Appendix A

Shallow Hazards Report

SHALLOW HAZARDS REPORT

CAPE WIND ENERGY PROJECT

HORSESHOE SHOAL, NANTUCKET SOUND

OSI REPORT # 10ES052

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These drawings accompany this report in a separate binder.

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ACRONYMS

Abbreviation	Definition
OSI	Ocean Surveys, Inc.
CWA	Cape Wind Associates, LLC
ESS	ESS Group, Inc.
PAL	Public Archaeology Laboratory, Inc.
GZA	GZA GeoEnvironmental, Inc.
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
USACE	United States Army Corps of Engineers
NOAA	National Oceanic and Atmospheric Administration
USCG	United States Coast Guard
WHOI	Woods Hole Oceanographic Institution
WHG	Woods Hole Group, Inc.
MHC	Massachusetts Historical Commission
MBUAR	Massachusetts Board of Underwater Archaeological Resources
WTG	wind turbine generator
ESP	electrical service platform
COP	Construction and Operating Plan
DEIR	Draft Environmental Impact Report
FEIR	Final Environmental Impact Report
GPS	global positioning system
NAD	North American Datum (of 1983)
MLLW	mean lower low water
R/V	research vessel
VHF	very high frequency
TOC	total organic carbon
PCB	polychlorinated biphenyl
PAH	polynuclear aromatic hydrocarbon
USCS	Unified Soils Classification System
SPT	standard penetration test
CTD	conductivity, temperature, density
NMEA	National Marine Electronics Association
TVG	time variable gain
HVDC	high voltage direct current
HVAC	high voltage alternating current
FM	frequency modulated
APE	Area of Potential Effect

Units	Definition
miles	statute miles
nm	nautical miles
ft	feet / foot
m	meters
ft/s	feet per second
Hz	hertz
kHz	kilohertz
ms	milliseconds

SHALLOW HAZARDS REPORT
CAPE WIND ENERGY PROJECT
HORSESHOE SHOAL, NANTUCKET SOUND

1.0 INTRODUCTION

From 2001 to 2006, several multi-disciplinary marine site investigations were conducted by Ocean Surveys, Inc. (OSI) in Nantucket Sound to study the surficial and subsurface conditions in support of the Cape Wind Energy Project (the Project). Cape Wind Associates (CWA) proposes to construct 130 wind turbine generators (WTGs) on and adjacent to Horseshoe Shoal (the Project Area, shown in red on Figure 1) to harness the wind as a source of power for the regional electric grid. The intention of this shallow hazards review is to identify natural and man-made hazards present within the Project Area. The report was prepared under contract with CWA, and based on discussions with the Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE).

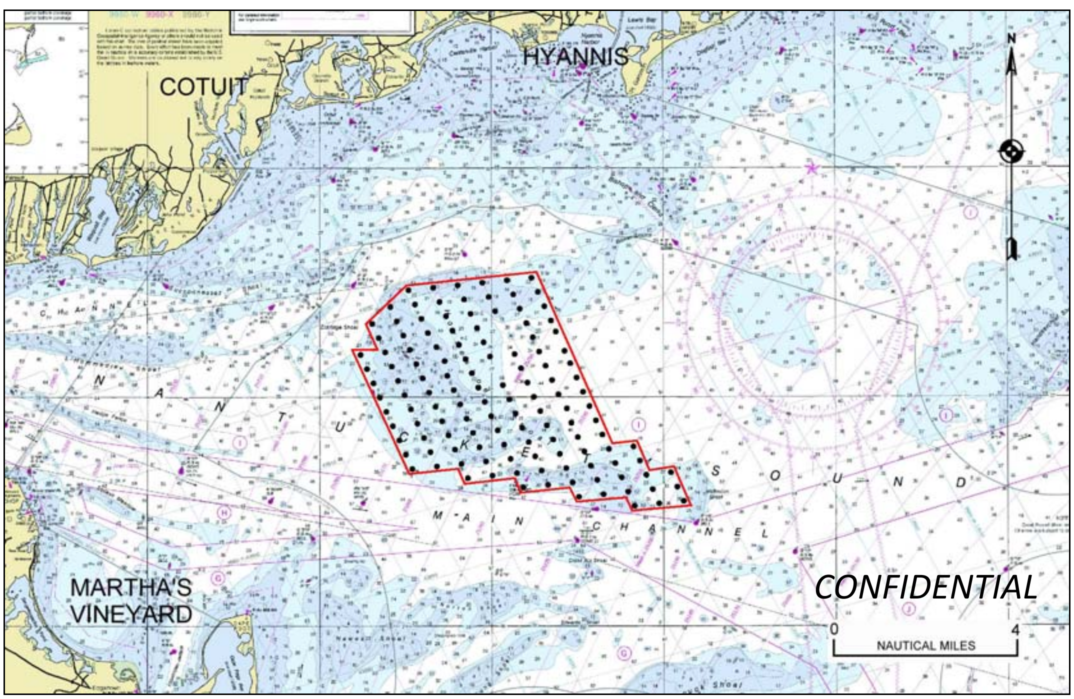

Figure 1. Project Area (in red) encompassing the final WTG design for the Cape Wind Energy Project in Nantucket Sound (NOAA Chart 13237 in background).

For the purposes of this report, the Project Area is defined as the current WTG layout. Although prior investigations (2001-2006) cover broader geographic areas due to changes in the project design since its initial conception, the data and results included in this submittal encompass the final WTG design. Upcoming pre-construction surveys will be conducted within the area of potential effect (APE) plus 1,000 feet beyond, as defined by BOEMRE and stipulated in the lease agreement.

1.1 Shallow Hazards Review Objectives and Tasks

The purpose of this study is to identify natural and man-made shallow hazards in the Project Area by re-examining existing geophysical and geological datasets. This data review addresses BOEMRE concerns regarding shallow hazards and compiles all existing information into a single document. Many hazards have been addressed previously, but these discussions were interspersed amongst numerous project documents. Members of the Project team supplying information for this shallow hazards review include:

- Ocean Surveys, Inc.
- Public Archaeology Laboratories, Inc. (PAL)
- GZA GeoEnvironmental, Inc. (GZA)
- ESS Group, Inc. (ESS)

Primary project documents for reference include prior OSI geophysical reports (2001, 2003, 2005), PAL cultural resource reports (2003, 2004, 2006), GZA geotechnical reports (2002, 2003a, 2003b), and the Draft (DEIR) and Final (FEIR) Environmental Impact Reports (CWA, 2004 and CWA, 2007).

OSI surveys focused on conditions in the immediate vicinity of each WTG location and inner array cable routes. Data products were developed to provide detailed information at each WTG site and focused on the upper 100 feet of the stratigraphic column, which is greater than the maximum depth of WTG monopile foundations. For the Construction and Operation Plan (COP), additional processing of the medium penetration seismic profiling data has been conducted to further evaluate shallow subsurface hazards to depths penetrated by the system (150-300 feet).

Data processing, analysis, interpretation, and documentation have been accomplished to adequately define the surficial and subsurface geology of the Project Area. Additional field surveys are planned in accordance with lease stipulations.

Specific tasks completed for this review include:

- Compilation of a navigation post-plot for all geophysical surveys
- Compilation of previous shallow hazards information from all CWA studies
- Re-analysis of datasets to identify surface and subsurface hazards
- Qualitative analysis of the surficial sand sheet
- Development and compilation of a surface hazards map
- Development and compilation of a subsurface hazards map
- Development of deeper, interpreted geologic cross sections

2.0 MARINE SCIENTIFIC PROGRAM HISTORY

This section provides a brief history of the OSI field program, which was conducted between 2001 and 2006 and included the investigations listed below in Table 1. These investigations were designed to document surface and subsurface conditions in the vicinity of the Project Area. Table 1 below summarizes the marine scientific field investigations completed to date.

Table 1. Program Chronology

OSI Project #	Survey Dates	Program
01ES047	25 June-15 July, 2001	Reconnaissance geophysical investigation of the proposed site
	29 July-19 August, 2001	Geotechnical investigation for seismic correlation and subsurface sampling for sediment analyses
	6-9 November 2001	Geophysical investigation of cable route approaches to landfalls
02ES055	16-17 August 2002	Geophysical investigation of meteorological tower site
03ES039	15 June-7 July, 2003	Geophysical investigation of proposed WTG array

OSI Project #	Survey Dates	Program
03ES039	9-12 September, 2003	Geophysical investigation of cable routes to shore
	10-20 October 2003	Geotechnical investigation for seismic correlation and subsurface sampling for sediment analyses
	December 2004	Geotechnical investigation near Lewis Bay landfall
05ES024	20 June-1 July and 15-17 July, 2005	Geophysical investigation of modified WTG locations
05ES043	12-19 November 2005	Geotechnical investigation in Project Area
06ES048	24-25 July 2006	Benthic study of sensitive habitats

2.1 Program Tasks and Overview

The OSI geophysical surveys provided information for a wide range of project tasks, including preliminary engineering and preparation of permit applications. To provide the necessary marine scientific information, the primary geophysical tools and ground truthing equipment utilized in support of the Project include: single beam depth sounder, side scan sonar, marine magnetometer, shallow penetration subbottom profiler (chirp), medium penetration seismic profiler (boomer), underwater video camera, grab sampler, and vibracorer.

The reconnaissance phase in 2001 was the initial exploratory field program which provided an overview of Horseshoe Shoal geologic conditions for subsequent positioning of the WTG array. To some extent, that dataset was superseded by the 2003 and 2005 programs, since the proposed WTG grid was modified and offset from the 2001 geophysical tracklines to avoid sensitive resources. Nonetheless, the 2001 dataset serves as excellent reference information for comparison and correlation with subsequent investigations that surveyed the final WTG locations and inner array cable routes.

The 2003 field program was the primary investigation of the WTG array, designed to provide detailed survey information at and between WTG locations. The interpretation of subbottom data focused on the upper 100 feet of the stratigraphic column, as a result of the design depth of WTG foundations (70-90 feet below the seafloor). Following the modification of some WTG locations after the 2003 survey, additional tracklines were surveyed in 2005 to provide data coverage of the extended Project Area.

2.2 Survey Designs

Surveys were designed, under consultation with the United States Army Corps of Engineers (USACE) New England District, the Massachusetts Historical Commission (MHC), and the Massachusetts Board of Underwater Archaeological Resources (MBUAR) to acquire scientific data focused on the WTG locations for engineering and archaeological assessment purposes. The surveys were also designed to provide information on the surface and subsurface geological conditions throughout the Project Area. To accomplish these objectives, tracklines were configured in a parallel, rhomboid pattern to bisect each proposed WTG location and follow the routes of WTG inner array cables and transmission cable system. In addition, trackline orientation was designed to provide transects perpendicular to bathymetric contours to the greatest possible extent.

All field data were positioned using a Differential GPS providing a manufacturer’s stated accuracy of +/-1 meter (3.28 feet), however, navigation checks routinely performed throughout each survey showed repeatability typically within 2 feet. Geographic coordinates from the DGPS were converted in the HYPACK navigation software to reference all data to the Massachusetts State Plane Coordinate system, Island Zone 2002, NAD83 in feet. During data acquisition, events (i.e. position fixes) were exported out of HYPACK every 200 feet along line to all geophysical systems to correlate vessel and sensor positions with time. Vertical referencing of depth and subbottom data was accomplished by adjusting acoustic data to a predicted tide curve relative to the mean lower low water (MLLW) datum for the nearest National Oceanic and Atmospheric Administration (NOAA) station. The same Coast Guard reference station (Acushnet, Massachusetts) and NOAA tide stations (Succonnesset Point and Hyannis Port) were used for all field programs.

The following paragraphs summarize the survey approach employed during the geophysical field investigations in 2001, 2003, and 2005. For more detailed information on each geophysical survey refer to previously submitted OSI reports.

2001

This initial field program for CWA was designed to provide reconnaissance level information of Horseshoe Shoal for WTG siting and project constructability. Originally a total of 170 WTGs were envisioned by CWA in the Project Area. One trackline was surveyed along each of the original WTG array alignments (Figure 2) utilizing a longer sonar sweep range (100 meters) to provide increased coverage of the seafloor. Table 2 outlines the major geophysical systems and survey parameters used in 2001 along every survey trackline. [Seismic time sections (in milliseconds) are referenced to two-way travel. Sweep range values represent distances out to both sides of the side scan sonar towfish/trackline.]

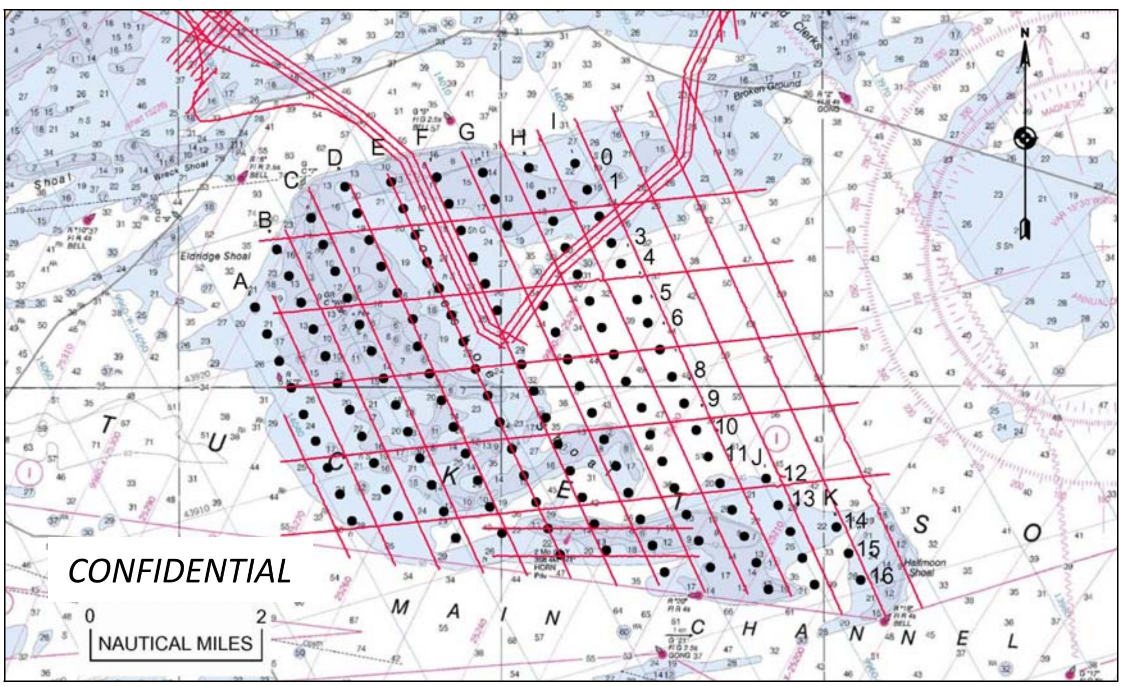

Figure 2. 2001 geophysical survey tracklines shown with the final WTG array.

