” due to the fact that additional investigations would be required to determine the true nature of the sediment even though the acoustic signature indicates mud or clay. No significant, essential or protected benthic habitats were identified during the sidescan sonar analysis; however, further analysis using towed-video or other ground-truthing methods is recommended as the sidescan sonar is an acoustic (and not visual) representation of the seafloor substrate.

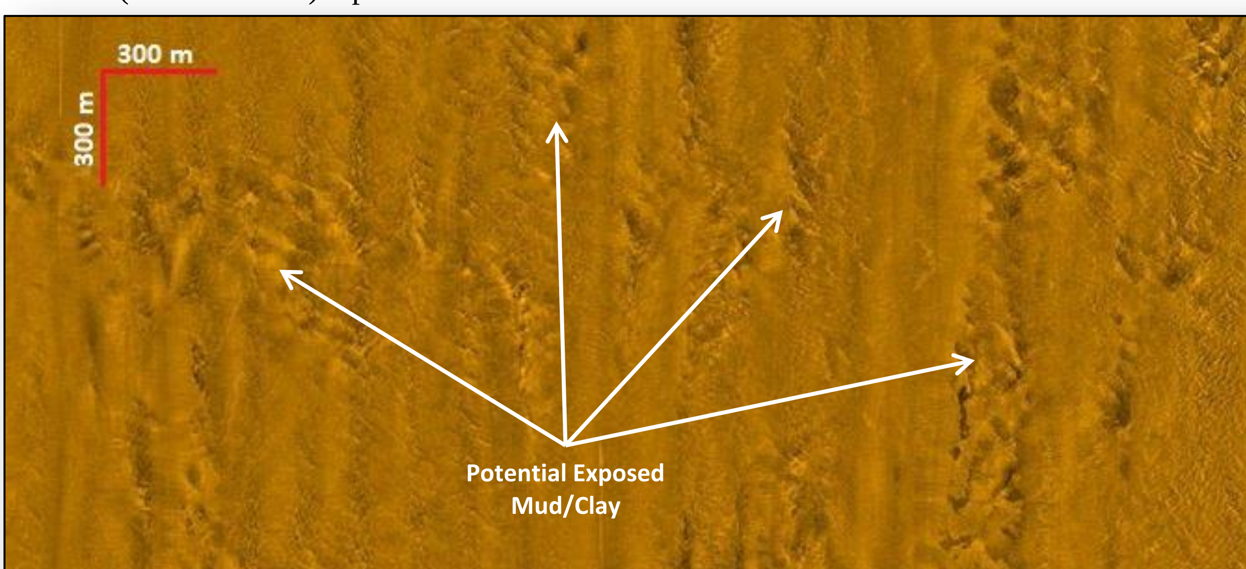


Figure 30: Representative sidescan sonar of potential exposed mud/clay found in the MEA HRG survey area.

Shallow-Penetration Chirp Sub-Bottom Profiler Survey Results

The overall quality of the chirp sub-bottom profiler data collected as part of the MEA HRG survey is very good. In most areas, the chirp sub-bottom profiler was able to clearly image 20 m or more of the subsurface geology immediately below the seafloor. CB&I geophysicists reviewed and interpreted the chirp sub-bottom profiler data for geologic and hazard features, while archaeologists from TAR reviewed the chirp sub-bottom profiler data for cultural resource significance. All raw chirp sub-bottom profiler SEG-Y digital files, and their associated SEG-P1 digital navigation files, are attached to this report as Appendix P (digital copy only).

The main concern affecting chirp sub-bottom profiler data quality was impacts caused by the multi-channel sparker seismic-reflection system. The sparker system was run simultaneously (during daylight hours) during the MEA HRG survey. As previously described, the sparker system emits electrical pulses to create an acoustic sound source for mapping subsurface geology. These sparker pulses, which are electrical arcs directly in the water column, are triggered on vessel distance traveled along the survey line. Every time the sparker system was triggered, the electrical arc would produce a very short and distinct vertical acoustic streak in the chirp sub-bottom profiler data (Figure 31). While visible in the data, the nature of the streak did not mask any potential geologic or hazard features in the data. The fact that the streak was timed evenly based on distance and had similar acoustic properties throughout the survey made it easy to differentiate between the anomalous streaks and real stratigraphic features.

Overall, the chirp sub-bottom data clearly indicated two main seismic facies units, Unit 1 (the surficial stratigraphic unit) and Unit 2 (immediately underlying Unit 1 except for where Unit 1 pinched out, exposing Unit 2 on the seafloor).

Unit 1 is the surficial seismic facies unit and consists primarily of well-developed linear sand ridges (to the west) and a thin sediment veneer (to the east) (Figure 31). These ridge deposits are thickest and most organized in the western portion of the survey area and thin to the east where

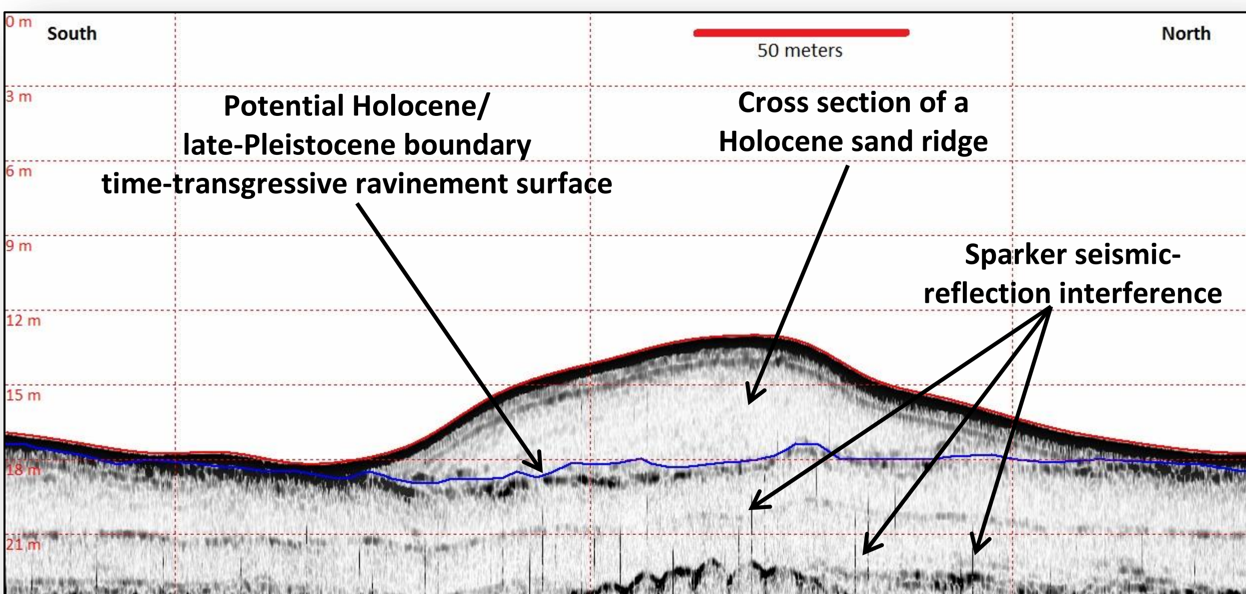


Figure 31: Example of a Holocene sand ridge overlying the likely Holocene/ late-Pleistocene boundary.

they become more sheet-like. Internal stratigraphy can be seen within many of the sand ridges, although in some cases, they may appear acoustically transparent, likely a result of being composed of large amounts of coarse-grained, sand-sized sediment (Figure 31). In areas where sand ridges are absent, the sediment veneer thins dramatically toward the east and the top of Unit 2 becomes exposed at the modern seafloor.

The nearshore shelf off the coast of Maryland has been previously described as a discontinuous, highly-variable sheet of medium- to fine-grained modern shelf sands distributed in shore-oblique ridges and swales, spaced approximately 2 to 4 km apart and extending tens of kilometers (Conkwright and Williams, 1996; Swift et al, 2003). These ridges are a dominant feature of the shelf, generally oriented southwest-northeast with a maximum relief of 5 to 10 m (Hobbs et al., 2008). As the Delmarva Peninsula is a mixed energy, wave dominated, barrier island shoreline, it is highly conducive to sand ridge development. As such, the Delmarva Peninsula has the greatest number and highest density of shoreface-attached and detached sand ridges along the eastern U.S. coastline (McBride and Moslow, 1991). These detached sand ridges, as described above, are the main component of Unit 1 as seen in the MEA HRG chirp sub-bottom profiler data. The larger, well-organized ridges in the western section of the MEA HRG study area likely represent late-Holocene deposits, while the thinner, disorganized, lower-relief ridges to the east, further offshore, likely represent early-Holocene deposits.

While the vast majority of Unit 1 consists of these detached ridge fields, there is evidence of a Holocene distributary channel located in the northwestern portion of the MEA HRG survey area. This feature appears to have incised Unit 2, Subunit B, a Pleistocene unit (described later in this section). It is likely that this Holocene distributary channel may have served as a drainage system at or near the beginning of the last sea level transgression. Consequently, this feature has been infilled with modern Holocene shelf sands and its bottom represents the Holocene/late-Pleistocene boundary (Figure 32).

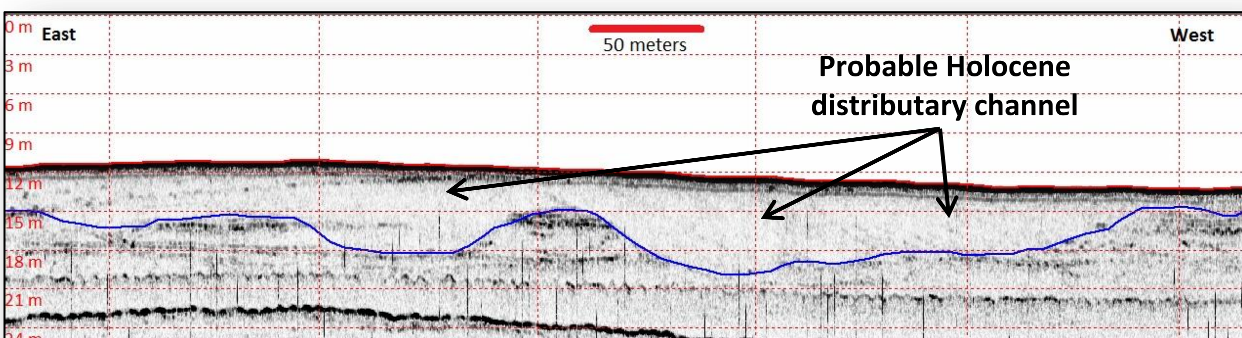


Figure 32: Example of a Holocene distributary channel in the northwest MEA HRG survey area.

Unit 1 is mostly underlain by a clear and distinct reflector that is acoustically indicative of a mixed sediment composition, consisting of clays, silts, muds, and gravels. This discontinuity is likely evidence of a time-transgressive ravinement surface which serves as the boundary between Holocene sand units above (Unit 1), and late-Pleistocene units below (Unit 2) (Figure 31). The ravinement surface is a result of shoreface erosional and depositional processes during Holocene sea-level rise. The shoreface was eroded as sea level rose and caused shoreface regression; as the shoreface retreated landward, shoreface sediments were re-deposited overlying the erosional surface (Conkwright and Williams, 1996). As such, the (ravinement surface) can then be classified as an erosional and sediment transfer surface (Nummedal and Swift, 1987). In some areas, this discontinuity is completely eroded exposing Pleistocene sediments and/or not apparent due to possible mixing of lithological boundaries during formation (Toscano et al., 1989), and/or masked due to its proximity to the seafloor (Conkwright and Williams, 1996). This ravinement surface, where possible, was mapped throughout the MEA HRG survey area in order to calculate a thickness (isopach) of the Holocene sand deposits comprising Unit 1. The Holocene deposits (Unit 1) range in thickness from approximately 10 m (at the organized ridge field in the western portion of the survey area) and thins to 0 meters toward the east. The Holocene thickness map is attached to this report as *Map Series 6: Shallow Isopach Map* (Appendix F). The location of the Unit 1 sand ridges evident in the chirp sub-bottom data can be seen in *Map Series 4: Geologic Features Map* (Appendix D).

Unit 2 lies immediately beneath Unit 1, except for the central- and eastern-most sections of the survey area where it becomes exposed, or nearly so, as Unit 1 thins. Unit 2 consists of multiple likely late-Pleistocene paleochannel complexes, often with multiple generations of paleochannels mixed throughout Unit 2 (Figure 33). The composition of the channel fill cannot be precisely determined solely on the geophysical methods conducted during this survey, follow-on geotechnical investigations will be required to ground truth the acoustic interpretations. However, based on seismic facies analysis of the acoustic returns and reflector geometries, some interpretations can be made about sediment types within the buried channels.

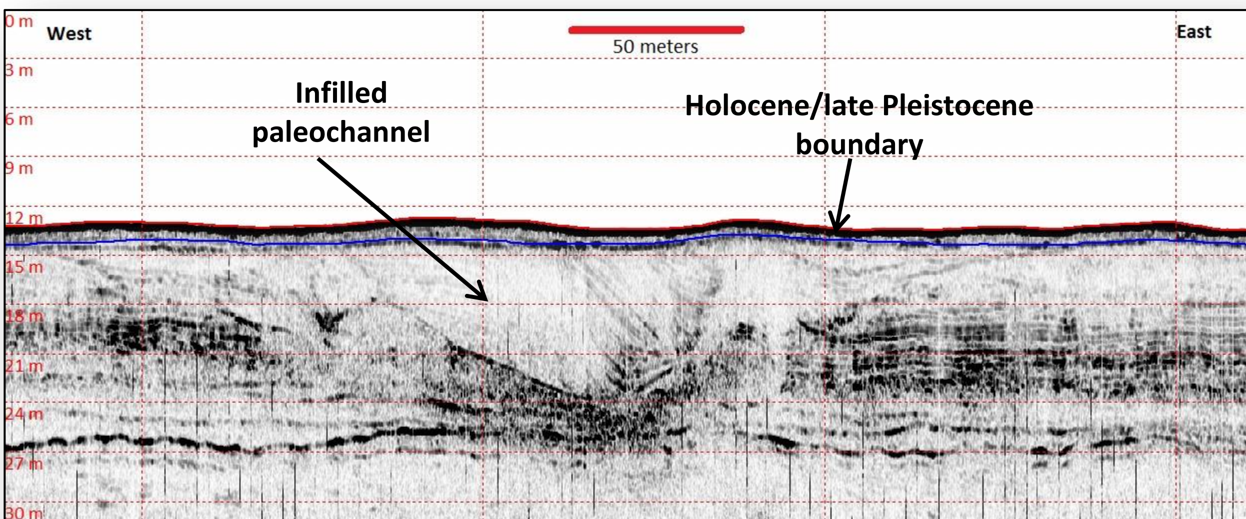


Figure 33: Infilled late-Pleistocene paleochannel beneath the Holocene/late-Pleistocene boundary.

Pleistocene sediment units, like those in Unit 2, typically represent a combination of littoral, fluvial, and marine sediments ranging from coarse to fine-grained (Belknap and Kraft, 1985). The buried channels in Unit 2, which were incised during sea-level lowstands, were subsequently infilled by fluvial, marine, estuarine, and coastal sediments during follow-on transgressions (Riggs and Belknap, 1988). As a result, the composition of the sediments within the paleochannels is likely highly variable, changing both laterally and vertically. The physical properties of the sediments within the buried channels may be significantly different from those of the strata in which they are incised.

Unit 2 consists of three subunits, mainly focused in the western and southern sections of the MEA HRG study area. These subunits include Subunit A: a poorly-organized tidal (potentially logoonal, estuarine, or nearshore marine) complex, Subunit B: a poorly-organized buried-channel and tidal complex, and a Subunit C: a highly-organized buried-channel complex.

Unit 2, Subunit A is categorized as a poorly organized tidal complex. The acoustic reflectors within this subunit are indicative of a low-energy depositional environment, similar to a present day back-bay lagoon (Figure 34). This complex exhibits evidence of transgressive and tidal deposition as interpreted by the broad horizontal stratigraphy with little-to-no evidence of fluvial incision. The sediments within Subunit A have high potential for significant fine-grained silts and clays and subsurface organics.

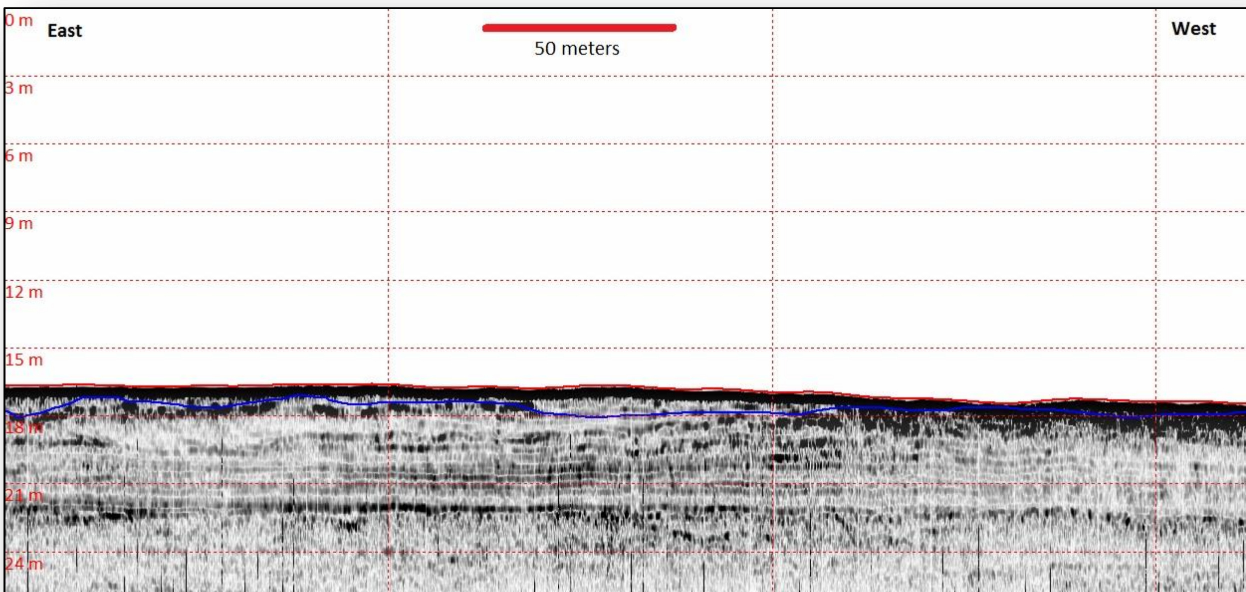


Figure 34: Unit 2 Subunit A; poorly-organized tidal complex. Broad horizontal depositional stratigraphy below the Holocene/late-Pleistocene boundary.

Unit 2, Subunit B is interpreted as a poorly organized buried channel and tidal complex. This complex exhibits evidence of multiple, nested, or multi-generational fluvial incisions and subsequent fluvial, transgressive, and tidal deposition. Features within this complex, such as interbedded clays, silts and sands and crossbedding indicate that this subunit is similar to a present day braided river system or salt marsh environment (Figure 35). This complex has potential for fine-grained silts and clays and subsurface organics.

Unit 2, Subunit C is characterized as two (2) highly-organized buried-channel complexes. This subunit shows evidence of clear fluvial incision and subsequent fluvial and transgressive deposition (Figure 36). These two (2), distinct paleochannel systems were independently mapped using the MEA HRG chirp sub-bottom profiler data and run from the northwest portion of the survey area, south and southeast, before switching back towards the west. The smaller channel appears to be a smaller version or the larger channel, occurring within the larger channel footprint, but stratigraphically higher, and therefore, more recent than the larger channel. This complex of paleochannels likely contains interbedded clays, silts and sands and some gravel.