Table 2. 2001 Geophysical Survey Parameters

System	Acquisition Setup
Depth (200 kHz)	13 samples per second Hull mounted transducer Recorded in HYPACK files
Side Scan Sonar (200 kHz swept frequency)	100 meter sweep range 7.7 pings per second Sensor altitude 10-15% of sweep (except where shallow water does not allow) Recorded in GeoDas as .OIC file
Magnetometer	10 samples per second Sensor altitude +/- 20 feet (except where shallow water does not allow) Recorded in HYPACK file
Shallow Penetration Subbottom Profiler "chirp" (2-16 kHz)	4 pings per second 15-20 meters recorded (below bottom) Towed 2-5 feet below water surface Recorded in EdgeTech .DAT format
Medium Penetration Seismic Profiler "boomer" (0.5-8 kHz)	3.3 pings/shots per second 125 ms time section recorded 62.5 & 125 ms sections printed Surface tow astern and outside vessel wake Recorded on EPC ADS640 as .DAT format

2003

Following review of the initial reconnaissance data and results, the array was reconfigured to include a total of 130 WTGs. A new survey was designed to provide data coverage of the modified WTG locations and inner array cable routes. Three tracklines, spaced 50 feet apart utilizing a 50 meter sweep range on the side scan sonar for enhanced resolution, were surveyed along each north-south oriented WTG array alignment and cable route (Figure 3). The medium penetration seismic profiler (boomer) was utilized on the centerline to acquire subbottom data (100-foot depth of interest) for foundation assessment. Along the west-east oriented cable routes, two 50-foot spaced tracklines were centered on the alignment connecting the WTGs. Medium penetration seismic profile data were not collected along west-east oriented tracklines.

A rectangular area, centered on the proposed electrical service platform (ESP) location, was surveyed along tracklines spaced 50-feet apart and oriented parallel to the north-south WTG array tracklines (Figure 4). The purpose of this phase of the survey was to provide sufficient data for siting the inner array cable routes into the ESP. Since inner array cables connecting to the platform will be buried less than 10 feet below the seafloor, medium penetration seismic data were not needed along these tracklines.

Table 3 outlines the major geophysical systems and parameters for the 2003 survey.

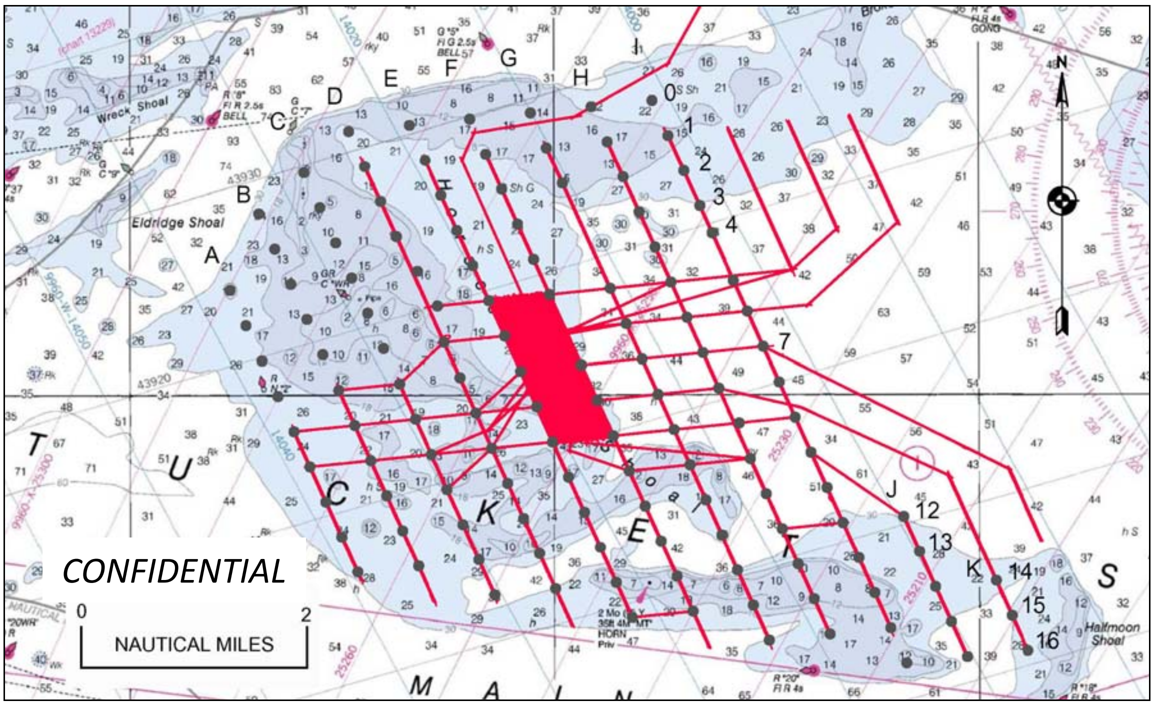

Figure 3. 2003 geophysical survey tracklines shown with the final WTG array.

Table 3. 2003 Geophysical Survey Parameters

System	Acquisition Setup
Depth (200 kHz)	13 samples per second Hull mounted transducer Recorded in HYPACK files
Side Scan Sonar (200 kHz swept frequency)	50 meter sweep range 14.3 pings per second Sensor altitude 10-15% of sweep (except where shallow water does not allow) Recorded in GeoDas as .OIC file
Magnetometer	10 samples per second Sensor altitude +/- 20 feet (except where shallow water does not allow) Recorded in HYPACK files

System	Acquisition Setup
Shallow Penetration Subbottom Profiler "chirp" (2-16 kHz)	4 pings per second 15-20 meters recorded (below bottom) Towed 2-5 feet below water surface Recorded in EdgeTech .DAT format
Medium Penetration Seismic Profiler "boomer" (0.5-8 kHz)	3.3 pings/shots per second 125 ms time section recorded 125 ms section printed Surface tow astern and outside vessel wake Recorded on TSS 360 as SEGY format

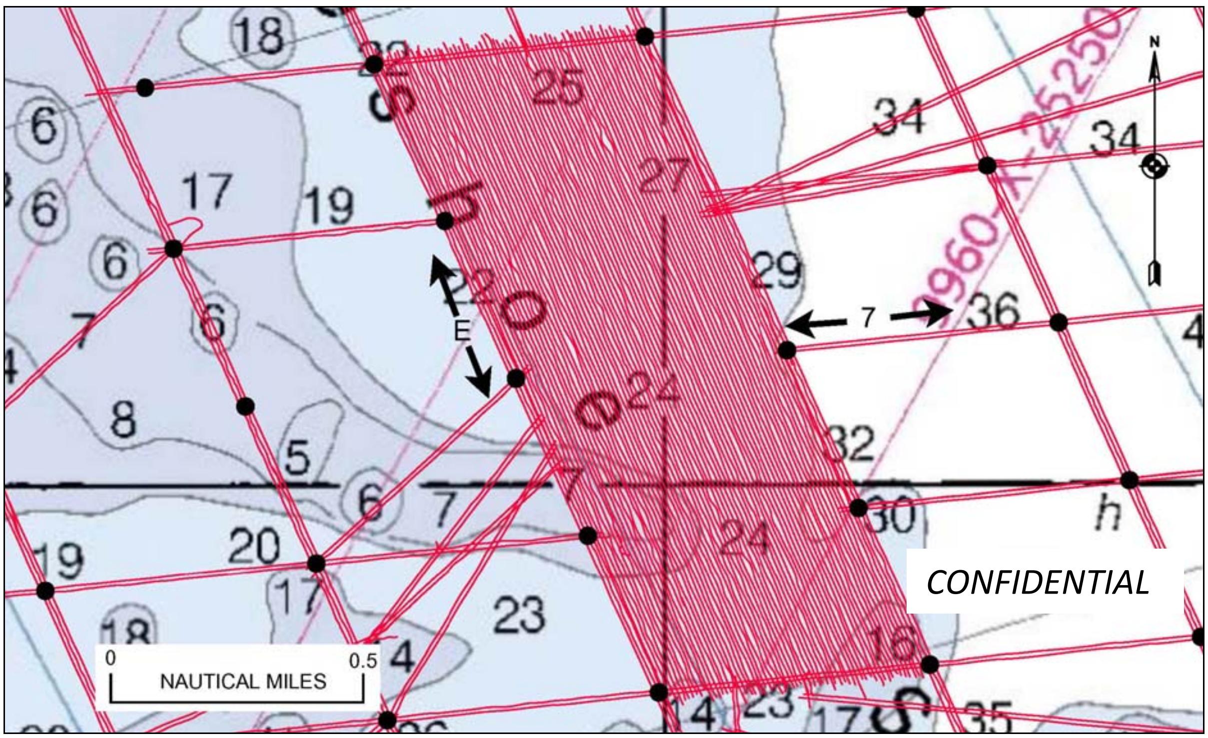

Figure 4. Electrical service platform survey area tracklines, 50-foot spacing.

2005

Between 2003 and 2004, a number of project issues came to light that resulted in modifications to the WTG array layout. These concerns included state-federal jurisdiction, proximity to ship traffic and fishing grounds, and avoidance of potential cultural resources (PAL 2003, 2004, 2006). The final WTG array layout based on the progression of survey investigations and ensuing results is shown in Figure 5. The north-south oriented array alignments are designated by letters (A to K from west to east) whereas the west-east array lines are numbered (0 to 16 from north to south). The overall WTG grid spacing averages approximately 2,075 feet in the north-south direction and 3,275 feet from west to east. As discussed previously, some individual WTGs deviate away from the grid nodes to avoid adverse impacts on or below the seafloor identified from the site investigations.

The purpose of the 2005 geophysical field investigation was to extend the survey coverage to the new WTG locations and associated inner array cable routes, following the same line orientations and spacing adhered to for the 2003 survey (see Figure 5). This resulted in WTG array lines being extended toward the north-northwest. Also, additional inner array cable routes were surveyed in other portions of the Project Area to provide options for the submarine transmission network. Table 4 outlines the major geophysical systems and survey parameters used in 2005.

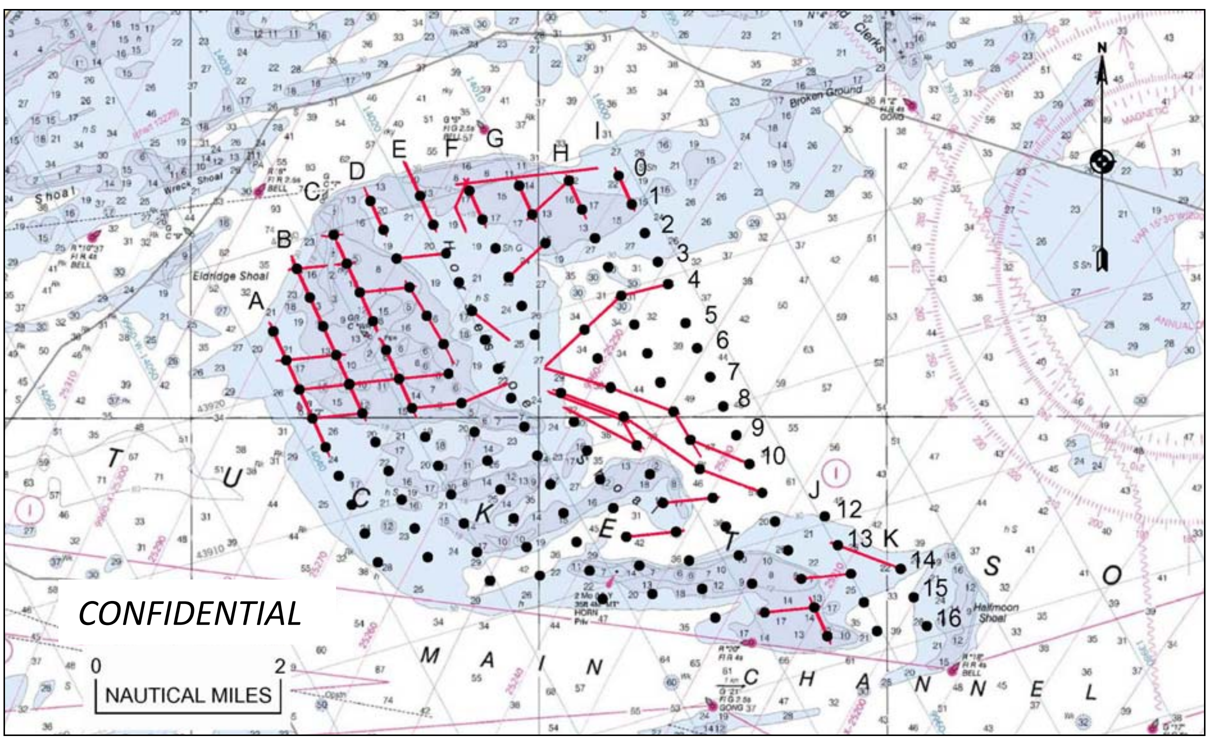

Figure 5. 2005 geophysical survey tracklines shown with the final WTG array.

Table 4. 2005 Geophysical Survey Parameters

System	Acquisition Setup
Depth (200 kHz)	13 samples per second Hull mounted transducer Recorded in HYPACK files
Side Scan Sonar (200 kHz swept frequency)	50 meter sweep range 14.3 pings per second Sensor altitude 10-15% of sweep (except where shallow water does not allow) Recorded in GeoDas as .OIC file
Magnetometer	10 samples per second Sensor altitude +/- 20 feet (except where shallow water does not allow) Recorded in HYPACK files
Shallow Penetration Subbottom Profiler "chirp" (2-16 kHz)	4 pings per second 15-20 meters recorded (below bottom) Towed 2-5 feet below water surface Recorded in EdgeTech .DAT format
Medium Penetration Seismic Profiler "boomer" (0.5-8 kHz)	3.3 pings/shots per second 330 ms time section recorded 125 ms section printed Surface tow astern and outside vessel wake Recorded on Octopus 760 as SEGY format

2.3 Scientific Survey Teams

Each survey was staffed by an experienced team of scientists and technicians, capable of conducting coastal surveys in a safe and efficient manner to the high standards set by OSI. During each geophysical survey, a senior geophysicist/geologist, who also served as the project manager, was accompanied by an electronics technician and the project archaeologist. This three-person team performed operations aboard small vessels with the technician also serving as the helmsman. During larger vessel operations, a licensed captain was responsible for boat maneuvers, in order for the technician to focus completely on the hydraulic winches for deep towing of geophysical sensors.

Similarly highly qualified individuals were assembled to conduct the geotechnical and benthic sample acquisition from other vessels, configured specifically for those tasks. Scientists involved in the field program were capable of performing onsite data interpretations for decision making, which is often a critical path for the modification of data acquisition plans in real time.

2.4 Geophysical Instruments and Survey Methods

The geophysical equipment suite utilized during these investigations was selected based on years of successful data acquisition experience in similar geologic settings throughout New England. A combination of the following instrumentation was used during all phases of the program. A complete description of this equipment, along with the operational procedures employed for data acquisition is provided in Appendix 2.

Navigation and Positioning:

- Trimble Differential Global Positioning System
- HYPACK Navigation Software

Seafloor Mapping and Inspection:

- Benthos DataSonics SIS1500 Digital Side Scan Sonar
- Geometrics G881/882 Cesium Marine Magnetometer
- Innerspace Model 448 Single Beam Depth Sounder
- TSS DMS-05 Motion Sensor
- Sea-Bird Electronics SBE19 SEACAT Profiler
- Simrad “Osprey” 9030 High-Res Color Underwater Video

Subbottom Profiling:

- Applied Acoustics 300J “Boomer” Subbottom Profiler
- TSS 360/Octopus 760 digital seismic control unit
- EPC ADS640 Digital Seismic Recorder
- EdgeTech GeoStar “Chirp” Subbottom Profiler
- EPC 1086 / 9800 thermal graphic printer

Due to shallow water in portions of the Project Area as well as the nearshore sections of the landfall approaches, a variety of survey platforms were necessary to access all areas of interest and provide the optimum work space for the marine scientific studies. Geophysical surveys were conducted aboard 27-28 foot Privateer/Parker style vessels as well as a 42 foot

Duffy featuring hydraulic winches for deep towed sensors. Figure 6 shows some of the vessels used for the CWA project. Ultimately, vessel usage was determined based upon equipment system and space requirements, water depths, and season (expected sea conditions).

All geophysical systems were run simultaneously to maximize survey efficiency, and in such a manner as to reduce interference between systems. Acoustic interference between systems was minimized during the investigations by the lateral separation of sound sources on the vessel, as well as the application of minimal signal transmit and/or receiver gain while still acquiring high-quality data. Survey speeds of 3-5 knots were realized, depending on weather conditions. Typically, as sea conditions worsened survey speed was decreased to maintain high quality data.

Figure 6. OSI survey vessels used for the marine scientific programs.

2.5 Geotechnical Equipment and Operations

The geophysical datasets were supported by a variety of geotechnical sampling methods to ground truth the interpretations and provide direct physical samples of surface materials and subsurface strata. Geotechnical methods used in support of the Project include grab sampling, vibracoring, and deep boring. Following each of the geophysical field programs, vibracore samples were collected by OSI from the upper 10-20 feet of the stratigraphic column. Between 2002 and 2003, GZA acquired borings to explore deeper stratigraphic units at strategic locations throughout the Project Area. Grab samples were also acquired by OSI in 2001 to ground truth side scan sonar imagery and in 2006 to support benthic habitat assessment. Table 5 below summarizes the geotechnical phases of work completed for the Project to date and Figure 7 is a cumulative illustration of all samples collected during the Program.

Table 5. Geotechnical Studies

Company	Dates	Description of Investigation
OSI	29 July-19 August, 2001	23 vibracore stations occupied; grab samples also collected at some locations (47 total stations; 24 along cable routes)
GZA	24-27 April 2002	3 deep borings completed
GZA	18-25 August 2003	10 deep borings completed
OSI	10-20 October 2003	12 vibracore stations occupied (23 total stations; 11 along cable routes)
GZA	13-18 October 2003	9 deep borings completed
OSI	December 2004	4 vibracore stations in Lewis Bay
OSI	12-19 November 2005	12 vibracore stations occupied
OSI	24-25 July 2006	13 grab samples recovered

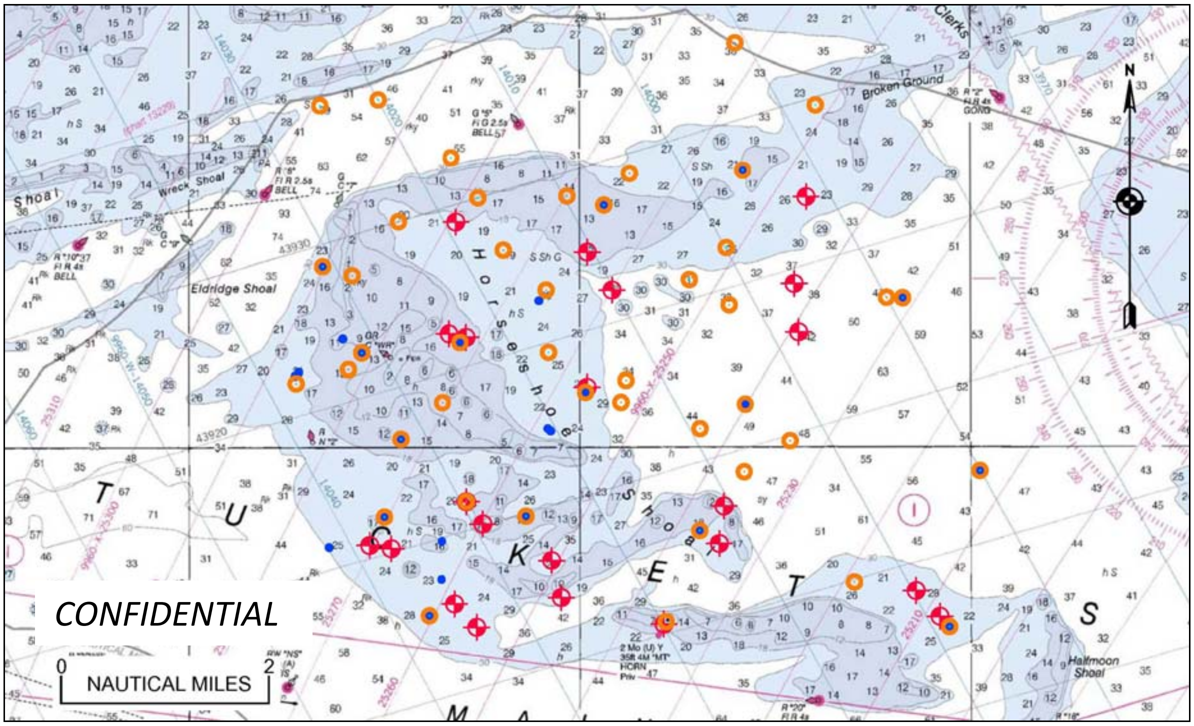

Figure 7. Cumulative plot of geotechnical samples collected in the Project Area; includes grab sample (blue), vibracore (orange), and boring (red) locations.

The equipment systems employed to obtain geotechnical samples and data for the Project are listed below. A complete discussion of this equipment and operational procedures can be found in Appendix 2.

- OSI Model BH1500 Vibratory Corer
- Van Veen Sediment Grab Sampler
- Diedrich D120 and Failing 1500 Rotary Drilling Rigs

All geotechnical operations require a stable platform for sampling. For vibracore investigations, OSI vessels were equipped with 3 to 4-point hydraulic anchoring capabilities as well as a winch and davit/A-frame/derrick for handling the heavy sampler. Vibracore work was performed off more than one platform; short cores (less than 15 feet) were collected using the 42-foot Duffy (vessel utilized during the geophysical surveys), while longer samples needed more deck space. For the longer core samples (15-20 feet) a 17x36-foot pontoon boat, specifically designed for geotechnical work was utilized (see Figure 6). For the deep boring investigations, GZA mobilized a 30x63-foot or 54x67-foot work barge with hydraulically actuated legs that allow the barge to be lifted above the water surface. This provides the stable, stationary platform necessary for drilling using standard rotary equipment.

Three different types of geotechnical sample/data acquisition systems were used for the Project based on variations in the depth of interest below the seafloor for sedimentological data (grabs = upper 1 foot, vibracores = upper 10-20 feet, borings = 100-150 feet). These samples were also used to address and collect other environmental data (ie. benthic habitats, chemical analysis, engineering parameters). Vibracores collected by OSI were delivered to ESS onsite who was responsible for the core analyses. Sediment samples were handled, stored and transported for specific analyses in accordance with laboratory protocols (ESS, 2006a). The cores were split, logged, subsampled, photographed, and archived. Samples were analyzed for physical parameters including grain size, moisture content, ash and organic content, and Atterburg limits (liquid and plasticity measures of finer grained sediments) Samples were also analyzed for chemical constituents including metals, total organic carbon (TOC), petroleum hydrocarbons, polychlorinated biphenyls (PCBs), pesticides, and polynuclear aromatic hydrocarbons (PAHs). Refer to the DEIR (2004) and FEIR (2007) for detailed laboratory results.

During boring operations conducted by GZA, field sampling and testing included: standard penetration test (SPT) sampling at 5-foot intervals, pocket penetrometer, torvane tests, with occasional pressuremeter tests and sampling of cohesive soils via Shelby tube. Select split spoon sediment samples obtained were run through a variety of laboratory tests, including grain size analysis, Atterburg limit tests on cohesive soils, and occasional pocket penetrometer and torvane measurements.

Refer to GZA project documents (2002, 2003a, 2003b) for a detailed summary of these results and boring logs (previously provided to BOEMRE under confidentiality agreement by CWA).

2.6 Sensitive Habitat Inspections

In 2006, underwater video inspections were conducted independently on a separate vessel due to differences in scope of work and required support equipment. The video survey of the seafloor was conducted at speeds necessary to obtain high quality video imagery of the benthos and of individual targets and organisms (generally less than 1 knot). Under suitable visibility, the video camera sled was "flown" above the seafloor and imaged a wider area. Under low light conditions, due to high concentrations of suspended material, the video camera sled was lowered onto the bottom in places to record potentially usable video.

Underwater video imagery of the seafloor was recorded and supplemented with grab samples to document benthic habitats present in the Project Area. Video imagery was targeted for areas where sensitive habitats were suspected based upon analysis of side scan sonar imagery. Review of the sonar records revealed areas of the bottom where patches of stronger acoustic reflections were evident relative to the surrounding seafloor. These reflections appeared generally chaotic and discontinuous over large areas with a similar but slightly different character than coarse material returns (acoustic shadows not always present). The areal extent of these surficial reflectivity patterns were mapped and verified by numerous underwater video transects along with sediment grab samples in select areas (Figure 8). These data supplement benthic studies carried out prior to 2006 in some regions of the Project Area by ESS and other project team members through dive inspections. Detailed macroinvertebrate laboratory analyses were completed on the sediment samples to document specific organisms present in the benthic communities (see the DEIR and FEIR).