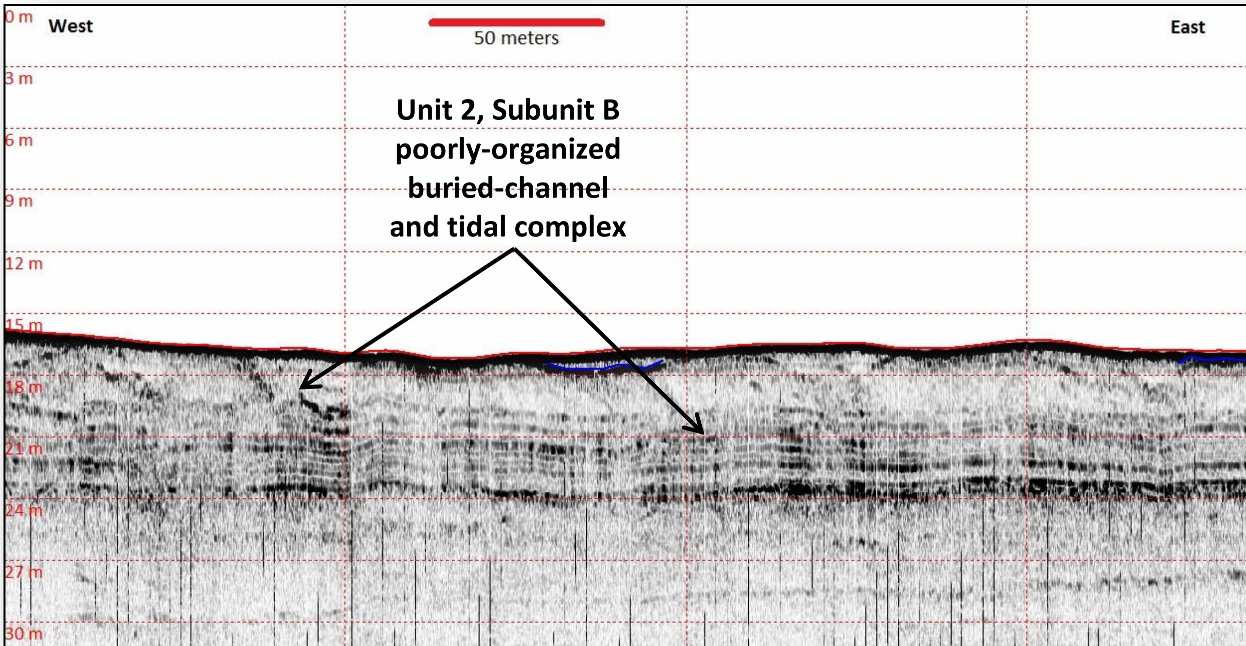


Figure 35: Unit 2 Subunit B; poorly-organized buried-channel and tidal complex. Crossbedding and poorly-organized fluvial incision below the Holocene/late-Pleistocene boundary.

Composition of Subunits A, B, and C cannot be precisely determined from the chirp sub-bottom profiler data alone. Subunit A potentially contains interbedded fine-grained sediments and has the highest potential for subsurface organic material. Subunits B and C contain highly variable sediments which can differ both laterally and vertically. Subunit B likely contains fine-grained sediment with a high potential for subsurface organics and Subunit C likely contains some fine-grained sediment and has the highest potential for coarse-grained sediment. The location of all of

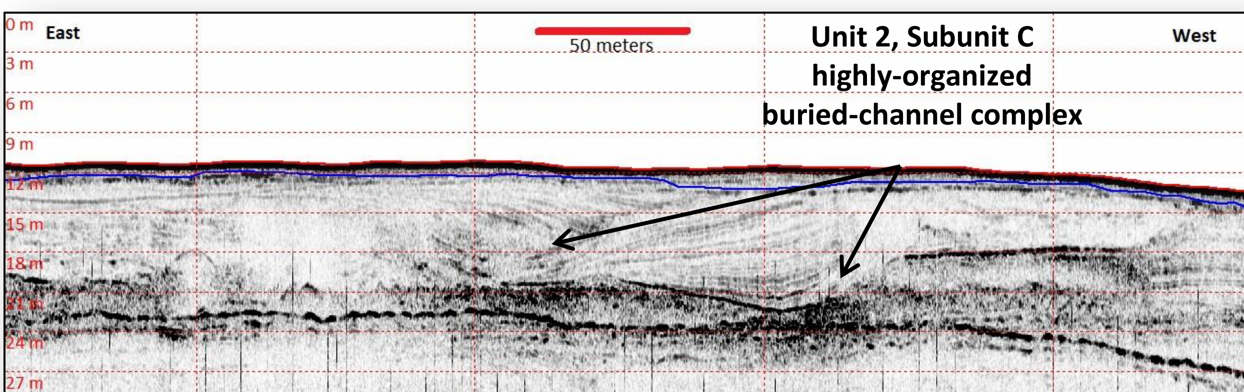


Figure 36: Unit 2 Subunit A; poorly-organized tidal complex. Broad horizontal depositional stratigraphy below the Holocene/late-Pleistocene boundary.

the Unit 2 paleochannel complexes can be seen as part of *Map Series 4: Geologic Features Map* (Appendix D).

A historic core sample taken approximately 17 km southwest of the MEA HRG survey area, taken from Toscano et al. (1989), is included below (Figure 37). Due to the lack of geotechnical data within the MEA HRG study area, this core sample is included as a representative ground truthing of the seismic data seen in the MEA HRG chirp sub-bottom profiler data. In this core, Holocene shelf sands overlie the Holocene/late-Pleistocene boundary, a subcropping mud ravinement surface. Below this discontinuity is sand/gravel with mud lamina and a large deposit

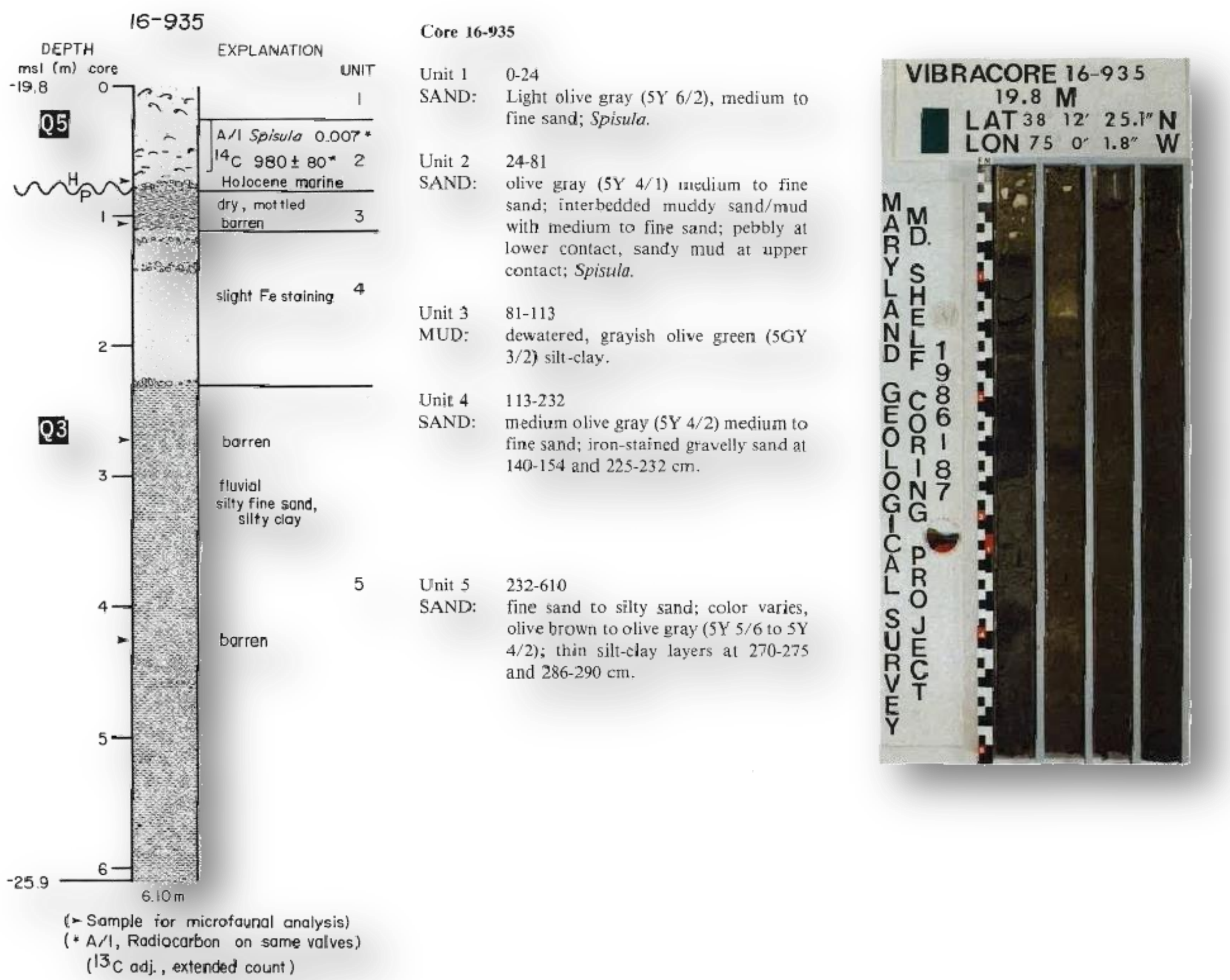


Figure 37: Historic core sample taken from Toscano et al., contains representative surficial stratigraphy as seen in the MEA HRG chirp sub-bottom profiler survey results.

of fluvial sediments. The stratigraphy in the core matches the interpretation of the MEA HRG chirp sub-bottom profiler data.

One final result identified as part of the MEA HRG chirp sub-bottom data was that the large, high-relief organized sand ridges were found collocated above the main Pleistocene paleochannel systems. This is a common occurrence on many continental shelf systems, as material that was previously transported within the paleochannel systems often are deposited nearby those systems, becoming available for reworking during subsequent sea-level transgressions. This is confirmed in McBride and Moslow (1991), where they note that the association of sand ridges with abandoned deltaic and/or paleochannel systems is an expected facies relationship, as the former ebb-tidal and fluvial deltaic systems were a product of the paleochannel systems. As such, McBride and Moslow (1991) state that paleochannels should indeed be found underneath shoreface sand ridges This relationship between older paleochannel systems and more recent, overlying sand ridges is evident in the western and southern section of the MEA HRG survey.

In order to determine the shallow structure of the MEA HRG survey area, the elevation of the Holocene/Pleistocene boundary (between Unit 1 and Unit 2) was determined by combining the MEA HRG survey multibeam bathymetry elevations with the MEA HRG survey Holocene isopach values. The resulting Pleistocene elevation map is attached to this report as *Map Series 8: Shallow Structure Map* (Appendix H).

Medium-Penetration Multi-Channel Sparker Seismic-Reflection Profile Survey Results

Medium-penetration multi-channel sparker seismic-reflection data quality was good throughout the MEA HRG survey area. There are clearly high signal-to-noise ratios in the data and detailed reflector geometries and seismic facies are imaged. Frequency content in the processed data ranged from 200 Hz to 1.4 kHz. Based on the Widess limit, vertical resolution in the very-near subsurface may be as good as 15 cm declining to around 1 m at a depth of 200 m. Widess (1973) defines vertical seismic resolution as the minimum resolvable bed thickness and states that beds as thin as 1/8 the seismic wavelength can be detected under optimum conditions. The resolution estimates given here are theoretical and represent best-case scenarios. All raw multi-channel sparker seismic-reflection SEG-Y digital files, and their associated digital navigation files, are attached to this report as Appendix Q (digital copy only).

Sub-seafloor penetration in excess of 250 milliseconds, two-way travel time (TWTT) or approximately 200 m (calculated using an average velocity of 1655 m/s based on normal move-out measurements conducted in velocity analysis during data stacking) was achieved consistently across the survey area. Penetration in excess of 300 ms (or approximately 250 m) was not uncommon.

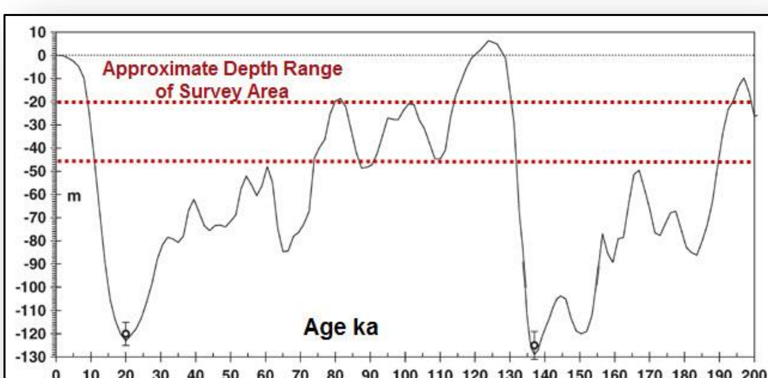


Figure 38: Sea-level curve for the Holocene and part of the Pleistocene. Red lines depict the approximate depth range of the survey area and approximate sea level behavior along that region of the OCS (modified from Waelbroecka et al., 2002).

Regional dip in the survey area is basinward (east) and toward the south. Based on seismic facies characteristics and reflection geometries, no basement rock was identified in any of the seismic profiles. No geotechnical work was done to confirm lithology types. All of the stratigraphic units imaged in these data are likely to be comprised of coastal plain type sediments ranging from muds to sands to gravel.

The seismic survey spans the inner to mid-continental shelf between 16 km and 42 km offshore the central Delmarva Peninsula. Water depths in the survey area range from approximately 10 m to 45 m. This location, the inner to mid continental shelf, has been subjected to highly variable sea level during the recent geologic past (Figure 38). The Delmarva continental shelf has experienced dozens of glacio-eustatic transgressions and regressions throughout the Quaternary Period (2.6 million years ago to present). The entirety of the survey area was sub-aerially exposed as recently as 12,000 years ago. This high frequency, high amplitude sea-level change has been the dominant influence on depositional patterns and stratigraphic architecture for the geologic time period represented by these data.

The broadband nature of these data has allowed for fine-scale resolution in the near-surface while achieving moderate penetration levels. As a result, the seismic profiles capture a great deal of stratigraphic detail and complexity. However, in broad terms, three (3) general seismic facies units are evident in these data. Unit 1, the uppermost unit is likely comprised of sandy sediments deposited or reworked during the Holocene. Unit 2, which lies beneath the modern surficial sediments, is heavily incised and is characterized by steeply dipping reflectors, cross-bedding, and erosional surfaces. Deeper in the seismic section, Unit 3, is characterized by parallel to sub-parallel high amplitude gently dipping reflectors (Figure 39).

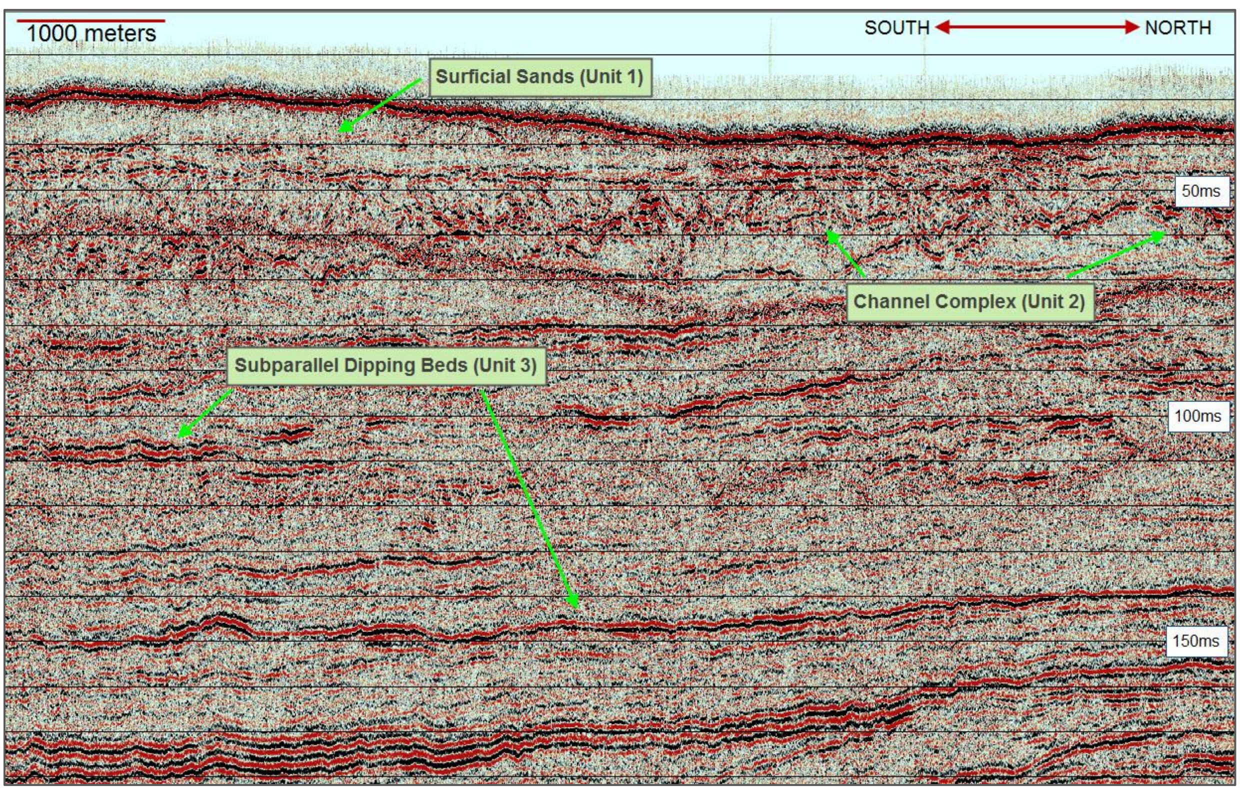


Figure 39: Portion of multi-channel sparker seismic Line 105 showing all three seismic facies units interpreted in this investigation.

The surficial geology (Unit 1, <10 m) depicted in the seismic profiles consists primarily of well-developed linear sand ridges and a thin Holocene sediment veneer (Figure 40). Sand ridge deposits are thickest and most organized in the western portion of survey area and thin to the east where they become more sheet-like. Internal stratigraphy can be seen within many of the sand ridges, although these bedforms may appear acoustically transparent in some cases. The base of the sand ridges has been interpreted to represent the Holocene-Pleistocene boundary. In areas where sand ridges are absent, Holocene sediments thin dramatically and the top of the Pleistocene surface may be exposed at the modern seafloor. Pleistocene sediment units represent a combination of littoral, fluvial, and marine sediments ranging from coarse to fine-grained (Belknap and Kraft, 1985).

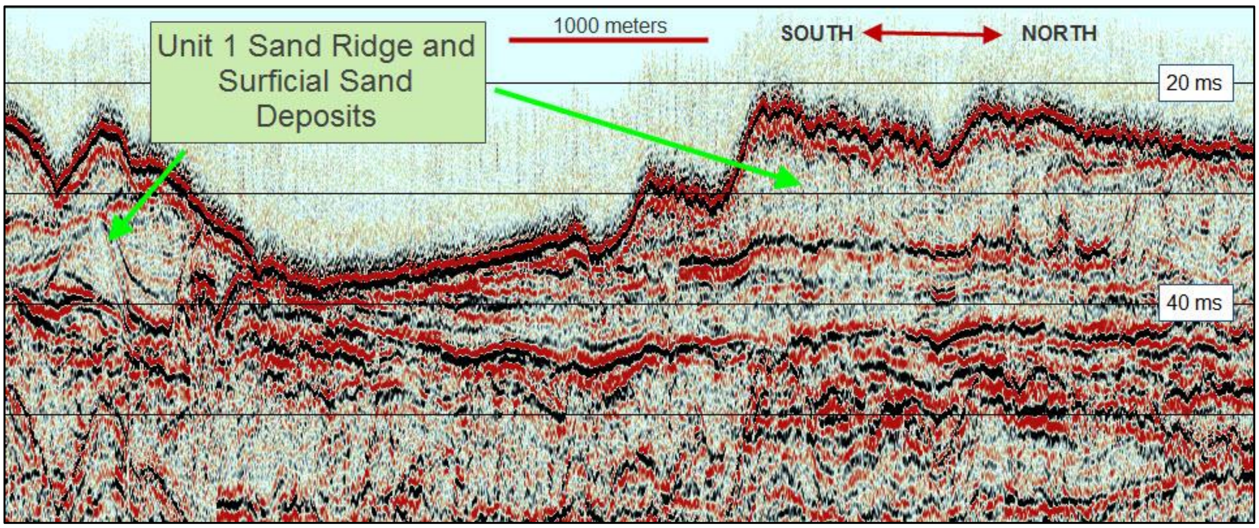


Figure 40: Portion of multi-channel sparker seismic Line 139 showing the Holocene sand ridges of Unit 1.

The seismic facies unit (Unit 2) beneath the Holocene/Pleistocene boundary is characterized by complex reflector geometry and variability (Figure 41). This unit is heavily incised by paleochannel systems (Figure 42). Multiple generations of channel features are evident within this unit. Higher amplitude seismic reflectors in this unit have been interpreted to represent low-stand erosional surfaces that have been incised by paleo-drainage systems. Reflection patterns indicating channel infilling (deposition) are also present in Unit 2. Cross-bedding structure is evident within many of the more well-defined channel features. It has been widely reported in the scientific literature that the paleo-Delaware River and its associated tributaries crossed the continental shelf during lowstands of sea level (Twichell et al., 1977).

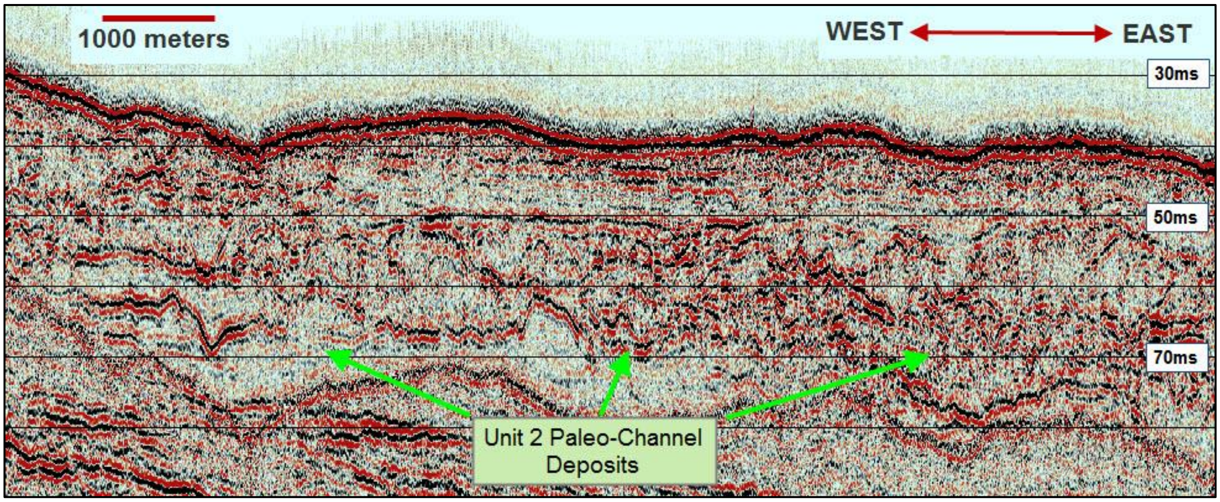


Figure 41: Portion of multi-channel sparker seismic Line 316 showing Pleistocene paleochannels within Unit 2.

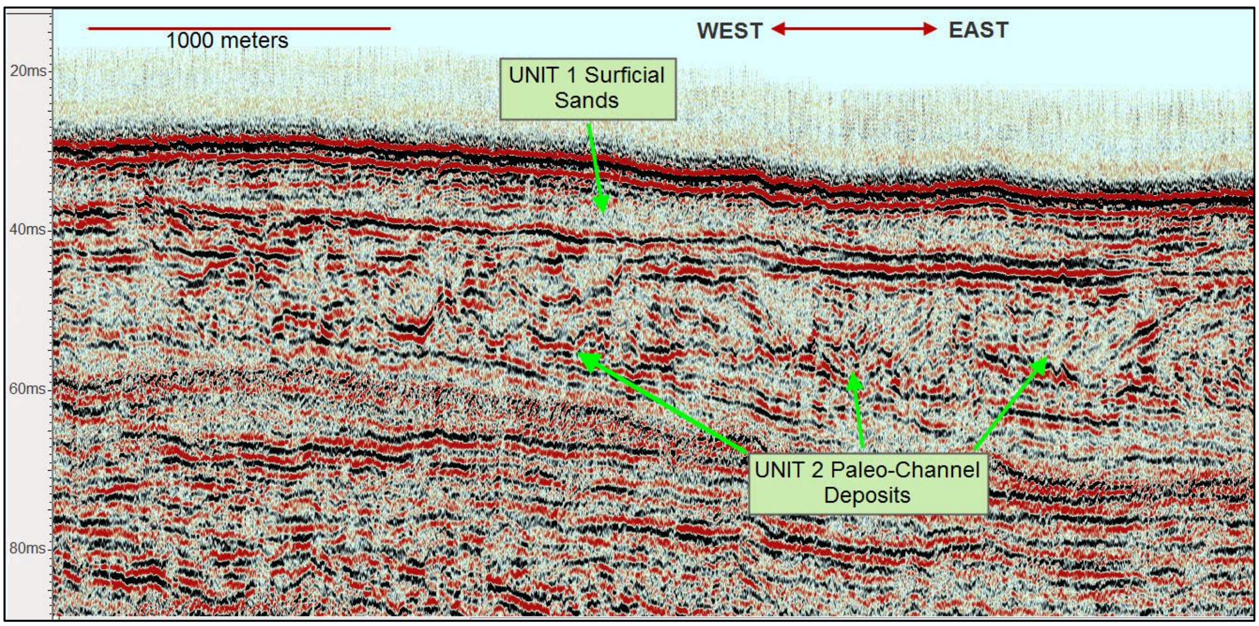


Figure 42: Portion of multi-channel sparker seismic Line 306 showing Pleistocene paleochannel complexes within Unit 2 overlain by the more recent (likely Holocene) sands of Unit 1.

Also, the ancestral St. Martin River has been mapped on the continental shelf offshore the Delmarva Peninsula using seismic techniques (Toscano et al., 1989). The river's main channel runs southeast from the Ocean City area where it separates into multiple branches. Multiple parallel paleochannels to the south of the ancestral St. Martin's River were also identified in the seismic data.

Several large-scale submarine canyons are incised into the continental shelf/slope directly offshore of the survey area. It is likely that many of these canyons were connected to the paleo-river systems that traversed the central Delmarva continental shelf at the various sea-level lowstands of the Quaternary. Twichell et al. (1977) has demonstrated with seismic-reflection profiling that the Pleistocene Delaware River linked up with the Wilmington Submarine Canyon at the shelf break. Bathymetry data suggests the possibility of a second channel system running southeastward from the Delaware Bay area across the shelf to the vicinity of the Baltimore and Washington Canyons.

Many of the buried channels depicted in the seismic data likely have their origin in the paleo-drainage systems of the various rivers and streams emanating from what are currently Maryland, Delaware and Virginia. In addition to fluvial processes incising and infilling channels, it is also likely that some channels in Unit 2 may be tidal in origin. The channels and infill of Unit 2 likely represent some composite of fluvial and tidal/marine processes operating over the Pleistocene time period.

The deepest seismic facies unit (Unit 3) imaged in these data is characterized by high amplitude, sub-parallel reflectors (Figure 43). The high amplitude reflectors range from continuous to moderately continuous and extend across the survey area. The seismic horizons in Unit 3 dip basinward toward the southeast. Some erosional truncation is evident within Unit 3 suggesting subaerial exposure during sea-level lowstands. Based on the work of Field (1979, 1980) and Toscano et al. (1989) who conducted stratigraphic investigations offshore the Delmarva Peninsula complete with dating techniques, Unit 3 has been interpreted to be pre-Pleistocene or Neogene in age (1.8 million to 23.03 million years ago (MYA)).

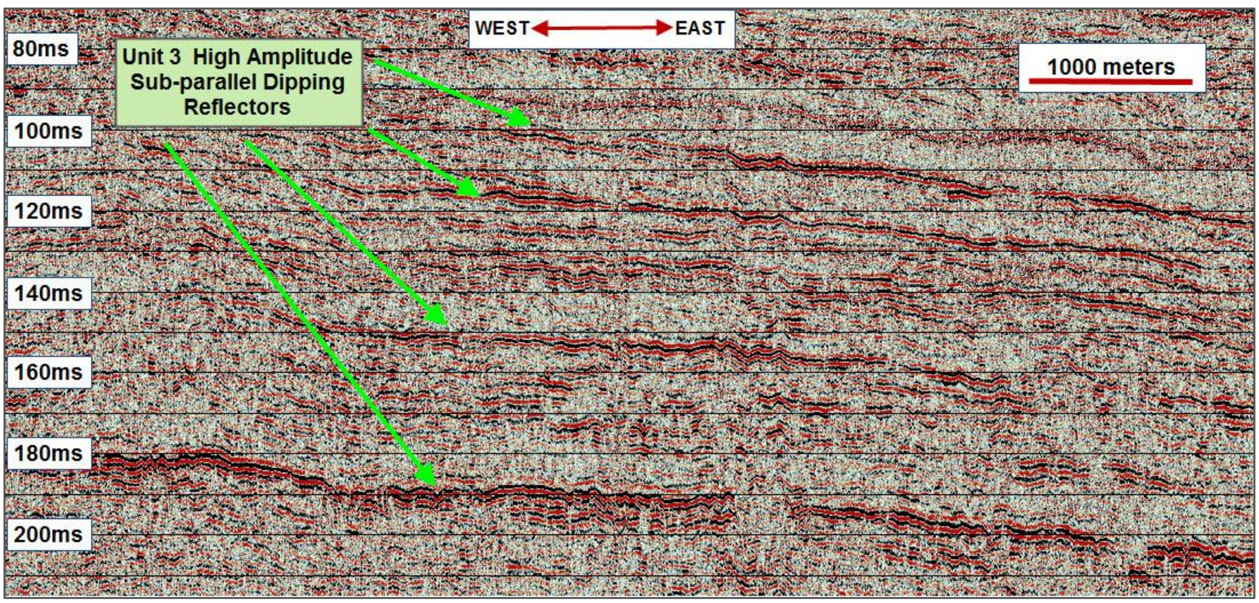


Figure 43: Portion of multi-channel sparker seismic Line 316 showing high-amplitude, sub-parallel dipping reflectors in the medium to deep subsurface.

The general stratigraphic structure throughout the survey area is represented in the three (3) dip-oriented (west-to-east) seismic profiles shown below. Line 304 (Figures 44 and 45) is indicative of the general geologic structure of the northern region of the survey area. Line 315 (Figures 46 and 47) is indicative of the general geologic structure of the central region of the survey area. Line 327 (Figures 48 and 49) is indicative of the general geologic structure of the southern region of the survey area. Each of the three (3) seismic facies units is present throughout the survey area.

Unit 1 (orange) which is interpreted to represent sandy sediments deposited or reworked during the Holocene, is thickest in the western and southern regions of the survey area. The thickest parts of Unit 1 correspond to areas where sand ridges are present. Unit 1 is thinnest in the northern and eastern parts of the survey area. These trends are depicted clearly in the Holocene isopach map series (Appendix F) and the multibeam bathymetric map series (Appendix C).

Unit 2 (green) is interpreted to represent a mixture of muds, sands and gravel which were deposited by a combination of fluvial, tidal, estuarine, and marine processes during the Pleistocene. Unit 2 appears to thicken to the east and south, or in the direction of dip. The channelization of Unit 2 becomes progressively more developed moving eastward across the survey area.

Unit 3 (blue) is interpreted to be pre-Pleistocene or Neogene (1.8 MYA to 23.03 MYA) in age. Unit 3 is likely comprised of a combination of fluvial, coastal, and marine sediments. Unit 3 is characterized by high amplitude, sub-parallel, gently dipping reflectors. Reflection patterns in Unit 3 indicate erosional surfaces, as well as onlap, downlap, and erosional truncation. These types of seismic-reflection terminations in a continental shelf setting indicate the influence of changing sea level.

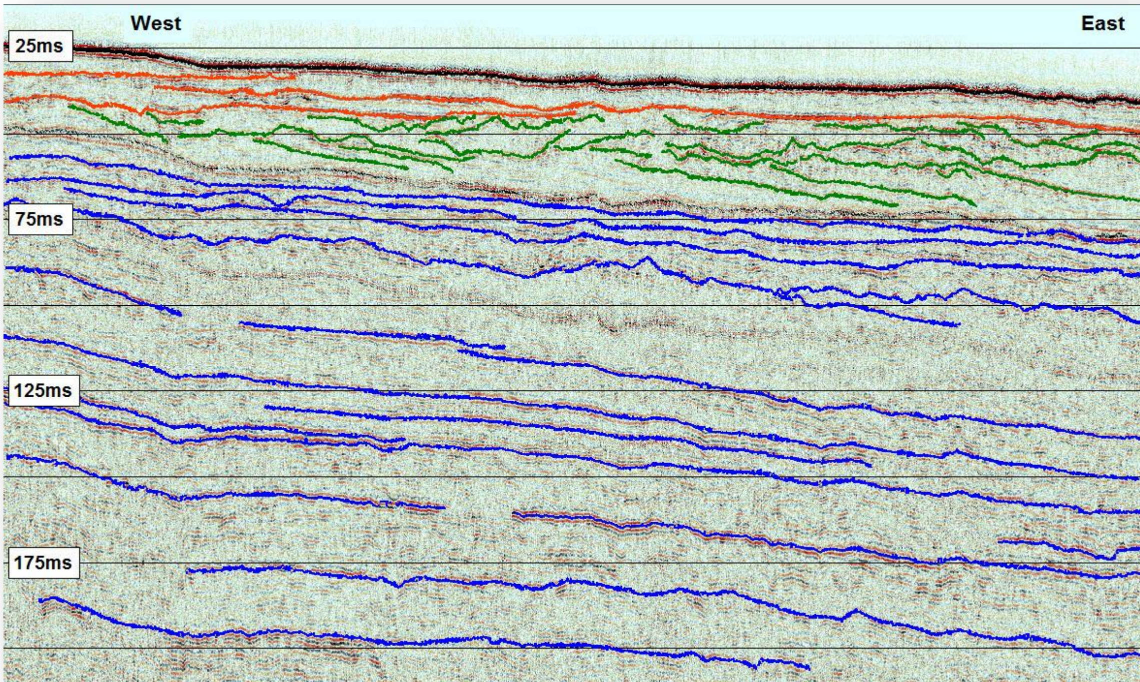


Figure 44: Multi-channel sparker seismic amplitude record for Line 304. Structurally relevant seismic horizons have been traced within the three general Seismic Facies Units identified. Reflectors within Seismic Facies Units 1, 2, and 3 are shown in orange, green and blue, respectively.

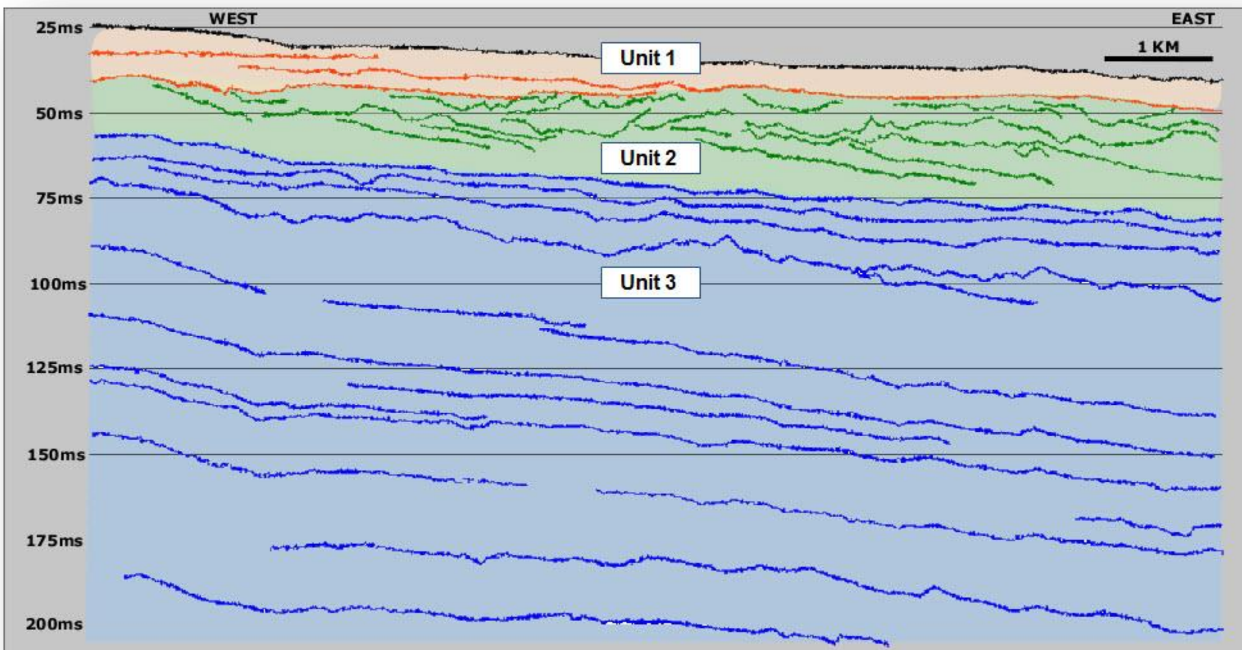


Figure 45: Interpreted seismic section from Line 304. The general stratigraphic structure is depicted for the three main Seismic Facies Units.