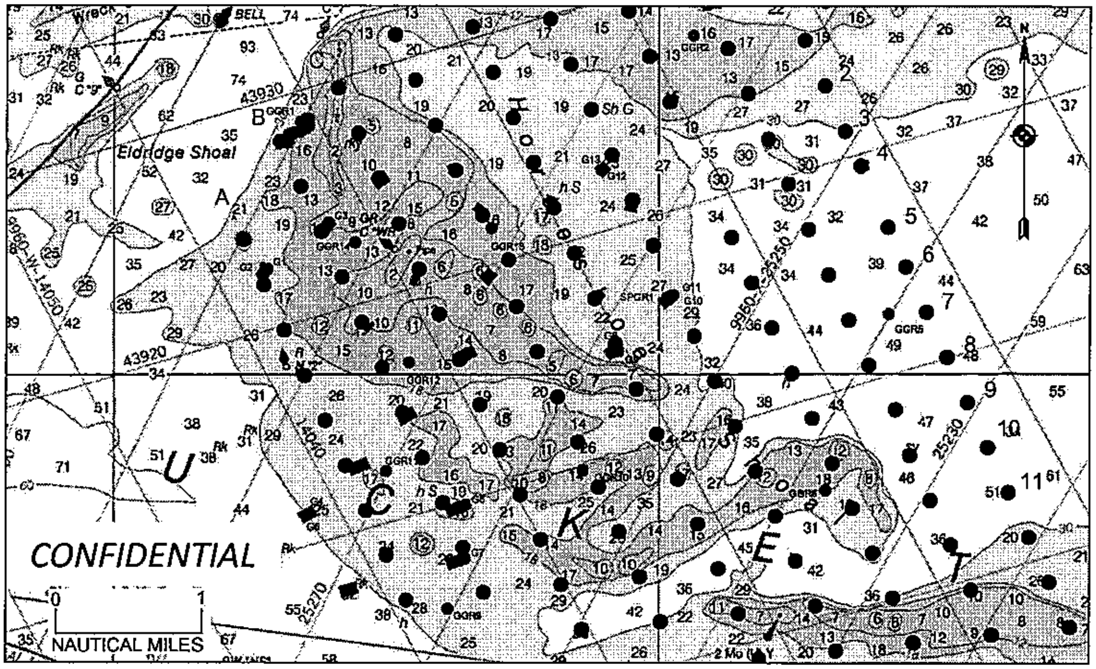

Figure 8. Underwater video transects (red areas) and grab samples (blue circles) acquired in 2006 in support of benthic habitat inspections.

3.0 SUMMARY OF DATA REVIEW

For this shallow hazards review, existing datasets have been re-processed as needed, compiled, examined, and plotted. The following paragraphs provide a brief summary of the steps performed on the datasets to develop the surface and subsurface hazards drawings and interpretations in this report. A detailed summary of data processing and analysis completed on all the existing datasets is presented in Appendix 3, including data processing performed after each geophysical survey as well as the analysis completed for this study.

3.1 Processing

Most of the geophysical datasets required limited additional processing (hydrographic, side scan sonar, magnetometer, shallow penetration subbottom profiler) and were reviewed for surface and subsurface hazards, using both raw and previously processed data files. [redacted]

[redacted] For the sand wave mapping, results from 2003 and 2005 were similarly integrated into a unified, color shaded product delineating the areal extent and height of the bedforms. The medium penetration seismic profiler (boomer) data needed to be completely re-processed in order to resolve deeper stratigraphy not presented in previous reports. A discussion of these products follows in Section 3.3.

REDACTED
Confidential business information.
Not for public disclosure

Figure 9. [redacted]

[redacted]

[redacted]

For six of the WTG array transects (A, B, E, G, H, and J), multiple seismic profiles were combined (2003 and 2005) to produce a representative cross section of the entire transect. Prominent acoustic reflectors present on each section were then interpreted and highlighted. For presentation purposes, a final processed digital file for each representative profile was exported out of ReflexW for input to AutoCAD, and adjusted to match the horizontal scale of the other drawings (1:12,000 or 1,000 feet per inch, as requested by BOEMRE).

3.2 Interpretation and Correlation

All surficial and subsurface data products were first assembled for review and comparison using a variety of graphics software packages (ie. Global Mapper, HYPACK, QuickSurf, AutoCAD). Many of these data components had been submitted previously (DEIR, FEIR) but not assembled together as hazard maps. Features identified from each system could then be correlated geographically for discussion and presentation.

[redacted]

[redacted]

3.3 Shallow Hazards Review Products

Datasets have been compiled in plan and profile view presentation formats (AutoCAD 2004) to map surface and subsurface features throughout the Project Area. Table 6 lists the presentation size and scale as well as information contained in each data product. Drawings were constructed at a scale of 1:12,000 as requested by the BOEMRE, resulting in 4 sheets to cover the Project Area (Figure 10). Different colors and symbols were used to designate various datasets to clarify the presentations as much as possible. Hard copies of the full size drawings accompany this report in a separate binder and are also available upon request. Full size 24x36" and reduced version 11x17" digital PDF files have been created for each drawing sheet and are provided on a data disk accompanying this report (Appendix 4). In addition, numerous figures are included in the text for illustrating survey results or data examples.

Table 6. Shallow Hazards Review Products

Product	Format / Scale *	Description
Report Figures	Figures (8.5 x 11")	Photos, diagrams, digital images
Drawing #1	24x36" (1:12,000)	Navigation post-plot (tracklines) with site bathymetry
Drawing #2	24x36" (1:12,000)	Seafloor Characterization; surficial sediment types with geologic features and sample locations
Drawing #3	24x36" (1:12,000)	Surface Hazards Map
Drawing #4	24x36" (1:12,000)	Subsurface Hazards Map
Drawing #5	24x36" Horiz. 1:12,000 Vert. 1"=50'	Interpreted Geologic Cross Sections of WTG Array Transects A, B, E, G, H, J

Note:
* Reduced versions (11x17") of the drawings are included in Appendix 5.
Full size hard copies of the drawings are available upon request.

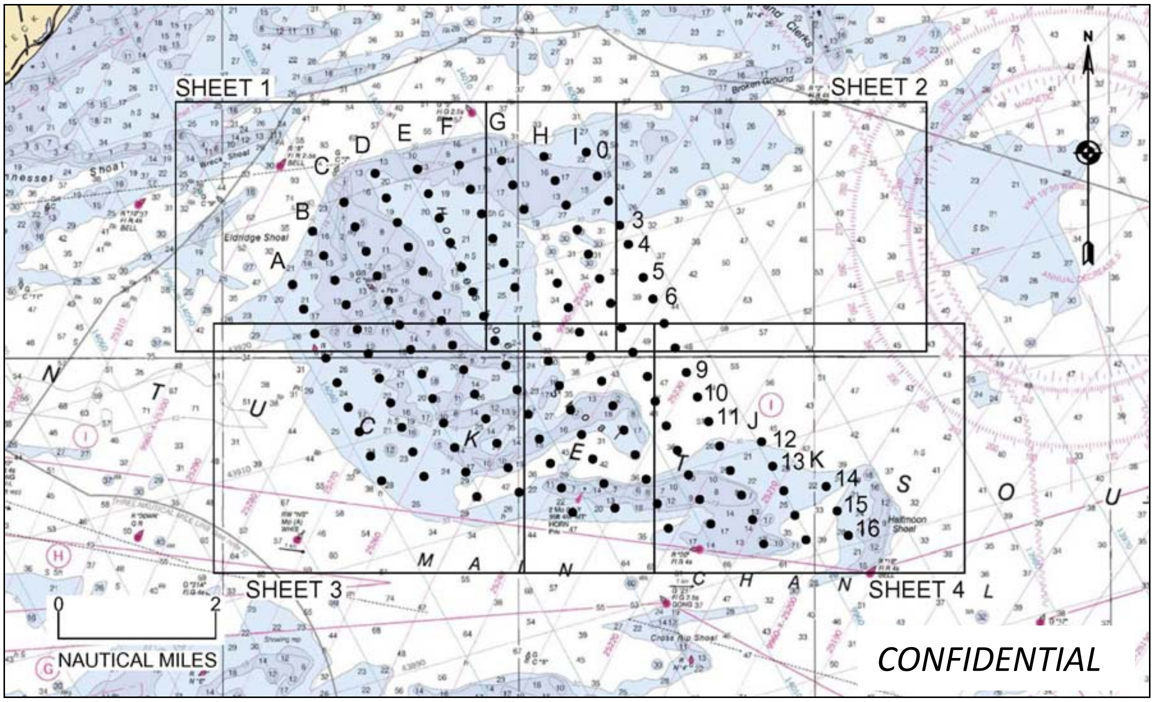

Figure 10. Sheet layout for the shallow hazards drawings/maps.

Navigation Post-Plot (Drawing #1)

The navigation post-plot/survey vessel trackline map includes all lines surveyed between 2001 and 2006 (color coded, see the legend). For presentation purposes, the trackline event numbers have been turned off but the circles designate the event positions (200-foot spacing). Bathymetry contours at a 5-foot interval were generated from a cumulative water depth x,y,z file including data from all three of the primary geophysical programs (2001, 2003, and 2005), referenced to MLLW.

Seafloor Characterization (Drawing #2)

This map represents the conditions that exist in the Project Area at the time of the surveys. It is a compilation of data from all previous geophysical and geotechnical investigations. Distribution of surficial sediment types is presented with geotechnical sample locations (grab samples, vibracores, borings). The mapping of surficial sediment types was based on side scan sonar reflectivity and geotechnical ground truthing (grab and vibracore samples). While type boundaries are interpreted from the datasets, these transitions are typically gradational in nature.

Surface Hazards Map (Drawing #3)

Hazards of concern to BOEMRE identified on the seafloor (see Tables 7 and 9) have been compiled from the three geophysical datasets and displayed together on a single map. For some data types, the process of incorporating the results of multiple surveys required a remapping of the cumulative dataset. For example, sand waves identified and mapped during the 2003 and 2005 geophysical surveys were combined into a unified, color shaded graphic presentation. Sonar targets and magnetic anomalies representing potential man-made debris have been overlain on this display, along with areas where submerged aquatic vegetation (SAV) was identified.

Subsurface Hazards Map (Drawing #4)

Subsurface hazards of concern (see Table 8) have been mapped from the medium and shallow subbottom profile data collected during the three field investigations. [redacted]

Interpreted Geologic Cross Sections (Drawing #5)

Representative geologic cross sections have been produced to illustrate the subbottom data interpretation and mapping. All the medium penetration seismic profiles were re-processed and examined as part of this supplemental review. Select transect lines are presented on the drawing to illustrate the general subsurface conditions encountered. Prominent seismic reflectors have been mapped with an interpretation of stratigraphic units across the Project Area. Geotechnical information (borings, vibracores) has been overlain on the cross sections to provide an indication of the acoustic signatures generated by different sediment types.

4.0 OVERVIEW OF SITE CONDITIONS

4.1 Geologic Setting

Similar to the rest of coastal New England and Long Island, Nantucket Sound was formed by processes associated with the Laurentide Ice Sheet that started some 50,000-70,000 years before present, during the final or Wisconsin stage of the Pleistocene Epoch (Oldale, 1992; Schlee et al., 1976). Before the Cape Cod region was glaciated, there was an extensive coastal plain consisting of Tertiary and Cretaceous rocks that extended seaward to the approximate location of present day Nantucket, Martha's Vineyard, and Block Island. The continental ice sheet advanced across Cape Cod to the islands about 23,000 years ago (Oldale, 1992), scouring bedrock and coastal plain deposits along its path. Its maximum southern advance is marked by gravel deposits on the continental shelf and by the outwash plains and moraines on the Islands (Oldale, 1982).

Most of the outwash plains were formed as deltas in glacial lakes and depressions during lower sea level stands, when ocean water was a constituent of over one-mile thick sheets of ice. The outwash plain deposits on the lower Cape were formed in the low-lying areas that occupied Nantucket Sound and Vineyard Sound (Oldale, 1992; Mulligan and Uchupi, 2004). These lower topographic regions within the Sound were formed by subaerial erosion during extreme sea level low stands as well as glacial meltwater scouring as the ice sheet retreated. The relatively higher elevation of the terminal and recessional moraines, with outwash plains sloping away from them, helped meltwater to erode the outwash plains and to generate channels that were later flooded by rising sea level to create many of the elongate embayments seen today on the southern shore of Cape Cod.

As sea level rose, flooding of the low-lying areas occurred with simultaneous erosion and transport of shoreline sediments by the transgressive sea. Areas of higher ground became islands (Martha's Vineyard, Nantucket Island) and promontories (Horseshoe Shoal, Handkerchief Shoal/Monomoy Spit) along the changing coastline. Sand was constantly redistributed in response to the lateral and vertical migration of the shoreline, forming new inlets, offshore bars, sand spits, and barrier islands as Nantucket Sound evolved.

The results of this coastal transformation that continues to this day, are evident by the geomorphology of the Sound and its surrounding relict landforms, dominated by accumulations of Quaternary age glacially-derived material. Piles of stratified glacial drift and end moraines comprise the Islands (Oldale, 1982; Uchupi and Mulligan, 2006) with deposits of outwash plain sediments accumulated in the Sound. Sediment sizes range from clay to boulders. Bedrock outcrops on the northwest shore of Buzzards Bay and slopes down to the southeast to approximately 1,600 feet below Nantucket (Oldale, 1969). A conservative projection of the bedrock surface suggests its depth exceeds 500 feet below Horseshoe Shoal (Oldale, 2001; Hallet et al., 2004).

Tidal and wind-driven currents are the primary forces behind the sediment transport and sorting within Nantucket Sound, as finer material (silt-clay) has been winnowed off many shoals and accumulated in deeper portions of the Sound. Coarser sediments (sand, gravel, cobbles, boulders) thus tend to occupy the surficial layer of many shallower features, with an abundance of bedforms indicative of active bottom transport throughout the area.

A summary of the Cape Cod regional geology is provided by the United States Geological Survey (USGS) on its website at http://pubs.usgs.gov/gip/capecod/index.html. Please refer to OSI Report No. 01ES047 for a more detailed description of Nantucket Sound geology and history.