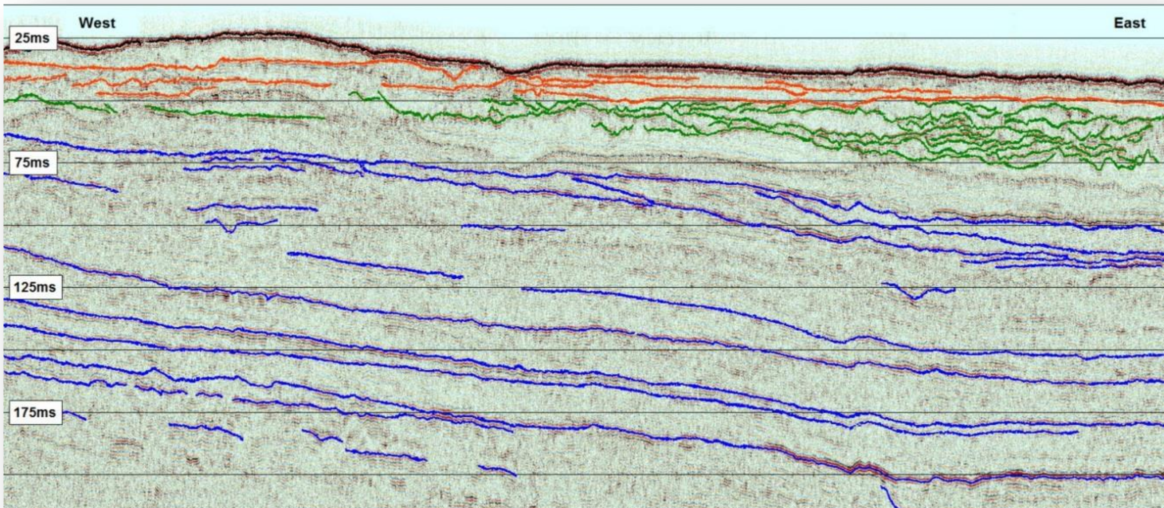


Figure 46: Multi-channel seismic amplitude record for Line 315. Structurally relevant seismic horizons have been traced within the three general Seismic Facies Units identified. Reflectors within Seismic Facies Units 1, 2, and 3 are shown in orange, green and blue, respectively.

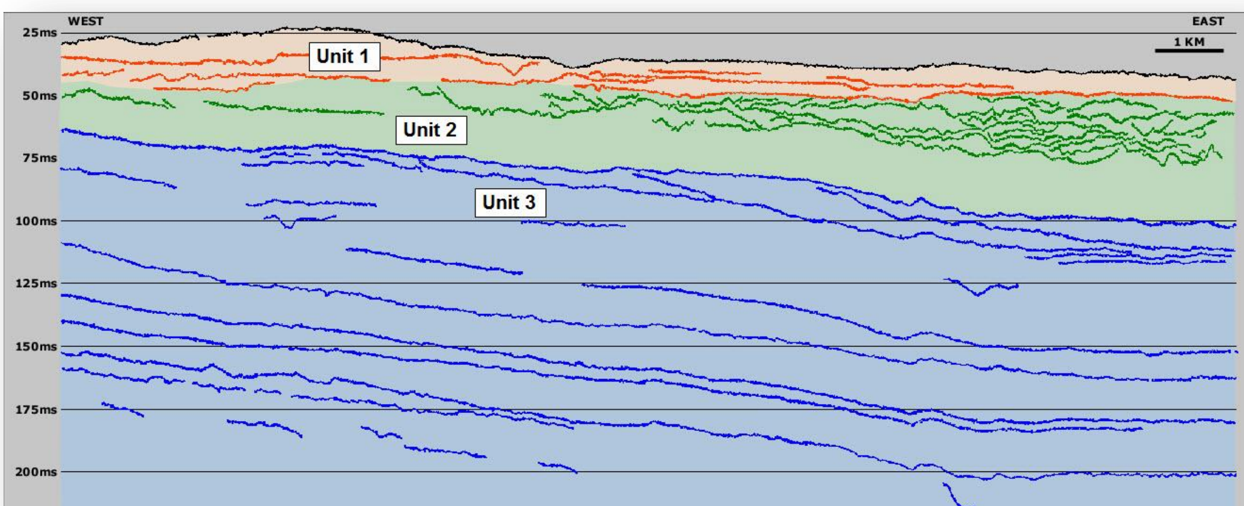


Figure 47: Interpreted seismic section from Line 315. The general stratigraphic structure is depicted for the three Seismic Facies Units.

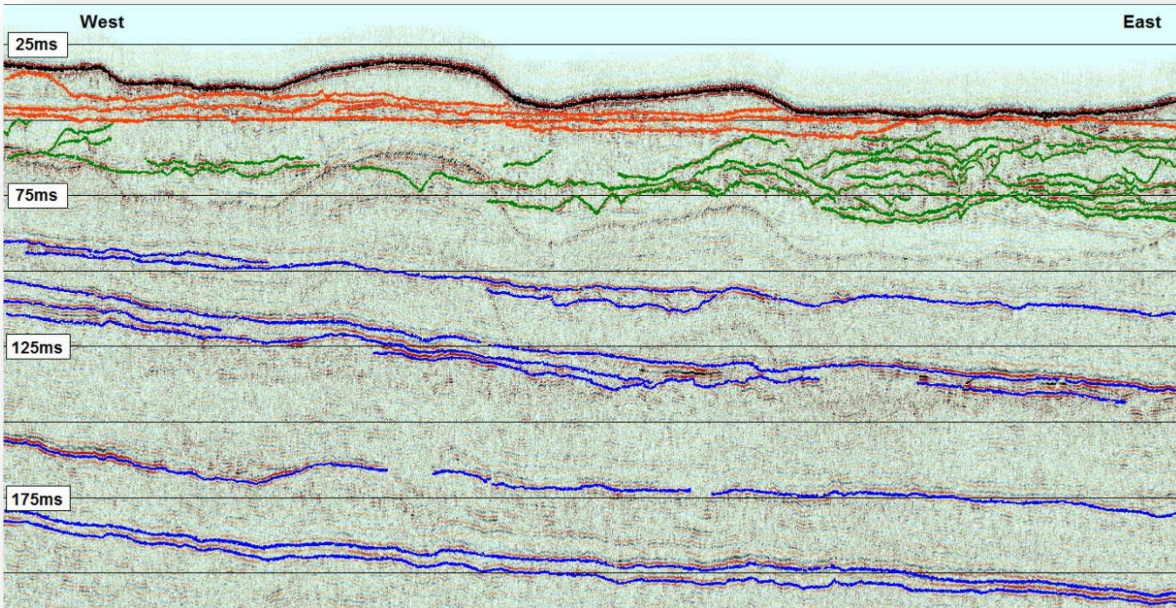


Figure 48: Multi-channel sparker seismic amplitude record for Line 327. Structurally relevant seismic horizons have been traced within the three general Seismic Facies Units identified. Reflectors within Seismic Facies Units 1, 2, and 3 are shown in orange, green and blue, respectively.

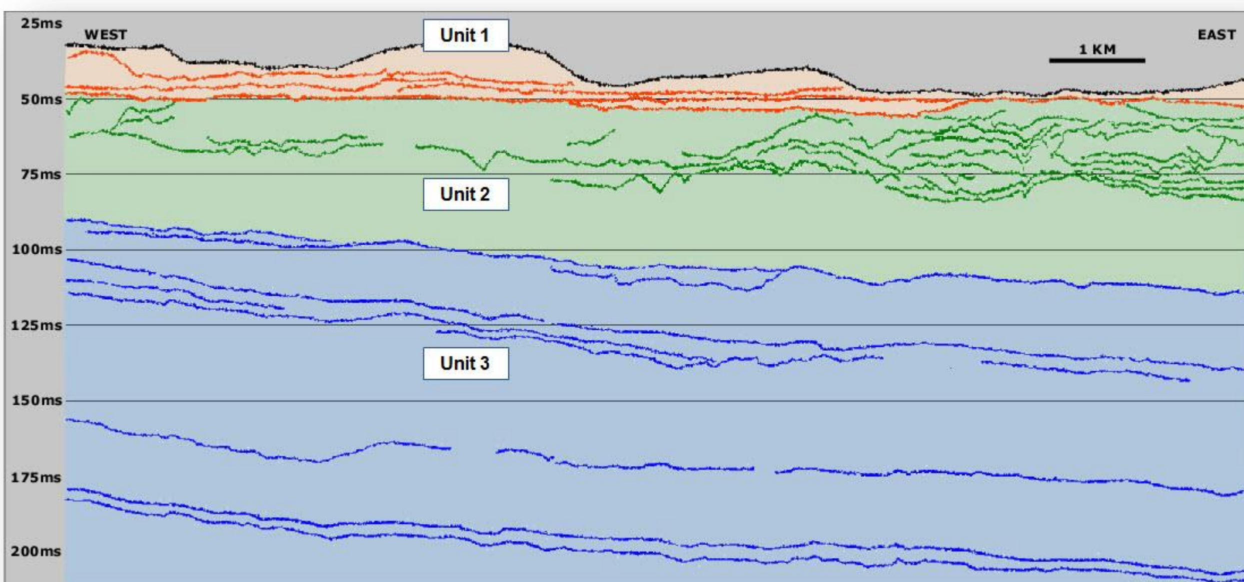


Figure 49: Interpreted seismic section from Line 327. The general stratigraphic structure is depicted for the three Seismic Facies Units.

Site Comparison

While CB&I is unable to conduct an official Constructability Assessment for the Maryland WEA due to a lack of geotechnical and proposed construction methodology information, CB&I is able to conduct a cursory comparison of the subsurface geology of the Maryland WEA to other offshore areas that have been, or are being considered, for offshore wind farm construction. As there are no existing bottom-founded offshore wind farms constructed within the United States, CB&I must look to Europe for comparable sites.

Europe is currently able to generate 117.3 gigawatts (GW) of wind energy, with 6.6 GW of that being produced offshore (EWEA, 2014a). As of the end of 2013, the European Union had 69 operational offshore wind farms, totaling 2080 installed turbines with an additional 12 projects in development (EWEA, 2014b). The leading European countries in the installation of offshore wind farms in 2013 were the United Kingdom (UK) and Germany, both installing 8 new wind farms in 2013, followed by Belgium, Denmark, Sweden and Spain (EWEA 2014b).

Of the projects under development which have publicly available geotechnical and geophysical information, five (5) have a similar geological framework as the Maryland WEA. Galloper, Triton Knoll and Kentish Flats II are in the “Approved” stage of the developmental process. Dogger Bank and Rampion are in the “Site Awarded” phase (RenewableUK, 2014c).

The Kentish Flats II project is a proposed extension to the already functional Kentish Flats, located in the southeast North Sea. This offshore wind farm has been installed in an area described as London Clay overlaying bedrock (Vattenfall Wind Power Ltd, 2010). It has been characterized as a series of clay/fine grain sands deposited while sea level was rising and the regional basin was sinking (subsiding) (Hight, et. al, 2003). The seismic report generated by Vattenfall Wind Power Ltd in 2010 further describes the area as having reminiscent channels, the main one being the Swale River, which flowed across that project area. The infill of the now Paleo-Swale River and its tributaries has been described as laminated silts, clays and silty sands with trace shell fragments (Vattenfall Wind Power Ltd, 2010).

Galloper Wind Farm is described as having paleochannels incised in the London Clay Formation. Like Kentish Flats, the London Clay Formation has several buried paleochannels. These channels are 750 – 850 m wide and partially infilled with Holocene-Pleistocene clayey sandy gravels and sandy gravelly clays (SSE and RWE Npower Renewables, 2011).

Triton Knoll wind farm will consist of 150 wind turbines and generate up to 900 megawatts (MW) of power (RenewableUK, 2014a). This wind farm will be located in a similar area as Kentish Flats, also having some paleochannels and tributaries; however they are incised in different sedimentary formations. Furthermore, RWE Npower Renewables state that these channels are narrow, partially to fully infilled with laminated clays and fine sands, with the lower part being more granular and upper more clayey (RWE Npower Renewables, 2010). Below the Bolders Bank Formation and the incised channels, there is the Egmond Ground, which is overlaying the Sand Hole formation, which are both marine sediments (Catt et al., 2006).

Rampion Offshore Wind Farm will be located in the East English Channel, in predominately shallow (10 – 40m) waters (E.On Climate and Renewables, 2012). The seabed is classified as having a thin mobile Holocene sand and gravel layer overlaying Holocene lag deposits, which compose a dense gravelly fine to coarse sand (E.On Climate and Renewables, 2012). Like several of the other areas, the next sedimentary unit is the London Clay formation with incised paleochannels. The channel sediment infill, deposited during the late-Pleistocene and early-Holocene, is mostly an organic peat with very soft clays and silt (E.On Climate and Renewables, 2012).

The other area under development is Dogger Bank, which is located in the central/northern area of the North Sea. This area has been characterized as one meter thick Holocene sand with some gravelly sands deposited over channelized glacial deposits (Forewind, 2011). The area of Dogger Bank has a complex system of channels with different sedimentary characteristics. Based on this, it is thought that there are three different channeling events, most likely associated with glaciation (Forewind, 2011).

While there are some significant geological differences between the Maryland WEA and European offshore wind farm locations, including the fact that most of the European subsurface geology has significant glacial influences, there are noteworthy similarities as well. In particular, most of the North Sea and English Channel sites have a mobile Holocene marine sand/gravel unit underlain by Plio-Pleistocene strata with multiple paleochannels and infilling events, filled predominantly by silts and clays. Beneath that, some sites contain an older, open marine stratigraphy beneath the Plio-Pleistocene strata. These are all very similar subsurface geophysical conditions to the Maryland WEA. As these conditions have proven conducive to offshore wind farm construction in Europe, they would likely be suitable for offshore wind farm development of the Maryland WEA. That said, no formal constructability determinations can be made on the Maryland WEA until after detailed geotechnical investigations are completed and specific construction methodologies developed.

CULTURAL RESOURCE SURVEY RESULTS

CB&I contracted with TAR to conduct a review of the geophysical and hydrographic data collected as part of the MEA HRG survey to determine potential for cultural resource significance. While TAR did not ride along during the MEA HRG survey activities, they assisted with the survey plan design and were provided all geophysical data in both raw and processed formats after completion of the MEA HRG field activities. The following sections on the cultural resource remote-sensing and assessment tasks have been prepared by TAR and included as a component of this report. TAR has also conducted a full, cultural resource archival research effort associated with this investigation. That effort, together with TAR's full cultural resource survey report titled "*Analysis of HRG Remote-Sensing Survey Data from the Maryland Wind Energy Area to Identify and Evaluate Magnetic and Acoustic Signatures",* is attached to this overall project report as Appendix T.

Magnetic Remote Sensing

The magnetometer represents one of the most valuable tools available for locating submerged cultural material. One distinct advantage associated with magnetic detection is that material can be buried and still generate an identifiable signature. However, magnetic remote sensing has limitations that should be acknowledged. Since disturbances in the earth's magnetic field are relative to both the mass and physical characteristics of ferrous and thermoremnant material, a number of factors influence detectable signatures. One of the most critical is survey line spacing. Acceptable line spacing must be determined based on the anticipated nature of submerged cultural resources in the survey area. For example the signature of a large iron ship would be detectable over a considerably longer distance than a small wooden vessel. Thus the line spacing adopted to reliably locate a large ship could be considerably greater than that employed for a small wooden vessel.

The proximity of the sensor to material generating the anomaly is another important factor. As the magnetometer is not range specific, the size and composition of material generating an anomaly in the earth's magnetic field combine to establish the distance at which magnetic material creates the detectable disturbance. For example a small anchor will be detectable for a much more limited distance than the iron hull of a vessel. Therefore, sensor elevation in the water column and line spacing have a great deal to do with the intensity, duration and signature characteristics of an anomaly that will be identifiable. Vessel speed and the cyclical rate of data collection will also have a bearing on the detectable characteristics of an anomaly. Higher speed and/or a slower cyclical rate can turn the subtle characteristics of a multi-component signature into one of the other three signature types; negative monopolar, positive monopolar or dipolar.

Currently, 30.42 m (100 ft) line spacing is considered to be the maximum acceptable for most offshore areas. In inshore areas or offshore areas where historical sources confirm that vessel traffic and losses have been high, 15.21 m (50 ft) line spacing is considered to be the acceptable maximum. However, neither of those line spacings will ensure 100% likelihood of identification. Vessel signatures vary significantly. Even at a 15.21 m (50 ft) line spacing, identifying the remains of small vessels could be a factor of the chance position of a single survey line in relationship to the wreck. Several examples of detectable limitations can be found in a report on "State-of-the-Art Remote-sensing Equipment, Software and Survey Methodology in Submerged Cultural Resource Identification, Protection and Management" incorporated in a Minerals Management Service publication titled: *Archaeological Damage from Offshore Dredging: Recommendations for Pre-Operational Surveys and Mitigation During Dredging to Avoid Adverse Impacts* (OCS Report MMS2004-005) (Research Planning, Inc. et al., 2004).

In addition to line spacing, background noise also plays a role in isolating small signatures. When small vessel remains and other cultural resources create limited disturbances in the earth's magnetic field, background noise can obscure the signature. Fortunately modern magnetometer systems are highly stable and background noise is limited unless there are significant geological features, solar activity and vessel-generated noise. In addition to background noise, modern debris, cables, pipelines and structures such as offshore rigs, bridges, docks and bulkheads and larger more modern wrecks can mask subtle signatures.

Unfortunately, shipwreck sites have been demonstrated to produce all signature types under certain circumstances. Some shipwreck signatures are more apparent than others. Large vessels, whether iron or wood, produce signatures that can be reliably identified. Smaller vessels, or disarticulated vessel remains, are more difficult to identify. Their signatures are frequently difficult, if not impossible, to distinguish from single objects and/or modern debris. In fact, some small vessels produce little or no magnetic signature. Unless ordnance, ground tackle or cargo associated with the hull produces a detectable signature, some sites are impossible to identify magnetically. It is also difficult to magnetically distinguish some small wrecks from modern debris. As a consequence, magnetic targets must be subjectively assessed according to intensity, duration and signature characteristics. The final decision concerning potential significance must be made on the basis of anomaly attributes, historical patterns of navigation in the project area and a responsible balance between historical and economic priorities.

Acoustic Remote Sensing, Sidescan Sonar

Used in conjunction with magnetometers, sidescan sonar can generate valuable diagnostic insight into the nature of material generating magnetic anomalies. In addition, sidescan sonar can identify the exposed remains of vessels and other cultural material that does not create a ferrous or thermoremnant magnetic signature. Because sidescan sonar generates highly valuable diagnostic data, sidescan sonars have also been adopted by archaeologists and submerged cultural resource managers to locate and identify shipwrecks and other submerged cultural resources.

Like magnetic signatures, shipwreck sites have been demonstrated to produce a variety of acoustic signature characteristics under different circumstances. Some acoustic shipwreck signatures are more apparent than others. Large vessels, whether iron or wood, produce signatures that can be reliably identified. Smaller vessels, or disarticulated vessel remains are inevitably more difficult to assess. Their signatures are frequently difficult, if not impossible, to distinguish from concentrations of snags and/or modern debris. In fact, some small vessels produce little or no acoustic signature. As a consequence, acoustic targets must be subjectively assessed according to intensity of return over background, elevation above bottom and geometric image characteristics. The final decision concerning potential significance of less readily identifiable targets must be made on the basis of anomaly attributes, historical patterns of navigation in the project area and a responsible balance between historical and economic priorities.

Sidescan sonar also has limitations to be considered. For different reasons, sensor to target distance is also critical. Again, the size of anticipated vessel remains or other submerged cultural material is a significant issue in survey line spacing. For targets such as the remains of large vessels, a broad survey pattern may generate acceptable results. For smaller and less distinctive targets such as the remains of small, disarticulated or partially exposed vessels, a much closer line spacing may be required to produce acceptable results.

Another consideration associated with line spacing is operational frequency and range selection. The lower the frequency the more extended the range but the lower the resolution. The higher the frequency the better the resolution but the more limited the range. Where larger targets are anticipated the lower frequency and higher range will produce reliable results. Where more subtle targets are anticipated, and that must generally be the case with submerged cultural resource surveys, a higher frequency and closer line spacing is essential. The 100-foot (30.42m) and 50-foot (15.21m) line spacing generally adopted for magnetometer surveys produces excellent high frequency sidescan sonar images on a 50-meter (164-foot) range scale. That range scale and line spacing also provides excellent overlap in coverage and multiple images of each target.

High quality diagnostic sidescan sonar image production can also be impacted by both environmental and survey conditions. Under certain conditions the water surface can produce a deceptive return that could be construed to represent real targets. Rough water conditions, particularly in shallower water where the transducer cannot be lowered sufficiently, can distort images. Biological and marine animal activity can also impact record quality as floating vegetation, shrimp, fish, dolphin and other marine organisms can create deceptive imagery. On more than one occasion schools of fish have been identified as ballast piles in submerged cultural resource reports. Vessel course and speed can also have an impact on sidescan sonar record quality. With the exception of sidescan sonars designed for high-speed operations, vessel speed over ground has a direct bearing on target resolution as the number of pings on a target relates directly to resolution. Finally, noise generated by vessel power sources and other acoustic equipment can also degrade record quality.

Acoustic Remote Sensing, Chirp Sub-bottom Profiler

On most submerged cultural resource surveys, chirp sub-bottom profilers are an integral part of the remote-sensing array. Like sidescan sonars, virtually all high-resolution chirp sub-bottom profilers operate on computer-based systems. Computer data processing has improved resolution greatly. Advances in the design of transducers have also contributed to improved stratigraphic definition. New transducers produce narrower beam widths with reduced side lobes and have a higher frequency range. Most produce a short sound pulse without ringing and have higher pulse rates. Many systems are compatible with heave, pitch, and roll compensators for much improved record detail (Research Planning, Inc. et al., 2004).

Used in conjunction with magnetometers and sidescan sonars, chirp sub-bottom profilers can generate insight into the nature of sub-bottom stratigraphy. On occasion, chirp sub-bottom profiler data can provide insight into the location and nature of buried material such as shipwrecks, cables and pipelines generating magnetic anomalies. While sub-bottom data has, on occasion, been useful in characterizing and evaluating sub-bottom anomalies, it has rarely been useful in identifying vessel remains without magnetic anomalies on which to focus.

Although chirp sub-bottom profilers have not generally produced a high degree of diagnostic insight into submerged cultural resources such as shipwrecks, the data they produce is extremely beneficial in locating, identifying and mapping relict landforms. This includes karst features like sink holes and ancestral river channels (paleochannels).

Like all forms of remote sensing, chirp sub-bottom profilers have limitations that must be considered. Unlike sidescan sonar, the chirp sub-bottom profiler provides insight into bottom sediments along each survey line. Large geological features can be extrapolated between lines, however smaller localized features that lie between lines may not be detected. For example, a shell midden or small karst feature could lie entirely between survey lines on 100-foot (30.42m) or greater centers.

As the analytical potential of data generated is relative to line spacing, decreasing the line spacing increases the likelihood of identifying and characterizing both localized features such as relict landforms, shell middens, or buried non-magnetic shipwreck remains. To effectively characterize a localized buried geological feature or wreck using a chirp sub-bottom profiler would require an exercise similar to that employed to generate a high-resolution sidescan sonar image. Additional lines run across all anomalies recommended for additional investigation or avoidance would generate more diagnostic data (Research Planning, Inc. et al., 2004).

Signature Analysis and Target Assessment

To date, no absolute criteria for identification of potentially significant magnetic anomalies and/or acoustic target signatures have been developed. However, available literature confirms that reliable analysis must be made on the basis of certain characteristics. Magnetic anomalies in the data were isolated and analyzed in accordance with intensity, duration, areal extent and other signature characteristics. Sonogram signatures in the data were analyzed on the basis of configuration, areal extent, elevation, target intensity and contrast with background and shadow image. Chirp sub-bottom profile data were reviewed for evidence of relict channels, lagoons and landforms with a potential for association with prehistoric resources. Assessment of each magnetic anomaly and acoustic target included recommendations for avoidance and/or additional investigation to determine the exact location and nature of the cultural material generating the signature and its potential National Register of Historic Places (NRHP) significance.

As we begin to discuss the results of the MEA HRG survey, it is important to point out that while data from the MEA HGR survey confirms the high cultural resource sensitivity of the Maryland Wind Energy Area, the 150 m data collection line spacing is not sufficient for reliably identifying submerged cultural resources. In addition it does not meet current standards for submerged cultural resource surveys identified in BOEM's Guidelines for Providing Geological and Geophysical, Hazards, and Archaeological Information Pursuant to 30 CFR Part 585. As such, detailed site-specific magnetometer investigations will be required for specific development sites prior to any development activity in order to fully understand the potential for cultural resource impacts.

Analysis of the magnetometer data carried out by TAR identified a total of 1,142 anomalies (Figure 50 and Appendix I). Appendix I identifies each of the anomalies with a signature code that identifies the survey line number, anomaly identification sequence on that line, signature characteristics, total gamma intensity and signature duration in meters. Appendix I breaks that code down into columns and includes the UTM Zone 18 X and Y coordinates, latitude, longitude, identification assessment, sidescan sonar target association and submerged cultural resource (SCR) potential. All magnetic anomalies have been plotted on both *Map Series 5: Sidescan Sonar and Magnetic Anomaly Map* (Appendix E) and *Map Series 7: Hazards Anomaly Map* (Appendix 6).

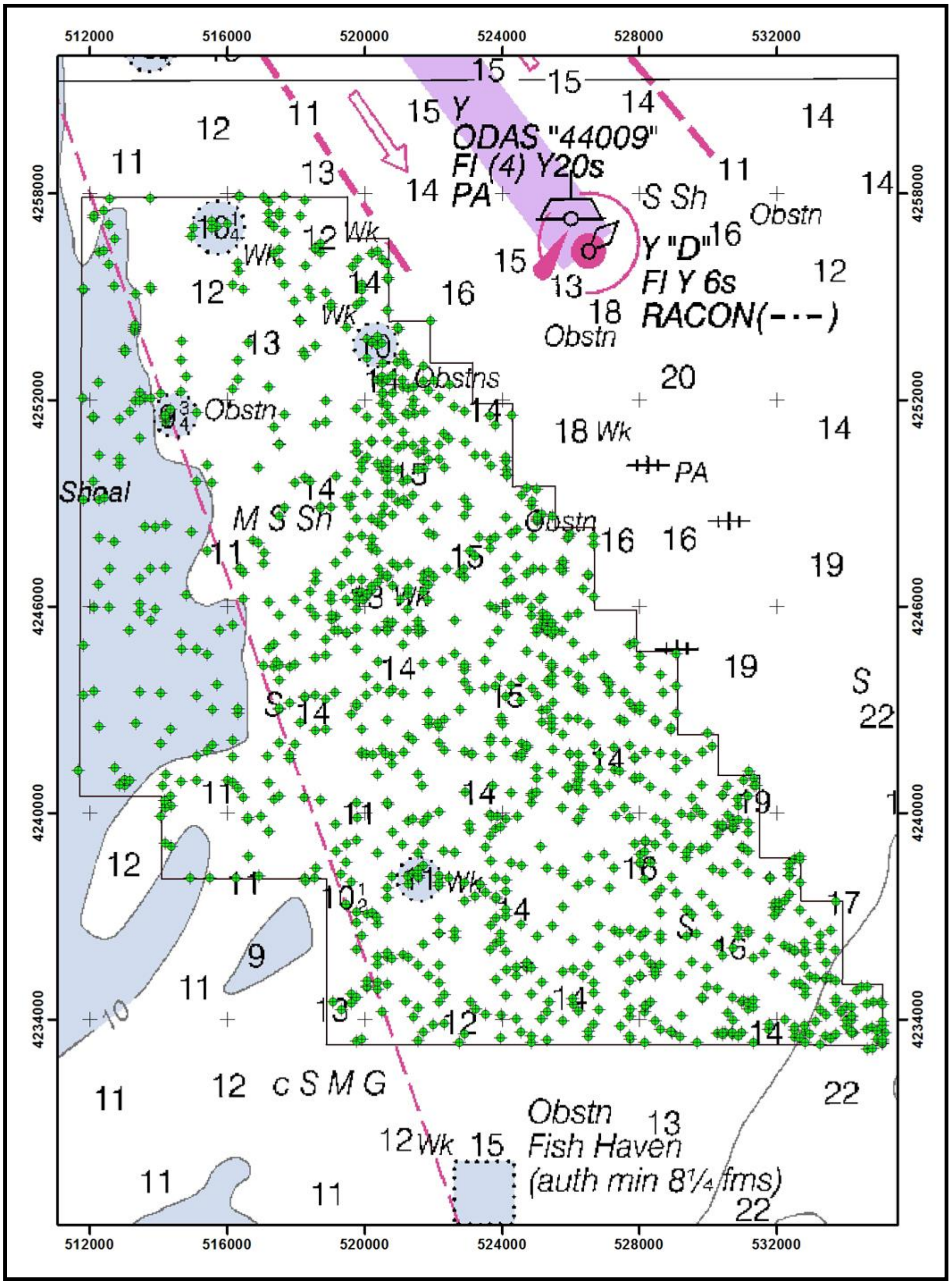


Figure 50: Distribution of magnetic anomalies within the MEA HRG survey area.

Forty-seven (47) anomalies are associated with shipwreck remains and another thirty (30) are associated with obstructions identified on NOAA Chart 12200: Cape May to Cape Hatteras. Three (3) anomalies are associated with uncharted shipwreck remains. Anomalies associated with those charted wrecks, charted obstructions and uncharted obstructions have been identified as “Buffered for Avoidance” to protect them from project-related construction activities (Figure 51). These avoidance buffers are included on *Map Series 7: Hazards Anomaly Map* (Appendix G). The recommended buffers are the largest and most conservative buffers possible based on the current data coverage. Subsequent, detailed data coverage and analysis would likely lead to the reduction of the size of these buffers.

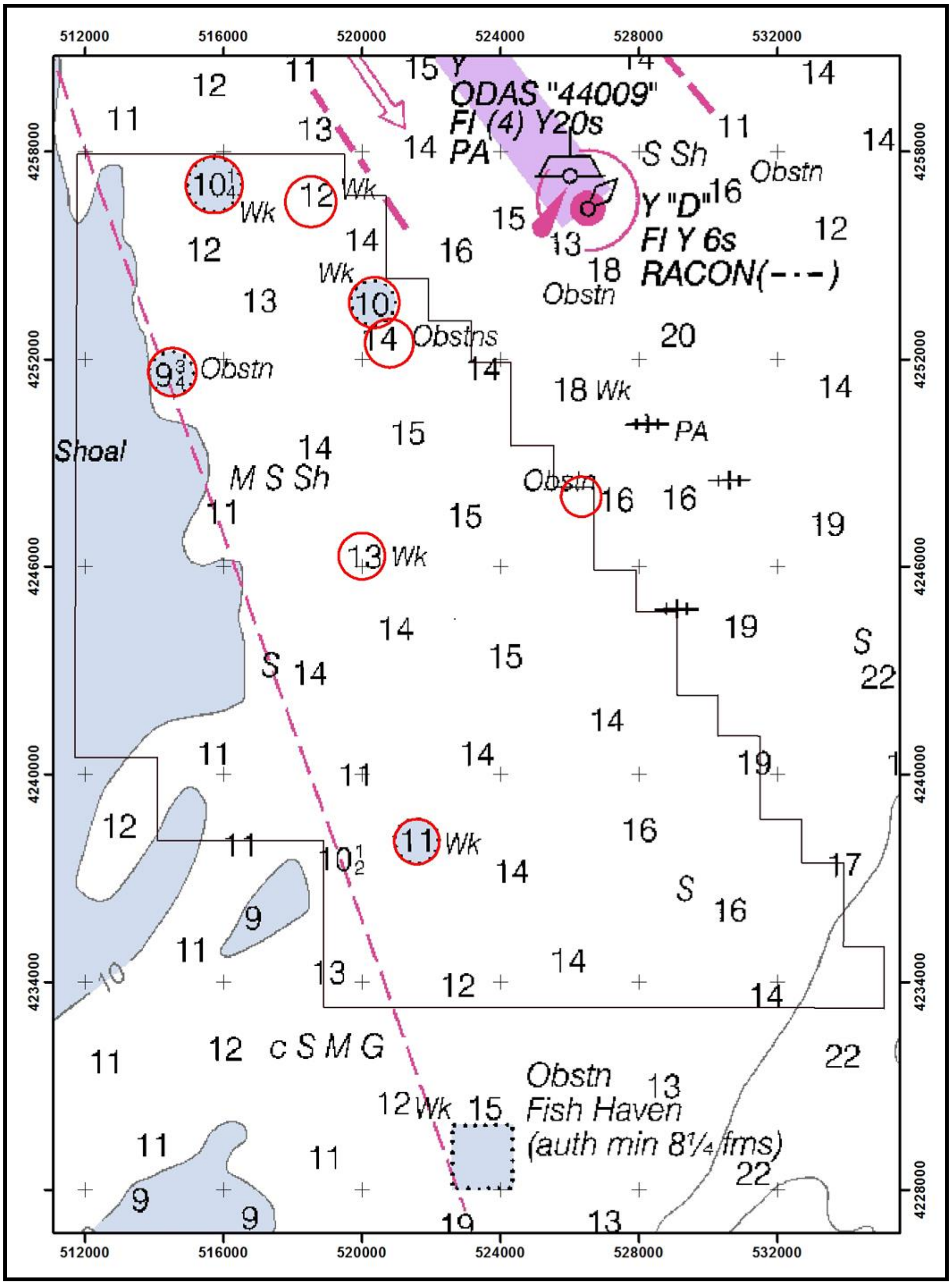


Figure 51: Charted shipwrecks and obstructions buffered for protection within the MEA HRG survey area.

Forty-six (46) anomalies, identified as “Object Cluster or Small Vessel”, have multi-component signatures that should be considered as having a high probability for association with historic vessel remains. All are multi-component signatures indicative of more complex concentrations of ferrous material. Although some are small in intensity and duration, the lack of adjacent data makes more comprehensive analysis impossible.

A total of 347 anomalies, each identified as “Potential Small Object”, are considered to be related to small single ferrous objects. That identification is based on signature characteristics and the assumption that material generating the signature is on or very close to the survey line. However, without adjacent data, that identification cannot be considered definitive.

An additional 652 anomalies, each identified as “Potential Moderate Object(s)”, should be considered to have a higher but also unclear potential association with historical vessel remains. That identification is based on signature characteristics and the understanding that neither the location nor extent of material generating the signature can be identified without adjacent data. Two (2) additional anomalies, each identified as “Potential Large Object(s)”, should be considered to have an even higher but also unclear potential association with historical vessel remains. That identification is likewise based on signature characteristics and the understanding that neither the location nor extent of material generating the signature can be identified without adjacent data.

The remaining seventeen (17) anomalies identified during the survey lie outside the survey area buffer. For that reason their signature analysis is not considered necessary.

A total of 91 sidescan sonar targets were identified in the survey data (Figure 52). A table describing these sidescan sonar contacts is included as Appendix R. Images of the sidescan sonar targets are included as part of the *Cultural Resource Sidescan Sonar Contact Report* (Appendix S). The location of these contacts is also plotted on *Map Series 7: Hazards Anomaly Map* (Appendix G). Twenty-three (23) of those targets are associated with charted or uncharted vessel remains and obstructions that are recommended for avoidance. Those targets are located within eight (8) buffers (Figure 51). These avoidance buffers are also included on *Map Series 7: Hazards Anomaly Map* (Appendix G). The recommended buffers are the largest and most conservative buffers possible based on the current 150 m data coverage. Subsequent, design-level (detailed) cultural-resource data coverage and analysis would likely lead to the reduction in the size of these buffers.

Of the remaining 68 sidescan sonar targets, nineteen (19) are associated with small single objects on the bottom. None are associated with a magnetic anomaly as most are well off the survey line. Although they resemble abandoned traps, other types of small debris could be responsible for the images. Five (5) additional sidescan sonar images represent clusters of more than one small object that could be associated with more complex material deposits.

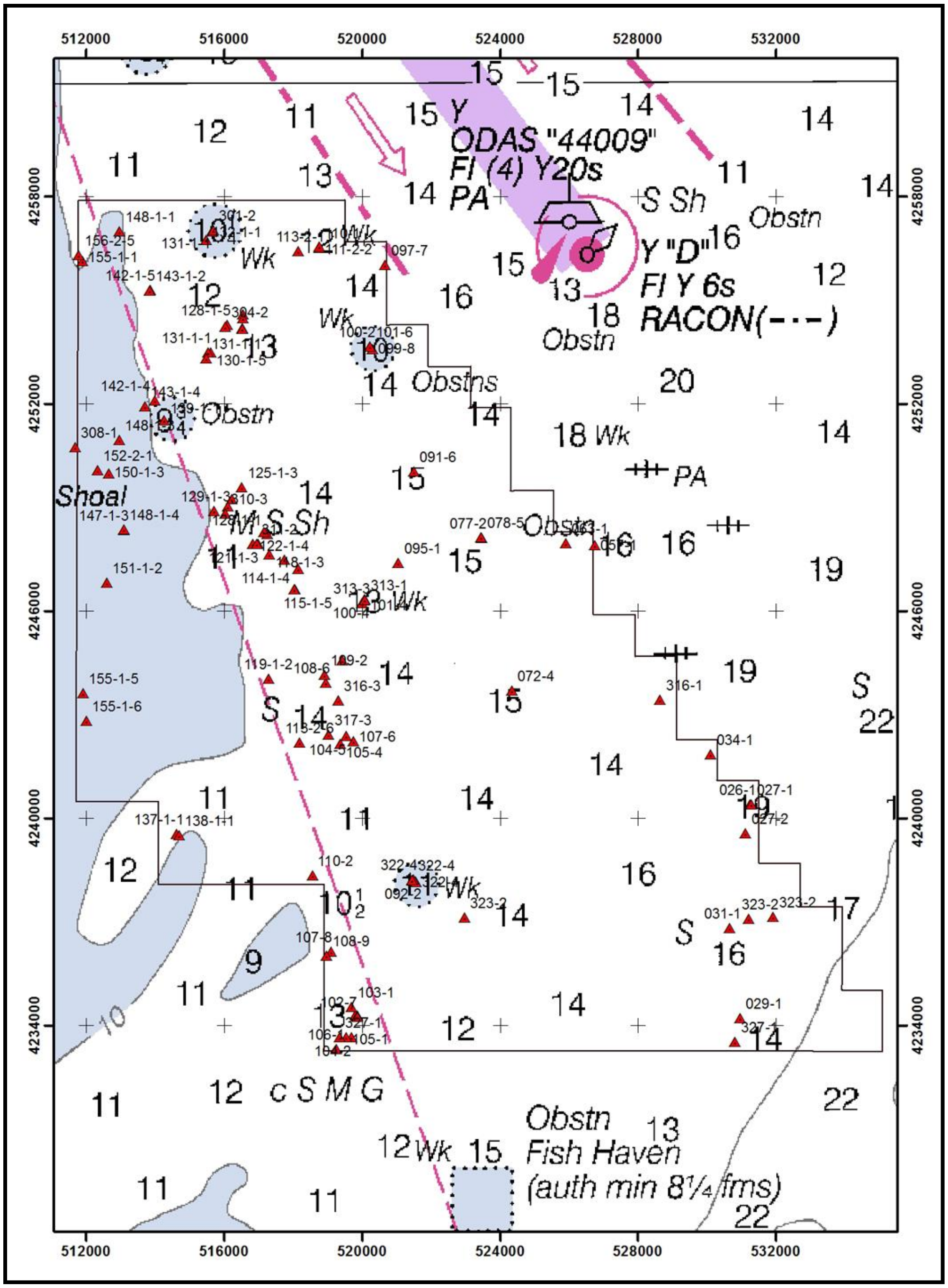


Figure 52: Distribution of sidescan sonar targets within the MEA HRG survey area.