4.2 Existing Conditions

A review of historical maps and charts indicates that Horseshoe Shoal (the Shoal) is a stable coastal feature that has existed in Nantucket Sound for decades. Furthermore, projections of paleo-land surfaces through the past using a predictive sea level model (Uchupi et al., 1996 and PAL, 2004) suggest the Shoal was once a subaerially exposed promontory surrounded by a variety of water bodies (kettle lakes, meltwater streams, and coastal embayments) prior to the flooding of Nantucket Sound. Today the Project Area resides in a semi-enclosed coastal embayment with a hydrographic setting that exerts erosional forces on the shallow portions of the Shoal via diurnal tidal currents. More intense physical reworking occurs during storm events that redistribute surficial sediments, winnowing finer material off the Shoal into deeper water and leaving a coarser lag deposit behind. As a result, primarily sand comprises the seafloor on the Shoal with patches of coarse material including scattered boulders. Silt and clay are more prominent in deeper areas, transported to the west and east by tidal forces. Reworking of the seafloor occurs on a daily basis as the water column interacts with the mobile surficial sands.

The physical conditions at the site have produced a variable seafloor topography with water depths less than 10 feet on the Shoal in numerous places, sloping down to over 50-60 feet and deeper in nearly all directions surrounding Horseshoe Shoal. A deep natural channel exists to the north of the Shoal and the Main Channel to the south serves as the primary thoroughfare for marine traffic. [redacted]

A number of man-made objects, many with a ferrous component, were identified on or just beneath the seafloor throughout the site. The majority of these objects appear as small targets on the side scan sonar images (less than 5 feet in size). Fishing gear may be the source for some of these targets as well as the numerous small amplitude magnetic anomalies (less than 20 gammas). Some of the sonar targets may also represent natural boulders on the seabed, particularly on the Shoal in the coarse material areas mapped. No large sonar targets clearly suggestive of shipwrecks or other large obstructions were recorded. Surficial features such as drag marks from fishing trawlers, as well as man-made objects may become buried below the bottom due to the continuously changing sandy substrate.

[redacted]

Coastal plain deposits underlie the region, incised by pre-glacial drainage patterns, glacial scouring and large glaciofluvial valleys and streams during sea level low stands. Common constituents of the coastal plain deposits are silt and sand, often more compact or semi-lithified than the overlying younger glacial sediments (OSI, 2006). Another deeper erosional unconformity marks the top surface of the coastal plain section. The similarity of sediments within all these unconsolidated units hinders the differentiation of the unconformities and correlation of regional strata. Thus, despite the relatively complicated geologic history of the region, the data reveals the similar nature of the unconsolidated sediments throughout the Project Area.

5.0 HAZARDS SUMMARY

Based on the re-examination of existing geophysical datasets, an assessment of surface and subsurface hazards has been completed for this study. Surface hazards have been evaluated using all pertinent datasets including hydrography, side scan sonar imagery, magnetic intensity measurements, grab and vibracore samples, underwater video, as well as a review of existing man-made features from the literature and other relevant sources, and consultation with the project archaeologist. Identification and evaluation of subsurface hazards were hazards were performed using the shallow penetration subbottom profiler, the medium penetration seismic profiler, and geotechnical datasets (vibracores and borings).

5.1 Descriptions

A list of hazards has been assembled and described (Appendix 1) to clarify those that are relevant to the Project Area, and those that are not applicable, as they are found in different geologic environments in other parts of the world. Hazard descriptions were compiled from reference material and standard industry documents to relate and describe the hazards in the context of this Project.

Potential shallow hazards of concern to BOEMRE have been included in this review and are summarized in the tables in the following sections. The discussion addresses shallow hazards that have been identified in the Project Area based upon the review and interpretation of the existing geophysical datasets. Wherever possible, relevant information from the scientific literature is included in the discussion of shallow hazards to provide additional detail.

5.2 Natural Surface Hazards

Of the 13 natural surface hazards listed in Table 7 and Appendix 1, three have been identified in the Project Area: sand waves, water scour, and biologically sensitive habitats. Table 7 below summarizes the results of the natural surface hazards review.

Table 7. Summary of Natural Surface Hazards

Hazard	Identified	Description
Fault/fault escarpment	No	Not Present
Steep/unstable slopes	No	Not Present
Diapiric structures	No	Not Present
Gas/fluid expulsion features/vents	No	Not Present *****
Collapse features (sink holes)	No	Not Present

Hazard	Identified	Description
Mass movement structures (mud flows, creep, slumps)	No	Not Present
Sand Waves	Yes	Sand wave migration; [redacted]
Water Scour	Yes	Erosion of the seabed via tidal currents, waves, and storms
Hardgrounds (rock outcrops, reefs, pinnacles)	No	Not Present; only patches or scattered boulders
Biologically sensitive habitats (hardgrounds /chemosynthetic communities, SAV)	Yes	Submerged aquatic vegetation on top and on slopes of Horseshoe Shoal
Ice scour--relict	No	Not present
Seabed subsidence	No	Undetermined; no research/data available; rates of subsidence and sea level change believed insignificant over the life span of the project
Gas hydrates	No	Not Present *

* Data were reviewed for these hazards but the features are not applicable to this site. See Appendix 1 for detailed descriptions of shallow hazards.

Sand Waves

Sand waves cover a portion of the seafloor within the Project Area and indicate active reworking of surficial sediments ([redacted]). Sediment transport via sand wave migration occurs daily along the flanks of these bedforms. These features are typical of coastal marine environments where sand is a dominant seafloor constituent with active tidal currents in the water column. Daily movement of sediment particles due to the ebb and flood tidal cycle involves relatively small displacements, although sand waves formations may occupy extensive areas of the seafloor. In general, more erosion and transport of sediment is likely to occur during storm events when increased wave action impacts the bottom.

[redacted] In general, bedform geometry is a function of tidal flow dynamics, wave action (storms), water depth and sediment grain size, among other factors.

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Figure 11. [redacted]

Isolated patches of sand waves are evident to the north and west, but the majority of the sand wave field is a nearly continuous mobile sheet of sand in the southern half of the site (see Figure 11). Analysis of subbottom profiles indicates that a basal reflector underlying the sand sheet was resolved in a number of places (Figure 12). This underlying reflector is believed to represent the erosional unconformity at the base of the mobile sand sheet, which is comprised of post-glacial Holocene sediments. Review of the data suggests a correlation may exist between the thickness of the sand sheet and bedform height. Depths to the basal reflector below the wave troughs are generally 2-5 feet where sand wave heights of less than 6 feet are present. In areas where the sand wave height was 6-12 feet, the depth to the basal reflector was measured to be 6-10 feet below the troughs of the bedform.

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Figure 12. [redacted]

[redacted]

While sand wave migration indicates active reworking of the seafloor, the dynamic equilibrium that exists in this surficial layer during normal flow conditions largely transports sediment back and forth with minimal net movement over the short term. This phenomenon is well understood and has been addressed in the engineering and design of the Project. For withstand surficial elevation changes and stress associated with the migration of sand waves past the base of each structure (see FEIR; CWA, 2007).

Water Scour

The erosion, transport, and reworking of surficial sediments is the result of water flowing over unconsolidated materials at the sediment-water interface. In places where the turbulence at this interface exceeds the force necessary to move sediments, scour of the seabed occurs. There are many factors that contribute to this phenomenon, the most persistent on Horseshoe Shoal being tidal currents. Some scour and reworking of the seabed takes place during these average flow conditions, in synch with the diurnal (two times daily) nature of the tides, mostly around maximum ebb and flood tide flows. While more intense scour and redistribution of sediments occur during storm events when above average flow and wave action take place. Natural scour in the Project Area is primarily associated with sand waves, isolated boulders, and other localized topographic highs that affect flow dynamics. Erosion/scour of the bottom may also occur around man-made debris identified from these investigations and scour mitigation is planned for the WTG monopoles as discussed below.

The placement of any man-made structure in a flowing body of water with an unconsolidated substrate will induce scour. To compensate for these physical forces of nature and protect coastal structures from scour that could impact their structural integrity, scour protection mats and armor will be used around the base of each WTG (ASA, 2006; ESS, 2006b; ESS, 2006c; WHG, 2004). This protection is engineered to safe guard the structure well beyond its anticipated life span, and has been in use for decades in dynamic marine environments. For more information concerning water flow characteristics (velocity, direction, modeling) and the scour protection proposed for use on the CWA project, refer to the DEIR (CWA, 2004), FEIR (CWA, 2007) and supporting documents.

Biologically Sensitive Habitats

Within the Project Area, submerged aquatic vegetation (SAV) was the only biologically sensitive habitat identified. For the purpose of this discussion, SAV is defined as any plant or "plant like" organisms that are found attached to the seafloor within the photosynthetically active zone of the ocean. [redacted] Strong amplitude reflections on sonar imagery with no acoustic shadows are generally associated with SAV, with the intensity of the acoustic signature dependent upon the concentration and percent coverage of the SAV which may vary seasonally. One of the most highly sensitive types of SAV is eel grass (*Zostera marina*), which is an important habitat type in coastal New England waters, providing shelter, foraging opportunities, and spawning and nursery grounds for a variety of dependent species (Green and Short, 2003).

While some eel grass beds were identified near the landfall approaches of the transmission cable route, eel grass was only observed at 1 of 20 underwater video and grab sample stations collected around Horseshoe Shoal in 2006. It was determined that the offshore SAV communities observed during previous field efforts consisted of different varieties of macroalgae, primarily seasonal species who are members of the Rhodyphytes (red algae) and Chlorpophytes (green algae) (FEIR; CWA, 2007). The single observation of eel grass during the 2006 survey consisted of several patches along a single transect. These patches ranged from one to several meters in diameter, and were irregularly spaced (FEIR).

SAV is known to inhabit a variety of habitat types and varying environmental conditions. While macroalgae in particular are known to utilize virtually any surface for attachment and subsequent anchorage (Lobban and Harrison,1994; Graham and Wilcox 2000) harder substrates such as boulders and rocky shorelines offer more stability and longevity than softer surfaces such as sand and mud. Eel grass however is known to inhabit "a range of sediment conditions from soft, highly organic muds to coarse sand and partial cobble" (Green and Short, 2003). This correlation is generally consistent with observations throughout the

Project Area where macroalgae is mapped in the same general area as coarse materials (gravel, cobble, and scattered boulders in a sand matrix).

[redacted]

[redacted]

[redacted]

[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
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5.4 Man-Made Hazards

Of the seven man-made hazards listed in Table 9 and Appendix 1, only one was detected in the geophysical datasets; debris. Man-made hazards may be located on the surface or in the shallow subsurface. No shipwreck sites have been positively identified, although target areas comprised of clusters of magnetic anomalies were interpreted from review of the geophysical data by the project archaeologist to have moderate probability of representing submerged Euro-American cultural resources (possibly shipwrecks), as discussed below. Table 9 summarizes the results of geophysical data review and a search of existing maritime information for man-made hazards.

Table 9. Summary of Man-Made Hazards

Hazard	Identified	Description
Pipelines	No	Not Present
Power cables	No	Not Present
Well heads/abandoned wells	No	Not Present *
Communications cables	No	Not Present
Debris	Yes	Sparse distribution of sonar targets and magnetic anomalies indicative of man-made objects
Shipwrecks	No	Not Present
Ordnance	No	Not Present

* Data were reviewed for these hazards but the features are not applicable to this site. See Appendix 1 for detailed descriptions of shallow hazards.

Debris

A sparse distribution of apparently man-made objects has been identified, based primarily on the analysis of side scan sonar and magnetometer data ([redacted]). [redacted]

A total of 161 sonar targets were identified during the three geophysical surveys in the vicinity of the Project Area. No large sonar targets characteristic of a shipwreck or wreck debris field were apparent based on thorough reviews of the datasets by OSI and the project archaeologist. The apparent low concentration of man-made debris is consistent with the site location, outside of primary shipping lanes and far from more intense commercial activities associated with industrial harbors.

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Figure 15. [redacted]

Many of the side scan sonar targets identified may in fact be natural boulders, as a conservative approach to data interpretation identifies all isolated sonar contacts exhibiting any size for further archaeological review. Groupings of such targets, correlated to subbottom profiles and other datasets, may allow patches of coarse material to be positively mapped as boulders and eliminated as man-made objects. For isolated targets, sonar characteristics of a man-made object often exhibit angular-shaped reflections. But the sonar image alone may not be adequate to distinguish between natural or man-made objects in all cases.

The magnetometer data assists with this determination as a ferrous man-made object will generate an anomaly in the earth's total magnetic field intensity being measured. Locations where a sonar target and magnetic anomaly exist represent ferrous man-made objects resting on the seafloor. Locations where only a magnetic anomaly was measured with no corresponding sonar target are suggestive of buried ferrous objects. The vast majority of the 225 magnetic anomalies identified in the vicinity of the Project Area from the three surveys exhibited small amplitudes possibly associated with fishing gear or other debris. [redacted]

[redacted]

Shipwrecks

There has been no conclusive identification of a shipwreck in the site, either modern or historical, although three locations have been given a designation of moderate archaeological sensitivity for Euro-American cultural resources (PAL, 2004 and CWA, 2007). [redacted]

[redacted]

No other sonar targets or magnetic anomalies were identified as concerns from the archaeological assessments performed by PAL (2003, 2004, 2006).

6.0 CONCLUSIONS

This shallow hazards review provides an examination of available scientific data for the Project, using geophysical and geotechnical data collected from 2001-2006 as well as additional research studies and public information sources.

Existing site conditions are typical for a coastal embayment located in a tidal environment and dominated by unconsolidated sediments on and below the seafloor. No unexpected features have been identified from the field investigations completed to date. Furthermore, surface hazards detected and interpreted from the data [redacted] are considered to be manageable through well established engineering practices and pose no major problems for the construction and operation of the Project.

The subbottom penetration and data recovery to depths greater than 200 feet, where site conditions allow, adequately characterizes the subsurface geology within the Project Area. Neither of the subsurface hazards identified ([redacted]) are expected to evidence of hazards detrimental to construction of the Project. While future data acquisition along closer spaced tracklines may provide greater detail on some existing surface and subsurface features, it is unlikely that any additional types of geologic features or hazards would be identified.