One or more linear objects make up another nineteen (19) of the sidescan sonar targets. However, only three (3) have a potential association with magnetic anomalies. Those could represent material such as pipe, pilings, logs, timbers or other material. Scatters of less well-defined targets make up a total of sixteen (16) additional sidescan sonar targets. Some could represent ballast or also bulk cargo such as stone, scrap iron or ore. Two (2) have associated anomalies. Bottom features that could represent vessel remains or geological features make up five (5) of the remaining sidescan sonar targets. None have associated magnetic signatures. The remaining four (4) sidescan sonar targets represent drag and anchor scars on the bottom surface.

The sub-bottom data identified a pattern of relict features. The features are divided into two (2) highly-organized buried-channel complexes (Figure 53), one (1) large poorly-organized buried tidal complex (Figure 54) and one (1) smaller poorly-organized buried channel and tidal complex with two (2) features (Figure 55).

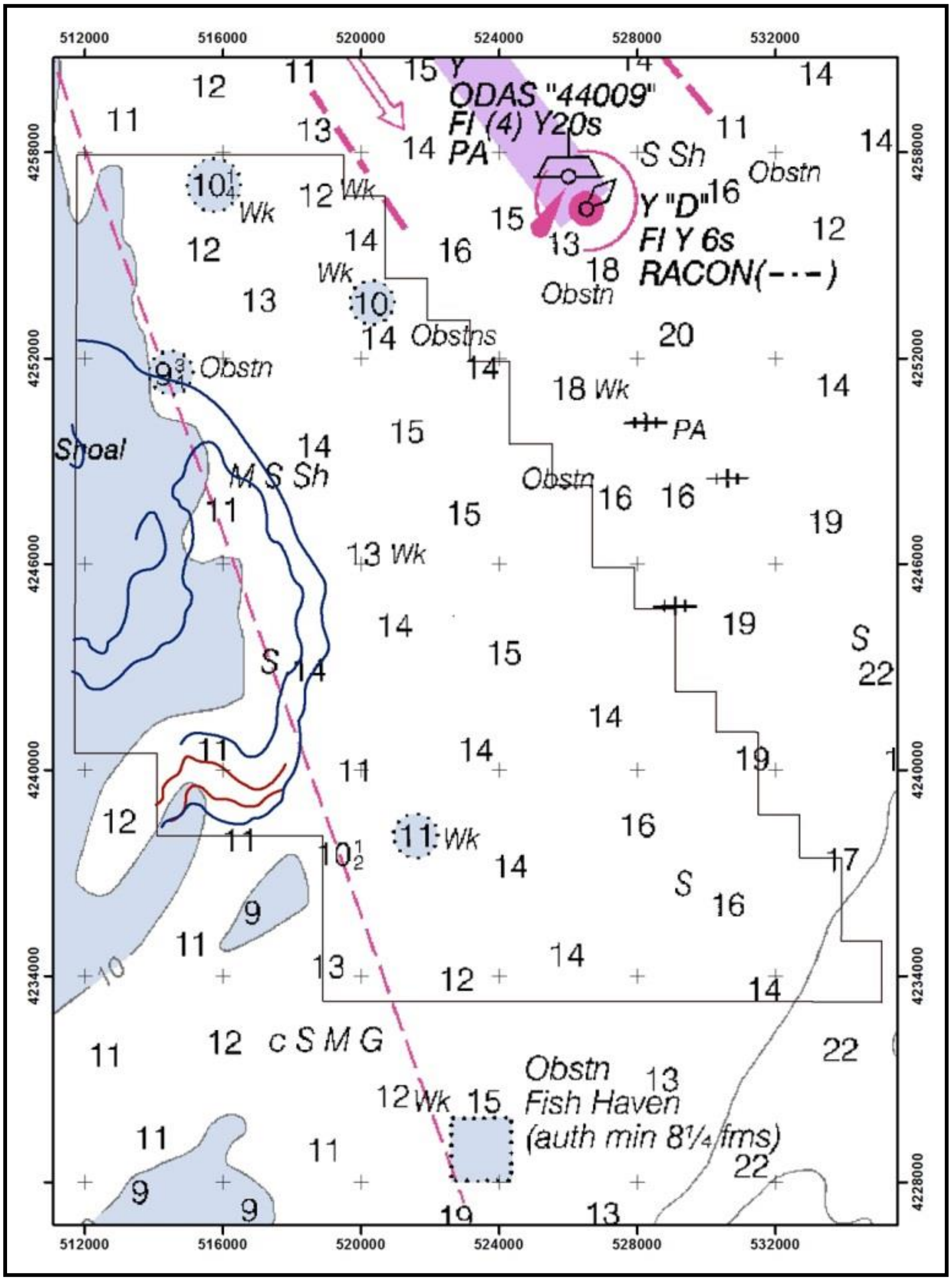


Figure 53: Location of two (2) highly-organized buried-channel complexes.

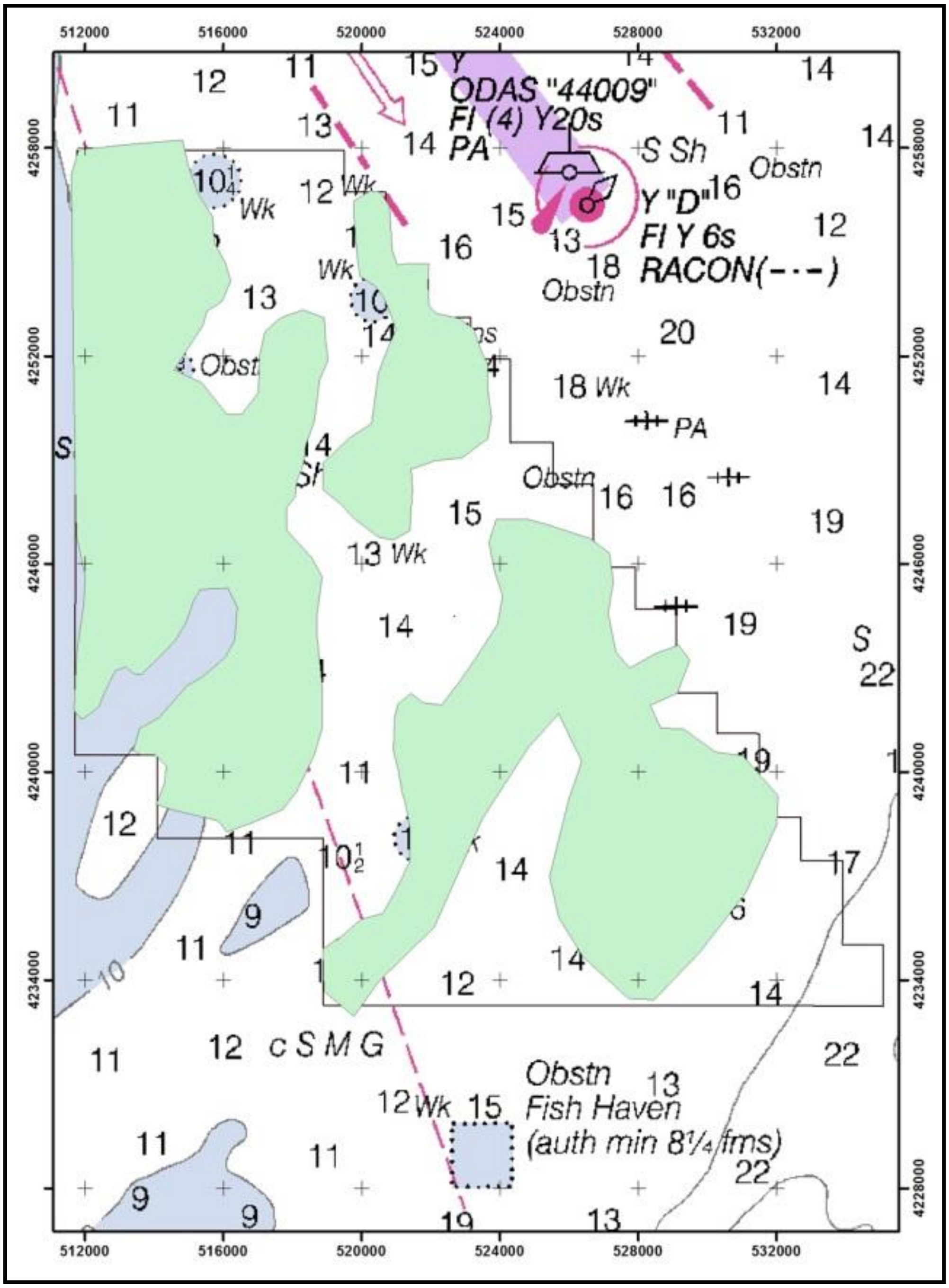


Figure 54: Location of one (1) large poorly-organized buried tidal complex.

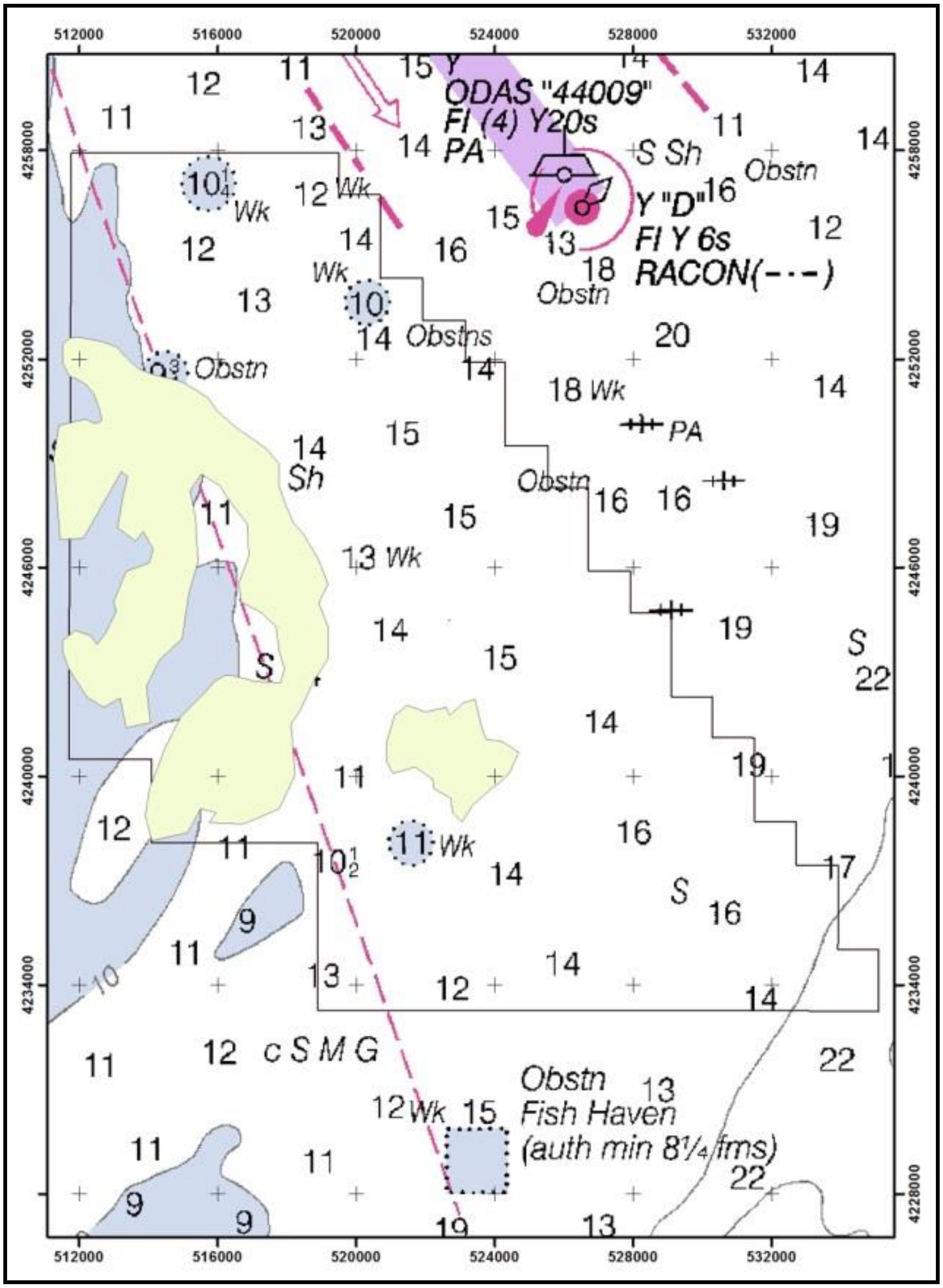


Figure 55: Location of one (1) smaller poorly-organized buried channel and tidal complex with two (2) features.

The smaller of the two (2) highly-organized buried-channel complexes is located in the southwestern corner of the survey area. The larger highly-organized buried-channel complex extends from the vicinity of Isle of Wight Shoal well into the survey area from the western perimeter. The largest feature of the poorly-organized buried channel and tidal complex corresponds with the location and configuration of the larger highly-organized buried-channel complex. The smaller tidal feature lies to the southeast midway into the southern portion of the survey area. The poorly-organized tidal complex includes three features. The first covers most of the western perimeter and extends well into the western third of the survey area. The second feature extends southwest into the survey area from the northeastern perimeter and almost reached the eastern perimeter of the first feature. The final feature of the poorly-organized tidal complex covers much of the southern and southeastern half of the survey area.

Evidence of a Holocene distributary channel (Figure 56) and an infilled late-Pleistocene paleochannel (Figure 57) in the northwest MEA HRG survey area confirm that intact landforms potentially associated with prehistoric habitation do exist in the northwestern portion of the project area.

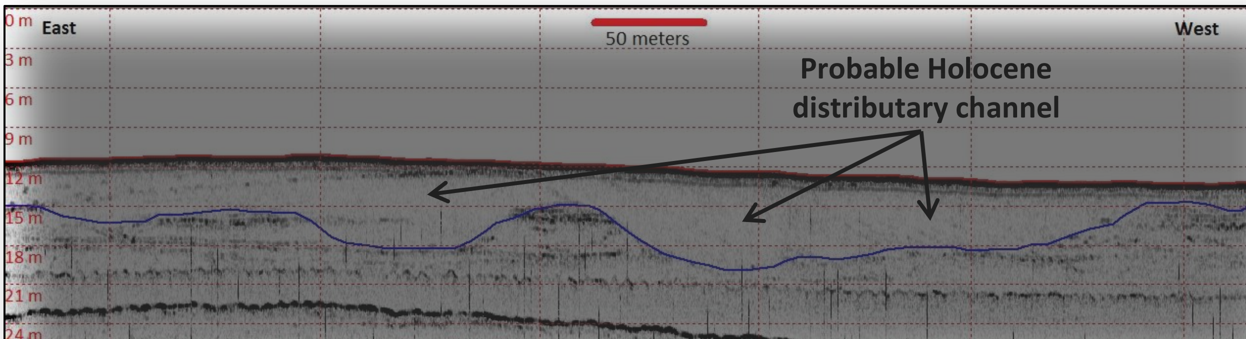


Figure 56: Example of Holocene distributary channel in the northwest MEA HRG survey area.

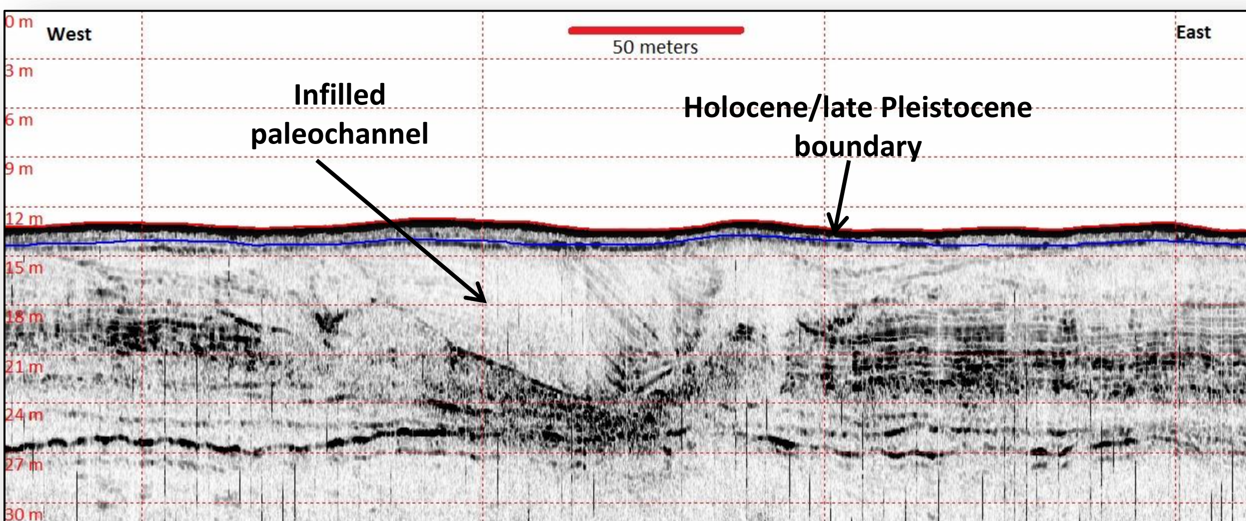


Figure 57: Infilled late-Pleistocene paleochannel beneath the Holocene/late-Pleistocene boundary.

HAZARD ASSESSMENT

The objective of the Hazard Assessment is to identify any potential hazards to wind farm construction/operation identified in these geophysical data. This hazard assessment should be viewed in general terms, as no specific information related to wind farm design or engineering was provided to CB&I. Oftentimes, hazards are design specific. For example, geologic conditions which may negatively impact a monopole foundation may be less critical to a gravity-based foundation and may be almost irrelevant to a floating turbine employing seafloor anchors. To truly identify all relevant hazards and to dismiss those deemed inconsequential would require a comprehensive understanding of the proposed turbine foundations.

It is also important to note that this hazard assessment is entirely based on the geophysical data acquired for the MEA HRG survey and relevant information from the scientific literature. A complete hazard assessment will require a comprehensive geotechnical investigation to confirm the geophysical analysis presented here. It is CB&I's opinion that such an investigation be conducted prior to any planning or construction of wind-energy structures in the MEA HRG survey area. Furthermore, CB&I suggests that current meter surveys and sediment transport measurements be undertaken to more fully understand any potential hazards associated with the movement of sediments.

Following the completion of any geotechnical or oceanographic surveys relevant to the survey area, a review of the geophysical analysis presented here should be undertaken. The geophysical methods employed in the MEA HRG survey are classified as remote-sensing techniques and therefore demand some form of ground-truth to confirm their interpretation. Integrating supplemental surveys, geotechnical or otherwise, with these geophysical data will strengthen the hazard analysis presented here and provide a high level of confidence in foundation design.

Sediment Transport

Based on analysis of sidescan sonar, bathymetry, and seismic (chirp sub-bottom and sparker seismic-reflection) data it appears that sediment transport is occurring within the MEA HRG survey area. Some spatial trends related to the movement of sediment are evident in the geophysical data, although discerning the temporal component is beyond the scope of this investigation. The primary mechanisms of transport are a combination of tides, currents, waves, and storms, with storm activity likely to be the most effective means of sediment movement. Sediment transport, which involves the removal of sediments from one area and their re-deposition in another location, has the potential to adversely affect wind turbine foundations.

The potential adverse effects of sediment transport on wind turbine foundations occurs in two primary ways; the removal of sediments from around the turbine foundation, referred to as scour, and the deposition of additional sediments on and around the turbine foundation, which may negatively impact foundation performance. The introduction of a seabed structure such as a turbine foundation results in the disruption and modification of the existing tidal and current regime and often tends to focus and exacerbate scour. Turbine foundations may also be depositional sites and become covered or partially buried through sediment transport. This also may have a negative impact on foundation performance due to the increased load of the sediments. Scour and sediment deposition are also important considerations regarding any seafloor cables associated with wind energy production. Scour may lead to exposure of buried cables or result in substantial excavation beneath cables leaving them in an unsupported free-span state (Malhorta, 2011).

The Delmarva Peninsula is a mixed energy, wave dominated, barrier island shoreline. This type of environment is highly conducive to sand ridge development and the Delmarva Peninsula has the greatest number and highest density of shoreface-attached and detached sand ridges along the eastern U.S. coastline (McBride and Moslow, 1991). Detached sand ridges are the most prominent seafloor feature in the survey area and may represent a potential hazard to wind farm construction and operation (Figures 21 and 22). The simple fact that these sand ridges create a variable and undulating seabed warrants their classification as a potential hazard to wind farm construction. In some instances the slope between the ridge crest and trough may be relatively steep (Figure 58). The steepening of sand ridge faces is likely the result of erosion and scour which is driven by the prevailing hydraulic regime comprised of tides, currents and wave action. The most intense periods of scour and sediment transport affecting sand ridges occurs during periods of storm activity. Previous studies, offshore the Delmarva coast and elsewhere, involving current meters suggest that a helical flow may be set up within the troughs between adjacent ridge crests during storms (Figure 59). This helical flow results from the interaction between the storm generated wave motion and currents and the existing sand ridge topography and drives trough scour and crest aggradation (Swift et al., 1973). Sand ridges and areas of potential scour are shown in *Map Series 7: Hazard Anomaly Map* (Appendix G).

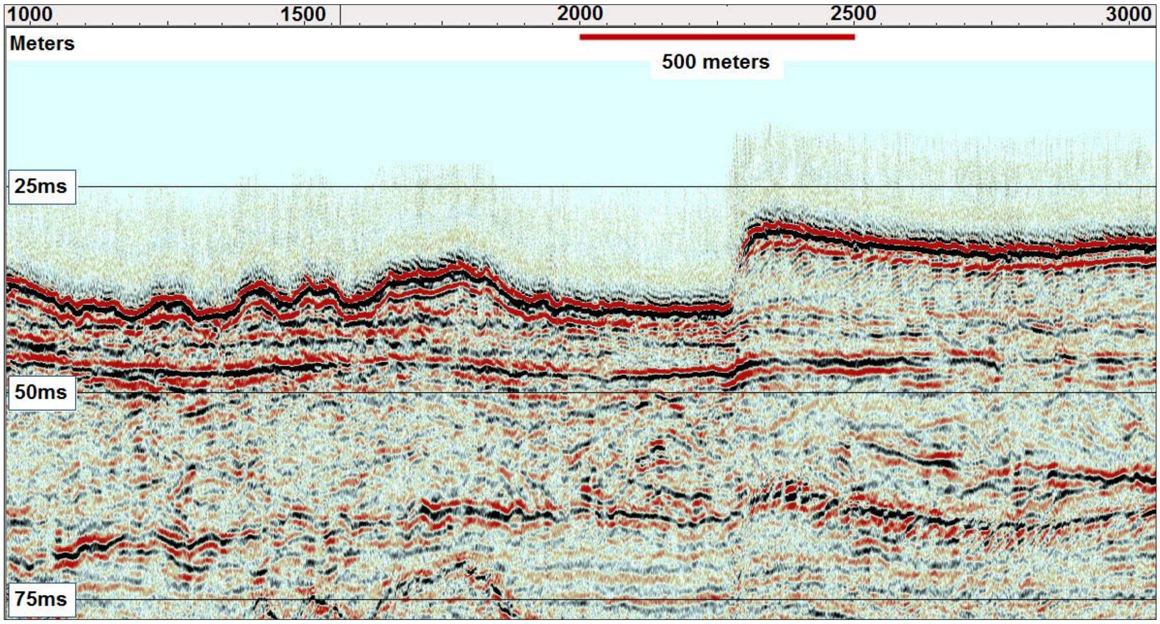


Figure 58: Multi-channel seismic Line 102 depicting an example of a steep sand ridge face. Crest to trough vertical relief is approximately 7.5 meters.

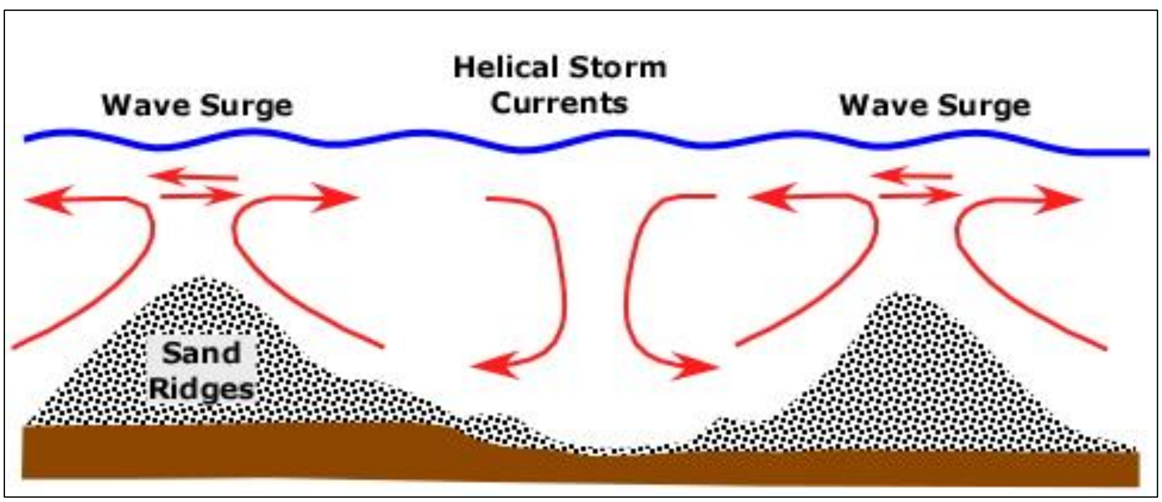


Figure 59: Figure adapted from Swift et al., 1973 depicting helical current behavior associated with ridge and swale topography.

Steep Slopes

All potentially significant slopes encountered within the survey area are associated with the ridge and swale topography of the sand ridges. The steepest slopes measured occur in the southern extent of the site. Here slopes may approach 10 degrees. A small portion of this region may also be experiencing scour. Areas of high slope are depicted as part of this report within *Map Series 7: Hazard Anomaly Map* (Appendix G). The areas with the largest slopes are depicted in dark red in Figure 61, which shows the slope data for the entire MEA HRG survey area based off of analysis of the MEA HRG survey multibeam data.

Elsewhere in the survey area the prominent sand ridges are surrounded by an apron of sediments which have been interpreted to have been shed from the main body of the sand ridge. The boundaries of the sand ridge in the southwest corner of the site are sharp and well defined. This suggests the possibility of ongoing modification to the sand ridge edge. Maintenance of this sharp boundary and steep sand ridge face may be the result of localized higher velocity flow.

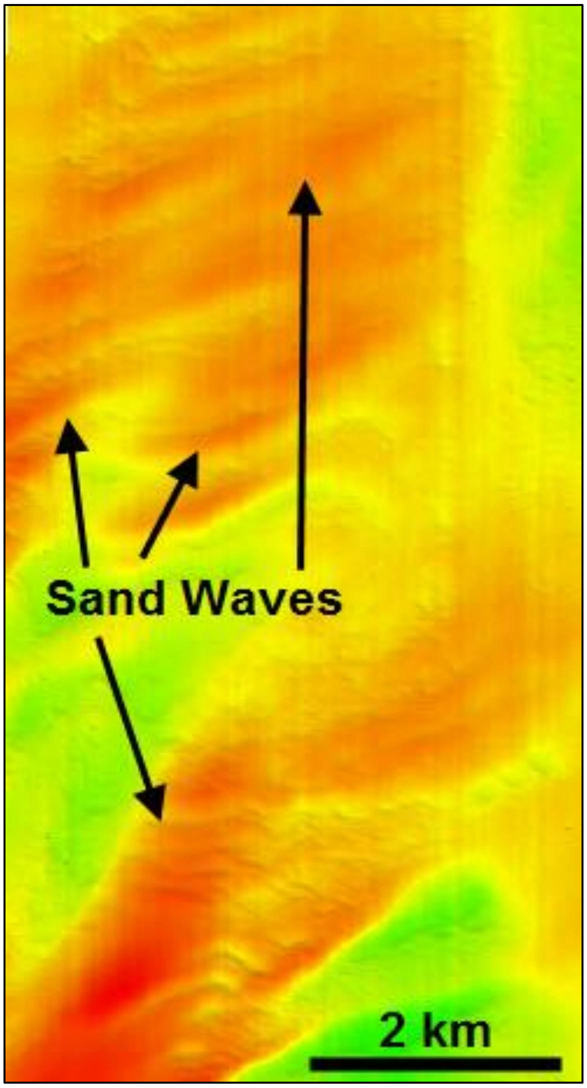
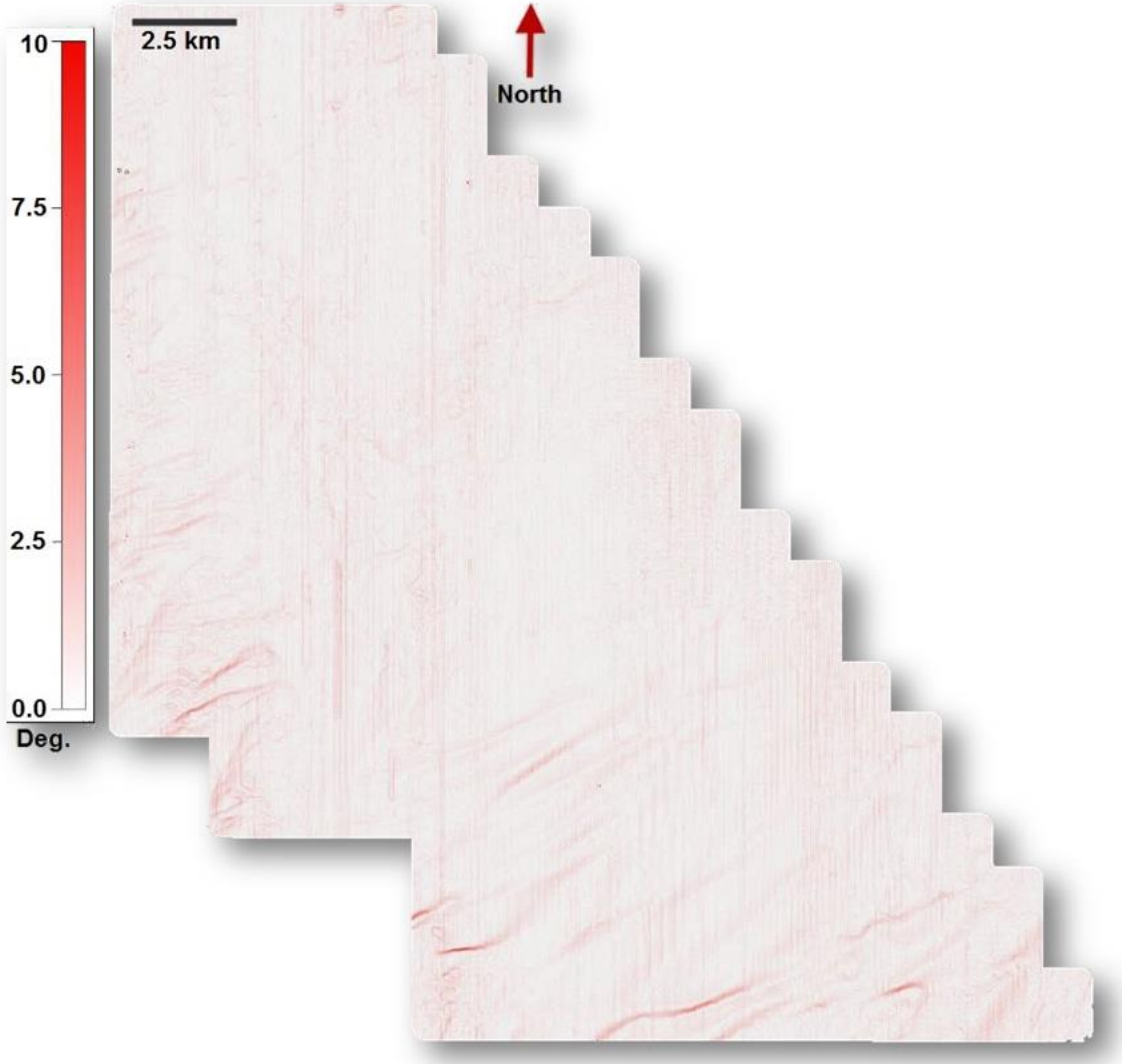


Figure 60: Sand waves associated with sand ridges as depicted from the 2013 MEA HRG multibeam bathymetry data.

The overall orientation of the large-scale sand ridges within the survey area is shore oblique. The axis of the ridges runs generally southwest to northeast. However, the morphology of the sand ridges is complex and smaller-scale sand waves are superimposed atop the oblique ridges (Figure 60). The orientation and morphology of the sand waves indicates a probable southerly movement of sediment. The presence of these sand waves provides further evidence of sediment transport occurring within the survey area. It appears, based on bathymetric and sidescan sonar data, that sand ridges in the survey area provide a source of sediment which is transported away from the ridges, generally to the south and offshore (east), by waves, tides and currents.

Soft Sediments

Soil conditions within the survey area may also pose potential hazards to wind farm construction and operations. Without the benefit of confirmatory geotechnical data, any discussion on soil type and conditions presented here will be based on interpretation of geophysical data and relevant scientific literature. Toscano et al. (1989) conducted an investigation into the Quaternary stratigraphy of the Maryland inner continental shelf and confirmed the presence of mud (silt and clay) in the subsurface. Where the surficial Holocene sand deposits pinch out, mud deposits may outcrop at the seabed.



Areas of potential mud exposed at the seafloor have been identified in sidescan sonar imagery. The sidescan's acoustic signal is useful for determining sediment grain-size and texture. The backscatter and reflectivity intensity of the returning sound wave can be used to diagnose sediment characteristics. High levels of backscatter/reflectivity generally indicate harder, rougher, or larger grain-size material. Diminished backscatter/reflectivity generally indicates soft, smooth, fine grain-size material. Regions interpreted to be surficial muds were identified based on their acoustic signature. These regions (mud) are characterized by very low backscatter/reflectivity and a lack of discernible surface texture. The interpreted surficial muds demonstrate a sharp acoustic contrast to the sand-sized sediments which surround and encroach upon this lower lying mud surface (Figure 62). The boundaries of the interpreted mud regions are highly irregular due to the migration of the coarser sediments off the elevated sandy bedforms. Areas of soft sediments are depicted as part of this report within *Map Series 7: Hazard Anomaly Map* (Appendix G).

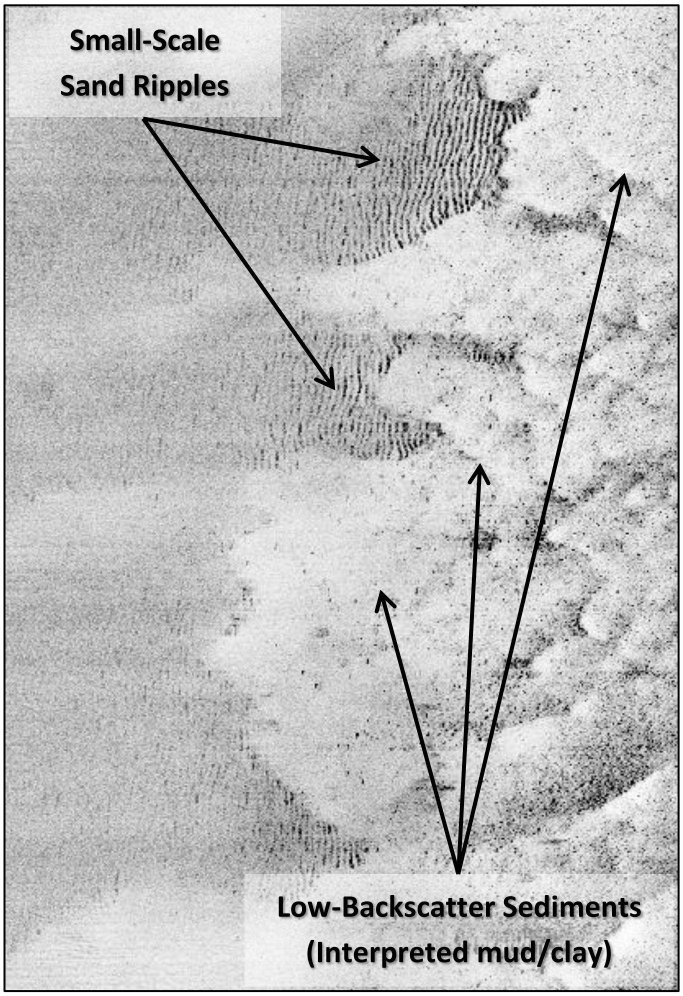


Figure 62: MEA HRG sidescan sonar imagery depicting sand ripples (high backscatter-dark shades) and sediments interpreted to be mud or clays exposed at the seabed (low backscatter-lighter shades).

Buried Channels

Analysis of chirp sub-bottom (very-high-resolution, shallow-penetration) and multi-channel sparker seismic-reflection (high-resolution, medium-penetration) data has revealed the presence of buried channels within the survey area. Buried channels are common and widespread throughout the survey area. Multi-channel sparker seismic-reflection interpreted seismic facies Unit 2, interpreted to be Pleistocene in age, contains the vast majority of the buried channels. Although considerably less frequent, buried channels also exist within the younger/overlying Seismic Facies Unit 1 Holocene strata as well as the older/deeper strata within Seismic Facies Unit 3.

The composition of the channel fill cannot be precisely determined via the geophysical methods conducted during this survey. However, based on seismic facies analysis and reflector geometries some inferences can be made about sediment types within the buried channels.

The buried channels, which were incised during sea-level lowstands, were subsequently infilled by fluvial, marine, estuarine, and coastal sediments during follow-on transgressions (Riggs and Belknap, 1988). As a result, the composition of the sediments within the channels is likely highly variable, changing both laterally and vertically. The physical properties of the sediments within the buried channels may be significantly different from those of the strata in which they are incised.

Reflection patterns indicating crossbedding is seen within some of the buried channels. Crossbedded strata are typically indicative of sand-sized sediments deposited by a flowing fluid, in this case fluvial or tidal channels (Figures 36 and 63). Crossbedding may indicate high-energy depositional conditions. Other buried channels are infilled with thin sediment layering possibly indicating that deposition occurred under low-energy conditions (Figure 64). These thinly layered sediments are likely to be smaller grain-sized, potentially silt or mud. Areas of buried paleochannels are depicted as part of this report within *Map Series 7: Hazard Anomaly Map* (Appendix G).