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APPENDIX 1

SHALLOW HAZARDS DESCRIPTIONS

Natural and Man-Made Hazards of Interest to the BOEMRE

Hazard	Geologic Description	Typical Environment
Natural—Seafloor		
Fault/fault escarpment	A fracture or fracture zone along which there has been displacement of the sides relative to one another, parallel to the fracture; an escarpment is the physiographic feature formed as the result of faulting activity; *def.* a steep face formed by the abrupt termination of stratified soils/rock.	Possible in all
Steep/unstable slopes	A stretch of ground forming a natural or artificial incline, with a slope that approaches the angle of repose (maximum angle at which the material remains stable)	Possible in all
Diapiric structures	A type of intrusion in which a more mobile and ductily-deformable material is forced into brittle overlying strata.; typically associated with massive mud or salt deposits at greater depth.	Most common in sedimentary environments.
Gas/fluid expulsion features/vents	Upward movement of gas/fluid via low resistance pathways through sediments onto the seafloor; may be related to other hazards listed (diapirs, faults, shallow water flows)	Most common in deeper water, sedimentary environments.
Collapse features (sink holes)	A sinkhole, also known as a sink, shake hole, swallow hole, swallet, doline or cenote, is a natural depression or hole in the Earth's surface caused by karst processes — the chemical dissolution of carbonate rock or suffosion processes in sandstone.	Most common in karst topography regions
Mass movement structures (mud flows, creep, slumps)	Mass movement structures result from the downslope movement of sediments due to gravity. In the submarine environment these structures are often found in slope environments along coastal margins. The velocity of the flow, angle of the slope and shape of the resultant structure are all factors in distinguishing the various types.	Possible in all; requires unconsolidated materials
Sand Waves	Bedforms (sand waves) are the result of the movement of sediment by the interaction of flowing water; critical angle and forces required for mass movement are dependent upon many factors	Possible in all; requires unconsolidated materials
Water scour	Erosion of material due to water flow.	Possible in all
Hardgrounds (rock outcrops, reefs, pinnacles)	Any semi-lithified to solid rock strata exposed on the seafloor; may include carbonate reefs, cemented carbonate layers, and all types of bedrock; sometimes refers to hard bottom areas comprised of nearly continuous fragmented rock or boulders.	Possible in all

Hazard	Geologic Description	Typical Environment
Biologically sensitive habitats (hardgrounds /chemosynthetic communities, SAV)	Benthic habitats of environmental or economical significance specific to locations around the world.	Possible in all; chemosynthetic habitats only in deep water areas
Ice scour	Narrow ditch or linear depression on the seafloor caused by the impact of drifting pack ice above.	Only in high latitudes (present) or glaciated regions (relict)
Seabed subsidence	Lowering of the Earth's surface via natural geologic processes or human activity; can be caused by dewatering, compaction, crustal warping, etc.; relative subsidence may occur via sea level rise	Possible in all
Gas hydrates	A crystalline solid consisting of gas molecules, usually methane, surrounded by a cage of water molecules (similar to ice). Location of gas hydrate is dependent upon pressure and temperature. Hydrates may form a cement in the pore spaces of shallow sediment layers.	Most common in ocean-floor sediments at water depths greater than 300-500 meters
Natural—Subsurface		
Shallow faults	A fracture or fracture zone along which there has been displacement of the sides relative to one another, parallel to the fracture; shallow denotes upper portions of the stratigraphic column and is a relative term dependent upon the depths of interest for each project	Possible in all
Faulting attenuation; extent and geometry	The translation of movement along a fault into surrounding mediums; the areal extent and pattern (geometry) of attenuation is dependent upon such factors as medium composition, density, degree of saturation, and more.	Possible in all
Shallow gas	Subsurface concentration of material in gaseous form that has accumulated by the process of decomposition of carbon-based materials (former living organisms, typically plants).	Possible in all
Gassy sediments	Unconsolidated materials exhibiting a moderate to high concentration of subsurface gas throughout a study area.	Possible in all
Slump blocks or slump sediments	A single coherent mass of material torn away from its original location, in which the slide mass remains virtually intact and moves outward and downward.	Possible in all
Diapiric structures	A type of intrusion in which a more mobile and ductily-deformable material is forced into brittle overlying strata.; typically associated with massive mud or salt deposits at depth.	Most common in regions of thick depositional sequences where extensive deposits of fine grained sediments are present

Hazard	Geologic Description	Typical Environment
Boulders	Large, rounded blocks of stone often mixed with other unconsolidated materials and believed transported to current location via natural forces (glaciers, rivers); technical term for grain size greater than or equal to 12 inches in diameter (USCS).	Common in many; typical of glacial and fluvial environments
Cavernous porosity (thief zones)	Geologic formation that exhibits large subsurface voids such as crevices and caverns; *Petroleum industry:* formation encountered during drilling into which circulating fluids can be lost; thief zone can be defined as a horizontal permeability conduit, common to carbonate geologic environments	Most common in carbonate environments
Buried channels	Formerly the deepest portion of a waterway filled in with sediment over time and preserved to some extent by depositional processes	Possible in all; requires relict or existing fluvial environment nearby
Shallow water flows	The movement of water in over-pressured sediment layers (often sand aquifers) at shallow depths (300-3,500 ft) below the bottom, but deep water areas of the world.	Possible in all; requires water depths >1,500 ft; most common in Gulf of Mexico and other locals
Gas hydrates	A crystalline solid consisting of gas molecules, usually methane, surrounded by a cage of water molecules (similar to ice). Location of gas hydrate is dependent upon pressure and temperature. Hydrates may form a cement in the pore spaces of shallow sediment layers.	Most common in ocean-floor sediments at water depths greater than 300-500 meters
Man-Made—Seafloor & Subsurface		
Pipelines	Usually steel, concrete or both forming a linear conduit (pipe) used for the transport of water, natural gas, sewage, fuel oil, or other commodity.	Possible in all
Power cables	Refers to HVDC or HVAC submarine transmission cables; commonly greater than 4-5 inches in diameter, often with multiple power cables bundled together, and frequently with fiber optic as well	Possible in all
Well heads/abandoned wells	Remnants of human activity in oil and gas fields; vertical pipes and associated debris	Possible in all; most common in Gulf of Mexico and other oil and gas frontier regions
Communications cables	Refers to submarine fiber optic cables; commonly less than 3 inches in diameter and may be bundled with power cables	Possible in all
Debris	Miscellaneous man-made objects that have been discarded in the ocean and are found on and below the seafloor	Possible in all

Hazard	Geologic Description	Typical Environment
Shipwrecks	Wreckage of ships ranging from intact to debris fields, from recent times or having historical significance	Possible in all
Ordnance	Exploded or unexploded ammunitions; from wartime activities or near test facilities	Possible in all
Cultural Resources	Any man-made object or feature having historical significance	Possible in all

Notes:

	Blue shading indicates hazards that are not naturally occurring in the New England region encompassing the CWA Project Area.

Hazard descriptions were compiled from pertinent reference material and standard industry documents to relate and describe the hazards in the context of this Project.

APPENDIX 2

EQUIPMENT OPERATIONS AND PROCEDURES

Trimble Differential Global Positioning System
HYPACK Navigation Software
Benthos DataSonics SIS 1500 Side Scan Sonar
Geometrics G881/882 Cesium Marine Magnetometer
Innerspace Model 448 Single beam Depth Sounder
Sea-Bird Electronics SBE19 SEACAT Profiler
TSS DMS-05 Motion Sensor
Simrad “Osprey” 9030 High-Res Color Underwater Video
Applied Acoustics 300J “Boomer” Subbottom Profiler
TSS 360/Octopus 760 Digital Seismic Control Unit
EPC ADS 640 Digital Seismic Recorder
EdgeTech GeoStar “Chirp” Subbottom Profiler
EPC 1086/9800 Thermal Graphic Printers
OSI Model BH1500 Vibratory Corer
Van Veen Sediment Grab Sampler
Failing 1500 / Diedrich D-120 Rotary Drill

EQUIPMENT OPERATIONS AND PROCEDURES

Trimble Differential Global Positioning System

The Trimble 4000 differential satellite positioning system provides reliable, high-precision positioning and navigation for a wide variety of operations and environments. The system consists of a GPS receiver, a GPS volute antenna and cable, RS232 output data cables, and a Coast Guard beacon receiver. The beacon receiver consists of a small control unit, a volute antenna and cable, and RS232 interface to the Trimble 4000 GPS unit. In this system configuration a position accuracy of ± 1 meter is quoted by the manufacturer.

Fully automated, the Trimble 4000 provides means for 9 channel simultaneous satellite tracking with real time display of geodetic position, time, date, and boat track if desired. The Trimble unit is mounted on the survey vessel with the beacon receiver which continuously receives differential satellite correction factors via radio link from one of the DGPS United States Coast Guard reference beacons. The Trimble 4000 accepts the correction factors and applies the differential corrections to obtain continuous, high accuracy, real time position updates. A standard NMEA string including geographic coordinates is output from the Trimble 4000 system and interfaced to the OSI navigation system running HYPACK software for trackline control.

HYPACK Navigation Software

Survey vessel trackline control and position fixing were obtained by utilizing an OSI computer-based data-logging package running HYPACK navigation software. The computer is interfaced with the Trimble DGPS onboard the survey vessel. Vessel position data were updated at one second intervals and input to the HYPACK navigation system which processes the geographic position data into State Plane coordinates used to guide the survey vessel accurately along preselected tracklines. The incoming data are logged on disk and processed in real time allowing the vessel position to be displayed on a video monitor and compared to each preplotted trackline as the survey progresses. Digitized shoreline, NOAA charts, and the locations of existing structures, buoys, and control points can also be displayed on the monitor in relation to the vessel position. The OSI computer logging system, combined with the HYPACK software, thus provide an accurate visual representation of survey vessel location in real time, combined with highly efficient data logging capability and post-survey data processing and plotting routines.

The HYPACK survey software digitally records the position data for each sensor, depth sounding data, motion sensor readings (heave, pitch, roll), and magnetic intensity measurements, as well as exports sensor position data (adjusted for offset and layback values) to external devices for recording with digital imagery (side scan sonar, subbottom profiles).

Benthos DataSonics SIS 1500 Side Scan Sonar

Side scan sonar images of the bottom were collected using a DataSonics SIS1500 high resolution sonar system operating at a swept frequency of 200 kHz, utilizing "chirp" signal processing technology. The system consists of a Pentium computer, monitor, keyboard, mouse, a thermal graphic recorder, an armored towcable and hydraulic winch, and sonar towfish. The system contains an integrated navigational plotter which accepts standard NMEA 0183 input from a GPS system. This allows vessel position to be displayed on the monitor and speed information to be used for controlling sonar ping rate.

Sonar control and data acquisition is controlled by the GeoDas software. All sonar images are stored digitally (OIC format) and can be enhanced real-time or post-survey by numerous mathematical filters available in the GeoDas program. Other software functions that are available during data acquisition include; changing range scale and delay, display color, automatic or manual gain, speed over bottom, multiple enlargement zoom, target length, height, and area measurements, logging and saving of target images, and annotation frequency and content. The power of this system is its real-time processing capability for determining precise dimensions of targets and areas on the bottom, and the combination of range and resolution achieved with the "chirp" sonar technology.

As with many other marine geophysical instruments, the side scan sonar derives its information from reflected acoustic energy. A set of transducers mounted in a compact towfish generate the short duration acoustic pulses required for extremely high resolution. The pulses are emitted in a thin, fan-shaped pattern that spreads downward to either side of the fish in a plane perpendicular to its path. As the fish progresses along the trackline this acoustic beam sequentially scans the bottom from a point directly beneath the fish outward to each side of the survey trackline.

Acoustic energy reflected from any bottom discontinuities is received by the set of transducers in the towfish, amplified and transmitted to the survey vessel via the tow cable where it is further amplified, processed, and converted to a graphic record by the side scan recorder. The sequence of reflections from the series of pulses is displayed on a video monitor and/or dual-channel graphic recorder on which paper is incrementally advanced prior to printing each acoustic pulse. The resulting output is essentially analogous to a high angle oblique "photograph" providing detailed representation of bottom features and characteristics. This system allows display of positive relief (features extending above the bottom) and negative relief (such as depressions) in either light or dark opposing contrast modes on the video monitor. Examination of the images thus allows a determination of significant features and objects present on the bottom within the survey area.

Geometrics G881/882 Cesium Marine Magnetometer

Total magnetic field intensity measurements at a 10 hertz sampling rate were acquired along the survey tracklines using a Geometrics G881 or G882 cesium magnetometer that has an instrument sensitivity of 0.1 gamma. The G881/882 magnetometer system includes the sensor head with a coil and optical component tube, a sensor electronics package which houses the AC signal generator and mini-counter that converts the Larmor signal into a magnetic anomaly value in gammas, and a RS-232 data cable for transmitting digital measurements to a data logging system. The cesium-based method of magnetic detection allows a center or nose tow configuration off the survey vessel, simultaneously with other remote sensing equipment, while maintaining high quality, quiet magnetic data with ambient fluctuations of less than 1 gamma. The G881 includes a pressure sensor to provide sensor depth (subtracted from water depth to obtain sensor height) while the G882 features an altimeter which outputs sensor height above the seafloor. Data were recorded on the OSI data-logging computer by the HYPACK software.

The G881/882 magnetometer acquires information on the ambient magnetic field strength by measuring the variation in cesium electron energy level states. The presence of only one electron in the atom’s outermost electron shell (known as an alkali metal) makes cesium ideal for optical pumping and magentometry.