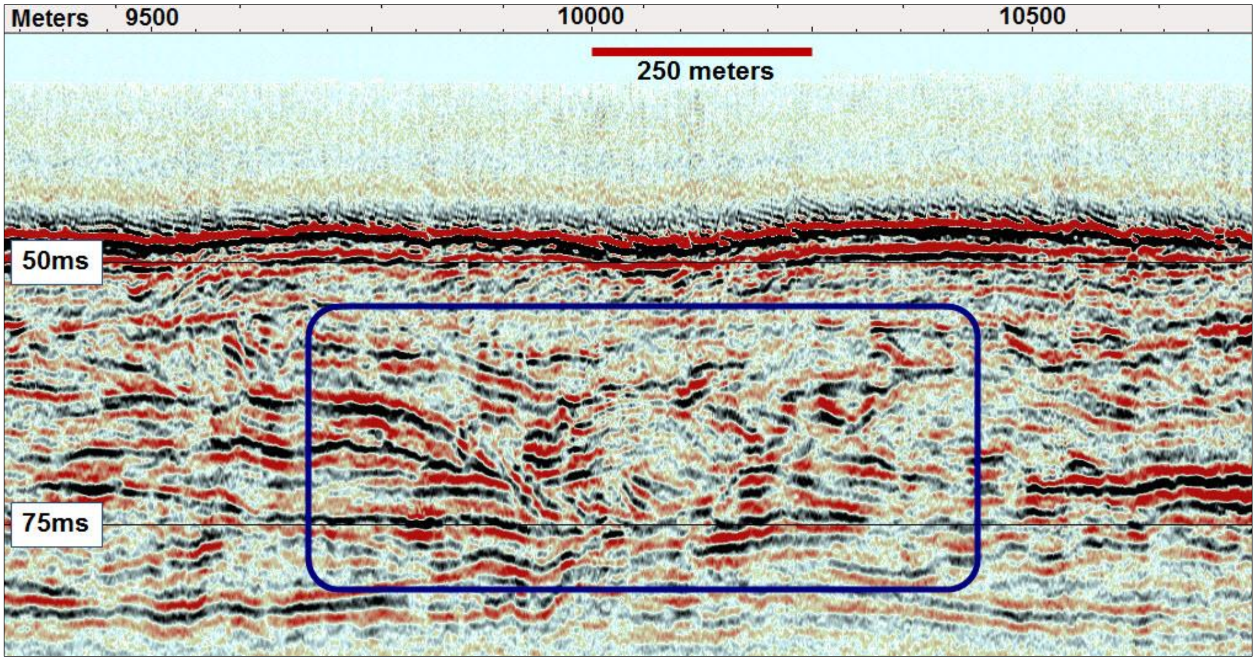


Figure 63: Buried channel feature in multi-channel seismic Line 327 depicting cross-bedded strata.

Any subsurface deposit, infilled channel or otherwise, that contains muds and/or clays will generally possess higher concentrations of organic materials. Muddy and clayey sediments are typically deposited in low energy environments, i.e. back bays, lagoons, and estuaries, where organic material settles and are subsequently buried. The presence of organic and finely-grained material may present a hazard to development, as these sediments may lead to stability issues for large structures.

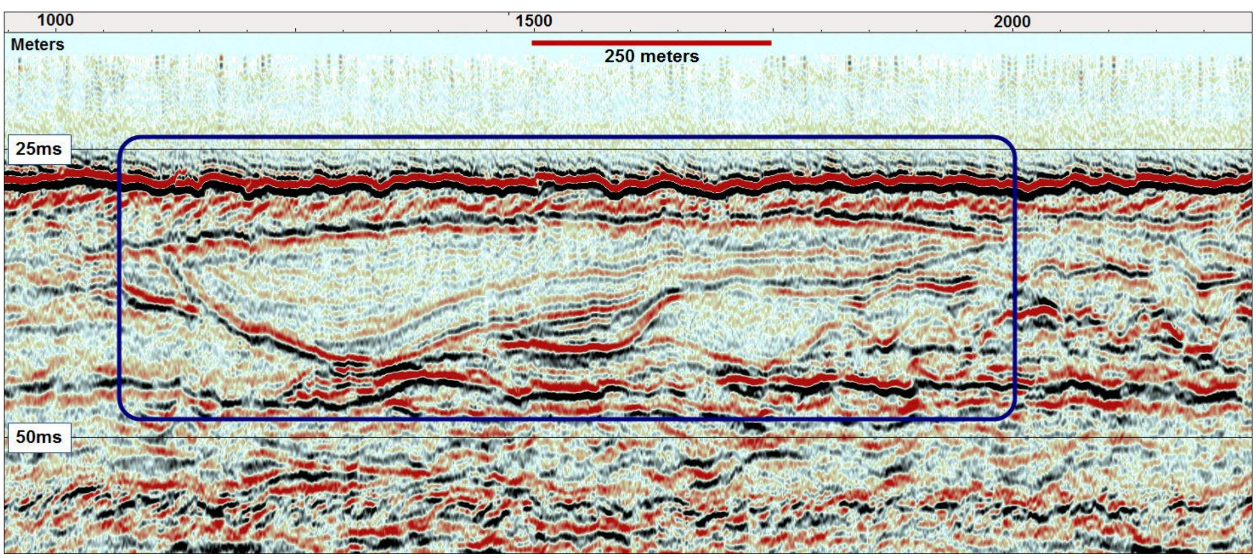


Figure 64: Buried channel feature in multi-channel seismic Line 130 depicting thinly layered sediment fill.

High-Amplitude Anomalies

Two high-amplitude anomalies were identified on Lines 136 and 137 (Figure 65). The exact cause and nature of these features cannot be determined from these seismic data alone. However, these anomalies appear to represent real changes in the seafloor and are correlated with changes in seabed conditions identified in sidescan sonar data. In addition, the fact that this type of feature is present on adjacent seismic lines and is also visible in the chirp sub-bottom profiler data eliminates the possibility of this anomaly being noise related or an artifact of processing.

The anomaly is characterized by a high-amplitude, “bright spot” reflector which is approximately 25 m across. Beneath this abrupt high-amplitude reflection there is a zone of acoustic wipe-out, where underlying reflections cannot be imaged. The most likely explanation for this anomaly is the presence of a substrate with an extremely high coefficient of reflection at the seafloor. When the seismic wave encounters such a material, nearly all of the acoustic energy is reflected upward. No acoustic energy achieves penetration into the underlying material resulting in no deeper reflectors being imaged.

A far less likely cause for this high-amplitude anomaly would be related to the presence of gas in the sediments. Gas laden sediments may also have very high acoustic impedance relative to overlying and surrounding sediments. This produces a high amplitude return beneath which there is acoustic wipe-out. The spatially restricted, small size and abrupt nature of these two anomalies would indicate they are not gas related, and as such, based on CB&I’s professional experience, we feel the likelihood of these anomalies being related to gas is very remote but cannot be ruled out. Locations of both high-amplitude anomalies are shown in *Map Series 7: Hazard Anomaly Map* (Appendix G).

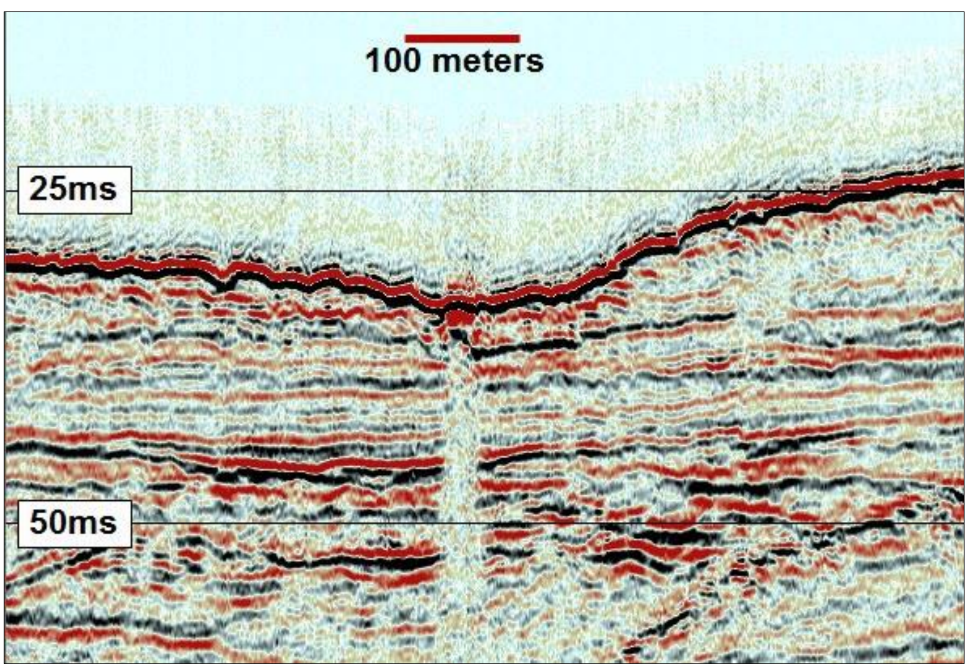


Figure 65: High-amplitude anomaly and associated acoustic wipe-out from multi-channel seismic Line 136.

CONCLUSIONS

The purpose of the MEA HRG survey was to acquire a high-quality geophysical dataset using state-of-the-art methods and technologies. The data acquired during the offshore phase of the MEA HRG survey, conducted July 4, through August 31, 2013, was subsequently processed, analyzed, and compiled into the preceding comprehensive report. The geophysical survey plan and the analysis contained in this report were designed to support future development of wind energy offshore the Maryland coast.

Specifically, the MEA HRG survey was designed to provide detailed information about bathymetry, seafloor conditions, subsurface geologic features, cultural resources, and magnetic anomalies within the pre-determined survey site. The ultimate objective of the entire MEA HRG survey was for CB&I to provide the MEA with a quality data product that will provide essential information to future wind-energy developers. The information obtained during this survey will assist future developers with the design, engineering, and positioning of wind turbines and associated offshore infrastructure.

To achieve the stated survey goals and objectives, CB&I employed a suite of geophysical and hydrographic instrumentation, including sidescan sonar, magnetometer, chirp sub-bottom profiler, multibeam echosounder, and multi-channel sparker seismic-reflection systems. The combination of these various datasets has provided a comprehensive view of the seafloor and the subsurface geology. Based on analysis and interpretation of these data, CB&I was able to draw the following conclusions regarding general seafloor conditions, geologic features, potential hazards, cultural resources, and significant benthic habitat.

The most prominent seabed features within the survey area are shore-detached sand ridges. The sand ridges are largely confined to the western extent of the survey area. Sand ridge orientation is generally southwest to northeast. Smaller scale sediment bedforms, sand waves, are superimposed on the tops of the larger sand ridges. The sand waves are oriented generally east-west. Moving east from the sand ridge field there are more sheet-like sand deposits likely shed from the adjacent ridges. The prevailing seafloor sediment cover within the survey area was divided into three different sediment types: potential exposed mud/clay, sand ridges and/or sand waves and sand with the possibility of some gravel component.

Regional dip in the survey area is basinward (east) and toward the south. Based on seismic facies characteristics and reflection geometries, no basement rock was identified in any of the seismic profiles. Generally speaking, three seismic facies units (geologic layers) are evident in these data. Unit 1, the uppermost unit, is likely comprised of sandy sediments deposited or reworked during the Holocene. This unit contains sand ridge deposits and some shallow buried channels. Unit 2, which lies beneath the modern surficial sediments, is heavily incised and is characterized by steeply dipping reflectors, cross-bedding, and erosional surfaces. This layer has been interpreted to be Pleistocene in age and contains the majority of buried channels within the survey area. The deepest unit (Unit 3) is characterized by high amplitude, sub-parallel reflectors. The high amplitude reflectors range from continuous to moderately continuous and extend across the survey area. Reflection patterns in Unit 3 indicate erosional surfaces, as well as onlap, downlap, and erosional truncation. These types of seismic reflection terminations are indicative of a continental shelf setting with depositional patterns reflecting changing sea level.

Based on analysis of sidescan sonar, bathymetry, and seismic (chirp sub-bottom profiler and multi-channel sparker seismic-reflection) data, five types of potential geologic hazards were identified. The five potential geologic hazard types include:

- Sediment Transport
- Steep Slopes
- Soft Sediments
- Buried Channels
- High-Amplitude Anomalies

Evidence of sediment transport was identified within the survey area. Sediment transport appears to be supported by the large sand ridges located in the western portion of the MEA HRG survey area. These sand ridges display a complex morphology and have smaller-scale sand waves superimposed atop their ridges. The orientation and morphology of the sand waves indicate a southerly movement of sediment. These data and previous studies suggest sediment transport is driven by a combination of tides, currents, waves, and storms. Periods of storm activity are likely to represent the most effective means of sediment movement. Sediment transport can adversely affect wind turbine foundations by removing sediments from around the foundation's base, referred to as scour, and through the deposition of sediments on and around the turbine foundation (Al-Bahadly, 2011).

Steep slopes may be a concern for positioning and constructing offshore wind turbines. Steep slopes may also represent a hazard for construction platforms used during wind farm development, i.e., jack-up barges. All potentially significant slopes encountered within the survey area are associated with the ridge and swale topography of the sand ridges. The steepest slopes, approaching 10 degrees, occur in the southern and eastern extents of the MEA HRG survey area.

Soft sediments within the survey area may pose a potential hazard to offshore construction/drilling operations due to a lack of support and/or stability. In the absence of supporting geotechnical data, acoustic data interpretation and existing scientific literature provided a basis for our interpretation regarding soil conditions. Toscano et al. (1989) conducted an investigation into the Quaternary stratigraphy of the Maryland inner continental shelf and confirmed the presence of mud (silt and clay) in the subsurface. Areas of potential exposed mud were noted in the sidescan sonar imagery particularly in the north-central section as well as the southeastern corner of the survey area. These bottom types are described as "potential" due to the fact that additional investigations would be required to determine the true nature of the sediment even though the acoustic signature indicates mud or clay.

Buried channels also represent a potential hazard to offshore wind turbine construction. Analysis of chirp sub-bottom (very-high-resolution, shallow-penetration) and multi-channel sparker seismic-reflection (high-resolution, medium-penetration) data has revealed the presence of buried channels within the survey area. Seismic Facies Unit 2, imaged in the chirp sub-bottom profiler and multi-channel sparker seismic-reflection data and interpreted to be Pleistocene in age, contains the vast majority of the buried channels. Although considerably less frequent, buried channels also exist within the younger/overlying Seismic Facies Unit 1 as well as within the older/deeper strata within Seismic Facies Unit 3. While composition of the channel fill cannot be accurately determined due to the lack of geotechnical data, previous studies indicate that the buried channels were infilled by fluvial, marine, estuarine, and coastal sediments (Riggs and Belknap, 1988).

Two high-amplitude anomalies were identified on Lines 136 and 137 of the chirp sub-bottom profiler and multi-channel seismic-reflection data. While the exact cause and nature of these features cannot be determined without further investigation, the anomalies appear to reflect real changes in the seafloor. These anomalies are correlated with changes in backscatter levels in sidescan sonar data. The anomalies are characterized by a high-amplitude, “bright spot” reflector which is approximately 25 meters across. Beneath this abrupt high-amplitude reflection there is a zone of acoustic wipe-out, where underlying reflections cannot be imaged. The most likely explanation for this anomaly is the presence of a substrate with a high coefficient of reflection at the seafloor, potentially an outcropping layer of dewatered clay. A second, and in CB&I’s professional opinion, a much less likely cause of these high amplitude anomalies could be the presence of gas within the sediments.

While no significant benthic habitat features were noted in the survey data, a number of potential cultural resource targets were identified. Extensive archival research confirms the high volume of historical vessel traffic and loss in the project area. Near the entrance to the Delaware Bay and within the Atlantic seaboard shipping lanes, the area has a high and well-documented potential for shipwreck remains. In addition, a total of eight (8) wrecks and obstructions on NOAA Chart 12200 Cape May to Cape Hatteras lie within the survey area and more are located in the vicinity. The number of magnetic anomalies (1,142) and sidescan sonar targets (91) identified by remote sensing reinforces the high probability that uncharted wreck remains are also present. Three (3) magnetometer anomalies were found to be associated with uncharted shipwreck remains. Anomalies associated with those charted wrecks, charted obstructions and uncharted obstructions have been identified as “Buffer for Avoidance” to protect them from project-related construction activities. While several significant targets were identified, the 150 m survey line spacing for data collection limits the certainty of anomaly location, characterization and assessment. Therefore, with the exception of small dipolar signatures that can be reliably associated with small objects on the vessel track, the majority of the anomalies must be considered to be potentially significant until more intense survey data are available. Both those uncharacterized anomalies and the charted shipwrecks and obstructions should be avoided pending additional investigation.

Chirp sub-bottom profiler data collected during the survey identified broad patterns of relict sub-bottom features. Those included two (2) highly-organized buried-channel complexes, one (1) large poorly-organized buried tidal complex and one (1) smaller poorly-organized buried-channel and tidal complex. While the highly-organized buried channel complexes could be associated with relatively intact prehistoric resources, the poorly-organized buried tidal complex and smaller poorly-organized buried-channel and tidal complex features appear to be re-sorted by marine transgression to the point that association with undisturbed prehistoric sites is unlikely.

Evidence of a likely Holocene distributary channel and an infilled likely late-Pleistocene paleochannel in the northwest MEA HRG survey area confirm that intact landforms potentially associated with prehistoric habitation do exist in the northwestern portion of the project area.

While this report represents a comprehensive analysis of geophysical data collected across the MEA HRG survey area, the 150 m spaced survey lines provide only a reconnaissance-level cultural resource investigation. More detailed conclusions, from a geologic and cultural resource stand point, would require tighter line spacing and geotechnical data collection. In the case of cultural resources, 30 m line spacing is likely required before any area can be cleared for development. All geologic hazard conclusions were made in general terms. No specific determinations were made in relation to actual wind farm design or engineering.

CB&I is unable to conduct an official Constructability Assessment for the Maryland WEA due to a lack of geotechnical and proposed construction methodology information, CB&I is able to conduct a cursory comparison of the subsurface geology of the Maryland WEA to other offshore areas that have been, or are being considered, for offshore wind farm construction. As there are no existing bottom-founded offshore wind farms constructed within the United States, CB&I must look to Europe for comparable sites.

While there are some significant geological differences between the Maryland WEA and European offshore wind farm locations, including the fact that most of the European subsurface geology has significant glacial influences, there are noteworthy similarities as well. In particular, most of the North Sea and English Channel sites have a mobile Holocene marine sand/gravel unit underlain by Plio-Pleistocene strata with multiple paleochannels and infilling events, filled predominantly by silts and clays. Beneath that, some sites contain an older, open marine stratigraphy beneath the Plio-Pleistocene strata. These are all very similar subsurface geophysical conditions to the Maryland WEA. As these conditions have proven conducive to offshore wind farm construction in Europe, they would likely be suitable for offshore wind farm development of the Maryland WEA. That said, no formal constructability determinations can be made on the Maryland WEA until after detailed geotechnical investigations are completed and specific construction methodologies developed.

The information gained from this HRG survey will be helpful to all parties involved with the future of Maryland's offshore wind farm program. These data and analysis will provide the foundation upon which future design, engineering, and site-location decisions will be made. The quality of the geophysical data acquired during the MEA HRG survey and the detailed analysis presented herein should inspire confidence in any potential developers as they decide how to invest in Maryland's energy future. Follow-on surveys, including design-level cultural resource and geotechnical investigations, conducted off Maryland's coast will only serve to strengthen the results and analysis presented here.

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