In operation, a beam of infrared light is passed through a cesium vapor chamber producing a Larmor frequency output in the form of a continuous sine wave. This radio frequency field is generated by an H1 coil wound around a tube containing the optical components (lamp oscillator, optical filters and lenses, split-circular polarizer, and infrared photo detector). The Larmor frequency is directly proportional to the ambient magnetic intensity, and is exactly 3.49872 times the ambient magnetic field measured in gammas or nano-Teslas. Changes in the ambient magnetic field cause different degrees of atomic excitation in the cesium vapor which in turn allows variable amounts of infrared light to pass, resulting in fluctuations in the Larmor frequency.

Although the earth's magnetic field does change with both time and distance, over short periods and distances the earth's field can be viewed as relatively constant. The presence of magnetic material and/or magnetic minerals, however, can add to or subtract from the earth's magnetic field creating a magnetic anomaly. Rapid changes in total magnetic field intensity, which are not associated with normal background fluctuations, mark the locations of these anomalies.

Innerspace Model 448 Single Beam Depth Sounder

Precision single beam water depth measurements were obtained by employing an Innerspace Model 448 digital depth sounder with a 200 kilohertz, 3-8° beam width transducer. The Model 448 recorder provides precise, high-resolution depth records using a solid state thermal printer as well as digital data output which allows integration with the OSI computer-based HYPACK navigation system. Depth sounding points were collected at the maximum rate of the system, 13 samples per second. The Model 448 also incorporates both tide and draft corrections plus a calibration capability for local water mass sound speed.

Sound speed calibrations are accomplished by performing "bar checks" in shallow water sites. The bar check procedure consists of lowering an acoustic target, typically a 20 pound lead disk, on a measured sounding line, to the specified project depth. The speed of sound control is adjusted such that the reflection from the disk is printed on the recorder precisely at this known depth. The acoustic target is then raised to successively shallower depths and calibration readings at these depths are recorded. Variations which exist in the indicated depth at these calibration points are incorporated in the sounding data processing to produce maximum accuracy in the resulting depth measurements. Bar checks were performed at the beginning of each day to check the surface water mass sound speed in comparison with the CTD profiler.

Bar checks are used for calibration when surveying in shallow water areas of generally less than 60-80 feet. For depth sounder calibration in the deeper water a Sea-Bird SBE19 CTD Profiler is utilized to measure the temperature, salinity, and density of the entire water column from which sound velocity can be calculated and input to the 448 echosounder. Both checks were performed during this field investigation for quality control and comparison.

Sea-Bird Electronics SBE19 SEACAT Profiler

Water column velocity measurements were logged a minimum of three times daily using Sea-Bird Electronics 19 SEACAT Profiler. The SBE 19 is the next generation personal CTD, bringing numerous improvements in accuracy, resolution, reliability and ease-of-use. The SBE 19 samples at 4 Hz, has a 0.005 accuracy and has 8 Mbytes of memory. Data are recorded in non-volatile FLASH memory and can be transferred and processed on a PC. The SBE 19 has a fast sampling and pump controlled TC-ducted flow configuration, significantly reducing salinity spiking caused by ship heave.

The sound velocity profiles collected using the Sea-Bird are important for adjusting the single beam depth soundings for velocity changes in the water column to attain the highest level depth accuracy possible. Sound velocity is also input to other geophysical systems that provide the option for applying sound corrections for distance plotting on imagery (side scan sonar, subbottom profilers).

TSS DMS-05 Motion Sensor

Vessel heave, pitch and roll information was measured and logged utilizing TSS's DMS-05 Dynamic Motion Sensor. Incorporating an enhanced external velocity and heading aiding algorithm for improved accuracy during dynamic maneuvers, the solid state angular sensor offers reliability and the highest performance of any TSS produced vertical reference unit. The DMS-05 motion sensor was designed for use with single and multibeam echosounders and incorporates advanced processing techniques and high grade inertial sensing elements to attain heave, pitch, and roll measurements with high dynamic accuracy and immunity to vessel turns and speed changes. The DMS-05 allows full utilization of all echosounder beams and survey capabilities to IHO standards. The DMS-05 has a dynamic roll and pitch accuracy to 0.05° over a 30° range and dynamic heave accuracy to 5 centimeters or 5% (whichever is greater). The unit can output digital data at a rate up to 200 hertz and accepts a standard NMEA 0183 message string. Digital data are logged by the HYPACK navigation computer. The DMS-05 permits survey operations to continue through degrading weather conditions, increasing project productivity and efficiency.

Simrad "Osprey" 9030 High-Res Color Underwater Video

A Simrad "Osprey" underwater color video system was utilized for inspection of surficial features on the seafloor. The system consists of a high resolution color video camera with 3.7 millimeter wide angle lense, 250 watt light with adjustable light intensity, a 250 foot cable, and power supply unit which includes the light and manual override focus controls. The "Osprey" camera features a corrosion and thermal shock resistant pressure housing made of stainless steel. The camera is designed to be extremely low light sensitive, has automatic focus, and its video output is DVD compatible. The system includes a VCR and DVD recorder with color monitor which were used to record all the video information and a microphone with amplifier to allow real time narration of the underwater scenes, if desired.

The power supply unit was mounted on the survey vessel for remote focus and light control while the camera and light were attached to a stainless steel sled frame designed for stable towing off the side of the vessel. Operationally, the camera and sled were towed at minimal vessel speeds, typically less than 2 knots, to maintain high quality video of the seafloor as the boat navigated around the site. The sled was usually towed at a height of 2-4 feet above the bottom except in areas where reduced visibility forced the sled to be even closer to the bottom. If necessary, the camera can be disconnected from the sled and used in diver hand held mode. The video data is annotated in real time on the imagery with date, UTC time (4 hours ahead of local), navigation light number, and survey line number.

Applied Acoustics 300J "Boomer" Subbottom Profiler

Subsurface exploration was accomplished utilizing an Applied Acoustics 300 joule "boomer" seismic reflection system comprised of a catamaran with boomer plate (sound source), 4,000 volt power supply, 10 element hydrophone array (eel; receiver), digital seismic control unit with filter and time-varied-gain functions, and a thermal graphic printer for real time hard copies.

The “boomer” employs a sound source that utilizes electrical energy discharged from a capacitor bank to rapidly move a metal plate in the transducer bed. The short-duration motion of the metal plate creates a broadband (500–8,000 Hz) pressure wave capable of penetrating hundreds of feet of marine sediments under suitable site conditions. In New England, these low frequency systems are used for any depth range to penetrate coarse glacial till commonly overlying bedrock. Higher frequency seismic systems have greater difficulty resolving the top of rock with a coarse till overburden.

Operationally, a seismic source (boomer) is used to create an intense, short duration acoustic pulse or signal in the water column. This signal propagates downward to the bottom where it is partially reflected at the sediment-water interface, while the rest of the signal continues into the subbottom. As the downward propagating signal encounters successive interfaces between layers of different material, similar partial reflections occur. The characteristics of the materials which cause acoustic signals to behave in such a manner are defined primarily by the cross-product of the bulk density and the compressional wave velocity of each material, a quantity known as the acoustic impedance. As a first approximation, the percentage of an acoustic signal which is reflected from an interface is directly proportional to the change in acoustic impedance across that interface.

The return signal consists of a continuous sequence of reflected energy that has a series of "peaks" correlative in intensity with the magnitude of change in acoustic impedance of the materials on either side of the interface. These return signals received by the transducer array are subsequently converted to electrical voltages which indicate the intensity of the return and hence how strongly the return is printed on the graphic recorder. Ambient noise is filtered out and the signal is then amplified with overall gain and/or TVG and displayed trace-by-trace iteratively on the recorder to yield a continuous display somewhat analogous to a geologic cross section.

The subbottom profiling system is installed aboard the survey vessel along with other scientific instrumentation, all of which is operated simultaneously along the desired survey lines. Both the energy source and the hydrophone array are deployed in an appropriate configuration to minimize the recording of background noise generated by the survey vessel.

For this investigation, the seismic source and hydrophone array were deployed astern of the vessel and electronic filter settings were adjusted to an approximate bandwidth of 800-4,000 Hz in the field. This towing configuration and filter setting provided a quiet environment even in moderately rough sea conditions.

TSS 360/Octopus 760 Digital Seismic Control Unit

The TSS 360 and Octopus 760 digital seismic control units are universal amplifiers and filters which include TVG (time varied gain) with bottom tracking, automatic gain control, real time signal stacking, and a swell filter. Digital seismic files were saved on these units using a standard seismic data format (SEG Y) and printed in real time on the EPC 1086 or model 9800 dual channel recorder. The 360/760 serves as the trigger source for the entire boomer system at a ~330 ms rate.

EPC ADS640 Digital Seismic Recorder

In addition to saving a hard copy of the remote sensing data on the graphic recorder, the subbottom profiles / side scan sonar images were also recorded digitally on the EPC Model ADS 640 seismic system. The ADS 640 system is a versatile digital seismic display and recording unit which is capable of many functions that are independent of the EPC thermal graphic recorders. Incoming analog data is digitized by two high speed A/D converters. Acoustic data are displayed at up to 256 levels of gray on an 8 inch square active matrix LCD video display. A large hard drive is contained within the unit for data storage and a 1.0 gigabyte Jaz™ drive is included for data download and transfer to other devices. Multiple RS-232 interface ports allow annotation input from the navigation system as well as output to a thermal graphic recorder.

Post-survey processing capabilities include powerful search tools that allow quick, systematic location of specific data scans via the random access disk storage. Data can be played back on the LCD display and even printed on a graphic recorder simultaneously.

EdgeTech GeoStar “Chirp” Subbottom Profiler

High-resolution subbottom profiling was accomplished utilizing an EdgeTech GeoStar Full Spectrum "Chirp" Subbottom Profiler system operating with frequencies of 2-16 kHz. The subbottom profiler consists of three components: the deck or topside unit (desktop computer processor, amplifier, monitor, keyboard, and trackball), an underwater cable, and a Model 216 towed vehicle housing the transducers. Data are displayed on a color monitor and EPC 1086 thermal printer while saved in a DAT type proprietary digital format on the topside computer.

The GeoStar Chirp sonar is a versatile subbottom profiler that generates cross-sectional images and collects normal incidence reflection data over many frequency ranges. The system transmits and receives an FM pulse signal generated via a streamlined towed vehicle (subsurface transducer array). The outgoing FM pulse is linearly swept over a full spectrum range of 2-16 kHz for a period of approximately 20 milliseconds. The acoustic return received at the hydrophone array is cross-correlated with the outgoing FM pulse and sent to the deck unit for display and archiving, generating a high-resolution image of the subbottom stratigraphy. Because the FM pulse is generated by a converter with a wide dynamic range and a transmitter with linear components, the energy, amplitude, and phase characteristics of the acoustic pulse can be precisely controlled and enhanced.

The “chirp” subbottom profiler is designed for acquiring high-resolution subsurface data from the upper portions of the stratigraphic column (20-50 feet depending on site conditions). The higher end frequencies allow good resolution of subbottom layering while the lower end acoustic frequencies provide significant penetration. This particular system is capable of providing excellent acoustic imagery of the nearsurface in a wide variety of marine environments.

During data acquisition, all records were annotated with relevant supporting information, field observations, line number, run number, navigation event marks and numbers for later interpretation and correlation with vessel position data.

EPC 1086/9800 Thermal Graphic Printers

Two models of EPC thermal printers have been used to produce real time hard copies of geophysical data for this project, the single channel 1086 (10 inches wide) and dual channel 9800 model (20 inches wide). Multiple RS-232 serial inputs allow navigation information to be input and displayed. The dual channel Model 9800, although it requires significant space, allows geophysical data to be printed at two different scales simultaneously.

OSI Model BH1500 Vibratory Corer

An OSI Model BH1500 vibratory corer was used to obtain continuous core samples of unconsolidated sediments within the survey area. The vibracore rig used for this study utilized a standard 3.5 to 4-inch diameter steel core barrel, a clear plastic lexan liner, a cutter head or shoe, a core catcher, and a pneumatically driven vibratory head attached to the upper end of the core barrel. The vibracore unit requires an air compressor to power the piston inside the head of the corer, which is the driving force of the system. A large stable platform is necessary to lay down the vibracore rig when not in use and provide support for the handling gear and hydraulic winches required to operate the rig.

Once securely on station, the entire coring rig is lowered over the side or stern of the coring vessel via the crane, winch, and connecting cable. The rig is lowered down through the water column to the bottom. Once in contact with the bottom the vibratory head is activated and the winch cable is slackened. The pneumatically powered vibratory head drives the core barrel into the underlying sediments while inducing only minor deformation in the sedimentary structures. The pneumatic head achieves its vibratory motion by means of a reciprocating air driven piston, powered by means of a flexible hose connected to a large-capacity air compressor located onboard the coring vessel.

Following penetration of the core barrel to the desired depth, the entire rig is lifted back onboard the vessel. Once on deck, the liner containing the core is removed, cut into manageable sections, the ends capped and sealed, and the core sections are marked for orientation, identification, and post-survey analysis. Only the accessible part of the core (top and bottom open ends) is examined to provide a brief sediment description onsite. The cores are stored vertically to prevent mixing of the stratigraphic layers in the sample and offloaded at the dock to a secure storage facility. Specific handling procedures for cores destined for chemical and/or biological analyses are followed carefully.

Van Veen Sediment Grab Sampler

A VanVeen grab sampler was used to obtain sediment samples of the upper 8 inches of the seabed for characterizing the surficial materials present in the survey area. The VanVeen grab sampler is used primarily to sample unconsolidated materials from soft mud to coarse sand, and is capable of retrieving a relatively undisturbed, unwashed sample from any water depth.

The sampler is constructed of steel designed for all types of benthic sediments and has a unique trigger mechanism upon striking the bottom which is capable of grabbing even some coarse sand and fine gravel sized materials. The unit is comprised of a half cylinder bucket divided in two, with each half welded to a lever arm and connected to wire cables with which the sampler is lowered. The sampler is lowered through the water column in the open position with the each half of the bucket and lever arms spread out to the side. Upon contact with the bottom, the upward motion of the down line pulls the lever arms and bucket halves together enclosing the sediment trapped within. The top of the unit is covered with mesh screen to prevent sediment and organisms from spilling out of the bucket during its ascent. Lead weights can be added to the sampler for increased penetration into the bottom, if necessary. The effective sampling area of the VanVeen grab sampler is 32 x 32 cm.

Once on deck, the sediment is subsampled according to project specifications. First the samples are photographed and visually described onboard the survey vessel. If the samples were collected as part of a benthic habitat survey, standard procedure is to seive the samples through a 1 mm (0.0394 inch) mesh screen with the living and non-living material remaining on the screen preserved in a 10% formalin solution. These processed samples can then be delivered to a benthic ecology laboratory for microscopic analysis. For geochemical analyses, subsamples of the sediment retained in the bucket are stored in appropriate glass or plastic containers, refrigerated, and delivered to the laboratory within the holding times specified for the chemical components being measured.

Failing 1500 / Diedrich D-120 Rotary Drill

Test borings for all three phases of geotechnical exploration program completed for the project were advanced using Rotary Drilling Equipment and methods. All equipment was mounted on a lift barge and work was completed while the barge was supported above the water surface. The hydraulic rotary drill rigs employed consisted of either a skid mounted Failing 1500 or a truck mounted Diedrich D-120. The borings were advanced by rotary drilling equipment using either standard "drive-and-wash" or "open hole" techniques. Drive and wash technique used 3” to 6” flush joint casing. The casing was advanced using either a 300 or 500 pound drive hammer and soils were removed by flushing to a mud tube on the barge deck. If the driller determined that the open hole technique may be used, the boring was advanced using a rotary drilling bit to cut the soils and drilling fluid circulation to remove cuttings and maintain boring opening.

Standard Penetration Test

Split-spoon soil samples were obtained at approximately five-foot intervals in general conformance with ASTM D-1586, the Standard Penetration Test (SPT), to obtain an indication of the relative density and consistency of the underlying soils. The SPT consists of driving a 1-3/8-inch inside diameter standard split-spoon sampler, at least 18 inches, with a 140-pound hammer dropping from a height of 30 inches. At some sampling intervals where extremely dense soils were encountered a 300 pound hammer was used to advance the sampler. The SPT N-value is the number of blows required to drive the sampler from the six to 18 inch penetration interval.

The sampler was opened on the deck of the lift barge, captured soil was logged and classified, and samples were taken and stored. Field soil classification was in accordance with the Burmister Classification System. Standard penetration test results and soil classification are indicated on the boring logs.

Shelby Tube Sampler

In some borings where cohesive soils or soft soils were encountered, undisturbed samples were obtained by pushing a Shelby Tube mechanically into the soft soil. The sampling was completed in general conformance with “Standard Practice for Thin-Walled Tube Sampling of Soils For Geotechnical Purposes” ASTM 1587. After retrieval the tube was sealed, capped and stored in an upright position. Prior to transport to the land based Geotechnical Lab the samples were installed in a protective container.

Pressuremeter Testing

Pressuremeter testing was completed in general conformance with “Standard Test Method for Pressuremeter Testing in Soils” ASTM Method D4719. The equipment used during the test included the following components: Roctest RRI-MOD pressuremeter probe, a P3500 Vishay Strain Indicator digital readout, Roctest Pneumatic Control Unit, and a compressed nitrogen source to facilitate the probe inflation. Prior to testing each day, the pressuremeter probe was calibrated in test cylinders.

At each test location the borehole was prepared by advancing an open hole using a 2-7/8 inch roller bit to approximately 1.5 feet beyond the test location and the hole was flushed with drilling fluid to remove cuttings. The probe was attached to drill rods and the probe was installed at the test elevation within the borehole. The test procedure was then implemented by incrementally inflating the probe to predetermined pressures. Once the test was completed the probe was deflated and removed.

APPENDIX 3

DATA PROCESSING AND ANALYSIS SUMMARY

Navigation and Hydrographic Data

Side Scan Sonar Imagery

Magnetometer Data

Subbottom Profile Data

Geotechnical Information

Underwater Video Imagery

DATA PROCESSING AND ANALYSIS SUMMARY

Navigation and Hydrographic Data

During the field investigation, vessel navigation files were continuously processed and entered into AutoCAD drawings to verify survey coverage and assist with the onsite review of geophysical data.

Upon completion of the field work, single beam hydrographic data were processed using HYPACK. Digital depth data were first checked against the graphic sounding records for verification of depth quality. Erroneous digital depths caused by floating and drifting debris, air bubbles from passing ship's wake, or fish in the water column were filtered out of the data. The editing process is performed with care to eliminate points attributed to objects in the water column (fish, floating line, etc.) while preserving small features important to the project (boulders and other potential obstructions). Depth processing procedures also incorporate the heave, pitch, and roll measurements to correct for beam position on the seafloor. The digital files containing vessel position and hydrographic data were then corrected for field calibrations (barchecks, CTD profiles) and adjusted to the required vertical datum.

The processed x, y, z data were then exported out of HYPACK and input to DTM (digital terrain modeling) software for mapping. QuickSurf Version 5.1 DTM software was used to generate the contoured surfaces of the seafloor. QuickSurf imports processed survey data points into an AutoCAD format drawing and generates surface models from these data. A number of contouring methods are available for different data applications and site specific conditions. A suite of sophisticated tools allows the user to manipulate modeled surfaces into high quality finished maps and perform a variety of engineering computations.

Side Scan Sonar Imagery

During interpretation of the side scan sonar records, areas on the seabed exhibiting different acoustical properties were identified. The variation in acoustical reflectivity of the bottom represents changes in surficial sediments and/or the presence of benthic communities and foreign material. In general, stronger reflectivity represents coarser materials (coarse sand, gravel, cobbles, boulders, bedrock) while weaker amplitude sonar returns are indicative of finer materials (silt, clay). Since acoustic signal reflection is a not a direct measure of sediment types, surficial reflectivity is best ground truthed via bottom sampling to verify specific sediment types corresponding to reflective strength for each project site. In this manner, sonar data combined with grab sample and vibracore information were used to develop a surficial sediment type map for the survey area.

Imagery were also reviewed for individual targets with the intent of identifying any object 1-foot in size or larger. Each target is interpreted and measured individually. A detailed spreadsheet summarizes specific information for each target such as position, number, size, relief, associated magnetic anomalies, and a description. The targets represent possible obstructions to the installation of wind farm structures and cables during future phases of work. In addition, the target spreadsheet with plan view map are provided to the project archaeologist for cultural resource assessment.

Magnetometer Data

The objective of the magnetometer survey was to locate any ferrous objects lying on or below the seafloor which (1) could represent potential archaeological sites of historic significance and/or (2) may impede WTG or transmission cable construction activities. Digital records of the magnetic data were reviewed and interpreted to determine the presence of ferrous material in the designated project areas. Anomalous readings above the regional geologic background gradient were identified. A coordinate and descriptive list of the anomalies as well as a map with associated to sonar contacts were provided to the project archaeologist in support of the archaeological assessment.

For discrete anomalies, determination of the location of an object producing a magnetic anomaly depends on whether or not the magnetometer sensor passed directly over the object and if the anomaly is an apparent monopole or dipole. A magnetic dipole can be thought of simply as a common bar magnet having a positive and negative end or pole. A monopole arises when the magnetometer senses only one end of a dipole as it passes over the object. This situation occurs mainly when the distance between opposite poles of a dipole is much greater than the distance between the magnetometer and the sensed pole, or when a dipole is oriented nearly perpendicular to the ambient field thus shielding one pole from detection. For dipolar anomalies, the location of the object is at the point of maximum gradient between the two poles. In the case of a monopole, the object associated with the anomaly is located below the maximum or minimum magnetic value.

Subbottom Profile Data

Once back in the office, digital seismic profiles were corrected for sound velocity, filtered, and enhanced to obtain maximum resolution for interpretation. For the shallow subbottom profiler (chirp) files, EdgeTech Discover Subbottom Processing software was used to review and interpret these data for acoustic reflectors in the upper portion of the stratigraphic column. Reflectors of interest were reviewed alongside the medium subbottom profiler (boomer) data with interpretations and products developed as requested for each phase of the project.

For the medium subbottom profiler (boomer) data, these lower frequency digital files were processed using the seismic analysis software ReflexW (Sandmeier Software Version 5.1). The program is a powerful 32 bit software package which runs in the Windows XP environment and allows the user full control over signal processing functions such as filtering, stacking, multiple suppression, a variety of gain adjustments, and many file manipulation options. Once all static corrections, filtering, and gain adjustments have been completed, acoustic reflectors of interest to the project can be picked manually by the user or automatically by the program in a cross-sectional format on the monitor. Adjustable threshold, amplitude scale, and gate window allow the automatic assignment of reflector picks to a selected phase. Separate pick codes, colors, and layer names allow the user to organize and export multiple reflector picks in a variety of file formats.

Since the vertical axis of the seismic records is signal travel time and not material thickness, a conversion from time to thickness or reflector depth was performed. A constant propagation velocity of 5,000 feet per second was used during depth and thickness computations as an average representative velocity of the saturated marine sediments in the site. Multiple layer modeling of the seismic traces allows different velocities to be assumed for each layer, if necessary. The program performs the time to distance/depth conversions using the input velocities and produces a corrected geologic cross section. Digital files can be exported containing the bottom and subbottom reflector depths in a number of formats for use with other modeling and mapping programs.

In general, the digital seismic processing steps performed using the ReflexW program are as follows:

1) File conversion and geometry/navigation checks
   SEGY formatted reflection shot point files were imported into ReflexW. All survey geometry parameters contained in the file headers, as well as coordinates and event marks were checked.
2) Band Pass Filtering
   A 1-D bandpass filter (~800-4,000 Hz) was applied to all traces to increase the signal/noise ratio improving the interpretability of reflected arrivals. This helped minimize interference recorded from the second subbottom system.
3) Deconvolution
   A spiking-deconvolution using the recursion-algorithm of Levinson (Wiener-Filter method) was applied to concentrate the signal wavelet in the time domain creating a highly broadband and smooth spectrum.
4) Envelope Calculation
   A complex trace-analysis was carried out using the Hilbert-Transformation to calculate the envelope or instantaneous amplitude. This instantaneous attribute gave an overview of the energy distribution of the traces and facilitated the determination of signal arrivals.
5) Signal Integration
   A spectral analysis filter that operates in the frequency domain; integrates the seismic signals in time for each trace. This emphasizes the lower frequency bandwidth of the signal for enhancing deeper seismic resolution.
6) Swell Filtering
   A lowpass filter in the distance dimension was applied to eliminate fluctuations in the x-direction smaller than a chosen wavelength. This step was used for smoothing the data to remove the effect of sea conditions.
7) Static corrections
   A muting curve above the sea floor was defined to set all data points in the water column to zero amplitude. This was done to clear out all reflections produced in the water column improving visualization and interpretability of the profiles. A time cut was applied to reduce trace length to the desired depth of interest.
8) Gain Adjustment
   AGC (automatic gain control) or manual gain curve applications are used, along with a TVG (time variable gain) curve, to adjust the gain settings over the depth of interest to optimize the visual display
9) Trace Editing & Interpolation
   Processing features in this function include combining multiple profiles into one file, trimming overlap from combined profiles, flipping profiles end to end so all are viewed from the same direction, and more.

Individual reflector and seismic facies characteristics were examined in an attempt to determine the possible material types represented on the profiles. Correlation with the geotechnical data (vibracores) then allowed lithological identities (clay, sand, bedrock, etc.) to be assigned to the shallow portion of the subbottom profiles.

Geotechnical Information

Geotechnical ground truthing of the shallow subbottom profile data was accomplished through use of the OSI vibracore system which retrieves nearly undisturbed samples of the upper 20 feet of sediment. The samples were also collected for engineering and environmental purposes for grain size analysis and other mechanical and chemical property analyses. Field core logs were compiled for each station to document the onsite conditions including position, water depth, penetration rate, and recovery. Cores were delivered onsite to ESS who was responsible for all logging, documentation, supervision of laboratory analyses, and vibracore sample reporting.

The acquisition of deeper geotechnical information was performed by GZA who conducted borings throughout the wind farm site in the upper 100-150 feet of the stratigraphic column. GZA was responsible for all post-survey analyses performed on the borings and subsamples, as well as boring log production and documentation of results.

Correlation of the vibracore and boring samples with specific seismic reflectors on the profiles allows the identification of the sediment horizons generating the acoustic interfaces. Those interfaces or reflectors can then be traced between geotechnical sampling stations to provide extrapolation of sediment units laterally below the survey area. Core and boring locations are shown on the final drawing in both plan and profile panels with sediment descriptions where appropriate.

Underwater Video Imagery

Underwater video was collected along selected transects in the CWA site where habitats of interest to the project were interpreted from side scan sonar images. The video was utilized to obtain representative footage of benthic habitats and seabed composition for documenting site conditions. Video navigation files were processed using HYPACK to generate trackline plots with time stamps at event marks that are directly correlated to the time shown on the video footage. This allows precise positioning of the underwater camera on the seafloor. A DVD containing the digital video files was delivered to ESS for review and analysis, with additional copies backed up for archival. Results of the side scan sonar interpretation and underwater video review were combined to develop a plan view map of submerged aquatic vegetation (SAV) in the site.

APPENDIX 4

Redacted
Confidential Business Information
Not for Public Disclosure

APPENDIX 5

Redacted
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